# Master's degree thesis

**LOG950 Logistics**

**A circular economy perspective on sustainable supply chain management: A single case study of the Norwegian paint industry**

Andrea Høvik and Robin Lovin Johannesen

Number of pages including this page: 95

Molde, 30.05.20

Molde University College
Specialized University in Logistics

# Mandatory statement

Each student is responsible for complying with rules and regulations that relate to examinations and to academic work in general. The purpose of the mandatory statement is to make students aware of their responsibility and the consequences of cheating. Failure to complete the statement does not excuse students from their responsibility.

| | | |
|---|---|---|
| *Please complete the mandatory statement by placing a mark **in each box** for statements 1-6 below.* | | |
| **1.** | **I/we hereby declare that my/our paper/assignment is my/our own work, and that I/we have not used other sources or received other help than mentioned in the paper/assignment.** | ☒ |
| **2.** | **I/we hereby declare that this paper**<br>1. Has not been used in any other exam at another department/university/university college<br>2. Is not referring to the work of others without acknowledgment<br>3. Is not referring to my/our previous work without acknowledgment<br>4. Has acknowledged all sources of literature in the text and in the list of references<br>5. Is not a copy, duplicate or transcript of other work | Mark each box:<br>1. ☒<br>2. ☒<br>3. ☒<br>4. ☒<br>5. ☒ |
| **3.** | **I am/we are aware that any breach of the above will be considered as cheating, and may result in annulment of the examination and exclusion from all universities and university colleges in Norway for up to one year, according to the Act relating to Norwegian Universities and University Colleges, section 4-7 and 4-8 and Examination regulations** section 14 and 15. | ☒ |
| **4.** | **I am/we are aware that all papers/assignments may be checked for plagiarism by a software assisted plagiarism check** | ☒ |
| **5.** | **I am/we are aware that Molde University College will handle all cases of suspected cheating according to prevailing guidelines.** | ☒ |
| **6.** | **I/we are aware of the University College's rules and regulation for using sources** | ☒ |

# Personal protection

## Personal Data Act

Research projects that process personal data according to the Personal Data Act, should be notified to Data Protection Services (NSD) for consideration.

**Has the research project been considered by NSD?** ☒**yes** ☐**no**

- If yes:

**Reference number: 818329**

- If no:

**I/we hereby declare that the thesis does not contain personal data according to Personal Data Act.:** ☐

## Act on Medical and Health Research

If the research project is effected by the regulations decided in Act on Medical and Health Research (the Health Research Act), it must be approved in advance by the Regional Committee for Medical and Health Research Ethics (REK) in your region.

**Has the research project been considered by REK?** ☐**yes** ☒**no**

- If yes:

**Reference number:**

# Publication agreement

**ECTS credits: 30**

**Supervisor: Antonina Tsvetkova**

## Agreement on electronic publication of master thesis

Author(s) have the copyright to the thesis, including the exclusive right to publish the document (The Copyright Act §2).

All theses fulfilling the requirements will be registered and published in Brage HiM, with the approval of the author(s).

Theses with a confidentiality agreement will not be published.

**I/we hereby give Molde University College the right to, free of charge, make the thesis available for electronic publication:** ☒**yes** ☐**no**

**Is there an agreement of confidentiality?** ☐**yes** ☒**no**

(A supplementary confidentiality agreement must be filled in)

- If yes:

**Can the thesis be online published when the period of confidentiality is expired?** ☒**yes** ☐**no**

**Date: 30.05.20**

# Abstract

There is still a debate about if circular economy (CE) is a part of sustainability or if it can contribute to the environmental aspect of sustainability. Further, there is a lack of understanding how to align both CE and sustainability. At the same time, the social aspect has been almost been neglected in manufacturing and supply chain management (SCM). Thus, this master thesis aims to *explore how CE principles contribute to the sustainable development of the manufacturing process and SCM practice in the Norwegian paint industry.*

The originality of our investigation is that we have revealed the interaction between the CE principles and sustainability in the Norwegian paint industry. This is an vital issue for this type of manufacturing because paint products are dangerous for people and the environment.

This master thesis applies a single case study approach. Data collection was based on fifteen semi-structured interviews, personal observations, and secondary data like newspapers, the focal company's reports and book on historical events. Data analysis was based on the construction of a chain of events during the development of the paint industry.

The investigation presents the historical development of the manufacturing process. Our findings have revealed the influence of the contextual settings and the internal processes within the focal company on how CE principles evolved in the practice. Our findings have shown that the CE have been found unexpectantly in the existing practice of the focal company. Thus, they can evolve naturally not intentionally without any regulatory pressure the government or initiation from top management.

Our findings have revealed the effects on sustainable development including, both the environmental aspect and the social aspect. Further, our findings disclose that CE can contribute also to non-core activities like SCM practices and special efforts on the cleaning of the environment.

Our future research suggestions are to provide deeper insights into how CE principles and sustainability can be aligned in other contextual settings, and what effects CE principles can provide.

## Acknowledgment

This master thesis represents the final chapter of two years at Molde University College.

We would like to thank the company and key personnel, that have made it possible to conduct this master thesis by sharing valuable data and information. We appreciate their time used to collect the necessary data for this research.

We would also like to express our gratitude to our supervisor Antonina Tsvetkova. She has provided excellent guidance and valuable discussions throughout the master thesis. We are appreciative for her great ideas and feedbacks, as well as her positiveness and good sense of humor.

We would also like to thank Morten Svindland for being a great support. We will always remember: "*Don´t overthink, just write it.*"

Furthermore, we would like to thank our family for good support, and our fellow students for great memories during these two years. We want to especially thank Ine and Monika for their ability to keep our spirits up!

Andrea Høvik & Robin Lovin Johannesen
Molde, May 2020

## Terms and definitions

**Sustainability** – "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland and Dahl 1987).

**Circular Economy** – "…an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, system, and business models" (Ellen MacArthur Foundation 2014).

**Supply Chain Management** – "the management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole" (Christopher 2016, p. 3).

# List of Tables, Figures, and Abbreviations

## List of Tables



## List of Figures

**List of Abbreviations**

| | |
|---|---|
| 3R's | Reduction, Reuse, Recycle |
| ADR | The European Agreement Concerning the International Carriage of Dangerous Goods by Road |
| BREEAM | Building Research Establishment Environment Assessment Method |
| C2C | Cradle-to-cradle |
| C2G | Cradle-to-gate |
| CE | Circular Economy |
| CEBM | Circular Economy Business Model |
| EEA | European Economic Area |
| EU | European Union |
| EPD | Environmental Product Declarations |
| HSE | Health, Safety, and Environment |
| HSEQ | Health, Safety, Environment, and Quality |
| LCA | Life Cycle Analysis |
| LCI | Life Cycle Inventory |
| LCIA | Life Cycle Impact Assessment |
| NAAF | Norwegian Asthma and Allergy Association |
| NIVA | Norwegian Institute for Water Research |
| NGI | Norwegian Geotechnical institute |
| NSD | Norwegian Center for Research Data |
| PCB | Polychlorinated biphenyl |
| R&D | Research and Design |
| SC | Supply Chain |
| SCM | Supply Chain Management |
| SCP | Sustainable Production and Consumption |
| TBT | Tributyltin |
| REACH | Regulation, Evaluation, Authorization, and Restriction of Chemicals |
| VOC | Volatile Organic Compounds |

# Table of Contents

# 1. Introduction

This chapter presents the background for the master thesis, shows the existence of a research gap, and provides insight as to why closing the research gap is necessary. The purpose of this study is clarified, and the research perspectives to examine the purpose are presented. Lastly, the structure of the master thesis is identified.

## 1.1. Background for the thesis

The circular economy (CE) represents a theoretical concept that aims at creating an industrial system where products and services are traded in closed loops or "cycles." The idea is to reduce the negative impact on the world by moving away from the traditional "linear" economic model for production and consumption, also described as a "take, make and dispose" model (Ghisellini, Cialani, and Ulgiati 2016). The CE is characterized as an economy that is regenerative by design, with the aim to retain as much value as possible of products, parts, and materials (Ellen MacArthur Foundation 2013). The aim is to create a system that allows for the long life, effective reuse, refurbishment, remanufacturing and recycling of products and materials (Kraaijenhagen, Van Oppen, and Bocken 2016), which requires changing consumption patterns, and creating new business models and systems (Elia, Gnoni, and Tornese 2017). Previous research has suggested that CE origins are mainly rooted in the ecological and environmental economics, and industrial ecology (Ghisellini, Cialani, and Ulgiati 2016, Wautelet 2018), and that the concept has primarily evolved as research on waste generation, resource use and environmental impact (Lieder and Rashid 2016). Thus, the majority of existing literature on CE has a high focus on the environmental aspect (Dao, Langella, and Carbo 2011, Geissdoerfer et al. 2017, Genovese et al. 2017).

There is an ongoing debate about whether CE is a part of sustainability or if it can contribute to the environmental aspect of sustainability. A number of previous research has emphasized that CE pushes the frontiers of environmental sustainability by emphasizing the idea of transforming products in such a way that there are workable relationships between ecological systems and economic growth. It is implied that CE is not just concerned with the reduction of the use of the environment as a sink of residual like sustainable supply chain (SC) strategies but rather with the creation of self-sustaining production systems in which materials are used over and over again (Genovese et al. 2017). The planet earth has only limited and finite resources, and the rate of production and consumption to meet the never-ending human needs through extraction, processing, manufacturing, and use, is alarming (Jawahir and Bradley 2016). Thus, the CE is often considered as a branch of sustainability science that aims to reach sustainable development goals (Geissdoerfer et al. 2018, Ünal and Shao 2019, Zhu, Geng, and Lai 2010).

Sustainability encompasses three aspects; economic, environmental, and social, and it seeks to evaluate business performance (Elkington 1998). The idea is that organizations need to engage in activities that positively affect the environment and society, besides maintaining their economic performance (Dao, Langella, and Carbo 2011). The escalating environmental concerns, such as pollution, over-use of scarce resources, and the creation of waste in landfills and the oceans (Jæger et al. 2019), have played a significant role in sustainability to influence traditional supply chain management (SCM) (Luthra and Mangla 2018).

Although sustainability aims to balance all three dimensions, the social aspect has been paid less attention to in literature. The literature on sustainability is primarily concerned with the environmental aspect to boost economic performance (Ghisellini, Cialani, and Ulgiati 2016, Wu and Pagell 2011). Many scholars have stressed the lack of attention to the social aspect of sustainability (Ahi, Searcy, and Jaber 2018, Carter and Rogers 2008, Dao, Langella, and Carbo 2011, Martins and Pato 2019, Tsvetkova 2020, Seuring and Müller 2008). The social aspect of sustainability measures the level of social responsibility of a company (Martins and Pato 2019) and concerns all stakeholders, including employees, suppliers, manufacturers, customers, and society (Carter and Rogers 2008). Research considers social sustainability as the promotion of human rights (Sauvé, Bernard, and Sloan 2016), working conditions, and employees well-being and motivation (Shou et al. 2019), the impact on local communities (Tsvetkova 2020), and the establishment of human safety, welfare, and wellness (Mani et al. 2016).

There are just a few studies that focus on the social aspect of sustainable SCM (Tsvetkova 2020). Thus, it seems like there is a shortfall in the literature that emphasizes the importance of embracing social sustainability in manufacturing. Further, there is a lack of understanding of how the social aspect can relate to the development of CE in manufacturing processes. Both sustainability and CE have been gaining increasing attention among researchers, business managers, and policymakers during the past two decades. However, there seem to be different underlying motivations between the two concepts, which lead to different systems being prioritized in the literature. While the motivation of sustainability is to benefit the environment, the economy, and the society at large, CE seems to prioritize the economic systems with primary benefits for the environment and only implicit gains for the social aspect (Geissdoerfer et al. 2017). The vague relationship between the two concepts represents a gap in the literature.

In recent years, a more circular approach to manufacturing has been adopted by many companies in various industries, including the paint industry. Paint companies are trying to find new solutions to become more sustainable, and in order to do so, elements of CE are evolving in business strategies (Challener 2019). Historically, the paint manufacturing practices have included particularly dangerous working conditions due to the highly flammable and toxic substances that are used in manufacturing. Although regulations and practices have been developed to reduce health risks and to ensure a safer workplace, paint manufacturing is still characterized by dangerous fumes and chemicals that may be harmful to the environment and society. Some paint products may cause severe health issues for employees and end-users, as well as to negatively impact the surroundings due to harmful emissions. At the same time, paint products may enhance the function and reduce the environmental impacts of the object that is painted, e.g., through durable marine paint that helps to increase the fuel efficiency of ships or reduce the need for maintenance. This means that the paint products' abilities may contribute to sustainability, as wells as CE, in a broader and longer-term sense.

## 1.2. Research purpose

Being motivated by the shortcomings in the literature mentioned above, the purpose of our study is "***to explore how CE principles contribute to the sustainable development of the manufacturing process and SCM practice in the Norwegian paint industry***."

The investigation in this master thesis presents an empirical case of the interconnections between CE and sustainability in the Norwegian paint industry. A paint manufacturer that has committed to sustainable growth was selected for the empirical case. Although not formalized in the company's strategies, the CE principles of reuse, recycle, remanufacturing, redesign, and renewable energy have evolved in the focal company during the past two decades. This makes it possible to explore how the CE principles contribute to the development of sustainable SCM practices in the Norwegian paint industry.

This research purpose of the master thesis is intended to be reached by focusing on three perspectives:

1. ***The reasons for how CE evolved in the Norwegian paint industry***
2. ***How do CE principles affect the social aspect of sustainability?***
3. ***How do CE principles affect the environmental aspect of sustainability?***

This study contributes to this field of research by exploring the extant literature combined with a qualitative research design through a single case study, supplemented by thorough research on the focal company's historical development of sustainable practices and the evolvement of CE principles. In doing so, our research contributes towards gaining a broad and holistic understanding, as well as to gain knowledge on the business practices of the main issue.

## 1.3. Structure of the thesis

The rest of this thesis is organized as follows:

Chapter 1: Presents the background for the thesis, the research purpose, and the structure of the thesis.

Chapter 2: Identifies the theoretical framework for the research to enlighten the current concepts on sustainable supply chain management and circular economy.

Chapter 3: Describes the research methodology, including the data collection techniques, research design, and research philosophy.

Chapter 4: A presentation of the context and description of the Norwegian paint industry.

Chapter 5: Consists of discussions.

Chapter 6: Research summary, theoretical- and managerial implications, and limitations, and suggestions for further research.

# 2. Theoretical framework

This chapter presents the main ideas in the existing theory in sustainability and CE.

## 2.1. Sustainability

Sustainability is a challenging concept and is increasingly discussed by policymakers, in business research and practices, and management science (Linton, Klassen, and Jayaraman 2007). The term sustainability originates from the French word *soutenir* - "to hold up or support," and the background for the concept has its origin in cultivating and maintaining forestry in such a way that the harvest should not exceed the volume that grows again (Geissdoerfer et al. 2017). The more modern interpretations of sustainability have its roots in the rapidly depleting of the world's scarce resources, as well as the worry of wealth disparity and business social responsibilities (Luthra and Mangla 2018, Naz, Rahim, and Jæger 2018). Thus, sustainable development is the attempt to balance the three aspects of sustainability, emphasizing economic, environmental, and social considerations (Elkington 1998).

However, the term sustainability is still very vague, and it is used to describe a large number of business goals, concepts, and strategies. Hence, there are many definitions and interpretations of sustainability with different perspectives. Some definitions specify the concern of how human activity is conducted while preserving the earth's ecosystem (Geissdoerfer et al. 2017), or more narrow definitions with less focus on the social aspect, which is more applicable for organizations to understand and apply (Dao, Langella, and Carbo 2011). However, the most adopted definition of sustainable development was published in the report "Our Common Future" in 1987 by the World Commission on Environment and Development (WCED). WCED defines sustainable development as *"…development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (Brundtland and Dahl 1987, p. 8). The report focused on the need for changes in industrial practice and consumption patterns. Since then, interest in sustainability-related studies in various businesses (Rajeev et al. 2017).

### 2.1.1. Dimensions of sustainability

To ensure sustainable development, the three aspects of environmental, social, and economic issues must be in a balanced and optimized manner, without one dimension dominating the others (Goh et al. 2020). However, the concept has no standardized method of how to measure the dimensions in a holistic matter (Goh et al. 2020). The literature argues that the research concerning sustainability mostly focuses on environmental issues, and the social aspect tends to under-represented (Ahi, Searcy, and Jaber 2018, Carter and Rogers 2008, Martins and Pato 2019). According to Seuring and Müller (2008), there is an apparent deficit in SCM literature on social issues, as well as a lack of a unified theory of all three dimensions of sustainable development. Dao, Langella, and Carbo (2011) state that research seems to be over-concerned with the environment and under-concerned with people. Figure 1 presents the three aspects of sustainability.

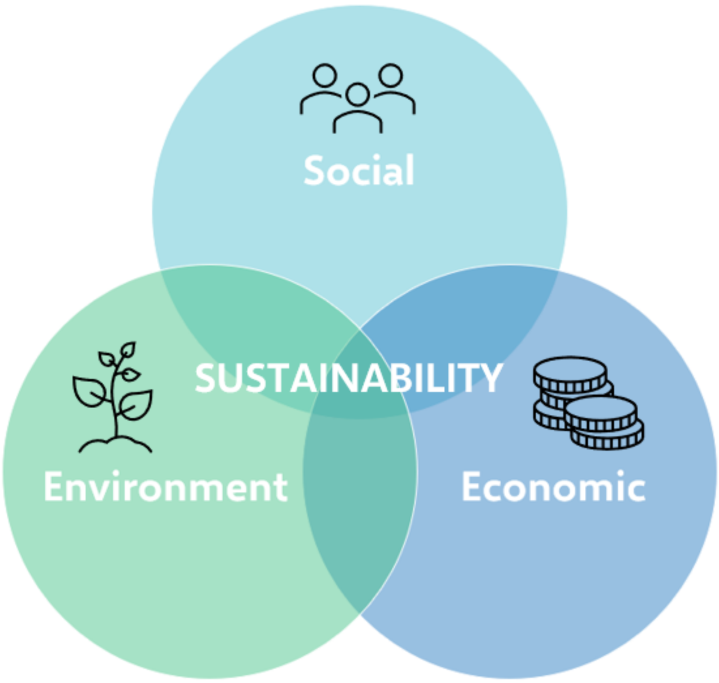



*Figure 1: The three aspects of sustainability (own production)*

Table 1 presents different views on the three aspects of sustainability provided by D'Amato et al. (2017), Goh et al. (2020), and Shou et al. (2019).

*Table 1: Core aspects of sustainability dimensions*

| Sustainability dimensions | Social | Environmental | Economic |
|---|---|---|---|
| **D'Amato et al. (2017)** | ▪ Education and training<br>▪ Social justice (e.g. inter- and intra-generational)<br>▪ Participation and democracy<br>▪ Health, quality of life and well-being<br>▪ Social inclusion<br>▪ Social capital<br>▪ Community network<br>▪ Safety<br>▪ Mixed tenure, employment and income (safety and equality)<br>▪ Social order and cohesion<br>▪ Cultural traditions, recreation, and tourism. | ▪ Water, carbon and nutrient cycles (including emissions and waste)<br>▪ Greening cities and logistics<br>▪ Quality of energy source and efficiency in production and use<br>▪ Maintenance of biodiversity<br>▪ Ecosystems and related services. | ▪ Satisfaction of basic needs<br>▪ Enhancement of equity<br>▪ Increasing useful goods and services |
| **Goh et al. (2020)** | ▪ Community development, public engagement<br>▪ User comfort, health, and safety<br>▪ Access to services, equality, and diversity | ▪ Aims to restore and maintain the harmony between the natural and the built environment for the whole life of a structure | ▪ Financial gains from individual projects for the benefit of project stakeholders |
| **(Shou et al. 2019)** | ▪ Employees' working conditions and well-being | ▪ Energy efficiency and pollution reduction | ▪ Sales and profit growth |

### 2.1.2. Sustainable manufacturing process and SCM

While sustainable practices in SCM have been developed into a common framework since the early 2000s (Seuring and Müller 2008), sustainable manufacturing is one of the recent beneficial areas which can bring the balance among the three aspects of sustainability (Malek and Desai 2020). A sustainable development goal in manufacturing and SCM is sustainable production and consumption (SCP), which refers to having more efficient and profitable production while using fewer raw materials as well as adding value to a product while creating less pollution and waste in the process (Govindan 2018). Initially, the supply chain (SC) considers the product from the processing of raw materials to delivery to the customer. However, the interaction between sustainability and SCs integrates issues beyond the core of SCM. Linton, Klassen, and Jayaraman (2007) present six fields of practices that connect sustainability to SCM: product design, manufacturing by-products, by-products produced during product use, product life extension, product end-of-life, and recovery processes at end-of-life.

- *Product design:* Through technics like life cycle assessment (LCA), organizations are able to minimize the environmental impact of the product through its design.
- *Manufacturing by-products:* Reducing and elimination of by-products through cleaner process technologies, and quality and leaner production techniques, e.g., use of waste heat for air condition.
- *By-products produced during product use:* Provide a service to supplement the product.
- *Product life extension*: Develop products that allow capturing more of the product value.
- *Product end-of-life:* Depending on the product design, products may be reused, remanufactured, recycled, incinerated, or disposed of.
- *Recovery processes at end-of-life*: Product recovery networks for SC members to be able to remanufacture, recycling, and refurbishing.

Veleva and Ellenbecker (2001) also present several principles of sustainable production in their research. They view social justice and community development as one of the main aspects. It is crucial that firms facilitate a good environment outside the business, i.e., promote equity and fairness. The communities around the workplace should be respected and enhanced socially, culturally, and physically. Also, the health and security of the firm's workers is an essential factor in sustainable production. Hence, workplaces should be designed to minimize or eliminate physical, chemical, biological, and ergonomic hazards (Veleva and Ellenbecker 2001).

The role of managing is prominent, and an essential step toward the broader adoption of sustainable manufacturing and SCM (Ahi and Searcy 2013, Linton, Klassen, and Jayaraman 2007). The three aspects of sustainability draw the attention of managers, as they are required to be able to identify and understand the sustainability challenges both internally and externally of their organization (Luthra and Mangla 2018). Furthermore, managers regard the integration of the three dimensions into their daily tasks in order to achieve sustainable performance (Tseng 2015). Hence, the literature argues that organizations need to integrate issues that go beyond the core of SCM, such as a broader focus on environmental and social challenges into their corporate strategies (Govindan 2018).

### 2.1.3. Drivers and barriers of sustainable manufacturing and SCM

One of the main drivers for the transition towards sustainable manufacturing and SCM is the increasing production and consumption. The tradeoff between economic development and the exploitation of the world's natural resources has made legislators, politicians, and consumers more aware of the damage inflicted on the environment. This awareness has resulted in laws and regulations that are more stringent to protect the surroundings (Rajeev et al. 2017). Seuring and Müller (2008) mention several triggers for sustainable SCM in their research. The legal demands/regulations are some of the most critical drivers. Government agencies can influence an organization's actions to adopt more sustainable initiatives through fines and trade barriers (Govindan 2018). The next trigger is customer demands and requirements. Customers/consumers are important facilitators towards more sustainable SC. The fear of consumers boycotting their products due to reports concerning environmental or social problems has put pressure on companies (Seuring and Müller 2008).

Another driver is how companies can achieve a competitive advantage through sustainable practices in the SC (Seuring and Müller 2008). By focusing on the dynamic capabilities of the SC, sustainable practices allow companies to enhance relationships between its partners and the flow of goods and information. By doing so, the companies maintain control over their SC (Govindan 2018). Besides, a focus on sustainability helps the companies to redefine and improve functions and operations, which can lead to innovation and strategic growth. Hence, the strategic actions of a single firm are not enough to achieve sustainability. Sustainable development is dependent on the cooperation of entire SCs (Dao, Langella, and Carbo 2011). According to Ahi and Searcy (2013), coordination and integration of the sustainability dimensions between key inter-organizational business systems aid companies to meet stakeholder requirements, and improve profitability, competitiveness, and resilience of the organization.

Although sustainable SCM initiatives have been adopted to reduce costs and increase efficiency (Rajeev et al. 2017), some of the barriers for sustainable manufacturing and SCM are higher costs, coordination complexity and insufficient communication in the SC. According to Seuring and Müller (2008) these barriers relate to supporting factors, including company-overlapping communication, new management systems, employee training, and monitoring, evaluation, and reporting - which are factors that may contribute to higher costs, complexity, and lack of communication. Also, the trade-off perspectives of sustainable SCM and operations orientations in actual practice is a dilemma for SC managers. Investments related to the improvement of operations-related practices may leave fewer resources towards sustainability efforts, especially when there are limited resources to allocate (Shou et al. 2019). In Govindan (2018)'s framework on SCP, he presents barriers depending on the role each stakeholder plays. From an organizational point of view, long SCs due to globalization could be a barrier towards more sustainable production. Consumer awareness of both sustainable consumption and production may hinder sustainable development. However, a general barrier for SCP results from the lack of cooperation and coordination among the stakeholders and their goals (Govindan 2018). Table 2 summarizes the drivers and barriers for sustainability based on Govindan (2018), Seuring and Müller (2008), and Shou et al. (2019).

*Table 2: Drivers and barriers of sustainability*

| Drivers | Barriers |
|---|---|
| Laws/regulations | Higher costs |
| Stakeholder requirements | Coordination complexity |
| Competitive advantage | Insufficient communication in the SC |
| Organizational resilience | Resource allocation |
| | Lack of coordination among the stakeholders and their goals |

### 2.1.4. Sustainable manufacturing and SCM strategies

Sustainable manufacturing and SCM concern the extent to which organizations incorporate the sustainability aspects into their SCs (Shou et al. 2019). In order to do so, companies seek to develop strategies for implementing sustainable SCM practices. According to Kang et al. (2012) the main strategies of sustainable SCM can be divided into environmental lead, strategic purchasing and supply, SC capabilities, product-based green supply, and greening the supply process. Strategic partnerships between actors in the SC drive companies to engage in sustainable management initiatives, e.g., monitoring social standards or environmental planning through purchasing and supply (Kang et al. 2012, Shou et al. 2019). Shou et al. (2019) consider the relationship with suppliers as a factor for sustainable practices, which may be established through supplier assessment standards, gathering and processing supplier-related information, and evaluating the sustainability performance of suppliers. To monitor and audit the suppliers, formal evaluation systems that include measures for environmental and social issues may be developed (e.g., waste disposal, pollution, working conditions). Also, the collaboration with suppliers along the SC regarding employee training is a practice to increase the employees' knowledge on, e.g., waste reduction, and health and safety-related work conditions (Shou et al. 2019). In their study, Luthra and Mangla (2018) present several strategies for sustainability for businesses to boost their performance, as well as to improve operations through the involvement of stakeholders continuously. The strategies are presented in Table 3.

*Table 3: Sustainable strategies in manufacturing and SCM (adopted from Luthra and Mangla (2018))*

| **Strategies for sustainability** | **Brief description** |
|---|---|
| Understanding of the sustainability impacts of their SC | Understanding the implications of sustainability enhances overall business performance |
| Management involvement, support, and commitment | Management involvement, support, and commitment drives the process change for successful adoption of sustainability |
| Establishing a vision and objectives for SC sustainability | Sustainability considerations can be integrated into organizational policies and visions for superior performance |
| Training, education, motivation and incentive programs of SC members about best practices | Training program and incentives of SC members would assist in adopting top-rated sustainable practices |
| Behavioral changes in the complete SC | Behavioral change is a significant aspect to successful sustainable adoption |
| Joint industry collaboration and partnerships | Industry collaboration and partnerships with other partners would help in successful sustainable adoption |
| Communicating business expectations with suppliers | Organizations should communicate with their suppliers to improve their sustainable performance throughout the value chain |
| Use of clean technologies and modern information management approaches | Use of clean technologies and modern information management approaches would reduce process wastage |
| Product stewardship | Industries should take responsibility for their products to reduce their ecological, societal, and safety impacts. |

### 2.2. Circular Economy

The CE concept has achieved increased attention from the perspectives of both academics, politicians, and business strategists all over the world (Geissdoerfer et al. 2017). The idea of CE is to develop self-sustaining production systems in which materials are used repeatedly, which will contribute to a more sustainable production and consumption (Geissdoerfer et al. 2017). The aim is to reduce the impact on the world by moving away from the traditional "linear" economic model, also described as a "take, make and dispose" model (Ghisellini, Cialani, and Ulgiati 2016). The increasing pressure from stakeholders about the environmental and social responsibilities are pushing companies to think in new ways. Therefore, businesses are now exploring and embracing new business models that are incorporating the CE concept, such as design for reuse or improved materials recovery. By doing so, companies seek to become more sustainable, as well as use CE as a mechanism to create a competitive advantage (Genovese et al. 2017). CE is based on reducing wasteful resources through effective design and implementation of products and processes for improved resource-efficiency with circular material flow involving recovery, reuse, recycling, and remanufacturing of products (Jawahir and Bradley 2016). According to academics, the CE concept is influenced by Kenneth Boulding's work from 1966, in which he describes the earth as a closed and circular system with limited capacity (Geissdoerfer et al. 2017, Ghisellini, Cialani, and Ulgiati 2016, Korhonen et al. 2018, Lieder and Rashid 2016, Millar, McLaughlin, and Börger 2019, Naustdalslid 2014). Figure 2, illustrates the differences between the different economies.

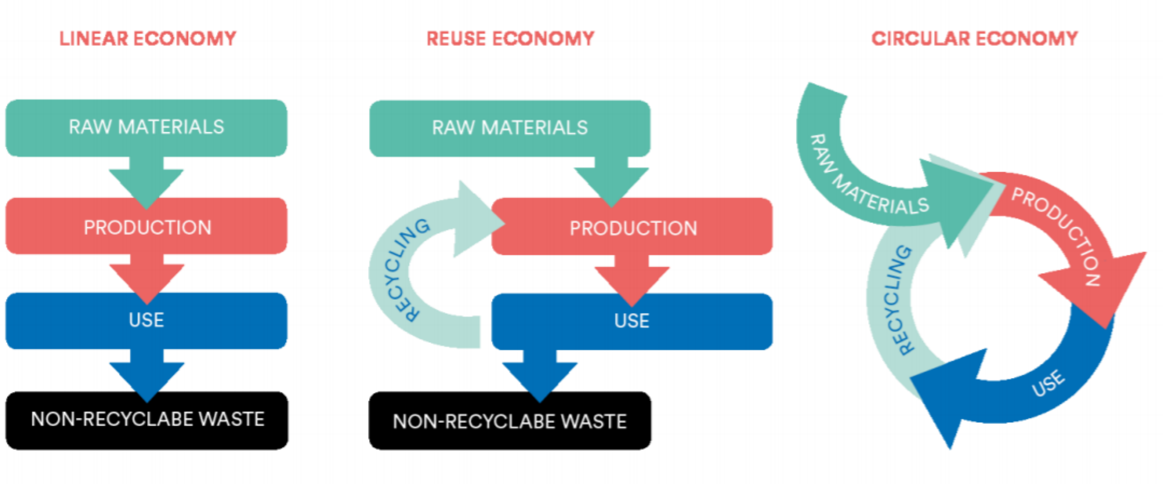



*Figure 2: Linear, Reuse, and Circular Economy (adopted from Barth (2019))*

Different schools of thought have emerged over the years. McDonough and Braungart's cradle-to-cradle (C2C), Commoner's laws of ecology, Stahel's looped and performance economy, Lyle's regenerative design, Graedel, and Allenby's industrial ecology, Benyus biomimicry and Pauli's blue economy (Geissdoerfer et al. 2017). Due to the complexity and the multitude of different perspectives within these concepts, there are many definitions of CE (Kirchherr, Reike, and Hekkert 2017). Korhonen et al. (2018) claim that it is almost impossible to identify a universal definition of CE as different stakeholders have a different view on the CE concept. However, the most common definition of the CE concept is from Ellen MacArthur Foundation (2014). One of the most used about CE:

> *"...an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, system, and business models."*

Even though there are several definitions of CE, the core aspect remains the same; it is based on "value retention processes," which includes the mechanisms to retain value in the economy through reuse, repair, refurbishment, remanufacturing, redistribution, and recycling (Haupt and Hellweg 2019).

### 2.2.1. The transition towards CE

Throughout the evolution and diversification, the industrial economy has barely moved beyond the fundamental characteristic established in the early days of industrialization of the linear model of resource consumption (Ellen MacArthur Foundation 2014).

Ellen MacArthur Foundation (2014) found trends that push business from linear thinking towards CE:

- High price volatility
- An increase in production efficiency does not generate real competitive advantage
- The paradox of energy efficiency
- Increase SC risks with global SCs
- Excessive use of virgin resources

In CE, three principles are prominent; reduction, reuse, and recycle (3R's). The reduction principle aims to minimize the input of primary energy, raw materials, and waste through the improvement of efficiency in production and consumption. The reuse of product appeals in terms of environmental benefits as it requires fewer resources, less labor in comparison to the manufacturing of new products from virgin materials. Recycling of waste allows benefiting from still useful resources and reduce the quantity of waste that needs to be treated and disposed of, reducing the environmental impact (Ghisellini, Cialani, and Ulgiati 2016).

Through the development of the CE concept, Ellen MacArthur Foundation (2013), proposed three principles that might align with the 3R principles. At the core, CE aims to design out waste, in which the product's design enables the product to be dissembled and reused, and none of the components goes to waste. Next, circularity introduces a strict differentiation between a consumable and durable component. Consumables are made mainly of biological ingredients that are not toxic and possibly beneficial and safely returned to the biosphere. Durable components, like plastic and metals, are designed from the start with the purpose of reuse. Lastly, the energy required to fuel this cycle should be renewable by nature to decrease resource dependence and increase system resilience (Ellen MacArthur Foundation 2013).

Ghisellini, Cialani, and Ulgiati (2016) list out the limits and challenges of the transition towards CE with regards to the 3R principles and the integrations of the principles that Ellen MacArthur Foundation (2013) introduced. The main limits and challenges of the transition to CE are presented in Table 4.

*Table 4: Main limits and challenges of transition to CE (adopted from Ghisellini, Cialani, and Ulgiati (2016))*

| Principles of CE | Limits or challenges |
|---|---|
| **Design** | Optimal product life scenario.<br>Design for disassembly, reuse, recycling.<br>Design for durable products.<br>Design for new business models of consumption. |
| **Reduction** | Overcome the rebound effect of eco-efficiency and eco-sufficiency strategies. |
| **Reuse** | Technical maximum reusability of materials.<br>Increase of consumer demand towards the reuse of products and materials.<br>Development of take-back mechanisms from the companies.<br>Ensuring repair and secondary use of products after their original use.<br>Taxation based on non-renewable energy rather than labor and renewable energies. |
| **Recycle** | Reinforcement of local markets of recycled materials.<br>Risk of global trade of materials. Plastic waste: unfeasibility due to the mixing of contaminants.<br>Cellulose: feasible until 4-6 times.<br>Rare metals (lack of economies of scale).<br>Food waste: further transformations before being used requires high costs in R&D.<br>Appropriate LCA modeling for reuse and recycling. |
| **Reclassification of materials into Technical Nutrients** | Reuse after the first cycle.<br>Safe return into the Biosphere or in a cascade of subsequent uses (biorefinery). |
| **Renewable Energy** | Increase their share compared to the share of fossil fuels. |

According to Ghisellini, Cialani, and Ulgiati (2016), the design principle is relevant because the sustainability of the product depends heavily on the initial design stage. By considering the CE principles in the initial design, the greater is the avoidance of negative impacts of the 3R's. A reduction of the impacts in one of the CE principles could give an increase in negative impacts on another principle. As an example, recycling is the leading principle of a positive impact on a practical level (Ghisellini, Cialani, and Ulgiati 2016). Moreover, Geissdoerfer et al. (2017) discuss that reduction in input could give efficiency gains and, consequently, reduction in waste.

In an SCM perspective and transition towards CE, Jain (2018), points out that in order to successfully transition towards a circular SC, it will require product redesigning, reducing SC complexity, adopting innovative business models, and continual measurement of progress towards circularity. Further, Van Eijk (2015) states that CE demands a system change with parallel action along the value chain, and not purely sector and product-focused approach. There is a need for a mix of complementary instruments and approaches across different parts of the CE and efforts to engage and link actors along the entire value chain (Van Eijk 2015).

**Drivers and barriers of CE**

China has implemented a CE promotion law, which states that CE is a generic term for reducing, reusing, and recycling activities in regards to production, circulation, and consumption. According to Ghisellini, Cialani, and Ulgiati (2016), this is not consistent with China's practice of steady growth of production and consumption. Further, Ghisellini, Cialani, and Ulgiati (2016) argue that Europe, Japan, USA, Korea, and Vietnam identify CE and its principles related to waste management. Van Eijk (2015) states that regulatory changes at an EU level, can take up to five years before the action happens at a national level. The UN Climate Conferences has a time span of a decade before it materializes, but at the local level initiatives could start within less than a year. Governments play a crucial role because they can strengthen business efforts and upscale small niche activities into robust circular measures that can impact entire economies. Systematic reshaping of the traditional production and consumption model requires a clear set of governmental actions to encourage all companies to apply circular business models (Van Eijk 2015).

CE has been studied in different contexts. Even though the targets of CE are consistently highlighted and adopted as part of the future strategies of different regulators and countries, e.g. EU and China, there are several environmental and economic barriers to CE (Tura et al. 2019). The barriers to implementation of CE can be situated both internally or externally (Govindan and Hasanagic 2018). Tura et al. (2019) presents a framework of CE drivers and barriers that includes; economic -, social -, institutional -, technological and informational -, SC -, and organizational barriers and drivers. Kirchherr et al. (2018)´s framework identifies cultural barriers, regulatory barriers, market barriers, and technological barriers for the implementation of CE. Furthermore, the authors identified possible interactions between barriers and chain reaction mechanisms that can lead to failure to implement CE. Ellen MacArthur Foundation (2014), see SC as a key to drive change. However, they have identified three main barriers to shift towards CE: geographic dispersion, materials complexity, and linear lock-in. Jæger et al. (2019), argues that firms are slow to make a transition towards CE due to the barriers, including the need for dramatic changes for the whole company and its stakeholders. The transition can begin when the hinge points are identified and acted upon in a concerted effort across companies, geographies, and along the SC. Based on our literature review, we made Table 5, which comprises Kirchherr et al. (2018)’s framework for CE barriers including cultural barriers, market barriers, regulatory barriers, and technological barriers. In the table, we adapted Ghisellini, Cialani, and Ulgiati (2016)’s identification on limits or challenges of the transition to CE.

*Table 5: Barriers and challenges of CE*

| **Cultural** | **Regulatory** | **Market** | **Technological** |
|---|---|---|---|
| Hesitant company culture | Obstructing laws and regulations | Lacking standardization | Lacking technologies to implement CE |
| Limited collaboration in the value chain | Lacking global consensus | High upfront investment costs | Too few large-scale projects leading by example |
| Lacking consumer interest and awareness | Risks of global trade of materials. | Limited funding for circular business models | Technical maximum reusability of materials |
| Limited knowledge about circular procurement | Safe return to the biosphere | Low virgin material prices | Limited circular designs |
| Risks connected to trust and security for consumers | | | Risk of rebound effects<br><br>Appropriate LCA modeling for reuse and recycling |

The implementation of CE presents a framework with opportunities for organizational and financial gains in the SC and manufacturing process. The root causes for accelerating the willingness to implement CE rise from the pressure to reduce negative environmental impacts, like resource scarcity (Tura et al. 2019). Since private companies are mainly profit-driven, CE is an attractive option (Govindan and Hasanagic 2018). The drivers are the same as barriers classified into the internal and external environment. The internal drivers identify what has to be done within the company, and the external drivers describe what has to be done outside the company so it can be adopted into the SC (Govindan and Hasanagic 2018). Based on Tura et al. (2019)´s framework, from an the economic perspective, CE is considered to provide opportunities for cost savings by reducing waste and energy costs. Also, CE provides new possibilities for new value creation, business growth, and an increase in margin and profits.

The social driver of CE is that it has the potential to increase jobs. The institutional drivers towards CE are governmental support through directional laws and regulations, and these have a clear enhancing role towards CE and global standards, and certifications like ISO 14001 inspire the development of CE. Technological development (e.g. a new technology that provides cleaner solutions) encourages companies to enhance CE. From a SC perspective, SC drivers that encourage CE is the potential to reduce the SC dependence, and also avoid high and volatile resource prices. From the organizational perspective, CE principles may give the company brand benefits and strengthen its image, thus enable differentiation (Tura et al. 2019). Table 6 presents the drivers of CE.

*Table 6: Drivers of CE (adopted from Tura et al. (2019))*

| **Environmental** | **Economic** | **Social** | **Institutional** | **Technological** | **Supply Chain** | **Organizational** |
|---|---|---|---|---|---|---|
| Preventing negative environmental impacts | Cost savings<br><br>New value creation | Increase jobs | Governmental support<br><br>Global ISO standards | New technology<br><br>Cleaner production | Reduction in supplier dependence<br><br>Avoiding high and volatile prices | Stronger brand |

### 2.2.2. CE strategies

**Cradle-to-cradle**

Cradle-to-cradle (C2C) proposes a positive vision of a future where products are redesigned to be beneficial to humans and the environment. The idea of C2C is not to reduce negative impacts but to increase positive impacts (Bjørn and Hauschild 2018). C2C as a concept was developed by William McDonough and Michael Braungart, and they combined the chemistry science and intentional design of products for industry. Several antecedents have been suggested to justify the theoretical roots of CE, including industrial ecology, cleaner production, and Cradle-to-Cradle (C2C). Following Ünal and Shao (2019), C2C grew into an operationalized version of CE compared to other antecedents by serving as a proxy for CE implementation. C2C is a concept that has become increasingly practitioner-oriented by developing its standards and a certification program that evaluates products under five CE capabilities:

- Material health
- Material reutilization
- Renewable energy
- Water stewardship
- Social fairness

(Ünal and Shao 2019)

To further elaborate on the CE capabilities in regards to CE implementation, Ünal and Shao (2019) explain that *material health* is about phasing out toxic materials, and *material reutilization* is material recovery and recycling activities. *Renewable energy* is technology such as hydropower, wind power, and solar power that enables companies to become more carbon-neutral. *Water stewardship* is that water is treated as a scarce resource, and *social fairness* is giving the capabilities a holistic approach as not only the environment is considered, but also improving the society.

According to Braungart, McDonough, and Bollinger (2007), C2C design enables the creation of a wholly beneficial industrial system driven by the synergistic pursuit of positive economic, environmental, and social goals. C2C design outlines a framework for designing products and industrial processes that turn materials into nutrients by enabling their perpetual flow within one of two distinct metabolisms: the biological metabolism and the technical metabolism (Braungart, McDonough, and Bollinger 2007).

Braungart, McDonough, and Bollinger (2007) came up with a concept of eco-effectiveness. With a C2C design, it proposes an alternative design and production concept to the strategies of zero emissions and eco-efficiency. Eco-effectiveness is a positive agenda for the conception and production of goods and services that incorporate social, economic, and environmental benefits. At the same time, eco-efficiency seeks to reduce the unintended negative consequences of processes of production and consumption, according to Braungart, McDonough, and Bollinger (2007). The goal of eco-effectiveness is not to minimize the cradle-to-grave flow of materials but generate cyclical cradle-to-cradle metabolism, which enables materials to maintain their status as resources.

**Cradle-to-gate**

Cradle-to-Gate (C2G) is opposed to Cradle-to-Cradle, which is the full life cycle assessment, a partial product life cycle assessment from resource extraction to the factory gate. C2G assessments are the basis for Environmental Product Declarations (EPD) (Cao 2017). The C2G scope includes raw material extracting and manufacturing (Abd El-Hameed, Mansour, and Faggal 2017).

**Closed-loop system**

CE promotes the production of goods through closed-loop systems of manufacturing. The consumption of virgin resources is reduced to optimize the use of by-products, and waste or recycling of discarded products are the primary sources of materials. In closed-loop systems, the entire flow of materials from suppliers to manufacturers, distributors, retailers, and consumers is considered, as well as the reverse flow of used products (Lieder and Rashid 2016). CE promotes the resiliency of resources where the production of long-lasting goods can be repaired, or dismantled and recycled easily (Sauvé, Bernard, and Sloan 2016). Braungart, McDonough, and Bollinger (2007) view technical nutrients in a C2C perspective as synthetic or mineral that cannot be put back to the biological sphere. Further, they argue that keeping industrial products in a closed-loop system of manufacturing by recovery and reuse while maintaining the highest value through the life cycles of the product promotes CE through this manufacturing process. Further, Braungart, McDonough, and Bollinger (2007) state that using toxic raw materials would be acceptable in a closed-loop system since it would not oppose any danger to the environment.

### 2.2.3. Life cycle assessment

Life cycle assessment (LCA) is a tool or methodology to assess the environmental impacts and resources used throughout a product's life cycle from raw material acquisition via production and use phases, to waste management (Finnveden et al. 2009). Also, according to Genovese et al. (2017), LCA can be used as an environmental analysis methodology to support cleaner production and greener SCs. LCA can help to identify opportunities to improve the environmental performance of products at various points in their life cycle, also informing decision-makers in industries, government or non-government organizations of the purpose of a product or process design or redesign and selection of relevant indicators of environmental performance, including measurement techniques (ISO 2006).

Genovese et al. (2017) indicate that LCA is a framework for a product, process or activity/operation can bring together the impacts of collaborative SC partners arising from extraction and processing of raw materials, manufacturing, transport and distribution, reuse, maintenance, recycling, and final disposal. Therefore, LCA is a holistic approach that brings environmental impacts into one consistent framework, wherever and whenever these impacts have occurred or will occur. In LCA literature, there have been some studies to integrate social aspects into LCA. Grießhammer et al. (2006), states that there are considerable hurdles to overcome because social impacts will require an entirely different type of modeling, also the difference in how different actors in different countries have very different appraisals of social aspects.

In an LCA study, there are four phases defined by ISO: Goal and Scope Definition, Life Cycle Inventory Analysis (LCI), Life Cycle Impact Assessment (LCIA), and Interpretation (Finnveden et al. 2009, Cao 2017, Muthu 2014). Following the logic of LCA, one can use the different environmental impacts associated with a product across its different life cycle phases. An LCA could identify the hot-spots through the entire life cycle (Muthu 2014). In order to complete a full LCA study, a complete data set of inputs are required (e.g., materials and energy). Also, the data should be collected from the beginning of the life cycle (Cao 2017).

### 2.2.4. Integration of the CE principles and sustainability in the manufacturing process and SCM

Geissdoerfer et al. (2017) present an overview of the main similarities and differences between sustainability and CE, as well as emphasizing the lack of a holistic view of all the three dimensions of sustainability within CE. They found out that the relationship between CE and sustainability is either conditional, beneficial, or a trade-off. The conditional relationship between sustainability and CE are distinct in regards to the environmental dimension, but it is needed for sustaining economic output.

CE business models are considered as a class of a generic strategy for sustainable business models (Geissdoerfer et al. 2017). For sustainable manufacturing, circularity in business models and SC are seen as a precondition, it is necessary for improved economic and environmental performance, and CE is an essential element of sustainable development (Geissdoerfer et al. 2017). Geissdoerfer et al. (2017) state that the goal of CE is focusing on closing the loop by eliminating all resource inputs and leakage of waste and emission. Sustainability is more open-ended with different goals depending on the stakeholder and their interests. The motivation of the CE concept is the observation that resources could be used in a better way, and waste and emission reduced. The motivation of sustainability is often diffused and diverse due to the embraced reflexivity and additivity to a different context. Sustainability benefits the environment, economy, and society, while CE priorities the economic system, in which the environment is the primary benefit. The social benefits are only implicit based on the improvement of the environment (Geissdoerfer et al. 2017).

SCM association with sustainability can be linked with the early interest in closed-loop reverse logistics, product recovery, and remanufacturing (De Angelis, Howard, and Miemczyk 2017). According to De Angelis, Howard, and Miemczyk (2017), "the power of circling longer" is an essential element in the transitioning from traditional or sustainable SCM towards circular SCs. This element involves extending the time during which materials are kept in use.

According to Genovese et al. (2017), the principle of CE is an idealistic ambition of pushing the boundary of sustainable SCM practices, and these practices are ultimately concerned with the reduction or delay of unintended negative impacts on the environment due to cradle-to-grave material flow. The CE paradigm has provided a framework where businesses are operating within the same supply network. In this context, the concept of Reverse SCM has been developed as an adaptation of CE principles to SCM (Genovese et al. 2017).

During the last decade has the integration of sustainable SCM and CE has been introduced in academics. Farooque et al. (2019, p. 884), proposed a definition of circular supply chain management (Circular SCM):

> *"Circular supply chain management is the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically restores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste management, involving all stakeholder in a product/service lifecycle including parts/product manufacturers, service providers, consumers, and users."*

In practice, Circular SCM attempts to produce zero waste through system-wide innovations to recover value from what was traditionally called waste (Farooque et al. 2019). According to Farooque et al. (2019), the two aspects that make Circular SCM unique is that its restorative and regenerative cycles are based on circular thinking, and the zero-waste economy's vision is inherent in the CE philosophy. In other words, Circular SCM focuses on end-of-life product management for reuse, repairing, re-assembly, remanufacturing, recycling, and waste disposal (Jain 2018). Circular SCM applies to manufactured products and service products. Organizations collaborate with others within and outside of the sector to maximize the utility of goods and materials in Circular SCM. This vision guides SC managers to achieve breakthrough performance in resource efficiency, and consequently, profitability (Farooque et al. 2019).

### 2.2.5. CE in manufacturing and SCM

Business concepts can be seen as the theoretical and architectural implementation of a business strategy and as the foundation of the application of business processes (Richardson 2008). However, these concepts also describe the way business is done (Bocken, Schuit, and Kraaijenhagen 2018). The concept of CE requires that companies need to rethink their business models. Circular economy business models (CEBMs) redefine how companies create value while following CE principles (Lüdeke-Freund, Gold, and Bocken 2019). To overcome a completely linear strategy, the firms need to redesign and reorganize their value propositions, value creation infrastructures, and value capture models (Hofmann 2019). Also, Geissdoerfer et al. (2018), argues that circular strategies achieve the best sustainability performance if all of the elements of the manufacturing are aligned to support value proposition, value creation and delivery, and value capture. Geissdoerfer et al. (2018, p. 17) define CEBM as:

> *"Sustainable manufacturing processes aim to create monetary and non-monetary value by the pro-active management with close relationships of multiple stakeholders and incorporate a long-term perspective – that are specifically aiming at solutions from the CE through a circular value chain and stakeholder incentive alignment."*

In our investigation, business models represent the style of the manufacturing process. Figure 3 illustrates the differences between these strategies and processes.

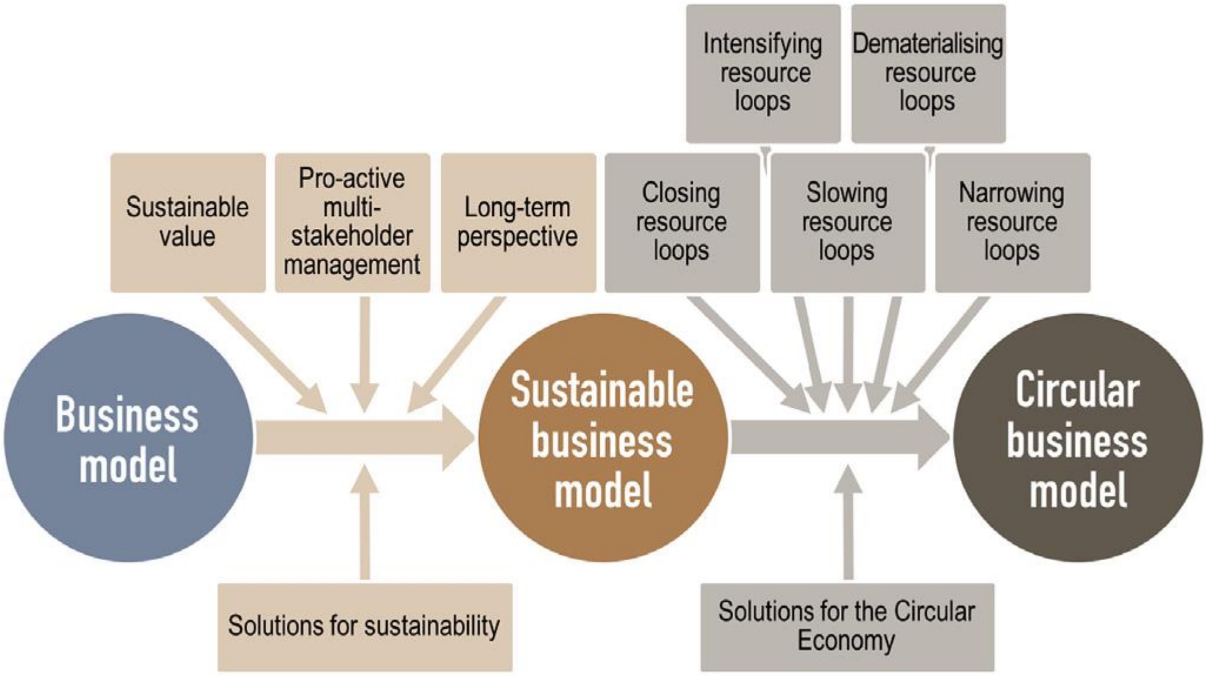



*Figure 3: Comparison of traditional, sustainable, and CEBM (adopted Geissdoerfer et al. (2018))*

The circular manufacturing process is based on supplying fully renewable, recyclable, or biodegradable resource inputs that support circular production and consumption systems. Recovery of embedded value at the end of one product lifecycle to feed into another promotes return chains and transforms waste into value through innovative recycling and upcycling services. Product life extension allows companies to extend the lifecycle of products and assets in order to capture the value that otherwise could be lost since materials are maintained or even improved by repairing, upgrading, or remanufactured. Sharing platforms promotes collaboration among product users, and this could either be individuals or organization. This facilitates the sharing of overcapacity or underutilization, increasing productivity, and user value. Product as a service is an alternative to the traditional "buy and own." Product is used by one or many customers through a lease or pay-for-use arrangements (Accenture 2014).

Richardson (2008), propose a framework, which is defined by three elements: value proposition (what the firm will deliver to its customers), value creation and delivery (how the firm will create and deliver that value to its customers), and value capture (how the firm generates revenue and profit). SCM can be an essential part or almost identical to the concept of the value chain and value creation and delivery. It is, therefore, an essential part of the strategy of organizations and plays a crucial role in transforming the organization for the CE. Closing, slowing, and narrowing of the material and energy flow is the main differences between conventional SC and circularity (Geissdoerfer et al. 2018). According to Lüdeke-Freund, Gold, and Bocken (2019), CE does not need to be the final goal, but rather a part of an ongoing process to achieve greater resource efficiency and effectiveness. However, they also argue that the fundamental challenge for companies is to rethink their SC, and as a consequence, need to rethink the way they create and deliver value through their business.

From a strategic view, large companies already understand the need for innovation to ensure survival and growth as they deal with an external threat of continual innovation (Bocken, Schuit, and Kraaijenhagen 2018). Circular manufacturing processes aim at running circular systems in an economically viable way. Circular manufacturing processes are business models that enable systems that are regenerative by nature, and they seek to maintain resource value at its maximum for as long as feasible, and eliminating or reducing resource leakage, by closing, slowing, or narrowing resource flows (Salvador et al. 2020). Lüdeke-Freund, Gold, and Bocken (2019) also argue that the primary goal of circular manufacturing processes is to help companies to create value by using resources in multiple cycles and reducing waste and consumption. Incorporation of CE aspects to existing manufacturing processes can contribute to the transition, and such incorporation may ease CE adoption, since it may be less radical and better accepted by both organizations and customers than conceptualizing utterly new business strategies. Circular manufacturing processes can help to create value from waste, optimize product and resource use, and develop new and less environmentally harmful means for value capture, providing additional options for the world economy (Salvador et al. 2020). According to Salvador et al. (2020), to adapt existing strategies towards greater circularity, it is necessary to make a clear value proposition, which needs to be supported by internal awareness and capacity to deliver the proposed value, and aligns it with the company's strategy, and communicates it to customers to find ways to engage them.

### 2.2.6. Social sustainability practices in relation to the CE

Environmental issues dominate in the literature on sustainability and CE. However, the social aspects are still underexplored by other researchers (Seuring and Müller 2008, Mani, Jabbour, and Mani 2020, D'Eusanio, Zamagni, and Petti 2019, Millar, McLaughlin, and Börger 2019). Murray, Skene, and Haynes (2017) have emphasized that the literature in CE is virtually silent on the social dimension, focusing on the redesign of manufacturing and systems to benefit the biosphere, supported by Geissdoerfer et al. (2017)´s statement that few papers mention the social aspects. The definition of sustainable development by Brundtland and Dahl (1987) are deemed by Carter and Rogers (2008, p. 361) as "*far-reaching and organizations find it difficult to find their role within a broader macro-economic perspective*." Seuring and Müller (2008)'s definition is also wide-reaching. However, it gives the organizations a more pointed out function towards the expectations of stakeholders and customers, including taking into account economic, environmental, and social aspects.

In general, social responsibility means that the organizations' behavior needs to be measured further than its economic desirability, it has to include how it affects the public overall, customers, and local communities (Tsvetkova 2020). Social sustainability in SCM has been defined form a corporate social responsibility perspective (Mani et al. 2016). However, in manufacturing, practices within social sustainability can be defined as the product and process aspects that determine human safety, welfare, and wellness (Mani et al. 2016). According to D'Eusanio, Zamagni, and Petti (2019), this means that companies are responsible for the social impacts of their products and their suppliers.

Researchers Mani, Jabbour, and Mani (2020, p. 2) refer to SC social sustainability as the *"ways firms address product and process aspects of the supply chain that affect the safety, health, and welfare of people associated with the supply chain."* With this referral, Mani, Jabbour, and Mani (2020) see that since the SC involves multiple parties and locations, all participants in a SC should be accounted for when it comes to sustainability for the SC. According to D'Eusanio, Zamagni, and Petti (2019), social sustainability addresses human well-being not only for current but also for future generations. The actors in a SC with the retrospect of the social aspect consist, according to Mani, Jabbour, and Mani (2020), of customers, suppliers, workers across the SC, and the population that the SC serves. Measures of social impact are often referred to as job creation in the SC, or health and safety aspects like missed workdays due to occurrences in regards to SC operations (Martins and Pato 2019).

Pagell and Shevchenko (2014) argued that future research in SCM has to treat a SC social and environmental performance on equal or more valid than economic performance. In recent research, Mani, Jabbour, and Mani (2020) acknowledge that there is a need for more in-depth research for many of the aspects of SC social sustainability to understand its effect on performance. It is unclear how CE will contribute to social equality, and essential moral and ethical issues are missing from the conceptual framework, and only if societal needs are included and defined in the basic formulation, is there hope to build on all three pillars of sustainability (Murray, Skene, and Haynes 2017). Authors Geissdoerfer et al. (2017) discussed different aspects of the social dimension within the CE concept. Job creation, efficient tax systems, and sharing economy is, according to the authors, unclear how it could contribute to the positive well-being of the society. Studies on social sustainability have focused on decisions within purchasing and issues regarding supplier behavior in the context of ethics, safety, human rights, welfare, and labor safety (Tsvetkova 2020).

# 3. Methodology

This chapter provides an overview of the research methods used in this master thesis. The research methodology is presented in this master thesis as a way to solve the research problem systematically and to develop knowledge about the phenomenon highlighted by Kothari (2004, p. 8) as "*a way to systematically solve the research problem.*" The chapter also describes how the design of the research is, and the methods relevant for this master thesis. Moreover, the chapter outlines how the data was collected and discussing the quality of the research.

## 3.1. Philosophical position

The philosophical position depends on the way the researcher perceives the development of knowledge of the research world. The philosophical position is the underlying factor in the research design. There are two dominant opposite philosophical paradigms; positivism and phenomenology or well-known as interpretivism or social constructivism. Positivism relates to the philosophical stance of the natural scientist and entails working with an observable social reality to produce law-like generalizations. As a positivistic researcher, the use of existing theory is used to develop hypotheses that would be tested and confirmed, leading to the further development of the theory that could be tested in further research. In this philosophical stand, researchers would try to remain neutral and detached from the research and data to avoid influencing the findings (Saunders, Lewis, and Thornhill 2016, p. 136). In other words, in positivism, the act of research is not affected by the investigation of it (Collis and Hussey 2013, p. 43), and in contrast, interpretivism studies meanings. The purpose of the research is to create new, richer understanding and interpretations of social worlds and contexts (Saunders, Lewis, and Thornhill 2016, p. 140). By investigating it, social reality is affected by the investigation, and the research is often inductive by providing interpretive (subjective) understanding (Collis and Hussey 2013, p. 44).

Both paradigms principally show their different view on ontological and epistemological assumptions (Collis and Hussey 2013, p. 47). This master thesis is based on interpretive ideas about the socially constructed nature of reality. Looking at our investigation, we will use social constructivism (interpretivism) as our philosophical position. Within social constructivism, the meaning is to seek understanding of the world we as individuals live and work in (Creswell and Creswell 2017, p. 46). In our master thesis, we built up a historical perspective of the development of the Norwegian paint industry that helped us reveal the environmental and social effects of CE principles in the manufacturing process and SCM practices. According to Creswell and Creswell (2017, p. 46) within social constructivism research, it focuses on specific contexts where people live and work, as we have a specific context and a narrow geographical location, we can justify this view.  Further, the nature of CE's theoretical vision on reality was investigated. Theory and reality are two different worlds, and this master thesis looked into how the theory is practiced in a real-world context.

## 3.2. Qualitative Research design

This master thesis presents a qualitative research design. The qualitative research design was helpful in our investigation because a qualitative approach to research is concerned with the subjective assessment of attitudes, opinions, and behavior. Since research is a function of the researcher's insights and impression; it generates results either in non-quantitative form or in the form that are not subjected to rigorous quantitative analysis (Kothari 2004, p. 5) Further our philosophical position of social constructivism is according to Saunders, Lewis, and Thornhill (2016, p. 168) often associated with qualitative research. The qualitative method helped us to construct subjective and social meanings and an in-depth understanding of our research questions of how CE principles evolve in the Norwegian paint industry and the effects of the environmental- and social aspects of sustainability. This master thesis was written in both and explorative and descriptive manner. The explorative way of our research was formed by our investigation and how we wanted to clarify our understanding of the phenomenon we studied. The explorative way of our research design helped reveal how CE principles affect the environmental and social aspects of sustainability. The descriptive way allowed us to describe the development of the Norwegian paint industry and the events of how CE principles evolved.

## 3.3. Case study approach

This master thesis applied a single case-study approach. We chose the focal company because CE principles have been developed naturally due to some historical events in its manufacturing process. Thus, the focal company provided interesting settings to investigate the effects of CE principles on sustainable development, which is an important issue for this type of manufacturing. The case study approach was helpful because it is a research strategy that focuses on understanding the dynamics present within single settings, and case studies typically combine data collection methods (Eisenhardt 1989). Yin (2003, p. 13) has defined the case study as:

*"A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. […] The case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as a one result relies on multiple sources of evidence, with data needing to converge in a triangulation fashion, and as another results in benefits from prior development of theoretical propositions to guide data collection and analysis."*

The case study approach helped to learn the phenomenon in real practice, disclose the contextual settings and internal processes within the focal company. The purpose of the case study is, according to Gustafsson (2017), to produce background material for a discussion about a concrete problem. We see that the case study is attractive due to it is a method of study in depth rather than in breadth. It is suitable for our investigation due to its emphasis on the full analysis of a limited number of conditions and their interrelations (Kothari 2004, p. 113). We apply a single case-study as a research design since we looked into the practice of one company. The single-case study approach was helpful for us to widen the existing theoretical knowledge about how CE principles work in real practice. The single-case can represent a significant contribution to knowledge and theory building by confirming, challenging, or extending the theory (Yin 2018). The benefits with a single-case study are that they are not as time-consuming as multiple case studies, and a single-case study gives a deeper understanding of the exploring subject (Gustafsson 2017).

## 3.4. Data collection

There are two categories of information that can be collected during the study, which is divided between primary and secondary data. Primary data can be gathered through interviews and observations, where the secondary data is, however, already existing data within areas where research is being done (Saunders, Lewis, and Thornhill 2016). This master thesis was based on both primary data and secondary data.

### 3.4.1. Primary data

We started our research by collecting primary data that included several qualitative methods of data collection.

### Interviews

In total, fifteen semi-structured interviews were conducted with representatives of different departments in the focal company. Seven interviewees were conducted via e-mail, four interviews were conducted in the interview participant offices, three interviews were conducted via Skype, and one interview was conducted over the telephone. The interviewees were selected with deliberate sampling, and they were selected due to their long experience, practical knowledge, and work in the Norwegian paint industry. The interviews were conducted in Norwegian and then translated into English. The interviews were recorded with the written consent of the interviewees and hand-written to ensure the validity of the obtained data. The interviews were conducted in the period December 13, 2019 – April 30, 2020. Semi-structured in-debt interviews made it possible for the interview participants to provide more detailed information and be more personal when responding to the questions. Semi-structured interviews were helpful due to it gave us the possibility to adjust our questions according to the flow of the conversation (Saunders, Lewis, and Thornhill 2016, p. 391), and the possibility to probe there we wanted our interview participants to explain or build on their answers.

Moreover, since our philosophical position was based on social constructivism, this helped us to understand the meanings the interview participants had on the phenomenon we studied (Saunders, Lewis, and Thornhill 2016, p. 394). We conducted follow-up interviews with seven interviewees. These follow-ups were conducted over mail correspondence with the interview participants in order to get more in-depth data. All transcribed answers from the interviews were sent back to the interviewees to avoid any misunderstandings of obtained data. The interview guide was formed in Norwegian and English, and as mention above, the interviews were performed in Norwegian and translated into English. The reason for that the interviews were performed in Norwegian was due to the interviewees were Norwegians, and in our opinion, speaking in the native language gave the interviewee a possibility to answer more freely and naturally when answering the question.

### Personal observations

Empirical data was collected during our visit at the production site and R&D center in Sandefjord on February 25, 2020. According to Kothari (2004, p. 96), observation is a collection where researchers do their observation, and the information relates to what is currently happening. Past behaviors or future intentions do not complicate it. We observed the day-to-day routine and studied how the process of paint manufacturing was conducted. Personal observation helped us to understand how production based on CE principles is organized and managed. During our visit, we saw how employees and managers collaborate. We also observed how the company focused on health, safety, environment, and quality (HSEQ) in production and on the production site. We observed that they had a waste board with numbers that got updated every week. All over the production site, we observed several safety campaign billboards. Everywhere in the production site and outside, we observed marked areas where employees were allowed to walk, and we also got to observe the new production line they were testing out.

**Triangulation**

This research applied different sources of data and thereby ensured the triangulation of the data. Triangulation of data is when data is collected through multiple sources to include interviews, observations, and document analysis (Creswell and Creswell 2017, p. 290). Data triangulation helps to strengthen the validity of our case (Yin 2018). Using multiple data sources helped us to study the phenomenon since it gave us a much broader description of the phenomenon due to the different perspectives the different sources had. According to Collis and Hussey (2013, p. 71), these separate impressions give us a much richer picture of the phenomenon.

### 3.4.2. Secondary data

Easterby-Smith, Thorpe, and Jackson (2012, p. 12) define secondary data as "information that already exists in the form of publications or other electronic media, which is collected by the researchers." The secondary data used for this master thesis was predominantly based on scientific articles and journals found through ScienceDirect and Google Scholar by searching for specific topics on CE and sustainable SCM. Also, a backward snowballing technique was applied in the search for literature since it starts from relevant papers. The secondary sources of the empirical data were also based on the Norwegian regulatory norms and acts, archival documents, press releases, annual reports of the focal company, and official websites. The collection of secondary data was vital as it gave us an excellent supplement to our primary data. It gave us the possibility to get more depth in our data, as well as to provide us with historical data since none of our interviewees were working at the focal company when the accident happened.

## 3.5. Data analysis

Data analysis was a critical step in the overall interpretation of our case study. The transcribed data, obtained during our interviews, was coded and marked by different colors in order to categorize the information and get an overview. This categorization helped us to distinguish different types of information obtained from multiple sources. This coding mechanism allowed us to rationalize them and analyze them more closely since our coding gave us the possibility to generate reports (Atkinson 2002). The data collected were analyzed with a thematic approach. Thematic analysis is according to Castleberry and Nolen (2018), a method of identifying, analyzing, and reporting themes within data. Since qualitative approaches are diverse and complex, the thematic analysis gives flexibility with the analysis (Braun and Clarke 2006). After data collection, we received a considerable amount of information as fragmented stories. Fragmented stories from the interviews and other sources were gathered and presented as storytelling, and we needed to compare this story with the existing knowledge in the literature. Data analysis was based on the construction of a chain of events during the development of the paint industry that allowed us to reveal how CE principles evolved and affected the existing practice.

## 3.6. Quality of research

This master thesis aims to provide good quality research. In this subsection, we outline how we worked and solved issues related to validity, reliability, and generalization of our master thesis.

### 3.6.1. Validity and Reliability

**Reliability**

*Reliability* addresses the repeatability of the experiment, and if replication is possible and the results will be the same. There are two keys to reliability in a case study context; first, a case study protocol, and the development of a case study database. The case study protocol is the interview guide, and the case study database could be copies of the completed interview guides, transcriptions, recordings, and secondary data collected (Ellram 1996). We provided our interviewees with the interview guide a couple of days before the interview. The interviews were transcribed, and then we sent the transcriptions back to our interviewees that they could verify the information and corrected it. This communication allowed us to avoid any possible misunderstandings.

During the interviews, we as researchers tried to avoid expressing our own opinions that could lead our interviewees in the undesired direction. We paid particular attention to how we interpreted the information obtained from the primary data. It was necessary because the way, researcher interprets the data, provides guidelines for the outcome of the study.

Secondary data was also used as a way to increase the reliability in our investigation. Secondary data from articles, the annual reports of the focal company, and press-releases supported primary data. This data is out there and could be used by anyone if they want to conduct a study.

**Validity**

According to Easterby-Smith, Thorpe, and Jackson (2015, p. 343), validity is defined as *"the extent to which measures and research findings provide an accurate representation of the things they are supposed to be describing."* We ensured validity by constructing a good research design and methods to collect data. We triangulated our data collection, and we ensured to use a combination of multiple data sources to get perspectives of the investigation. According to Creswell and Creswell (2017, p. 274), this adds validity to the study.

### 3.6.2. Generalization

The case study has been criticized because one cannot generalize from a single case study, and therefore it is unscientific (Flyvbjerg 2006). The issues of generalization of case studies presented by Flyvbjerg (2006), we used these attempts for solutions to solve our generalization. Our case is based on knowledge within the context of CE principles and sustainable SCM. Flyvbjerg (2006) argues that concrete context-dependent knowledge is more valuable than predictive theories. Further, our case could contribute to the development or a supplement to other methods, and therefore one can generalize based on this single case study (Flyvbjerg 2006). Since one can generalize from a single case-study, it is not limited to generating and hypotheses testing. We, as researchers, have had continuously in the back of our mind not to be biased of the data, and according to Flyvbjerg (2006) researchers, bias is also happening in other research methods. We presented the historical development of how CE principles evolved as a narrative and this narrative was helpful to present our findings and make them generable.

According to Yin (2018), there are two categories of generalizing the results form a case study: statistical and analytical generalization. Statistical generalization relies on research based on surveys there a conclusion is made about a population based on empirical data collected from a sample. Analytical generalization relies on the case studies, and the findings go beyond the setting for the case. The theoretical propositions from the initial design of our case study form groundwork for our analytical generalizations (Yin 2018).The findings in this master thesis were generalized through analytic generalization as the most common case study approach. Previous research was compared with the findings received from the case study.

### 3.7. Research Ethics

In research, ethics are according to Saunders, Lewis, and Thornhill (2016, p. 264) *"standards of behavior that guide your conduct in relation to the rights of those who become subject of your work, or affected by it."* When we conduct our investigation, we will encounter ethical concerns. Ethical concerns could appear in all stages of research, when we approach the company we were open with the company about the investigation and the thematic, we obtained what Saunders, Lewis, and Thornhill (2016, p. 222) calls traditional access there we had face-to-face interaction as mention earlier with interviews and observation. Ethical considerations need to be reflected in the research process (Creswell and Creswell 2017, p. 146). Molde University College has rules that we as investigators need to follow, and these cohorts with Creswell and Creswell (2017, p. 153) notations of do not plagiarize, falsifying authorship, evidence, data, findings, or conclusions.

Before the data collection, we sent the informed consent to our interviewees, which provided them with the depiction of our investigation, and the information about their rights when participating as interviewees. The interviewees asked to be anonymized, and according to Saunders, Lewis, and Thornhill (2016), once the promise of confidentiality and anonymity, it is essential to make sure that these are maintained. This anonymity also applies when we analyze the collected data from the interviewees (primary data). This is the reason why we have gone to great length to ensure that the interviewees are anonymized, and quotes used from them cannot be traced back to the interviewees. Before starting data collection, we needed to get approval from Norwegian Centre for Research Data (NSD), we had to explain and justify how and why we needed to collect data and how we stored our data, and what kind of data we stored. All personal data and recordings were stored in a data cloud that encrypted the data. In order to get access, one needed a password, and it was visible of whom had been in the system. Based on this, we feel secure that we have done everything to secure good ethical standards during the investigation.

# 4. The development of the paint industry in Norway: Context and case description

This chapter of the master thesis describes the research context that is the paint industry in Norway, as well as presents the empirical case. The focal company is the largest paint and coating company in Norway and has considerably affected the development of the whole paint industry since the 1920s. We combine here both the context description and case presentation to make the reasons for the arrival of CE principles into the paint production more vivid. We begin with a presentation of the main characteristics of paint products to show their harmful effects on the environment and danger for both the employees and end-users. Then, we follow the historical development of the paint industry in Norway to recognize the reasons for the arrival of CE principles. Also, we consider the change in regulations and requirements for the paint industry in Norway. This chapter ends with the description of a new practice of paint production based on the CE principles.

## 4.1. Main characteristics of paint products

The paint production is historically well known as not being environmentally friendly. Its products contain harmful chemicals and substances that are dangerous for the environment and people – both employees and end-users.

**A special industry**

The paint and coating industry is fragmented into numerous market segments that generally fall into either decorative paints or industrial coatings. The focal company is a manufacturer and distributor of paints and coatings, and it provides paint products within four segments: marine coatings, protective coatings, powder coatings, and decorative paints. The distribution of sales in each segment in 2019 is shown in Figure 4.

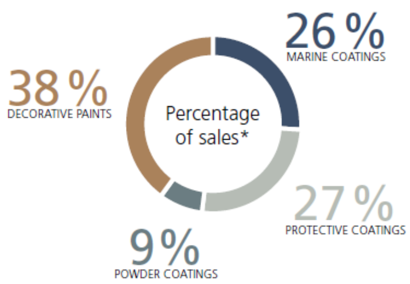



*Figure 4: Percentages of sales in 2019 (adopted from the company's report)*

The paint products in each segment are developed to meet the need of numerous industries and markets, which makes the paint and coating industry unique. Marine coatings are provided to the Newbuilding, Drydock, and SeaStock markets, and the focal company is a world-leading supplier within this segment.

Further, protective coatings are sold to companies active in industries related to offshore, energy, infrastructure, and hydrocarbon processing. The focal company supplies powder coatings to companies active in sectors related to appliances, furniture, building components, pipelines, and general industries. Decorative coatings are provided to commercial buildings, public buildings, and homes, serving both professionals and homeowners.

**The manufacturing process and its effects on the environment**

The manufacturing process of paints and coatings are quite different, though it technically can be divided into the same stages. Figure 5 shows a basic outline of the technical stages of paint production.

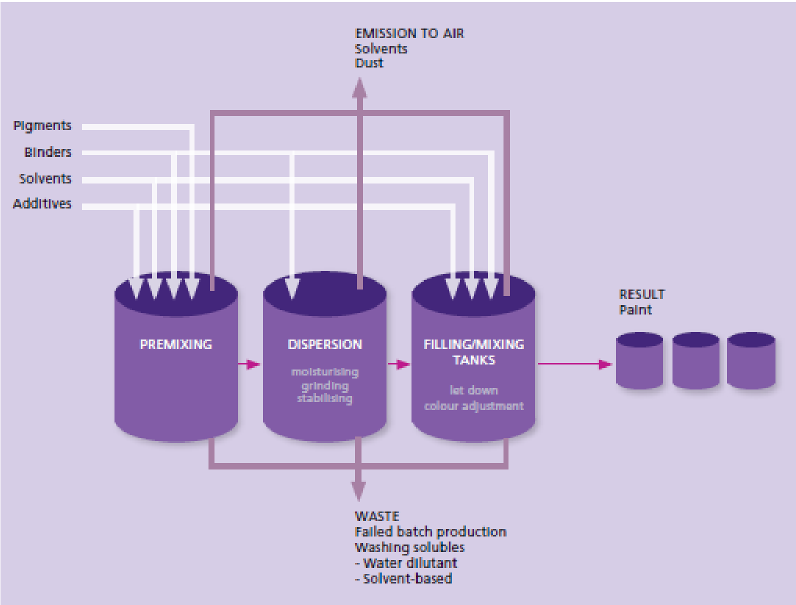



*Figure 5: An illustration of paint production (adopted from the company's report)*

The four stages in paint production include premixing, dispersion, adjusting, and filling, and the sequence in which they come is essential. In the first stage are pigments, binders, solvents, and additives weighed and mixed. Paint is either oil-based or water-based, and they each have distinct characteristics. Oil-based paint uses organic substances as a solvent, which is the liquid that carries the solid components in the paint. The solvents are, for example, mineral spirits, turpentine, and ethylene glycol (Folkehelseinstituttet 2017). The primary purpose of using a solvent is to get the correct consistency for application by brush, roller, or spray. In water-based paint, there are no solvents. The pigments are fine solid particles that contribute to color and opacity (hiding powder) to the paint and protect the binders and substrate from UV degradation. Extenders are natural or synthetic minerals like talc and clay, which are evenly dispersed in the paint. An essential component is the binder (or resin), which binds the pigments "like glue" and sticks them to the surface. The last component is the additives, which are the specialized components that give the products their final performance and characteristics. The second stage is dispersion, which is critical for the quality of the product. During this process, the air surrounding the pigments and extenders are replaced with binders, grinding functions ground the interconnection between pigments in lumps so that each pigment can be moisturized, and the final mixture is stabilized by adding more binders. The next stage is the adjusting, where the mixture is drained into large tanks, and binders and additives are added. The mixture is then adjusted with color and viscosity. Before the product is filled into containers, it goes through a quality control inspection to check factors such as consistency of the paint and its suitability for the application and to measure the weight to control if all the right raw materials have been added. Figure 6 shows the outline of powder coating production.

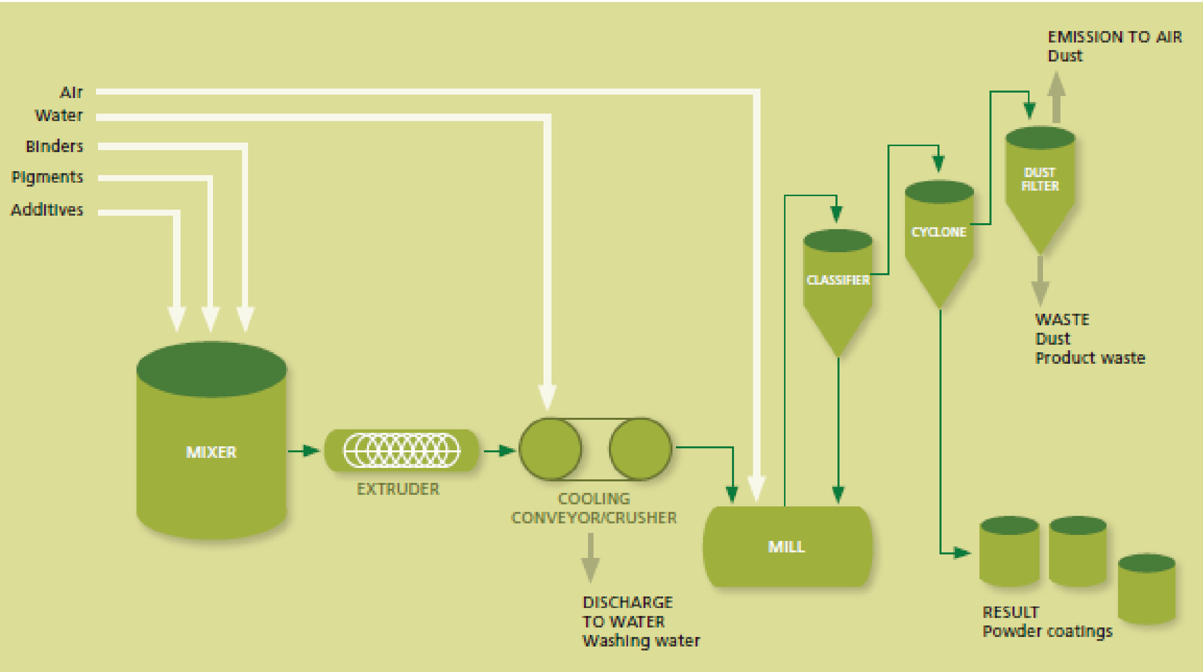



*Figure 6: An illustration of powder coating production (adopted from the company's report)*

The process can be divided into five stages: mixing, compounding, cooling and flaking, milling and classification, and collection. In the first stage are the raw materials accurately weighed and mixed, as in paint production. However, a significant difference is that solvents are not used in powder coatings. In the compounding stage, the mix goes into an extruder where it is melted. During the third stage is the mixture cooled and broken into small flakes using a crusher. The milling process ground the flakes into a fine powder with specified particle size. If there are any oversized particles, an airstream sorts them out and drop them down for a return to the milling chamber. The last stage is the collection. This may be a cyclone in which powder falls to the bottom while air is exhausted from the top, filtered, and then exhausted into the atmosphere or a bag filter system.

The environmental impact and the risks for both the employees and customers of the manufacturing of paints and coatings are diverse. Traditional painting materials and the manufacturing process can have harmful effects on the environment, i.e., through volatile organic compounds (VOCs), antifouling paint, and the use of heavy metals. The solvents used in oil-based paint often contain high quantities of VOCs, which are gases emitted from various substances in the solvents. VOCs can cause high levels of ozone and urban pollution, and lead to short- and long-term health effects for both employees and customers, such as damage to the brain, the nervous system, allergies, asthma, or other types of illness (Allergiviten 2016). The risks also include chemicals in manufacturing that are corrosive to the skin or dangerous through inhalation of hazardous fumes.

Further, antifouling paint (or bottom paint) is used to protect the hulls of boats from fouling by marine organisms. The most common form of antifouling coatings acts by releasing toxic compounds into the seawater adjacent to the surface. This process presents a harmful effect on the environment as these chemicals prevent the settlement and growth of fouling by killing the settling organisms (or disrupting their biochemistry) before they become permanently attached (Bleile and Rodgers 2001).

Lastly, heavy metals are present in the pigments in paint products. The exposure of heavy metals may lead to adverse health impacts such as unfavorable conditions of the respiratory, cardiovascular, and gastrointestinal tissues as they interfere with various physiological and biochemical processes (Ogilo, Anam, and Yusuf 2017). Consequently, due to the adverse effects mentioned, many requirements are needed to secure the safety and health of the employees and the customers. Thus, numerous regulations and practices have evolved throughout the historical development of the Norwegian paint industry.

## 4.2. Historical development of the Norwegian paint industry

The focal company is the largest paint and coating company in Norway, as well as it is considered one of the largest companies in the global industry with manufacture and distribution facilities on all continents. The company's head office is located in Sandefjord. The city has a close relationship with different segments of the ocean industry, which has been essential for the historical development of the company since its establishment in the 1920s.

The production of paint products during the 1920s was a lot different from how it is today. The retailers had a variety of oils, lacquer, turpentine, and dry pigments. The consumers bought the necessary raw materials in bags and bottles and then stirred it together as well as possible. In the premixed paint products were detergents, such as lye, ammonia, soda, green soap, and any kind of chemicals central. These products were bought in bulks at the paint retailers, as the grocery stores had to sell them in containers. Also, essences from almond and lemon, baking powder, and ammonium bicarbonate could be used in the paint (Bryn 1997, p. 41). Today, most of these materials and products are sold in sealed containers and labeled as hazardous.

**Dangerous working conditions**

During the 1950s, Norway was in the process of rebuilding the country after the war. There was a high demand for paint products, and the paint companies sold their products with good profits as it was a cheaper option wallpaper. At this time, Norway had the highest paint consumption per capita in the world, and the Norwegians appreciated high-quality paint products (Bryn 1997, p. 16). During this time, a healthy work environment was not considered as vital in paint manufacturing. There was little knowledge of the effects on the employees of working with the raw materials and chemicals. The lack of ventilation in the factories made it hard for the employees to breathe due to the strong fumes from solvents. The windows could not be opened, and the solution was to break the windows. Consequently, the windows were often replaced – and then broken again. Also, there was a high risk of fire in the facilities. Antifouling, consistent with many dangerous chemicals, was drained right next to huge ovens, and open fires were used for cooking alkyds. Alkyds are still one of the most important solvents in many paint products. Also, mercury and arsenic were common chemicals in antifouling, but it was not considered as dangerous to the workers in the factory (Bryn 1997, p. 80).

**The rapid development of new products**

In the 1960s and 1970s, there were too many paint companies, and the competition in the industry increased. All the companies had large debts due to investments in new facilities, and the market growth was at a standstill. Consequently, in 1971 did the four largest paint companies in Norway merge into one (the focal company) to secure growth and reduce costs (Bryn 1997, p. 16). The merge resulted in a new market structure as the focal company became the largest company in the Norwegian paint industry with a market share of 90% (Bryn 1997, p. 238). Initially, the focal company was a dominating actor in the marine paint segment in both Norway and Europe because of its products and technologies. This was connected with large orders from the many whaling companies in the area, which needed paint products for their vessels. One of the most important features of the merge was a higher focus on the development of other types of surface treatments. At this point, there was a rapid development in the chemical industry, and a variety of new raw materials contributed to new paint products. Especially was the introduction of polyester as a binder system in paint products essential for further growth. Polyester coatings have high abrasion resistance, making them ideally suited for application on decks and walkways, hulls of icebreakers, steel structure, and concrete. However, polyester paint products have a negative side effect as it causes microplastics to be released into the surroundings, which causes undesirable impacts on the environment and society. As noted by one of the interviewees: *"It was a fantastic development when we went from lead to plastic in paint products. Nevertheless, it is clear that the plastic ends up in our oceans."* Today, paint is the second-largest source of microplastics in the Norwegian ocean (Miljødirektoratet 2019).

**Social and environmental issues for local communities**

Although new chemicals and products were developed in the 60s and 70s, many of the raw materials that were used represented a potential danger for both employees and end-users of paint products. As an example, lead paint was previously commonly used in both decorative and industrial paint products. High exposure to lead may cause increased blood pressure and increased risk of cardiovascular disease (Folkehelseinstituttet 2015). Some restrictions of lead in decorative paint products were introduced in Norway as early as in 1921, and lead was substituted with zinc and titanium in many products (Ottesen 2012). Although lead has been banned in many countries, lead from paint products continues to be a potential health risk due to old paint on houses and buildings. In 2014, the focal company phased out lead chromates from all formulations for all product categories.

Another example is the previous usage of Tributyltin (TBT) in antifouling. The compound became popular in the 1970s as it prevented the growth of marine organisms. In 2008, TBT was banned after it was discovered that it led to the collapse of local populations of organisms. Along the Norwegian coastline, especially the dog whelk (a type of snail) was at risk because TBT made the species change sex (NIVA 2019). Polychlorinated biphenyl (PCB) was also a popular compound in paint products in the 60s and 70s. PCBs are highly degradable and have high-fat solubility. These properties cause PCBs to be stored in fat-rich parts in organisms. It has been discovered that PCB can cause a variety of adverse health effects in humans and animals, such as cancer, and effects on the immune system and the reproduction system (EPA n.d.). Today, PCB is banned.

During this time, vast quantities of substances such as TBT and PCB were leaked in the fjord of Sandefjord due to the high frequency of boats in the area. Further, a special report indicates that the focal company dumped 500 tons of paint residue in the water during the 70s and 80s, causing high values of pollutants in the fjord (Wiborg 1999, p. 13).

**First signs of change in existing practice**

Despite such significant social issues like health risks linked to the dangerous substances and the negative environmental impact, the Norwegian society was not concerned so much with issues regarding health and pollution from organic solvents in the 1960s. However, during this decade, professionals in the paint industry started to focus on safer products and a safer working environment. This focus resulted in increased efforts to reduce the solvents in paint products, and in 1983 was the first of the focal company’s low-solvent products launched (Bryn 1997, p. 325). As the interest for the negative impacts on the environment increased, the focal company developed more products with fewer solvents, as well as water-based paint products. During the same period, powder coatings were introduced as an environmentally friendly alternative to other paint products. The use of powder coatings has several advantages compared to wet paint. First, emissions of solvent vapors to the atmosphere are eliminated, as well as potential health effects for those who do the paintwork. Waste is also significantly reduced. Powder coatings are used for industrial surface treatment, both for decorative purposes and corrosion protection (Bryn 1997, p. 330).

**Accident**

In September 1976, the focal company experienced an explosion in its manufacturing facility in Sandefjord. The explosion led to a massive fire, and six people were killed. The fire occurred as a result of a leakage of a highly flammable product in the paint factory called shop-primer. This product is a marine paint product that needs to dry quickly when applied, and, therefore, contains large amounts of solvents that evaporate quickly. A piping connection underneath the tank containing the shop-primer cracked and the paint was sprayed out. An employee discovered that there was paint pouring down from the floor above, and he ran upstairs to attempt to close off the valve between the tank and the piping connection. During the attempt, he got the paint in his face, which caused him to be temporarily blinded. Despite the attempt, the employee did not manage to close it off. He tried to warn other employees on his way out of the building, but could not see anyone. Simultaneously, thousands of liters of paint poured out. The solvent vapor from the paint, which weighs more than air, found its way through an open door on the floor below. On this floor, there was an oven, and consequently, the gas was ignited, which caused the explosion (Bryn 1997, p. 274). The entire building collapsed, and tanks with chemicals were caught on fire. This resulted in a fierce pillar of fire, reaching 400 meters into the sky (Bryn 1997, p. 267). Although the risks connected with health concerns and fire safety had received more attention during the 60s and 70s, the fire shook all the focal company's employees and management, the industry as a whole, the local community, and the entire nation.

Immediately after the explosion, there was a concern that there could be another explosion, and about 200 of the local residencies were evacuated to schools and hotels outside the estimated risk zone. The reason for this decision was that the police received information about the vast quantities of solvent-containing binders and polyester that were preserved on tanks inside the mountain behind the facilities of the focal company. The fear was that the fire would spread inside the storage halls, and consequently blow up the entire mountain. In reality, there was no risk of such an explosion due to limited oxygen in the storage halls, but the police took every precaution (Bryn 1997, p. 268). An additional concern was if the chemical fumes would be dangerous for the residence near the factory. This concern was especially connected with another chemical accident earlier the same year, known as the Seveso disaster. A small manufacturing site in Italy had an accident which caused one of the highest exposure of chemicals in residential populations, resulting in acute skin disorders, as wells as long term effects on farming, and numerous health issues for thousands of people (DSB 2017). It was quickly established that the exposure was not an immediate danger (Bryn 1997, p. 271). Though, our data do not say anything about the long-term health effects on the local residents.

An inevitable consequence of the fire was the substantial amount of paint and raw materials, as well as cans, barrels, and building parts, that ended up in the fjord adjacent to the facilities. Back then, the negative impact on the environment was not underlined as significant. Much later, in 1994, the first examinations of the contamination in the fjord were conducted. The results of the analysis indicated that the fjord was loaded with pollutants such as PCB, TBT, lead, and mercury. The question about whether there was a current source on land that caused the pollution was raised. In 2001, new analyses by the Norwegian Institute for Water Research (NIVA), assigned by the municipality of Sandefjord, were conducted. The conclusion was that the area around the focal company was likely to be one of several local pollutant sources. It was believed that drains from the contaminated ground had to be the cause of the pollutants. However, the swirling of contaminated sediments was not considered to be any source of significance.

In 2005, the focal company invited NIVA and Norwegian Geotechnical Institute (NGI) for further analysis both on land and in the fjord outside the facilities. In the seabed adjacent to the focal company, high concentrations of many environmental toxins were found, including PCB and mercury. The highest concentrations were found a few centimeters down in the sediments in the area closest to the buildings that burned down in 1976. Age determination analyzes confirmed that the most considerable contamination of environmental toxins was from the same time as the explosion. It was also proved likely that the pollutants from the area lead to pollution in the adjacent areas in the fjord, probably due to swirling caused by shipping traffic. Further analyses showed that there was a formation of methyl mercury in the sediments that were bioavailable for animals living on the seabed (Aagaard 2010). Methyl mercury is a hazardous substance that is condensed through the food chain, ingested by humans, and consequently affects human health (Hong, Kim, and Lee 2012). The risk of human health, as a direct consequence of mercury from the relevant sediment areas, was considered low. However, the risk to certain bioaccumulation (risk to the ecosystem) could not be ruled out (Aagaard 2011).

## 4.3. Effects of the accident: new regulations and practices for the paint industry in Norway

The accident in 1976 was, in a way, a starting point of significant changes in the Norwegian paint industry. In the years after and up until today, numerous new regulations and practices have been implemented to ensure safer and more environmentally friendly production of paint products. Some of these changes were a direct consequence of the accident. In contrast, other changes have been implemented due to an increased focus on sustainable practices in the industry during the last two decades. As noted by one of the interviewees:

> *"The employee awareness concerning safety has changed tremendously since the 1970s. At that time, safety equipment was not important. While today, every worker has personal safety equipment. The whole attitude has changed. Also, the accident in 1976 showed how dangerous paint production really could be."*

### 4.3.1. New regulations

Today, the focal company is subject to many rules and regulations to ensure a safe workplace and to reduce the negative impact on the environment.

**Internal Control Regulation**

The accident in Sandefjord led to a review of internal control auditing for Norwegian companies dealing with dangerous substances. The accident also contributed to the establishment of the Internal Control Regulation, which is a regulation on Norwegian companies' responsibility regarding systematic HSE activities (Internkontrollforskriften 2014). After the accident, the focal company built a new factory following new and stricter technical requirements. It was argued later that the requirements made by the government were too strict in the rebuilding process due to unclear requirements and regulations concerning the prevention of fire and explosion. However, the focal company did not want to save anything on health and safety concerns. In subsequent years, the focal company became a company with a high focus on HSE, fire safety, and preparedness (DSB 2016). In 1993, the focal company received the certificate "Highly Protected Risk," which identified the best classification that was possible to receive and claimed the focal company as a leader among all the Norwegian companies in the paint industry (Bryn 1997, p. 305).

### The Substitution Principle

As a consequence of the usage of dangerous substances in the paint industry, the Substitution Principle was enforced in Norway on January 1, 2000. Chemical companies must evaluate existing formulations to determine if they can replace hazardous substances with less harmful alternatives (Miljødirektoratet 2000). The focal company's chemical policy is to substitute hazardous raw materials whenever it is possible while maintaining the quality of the paint product, even if the chemical is not restricted by legislation. The company recognizes that chemicals may represent a risk to its customers, employees, property, and the environment. Thus, assessments of chemicals are essential to reduce the risks to a minimum. The Substitution Principle also enforces companies to prevent pollution and to reduce the risks associated with the use of hazardous substances.

### Limitations of VOC

VOCs (volatile organic substances) used in paint products can give chronic health effects and contribute to high levels of ozone and smog at ground level. Therefore, they are regulated in many countries. In 2007, the Directive 2004/42/EC (the so-called VOC Paints Directive) entered into force by limiting values of VOC content due to the use of organic solvents in certain paints and varnishes (European Commission 2019). This regulation includes the industrial and chemical companies in Norway through membership in the European Economic Area (EEA). One interviewee stated how the focus on VOC has improved the standards in manufacturing. One of the interviewees stated:

> *"The most dangerous for the employees are damages due to solvent intoxication. This could lead to tendon damages that are not discovered right away, but maybe ten or even twenty years later. This is why we have something called a VOC extractor. It filters out the particles that are harmful and turn it into fresh air".*

### REACH

In June 2007, the European Union's (EU) chemical regulation REACH (Regulation, Evaluation, Authorization, and Restriction of Chemicals) was entered into force (ECHA n.d.). The main objective of the regulation is the improvement of the protection of human health and the environment. Thus, the regulation aims to improve the knowledge about hazardous chemicals, increase the availability of information to the public, improve management of risks associated with the use of chemicals, limit and replace the use of the most hazardous chemicals that pose a risk, and encourage innovation and development of less hazardous chemicals. This represented a significant challenge for the companies in the industry, and the focal company prepared for this challenge by screening all substances, raw materials, and products. Today, more than 20 employees in the focal company work with product documentation following the REACH regulations. Among other matters, this department works with safety data sheets, which are documents that list information relating to occupational safety and health for the use of the paint products. Without this information, the production of paint products is to be stopped.

**ADR**

The transportation of paint products is heavily regulated under the ADR agreement, which is an international regulation of transportation of dangerous goods within the EEA. The agreement came into force in 1968 in the EU but was not enforced in Norway before in 1976 (ADR 1957). It has since been amended and updated to ensure safe transportation for humans and the environment. The purpose of ADR is to prevent and guard against unwanted incidents in road transportation, which comprises every aspect of transportation, including vehicles, loading and unloading, and packaging of dangerous goods.

The focal company outsources its external transportation of paint products. Nevertheless, the company is accountable for making sure the transportation is performed according to the current transportation contracts, as well as the ADR regulations. In recent years, the focal company has changed its approach to transport contracts. One of our interviewees said: *"In the past, it was largely price-driven, now it is much more driven by that we operate properly, have good materials, and we avoid accidents."* A transport advisor has the responsibility to audit the transportation company, and to ensure that they comply with what is agreed upon in the contract. Also, the focal company needs to make sure that the goods are labeled correctly regarding the classification of danger. The transport of raw materials are usually in big bags or IBC tanks, and the finished products are usually on pallets.

### 4.3.2. New practices

Since the accident, there been many changes to the previous practices.

### International practices for emergency psychiatric response

An important effect of the accident in 1976 was the start of international practices for the emergency psychiatric response for industrial accidents. On the same day of the accident, two doctors, Arne Sund and Lars Weisæth conducted psychiatric examinations of the workers who were inside or near the factory, as well as the people who helped to extinguish the fire (Bryn 1997, p. 290-291). These examinations have later proved to be important, as the study helped to map the reaction patterns of the employees after being inflicted with such a stressful incident (Os 2011). The immediate time after the accident has later been described as a "warlike" situation for the employees, as well as for the locals that quickly had to move out of their homes (Bryn 1997, p. 274). Some of the employees had been sailors during the second world war, and an interesting finding in the study was how this group had acted in a rational matter and shown leadership during the accident (Bryn 1997, p. 290).

At that time, emergency psychiatry was almost an unknown term, and such examinations were carried out for the first time in international medical history. In cooperation with the focal company's occupational health services, the two doctors initiated a research project over four years. Personal interviews, medical examinations, tests, and surveys were conducted of those employees who were at the epicenter of that explosion and those who were not there. The study showed that if one can quickly identify where an individual is in an accident, as well as the person's level of preparedness or training, one can also predict the reaction pattern afterward. The accident gave rise to corporate business models in international crisis psychiatry and formed the basis for international diagnostic standards and prevention of post-traumatic stress disorders. (Bryn 1997, p. 290-291).

### Lessons learned

A higher focus on fire safety and health, safety, and environment (HSE) practices was the biggest lesson in the aftermath of the accident. One of the interviewees said: *"The fire was perhaps the first real wake-up call. Moreover, it put HSE on the agenda in a different way than before."* Work on the focal company's HSE standard began in 1994, and in 1998 it was introduced throughout the factories. Since then, the standard has evolved into a systematic HSE program. The focus on HSE is a top priority among management and employees. As emphasized by one of the interviewees:

> *“The focus on safety has increased even more during the past 8-10 years. This is connected with the management’s high focus on HSE. As an example, the standards for tidiness and cleaning have improved massively. You would not recognize our factories from 10 years ago.”*

Today, the program comprises 15 HSE and quality elements, including features such as risk management, training, industrial safety, personal safety, and occupational health. Also, new HSE practices have been developed, i.e., “Lessons Learned,” “Near Miss,” and the “I Care” campaign. In case of a fire or serious damage, “Lessons Learned” is sent out to every employee in the focal company. It describes what happened, how it happened, and if any measures need to be taken. The “Near Miss” program encourages employees to report incidents that could have turned into an accident. In this way, the company can learn how to prevent it from happening again. The “I Care” campaign was launched in 2014, and the concept is designed to involve important themes relevant to specific topics of HSE. Every year, the focal company runs a mandatary campaign topic with the focus on engaging employees, raising safety awareness, and reducing operational risk. Besides, the local facilities run two HSEQ initiatives tailored to address their own specific needs and risks for the environment. These have documented positive impacts on employee behavior and safety, as demonstrated by 2018’s mandatory campaign targeting the ‘man-machine interface,’ which reduced relevant lost time injury rates by 48 percent. In 2019, the campaign was about static electricity, which is a significant risk in areas where solvents are stored and used in manufacturing processes. As emphasized by one of the employees:

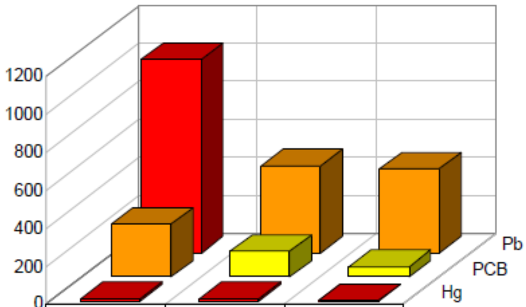
> *“There are many rules regarding electrical equipment. It is in the back of everyone’s mind that if there is a fire here, it is quite scary and dangerous. Thus, we have a great industrial safety, which includes 90 industrial safety workers. We have firefighters and smoke divers. So there is a big focus on that.”*

**Cleaning the fjord of Sandefjord**

Subsequently to the examinations, as mentioned earlier, of the fjord of Sandefjord in 2005, the Norwegian government ordered a cleanup of the seabed adjacent to the focal company. In 2008, 42 tons of metal, construction elements, and various sorts of trash were removed from the seabed. The following year, the environmental measures were implemented. In the critical area, 50-100 centimeters of the sediments were dredged and brought to a landfill. Then, the muddy area was covered with pebbles (ca. 2900 m3) before fine crushed rock (sand) was laid on top. Moreover, the areas nearby the critical area were covered in fine crushed masses (a total of about 6300 m3). Several measures to prevent damage to the surrounding environment and contribute to controlled management of water-borne particles during the dredging were conducted. One such measure was to use silt curtains to reduce the dispersion of contaminated sediment, which proved to be effective. As a supplement to the environmental measures, ten artificial reefs, shown in Figure 7, were situated on the seabed as habitats for marine fauna in 2010 (Aagaard 2010).

*Figure 7: Artificial reef for large fish (adopted from Aagaard (2010, p. 26))*

The analysis of the sediments after the dredging showed that there were relatively significant differences in the presence of environmental toxins. Figure 8 presents a graphical representation of average values from analysis of lead, mercury, and PCB before dredging, after the first dredging in April 2009, and after the second dredging in June 2009. The colors indicate the condition classes for contaminated soil. Red categorizes as class V (very poor), orange is class IV (poor), and yellow is class III (moderate). Although the objective of the dredging was to reach classification II (good) or better was obtained for all samples analyzed, the short-term effects were considered as satisfactory due to the significant intervention the projected represented (Aagaard 2010).




| | 2006 | 2009 April | 2009 Juni |
|---|---|---|---|
| Hg | 13,5 | 11,2 | 1,8 |
| PCB | 279 | 137 | 58 |
| Pb | 1023 | 462 | 446 |

*Figure 8: Analysis of lead (Pb), mercury, (Hg), and PCB in the fjord. (adopted from Aagaard (2010, p. 23))*

Despite the focal company's efforts, the fjord of Sandefjord was still categorized as one of the most polluted sea areas in Norway. Therefore, a new project to clean the fjord was set in motion in 2017. This time, the Norwegian government covered most of the costs related to the project, which made it possible to clean a larger area. Other parties contributing to the project included the municipality of Sandefjord and actors in the local industry. The focal company was the investor form the local industry that invested most, with its contribution of 2,7% of the costs, equivalent to NOK 4,6 million (Miljødirektoratet 2016). Between 2017-2018, about 50 000 m3 contaminated soil was dredged and removed from the seabed of the fjord. Then, an area of about 1 000 000 m2 was covered with crushed rocks. The seabed will be monitored until 2023 to ensure that the covering works as intended (Sandefjord kommune n.d.).

**Risk assessments**

Every employer that runs a business where the employees are dealing with dangerous substances must ensure their safety. The employer must identify and assess the risk of all substances and chemicals used at work to prevent health damage. In Norway, 20% of all cases of lung cancer are caused by hazardous chemicals at work (Arbeidstilsynet 2019). The focal company has a chemical risk assessment every other year, which is provided by an external auditing firm. This assessment includes critical factors such as exposure of chemicals for employees, including how long each employee is allowed to be exposed in one go, and the chemical dangers at the focal company's manufacturing site. Although many of the raw materials and products are not classified as hazardous, some substances have a high degree of a health hazard - which requires practices that help the employees to act cautiously. As the assessment is outsourced, the focal company cannot influence the outcome and will have to change practice if there are any issues related to the health and safety of the employees. The last risk assessment was conducted in 2018. It concluded with improved practices since the previous assessment due to factors such as better routines, clearly marked packaging, well-equipped ventilation and extraction systems, and a high focus on protective measures as a result of personal protective equipment. Besides, the assessment stated that most of the workplaces in manufacturing have short exposure time and low exposure to chemicals.

### 4.3.3. Building new practices to improve logistics operations and environmental performance

The focal company invested significantly in its facilities to improve logistics performance, as well as to improve its environmental performance. The company always builds its own facilitates from scratch. By doing so, the company has the opportunity to monitor the process to make their facilities as energy- and resource-efficient as possible, as well as to ensure the safety and HSE aspects. This process includes factors such as LED lights, noise, pollution, energy consumption, ventilation, heating, and cooling. When possible, daylight and natural ventilation replaces technical solutions.

**Modern and advanced warehouse**

Already the same year as the accident, the rebuilding of a new storage unit for finished products started. Before the accident, the management had made a partial plan to gather all storage facilities in Norway into a central warehouse on a new property in Sandefjord. Some rough drafts had already been drawn up, and the plans included highly technological solutions to meet future demand. However, there had been discussions if it was necessary and cost-effective to make such a significant investment. The accident led to a quick decision to move forward with the plans.

In 1978, the building project was finished, and the technological solutions made the warehouse the most modern and advanced storage unit in Europe. The facility was built to be fully automatic storage where robotic cranes would place and retrieve goods controlled by a computer system. As orders were placed in the system, the automatic cranes would pick out the right pallets, and then send them into the picking stations. Here, the operators picked out the right number of paint cans per customer. As soon as the pallet was pre-packed, it automatically was sent to a labeling station and further to the car loading area. The system could handle 205 pallets in and out of the facility per hour, and the manual handling was therefore minimized. The new warehouse system led to a high degree of security against error deliveries as the system knew how many units should be on each pallet. This information was logged by weighing the pallets at a checkpoint before labeling. Another benefit of the new warehouse was a more accessible and systematic placement of seasonal paint products. As an example, paint products used for outdoor painting was placed near the exit point. In this way, the cranes spent less time to pick out the products that had a high demand (Bryn 1997, p. 294).

**Manufacturing in closed systems**

In 1991, a manufacturing facility was built next to the warehouse. The factory was built "to meet the environmental demands of tomorrow," meaning that it was built according to requirements of how to reduce emissions and to ensure healthier working conditions for the employees. The new manufacturing system made sure that all processes from weighing the raw materials to the pouring of the finished products were in closed systems. As noted by one of the interviewees*: "One measure that has reduced the danger in paint manufacturing is that we put all the processes into closed systems."* The processes became fully automated, as well as more efficient. The new system ended heavy lifting, and odors and dust from the production were significantly reduced (Bryn 1997, p. 355).

In 2019 the focal company installed a new high speed, fully automated filling lines in the manufacturing facility. By using new technology in manufacturing, the focal company reduces the operational risk for the employees and mitigates problems with filling the paint products into cans. This reduces waste of obsolete goods, as well as the need for rework due to fewer errors. However, one drawback of the new system is that it requires more water for washing operations. The new production line was implemented as the first phase of the ongoing upgrade of the facility.

**Reduced internal transportation costs**

At the cost of NOK 500 million, a new manufacturing facility was opened in 2012, and it serves the Scandinavian market (Coatings World 2012). The facility was built according to the environmental program initiatives, equipped with the latest technology to improve safety, working conditions, and environmental performance. The improvements and efficiency gains for the facility included a reduction of CO2 emissions from internal transportation, new production which enables a reduction in the use of solvents and use of less hazardous chemicals, waste reduction due to the application of new technology, cleaning and recycling of waste instead of disposal, and a reduction in energy consumption.

Before the opening of the new factory, the focal company's costs of internal transport were NOK 11 million each year. The company operated with 5500 truck movements, which equated to a total of 250.000 kilometers driven and 185 tons of CO2 emissions each year. With the new warehouse, the company reduced its truck movements by 77%, the driven kilometers by 82%, and their CO2 emissions by 81%. Also, they cut their internal transportation costs by half (Moderne Transport 2010).

**BREEAM standard**

The focal company is currently building a new corporate and research center in Sandefjord. The facilities shall satisfy requirements according to the Building Research Establishment Environment Assessment Method (BREEAM) standard, which is a sustainability assessment method for master planning projects, infrastructure, and buildings (BREEAM n.d.). The standard includes elements such as ecological values, wall thickness, sun protection, cooling, lights, airflow, and energy consumption. As noted by one of the employees:
*"Before we started, we had to research the ecology of the area. There was one big old oak that had to be taken care of and fenced in before they started to blast the area"*. The importance of the BREEAM standard is, according to the company, that this creates a forward-thinking and solutions-oriented approach to resolve challenges with energy and water use, health and wellbeing, pollution, transport, materials, waste, land use, ecology, and management processes.

Today, the focal company has facilities on three different sites in Sandefjord. The warehouse built-in 1978 (now called the Logistics center), the two manufacturing facilities built in 1991 and 2012, and offices built in 2017 and 2018 are located at Vindal. The administration facilities and the binder factory are located at Gimle. The current research center is located in the city center. However, it will be moved when the new corporate and research center at Gimle.

#### 4.3.4. Change in the thinking

The regulations mentioned above were enforced to make the industry safer and more environmentally friendly, and new norms and practices have come into practice. Especially the accident in 1976 gave rise to new regulations and practices in the industry. Nevertheless, one of the most important reasons for the evolvement in the last four decades is how the thinking process changed. The authorities, the management, the employees, and the end-users are more aware of the risks and dangers connected with the manufacturing and usage of paint products. One of our interviewees gave an example of how the mindset has changed:

> *"When I was little, seatbelts in cars were not common. My parents sat in the front with seatbelts, while I sat in the back with no seatbelt. Today, this is unthinkable, and so it says something about how our thinking process has changed."*

In the same way, a focus on sustainability and sustainable practices in the focal company has evolved.

**How does the focal company view sustainability?**

The term "sustainability" was used for the first time in the focal company's reports in 2006. However, the concept, including all three aspects of sustainability, did not receive much attention before 2010. Figure 9 shows a graphical presentation of how many times the word sustainability/sustainable is mentioned in the company's reports from 2005-2019.

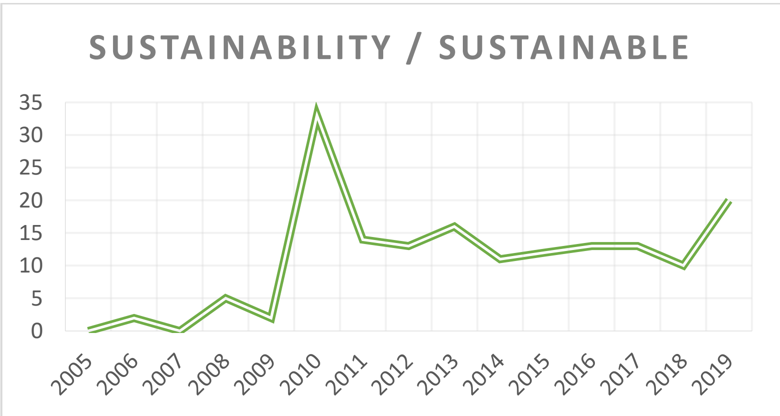



*Figure 9: Graphical illustration of a word search from the focal company's reports*

In 2010, the management of the focal company stated:

> *"While we remain committed to organic growth, the company has taken bold steps to accelerate the implementation of this strategy to ensure long-term sustainable development." and "The company has stepped up its commitment to operate an economically, socially, and environmentally sustainable business."*

The following year, the focal company launched its environmental program, which describes their environmental efforts based around five key objectives: reducing VOC emissions, reducing hazardous materials, reducing energy consumption, reducing carbon footprint, and reducing waste. The program has allowed them to define, structure, and clarify how the company acts and how they aim to achieve enhanced sustainability.
One of the interviewees explained how sustainability has evolved in the company:

> *"If you go back 50 years, the challenge was to remove lead and tin in the paint. This was a drive for sustainability, and it was perhaps more important than what we are doing today. However, sustainability is continuous work, and now we have put our efforts into systems."*

All the interviewees are familiar with the term "sustainable development," and they all confirmed that the focus on sustainability has increased within the focal company during the last ten years. However, the perception of the term varies. One of the interviewees told:

> *"My perception of sustainability is linked to the fact that we create a company with a healthy economy based on long-term decisions and working methods that take into account the employees, the environment, the local environment, and the society around us. Although we are a chemical production unit, we must offer green solutions and opt-out of raw materials that can adversely affect people and or the environment."*

Another of the interviewees explained that sustainability is *"about safety and environmental work and that to avoid waste is one of the most important factors."* This also applies when the focal company chooses its suppliers, as it seeks to make sustainable decisions before the manufacturing processes. Nevertheless, one of the interviewees emphasized an issue of using the term in paint manufacturing:

> *"The concept of sustainability is used in many different contexts without really being defined. Of course, you can use the Brundtland definition, but it is a bit basic. That is why I am careful about using the term. Because if we do, we need to have comprehensive documentation that shows that we are sustainable. Moreover, that is why very few in the paint industry use the word sustainable products."*

**Water-based products**

A lot has happened with the use of water-based products during the last decades. Notably, the decorative paint segment has increased its market shares for water-based paint products. The use of water instead of organic solvents in paint products has contributed to both safer working conditions and more environmentally friendly products. One of the interviewees told:

> *"A measure to reduce the risks is to use protective equipment. After all, some chemicals are corrosive if you get them on your body. However, the most important measure is the increased amount of water-based paint products."*

The focal company has made a big step in the development of more health-friendly paint products. In 2008, they launched a paint brand that contains no solvents, and it emits no dangerous fumes. The brand is the only series of paint approved by the Norwegian Asthma- and Allergy Association (NAAF), which has the strictest regulations on paints in the world. The focal company states that the level of preservations in the brand is less than the EU's cosmetics directive allows in skin creams. One of the interviewees explained the development:

> *"The focus has changed to include the end-user. We work to prevent that the end-user is harmed because of dangerous fumes. As an example, some chemicals in paint products are reduced because the chemicals may cause allergies when using the products. That also includes the people who work here. They are less exposed."*

We found that this thinking process evolvement has a significance of how CE has come into practice in the Norwegian paint industry.

## 4.4. The arrival of CE principles in the Norwegian paint industry

CE is a relatively new topic in the Norwegian paint industry. Although profoundly influenced by the EU's politics, the Norwegian government has, during recent years, recognized that the current laws are not enough to ensure sustainable development in manufacturing. Subsequently, it has been decided that Norway will be a pioneer in the development of a CE that exploits resources better.

**CE is gaining importance in Norway**

In March 2020, the EU published “The Circular Economy Action Plan.” CE is a trending topic on the political agenda in the EU, and the action plan is highly prioritized in the EU’s green growth strategy that ensures a cleaner and more competitive Europe. The efforts of the EU have significance for Norway through the EEA Agreement. The action plan contains 35 initiatives that will be presented over the next three years. The overall purpose of the action plan is to provide a framework on regulations for sustainable products. It is estimated that 80% of a product’s environmental impact during its life cycle is determined by how it is designed. Initially, the notified initiatives and regulatory changes will address value chains that are characterized by high environmental impact and a low degree of circularity. This includes a different approach to aspects such as packaging, plastic, and hazardous substances (Regjeringen.no 2020). Consequently, many of these measures will have a direct impact on the Norwegian paint industry, ensuing in increased utilization of the industry's side streams for new raw materials, more resource-efficient production, increased waste recycling, and the development of more health and environmentally friendly paint products, as well as exploring bi-products as new raw material instead of looking at it as waste (Norsk Industri 2019).

### 4.4.1. CE into practice

Although it is not formalized in the company strategy or recognized by the management and the employees, our investigation has shown that elements of CE have evolved occasionally in the focal company’s manufacturing processes.

**How does the focal company view CE?**

Generally, the term “circular economy” is not present in the business language in the focal company. It is not mentioned in the company reports, nor a familiar term for most of the interviewees. However, our data suggest that many of the principles of CE are implemented or evolving in the way the company does business. As noted by one of the interviewees:

> *“I have no relation to the term, except that I work with it without thinking that it is a circular economy. We try to reuse, recycle, and to focus on reducing energy consumption. We have a high degree of rework here, and we do not create much waste.”*

Some of the interviewees pointed out that the issue with CE in paint manufacturing is when the paint product is applied on a surface, it cannot be reused. So if a painted surface should be reused, it has to be well maintained. This was emphasized by one of the interviewees:

> *"It is clear that in the circular economy, materials used are kept in a circle and preferably do not go out. So it should be reused and so on. For chemical products, many people focus on that there should not be any classified substances. In my opinion, this is wrong. Of course, there should not be the most harmful substances, but some of the most important features of our products are to increase the durability of the materials. The materials in itself are more important drivers for the environmental aspect and energy consumption. If the paint can make the product last longer and be reusable, then that is an essential factor for our products."*

Further, if the quality of a paint product is low, the surface has to be painted over and over to protect the material underneath the paint. Therefore, it is necessary to use some "unfriendly" substances to be able to ensure the purpose of paint products. An interviewee noted:

> *"The paint should protect against biological organisms, corrosion, etc. In order to do so, we need substances that work. If not, the purpose disappears. If you have to apply low quality paint several times, the overall environmental footprint of that product becomes larger."*

One of the interviewees pointed out that a driver for CE within the focal company is the increasing focus on circular solutions in the EU, and that this will impact the Norwegian paint industry through new laws and regulations shortly. Also, several of the interviewees remarked that the CE might not be formulated internally in the company. However, they believe such formulations are on their way. This is primarily linked to the company's work on life cycle analyses of its products.

**Life Cycle Analysis of paint products**

As early as 1995, the focal company started to work with suppliers and customers to provide detailed life cycle analysis (LCA) data on a specific project, which over four years included assessments of 42 of the company's coatings products. As previously mentioned, LCA is considered essential to measure the impacts of the new CE products and business models. More recently, in 2013, the focal company was a part of an EU project to provide documentation on CE within the paint industry. Along with five other coating manufacturers, the EU project aimed to provide standardized environmental footprint labels, so-called Environmental Product Declarations (EPDs), to help consumers to make more informed decisions. The data collected from the project can be used by manufacturers to evaluate the environmental impact of their products from cradle to factory gate and allow users to determine and compare the environmental footprint of different products. One of the interviewees explained why it is vital for the focal company and its customers:

> *"We work with what is called "cradle to gate" because green building standards demand that. When a product is bought for a building project, the project owners are responsible for the application and maintenance. Thus, they want an EPD of the product to be able to make a full LCA on the entire building."*

The focal company has developed an LCA system that has simplified the process of making EPDs. The system stores large amounts of data on raw materials, transportation methods, and technical factory data. The information on a product is simply plotted into the system, and an EPD is generated. This process can be done relatively fast. One of the interviewees gave an example: *"The last one we made was to a special project. We spent a total of eight days. Normally, an LCA takes 1-2 years and costs NOK 200 000."*

**Recycle through the reduction of waste**

One of the focal company's key objectives is to recycle waste. Through the years, they have had a high focus on how to recycle, as well as to limit waste. In 2012, they set a target to reduce waste to 2% of the production volume by 2016. By 2015, the waste volume was 1.9%. In 2019 this had dropped to 1,8%, but still, it is above the 2018 goal of 1,5%. The company views less waste as proof of more efficient paint manufacturing, and it attempts to reduce waste by using efficient materials, in which it is possible to recycle. In the manufacturing facility, there are several recycling stations for plastic, cardboard, and hazardous waste. One of the employees explained how they handle waste in manufacturing*: "Waste management has to be effective, easy to figure out, and it has to be clear."*

The focal company sees obsolete goods as a major contributor to chemical waste. Waste is continuously monitored with target KPI´s as a measuring point to track the development of waste in the production and could act according to the development. Also, the focal company often has small improvement projects to try to find new, better solutions to handle the waste.

Further, the company works with several ideas on how to help both their suppliers and their customers to reduce their waste. One approach is to use the focal company´s environmental program to outline wording in contracts regarding waste. Another idea they have is the inclusion of audit schematics and "Rapid plant assessment," where the environmental program is introduced to look into how the sub-contractors work with recycling and waste management. Using the environmental program, they could look at if their waste sub-contractors have the right certifications and are approved by the government. An example of using the focal company´s is, according to one interviewee, that they work with their suppliers to reduce the use of packaging on the raw materials they purchase, as a way to reduce waste at the factory.

**Reuse of wastewater**

During the manufacturing process of paint products, wastewater is generated. The wastewater is primarily used in cleaning operations. Due to the various chemicals used in paint manufacturing, the wastewater may contain concentrations of toxic substances. The discharge of such wastewater into the environment can be harmful to food chain organisms and marine life. To be able to reuse the wastewater, the focal company is currently building a wastewater treatment plant. The technology used in the project is the first of its kind in Norway. When the project is finished, it is estimated that the wastewater will be reduced by 90%. Today, thousands of liters of wastewater from the paint manufacturing is sent to a treatment plant where it is either evaporated or combusted. By eliminating this process, the transportation cost will be massively reduced. The company will still have to buy supplements of freshwater from the county, but this cost will be significantly reduced. The project contributes to a more environmentally friendly manufacturing process as it will replace the processes the evaporation and combustion. Due to the positive effects, the focal company has received economic support from ENOVA (ENOVA n.d.).

**Rework of production errors**

The focal company reduces its waste by "reworking" production errors in manufacturing. If a batch of paint does not meet the quality standards, the batch may be reworked into a new mix. Thus, the rework of products helps to reduce the cost associated with waste. Besides, some paint product errors are sold to companies in Britain that use it to paint football fields, or to companies in Norway that use it to paint tunnel walls.

**Renewable energy**

As mentioned above, reducing energy consumption is one of the focal company's key objectives. The company states that the energy consumption is linked to its facilities, including production and warehouse. In 2018, the facilities at Vindal had an energy consumption of approximately 6,7 million kWh. Because the site consists of several facilities that are built in different eras, they have various technical solutions. In 2017, the ventilation system was changed from using an oil boiler to using wells with groundwater to regulate the heat in the Logistics Center. In this way, fossil fuel was replaced with renewable energy. The roofs in the facility were also re-isolated to reduce the loss of heating. At the binder factory at Gimle, they had an energy consumption of 4,5 million kWh in 2018. At this facility, they still use an oil furnace for heating in the production. However, the plan is to change to an electric furnace. Also, at Gimle, they use seawater from the fjord as a tool for cooling in the manufacturing process.

The focal company acknowledges that they have a high use of energy in their production. They continually work towards reducing their energy use. One example that one interviewee highlight is to take advantage of the heat exchange. Another example is how the company has invested in electric cars. Since the company's facilities are scattered around Sandefjord, the use of electric cars reduce the need for fossil power transportation.

**Innovations**

In order to handle the increasingly stricter safety and environmental regulations, the company's success relies on innovation. The company invests heavily in R&D, and in 2020, a new R&D center is scheduled to open in Sandefjord. The new facility will accelerate the development of innovative products and services. Innovation is viewed as the key to the company's future and how it operates towards more sustainable manufacturing. One of our interviewees stated that *"the driving force of R&D has always been sustainability and a safer environment for the end-user."* The focal company states in their rapport that during the past five years, the main focus has been to innovate paint products that are more environmentally friendly to meet the pending environment regulations.

Moreover, the company invests in innovations that aim to aid its customers in reducing their environmental footprint. One of the interviewees said: "*Paint is only one part of this. It is more about what paint can do"*. Shipowners and operators want their vessels to operate faster, cheaper, and greener to meet the rising competition and new environmental regulations. In 2010, the focal company started to measure the antifouling effect on the vessels' performance. This concept is called "hull performance solutions," and it aims to provide new antifouling technologies that reduce the environmental impact of unwanted biological waste and reduce the fuel consumption of the vessels. The settlement and growth of marine organisms can increase a ship's fuel consumption by 10-20%, as well as increasing sailing time with its attendant costs (Bleile and Rodgers 2001). Thus, the shipping industry depends on innovative antifouling paint products to protect the vessel hulls from marine organisms and corrosion.

In March 2020, the focal company released its newest technology for cleaning hulls – Hull Skating Solutions, in collaboration with Norway's biggest actor within marine technology. The Hull Skating Solution, shown in Figure 10, is a robot that goes along the ship hull and cleans the hull for biological waste while the ship is operative.

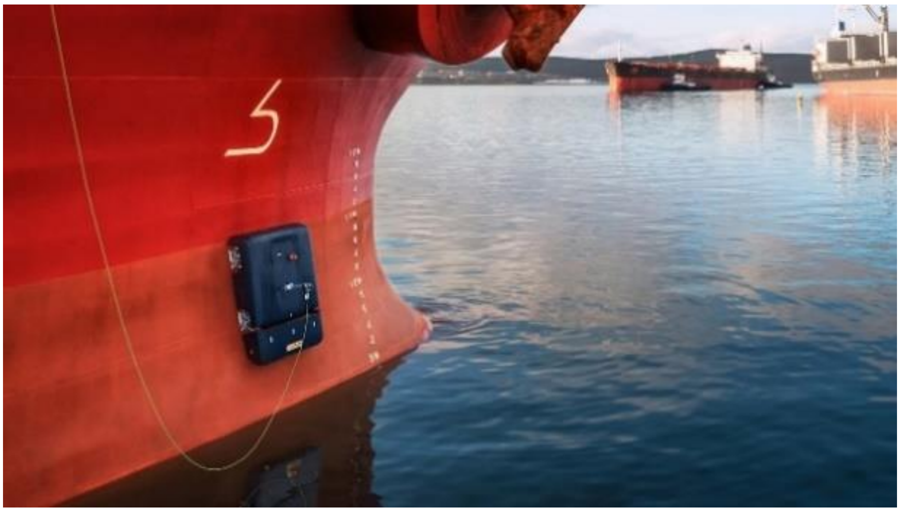


*Figure 10: Hull Skating Solutions (adopted from Kongsberg (n.d.))*

The machine works like a vacuum cleaner attached to the vessel, which causes less damage to both the antifouling coating and the local environment while reducing fuel consumption on the voyage. Typically, the cleaning of hulls is performed by divers when the vessels berth. This process is very costly and time-consuming, as well as dangerous for the divers. Another issue is that the cleaning is often performed when the marine organisms have settled, which is too late. The robot removes the need for divers, and the cleaning can be done regularly and at a lower cost. An additional advantage is that it reduces the risk of bringing unwanted alien marine life to the docks. Today, some ports demand that vessels have a clean hull before it is allowed to berth in order to reduce the negative impact on marine life. Therefore, the ship owners and operators need to provide documentation through underwater inspections, which is very costly.

On a global basis, if 25% of ships in challenging operations convert to Hull Skating Solution by 2030, this would result in a $CO_2$ emissions reduction of at least 10 million tons per year – equal to around a quarter of the total Norwegian $CO_2$ emissions in 2018.

## 4.5. Summary of the research findings

The historical development of the Norwegian paint industry was helpful for us to find the interaction of the three aspects of sustainability and the CE principles. The early days of paint production were characterized by dangerous practices, and there were few thoughts on the health risks and the negative environmental impact of manufacturing. We find that the accident in 1976 played a significant role in how the practices in the Norwegian paint industry has changed. The accident led to new perspectives on how to ensure the safety of employees, as well as to increase environmental performance in paint manufacturing. New building standards, technologies, and innovative solutions made it possible for the focal company to improve its SC practices in terms of efficiency and to reduce the environmental impact of manufacturing. Also, the lessons learned by the management and the employees in the matter of personal safety, routines, and safety equipment encouraged the focal company to put more effort into risk management, as well as how to handle the success of an accident. The research findings are summarized in Table 7.

*Table 7: Summary of research findings*

| Period of time | Event | Outcome |
|---|---|---|
| **1921** | The focal company was established | Paint products were made with dangerous chemicals and manufacturing practices. |
| **1950–1970s** | Dangerous working conditions | Lack of focus on the negative environmental impact and the workers' health and safety. |
| **1970–1980s** | Congestions of pollutants in the fjord | High values of dangerous substances in the fjord.<br>Five hundred tons of paint residue was dumped into the fjord. |
| **1971** | Merging the four biggest Norwegian companies into the focal company | New market structure and products. Polyester became a vital substance in paint products. |
| **1976** | The accident | Changes in the regulations, both internal and external, of the focal company. Implementation of new practices. |
| **1976** | ADR agreement enforced in Norway | Safer transportation of dangerous materials. |
| **1978 – 2020** | 1978: New warehouse<br>1991: New manufacturing facility<br>2012: New manufacturing facility<br>2020: New R&D and headquarter | Improved logistic operations.<br>New solutions to make paint manufacturing safer and less harmful to the surroundings. |
| **1983** | The focal company's first low-solvent paint products. | The negative environmental impact and health risks were recognized. |
| **1995** | The beginning of LCA analysis | The focal company obtained an extensive LCA database. |
| **2000** | Substitution Principle | Chemical companies must evaluate existing formulations to determine if they can replace hazardous substances. |
| **2005 – 2018** | Cleaning of the fjord | Covering the seabed outside to clean the fjord for contaminated soil |
| **2007** | Limitations of VOCs and REACH regulations | Less solvents in paint products.<br>Increased knowledge and documentation of hazardous substances. |
| **2008** | The launch of a paint brand with no solvents. | It is recommended as allergy-friendly paint as the only brand in the world. |
| **2010** | Sustainable growth strategy | Sustainability was recognized by the management, and it was implemented into corporate strategies. |
| **2015** | BREEAM standard | The new facilities shall be approved according to sustainability measures. |
| **2020** | The introduction of CE in the Norwegian paint industry | The company is currently adapting to regulations on circularity. |

# 5. Discussion

In this chapter we discuss our findings through the research perspectives of our study: 1) the evolvement of CE in the Norwegian paint industry; 2) effects of the CE principles on the environmental aspect of sustainability; 3) effects of the CE principles on the social aspect of sustainability. The findings are considered in relation to current knowledge provided in our theoretical framework on CE and sustainability.

## 5.1. The evolvement of CE in the Norwegian paint industry

Our findings have shown how CE principles have evolved in the Norwegian paint industry. In our empirical case, we have found that the evolvement of the CE principles of reuse, recycling, and reduction have evolved unexpectedly in the manufacturing of paint. This finding does not conform with the CE theory that pressure from stakeholders on the environmental and social sustainability pushes companies to rethink their manufacturing practice (Genovese et al. 2017).

The old practice of paint manufacturing paid little attention to the social aspect and the environmental aspect of sustainability. Our empirical case has illustrated that toxic chemicals ended up as pollutants in the fjord, dangerous materials were not handled with caution to prevent spills, and open manufacturing systems caused hazardous fumes for the employees. After the accident in 1976, the practice changed. The new practice led to a shift in the top managements' thinking on how manufacturing should be more sustainable. Also, new laws and regulations were developed as a result of the accident. This is partly consistent with the theoretical assumption by Seuring and Müller (2008) on drivers for sustainable practices, as they view governmental regulation as the most critical driver.

In parallel to the changes in the manufacturing practice, our findings have shown that CE principles evolved in the new practice. Our investigation has shown that the CE principles were not initiated by regulatory pressure or the initiation by the focal company but evolved naturally. Previous research has pointed out that regulatory pressure from the government is the primary driver for the implementation of CE principles (Govindan 2018, Tura et al. 2019, Van Eijk 2015). However, regulatory pressure, in our case, has mostly been focusing on the environmental aspect of sustainability. Thus, our findings have shown how CE principles have evolved naturally.

Our empirical case has illustrated that the LCA methodology was the first systematic approach to assess the environmental impact of the focal company's products and manufacturing practice. Some research note that LCA can help to identify and improve opportunities for the environmental aspect in the manufacturing practice (Genovese et al. 2017). Our findings have revealed that the focal company applies LCA as a tool to develop EPDs. This is in line with previous research on how the LCA methodology can be applied in a company (Cao 2017). Further, some research says that LCA is a tool included in both the concept of sustainability (Linton, Klassen, and Jayaraman 2007) and CE (Genovese et al. 2017). However, our findings have illustrated that the tool is only recognized as a measurement of the environmental aspect of sustainability and not from a CE perspective. Further, our findings have confirmed that LCA does not include the social aspect. Some research argues that it is challenging to include measurements of the social aspect (Grießhammer et al. 2006). In our empirical case, the social aspect is not measured in the LCA. At the same time, our findings have revealed that the social aspect was taken into consideration through the environmental aspect when the fjord was cleaned.

Further, our empirical have revealed that the focal company views LCA as a part of a C2G strategy because it only measures the life cycle from resource extraction to the factory gate. This is in line with the research of Cao (2017) on C2G. In our empirical case, we have found that it is challenging to include measures beyond the factory gate because it will require a complex collaboration between the focal company and its customers.

Furthermore, our findings have shown that CE is not recognized as a concept within the focal company. At the same time, our findings have illustrated that the practitioners recognized that they were already working around the CE principles when the principles were already in practice. Ghisellini, Cialani, and Ulgiati (2016) state that hesitant company culture is a significant barrier towards the implementation of CE principles. However, in our empirical case, we have found that the corporate culture can be a driver for further development of CE principles. Our findings illustrate that the focal company has developed an environmental program to systemize their environmental efforts and that CE principles are formulated as key objectives to make the manufacturing practice more sustainable. We have found that the focal company has developed new technologies during the recent years to improve their efforts to reuse, recycle, and reduce. This is consistent with the research presented by Tura et al. (2019)

concerning drivers for CE. In their research, the main driver for CE is to develop new technology to promote cleaner manufacturing.

## 5.2. Effects of CE principles on the social aspect of sustainability

Our findings have revealed several effects of CE principles on the social aspect of sustainability. We have found in our empirical case that in the previous practice of paint manufacturing, many harmful substances were used, without considerations on how it affected the health of employees and local residents. However, our findings have illustrated that the accident was a starting point for changes in the manufacturing practice, including considerations on the social aspect. New social responsibility practices have evolved, focusing on improving the health of the workers and local residents by reducing the harmful impacts. This is in line with Veleva and Ellenbecker (2001), which states that the health and security of the firm's workers is an essential factor in sustainable production. Hence, workplaces should be designed to minimize or eliminate physical, chemical, biological, and ergonomic hazards. Further, our empirical case illustrates how the social aspect is a part of the focal company's sustainability strategy. Some research says that the development of sustainable practices can lead to improved organizational resilience (Ahi and Searcy 2013). This is consistent with our findings, which have shown that the focal company improved its manufacturing practice through sustainable thinking. Also,

In our empirical case, we have found that HSEQ management have been systematically developed within the focal company and that the top management has a significant focus on the health and security of the employees through reducing dangerous emissions in the manufacturing practice. Some research note that governmental pressure is the most crucial driver for improving the social aspect of sustainability (Seuring and Müller 2008) and for the implementation of CE principles (Geissdoerfer et al. 2017). In contrast, our findings have illustrated that top management was the most crucial driver. This also contradicts the research on how corporate culture is a barrier to CE (Ghisellini, Cialani, and Ulgiati 2016).

The findings have shown that in manufacturing, there have been numerous projects both on a governmental level, but also within the focal company. The new manufacturing going from solvent-based production towards water-based production has shown a dramatic change in phasing out harmful substances. This shift in manufacturing is according to our empirical findings due to new consumer demands. This is not in accordance with Govindan and Hasanagic (2018), who underlined that CE barriers were awareness of consumption and production. The focal company´s chemical policy is to substitute harmful substances whenever it is possible, even if the substance is not restricted by legislation. Reducing the use of harmful substances improved the working conditions and subsequently reduced the risk of harm to workers and the surrounding local community. These empirical findings are aligned with the theory of suitability (D'Amato et al. 2017, Goh et al. 2020, Shou et al. 2019) and the theoretical aim of circular principles in manufacturing (Ghisellini, Cialani, and Ulgiati 2016).

Our empirical case has revealed that cleaning of the nearby fjord purpose a new perception of social sustainability. Concerning the collaboration with the local government, our findings have shown there is a close interaction between the manufacturing process and the external environment. There is an interrelation between the focal company and the government to clean up the nearby fjord contaminated seabed. Literature emphasizes on governmental practices in the form of regulations (Geissdoerfer et al. 2017, Seuring and Müller 2008). However, in our case, the focus on the social aspect evolved because of the new collaboration. The findings have revealed that the development of social responsibility is because of close cooperation between the government and the focal company and this new social responsibility practices. However, these findings do not consist with Geissdoerfer et al. (2017) view on sustainable manufacturing and circularity. Our findings have illustrated that the government was involved with economic incentives to secure the project, but the focal company also invested in the project. We have found that the new social responsibility practice of cleaning the fjord evolved only due to the fulfillment of the economic aspect of the government. These findings are consistent with Tsvetkova (2020) that the social aspect of sustainability can be developed only after meeting the requirements of the economic aspect of sustainability. The empirical findings show an interrelation between the focal company and the government as a new perception of how non-core activity leads to improving the social aspect of sustainability. However, our findings have revealed that the improvement of the social aspect was only possible after the environmental aspect was fulfilled.

Our empirical case has also shown that the focal company does audits towards their subcontractors and suppliers to evaluate their performance. They outsource non-core activities like transportation to external companies, and they also buy their packaging materials from sub-contractors. In an SCM perspective, social sustainability seeks to move beyond the focal company boundaries (D'Eusanio, Zamagni, and Petti 2019), and this multi-tier approach from the focal company is in support of our findings of seeking to take responsibly beyond their boundary, with audits to ensure proper ethical performance from their suppliers and sub-contractors.

### 5.3. Effects of CE principles on the environmental aspect of sustainability

Our findings have revealed several outcomes of how CE principles have contributed to the environmental aspect of sustainability. Our empirical case has illustrated revealed that the environmental improvements started with the substitution of materials like lead and tin, with less harmful materials, as well as a reduction of volatile organic compounds and heavy metals. Our findings have illustrated that the reduction of hazardous materials in paint products and the efforts to clean the fjord have contributed to less negative impacts on the environment. We have found that the main driver for these improvements has been that the manufacturing practice in itself has been recognized as dangerous, and therefore the practice needed to change. At the same time, many new regulations have imposed new guidelines within the manufacturing practice. This is partly consistent with the theoretical assumption by Seuring and Müller (2008) on drivers for sustainable practices, as they view governmental regulation as the most critical driver.

The development of new facilities has contributed to the improvement in making paint manufacturing more environmentally friendly. Our findings have revealed that the focus on the three CE principles in the manufacturing process is persistent. There is continuous work to reduce the environmental impact of the manufacturing practice. We have found that wastewater in manufacturing can be recycled and reused in order to reduce the environmental impact. This practice reduces the demand for water from the local reservoir and reduces the emission to waste. Further, our empirical case has shown that the focal company has invested in new filling lines in the manufacturing to reduce the operational risk and mitigate problems with the production, and to reduce waste of obsolete products. This aligns with the findings from Ghisellini, Cialani, and Ulgiati (2016) that the environmental aspect will improve due to the reduced use of new materials and energy in the production process. However, our findings have revealed that the new filling line increased the use of water in production. This finding is consistent with Ghisellini, Cialani, and Ulgiati (2016) that the CE principles could

have a different effect on each other, also in a negative manner. However, this finding also contradicts Geissdoerfer et al. (2017) discussion on waste and efficiency gains.
Further, our findings have illustrated that the new facilities have enabled a new system and that combining all of the functions within an SCM perspective have reduced the emissions within the focal company due to a reduction of the internal transport. Our findings have shown a substantial reduction in transport movements, which subsequently reduces emissions from transport activities.

Our empirical case has revealed that antifouling paint applied on ships contributed to reducing the CO2 emission and the consumption of fossil fuels. This is in line with Linton, Klassen, and Jayaraman (2007), which state that products should be developed to allow capturing more of the product value. In collaboration with another company outside of their SC, the focal company introduced a new type of service to clean the hulls of the ships with robotics technology. This new way of thinking is aligned with Lüdeke-Freund, Gold, and Bocken (2019) theoretical arguments that companies need to rethink their value creation and delivery in regards to CE principles practices.

# 6. Conclusions, limitations, and suggestions for future research

This chapter presents the implications for theory, the implications for practitioners and decision-makers, and the limitations and suggestions for further research.

## 6.1. Implications for theory

This master thesis aims to *explore how the circular economy principles contribute to the sustainable development of manufacturing processes and SCM practices in the Norwegian paint industry*.

Our empirical case has illustrated how the CE principles have evolved in the Norwegian paint industry. Previous research has empathized that the CE principles are implemented by drivers, such as regulatory pressure and companies' intentions. However, in our case, the CE principles have evolved not intentionally under the regulatory pressure or the focal company´s initiative but evolved naturally.

In the literature, there is still a debate on how CE principles and sustainable manufacturing processes and sustainable SCM interact and affect each other. This investigation has made an attempt to provide deeper insights into this issue and reveals the effects of the CE principles on sustainability in the manufacturing process in real practice. At the same time, our findings disclose that CE principles can also contribute to non-core activities like SCM practices and special efforts on the cleaning of the environment. This investigation illustrates a considerable change in the existing practice of the paint manufacturing after CE principles evolved naturally and began to affect the existing practice.

Literature argues that the effects of the CE principles on the environmental aspect of sustainability can have different impacts on each other because the principles interrelate in manufacturing and SCM. Our findings show that the positive effect of one principle can have a negative effect on another principle.

The originality of our investigation is that we have revealed the interaction between the CE principles and sustainability in the Norwegian paint industry. Our investigation emphasizes that it is crucial to take into account all the three aspects of sustainability because of their interrelation. The previous research on sustainability has primarily focused on the environmental aspect, but our research also includes the social aspect.

## 6.2. Implications for practitioners and decision-makers

This master thesis includes several findings worth considering for managers. Our findings presented in this master thesis are relevant for managers involved in manufacturing processes and SCM. Increased knowledge of CE principles can contribute to sustainable development and provide valuable insights into developing new sustainable practices in manufacturing, including all three aspects. Our findings are not only relevant for the managers of the focal company presented in our empirical case, but also for various practitioners who make decisions of implementation of CE principles in the manufacturing process and SCM.

The insights on how CE principles evolve can aid managers in identifying the effects and changes in manufacturing practices. Moreover, the findings in this thesis show that the CE principles can provide positive outcomes in manufacturing practice because of the 3R´s. This knowledge can be useful for practitioners, as it suggests that the principles should be assessed in the CE implementation in a company. This perception of how CE principles affect the existing practice making it more sustainable is significant for decision-makers.

The increased knowledge of barriers can help company's overcome the challenges when transitioning towards CE. A proactive approach can eliminate or reduce the barriers.

Practitioners and decision-makers can use our findings concerning the effect CE principles have on the social aspect of sustainability to develop new social responsibility practices. Further, our findings can apply to different industries to make them more environmentally friendly and improve the conditions for the health and safety of workers and local residents.

### 6.3. Limitations and suggestions for further research

The findings of how the CE principles contribute to sustainable development are reflected only in the Norwegian paint industry. CE principles can work differently in other practices and provide other outcomes for sustainability. Therefore, we suggest that other researchers analyze how CE principles affect sustainable development in other practices.

The investigation focuses mostly on CE principles within the manufacturing process. The findings have revealed that the manufacturing process based on the CE principles can provide positive outcomes for non-core activities like SCM and to societal values. Our limitations of the investigation are that it was strenuous to provide deeper insights into how the CE principles contribute to SCM only. Our suggestion for further research is to use our findings but to focus more on SCM.

Given that the thesis is based on a single case study methodology, analyzing no more than one company, one should be cautious in generalizing the results obtained to the paint industry at large – in Norway or for that matter in other countries. However, analyzing one paint manufacturer through case study methodology, allows one to unfold the complexity of the industry and by doing so reveals valuable insights which would not be uncovered by other methods. Therefore, our findings should be looked upon as a contribution to the body of knowledge, and combined with the findings brought forth through other methodological approaches, would paint a more complete picture of the application of CE principles in the paint industry. Further, previous research was compared with the findings received from the case study. Our conceptual investigation was based on CE and sustainability. However, we suggest providing more in-depth insights into how the CE principles can align with sustainability through different theoretical lenses.

# 7. References


Aagaard, P. K. 2010. Rapport fra miljøtiltak i forurensede sedimenter ved Gimle i Sandefjord. Sandefjord kommune.

Aagaard, P. K. 2011. Rapport fra miljøtiltak i forurensede sedimenter ved Gimle i Sandefjord - Supplerende tillegg. Sandefjord kommune.

Abd El-Hameed, Ahmed K., Yasser M. Mansour, and Ahmed A. Faggal. 2017. "Benchmarking water efficiency of architectural finishing materials based on a “cradle-to-gate” approach." *Journal of Building Engineering* 14:73-80. doi: https://doi.org/10.1016/j.jobe.2017.10.001.

Accenture. 2014. Circular Advantage - Innovative Business Models and Technologies to Create Value in a World without Limits to Growth.

ADR. 1957. "Europeisk avtale om internasjonal vegtransport av farlig gods (ADR)." https://lovdata.no/dokument/TRAKTAT/traktat/1957-09-30-1.

Ahi, Payman, and Cory Searcy. 2013. "A comparative literature analysis of definitions for green and sustainable supply chain management." *Journal of Cleaner Production* 52:329-341. doi: https://doi.org/10.1016/j.jclepro.2013.02.018.

Ahi, Payman, Cory Searcy, and Mohamad Y. Jaber. 2018. "A Quantitative Approach for Assessing Sustainability Performance of Corporations." *Ecological Economics* 152:336-346. doi: https://doi.org/10.1016/j.ecolecon.2018.06.012.

Allergiviten. 2016. "Maling og helse." Norges Astma- og Allergiforbund, accessed 10 April. https://www.naaf.no/AllergivitenSite/Miljoforhold/Maling-og-helse/.

Arbeidstilsynet. 2019. Kom i gang med risikovurdering av farlige stoffer. edited by Ministry of Labour.

Atkinson, John. 2002. "Four steps to analyse data from a case study method." *ACIS 2002 Proceedings*:38.

Barth, C. 2019. "Sirkulær Økonomi." accessed 20 May 2020. https://www.regjeringen.no/contentassets/cc604d7eaec14e158e974a5121d2e84f/2019-1519-cn-sirkular-okonomi-nfd2--final.pdf.

Bjørn, Anders, and Michael Z Hauschild. 2018. "Cradle to Cradle and LCA." In *Life Cycle Assessment*, 605-631. Springer.

Bleile, H., and S. D. Rodgers. 2001. "Marine Coatings." In *Encyclopedia of Materials: Science and Technology*, edited by K. H. Jürgen Buschow, Robert W. Cahn, Merton C. Flemings, Bernhard Ilschner, Edward J. Kramer, Subhash Mahajan and Patrick Veyssière, 5174-5185. Oxford: Elsevier.

Bocken, N. M. P., C. S. C. Schuit, and C. Kraaijenhagen. 2018. "Experimenting with a circular business model: Lessons from eight cases." *Environmental Innovation and Societal Transitions* 28:79-95. doi: https://doi.org/10.1016/j.eist.2018.02.001.

Braun, Virginia, and Victoria Clarke. 2006. "Using thematic analysis in psychology." *Qualitative Research in Psychology* 3 (2):77-101. doi: 10.1191/1478088706qp063oa.

Braungart, Michael, William McDonough, and Andrew Bollinger. 2007. "Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design." *Journal of Cleaner Production* 15 (13):1337-1348. doi: https://doi.org/10.1016/j.jclepro.2006.08.003.

BREEAM. n.d. "What is BREEAM?", accessed 19 March. https://www.breeam.com/.

Brundtland, Gro Harlem, and Oddvar Dahl. 1987. *Vår felles framtid, Our common future*. Oslo: Tiden norsk forlag.

Bryn, T. 1997. *Visjon, farve, form, Jotuns historie samlet og fortalt av Torstein Bryn*. Edited by Sandefjord Jotun A/S. Drammen: Tangen grafiske senter AS.

Cao, C. 2017. "21 - Sustainability and life assessment of high strength natural fibre composites in construction." In *Advanced High Strength Natural Fibre Composites in Construction*, edited by Mizi Fan and Feng Fu, 529-544. Woodhead Publishing.
Carter, C., and D. Rogers. 2008. "A framework of sustainable supply chain management: moving toward new theory." *International Journal of Physical Distribution & Logistics Management* 38 (5):360-387. doi: 10.1108/09600030810882816.
Castleberry, Ashley, and Amanda Nolen. 2018. "Thematic analysis of qualitative research data: Is it as easy as it sounds?" *Currents in Pharmacy Teaching and Learning* 10 (6):807-815. doi: https://doi.org/10.1016/j.cptl.2018.03.019.
Challener, Cynthia. 2019. "An Update on Sustainability in the Coatings Industry." accessed 24 November. https://www.paint.org/article/an-update-on-sustainability-in-the-coatings-industry/.
Christopher, Martin. 2016. *Logistics & supply chain management*. 5th ed. ed. London: FT Publishing International.
Coatings World. 2012. "Jotun opens its manufacturing facility for decorative paints, tinters and fillers at Sandefjord." accessed April 27. https://www.coatingsworld.com/issues/2012-04/view_paint-amp-coatings-manufacturer-news/jotun-opens-its-manufacturing-facility-for-decorative-paints-tinters-and-fillers-at-sandefjord/.
Collis, Jill, and Roger Hussey. 2013. *Business research: A practical guide for undergraduate and postgraduate students*: Macmillan International Higher Education.
Creswell, John W, and J David Creswell. 2017. *Research design: Qualitative, quantitative, and mixed methods approaches*: Sage publications.
D'Amato, D., N. Droste, B. Allen, M. Kettunen, K. Lähtinen, J. Korhonen, P. Leskinen, B. D. Matthies, and A. Toppinen. 2017. "Green, circular, bio economy: A comparative analysis of sustainability avenues." *Journal of Cleaner Production* 168:716-734. doi: https://doi.org/10.1016/j.jclepro.2017.09.053.
D'Eusanio, Manuela, Alessandra Zamagni, and Luigia Petti. 2019. "Social sustainability and supply chain management: Methods and tools." *Journal of Cleaner Production* 235:178-189. doi: https://doi.org/10.1016/j.jclepro.2019.06.323.
Dao, Viet, Ian Langella, and Jerry Carbo. 2011. "From green to sustainability: Information Technology and an integrated sustainability framework." *The Journal of Strategic Information Systems* 20 (1):63-79. doi: https://doi.org/10.1016/j.jsis.2011.01.002.
De Angelis, R., M. Howard, and J. Miemczyk. 2017. "Supply Chain Management and the Circular Economy: Towards the Circular Supply Chain." *Production Planning & Control*. doi: DOI: 10.1080/09537287.2018.1449244.
DSB. 2016. "40 år siden Jotun-brannen." accessed April 18. https://www.dsb.no/nyhetsarkiv/2016/40-ar-siden-jotun-brannen/.
DSB. 2017. "Viktig informasjon om storulykkeforskriften." accessed May 7. https://www.dsb.no/lover/farlige-stoffer/andre-publikasjoner/viktig-informasjon-om-storulykkeforskriften/#seveso-iii-direktivet.
Easterby-Smith, Mark, Richard Thorpe, and Paul R Jackson. 2012. *Management research*: Sage.
Easterby-Smith, Mark, Richard Thorpe, and Paul R Jackson. 2015. *Management and business research*: Sage.
ECHA. n.d. "Understanding REACH." https://echa.europa.eu/regulations/reach/understanding-reach.
Eisenhardt, Kathleen M. 1989. "Building theories from case study research." *Academy of management review* 14 (4):532-550.

Elia, Valerio, Maria Grazia Gnoni, and Fabiana Tornese. 2017. "Measuring circular economy strategies through index methods: A critical analysis." *Journal of Cleaner Production* 142:2741-2751.
Elkington, John. 1998. "Cannibals with Forks: The Triple Bottom Line of 21st Century Business. Gabriola Island, BC." *Environmental Quality Management* 8:37-51. doi: 10.1002/tqem.3310080106.
Ellen MacArthur Foundation. 2013. Towards a Circular Economy: Economic and business rationale for an accelerated transition. Isle of Wight: The Ellen MacArthur Foundation.
Ellen MacArthur Foundation. 2014. Towards the Circular Economy - Accelerating the scale-up across global supply chains. Isle of Wight.
Ellram, Lisa M. 1996. "The use of the case study method in logistics research." *Journal of business logistics* 17 (2):93.
ENOVA. n.d. "Gjenbruk." accessed 21.05. https://www.enova.no/om-enova/om-organisasjonen/teknologiportefoljen/gjenbruk/.
EPA. n.d. Learn about Polychlorinated Biphenyls (PCBs). edited by United States Environmental Protection Agency.
European Commission. 2019. The Paints Directive Legislation.
Farooque, Muhammad, Abraham Zhang, Matthias Thürer, Ting Qu, and Donald Huisingh. 2019. "Circular supply chain management: A definition and structured literature review." *Journal of Cleaner Production* 228:882-900. doi: https://doi.org/10.1016/j.jclepro.2019.04.303.
Finnveden, Göran, Michael Z. Hauschild, Tomas Ekvall, Jeroen Guinée, Reinout Heijungs, Stefanie Hellweg, Annette Koehler, David Pennington, and Sangwon Suh. 2009. "Recent developments in Life Cycle Assessment." *Journal of Environmental Management* 91 (1):1-21. doi: https://doi.org/10.1016/j.jenvman.2009.06.018.
Flyvbjerg, Bent. 2006. "Five misunderstandings about case-study research." *Qualitative inquiry* 12 (2):219-245.
Folkehelseinstituttet. 2015. "Fakta om bly i mat og miljø." accessed 15.05. https://www.fhi.no/ml/miljo/miljogifter/fakta/bly-i-mat-og-miljo---faktaark/.
Folkehelseinstituttet. 2017. "Maling, lakk og beis." Giftinformasjonen, Folkehelseinstituttet, accessed 10 April. https://helsenorge.no/Giftinformasjon/Produkter-og-kjemikalier/oppussing/maling-lakk-og-beis.
Geissdoerfer, Martin, Sandra Naomi Morioka, Marly Monteiro de Carvalho, and Steve Evans. 2018. "Business models and supply chains for the circular economy." *Journal of Cleaner Production* 190:712-721. doi: https://doi.org/10.1016/j.jclepro.2018.04.159.
Geissdoerfer, Martin, Paulo Savaget, Nancy M. P. Bocken, and Erik Jan Hultink. 2017. "The Circular Economy – A new sustainability paradigm?" *Journal of Cleaner Production* 143:757-768. doi: https://doi.org/10.1016/j.jclepro.2016.12.048.
Genovese, Andrea, Adolf A. Acquaye, Alejandro Figueroa, and S. C. Lenny Koh. 2017. "Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications." *Omega* 66:344-357. doi: https://doi.org/10.1016/j.omega.2015.05.015.
Ghisellini, Patrizia, Catia Cialani, and Sergio Ulgiati. 2016. "A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems." *Journal of Cleaner Production* 114:11-32. doi: https://doi.org/10.1016/j.jclepro.2015.09.007.
Goh, Cheng Siew, Heap-Yih Chong, Lynne Jack, and Adam Fuad Mohd Faris. 2020. "Revisiting triple bottom line within the context of sustainable construction: A

systematic review." *Journal of Cleaner Production* 252:119884. doi: https://doi.org/10.1016/j.jclepro.2019.119884.
Govindan, Kannan. 2018. "Sustainable consumption and production in the food supply chain: A conceptual framework." *International Journal of Production Economics* 195:419-431. doi: https://doi.org/10.1016/j.ijpe.2017.03.003.
Govindan, Kannan, and Mia Hasanagic. 2018. "A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective." *International Journal of Production Research* 56 (1-2):278-311.
Grießhammer, Rainer, Catherine Benoît, Louise Camilla Dreyer, Anna Flysjö, Andreas Manhart, Bernard Mazijn, Andrée-Lise Méthot, and Bo Weidema. 2006. "Feasibility study: integration of social aspects into LCA."
Gustafsson, Johanna. 2017. Single case studies vs. multiple case studies: A comparative study.
Haupt, Melanie, and Stefanie Hellweg. 2019. "Measuring the environmental sustainability of a circular economy." *Environmental and Sustainability Indicators* 1-2:100005. doi: https://doi.org/10.1016/j.indic.2019.100005.
Hofmann, Florian. 2019. "Circular business models: Business approach as driver or obstructer of sustainability transitions?" *Journal of Cleaner Production* 224:361-374. doi: https://doi.org/10.1016/j.jclepro.2019.03.115.
Hong, Young-Seoub, Yu-Mi Kim, and Kyung-Eun Lee. 2012. "Methylmercury exposure and health effects." *Journal of preventive medicine and public health = Yebang Uihakhoe chi* 45 (6):353-363. doi: 10.3961/jpmph.2012.45.6.353.
Internkontrollforskriften. 2014. Forskrift om systematisk helse-, miljø- og sikkerhetsarbeid i virksomheter (Internkontrollforskriften). Lovdata.
ISO. 2006. "ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework." accessed 28 January. https://www.iso.org/obp/ui/#iso:std:iso:14040:ed-2:v1:en.
Jain, Sourabh. 2018. "Strategic framework towards measuring a circular supply chain management." *Benchmarking: An International Journal* 25 (8):3238-3252. doi: 10.1108/BIJ-11-2017-0304.
Jawahir, I. S., and Ryan Bradley. 2016. "Technological Elements of Circular Economy and the Principles of 6R-Based Closed-loop Material Flow in Sustainable Manufacturing." *Procedia CIRP* 40:103-108. doi: https://doi.org/10.1016/j.procir.2016.01.067.
Jæger, Bjørn, Lise Lillebrygfjeld Halse, Farah Naz, and Khadija Khudai Rahim. 2019. "Towards circular economy in manufacturing: identification of barriers seen by Norwegian manufacturing companies."
Kang, Suk-Ho, Bokyoung Kang, Kwangsup Shin, Daeyoung Kim, and Jihee Han. 2012. "A theoretical framework for strategy development to introduce sustainable supply chain management." *Procedia - Social and Behavioral Sciences* 40:631-635. doi: https://doi.org/10.1016/j.sbspro.2012.03.241.
Kirchherr, Julian, Laura Piscicelli, Ruben Bour, Erica Kostense-Smit, Jennifer Muller, Anne Huibrechtse-Truijens, and Marko Hekkert. 2018. "Barriers to the Circular Economy: Evidence From the European Union (EU)." *Ecological Economics* 150:264-272. doi: https://doi.org/10.1016/j.ecolecon.2018.04.028.
Kirchherr, Julian, Denise Reike, and Marko Hekkert. 2017. "Conceptualizing the circular economy: An analysis of 114 definitions." *Resources, Conservation and Recycling* 127:221-232. doi: https://doi.org/10.1016/j.resconrec.2017.09.005.
Kongsberg. n.d. "Jotun Hull Skating Solutions." accessed 24.05. https://www.kongsberg.com/maritime/campaign/hullskater/.

Korhonen, Jouni, Cali Nuur, Andreas Feldmann, and Seyoum Eshetu Birkie. 2018. "Circular economy as an essentially contested concept." *Journal of Cleaner Production* 175:544-552. doi: https://doi.org/10.1016/j.jclepro.2017.12.111.

Kothari, C. R. 2004. "Research methodology : methods & techniques." In. New Delhi: New Age International P Ltd., Publishers.

Kraaijenhagen, Christiaan, Cécile Van Oppen, and Nancy Bocken. 2016. *Circular business: collaborate and circulate*: Chris Bernasco en Lucy Goodchild-van Hilten.

Lieder, Michael, and Amir Rashid. 2016. "Towards circular economy implementation: a comprehensive review in context of manufacturing industry." *Journal of Cleaner Production* 115:36-51. doi: https://doi.org/10.1016/j.jclepro.2015.12.042.

Linton, J. D., R. Klassen, and V. Jayaraman. 2007. "Sustainable supply chains: An introduction." *Journal of Operations Management* 25 (6). doi: https://doi.org/10.1016/j.jom.2007.01.012.

Luthra, Sunil, and Sachin Kumar Mangla. 2018. "When strategies matter: Adoption of sustainable supply chain management practices in an emerging economy's context." *Resources, Conservation and Recycling* 138:194-206. doi: https://doi.org/10.1016/j.resconrec.2018.07.005.

Lüdeke-Freund, Florian, Stefan Gold, and Nancy Bocken. 2019. "A Review and Typology of Circular Economy Business Model Patterns." *Journal of Industrial Ecology* 23:36-61. doi: 10.1111/jiec.12763.

Malek, Javed, and Tushar N. Desai. 2020. "A systematic literature review to map literature focus of sustainable manufacturing." *Journal of Cleaner Production* 256:120345. doi: https://doi.org/10.1016/j.jclepro.2020.120345.

Mani, V., Rajat Agarwal, Angappa Gunasekaran, Thanos Papadopoulos, Rameshwar Dubey, and Stephen J. Childe. 2016. "Social sustainability in the supply chain: Construct development and measurement validation." *Ecological Indicators* 71:270-279. doi: https://doi.org/10.1016/j.ecolind.2016.07.007.

Mani, V., C. J. C. Jabbour, and K. T. N. Mani. 2020. "Supply chain social sustainability in small and medium manufacturing enterprises and firms' performance: Empirical evidence from an emerging Asian economy." *International Journal of Production Economics* 227:107656. doi: https://doi.org/10.1016/j.ijpe.2020.107656.

Martins, C. L., and M. V. Pato. 2019. "Supply chain sustainability: A tertiary literature review." *Journal of Cleaner Production* 225:995-1016. doi: https://doi.org/10.1016/j.jclepro.2019.03.250.

Miljødirektoratet. 2000. "Substitution of hazardous chemicals." http://tema.miljodirektoratet.no/old/klif/publikasjoner/kjemikalier/2007/ta2007_00.html.

Miljødirektoratet. 2016. Tilskudd til opprydding i forurenset sjøbunn i Sandefjordsfjorden – avtalenummer 16028066.

Miljødirektoratet. 2019. Mikroplast. edited by Miljødirektoratet. Miljøstatus.

Millar, Neal, Eoin McLaughlin, and Tobias Börger. 2019. "The Circular Economy: Swings and Roundabouts?" *Ecological Economics* 158:11-19. doi: https://doi.org/10.1016/j.ecolecon.2018.12.012.

Moderne Transport. 2010. "Startet Jotun-revolusjonen." accessed 16 may 2020. https://www.mtlogistikk.no/artikler/startet-jotun-revolusjonen/354259?fbclid=IwAR212XZgz_ATOkWmT5SQNjsVoak3O_i-dgSOj2-_M_fwF91SsCyI_WSiFYw.

Murray, Alan, Keith Skene, and Kathryn Haynes. 2017. "The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context." *Journal of Business Ethics* 140 (3):369-380. doi: 10.1007/s10551-015-2693-2.

Muthu, Subramanian Senthilkannan. 2014. "6 - Estimating the overall environmental impact of textile processing: life cycle assessment (LCA) of textile products." In *Assessing the Environmental Impact of Textiles and the Clothing Supply Chain*, edited by Subramanian Senthilkannan Muthu, 105-131. Woodhead Publishing.

Naustdalslid, Jon. 2014. "Circular economy in China – the environmental dimension of the harmonious society." *International Journal of Sustainable Development & World Ecology* 21 (4):303-313. doi: 10.1080/13504509.2014.914599.

Naz, Farah, Khadija Khudai Rahim, and Bjørn Jæger. 2018. Shift towards Circular Economy in technical industries with the help of the product information system & standardization. Høgskolen i Molde - Vitenskapelig høgskole i logistikk.

NIVA. 2019. "Miljøgiftforbud virker: Kjønnsforstyrrede purpursnegler er friskmeldte." accessed 15.05. https://www.niva.no/nyheter/miljogiftforbud-virker-kjonnsforstyrrede-purpursnegler-er-friskmeldte.

Norsk Industri. 2019. "Overleverte ny mulighetsstudie for sirkulær økonomi i prosessindustrien." accessed April 30. https://www.norskindustri.no/dette-jobber-vi-med/energi-og-klima/aktuelt/overleverte-ny-mulighetsstudie-for-sirkular-okonomi-i-prosessindustrien/.

Ogilo, Joel, Onditi Anam, and Amir Yusuf. 2017. "Assessment of Levels of Heavy Metals in Paints from Interior Walls and Indoor Dust from Residential Houses in Nairobi City County, Kenya." *Chemical Science International Journal* 21:1-7. doi: 10.9734/CSJI/2017/37392.

Os, T. T. 2011. "Hvordan bør pårørende ivaretas ved katastrofer?", Det medisinske fakultet, , University of Oslo.

Ottesen, R. T. 2012. "Bly i 6000 år – og fortsatt et problem." *Adresseavisen*. https://www.midtnorskdebatt.no/meninger/article1512727.ece.

Pagell, Mark, and Anton Shevchenko. 2014. "Why Research in Sustainable Supply Chain Management Should Have no Future." *Journal of Supply Chain Management* 50 (1):44-55. doi: 10.1111/jscm.12037.

Rajeev, A., Rupesh K. Pati, Sidhartha S. Padhi, and Kannan Govindan. 2017. "Evolution of sustainability in supply chain management: A literature review." *Journal of Cleaner Production* 162:299-314. doi: https://doi.org/10.1016/j.jclepro.2017.05.026.

Regjeringen.no. 2020. Handlingsplan for sirkulær økonomi, 2020. edited by Klima- og miljødepartementet.

Richardson, James. 2008. "The business model: an integrative framework for strategy execution." *Strategic change* 17 (5-6):133-144.

Salvador, Rodrigo, Murillo Vetroni Barros, Leila Mendes da Luz, Cassiano Moro Piekarski, and Antonio Carlos de Francisco. 2020. "Circular business models: Current aspects that influence implementation and unaddressed subjects." *Journal of Cleaner Production* 250:119555. doi: https://doi.org/10.1016/j.jclepro.2019.119555.

Sandefjord kommune. n.d. "Nå er det ryddet!", accessed 15.05. https://www.sandefjord.kommune.no/renere-sandefjordsfjord/na-er-det-ryddet/.

Saunders, M, P Lewis, and A Thornhill. 2016. "Research methods for business students (Vol. Seventh)." *Harlow: Pearson Education*.

Sauvé, Sébastien, Sophie Bernard, and Pamela Sloan. 2016. "Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research." *Environmental Development* 17:48-56. doi: https://doi.org/10.1016/j.envdev.2015.09.002.

Seuring, Stefan, and Martin Müller. 2008. "From a literature review to a conceptual framework for sustainable supply chain management." *Journal of Cleaner Production* 16 (15):1699-1710. doi: https://doi.org/10.1016/j.jclepro.2008.04.020.

Shou, Yongyi, Jinan Shao, Kee-hung Lai, Mingu Kang, and Youngwon Park. 2019. "The impact of sustainability and operations orientations on sustainable supply management and the triple bottom line." *Journal of Cleaner Production* 240:118280. doi: https://doi.org/10.1016/j.jclepro.2019.118280.
Tseng, MingLang. 2015. "Sustainable supply chain management." *Industrial Management & Data Systems* 115 (3):436-461. doi: 10.1108/IMDS-10-2014-0319.
Tsvetkova, Antonina. 2020. "Social Responsibility Practice of the Evolving Nature in the Sustainable Development of Arctic Maritime Operations." In, 119-143.
Tura, Nina, Jyri Hanski, Tuomas Ahola, Matias Ståhle, Sini Piiparinen, and Pasi Valkokari. 2019. "Unlocking circular business: A framework of barriers and drivers." *Journal of Cleaner Production* 212:90-98. doi: https://doi.org/10.1016/j.jclepro.2018.11.202.
Van Eijk, F. 2015. "Barriers & Drivers towards a Circular Economy. Literature Review." *Acceleratio: Naarden, The Netherlands*:1-138.
Veleva, Vesela, and Michael Ellenbecker. 2001. "Indicators of sustainable production: Framework and methodology. Journal of Cleaner Production, 9, 519-549." *Journal of Cleaner Production* 9:519-549. doi: 10.1016/S0959-6526(01)00010-5.
Wautelet, Thibaut. 2018. *The Concept of Circular Economy: its Origins and its Evolution*.
Wiborg, M. L., Schulze, P. E., Konieczny, R.,. 1999. Resultater fra Den store giftjakta, Kysten Kristiansund - Oslo. Naturnverforbundet.
Wu, Zhaohui, and Mark Pagell. 2011. "Balancing priorities: Decision-making in sustainable supply chain management." *Journal of Operations Management* 29 (6):577-590. doi: https://doi.org/10.1016/j.jom.2010.10.001.
Yin, Robert. 2003. "Case Study Research: Design and Methods London: SAGE."
Yin, Robert K. 2018. *Case study research and applications : design and methods*. Sixth Edition. ed. Los Angeles: SAGE.
Ünal, Enes, and Jing Shao. 2019. "A taxonomy of circular economy implementation strategies for manufacturing firms: Analysis of 391 cradle-to-cradle products." *Journal of Cleaner Production* 212:754-765. doi: https://doi.org/10.1016/j.jclepro.2018.11.291.
Zhu, Qinghua, Yong Geng, and Kee-hung Lai. 2010. "Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications." *Journal of Environmental Management* 91 (6):1324-1331. doi: https://doi.org/10.1016/j.jenvman.2010.02.013.

# 8. Appendices

## 8.1. Interview guide

**General questions**

1. What is your position within the company?
2. What are your tasks?
3. How long have you been working at the company?
4. Could you describe what your department does in the company?
5. What is your perception of the concept "*Sustainability*" in terms of the job you do?
6. What is your perception of the concept of "*Circular Economy*"?

**Sustainable development in production operations and transport**

1. In which stages of the production system are particularly suitable for sustainable work?
2. What kind of measures is being taken for sustainable production?
3. What requirements do you have for the transport carriers regarding environmentally friendly transport?
4. How is toxic waste secured during transport?
5. How is paint packed to minimize the risk of hazardous emissions?
6. How did the company begin to focus on sustainability as a strategy?
7. Has the focus on sustainability contributed to more efficient production?

**Circular Economy**

1. How is CE organized and formulated in your system?
2. What is the reason why CE is becoming more focused on now?
3. Where is the potential for using CE?
4. Does the company apply any of these principles, and in what way?
   a. Remanufacturing
   b. Reuse
   c. Recycling
   d. Maintenance
   e. Prolong/long-lasting design

5. Dust is a by-product of refining plants that can be used in the paint industry due to high pigment content. Is this right? Is this used in the company?
6. What is your understanding of the terms *“LCA”* and *“Cradle-to-Cradle”*?

**Health, safety, and environment (HSE)**

1. What do you do to make it safe and secure for employees?
2. In what way do you focus on HSE in everyday life?
3. What guidelines do you follow to ensure the end-users of paint?
4. According to the annual report, the company is concerned about corporate social responsibility around the world. What is being done locally in Sandefjord and in Norway?
5. How often are safety routines checked/reviewed in the production premises?
6. The 1976 accident: What changes were made with a focus on the safety of the company’s employees?
7. Has the accident changed the view of sustainable work in the company?