Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Geography

Jenny Nøkleberg Sandbæk

From Grey to Green

Environmental Upgrading in Norwegian Cement Industry

Master's thesis in Innovation, Entrepreneurship and Society
Supervisor: Henrik Brynthe Lund
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Abstract

The cement industry is recognized as a hard-to-abate industry due to the continuous demand for the product. As one of the most utilized building materials in the world, cement contributes a significant amount of carbon dioxide emissions. Due to high emission rates, the cement industry is under immense pressure to reduce emissions and the negative environmental impact.

This thesis aims to contribute to the literature and research on Environmental Upgrading in Global Value Chains. I will be doing so by researching an industry that has no previous research within the literature; the Norwegian cement industry. This thesis aims to better understand the different strategies being implemented by the different actors in the value chain to achieve Environmental Upgrading. The different strategies to achieve it will be analysed through the different dimensions of Environmental Upgrading. By applying the global value chain perspectives to the subject of environmental upgrading, this thesis understands how development is occurring in this industry and why. This thesis has investigated environmental upgrading in the Norwegian cement industry through a qualitative case study, consisting of nine semi-structured interviews with relevant actors in the value chain and industry. This thesis has identified the different strategies, drivers and barriers through the dimensions of environmental upgrading: product upgrading, process upgrading, organizational upgrading, and product end-of-life upgrading.

Through the thesis, I argue that strategies for environmental upgrading occur within this value chain and industry. This process is also driven by an interplay of different drivers and barriers resulting in this greening process. I also argue that the strategic approaches in this value chain to achieve environmental upgrading are significant for other hard-to-abate industries, due to the technological advancement happening in the Norwegian cement industry.

Sammendrag

Sementindustrien er anerkjent som en industri som er vanskelig å redusere, på grunn av den kontinuerlige etterspørselen etter produktet. Som et av de mest brukte byggematerialene i verden, bidrar sement med store mengder karbondioksidutslipp. På grunn av høye utslippsrater er sementindustrien under et enormt press for å redusere utslippene og den negative miljøpåvirkningen.

Denne oppgaven har som mål å bidra til litteraturen og forskningen om miljøoppgradering i globale verdikjeder. Det vil jeg gjøre ved å forske på en bransje som ikke har tidligere forskning innen litteraturen; norsk sementindustri. Målet med denne oppgaven er å bedre forstå de ulike strategiene som implementeres av de ulike aktørene i verdikjeden for å oppnå miljøoppgradering. De ulike strategiene for å oppnå dette, vil bli analysert gjennom de ulike dimensjonene av miljøoppgradering. Ved å bruke de globale verdikjedeperspektivene på spørsmålet om miljøoppgradering, forstår denne oppgaven hvordan utviklingen skjer i denne industrien, og hvorfor. Denne oppgaven har undersøkt miljøoppgradering i norsk sementindustri gjennom en kvalitativ casestudie, bestående av ni semistrukturerte intervjuer med relevante aktører i verdikjeden og industrien. Denne oppgaven har identifisert de ulike strategiene, driverne og barrierene gjennom dimensjonene for miljøoppgradering: produktoppgradering, prosessoppgradering, organisasjonsoppgradering og oppgradering av produktets levetid.

Gjennom oppgaven argumenterer jeg for at strategier for å oppnå miljøoppgradering forekommer innenfor denne verdikjeden. Prosessen med dette er også drevet av et samspill av ulike drivere og barrierer som resulterer i denne grønne prosessen. Jeg argumenterer også for at de strategiske tilnærmingene som forekommer i denne verdikjeden for å oppnå miljøoppgradering, er viktige for andre næringer som har krevende omstillingsprosesser, på grunn av de teknologiske fremskrittene som skjer i norsk sementindustri.

Acknowledgment

The process of writing this thesis has taught me so much about myself. Such as my ability to gain knowledge on something I never imagined I would write a whole thesis about, and had no prior knowledge about, cement. But most importantly, I have gained a lot of knowledge on topics of great interest, sustainability, and technology.

I want to start by expressing gratitude to my supervisor, Henrik Brynthe Lund. Thank you for all the excellent guidance, constructive criticism, knowledge, and encouraging and calming conversations.

To all the informants of this study, thank you. Without your knowledge, expertise, and willingness to participate, this thesis would not have happened. The knowledge and input you all have provided are deeply appreciated.

Many people have supported me during the last months and filled my life with laughter and joy. This has made the process of writing this thesis a lot more enjoyable.

To my family, thank you for always loving and supporting me. Even though we are far apart, you are always close to my heart.

To my friends, thank you for the support and always being there for me. The laughter, joy, and good times are invaluable. Thank you to my roommates for all the fun nights at home, even though we all have been stressed with our thesis´.

I would also like to thank myself for pushing through and always keeping going, even when life was not the brightest.

I made it.

Jenny Nøkleberg Sandbæk

Trondheim, 14.05.23

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List of Abbreviations

CCS	Carbon Capture and Storage
CO_2	Carbon Dioxide
CSI	Cement Sustainability Initiative
GCCA	Global Cement and Concrete Association
EnvU	Environmental Upgrading
ESG	Environmental Social Governance
EU	European Union
ETS	Emission Trading System
GCC	Global Commodity Chain
GPN	Global Production Network
GHG	Greenhouse Gases
GVC	Global Value Chain
IEA	International Energy Agency
NSD	Norwegian Centre for Researched Data
R&D	Research and Development

TCM	Technology Centre Mongstad
UN	United Nations
SDG	Sustainable Development Goals
WBCSD	World Business Council for Sustainable Development

Chapter 1: Introduction

This thesis aims to research sustainable development and green production in cement within the geographical context of Norway. Applying the theoretical framework of Global Value Chains to further understand the Environmental upgrading occurring in the value chain, the thesis is set to investigate the different strategies emerging in the Norwegian cement value chain to achieve Environmental upgrading. Four dimensions of Environmental upgrading are being assessed in the thesis, as well as drivers and barriers of the phenomenon occurring within the Norwegian cement value chain. This research will provide actors with valuable insights and information to act upon in further development.

1.1 Introduction to the Field

Environmental consciousness has become increasingly important the in recent years. This awareness has risen, especially within emitting industries. There is a delicate balance of gases in the atmosphere; however, it is evident that this delicate balance has been violently disrupted by human activities (Dicken, 2015). Due to climate change and its correlation with human activity, there is a need for more sustainable development. The Brundtland Commission in Our common future presented the term sustainable development in 1987. The concept of sustainable development was initially defined as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Brundtland, 1987, p. 1). A lot has happened since 1987, and today there is an excellent focus on sustainable development, climate change, and green transitions. Today, the world has a shared duty to reach different goals through the United Nations Sustainable Development Goals (UN SDGs) and the Paris Agreement, in which 186 countries participate (U.N., 2019). But with sustainable development on the agenda, how do we build a world using highly emitting materials while trying to save the world from carbon dioxide emissions and climate change?

The construction industry is essential in terms of building and constructing the world we live in. Although an important industry, it is also a significant user of fossil fuels, non-renewable energy

sources, and minerals (Spence & Mulligan, 1995). However, global initiatives such as the UN SDGs and the Paris Agreement are set to work against fossil fuels and non-renewable energy sources and reduce emissions. Another aspect of the construction industry contributing to high greenhouse gas (GHG) emissions is using materials such as steel and cement.

Cement is an essential material in the construction industry because it is the main ingredient in concrete. The global cement industry contributes 5% of all total GHG emissions in the atmosphere (Worrell et al., 2001). The main ingredient in cement, clinker, is directly correlated to CO_2 emissions. The amount of clinker used in cement production is directly proportional to the CO_2 emissions generated (IEA, 2022). As for the Norwegian cement industry, cement production contributes 2.5% of GHG emissions from Norwegian emissions (Bjerge & Brevik, 2014). With these emissions, the gases emitted into the atmosphere consist of carbon dioxide, nitrogen oxide, ammonia, and more (Chen et al., 2010; Schneider, 2019). With these numbers, the Norwegian cement industry is one of the most emitting points in Norway (Berg, 2013). Due to many different gases being emitted and polluting the air, it is safe to say that the cement industry is a great contributor to disturbing the delicate balance of gases in the atmosphere.

From 2015 to 2021, the carbon dioxide emission increased by 1.5% each year in the cement industry globally. This means that to reach the net-zero emission goal in 2050; the cement industry needs an annual reduction of their emissions by 3% by 2030 (IEA, 2022). Even though the cement industry is essential in constructing and building the world, it must reduce its emissions. Changes must be made as they account for 5% of all total GHG emissions. The cement industry is under pressure and is facing challenges to reduce its emissions and negative environmental impact. Due to high emission rates, the industry faces challenges in reducing its emissions, especially within the product regarding clinker and the production process. To further understand the development occurring within this industry, it is not adequate to investigate one firm. A Global Value Chain (GVC) perspective is needed to understand the development trajectories of this industry.

1.2 Research Challenge

The cement technology and the way of producing it has been around for approximately two centuries (Ryan, 1929), meaning that the cement and the method of producing it are highly embedded in the industry. Therefore, the cement industry faces great challenges regarding production and emissions reduction. However, there is a need to reduce the negative environmental impact. Work is needed to mitigate these impacts, and there are many different approaches to do this. This thesis will investigate the emission reduction in the cement industry in Norway through the theoretical framework of GVC and its analysis of environmental upgrading (EnvU). This thesis will define the Norwegian cement industry and the Norwegian cement value chain as the cement production occurring within Norway, as well as the suppliers that supply to Norway and customers that utilize the cement produced in Norway. The theoretical framework of GVC will be based on "*the full range of activates that firms, farmers and workers carry out to bring a product or service from its conception to its end-user, recycling or reuse"* (Ponte et al., 2019, p. 1). As for the EnvU definition, it refers to "*the process of improving the environmental impact of value chain operations (including production, processing, distribution, consumption and disposal or recycling)*" (Poulsen et al., 2016, p. 60). When analysing the EnvU processes occurring in this GVC, the thesis aims to investigate and highlight what strategies are being applied through the value chain to achieve EnvU and reduce negative environmental impacts. I will also explore why this is done by looking into the drivers and barriers.

Based on this, the thesis will investigate the following research questions:

> *Which strategies are implemented throughout the Norwegian cement value chain to achieve environmental upgrading?*
>
> *Why is the Norwegian cement value chain working to achieve environmental upgrading?*

The purpose and goal of this thesis are to understand the processes of EnvU occurring in the context of the Norwegian cement value chain and then further understand the development trajectories of the Norwegian cement industry. The thesis will aim to gain deep insight, understand, and investigate EnvU processes' complexity in the Norwegian cement value chain.

By focusing on the Norwegian cement value chain, this thesis will contribute to understanding the industry and the upgrading processes occurring.

1.3 Significance of the Research

The further construction and building of our world will continue, and as presented above, it is not without emissions. New technologies, as well as new ways of thinking, are required in terms of reducing the negative impact inflicted by human activity. New ways of using cement technology and producing it will contribute to reducing these negative impacts. In 2009 the International Energy Agency (IEA) and World Business Council for Sustainable Development (WBCSD) presented a technology roadmap for the cement industry. This technology roadmap states that there is a need for green improvements in this industry and suggests different paths for transitions. These transition paths presented are linked to new technology, improvements in the products, and the use of alternative fuels in production (IEA & WBCSD, 2009). The demand for materials such as cement will not stop because of the human population's growth and increased living standards. Therefore, it is essential to investigate changes and development trajectories within the cement industry. It is important because the planet needs to be both liveable and inhabitable.

1.4 Thesis Outline

This thesis consists of six chapters. The thesis outline is set as follows; following this introduction chapter, chapter two will provide sufficient background information on the global cement industry and the Norwegian national level. Chapter two will also provide information regarding cement as a product and how it is produced. Further moving to chapter three, the focus will be the theoretical concepts applied in this thesis. Elaborations on the theoretical ideas of GVC and EnvU will be provided, as well as a theoretical proposition. Chapter four presents the employed methodological approach used in the research; here, I will also discuss the chosen research approach, data collection, analysis method, limitations and ethical considerations. Chapter five will be a theoretically derived analysis and discussion chapter, where I will analyse my empirical data gathered through the interviews. Chapter five will start of with analysing the

different driver and barriers of EnvU. Chapter five will also have a subchapter for each dimension of EnvU I am employing in the analysis; product EnvU, process EnvU, organizational EnvU, end-of-life upgrading. Throughout this chapter, there will be a discussion simultaneously with the analysis. The last chapter, chapter six, will conclude. In chapter six, I will also suggest further research topics on this industry.

Chapter 2: The Cement Industry

Cement has been around for several years; it dates back approximately 2000 years ago (Schneider et al., 2011). The cement technology as we know it today was invented and patented about 199 years ago (Ryan, 1929). Cement is the second most utilized product on a global scale, after steel (Farfan et al., 2019). Due to its popularity on a worldwide scale, emissions follow. The cement's popularity also reflects the need for it.

Cement is the main ingredient in concrete, a substance precious to the construction industry on a global level. As mentioned, the global cement industry contributes to carbon dioxide emissions; the emissions from the industry contribute to 5% of the CO_2 emissions (Worrell et al., 2001). Even though it contributes to emissions, it is still a product that is of great need. But what is cement? And why is it so valuable? In this chapter, I will l investigate the cement industry, starting globally, before moving into the Norwegian cement industry. After this, I will include a subchapter focusing on cement production; however, this chapter contains a simplified production process; it is helpful to keep this in mind throughout the thesis to understand where emissions are occurring. Lastly, I will explore low-carbon cement and the green shift within the cement industry.

2.1 The Global Cement Industry

The construction industry is important regarding various value creations, such as employment and construction of accommodations and infrastructure. This industry contributes to meeting humanity's social and physical needs (Durdyev et al., 2018). However, the construction industry is one of the most emitting industries in the world, contributing to approximately 40% of the total GHG emissions and 36% of the energy usage (Crawford, 2022). A sustainable construction industry is essential in further meeting humanity's needs and meeting the environmental needs (Sev, 2009). Although action is taken globally to reduce emissions and improvements are made, living standards and population growth are coinciding. The construction of our world will not stop, but there is a need for change in the materials we use.

Cement plays a crucial role in the construction of the world we live in. Not only is it used to urbanize the world, but it is also used in infrastructure, such as roads, along with further industrialization of the globe (Schneider, 2019). With the expectancy of population growth being at 9.7 billion people by 2050 (Roser et al., 2013), it is only reasonable to think that using cement in further developing and modernizing the world we live in will continue. Even though several material and construction industries are moving toward more energy-efficient production facilities and processes, the emissions are significant. However, today's modern cement is one irreplicable construction material (Schneider, 2019). This also reflects the value cement and concrete inhabits in the world nowadays. It also reflects cement's continuous importance as a material. In other words, the cement industry is precious for our world's further building and construction. The cement industry is recognized as *hard-to-abate,* meaning that the demand for industrial products, such as cement, is expected to grow. This results in challenges regarding reducing GHG emissions because of the market and the dependences on the product (Paltsev et al., 2021).

Cement is one of the most utilized building materials in the world (Norcem, 2019); therefore, it is safe to say it has great value. Since this is a hard-to-abate industry, there is a need for new and innovative solutions to reduce this industry's emissions (Paltsev et al., 2021). Changes need to happen, and many countries worldwide are working toward goals within the Paris Agreement framework and the United Nations Sustainable Development Goals. When working toward the goals of the Paris Agreement and UN's SDGs, it means working toward reducing GHG emissions, and becoming more sustainable. Cement manufacturing is highly emitting, and the cement industry is highly valuable globally. Therefore, global political goals such as the Paris Agreement and the UN's SDGs are essential frameworks for industries like these.

Although there are some benefits to using cement and concrete as a building material, several negative aspects of the substance, such as the emissions, still need attention and focus. In 2009 the International Energy Agency and the World Business Council for Sustainable Development published a “Cement Technology Roadmap” to investigate technological advancements that can contribute to reducing the emissions in the industry (IEA & WBCSD, 2009). IEA and WBCSD, together with the Global Cement and Concrete Association (GCCA), launched Cement Sustainability Initiative, CSI, a voluntary business initiative focusing on the cement industry's

negative environmental impacts on the world. The CSI members comprise 24 major cement and concrete producers, operating within more than 100 countries (WBCSD, n.d.). Although the CSI and the members of CSI work to address the negative consequences, cement and concrete aren't all bad, there are some benefits of this material. When using concrete, it can endure for a long time with little need for maintenance, but when reaching the end of its lifespan, concrete is recyclable. Concrete is often recycled into aggregates, whereas aggregates are granular materials such as sand, gravel, or crushed stone (Alexander & Mindess, 2005). When old concrete is turned into aggregate, it is used as aggregate in new cement and concrete (IEA & WBCSD, 2009).

When IEA published its technology roadmap for the cement industry, no materials were known to substitute cement. However, research is being done to find appropriate substitute materials (IEA & WBCSD, 2009). The IEA identified four levers for reducing carbon emissions in cement; these four levers are also based on research. The first lever for reducing emissions is deploying current technologies concerning thermal and electric efficiency for more energy-efficient technologies. The second lever is using alternative fuels to manufacture cement instead of fossil fuels. The third lever is finding substitutes for carbon-intensive clinker and other low-carbon materials that are still cementitious. The last and fourth lever is the implementation of CCS technology. CCS, or *carbon capture and storage*, is a technology that focuses on capturing CO_2 emissions before they are released into the atmosphere (IEA & WBCSD, 2009). These four levers are individual actions that the cement industry can take to reduce its emissions. However, combining the levers can affect each potential for emission reduction. Therefore, finding the right way to do it can be challenging.

Today, China is the major cement producer, with India and the EU following behind. China produces approximately 56.1% of all cement globally, contributing significantly to CO_2 emissions (Guo et al., 2023). Globally, cement plants are highly dispersed geographically. Due to the distributed plants, cement is rarely traded internationally, unlike other materials in the construction industry, such as steel. This results in a more individual approach to reducing carbon emissions for countries, regions, or plants. Concerning the countries within the EU, the goal is to be net zero CO_2 emissions by 2050 (EC, 2019). This is based on the *European Green Deal.* As for the cement industry within Europe, 239 million tons of cement had been produced

by 2019, meaning that Europe accounted for approximately 5,8% of cement production globally (Guo et al., 2023). The EU emission trading system (ETS), a minor part of the law enforcement in the Green Deal, enforces taxation on emissions amongst different industries, including the cement industry. The European cement industry is bound to pay taxes for their emissions; the more they emit, the more taxation (Convery, 2009). Even though the European countries are working within the European Green Deal, each country still has individual approaches.

Taking a further look into a cement value chain, which this thesis is based upon, it is helpful to understand the process of not only the production but all the steps from raw material to the end product to the customers. In this thesis, it is essential to investigate the different actors in the various steps in the value chain. This enables understanding the processes and strategies occurring along the value chain between the actors. As illustrated in Figure 1, a generalized cement value chain could look like this.

Figure 1: Generalized cement value chain.

Cement is the main ingredient in concrete, a substance used globally in construction and civil engineering projects (Stokke & Kvellheim, 2020). When produced normally, one ton of cement equals one ton of CO2 emissions. Cement is a substance with significant emissions. Not only is CO_2 released due to the usage of fossil fuels, but the production process itself produces CO_2 emissions (Vatopoulos & Tzimas, 2012). Due to the large scale of emissions from the production process, large companies like Norcem estimated an operational cost of 25%-50% if implementing CCS technology (Stokke & Kvellheim, 2020). Therefore, cooperation and burden-sharing are needed throughout their value chain. The cement technology roadmap (IEA &

WBCSD, 2009) has highlighted the importance of sustainable development in the cement industry. Not only the importance but also suggestions on how to tackle the challenges.

2.2 The Norwegian Cement Industry

The construction industry is highly valuable on a global level; however, its emissions are inevitable and affect the environment. Both energy usage and material resources are the polluters of construction sites. Materials such as cement and concrete are crucial in this industry. Norwegian cement is being produced and manufactured by only one company, Norcem.

Norcem is one of Europe's most modern plants regarding energy consumption and production facilities (Bjerge & Brevik, 2014). The Norwegian cement industry and market are seen as small because it is only one cement producer in the country. Norcem is a Norwegian cement producer owned by the multinational Heidelberg Materials Group. At the same time, Heidelberg Matierials Group is a member of the CSI. Before the founding of Norcem AS in 1968, there were three different cement producers: Christiania Portland Cement Factory, Dalen Portland Cement Factory, and Nordland Portland Cement Factory (HeidelbergMaterials, n.d.). Norway's three separate cement factories operated cement production until 1968, until all three merged and created today's Norcem (HeidelbergMaterials, n.d.). Since there is only one cement producer in the Norwegian cement industry, Norcem plays a vital role in Norway in terms of supplying cement to the industries utilizing the material (Stokke & Kvellheim, 2020). However, other cement producers, such as Schwenk, also supply their cement to Norway. However, Schwenk produces cement in Germany (Schwenk, n.d.) but can still be seen as a competitor for Norcem.

Norwegian cement production accounts for approximately 2,5% of the national emissions (Bjerge & Brevik, 2014). Norcem produces approximately 1.2 million tonnes of cement annually, which results in 0.925 tonnes of CO_2 emissions. With these numbers, Norcem contributes to Norway's third most emitting point on land (Berg, 2013). Norcem is also the most significant contributor to CO_2 emissions that are not from the oil and gas industry. Norcem operates cement production in Brevik and Kjøpsvik, whereas the Brevik plant emits the most (Lothe, 2011).

Figure 2: Map of Norcems two cement plants. Illustrated by the author.

Since Norcem is owned by the multinational building material company Heidelberg Materials, Norcem is working and operating within their framework, as well Norwegian regulative framework, such as the carbon credits, and working toward the goals of the Paris Agreement. Although the production rate and emissions from Norcem are somewhat low compared to the global context, they are stable due to Norcems market position (Stokke & Kvellheim, 2020). The multinational company is working to reduce carbon emissions by 25% compared to 1990 (Jakobsen et al., 2017). To achieve this goal, the strategic approach includes investments in

energy-effective technologies to optimize the manufacturing process. Also, in cooperation with Norcem, investigate the possibilities for implementing CCS technology. As for implementing CCS technology, Norcem will be the first in the world to operate a full-scale CCS on the cement plant Brevik.

2.3 The Process of Making Cement

When making cement, the manufacturing process is long and complex. However, it can be divided into three stages. The first stage is preparing the raw material, the next stage is producing the clinker, and the last step is grinding clinker with different materials to produce cement (IEA & WBCSD, 2018). Cement is the main ingredient in concrete, and concrete is one the most essential materials, together with steel, in the construction industry. Looking further into what cement is, apart from the main ingredient in concrete, it consists of different elements. Cement mainly consists of limestone, which is crushed and ground; after the limestone is crushed and ground, it is also common to add in small amounts of slags, such as aluminium, silicon, and iron (Norcem, 2019).

Further, this raw meal of limestone, aluminium, silicon, and iron, is burned at approximately 1450 degrees Celsius. When being burned at high temperatures, the crushed and ground limestone is turned into a clinker. The burning of the raw meal occurs in two steps; first, in a serial connected cyclone tower, when burning the limestone here, a chemical process called “calcination” occurs, which is when carbon dioxide is emitted directly from the limestone during the process (Norcem, 2019). This part of the production is recognized as the most emitting step in the process (Schneider et al., 2011). The production of clinker contributes to 2/3 of the emissions, while the rest 1/3 is the fuels used to burn the raw meal (Norcem, 2019). After being burned in the cyclone tower, it is further burned in a klin, turning into clinker. In the production of clinker, the usage of different raw materials is being used. However, the most common raw materials are together with limestone, clay, and sand. After the limestone is turned into clinker, it is ground with different slags and aggregates. The different slags and aggregates can be materials such as fly ash, iron and metal, natural pozzolana (volcanic ash), sand, puck, and gravel (Worrell et al., 2001). After this is ground together with the clinker, the cement is finished and ready for use.

Due to the manufacturing of cement being highly emitting, and the cement industry being a highly valuable building material globally, changes need to happen. As mentioned, clinker burning during the process is recognized as the most emitting production step. This is because of the usage of fossil fuels to generate the heat to burn the limestone, but also due to emissions from the chemical process of calcination occurring when burning limestone (Schneider, 2019). Therefore, this part of the production process needs attention in reducing GHG emissions, even though reducing them all over the manufacturing process and value chain is important. However, a crucial step in making the cement, the decomposition of limestone, and the creation of clinker contribute 50-60% of the GHG emissions. And another 30-40% of emissions are generated from fossil fuels, energy, and electricity use (Guo et al., 2023). Therefore, reducing the emissions is challenging because most of the emissions come from a crucial step in production.

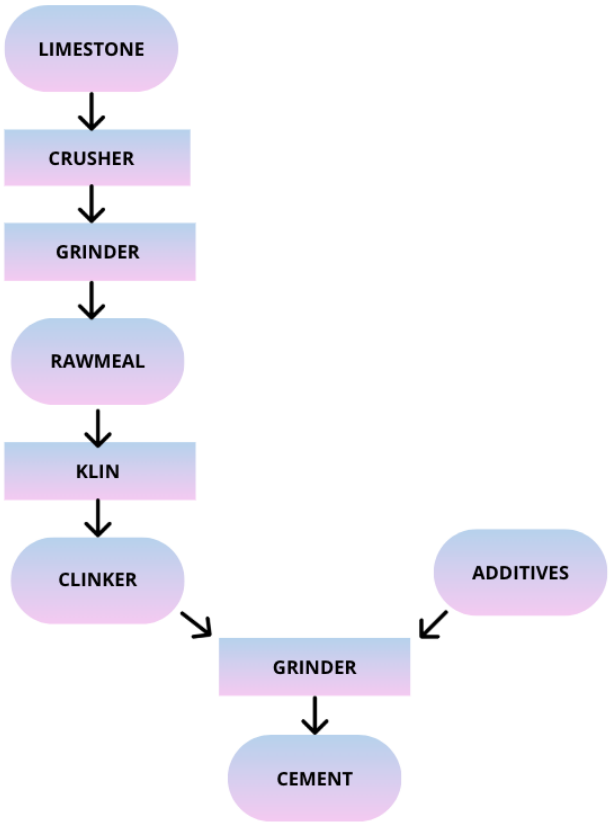

Figure 3: Simplified cement production. Source: (Worrell et al., 2001)

2.4 Reducing Emissions with CCS Technology in Norway

Project Longship was officially launched in September 2020 by the government and Norcem. The project is discussed as being Norway's biggest climate focuesed project so far (Ministry of Petroleum and Energy, 2021). The project is based on implementing CCS technology at the Norcem cement plant Brevik (see figure 2, p. 11). As mentioned, the CCS technology implemented at Brevik will be the world's first CCS technology on a cement plant. This project is in collaboration between the Norwegian government and Norcem. The government is funding the project to make it more feasible.

Due to the inevitable byproduct of cement production – carbon dioxide – one of the presumably best options for reducing emissions is implementing CCS technology (Jakobsen et al., 2017). As mentioned earlier, CCS technology was one of the four levers highlighted by the IEA and WBCSD for reducing GHG emissions. This technology is based on capturing carbon dioxide emissions and storing them elsewhere instead of being emitted into the atmosphere. This technology allows for decreasing carbon dioxide emissions at a quick rate (Stokke & Kvellheim, 2020). Between 2013 and 2016, Norcem conducted CCS trials on the Brevik plant with *chemical absorption*, which is highly effective and enables approximately 95% capture yields (IEA & WBCSD, 2018). Even though CCS technology implementation on industrial plants is increasing, almost 60% are located in North America, and none are in a cement plant (Stokke & Kvellheim, 2020). Therefore, Norcems CCS technology on the Brevik plant is a big move toward sustainability and green transitions in the cement industry. Implementing this technology is expected to reduce the emissions with 400 000 tonnes of CO_2 emissions (Miljødirektoratet, 2022).

According to the Norwegian government, the background reasoning for the Longship project is to invest in long-term green technology that contributes to reaching the climate goals in Norway and Europe with low costs (Meld. St. 33 (2019- 2020)). Most of the emissions in the production of cement, as explained in the previous subchapter, decomposing limestone, and creating clinker is the most emitting part of the process. Therefore, Norcems full-scale CCS technology will be placed to capture the emissions from this step in the process.

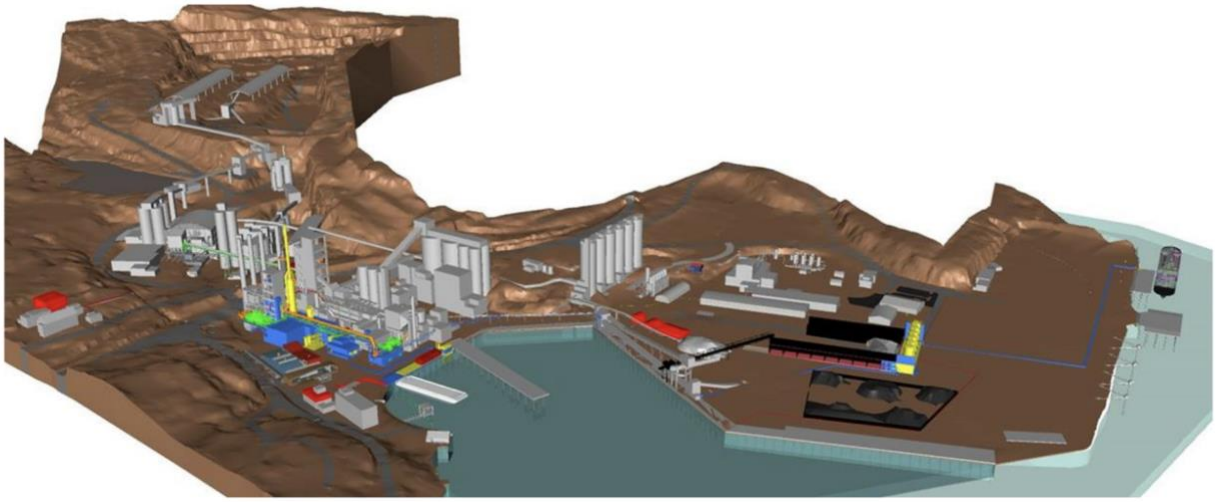

Figure 4: Illustration of Norcems Brevik cement plant with CCS. Source: (Stokke & Kvellheim, 2020)

2.4.1 Norwegian Regulations

Norway has been a member of the Paris Agreement since the 1990s, meaning Norway is working to reduce emissions to keep global warming under 2 degrees Celsius (Haarstad & Rusten, 2018). Norway is also acting within the UN's SDGs as joint work to reduce emissions and promote sustainable development. Norcem is also working within Norwegian regulatory frameworks. As a part of the ETS, the carbon dioxide fee is a regulation affecting many industries, including the cement industry. The Norwegian government implemented a CO_2 fee for the oil and gas industry in 1991. Still, due to the rising awareness of emissions, it was also implemented for other industries (Ministry of Finances, 2020). This carbon dioxide fee was implanted to ensure low emissions of greenhouse gases.

Norway's membership through the European Economic Area Agreement also means European law enforcements affect Norway and its industries. This law enforcement is a part of the executive goal of the EU to reduce the emissions by 55% from 1990 to 2030 (Ministry of Climate and Environment, 2014). As mentioned earlier, the ETS enforces taxations for emissions, which has been a part of the agreement between Norway and the EU since 2008. Through the ETS, it is for the Norwegian and European industry, a possibility buys carbon credits (Ministry of Climate and Environment, 2014). The idea of carbon credits is to allow for a

certain number of emissions, but over time the access to carbon credits will be reduced, resulting in less emissions. This is a governmental strategy for tackling global warming and reducing emissions. The European emission trading system, carbon credits, and the goals of the Paris Agreement and the UNs SDGs, create a fundament for the Norwegian government and industry to work toward reducing their emissions. The Norwegian cement industry is working toward lowering emissions by implementing new technology.

Chapter 3: Theoretical Framework

This chapter is set to present the theoretical framework that this thesis is based on. When applying a GVC framework, it is important to highlight dimensions of GVC theory which is essential in understanding how greening occurs in industries. I will also be further diving into the literature on EnvU in industries and look further into the different dimensions, drivers and barriers for EnvU. This is to provide the knowledge relevant to understanding how strategies for EnvU occur throughout a GVC. This chapter will end with a critical discussion of the chosen theoretical framework for the analysis.

3.1 Global Value Chain

The global economy can be seen as deeply interconnected, and more independent Global Value Chains (GVC) can be viewed as a framework for understanding the connectivity in the world economy. This theoretical framework was first introduced in the early 2000s (Backer & Miroudot, 2013). Using a GVC framework allows you to understand how global industries are organized by investigating the dynamics and structure of the actors involved (Gereffi & Fernandez-Stark, 2016). The concept is based on the configuration of multiple coordinated activities, divided between actors on a global scale (Poulsen et al., 2016). The GVC framework entails activities such as design, production, marketing, distribution, and support to the final customer, retail, and recycling. These activities are being distributed among firms on a global scale (Backer & Miroudot, 2013; Poulsen et al., 2016). To illustrate, a typical GVC would look like this:

Figure 5: Global value chain. Source: (Backer & Miroudot, 2013; Poulsen et al., 2016)

Global Production Networks and Commodity Chains can be applied to analyse global supply chains (Gereffi, 2014). All three of these frameworks focus on the global economic connection through chains of activity; the frameworks view the global economy as "*complex and dynamic economic networks made up of inter-firm and intra-firm relationships*" (Gereffi, 2014, p. 10). A theoretical framework like GVC is today an essential feature in understanding the global political economy due to its focus on the connectedness of the world economy and fragmentation of production.

In the GVC framework lies the curiosity of investigating and understanding the dynamics of the global economy (Backer & Miroudot, 2013). Historically, the idea of looking into production circuits on a global level can be found back in the 1970s, within the term *commodity chains* (Bair, 2009). The idea behind the commodity chains was to investigate all the inputs and outputs that result in a final product. In 1994 Gary Gereffi introduced the concept of *Global Commodity Chains* (GCC), which aimed to highlight how a product came to be from raw materials. The emergence of this framework was inspired by changes in industrial governance, organization, and international trade in the 1980s. This also marks the introduction of buyer-driven and producer-driven chains (Gereffi, 2014; Gereffi et al., 2005). When the 2000s came, the GCC was turned into GVC, which aimed to "*capture the determinants of the organisation of global industries*" (Bair, 2009). In newer times, the concept of GVC has also branched out into the *Global Production Networks* (GPN) concept. The idea of GPN was to investigate the importance of networks rather than chains (Backer & Miroudot, 2013). Although GCC, GVC, and GPN are somewhat different, they are all valuable tools and frameworks when analysing global economies and industries. All the other frameworks aim to look into the characteristics of the global economy as consisting of complex and dynamic economic networks and relations (Gereffi, 2014).

The emergence of GVC has also been an important driver for economic development at local, regional, national, and global levels (Neilson et al., 2014). Looking further into the background of the GVC framework, it has been used to investigate the characteristics of the world economy, such as the fragmentation of production on a geographical scale, the interconnectedness of economies, and the role of global networks. The GVC framework focuses on how value is created and captured through the different segments and sequences of the production. "*The value*

chain describes the full range of activities that firms and workers perform to bring a product from its conception to end use and beyond» (Gereffi & Fernandez-Stark, 2016, p. 7). Gereffi and Fernandez-Stark (2016) refer to the full range of activities such as research and development, production, design, marketing, distribution, and support to the final customer at the end. All these activities contribute to creating and capturing value throughout the value chain. These activities consist of intangible and tangible activities, but both the intangible and tangible contribute to the value-adding process (Gereffi & Fernandez-Stark, 2016; Ponte et al., 2019). The chain represents the entire in-puts and out-puts that a product or service consists of from the first conception to the end consumer. Based on this information, this is a helpful framework due to its ability to investigate development trajectories, internationalization, and greening of industries (De Marchi & Di Maria, 2019a).

When using a GVC framework for analytical purposes, it is analysed through different dimensions. When using this approach, there are six dimensions divided into global and local elements, whereas the global approach is seen as *top-down,* and the local approach is *bottom-up*. The global dimension is set to investigate international dynamics within an industry on a global scale; the local dimension looks more into how separate and individual countries, regions, and economic actors operate and participate within a GVC (Gereffi & Fernandez-Stark, 2016; Gereffi et al., 2005). Looking at Figure 4, it is apparent that governance is the central concept within the global approach. But as for the local bottom-up approach, upgrading is the crucial concept (Gereffi & Fernandez-Stark, 2016).

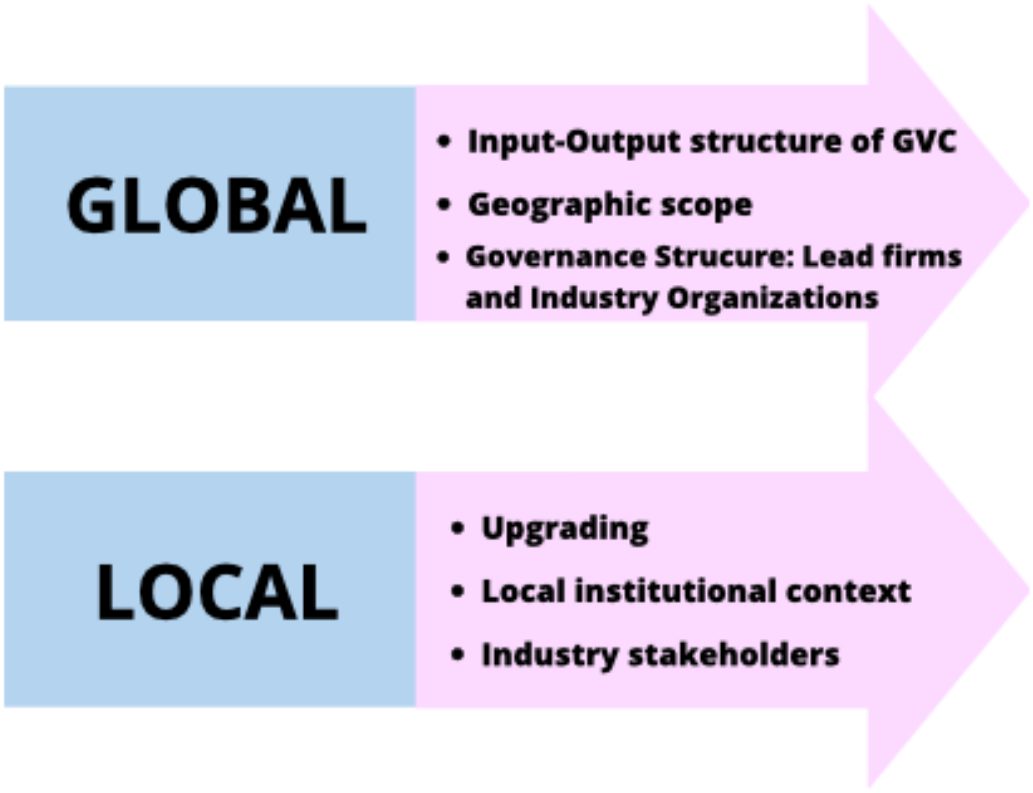

Figure 6: The dimensions of GVC analysis. Source: (Gereffi & Fernandez-Stark, 2016)

Today, industries have become increasingly globalized; this is due to advancements within both communication infrastructure and transportation (Gereffi & Fernandez-Stark, 2016). GVCs operate at different geographical scales, local, national, regional, and global. The cement industry often operates at national levels, meaning there is little international trade of cement.

3.1.1 Upgrading in Global Value Chains

Upgrading in GVCs is the key concept within the local bottom-up approach within GVC analysis. Upgrading in GVC is often occurring, according to Gereffi and Fernandez-Stark (2016), meaning that processes to upgrade or maintain the position in the global economy is often occurring. There are different types of upgrading, which can be categorized into social, economic, and environmental upgrading, although it is economic upgrading that traditionally has been studied the most. Upgrading can be viewed as the different strategies a firm, country, or

stakeholder implements to improve or maintain their position in the global economy (Gereffi & Fernandez-Stark, 2016).

Economic upgrading in value chains can be seen through four typologies; it is typically performed by a firm, country, or region moving toward higher value activities to achieve more significant benefits (Gereffi & Fernandez-Stark, 2016; Ponte, 2022). The four dimensions include process upgrading, meaning inputs are transformed into outputs with higher efficiency. Implementing new technology or reorganizing the system is needed to increase the efficiency of inputs into outputs. Product upgrading, entailing a more advanced product line. Functional upgrading entails moving from a part of the value chain associated with lower value capture, to conducting higher value capturing activities. Lastly, chain/inter-sectoral upgrading includes working towards a more technologically advanced chain (De Marchi et al., 2013). Social upgrading generally refers to upgrading and improving employment conditions, wages, and social standards (Khan et al., 2020; Ponte, 2022). Social upgrading emphasizes the importance of good social working conditions for workers within firms and the social rights of social actors.

This thesis will employ the local bottom-up dimension within GVC analysis due to its focus on upgrading within GVC. This perspective sheds light on the strategies countries, regions, and economic actors use (Gereffi & Fernandez-Stark, 2016). Applying this framework to investigate how strategies for EnvU are applied throughout the Norwegian cement value chain is appropriate because the relation between actors in the value chain is highlighted. It is then possible to see what is happening within the value chain, where, and by whom. At the same time, it also highlights how the Norwegian cement industry is geographically spread. GVC can help highlight actors and relations in the Norwegian cement value chain and how upgrading occurs. In terms of the local bottom-up perspective, where upgrading is the key concept, the thesis will investigate how environmental upgrading occurs.

3.2 Environmental Upgrading

When speaking of upgrading in GVC, a relatively new concept has arisen. Environmental and sustainable strategies in GVC have often been seen as *environmental upgrading* (De Marchi & Di Maria, 2019a). The need to analyse how industries improve their environmental impact

instead of their economic position has become increasingly more important for industries and understanding these processes. The concept of "environmental upgrading" was first introduced in the early 2000 (Jeppesen & Hansen, 2004, p. 263), which means that the analysis of EnvU is a relatively new concept. The initial definition of EnvU was "*environmental upgrading takes place when a company improves its environmental performance through changes in product and process technology, management systems, waste, and emission treatment, and so on*" (Jeppesen & Hansen, 2004, p. 263). Newer research upon EnvU defines it as "*the process of improving the environmental impact of value chain operations (including production, processing, distribution, consumption and disposal or recycling)*" (Poulsen et al., 2016, p. 60). In some cases, EnvU can reduce costs due to increased efficiency or reduced energy consumption. Other issues have shown that EnvU contributes to increased net value, such as certifications of environmental qualities and the creation and valorization (Poulsen et al., 2016). For this thesis, the second definition from Poulsen et al. (2016) will be the one that the thesis is based on.

The idea of EnvU is all about minimizing the environmental impact of the activities in a GVC (Poulsen et al., 2018). EnvU is somewhat different from the traditional ideas of upgrading within GVCs. Economic upgrading is based on moving up to a higher position in the value chain; EnvU focuses on reducing negative environmental impact through the value chain. The literature emphasizes the need for more distinction between an upgrading process and an upgrading outcome (Khan et al., 2020). Upgrading can be seen as the specific strategies and choices made and adopted by countries, industries, and firms to capture more value within GVCs. Upgrading as an outcome can be seen as the actual results and achievements of greater value addition and profitability. When it comes to EnvU, it is then essential to consider both process and outcome and understand both. Not only investigate the process of EnvU but also look at the actual outcomes. The process trajectories that lead to a better environmental outcome while reducing environmental impact.

Four different typologies have been identified regarding EnvU (De Marchi & Di Maria, 2019a); these typologies range from process EnvU, product EnvU, and organizational EnvU. But in 2021, a fourth typology was suggested to be added to EnvU, *product end-of-life improvements* (Hansen et al., 2021). EnvU in a process involves redesigning the process or investments in technology to decrease environmental damage and increase efficiency from an environmental

perspective. EnvU in a product entails offering more environmentally friendly products. This may include transforming the existing product into a more environmentally friendly one or extending the life cycle. Product EnvU also opens for innovation by launching new products with more sustainable inputs. The following typology identified within EnvU is the organizational EnvU, which includes the processes within the organization, such as managerial practices. These managerial practices recognize environmental requirements and pressures (De Marchi & Di Maria, 2019a). These typologies are the different forms of EnvU that can occur within economic actors. The newly introduced and last typology is related to product end-of-life improvements. This final typology refers to how firms, suppliers, and customers reduce their end-of-life waste flows by including waste collection and management and recycling as a part of their products and production (Hansen et al., 2021). These initiatives related to waste collection and recycling are something that can be done by the firms themselves but are often outsourced. This is relevant regarding value chains and how to create sustainable value chains.

3.2.1 Strategies for Environmental Upgrading

Research has identified the different strategic approaches in the process of EnvU. Hansen and Jeppesen (2004) present the idea that lead firms engaging in the EnvU processes in the GVC can differentiate between deep and shallow strategies. Another emerging approach is the drivers for the greening process, which can be distinguished between standard-driven and mentoring-driven greening (Poulsen et al., 2016). The standard-driven greening process is when lead firms work to identify the main environmental impacts in the value chain that needs to be reduced, and from then, in charge of how to deal with how to reduce it. The information on the identified environmental issue is then made into a standard, which the suppliers need to comply with (De Marchi et al., 2013a; Poulsen et al., 2016).

The standards applied are related to products and processes; the standard is set for the suppliers to ensure green product production. The standards are employed through a strong form of monitoring and knowledge sharing. This standard-driven greening is efficient in terms of greening the production process. This form of standard-driven greening can be seen as a form of shallow strategy from lead firms. This is because the motivation and drive for engaging in environmentally friendly development occurs through meeting standards. This strategy is

effective when lead firms seek to identify environmental impacts in production processes. It is also linked to when suppliers meet standards through different certifications, which can also be complied with protocols (Khan et al., 2020).

Another strategy linked to EnvU is mentor-driven greening. This strategy is based on personal interactions between lead firms and suppliers, and the actors are mutually dependent on knowledge and skills in this type of greening (De Marchi et al., 2013a; Poulsen et al., 2016). This type of greening process is linked to deep strategies and engagement because of the importance and focus on personal interactions, trust, reputation, and face-to-face meetings. It is also common in mentor-driven greening that lead firms exert leadership on the environmental knowledge while the suppliers take the lead on the technical expertise (De Marchi et al., 2013a; Khan et al., 2020; Poulsen et al., 2016). Mentor-driven greening and deep strategies occur when standards are unavailable, or the suppliers lack the capacity to comply.

3.2.2 Drivers and Barriers for Environmental Upgrading

Research also defines the drivers and barriers to implementing strategies to achieve EnvU. As for the drivers, there are both internal and external drivers. One of the identified external drivers is related to market demands, requests from stakeholders, and the need to cope with external regulations, opportunities related to collaboration with GVC partners, and institutional contexts (De Marchi & Di Maria, 2019a). The internal drivers are associated with the internal conditions within firms and economic actors. These internal drivers and conditions are proactive leadership, values, corporate cultures, reputation, and market drivers. These forms of internal drivers are often linked to new market opportunities. Considering external and internal drivers simultaneously will provide a more holistic analysis (De Marchi & Di Maria, 2019a).

Another approach when looking into drivers is environmental innovation. The environmental innovation approach identifies three main drivers: technology, regulation, and market. The first driver is technological innovation, which can be seen as a *technology-push*. This technology-push is seen as new technical solutions for process developments or product production and new materials that allow firms to reduce negative impacts on the environment (De Marchi & Di Maria, 2019a). Developing new technologies is important to enable a more environmentally

friendly transition. The second driver, regulation, is important due to government demands concerning product and process standards. The regulatory standards may often be related to more sustainable and environmentally friendly products and processes. This can be seen as a form of a government push to adopt these changes to be environmentally friendly (De Marchi & Di Maria, 2019a). The last and third driver is the market. The rising demand for more environmentally friendly and green products from the market and consumers is seen as a *market-pull.* Customers being more aware of the products in the market and the impacts on the environment results in new demands in the market and is, therefore, a strong driver for firms to become greener and environmentally friendly (De Marchi & Di Maria, 2019a).

Internal Drivers	**External Drivers**	**Environmental Innovation**
Proactive leadership	Market demand	Development of new technologies (technology-push)
Values	Requests from stakeholders	Demands from the government
Corporate cultures	Coping with external regulations	Demands from the market (market-pull)
Reputation	Opportunities for collaboration with GVC partners	
Market drivers	Institutional context	

Table 1: Overview of Drivers for Environmental Upgrading. Source: (De Marchi & Di Maria, 2019a)

Although there are many drivers, there are also barriers to environmental upgrading. Barriers may differ from industry to industry due to different contexts surrounding the appointed industry. However, research has identified some relatively common barriers in terms of EnvU. As mentioned, a regulatory framework and law enforcement are important drivers in EnvU; however, they can also act as a barrier. Regulatory frameworks can become a barrier when fragmented and uncertain (Poulsen et al., 2016). Another challenge that may occur while

achieving EnvU is the competitive market. Although a competitive market for achieving EnvU is often seen as a driver, it can also be seen somewhat as a challenge. The awareness of consumers and customers has increased simultaneously as firms widespread work to achieve EnvU (Poulsen et al., 2016). This has resulted in first movers in EnvU processes losing their competitive advantage on achieving EnvU (Khan et al., 2020).

3.3 Theoretical Proposition

To discuss the chosen theoretical and analytical framework for the selected research topic, I would like to present a theoretical proposition based on the theory presented in Chapter 3, even though this thesis will draw an analysis based on all the theories presented. However, I would like to highlight the aspects of the theory of higher importance in the research.

Starting with the typologies of EnvU presented in subchapter 3.2. These typologies will be important because the analysis will be structured around these four topics. The analysis will draw on the four typologies: process EnvU, product EnvU, organizational EnvU, and product end-of-life EnvU. The analysis will be structured around these typologies to highlight where the different strategies for EnvU are occurring in the different typologies of EnvU. At the end of the analysis, I will illustrate the strategies occurring through a value chain in a table. I will also include concepts such as value chain cooperation because this thesis will likely show that strategies for EnvU are happening in GVCs with strong cooperation, adaptability, and long-term investments in green technology. Moreover, the thesis will also include drivers and barriers as a part of the analysis to add dimension to the complexity of achieving EnvU in the cement industry. The strategies identified through the analysis will also be evaluated through theoretical perspectives of EnvU strategies, deep and shallow strategies, as presented in subchapter 3.2.1.

The theory presented in Chapter 3, both theories related to EnvU and GVC, is expected to be used in the analysis. However, to highlight the strategies occurring, the theoretical concept of EnvU will be used as the main framework. GVC is of equal importance, GVC theory will be part of the analysis in terms of a local bottom-up perspective highlighting the importance of upgrading.

Chapter 4: Methodology

This project has been submitted to and approved by NSD (Norwegian Centre for Researched Data). This chapter will describe and discuss the research methodology employed in this thesis. First, I will present and discuss the research approach and how it has been applied to the project. Secondly, I will further elaborate on the data collection and analysis method applied; I will also discuss the quality of the chosen research approach and any limitations of this approach. This chapter will finish of with ethical considerations and discussion.

4.1 Research Approach

When researching the topic of strategy for environmental upgrading in the Norwegian cement value chain and how the actors in the value chain strategically work to reduce their emissions, there are multiple fitting research approaches. However, a qualitative case study was chosen as my research question's most relevant research approach. For data collection, qualitative semi-structured interviews will provide an in-depth perspective on the topic. This qualitative case study also will apply the theoretical perspectives of GVC and EnvU to understand and analyse the case and the empirical data.

With a qualitative research approach, you can gain deep insight and understanding of a topic or phenomenon (Crang & Cook, 2007). The characteristic of qualitative research is the data being interpreted, which is empirical rather than numerical. According to Crang and Cook (2007), the qualitative method acknowledges the empirical data, providing an inductive approach due to linking empirical data and theory (Hay & Cope, 2021). Qualitative research also considers epistemological aspects and the different ways of knowing (Hay & Cope, 2021).

This master's thesis is based on a case study. "*A case study is an empirical inquiry that investigates a contemporary phenomenon in depth within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident"* (Yin, 2009, p. 18). When employing a case study method, one would understand a real-life phenomenon deeply.

However, the phenomenon's surrounding context is highly relevant (Yin, 2009). The cement industry will differ from country to country; various contextual factors should be considered when studying this phenomenon. Therefore, a case study on EnvU in Norwegian cement value chain is appropriate because it will highlight the surrounding context. Getting a holistic view of all the factors contributing to the case is important. Due to it being a case study, transferability can be limited; however, similar industries with similar sustainability goals/targets can learn from this study.

Even though a qualitative research approach can provide deep understanding, it also can provide some issues. These issues may include the research being perceived as more subjective than objective due to the personal involvement (Hay & Cope, 2021). During my research, I have been careful and put my thoughts and opinions on the matter aside, especially during the interpretation of the data. Another challenge is the transferability of the knowledge produced in qualitative research. Transferability is identifying trends and similarities in similar contexts of the specific research (Hay & Cope, 2021). Transferability can be challenging when studying complex and changing phenomena. Such as the cement industry in Norway; when researching this topic, I need to consider the changing nature surrounding the industry. Change is a part of this research project because of its focus on processes of EnvU. There are also changes in the world economy, and global problems arise and become highly relevant to the rest of the world, especially concerning the environment. Therefore, change needs to be considered.

Speaking of change, qualitative methods rarely follow a linear "read-then-do-then-write" (Crang & Cook, 2007, p. 4) research order. Crang and Cook recognize the unpredictability and chaotic nature of the process. Awareness that qualitative research is non-linear is important because it can change during the process. However, not being bounded to follow a specific structure, provides freedom to work parallelly with data, theory, and writing. It gives a freedom of structure. In this thesis, there has not been an entirely linear process. Reading, interviewing, gathering data, and writing have been occurring simultaneously. Since a qualitative research approach provides this freedom of research structure, it has been more feasible to see connections from theory, literature and empirical data.

4.1.1 Critical Reflexivity

Discussing my influence on the research is important because being objective in research projects is important. Even though my thoughts and opinions has been set aside during the research, it does not mean I have not influenced the research. Discussing reflexivity and self-reflexivity, it is essential to be critical. It is important to take critical reflexivity into account when conducting qualitative research. Reflexivity is "*the dynamic interplay whereby participants may be influenced by the presence and actions of the researcher, and conversely the influence on the researcher's thinking and observations resulting from the presence of and actions of the participants*" (Yin, 2011, p. 312). Based on this quote, the influence goes back and forth between the researcher and the participants. It is also important to consider the self-reflexivity. This is based on the reflexive conditions that can be identified in the study that may affect the results and conclusions of the research (Yin, 2011). Applying this to my thesis, I would like to identify my influence in different parts of the research.

Critical reflexivity is recognizing how a researcher's situatedness affects the research (Hay & Cope, 2021). Starting chronologically, the research question is formed by me; in terms of reflexivity, I have, from the beginning, shaped how this research will go from what I have chosen to investigate. Also, during the methodological planning, I wrote the interview guide and formulated the questions. However, I did base the questions on the theoretical approach employed in the thesis, but it does not mean I did not influence the questions. When analysing the data, it has been coded and set against the theory, but I still interpret it. This is an important topic to discuss because research can never be 100% neutral; both I and the participants influence the process and results. This also means this research cannot be replicated identically because it is my research.

4.2 Data Collection

This project has applied to both primary and secondary sources of data. The primary data has been collected through semi-structured interviews with informants from different Norwegian cement value chain actors. Due to geographical distances, the interviews were conducted through the digital platform Microsoft Teams. There have also been representatives from beyond the

Norwegian border; Microsoft Teams then enabled me to conduct those interviews. The secondary sources employed in this project are peer-reviewed scientific papers, articles, governmental documents, and white papers on cement technology.

4.2.1 Semi-structured Interviews

According to Hay and Cope (2021), interviews as a research method are used for four primary purposes; gaining insight into the complexity of motivation and behaviours, gathering a diversity of meaning, and to show respect and empower the ones being studied, and filling knowledge gaps. When doing research through interviews, the styles vary through structured, semi-structured, and unstructured interviews. Interviews help fill gaps in knowledge and provide knowledge you could not access elsewhere. Hereunder, semi-structured interviewing helps fill gaps in the knowledge, gather a diversity of meaning, and gain deep understanding.

I chose to conduct semi-structured interviews because when studying a complex topic – EnvU in GVC – the semi-structured interview can provide possibilities (Galletta, 2013). The semi-structured interviews allowed me to ask follow-up questions and have more of a conversation around the topic. I also chose this method because it is both flexible and predetermined. Flexible through the ability to ask follow-up questions and predetermined due to the preparation beforehand through research on the topic and preparing the interview guide (Hay & Cope, 2021). By interviewing central actors within the cement industry, the data has given me greater insight into the processes and strategies of EnvU and reducing emissions. The knowledge I have gained through the interviews, which I will also present in later chapters, holds transferability. The knowledge gained through the interviews and the research can be transferred into other industries working with EnvU or the reduction of GHG.

4.2.1.1 Preparing the Interviews

Before I started the interviews, I did preparation work. This included doing background research on the industry's emissions and central actors, creating a theoretical fundament, and preparing the interview guide, which can be found in the appendix. To complement my semi-structural

interview method, an interview guide, instead of an interview schedule that focuses on following the exact questions, felt most appropriate due to being less structured (Hay & Cope, 2021). Much work was put into the interview guide (see **Appendix A**), because I wanted to ensure the questions were clear, coherent, and easy to understand for every participant. The interview guide started with general and open questions, enabling the participants to tell me what they felt were important. After the broad and open questions, I aimed toward the value chain and internal and external drivers and barriers of EnvU. From there, I found it appropriate to ask questions related to the different dimensions of EnvU. When the interview moved to an end, I closed the interview by asking if there were something they would like to mention before ending.

The interviews were initially conducted in Norwegian. However, some informants did not speak Norwegian due to not being from Norway. This resulted in translating the interview guide into English; I then found it more challenging to translate the question and maintain clarity of the questions. The interviews followed a funnel structure, starting with more general questions before moving toward more specific questions.

4.2.1.2 Snowball Sampling

The informants in a project can be viewed as the building blocks due to their knowledge about the researched topic and their ability to fill knowledge gaps (Galletta, 2013). All the informants in my research worked within the cement industry. There are different ways of approaching and sampling the participants for research projects; I employed the "snowball sampling" method for my project. This method entails asking participants for recommendations for other relevant individuals willing to participate (Galletta, 2013). This method of sampling my participants was the most feasible method due to a lack of information online on who would be most fitting to contact. When I started the sampling, I sent a general email to the communication department of Norcem, asking to be referred to a relevant individual with a suitable position in the company for my thesis. From there, this respondent again referred me to a set of their customers. This was very useful but limiting due to not being referred to any suppliers. But when this respondent referred me to their customers, the respondent also referred me to their head of Research and Development (R&D). After the interview with the head of R&D, this respondent referred me to

their supply manager. I then got the contact information from their suppliers and arranged interview sessions with some of them.

Firm	Informant	Coded in analysis
Multinational Building Material Company	Sustainability Manager	Respondent A
Norwegian infrastructure Company	Director for Sustainable Business Development	Respondent B
Norwegian Cement Manufacturer	Research and Development Manager	Respondent C
Norwegian Governmental Construction firm	Director of sustainability	Respondent D
Norwegian Concrete supplier	Technology manager	Respondent E
Norwegian Concrete supplier	Technology manager	Respondent F
Norwegian Raw Material supplier	Chief Executive Officer	Respondent G
Belgian Raw Material supplier	Chief Executive Officer	Respondent H
German Raw Material supplier,	Sales manager	Respondent I

Table 2*:* Overview of Respondents

Some challenge occurring with this method is that the confidentiality of some of the participants was not remained (Galletta, 2013), this is due to when I was referred, I also had to introduce the participant that referred me, meaning the confidentiality did not remain in that context. Another challenge was that only some potential participants replied to my inquiry about participating in the project. I found it hard to identify the boundaries of the appropriateness of sending a follow-

up email even though they had yet to reply. However, in some cases sending that follow-up email did result in an interview session. But also, in other cases the email was yet again not replied to.

4.2.1.3 Conducting and Transcribing the Interviews

As mentioned in subchapter **4.2.1.1**, extensive time was set to prepare for the interviews. I gained much knowledge by studying and analysing the existing literature, news articles, webpages, and governmental reports. However, some gaps needed to be filled through the interviews. Through the preparation work I did before the interviews, I found inspiration for the questions and the themes in the interview guide (**Appendix A**). The themes of particular interest were:

1. Their vision for the company/industry
2. External and internal drivers for EnvU
3. External and internal barriers for EnvU
4. Different activities for EnvU (process, product, organizational, product end-of-life) in the various segments of the value chain
5. The value chain
6. How the different actors work with strategies for EnvU in the value chain

The interview guide was a valuable tool to ensure the direction of the conversation, but still with flexibility due to the semi-structured style. As mentioned earlier, this method provides the chance to ask follow-up questions. When doing so, being enlightened on the topic is advantageous when limited knowledge can exclude other appropriate questions. Therefore, good preparational work is advantageous for gaining as much knowledge as possible through the interview.

Research has been modernized by the ability to conduct research online. All my interviews through the research have been conducted through the digital platform Microsoft Teams. The informants provided thorough and detailed descriptions of the topic through the semi-structured interviews. Even though the interviews were digital, it did not take away the face-to-face interaction, which is important in the relationship between the researcher and the informant. This

also enabled the opportunity to interview informants with geographical distances within Norway and spreading into Europe.

As mentioned, I conducted semi-structured interviews and chose to do this due to its flexibility. Due to the flexible nature of semi-structured interviews, the time of the different interviews varied. The time of the interviews ranged between 30 minutes to 1 hour and 15 minutes. When doing the interviews through Microsoft Teams, I used the function that both recorded and transcribed the interview. With the digital function of transcribing the interviews, I could be more engaged in the interview and conversation; this ensured that my attention and focus was entirely on the interview. However, if the informant said something of particular interest, I noted it, so I remembered. These types of interviews also allowed the informants to communicate their opinions and knowledge more freely; therefore, it is also important to engage in a conversation, which ensures the expression of knowledge more freely. Remembering that one cannot guarantee a fully honest conversation is important. The risk of honesty in a conversation can be minimized by ensuring anonymity. The interviews with the Norwegian participants were conducted in Norwegian; this made it easier for the informants to speak more freely. However, it did make the coding of the interviews more challenging due to the translations.

All the interviews have been transcribed parallelly as the interviews have been conducted. As mentioned, a transcribing function was used during the interviews. This resulted in most parts of the interviews being transcribed as the interviews were conducted. This function was very useful and made the transcription process more manageable. However, it did not transcribe perfectly. With different Norwegian accents and variations of microphone quality, it only sometimes caught the right words; this resulted in me correcting the errors in the transcript from Microsoft Teams. It is important to transcribe the interviews, although it is time-consuming and resource-intensive (Hay & Cope, 2021), which is why I also chose to use the transcribing function to save time. The transcripts of interviews are the data that is being analysed. Therefore, it is important to have thorough transcriptions (Hay & Cope, 2021).

4.2.2 The Challenges and Opporutinities of Digital Interviews

Throughout this project, all the interviews have been conducted through Microsoft Teams' platform. Therefore, I would like to discuss the challenges and opportunities I have experienced through the interviewing process. One challenge that may occur in a digital interview is that technological failures can occur. Also, internet access may vary (Hay & Cope, 2021). Another challenge Hay and Cope (2021) emphasizes is the ethical challenge concerning the powerful record consisting of both audio and video. Some of these challenges have occurred during my interviews. Concerning technical failures, I experienced lagging from both sides during the interview. Luckily, when lagging, it has mostly been from my side. Therefore, it has not affected the audio due to it being recorded from both sides. The lagging mainly occurred when conducting interviews from home. Due to the varying access to quality internet from my side, I connected my computer to my phone 4G, when conducting interviews from home. I decided to do this because it is more stable.

There are also many advantages and opportunities with digital interviewing, including keeping face-to-face interaction during video interviews. This has a lot to say in developing the researcher-informant relationship. Another advantage of digital interviewing is that it can also humanize the experience (Hay & Cope, 2021) when seeing their office, home space, or other domains. It has also provided the opportunity to interview people with greater distances within Norway and stretching into Europe. I would not have been able to interview the participants from outside of Norway if I could not do it digitally.

4.3 Analysis Method

I have chosen to conduct a theoretical analysis to analyse the gathered data. I will analyse the data through the theoretical concept of EnvU and GVC. I have decided to do this because I am looking at the strategies through the value chain (*GVC*) for *EnvU*. When analysing the data, I will look at the different typologies within EnvU; process upgrading, product upgrading, organizational upgrading, and product end-of-life upgrading (De Marchi et al., 2019b; Hansen et al., 2021). It is also fitting to conduct a theoretical analysis because many of the questions in the

interview guide (Appendix A) are based on these typologies in EnvU. Therefore, it is appropriate to conduct the analysis through a theoretical approach.

To establish an overview, I mapped out the different dimensions of EnvU, the various segments of the value chains, and the firms the informants represented. From there, I tried to identify the different dimensions of EnvU within the mapped-out value chain and which actor did what. Hereunder, I also looked into why they implemented the strategies to get an overview of drivers and potential barriers. When doing this, the coding of the interviews was necessary. When coding, I placed the responses from the different informants in categories based on the dimensions of EnvU. When doing so, it was easier to investigate the different strategies in the different dimensions.

4.4 Quality of Research Design

Validity and reliability are two essential factors to consider when doing research. Validity refers to the truthfulness and integrity of the data in the research (Hay & Cope, 2021). This is important to evaluate the quality of the research design. To assess the quality of my research design, I will look further into internal validity, external validity, and reliability (Yin, 2009). Starting with internal validity, which concerns causality, means that the research has been able to create a causal connection from the data that has been collected (Yin, 2009). Therefore, it is essential to have multiple sources to collect data from various sources to create a stronger connection. The external validity concerns the research's ability to be generalized (Yin, 2009). The research and the conclusion drawn from the findings in this thesis can be generalized. The conclusions drawn can to some degree be generalized for the cement industry, or similar industries, in other countries as well. However, one needs to consider the industry's changing environment, and this thesis is also focused on a specific country changing context.

Reliability is similar to transferability, as discussed earlier. Reliability focuses on the research's ability to replicate (Yin, 2009). However, as mentioned, the concepts studied in this thesis are changing, such as the market and the environment. Since these concepts are always changing, replicating the research may be challenging. What is found in this research might be completely different in a year or two. Also, by analysing the data material through a theoretical lens might

also contribute to challenging replicability. This is also why it is important to study topics like this, because it is highlighting the changing world. Understanding what is happening now is important for what is happening in the future.

4.5 Limitations of the Research

Although the chosen methodological approach has provided many possibilities, it is also important to investigate the limitations that has occurred during the research process. A challenge and limitation have been translating the interview guide from Norwegian to English when interviewing foreign informants. Out of nine interviews, two of them were conducted in English. The English interview guide led to some confusion around the actual meaning of the questions, resulting in me needing to explain the question. When explaining the questions, I felt like it made the questions more leading.

Another limitation is that with both the limited time and scope of the thesis, I have not been able to interview as many participants as I wanted. Ideally, I would have been able to interview more parts of the value chain, but with limited time and replies, I could not do so. By doing so, the total representation would be higher and include other important industry aspects, which would have provided a more holistic view and knowledge of the value chain.

4.6 Ethical Considerations

Including and discussing ethical considerations when conducting qualitative research is essential. This research's ethical considerations concern mainly anonymity, participant consent, and harm. Understanding the ethical issues is contributing to the credibility of the research, as well as it highlights the respect for the participants in the study.

When doing qualitative research through interviews, as I have done for this thesis, personal opinions and information comes through (Hay & Cope, 2021). Therefore, I have chosen to anonymize the participants throughout the thesis (Table 2, p. 32). This is also out of respect for the participants' privacy. Ensuring privacy and anonymity can contribute to a more honest conversation with the participants, which is important when gathering data. Since the interviews

were conducted digitally, both the video and audio recordings and transcriptions have been worked with privately. These documents have also been saved with password protection. This has contributed to minimizing the risk of losing privacy, anonymity, and exposure to harm. By coding the participants (Table 2) through the analysis I have done all I can to ensure privacy and anonymity, but there is always a risk of tracing the participants.

Consent is another aspect of the research that needs to be respected. Informed consent is when the participants for the research have been provided with as sufficient information as possible and required about the project, which makes them able to decide if they want to participate or not (Hay & Cope, 2021). When reaching out to the participants, a formal consent form (**Appendix B**) was sent to provide the information needed, together with the interview guide. The form includes the project's aim, what the data will be used for and why, and how I will handle it. It also includes information about their rights during the project, such as their right to withdraw their consent without justification. The consent form was submitted and approved by NSD. At the start of each interview, I started by asking if the consent form was ok and if there were any questions about their rights as participant, and from there asked for oral consent before starting the interview.

Chapter 5: Theoretically Derived Analysis and Discussion

This chapter will present the following findings gathered throughout the research project. The findings presented are collected through a total of nine semi-structured interviews; the findings analysed will be simultaneously discussed with secondary literature and research, as well as relevant examples. Remembering the definition of EnvU presented in Chapter 3, "*the process of improving the environmental impact of value chain operations (including production, processing, distribution, consumption and disposal or recycling)*" (Poulsen et al., 2016), I will be using the four typologies from the theoretical perspective EnvU to analyse and discuss the empirical data: product upgrading, process upgrading, organizational upgrading, product end-of-life upgrading. This way, identifying specific strategies within the different aspects of EnvU will be easier. Before analysing the different dimensions, I will also look into the drivers and barriers for EnvU in the Norwegian cement industry, to look into the landscape of why strategies for EnvU are implemented. Lastly, I will present the strategies and how they occur through the value chain through a table. This way, I will be shedding light on the complexity of the process of achieving EnvU through the value chain.

Before starting the theoretically derived analysis and discussion, I would like to present the research question for this thesis again, as presented in Chapter 1.

> *Which strategies are implemented throughout the Norwegian cement value chain to achieve environmental upgrading?*
>
> *Why is the Norwegian cement value chain working to achieve environmental upgrading?*

With these research questions, the first one will focus on the specific strategies applied through the value chain, analysed through the four dimensions of EnvU. As for the second research question, the focus will be on identifying and analysing the drivers and barriers of EnvU occurring.

5.1 Norwegian Cement Industry

To conceptualize and contextualize the EnvU processes occurring in the industry, I want to look back into the Norwegian cement industry. The cement industry is complex and consists of different segments and actors that all contribute to the final product of cement, and later concrete used in the construction industry. Therefore, implementing strategies to reduce emissions to reach the goals set in different agreements. Several strategic approaches can be implemented to achieve EnvU, and although there are many drivers to promote such developments and solutions, there are also barriers. The drivers and barriers push or pull the industry in developing strategies and solutions for tackling the problem concerning reducing GHG emissions or delaying the development of further greening of the industry.

Global value chains enable the production and distribution of cement. Even though cement is a substance that is mostly locally produced and not internationally traded, the GVCs related to the cement industry still stretch across international geographic borders. The GVC for Norwegian cement production serves Norwegian construction, industrialisation, and urbanization, contributing to important value creation.

Figure 7: Norwegian Cement Value Chain

Looking at Figure 7, we can see the value chain segments in the Norwegian cement industry. The first step is the different raw material suppliers, who supply some of the components in the cement. These materials are then transported to Norcem. The production of cement, as well as concrete elements, is occurring within the cement producer. After being produced, the product is then further transported to its customers.

5.2 Drivers and Barriers for Environmental Upgrading

Investigating the drivers and barriers of EnvU is important for this thesis due to its ability to highlight both motivations and obstacles in working toward achieving EnvU. The informants were asked about internal and external drivers and barriers in the nine semi-structured interviews. My finding varies from internal values to governmental initiatives resulting in a push to become greener.

5.2.1 Drivers

There are many different drivers to look for and consider when analysing the greening of industries. The drivers presented in table 1 are the ones I will be focusing on when analysing the drivers for EnvU in the Norwegian cement value chain.

> "We are in the carbon credits regime, so we have been allowed a proportion of carbon credits for emitting CO_2, but there will be fewer and fewer of these carbon credits, so then we must buy more and more in order to maintain the same production if we do nothing. Then of course, implementing CCS, we do not have to buy carbon credits. The price of these has risen drastically in the recent years, so it is undoubtedly an economic motive … So, that is the completely selfish reason for it" (Respondent A)

As Respondent A, representing the production segment of the value chain, argues, the carbon credit regime, which is strategic law enforcement from the EU ETS and Norwegian government, is a driver to become more sustainable. The carbon credits are developed from the EU ETS and has been a part of Norway since 2008 (Ministry of Petroleum and Energy, 2014). This law enforcement has become an external driver in coping with external regulation. It is driving the cement industry to be sustainable due to its economic inefficiency by not doing so. According to Respondent A, this has also motivated the development of CCS. The idea of the carbon credits is to push industries to find new solutions for their emissions, which is why fewer credits each year (Ministry of Petroleum and Energy, 2014). As seen through the CCS project, this strategy from EU and the Norwegian government has resulted in new solutions for emissions in the cement industry. This is, according to theory, a technology-push (De Marchi & Di Maria, 2019a). This is due to new and innovative technology allowing for process and product solutions regarding

emissions. This technology-push through the CCS technology is an important driver in further transitions in the green shift for other industries, which can also invest in such technological facilities.

Another driver for Norwegian cement industry is the wish to become more sustainable than other competitors on the market and to deliver better and more environmentally friendly products than competitors (Respondent A). According to theory, the drivers Respondent A can be seen as external drivers (De Marchi & Di Maria, 2019a).

> "We also have motivations to actually be better because it is better for society" (Respondent A)

Respondent A further elaborates that there are internal drivers as well. As seen through the quote, there are motivations to be better for society. This motivation and driver can be seen as an internal driver in terms of market demands (De Marchi & Di Maria, 2019a). There is a demand from the market to become more sustainable, and by doing so, it is also better for society. Respondent C, also representing the manufacturing segment, argues that if they do not work voluntarily to reduce their emissions, there will be enforcement to reduce emissions. Another identified driver for the cement producer is the demand from the market for low-emission cement products. This is theoretically viewed as a market-pull since they experience expectations from the market in terms of what the customers want. Market-pull, market demand, and market driver are seen as both internal, external, and environmental innovation drivers (De Marchi & Di Maria, 2019a), and in this context, there is an interplay of these drivers resulting in new technological solutions product development and meeting the markets demands and needs. Respondent A recognizes the competition regarding raw materials and resources and finds using recycled raw materials and minerals from waste is more efficient than mining new metals and minerals. This strategy also contributes to fulfilling the market wishes through the market-pull Respondent C talked about.

On the customer side of the value chain, Respondent B provided examples of how some of their internal drivers became important.

> "Many years ago, one of our customers scolded one of our directors for not doing more to be sustainable. This resulted in becoming more motivated to be sustainable"

As Respondent B argues, this example resulted in becoming more sustainable and became an internal driver to be sustainable. Further, Respondent B also elaborate on how sustainable values are important for them as an organisation. There are also external drivers that Respondent B highlights: being more attractive on the stock market when having sustainable values and becoming more environmentally friendly. This can also be seen as a market-pull. However, Respondent B's said experience has also contributed to a set of values and proactive leadership, which are common in internal drivers (De Marchi & Di Maria, 2019a).

An external driver affecting most of the informants in this project are the Paris Agreement and UN SDGs. The Paris Agreement and UNs SDGs are frameworks and goals that contribute to driving the industry to become environmentally friendly, and can be seen as an external driver, by coping with external regulations. Respondent D argues that their greatest driver and motivation as a governmental firm is the Paris Agreements' goals. Respondent D also argues that other than the Paris Agreement, having competence regarding emissions and negative impact is important for their work. Respondent E also exemplifies the Paris Agreement as a driver for their work in reducing emissions. Respondent E also argues that different certifications also drive them, but they also have internal values regarding the wish for longevity in their products. However, many firms are working within these goals as a set of values. Therefore, The Paris Agreement and UNs SGDs can also be seen as an internal drivers due to it becoming a value.

> "We want our grandchildren to be able to drive over the same bridge as we do today" (Respondent E)

Respondent F also argues that it is the demands from the market and customers that are the most significant driver for them as a company to become more sustainable, which is seen as an external driver as market demand and market-pull. My findings suggest that there is an interplay of different drivers, both internal and external. According to theory, the drivers presented by Respondent D, E, and F are mostly seen as external drivers. However, through the interviews, all the informants do further tell about values in the organization and structures and proactive leadership, which are recognized as the internal drivers (De Marchi & Di Maria, 2019a). The drivers are equally important for the firms in the value chain and are resulting in proactive work for green transitions.

In the supplier segment of the value chain there are identified different drivers. This is also because two suppliers are not working within the Norwegian governmental framework. As for respondent G, who is the Norwegian raw material supplier:

> "No, we do not have any internal values regarding the environment. But you do have to contribute to the environment in your own way."

As Respondent G says, there are no internal drivers for their firm to become more sustainable but does recognize the need to do something. However, this is through the expectations from the state and the municipality. Therefore, external drivers are the main motivation for Respondent G. Respondent Hs company, which supplies raw materials as byproducts from other industries, has based their entire company and business model on internal drivers. Their business idea is to be sustainable and reduce the mining of raw materials. Therefore, their drivers and motivations are seen as internal, in terms of values, proactive leadership. Respondent I, who is also a supplier of waste raw materials, argue that their firm is operating on recycling

> "We want to be a part of the recycling industry in Germany. And we are a part of the general phrase of sustainability. We are taking care of and saving natural products and using alternative raw materials. This is our focus" (Respondent I).

Respondent I argue that there are strong internal drivers regarding values and their overall business, similar to Respondent H.

As seen through my findings, internal and external drivers affect the value chain processes, both equally important to provide a holistic view (De Marchi & Di Maria, 2019a). The informants from Norway mostly focus on the importance of reaching official goals set through the Paris Agreement, but also have values and proactive leadership in their firms. This shows an interplay of both internal and external drivers, as well as environmental innovation as a driver. The implementation of CCS in Norwegian cement production and industry is an environmental innovation that can become a driver for other industries. There are also expectations and demands from customers and the market, both in terms of how the products should be produced and made of and the need to focus on their internal values. There are also initiatives and law enforcement from the EU and the government such as the carbon credits; this is also an important driver. Even though it is an external driver, my findings suggest that it has been a

central motivation for developing CCS technology and implementation. Therefore, it is evident that in the Norwegian cement value chain, there is an interplay of internal, external, and environmental innovation drivers.

5.2.2 Barriers

When it comes to the drivers identified through the data, it is evident that my findings suggest financial barriers in the EnvU processes. EnvU theory emphasises that barriers may differ for different industries (Poulsen et al., 2016) because of different contexts and frameworks for industries. In this thesis, the main barrier identified has been economic barriers. Respondent A mentions high costs in terms of the CCS project, which is an important part of the EnvU process. Further, Respondent A argues that if the Norwegian government did not fund parts of this project, it would not be possible to go through.

> "It is a huge cost implementing this CCS technology. But it is truly a great investment for the company" (Respondent C).

Therefore, it can be seen as an internal barrier in terms of their financial capacity to go through with the project. Therefore, it would likely be impossible without financial funding from the government (Respondent A). Several of the informants emphasizes financial barriers. In terms of it not always being cost-effective. It is often a matter of cost if it is expected to use more green materials and products. Respondent B also argues that being more sustainable requires changing the existing process elements. Respondent B argues:

> "But if we are to have these big and heavy construction machines to become emission-free by 2030, then every machine must be re-built manually, right? That is at least the doubled, or maybe triple, the price of each machine … So, the question is, who is taking such a cost?"

As Respondent B argues and emphasizes, many changes need to be done to be net zero emissions. The informants recognize the need to be more sustainable and environmentally friendly but are experiencing its costs as a barrier. Therefore, an apparent barrier is the costs of this, which is an economic barrier. Respondent D also emphasises that some builders and construction firms require certain levels of ambitions of products and materials to be

environmentally friendly. This also results in increased costs, which can sometimes be experienced as a challenging barrier to overcome.

> "On products like cement and concrete, it is a lot onto how to produce this, and how it should be used. And that is to a great extent determined by standards, which are basically European standards, meaning standards that are then later adopted in Norway. And they are basically quite conservative" (Respondent C).

As Respondent C argues that the cement industry is relatively conservative, it is seen as a barrier in terms of product development. This results in restrictions on implementing new and other materials used as slags and aggregates in cement production. Respondent C further argues that these conservative standards are seen as a barrier in terms of product development. For further development of cement as a product and to become more sustainable and emission-free, the standards need to be revised, Respondent C argues.

The barriers in EnvU processes vary for each industry (Poulsen et al., 2016). The identified barriers in the Norwegian cement industry are experiencing barriers, mainly financial barriers, and product development barriers. My findings also highlight the uncertainty regarding how to overcome these barriers, especially regarding economic barriers. As for the barriers in the product development of cement, the standards need to be revised; and might be something happening over time as the industry develops.

5.3 Product Upgrading

In the theoretical approach of EnvU, product upgrading is the part of EnvU that focuses on creating a more environmentally friendly product. This can be through transforming existing products into more green products or ensuring an extended life cycle of the product (De Marchi & Di Maria, 2019a). Analysing through product EnvU, making a product more environmentally friendly is essential in this dimension (Hansen et al., 2021). Through my data collection, several interesting perspectives emerged on this topic. During my interview with Respondent C, who is the R&D manager for the Norwegian cement manufacturer, product strategies were central for that department. There have been several changes made to the cement product. These changes

include adding more substitute materials in the product to replace Portland clinker (Respondent C).

> "The most emitting step in the production is the production of Portland clinker. It's the most reactive part of the process … Former cement production only consisted of Portland clinker, but we have increased the amount of substitute materials to replace Portland clinker" (Respondent C).

As mentioned in subchapter 2.4, which highlights the process and steps into making cement, it is recognized that clinker production is the most emitting step. To make the cement more sustainable, a significant contributor has been to use substitute materials, also known as aggregates. According to Respondent A, fly ash is one of the more essential substitute materials. Fly ash is a coal industry waste product that mixes well into cement. Today, Norwegian cement consists of approximately 20% fly ash and acknowledges this as one of their most important steps toward circularity in their products (Respondent A). Respondent A also emphasizes implementing fly ash and other aggregates, such as limestone flour, which they produce themselves, has contributed to reducing emissions in their product. Although implementing fly ash has been a great success in the strategic approach of product EnvU, the coal industry and fly ash are decreasing. This results in the need to find new materials. Respondent C elaborates further about how they are working on a project for the last 4 to 5 years to look for new substitute materials. Such materials could come from other industries, such as the steel and copper industries (Respondent C; Respondent A). However, this strategic approach can also be viewed as an example of circular economy, due to the utilization of waste as a resource. The dimension of product EnvU focuses on the changes made to the product, hence, product EnvU. This dimension looks into the development of products and how they can become more environmentally friendly in different ways (Hansen et al., 2021). According to theory, product EnvU can be achieved by using recycled material in the product. As shown through the responses of Respondents A and C, the implementation of fly ash, recycled material from the coal industry, has contributed significantly to reducing emissions. Hence, being a more environmentally friendly product. Analysing this strategy, the implementation of fly ash matches the dimension of product EnvU due to the usage of recycled material in the product to make it more environmentally friendly. The changes have also been made due to the ETS carbon credits,

which are becoming increasingly expensive and lesser credits (Ministry of Finances, 2020). Respondent A talks about how the carbon credits costs and how they are only increasing; this is a push toward making changes both in the product and in general. In terms of EnvU theory, this can be seen as an external driver in terms of market demand and coping with external regulations (De Marchi & Di Maria, 2019a).

EnvU is a set of processes related to complex strategies in which changes are employed to environmentally friendly manage products and processes along a GVC (Krishnan et al., 2022). As mentioned earlier, much of the focus in EnvU literature and research has been on the processes of achieving EnvU and looking into what is being done, but not necessarily looking into the outcomes of the strategies. In terms of Norwegian cement production, has the product EnvU resulted in any outcomes?

> "Yes, we have made changes to our products, it is what is cutting the emissions the most" (Respondent C).

Since Norwegian cement consists of approximately 20% fly ash, it has reduced emissions by 20% (Respondent A). Although the changes made in the product at Norcem, we need to investigate the suppliers and customers as well. In terms of the raw material suppliers that have been interviewed during this project, Respondent G, H and I, there have been some common perspectives. Respondent G, the Norwegian raw material supplier, states, "We drill a hole in the mountain and blow it up, then we crush it and send it by boat to the guys at Brevik", and further elaborates on the limitations concerning the changes that can be made to rock itself.

The suppliers in the cement production deliver products such as quartz and other raw materials. Respondent H, a supplier of raw materials from Belgium, supply waste and byproducts from other raw material production, as an alternative to virgin materials. Respondent H elaborates on how Norcem different wastes and byproducts to substitute the harnessing of new scarce raw materials. This raw material supplier primarily supplies waste and byproducts from the steel industry to Norcem. Regarding strategies in products from this supplier, it is again limited what changes you can make to the product itself. However, supplier H and I focus on supplying waste materials and byproducts from other industries. When supplying these materials, the suppliers themselves are not necessarily making changes to the products they supply but enable a product EnvU for Norcem. However, Respondent I elaborate onto how they make recycled material into

materials fit for supply. Making the changes Respondent I tells about, is a type of product upgrading, regarding the usage and treatment of the recycled materials (De Marchi & Di Maria, 2019a; Hansen et al., 2021).The chosen suppliers in this cement production are a form of strategy to enhance their cement to be more environmentally friendly. Even though there is little to no direct product upgrading on the supplier side of the value chain, the materials supplied enable product upgrading in cement production.

Having suppliers that focuses on supplying waste material instead of harnessing new virgin raw materials, is contributing to making the cement product greener. As stated by Respondent A, they are also motivated to reduce their emissions, because it is better for society, which can be connected to internal values as a driver. Respondent B, states that it is important for them as a customer that the product they use is more environmentally friendly because it corresponds with their values. These statements can be viewed as external drivers through market demand and market-pull (De Marchi & Di Maria, 2019a). Therefore, being supplied with these recycled waste materials is contributing to a product upgrading, but can also be seen as a response to market demands and market-pull.

Regarding the strategic choice of suppliers, the sum of the process so far has resulted in an outcome; 20% reduced emissions. Other slags and aggregates, such as byproducts from the metal industry, are very efficient, although those resources are limited "it is a fight over the resources in itself" (Respondent A). It is further argued that mineral byproduct substitutes and raw material byproduct substitutes are preferred over harnessing and mining new minerals and materials (Respondent A). Based on this, it is possible to identify a product EnvU through the supplier side of the value chain due to the suppliers enabling the usage of recycled material in the cement product.

Looking over to the other side of the value chain, the customer side, we are primarily looking into concrete producers, builders, contractors, and construction sites. But Norcems plants also offer concrete as a product. As a part of all the interviews, a question regarding cooperation through the value chain, especially regarding the relationship with Norcem. All the respondents, who were either suppliers or a customer, positively responded to this. Some respondents elaborated on how the relationship was built on knowledge about the bought product and trusted due to the many years of working together. Respondent B stated something of particular interest,

which some other respondents also insinuated. The importance of the cement having a product upgrading is vital for the customers in terms of their internal values and perspectives on being environmentally friendly. For them, it is important to utilize green products to maintain the green profile (Respondent B). Although some customers, concrete producers, also say that the cement is also bought in terms of price and availability over whether it is produced in an environmentally friendly manner. This is because some of the concrete producers have their standards to follow; therefore, the cement is not necessarily important (Respondent E). Respondent F states "as you probably know, Norcem is one of the biggest contributors to the CO2 that we all live with". Respondent F emphasises that even though their concrete production is as environmentally friendly as possible, approximately 90% of the carbon dioxide emissions are generated from cement production. Respondent F further argues how important it is for their company that Norcem is working toward reducing their emissions. Respondent D also talks about the importance of cement and concrete being produced according to the Norwegian goals and standards, and that this is crucial for many building projects. Therefore, cement must have low emissions. All respondents are very optimistic about their CCS project.

> "It is very important. It is essential to put it bluntly. If Norcem had not started as early as they did, they were the first in the whole world to say the least and was stubborn by nature and they did not give up on implementing it and then got funding from the government to do it. I would say that this has been absolutely crucial for the industry" (Respondent F)

Respondent E also argues that Norcem has a strong power in the Norwegian cement and concrete market and is an essential leader in moving toward green cement and concrete. Even though implementing CCS is a big part of the production process, it is also a part of making the product, cement, more environmentally friendly.

To summarize the findings within product upgrading from the collected data, it is evident that all the actors in the value chain recognize the importance of reducing the emissions in cement. By doing so, product changes are made using aggregates and slag, which are other substitute raw materials. Looking back into the definition of product upgrading in EnvU "*development of sophisticated, environmentally-friendly product lines (e.g. usage of recyclable or recycled natural inputs, de-materialization of products, avoidance of use of toxic or impacting materials)*"

(De Marchi & Di Maria, 2019a; Hansen et al., 2021), the strategies in the product development is sufficient for the dimensions of product EnvU. By analysing this theoretical dimension of EnvU, the strategies identified have shown to be product upgrades that are better for the environment. This is seen through the supplies and usage of recycled material in the cement. The most evident driver for conducting product upgrading is to cope with external regulations through the ETS carbon credits, but there are also internal values that correspond with the product upgrading. However, it is also a market driver, due to requests from customers. It is evident that there is an interplay of several drivers that contributes to the strategies for product upgrading.

5.4 Process Upgrading

My findings show that the changes made in the production process is one of the most crucial upgrades. In EnvU theory, a process upgrading is when strategies are transforming the process according to new environmental standards or goals (Marchi et al., 2013). The process upgrading is all about increasing eco-efficiency and reducing the environmental impact of the process. This also entails investments in technology and process redesign to reduce negative impacts (De Marchi & Di Maria, 2019a). Looking back at the technology roadmap for the cement industry, the IEA and WBCSD suggest investment in technological solutions to reduce emissions in the production process (IEA & WBCSD, 2009, 2018). Specifically, IEA and WBCSD suggest investing and scaling in CCS technology is an opportunity in the cement industry to reduce emissions. Although this suggestion was proposed in 2009, it has taken many years to set up this solution. Even though it has taken many years, Norcem will be the first cement plant in the world to implement this technology as a part of the process. “We will never be the best in the world, but at least we will be the first” (Respondent A), says about the CCS technology on the Brevik plant.

> “At the beginning of the 2000s, so 20 years ago, long before anyone else I think in the industry. But that’s typical with such large technological developments, it often takes 20 years before it is realised. This has gone step by step and now the facilities are under construction and are planned to be ready and operational within 2024” (Respondent C).

The implementation of CCS technology is the most remarkable of all the interviews and is the newest strategy at Norcem Brevik and in the Norwegian cement industry. All respondents emphasize the importance of Norcem implementing this, especially on the customer side of the value chain. The CCS technology implementation will reduce approximately 400 000 tonnes of carbon dioxide in a year (Miljødirektoratet, 2022); this can be seen as one of the most important strategies. As mentioned earlier, the CCS technology will be implemented to capture the carbon dioxide from the production, which mostly occurs in the production step that produces clinker. This is significant process upgrading, although it is not functioning now, it is supposed to be fully operated in 2024 (Respondent A, Respondent C). This project is also highly supported by Norcems customers in the value chain, due to them being able to access more green-produced cement, which is helping them become greener in their processes. Regarding process EnvU, the CCS technology will greatly contribute to making the process more environmentally friendly. This due to the technologies ability to capture the carbon dioxide emissions from the most emitting step in the production process. But why is Norcem investing in this technology? And why is this being funded by the government?

> "Cement production is an old technology, patented approximately 199 years ago, so cement has been produced with the same method for many years now, but there has of course been changes on the technical equipment" (Respondent A).

As Respondent A states, the method of producing cement is not new. As mentioned in Chapter 2, the cement industry is recognized as a hard-to-abate industry, due to the continuous demand of the product, and therefore changing the mays of production can be challenging. Therefore, implementing CCS technology will not involve in changing the method of production, but rather extracting the emissions before being released into the atmosphere. Respondent A highlights that without funding from the government, the implementation of CCS technology would be a financial barrier for them. Respondent C argues that even though the government is contributing financially, it is still a great investment for Norcem. This technological investment enables the cement production to be done with the classic methods, but still reduce the emissions from the process. The government is also investing in the implementation of CCS technology because it increases the chances of reaching the goals within the Paris Agreement (Meld. St. 33(2019-2020)). The government also recognizes this technology as vital in reaching the goals, therefore

wanting to enable the further development of this technology. Investing in this technology will also contribute to value creation for Norway, due to the contributing to jobs and employment. And earlier this year the first positions as a carbon capturer were released (Respondent A). Therefore, by having the government contributing to this CCS projects, fulfils the wishes both from the government as well as the Norwegian cement industry. Hence, we can see this being driven by the need to cope with external regulations, whereas the Paris Agreement is the external regulation that the Norwegian government has signed up to participate in.

According to the informants, the CCS project is seen as an important and somewhat revolutionary strategy for the industry. Analysing the CCS technology through the dimension of process EnvU, CCS technology is a big part of upgrading the process by utilizing superior technology (Hansen et al., 2021). However, this CCS project is not the first CCS project in Norway. In 2012 Technology Centre Mongstad, TCM, was the world's largest facility for testing and developing CCS technologies (Ministry of Petroleum and Energy, 2021). This project was recognized as Norway's "moon landing" by former prime minister Jens Stoltenberg. Now, over ten years later, Norcem is soon ready to operate its CCS facilities on their production plant fully. The TCM project did not go according to plan and was shut down in 2013 (Haugan, Husby & Eisenträger, 2013). Considering this TCM project, how will we know that the new CCS facilities at the Brevik plant will not fail? There has been much new research regarding the new Longship project. However, the Norwegian government says through a press release that they will use their knowledge and experience from the TCM project in new CCS projects (Ministry of Petroleum and Energy, 2013). Even with experiences, research, and knowledge, will this be a new moon landing?

Although the CCS project is one of the bigger upgrading and technological investments in producing cement, other strategies are also being implemented. For example, for the last 30 years, Norcem have focused a lot on implementing alternative fuels instead of coal and fossil fuels in their process. Respondent A and C emphasizes that this strategy has been around for a long time and is still going strong today and as of today the usage of alternative fuels is at approximately 80%.

> "The use of alternative fuels, we were also early on with that strategy. We started with this over 30 years ago, so replacing coal. Traditionally, fossil fuels were used in the

> clinker ovens. So, we started using waste-based fuels around 1990. And it has increased year by year, large investments have been made to be able to do this and as of today the factory in Brevik is one of the foremost in this regard in our system … In other words, we have had a strategic focus on sustainability for a long time, especially concerning the reduction of CO_2 emissions" (Respondent C)

Process EnvU focuses on reducing the negative environmental impacts of the process (De Marchi & Di Maria, 2019a), hence, the usage of alternative fuels. Alternative fuels mostly consist of waste used as fuels, some of which are fossil fuels. Although it is still a fossil fuel, it is from others' waste. Therefore, they argue that it is a good contribution to society that they burn others' waste for production. This has been of great success, according to Respondents A and C. The use of alternative fuels is also a strategy presented by the IEA and WBCSD, which can be a sufficient contribution to reducing emissions (IEA & WBCSD, 2009, 2018). Some of the respondents (A, C, F) argue that using slags and aggregates is a part of the product strategy, it is also important in terms of the process strategy (Respondent A). Respondent A argues that adding different slags and aggregates will reduce the emissions because of the need to produce less clinker. At the same time, the cement will still have cementous properties and become concrete. As discussed in the previous subchapter, 5.2 product upgrading, implementing the waste product fly ash, has reduced the emissions by 20%. Therefore, arguing that the implementation of waste materials in the cement product has contributed to a process upgrading due to reduced emissions in the process.

Another strong strategy amongst almost all the actors in the value chain and the respondents in the interviews. This strategy evolves around the electrification in the process, especially in terms of machinery and transportation. The cement is often transported by different methods, sometimes by a cement truck or boat. Respondent B emphasizes the wishes for more zero-emission machinery and highlights this as an important strategy to fulfill the national and international goals in terms of emissions. Respondent E, who owns cement trucks, aims to fully electric cement trucks within a year. Respondent E further argues that the electrification of the trucks has been an important contribution to reducing the emissions in the process. However, the electrification of these trucks has been demanded by the transporters of the product. Electrifying

the process would upgrade the process in terms of reducing the need for fuels, hence decreasing emissions. This can also be a process upgrading by investing in technology.

Looking at the supplier side of the value chain, some suppliers also recognize the importance of electrification and the reduction of emissions in the process, but it is limited to what to do. Respondent G states, “Electric excavators are just bullshit it has nothing to do with a quarry,” and questions batteries ability to handle the processes occurring in the quarry. Later, Respondent G did talk more about how a complete focus on the environment and electric machinery would result in less profit for the company. Still, they are following local standards in terms of the environment and emissions. However, the production line is fully electric until the material from the quartz from the quarry ends up on the transportation boat (Respondent G). Respondent H elaborates on how their process is relatively low in emission; this is because they do not have an entire production process, therefore the implementation of alternative fuels for instance, is per now not of priority. Although if customers request it to be, it will impact the price of their products. Respondent I also emphasize that the process emissions are not a problem. Respondent H and Is companies focus on supplying waste material, recycled material, and byproducts from other industries. Therefore, process emissions are very low within these actors. There are different views and opinions regarding the process and how to upgrade it on this side of the value chain. Some argue that there are little to no changes needed to be done to the process because there are not many emissions from the existing process. However, Respondent G talks about a process upgrading that will be occurring in terms of electrifying the current process, which according to theory upgrading in terms of investing in superior technology (De Marchi & Di Maria, 2019a)

In terms of process upgrading throughout the value chain, it is evident that the impact of the process varies. The definition of process upgrading in EnvU is based on eco-efficiency and reducing negative environmental effects through the process (Hansen et al., 2021; Marchi et al., 2013). The emissions from the suppliers are low due to their material practices, using waste material, recycled material, and byproducts from other industries. At the same time, other suppliers have a fully electric production line. Due to the variation in processes, it is natural that it varies in the strategic approach. As for cement production, three strategies have been identified: alternative fuels, adding aggregates and slags in the cement, and the new investment

in CCS technology. According to the informants, the strategy concerning alternative fuels and adding slags and aggregates has succeeded. The CCS technology is expected to reduce emissions by 400 000 tonnes per year (Miljødirektoratet, 2022), but it is yet to see if this strategy will succeed. Transportation electrification has also been recognized through the value chain as an excellent strategic approach amongst the informants. Although it is not yet realized for many, it is believed that this will contribute to reducing the emissions in transportation processes.

5.5 Organizational Upgrading

Implementing environment and sustainability departments in organizations has become increasingly important. In terms of EnvU theory, organizational upgrading looks into organizational improvements and managerial practices favoring the environment and the green shift (De Marchi & Di Maria, 2019a). Organizational upgrading is investigating not only the manufacturing domains but also each business activity and behavior that can contribute to reducing impacts on the environment (De Marchi & Di Maria, 2019a). Research suggests that attention to detail regarding organizational structures, behavior, and values is important for a holistic view of EnvU. This often happens through the need to cope with societal pressures and the adoption or development of standards. The informants have provided rather homogenous information regarding this topic by gathering data.

Some of the informants have different structures in how the companies work toward a positive environmental impact. Respondent F argues that it is important for their company to have structures and methodological approaches regarding environmental management. Respondent F further argues that it is essential for the company to act responsibly in its projects. Therefore, it is important to include environmental management and environmental responsibility in all their projects, together with its own department solely focusing on environmental management. Organizational EnvU highlights the importance of the overall way of doing business as a part of EnvU (Hansen et al., 2021), and looking at Respondent Fs responses, environmental consciousness, and responsibility is a part of their way of doing business. Respondent B argues on how important it is to implement environmental strategies and structures within their company “I was hired in June last year to do business development based on the green shift.” This statement highlights how Respondent B job is entirely devoted to advancing the company’s

internal environmental performance and work. As Respondent B tells about, structures contribute to an organizational EnvU based on the work to ensure the firm's overall environmental performance.

> "I am responsible for what we work with regarding ESG, environmental social governance, so it's an extended concept of sustainability to say the least. Also working toward the businesses by following up on the sustainability goals, also helping them setting sustainability goals … it is also important to show the world the work we do regarding the sustainability side" (Respondent A)

Respondent A, working within the multinational material company, also owns Norcem as a company. As Respondent A stated, working with ESG and the UNs SDGs is important for them as a company. Implementing such goals in their company and work is contributing to working toward reducing emissions and becoming more sustainable. Also, working within an ESG framework entails that sustainability is a great part of the organizational structure. A part of organizational EnvU is also working within standards and certifications (Hansen et al., 2021); therefore working within an ESG certification sets a framework for how a business operates. The company Respondent A represents, is also a member of the CSI, contributing to work for sustainable cement and concrete. Therefore, this is a form of organizational EnvU. Since Respondent As company is working with these environmental management structures, as well as a CSI membership, it is also affecting the ways of working within Norcem since they are working out toward their companies.

On the customer side of the value chain, Respondent E argues:

> "It is in all of us, we do not have one environmental department managing and controlling the environmental management. For us, it pervades everything … Everyone in our projects knows that they have to be aware of the CO_2 emission into nature and to use the least amount of raw materials."

What Respondent E says is still, according to theory, a way of organizational EnvU, due to it being an overall way of doing their business. Although most informants talk about their own departments that is responsible for environmental management, it is still evident that environmental consciousness pervades most of the activity companies on the customer side.

Respondent F also argues that having an R&D manager and an environmental and sustainability manager has successfully handled product and environmental questions and issues for their products. As the theory on organizational EnvU states, it entails the overall way of doing business. And as seen through the respondents on the producer side and the customer side of the value chain, it is evident that sustainability and environmental consciousness is a greater part of how the firms are being managed.

Looking into the supplier segment of the value chain in terms of organizational EnvU, my findings show that some of the suppliers' activities are purely based on being environmentally friendly. Respondent Hs Belgian raw material supplier company bases their activities on circularity of raw materials.

> "So, we are in essence a trading company, specializing in circular raw materials. All the materials we supply are waste of byproducts from other processes, so we always substitute raw materials."

Organizational upgrading in EnvU theory, looks into how firms are being managed, and what managerial practices are implemented to reduce negative environmental impacts (De Marchi & Di Maria, 2019a; Hansen et al., 2021). As Respondent H argues that in terms of organizational EnvU, no changes have been made. This is because the sole purpose of their business is to be circular, and therefore changes in their managerial practices and organization is not evident. Respondent H also argues that since their company is an intermediate, it is limited to what they can achieve. Other suppliers such as Respondent I, representing the German raw material supplier, also have a similar approach to organizational EnvU. Respondent I, like Respondent H, argues that their business entails trading byproducts from other raw materials. Respondent I further elaborate on how their business is based on recycling the raw materials and further trading byproducts of raw materials from other processes and the recycling. These are often iron materials left over from the iron industry. Both Respondent H and Respondent Is business approaches focus on recycling, circularity, and the second life of raw materials. Therefore, environmental- and waste management pervades both of their companies. Thus, when analysing the supplier side of the value chain, it is evident that there are processes for organizational EnvU, within the firms of Respondent H and Respondent I, based on the fact that their firms are solely based on being environmentally managed.

Looking back at the definition of organizational EnvU. Organisational EnvU focuses on how enhancements through a firm's overall way of doing business and managing the organization to reduce the negative impacts on the environment (De Marchi & Di Maria, 2019a; Hansen et al., 2021). Looking at the strategies presented through data regarding this topic, my findings highlight various approaches to this type of EnvU. Most informants talk about different organizational structures regarding environmental management and responsibilities. Regarding the theoretical definition, almost all the informants talk about structures and approaches that match the definition and processes of organizational EnvU. Even if it is through setting specific goals through the UN SDGs, having an environmental consciousness in all departments and projects, or having their business solely dedicated to being environmentally friendly. Although some strategic approaches are rather different, the different actors in the value chain are put strategic work through their own individual organizations to reduce negative impact through their activities.

5.6 Product End-of-Life Upgrading

As mentioned earlier, product End-of-life upgrading, and improvements is a relatively new contribution to the EnvU theory. This theoretic dimension is based on the products end-of-life improvements, which evolve around specifically lead firms to reduce end-of-life flows of waste (Hansen et al., 2021). EnvU literature exemplifies this through waste collections and recycling initiatives for their products. Looking into this type of strategic approach when it comes to end-of-life improvements in the cement industry, we need to remember what cement is used for.

Cement is the main ingredient in concrete, meaning that cement is just an ingredient for another product, and is not necessarily a final product itself. As presented in Chapter 2, cement is used to construct the world we live in and the infrastructure. Looking back at the cement technology roadmap, the WBCSD CSI initiative addressing climate issues regarding this industry (IEA & WBCSD, 2009). The roadmap also investigates the benefits of using concrete as a material, such as the longevity of the material. When using concrete, buildings, and infrastructure can last up to several decades, even with limited maintenance (IEA & WBCSD, 2009). Due to the materials' longevity, how much can you recycle when producing new concrete? Are there possibilities for end-of-life product EnvU in this industry?

Respondent A and Respondent C, representing the production segment, emphasize that using different slags and aggregates in the cement contributes to the use of recycled material, due to it being waste material from other industries (Respondent A, Respondent C). Respondent C also argues:

> "Nothing is turned to waste. Yes, we have leftover material from our production, and that is something we call bypass dust. This is a type of cement dust, that contains slightly too high concentrations of chlorides and alkalis, which you don't want too much of in cement"

As Respondent C discusses, this cement dust was usually deposited in different mines (Respondent A). However, a newer product has given new life to this leftover dust.

> "Now we reuse the most of it. We have our own product called multisystem, which consists of a mixture of 50% cement and 50% of this residual material … So, in periods, all of this excess material goes into this product" (Respondent C).

As Respondent C says, Norwegian cement production can make a new life of byproducts from their cement production. Respondent A also emphasizes the importance for them as a company to recognize their responsibility to make sure all the products are utilized and not wasted. The usage of other waste materials and making a product of the little waste they produce contribute to an end-of-life product EnvU (Hansen et al., 2021). This is due to them making new life of waste materials as a part of their product, and even though this is also a part of their product strategy, the information gathered highlights this as a product end-of-life improvement. Utilizing waste material contributes to the reduction of waste from others, as well as their own bypass dust waste, by giving it new life in products. According to EnvU theory, this is a product end-of-life upgrading.

Remembering cement is the main ingredient in concrete and recycling cement means recycling concrete. The WBCSD CSI also suggests that recycling concrete is advantageous because the recycled concrete can be used as an aggregate when making new concrete (IEA & WBCSD, 2009, 2018). Respondent B argues that recycling material in terms of concrete is more common in construction than infrastructure, whereas the infrastructure is tunnels, bridges, and roads.

However, there is an own department in Respondent Bs construction and infrastructure company dedicated to circularity.

> "They work with concrete recycling and are linked up to this by our crushing plants where concrete saws are. Old concrete is brought in and crushed, then going back to the concrete drill, then selling it to a concrete supplier. So yes, we do work with recycling of materials."

Here, Respondent B provided a detailed example of how their company works with recycling concrete, making a new life for their products accordingly product end-of-life product EnvU. As for Respondent D, working within a governmental construction company, recycling, and rehabilitating materials in new and existing projects are important. Respondent D argues for this through examples of the project in the Norwegian "regjeringskvartalet," where they focus on different material groups and how to use them. This ranges from the reuse of concrete elements and windows for this project. This can be seen as a recycling scheme for using existing materials, especially if they are in good shape, which is a part of this form of EnvU. However, Respondent F argues that there are some challenges regarding recycling concrete. Although they use recycled slags and aggregates, focusing on recycling material is a matter of cost and benefits. Respondent F elaborates further that there are more significant usage restrictions on what to put into concrete when using recycled material. Therefore, they experience challenges in terms of recycling.

Two raw material suppliers focus on giving new life to waste and byproducts from other industries. Looking at the supplier segment of the value chain, the raw material suppliers are as mentioned earlier, devoted to the recycling of raw materials. Respondent H argues about how their raw material supply business is fully circular:

> "We make it possible so that no raw materials have to be mined or quarried."

Respondent I, also a supplier, describe their company as a 30% raw material supplier and 70% recycling company. Their focus on using the waste and byproducts opens for circularity and recycling of the raw materials, resulting in not needing to mine or quarry new materials. In this way, the raw material supplier ensures that no scarce raw materials are being harnessed and contributes to a circularity by supplying these materials. This raw material supplier works by recycling waste products from other industries, then treating them into products to supply to

other industries, including the cement industry with iron materials. This is a form of product end-of-life EnvU due to giving waste a new life in other products, also, by treating the waste products to become solid products to supply to other industries, refurbishing the waste products (Hansen et al., 2021). However, when supplying a raw material such as Respondent G, who supplies quartz from a quarry, there is little to be done regarding recycling.

Looking back on the definition of product end-of-life upgrading, reducing the end-of-life flows and waste (Hansen et al., 2021), there are strategies within the actors in the actors in the value chain. Most of the informants seem to recognize the importance of recycling and using recycled material in production and in the products. My findings suggest that the recognized importance of using recycled material is resulting in strategic choices from the cement producer regarding the choice of a raw material supplier whose focus is to be circular and supply usable waste products. My findings also highlight that most of the Norwegian cement value chain actors are actively contributing to product end-of-life upgrading, in terms of reducing waste. Also, in terms of using other waste materials in their products, hence, giving new life to materials.

5.7 Strategies and GVC Cooperation

According to theory of EnvU there are different strategic approaches, such as standard-driven and mentor-driven greening, and deep and shallow engagement, as presented in subchapter 3.2.1. Standard-driven greening is based on a lead firm identifying an environmental issue. From there on is based on a standard implemented by the lead firm, and suppliers must comply (De Marchi et al., 2013a; Poulsen et al., 2016). Looking back into the deep and shallow strategies (Jeppesen & Hansen, 2004), standard-driven greening is seen as a shallow strategy based solely on standards. Mentor-driven greening is based on personal interaction, and equally depends on knowledge and skills (De Marchi et al., 2013a; Poulsen et al., 2016). Mentor-driven greening is linked to deep strategies for deep engagement through personal interactions, knowledge, and skills.

Regarding this case, the Norwegian cement value chain, we are looking at a mentor-driven greening with deep strategies. Through my nine semi-structured interviews, I have asked questions regarding experiences of the relationship with Norcem on both sides of the value

chain. The responses regarding this question through all the interviews come out as positive. This means that all the value chain actors experience a positive relationship with Norcem. However, more than a positive relationship is needed to evaluate this GVC as a mentor-driven greening with deep strategies.

> "I experience Norcem as a dutiful and incredibly good supplier. And they are extremely engaged in terms of sustainability due to their CCS project" (Respondent B)

Respondent B also emphasizes the good relationship due to research projects with Norcem. However, Respondent B also argues that there is a certain distance between them and Norcem. This is due to it being more direct contact with the concrete supplier. However, they do buy some cement directly from Norcem. Therefore, there is still a relation there that is experienced as a good one. And as mentioned earlier, for customers such as Respondent B, E, and F, Norcems implementation of CCS technology is important for customers, but also the industry in general, due to Norcem being a supplier. Respondents E and F argue that they, as customers, are rooting for Norcem and their prominent role both in the industry and in Norway, regarding green development and technology. Although Respondents E and F are very independent in their work, they emphasize Norcem as an essential knowledge contributor regarding technical and environmental questions. These relations contribute to deep strategies due to the focus on knowledge and skills (Jeppesen & Hansen, 2004; Poulsen et al., 2016). Research projects like Respondent B emphasize contributing to a mentor-driven greening with deep strategies. Respondent D also argues

> "The times I have personally engaged with Norcem it has been through research and development activities, rather than in projects. So, that has been very fruitful and educational."

As Respondent D emphasizes, the activities regarding R&D activities have resulted in knowledge and skill. This further strengthens mentor-driven greening with deep strategies (Jeppesen & Hansen, 2004; Poulsen et al., 2016).

The supplier segment in the value chain also experiences good, strong, and long-term relationships with Norcem. Respondent I mention that they have been supplying Norcem for decades. Respondent I further argue:

"We have a very long-lasting relation, and it is also very personal."

The relationship described is good, and Respondent I also emphasize the relationship being strong enough for oral agreements instead of long contracts for agreements. This is a good example of deep engagement strategies (Jeppesen & Hansen, 2004).

In terms of GVC and upgrading, having good cooperation through the value chain is important in achieving goals. Through the findings, it is highlighted that there are strong relations with flows of knowledge. This further strengthens the idea of the Norwegian cement value chain having a mentor-driven greening process with deep strategies.

5.7.1 Summarizing Table

To summarize the findings presented and discussed through chapter five, I am through the table below summarizing which strategies occur in the different forms of EnvU. This table will also include the drivers and barriers to highlight why these strategies are implemented.

The following table is highlighting where the different strategies are occurring in the actors in the value chain. The table makes it possible to identify differences and similarities between the different actors in the value chain and where the different activities presented in the analysis are occurring. The table also shows the drivers and barriers that are experienced by the actors, which can be seen as the "why" they are implementing the different strategies. It is necessary to remember that not all forms of EnvU are occurring within all the actors, but the sum of all the activity is contributing to reducing emissions and negative impact in the Norwegian cement value chain.

INFORMANT	PRODUCT ENVU	PROCESS ENVU	ORGANISATIONAL ENVU	END-OF-LIFE ENVU	DRIVERS	BARRIERS
A	Waste materials in cement	CCS technology, Alternative fuels	ESG, UNs SDG, Environmental Management	Waste materials in cement	EU ETS	Economy
B	X	X	Environmental Management	Crushed concrete as slag in new concrete	Internal values, Attractive on stock market	Economy
C	Waste materials in cement	CCS technology, Alternative fuels	Environmental Management	Waste materials in cement	EU ETS	Conservative standards, Product development barriers
D	X	X	Paris Agreement, Governmental standards, Environmental Management	Utilizing old materials in new buildings	Paris Agreement, Governmental standards, Knowledge	High ambition and expectation barriers, Economy
E	Following concrete standards	Electric cement trucks	Pervading Environmental Management	X	Paris Agreement, Certifications, Internal values	X
F	Following concrete standards	X	R&D, Environmental Management	Waste material in concrete	Market demand	X
G	X	Electrified process facilities	X	X	Market demand	X
H	X	X	Based on being sustainable	Supplying waste material	Internal values	X
I	X	X	Based on being sustainable	Supplying waste material	Internal values	Competence

Table 3: Summary of Strategies, Drivers, and Barriers

5.8 Strategies for Environmental Upgrading in the Norwegian Cement Value Chain

Looking back at the research questions:

> *Which strategies are implemented throughout the Norwegian cement value chain to achieve environmental upgrading?*
>
> *Why is the Norwegian cement value chain working to achieve environmental upgrading?*

The results from this thesis have shown many different strategies and approaches in the value chain. The different strategies to achieve EnvU vary based on which forms of EnvU that are being worked on. However, it is evident that in the Product EnvU, the firms in the value chain have strategic approaches in terms of using waste material to reduce product emissions. As well as using suppliers who supply waste materials instead of freshly harnessed raw materials, which is enabling product EnvU strategies.

Looking at the process of EnvU, it is evident that the implementation of CCS technology will be revolutionary for the industry. However, strategic choices for the usage of alternative fuels have been around for more than 30 years and will further be a part of the process strategy. The electrification of process and transportation is shown as a wish from several actors, and one supplier is currently working to achieve a fully electric process. Therefore, it is interesting to see how the further process of Process EnvU will develop. In terms of Organisational EnvU, most of the actors in the value chain have achieved this by having sustainability and environmental management as a part of their overall business. With solid organizational structures devoted to environmental management in several firms in the value chain, organisational EnvU is seen as achieved in this value chain. The last dimension of EnvU, product end-of-life EnvU, is also a strategic process being achieved by several firms in the value chain. By utilizing waste products in the production of new products and refurbishing waste materials, the firms in the value chain have been able to give new life to waste materials, hence, achieving product end-of-life EnvU by reducing waste.

Looking into why these strategies are implemented through the value chain, it is an evident interplay of drivers and barriers. The drivers identified in this value chain are an interplay of internal and external drivers, contributing to the motivation to become increasingly

sustainable and environmentally friendly. The drivers range from values and proactive leadership, and other external drivers, such as meeting goals and coping with external regulations. EnvU theory emphasises that barriers to EnvU vary from industry to industry. The most evident barrier in the Norwegian cement industry is the economic one. The work needed to be done is not without cost; to fully achieve the strategies the actors want to implement, there are economic barriers to this. Another barrier is the conservative industry in terms of traditional standards in the products, which need to be updated to have more green product standards.

Chapter 6: Conclusion

The global cement industry is under immense pressure regarding green transitions and reducing the negative environmental impact, as its accounts for 5% of all anthropogenic emissions. And if action is not taken, it is expected to increase due to the continuous demand of cement. This thesis has through five chapters aimed at investigating and understanding the complexity of EnvU processes and conditions in the Norwegian cement value chain. Hence, its goal is to contribute to understanding an empirical case perspective of EnvU analysis in GVC.

To answer the research challenges presented in subchapter 1.2, this thesis has applied a qualitative case study with semi-structured interviews as data collection. By gathering data through nine semi-structured interviews, I have identified the main strategies for EnvU occurring through the value chain. This also enabled me to identify what the actors in the value chain experienced as drivers and barriers for EnvU.

This thesis has identified strategies within four dimensions of EnvU; product EnvU, process, EnvU, organizational EnvU, and product end-of-life EnvU. Some main drivers and barriers have also been identified, which can be linked to the strategies. In this case, the drivers and barriers can be the answer to "why" these identified strategies are occurring. The thesis has shown that the processes regarding EnvU in the Norwegian cement value chain are complex. This emphasises the importance of connecting and looking at all parts of the value chain simultaneously to better understand the development toward emission reductions.

My findings in this thesis highlight the various strategic approaches to the different actors in the value chain and the importance of interplay and value chain cooperation. My results suggest that EnvU in the Norwegian cement value chain is a complex process with different strategic approaches.

From implementing different slags and aggregates such as fly ash and iron materials in the cement to reduce the amount of clinker or implementing CCS technology in the process, as well as working with internal values linked to ESG, SGDs or the Paris Agreement, or having a sustainability mindset as something that pervades all projects and work. The approaches regarding recycling and reusing in this industry are also present in different approaches,

whether using waste material in the cement and concrete or using old concrete as slag for new concrete. Moreover, EnvU in the cement industry is likely to happen within market structures that enable sustainable development and not hindering. Here, the drivers linked to law enforcement are important regarding being an external force in the right direction. However, the economic situations are the most experienced barrier in this value chain. There are also evident positive outcomes from these strategies, regarding that emissions have already been reduced by specific strategies. However, there are some strategies that are yet to be realised, meaning that there are still many processes occurring in the Norwegian cement industry. However, there is an expected positive outcome regarding these strategies, such as when Norcem is fully operating the CCS technology.

This thesis' results can be applied in a broader global perspective within other industries looking to reduce their emissions. Even though this case is within the geographical context of Norway, there are still results to learn from. Such as the experienced importance of research and development projects through the value chain and the importance of new technology in this hard-to-abate industry. Therefore, other industries recognised as hard-to-abate can learn and gain relevant knowledge from the results presented in this thesis.

This thesis has limitations I would like to address. Even though many valuable insights have been provided, there are limitations. There have only been nine interviews conducted, which the analysis is based upon. Having only nine representatives from the value chain opens a natural restriction in inclusion and information. The time limit and scope of the thesis have resulted in these limitations. Therefore, it is essential to investigate what can be further researched within this field. In the following subchapter, I will propose suggestions for future research.

6.1 Looking Ahead

After analysing the cement industry's sustainability trajectories, I propose suggestions for future research. Further research may explore CCS technology's future role in the cement industry and other hard-to-abate industries. It will also be interesting to look further into after Norcem entirely operates its CCS facilities and explore the actual results from this technology. Therefore, looking further into investments in this technology in other parts of the world and other industries would be interesting. Further research could also be done on the cement product itself, and how the materials used can further contribute to making this

product zero-emission. Investigating EnvU in other cement value chains would also be interesting, as this is seemingly an uninvestigated topic. This would provide further knowledge on this topic, hence, further development in the cement industry by learning from each other.

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Appendices

Appendix A: Interview Guide

Introduction:

1. Kan du fortelle om deg selv og din rolle i verdikjeden?
2. Kan du fortelle om verdikjeden deres?
    a. Kan du utdype om de ulike stegene fra leverandør, produksjon og helt til sluttbruker?
3. Hvordan jobber dere strategisk med EnvU/grønn produksjon/utvikling av deres sement?
    a. Hvilke konkrete strategier har dere implementert for å kutte utslipp i produksjonen?

Internal/external drivers:

4. Hvorfor jobber dere mot å redusere utslippet deres?
5. Hvilke motivasjoner har dere for å bli grønnere?

Internal/external barriers:

6. Opplever dere hindringer for å oppnå strategiene dere ønsker?
    a. Hvilke hindringer?

Value chain/Environmental upgrading:

7. Hvordan jobber dere med implementering av strategier i de ulike leddene av verdikjeden deres?
8. Har dere gjort endringer innad i organisasjonen?
    a. Hvordan er deres organisasjon lagt opp til å jobbe mot å redusere utslipp?
9. Har dere gjort endringer i prosessen?

    a. Hvordan har endringene deres gjort prosessen (/produksjonen) mer miljøvennlig?
10. Har dere gjort endringer på produktet deres?
    a. Har dette redusert utslipp?
11. Har dere gjort teknologiske endringer som en del av strategien?
    a. Hvis ja: hvordan har dette forbedret prosessen/produktet (sementen)/organisasjonen deres?
12. Jobber dere med gjenbruk/resirkulering av materiale?
13. Har dere samarbeid dere med deres kunder/leverandører/Norcem gjennom verdikjeden for å oppnå innovative løsninger for å redusere utslipp?
14. Jobber dere med å kutte utslippene uten å miste økonomisk gevinst?

Relations:

15. Hvordan jobber dere med deres kunder for å oppnå en reduksjon av utslipp i deres produksjon?
16. Hvordan jobber dere med deres leverandører for å oppnå en reduksjon av utslipp i deres produksjon?
17. Hvordan opplever du som kunde/leverandør deres samarbeid med Norcem?

Closing up the interview:

18. Er det noe mer du ønsker å tilføye?

Appendix B: Consent Form

Vil du delta i forskningsprosjektet

«Strategi for environmental upgrading i norsk sementproduksjon?»

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å analysere strategier for å oppnå «environmental upgrading» i verdikjeden i norsk sementproduksjon. Dette skrivet er for å formidle målet med prosjektet, samt hva deltagelse innebærer for deg.

Formål

Formålet med denne masteroppgaven er å få en bedre oversikt og forståelse av hvordan sementproduksjonen i Norge er i et grønt skifte, og hvordan Norcem som Norges eneste sementprodusent jobber med «environmental upgrading» gjennom verdikjeden. Dette vil bli analysert gjennom de teoretiske verktøyene *Global Value Chain* (verdikjede) og *Environmental upgrading*. Problemstillingen til denne masteroppgaven vil omhandle strategi for «Environmental upgrading» i den norske sementproduksjonen.

Hvem er ansvarlig for forskningsprosjektet?

Norges tekniske- og naturvitenskapelige universitet (NTNU) er ansvarlig for prosjektet. Oppgaven vil bli levert til og vurdert av NTNU.

Hvorfor får du spørsmål om å delta?

Utvalget for denne masteroppgaven er representanter fra ulike aktører i verdikjeden til norsk sementproduksjon, samt aktører utenfor verdikjeden. Du blir spurt om å delta i prosjektet basert grunnet din stilling i en etablert bedrift som er del av/bidrar til norsk sementproduksjon.

Utvalget vil bli rekruttert av meg personlig. Utvalget til dette prosjektet vil bestå av mellom 7 og 10 personer.

Hva innebærer det for deg å delta?

Hvis du velger å delta i dette prosjektet, innebærer at du svarer på noen spørsmål i et intervju. Intervjuet vil ta ca. 1 time, og svarene dine vil bli transkribert og elektronisk registrert. Spørsmålene i intervjuet omhandler hvordan deres virksomhet jobber med strategi for grønn produksjon i verdikjeden til sement.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Dette innebærer at hvis du velger å delta, kan du når som helst trekke samtykket uten å oppgi noen grunn. Alle dine personlige opplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke ønsker å delta, eller velger å trekke deg senere.

Ditt personvern

Opplysningene om deg vil bli brukt til formålet presentert i dette skrivet. Vi behandler opplysningene dine konfidensielt og i samsvar med personvernregelverket. Personopplysninger som selskapet du jobber i samt stillingen du har vil bli nevnt i oppgaven. Navn og kontaktopplysninger vil bli anonymisert. Det er kun masterstudent Jenny Nøkleberg Sandbæk og veileder Henrik Brynthe Lund som vil ha tilgang til disse opplysningene.

Hva skjer med opplysningene dine når prosjektet er avsluttet?

Forskningsprosjektet er planlagt å avsluttes i perioden mai/juni 2023. Etter prosjektets slutt vil personopplysninger og opptak/datamateriale slettes.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- Innsyn i hvilke personopplysninger som er registrert om deg, samt få utlevert en kopi av opplysningene
- Å få rettet personopplysninger om deg
- Å få slettet personopplysninger om deg
- Å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysningene om deg basert på ditt samtykke.

På oppdrag fra NTNU har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Spørsmål?

Hvis du har spørsmål om prosjektet, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- NTNU ved Henrik Brynthe Lund (veileder) via e-post henrik.brynthe.lund@sintef.no. Eller ved student Jenny Nøkleberg Sandbæk via e-post jennyns@stud.ntnu.no.
- Vårt personvernombud: Thomas Helgesen, NTNU, via e-post thomas.helgesen@ntnu.no

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

Henrik Brynthe Lund (Veileder)

Jenny Nøkleberg Sandbæk

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet «strategi for environmental upgrading i norsk sementproduksjon?», og har fått anledning til å stille spørsmål.

Jeg samtykker til:

☐ å delta i intervju om «strategi for environmental upgrading i norsk sementproduksjon?»

☐ at intervjuene blir tatt opp via lyd.

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

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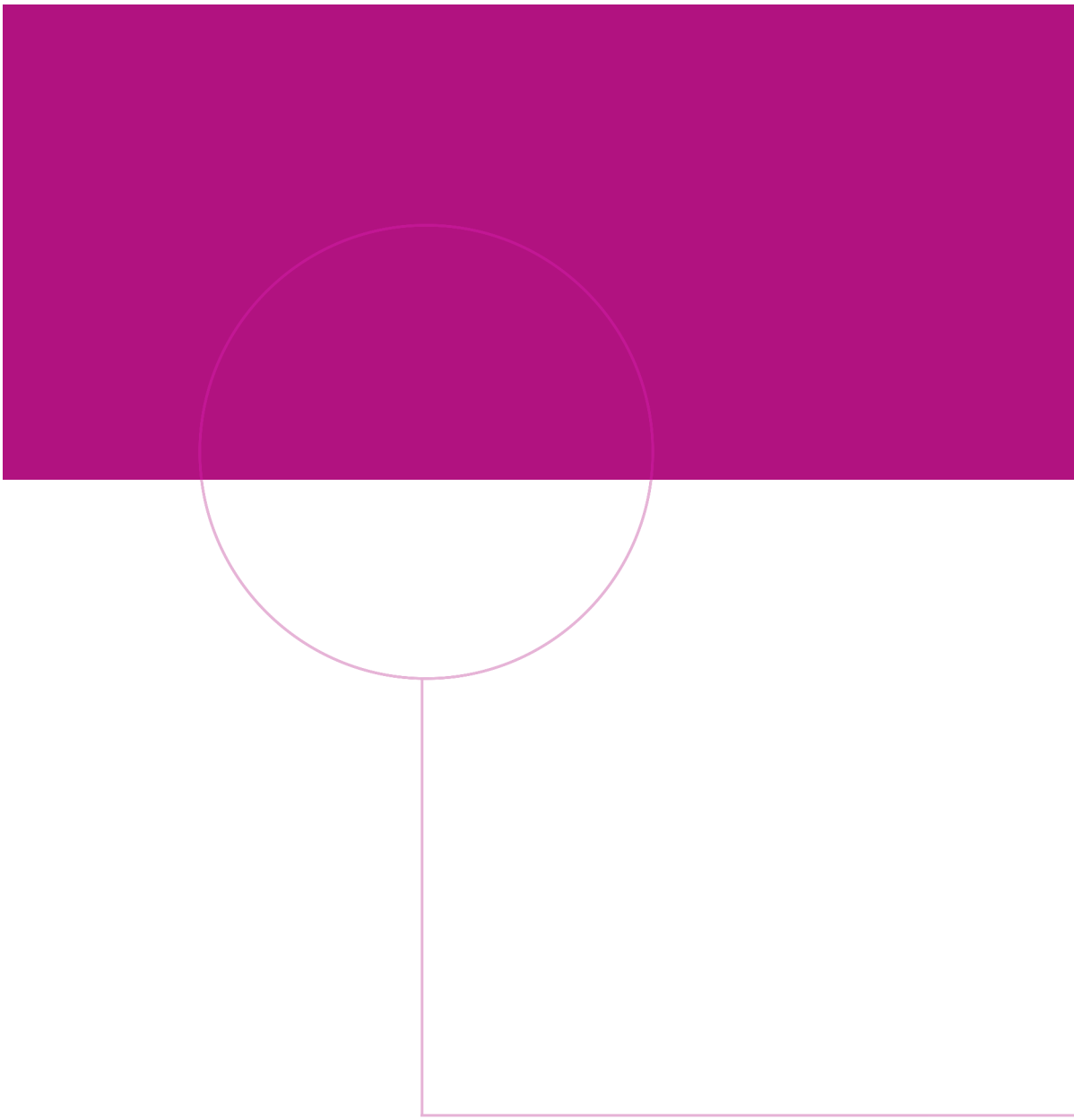
(Signert av prosjektdeltaker, dato)



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