10 Carbon Capture, Transport, and Storage Projects in Norwegian Seabed

Sustainable Implications and Challenges of New Green Technologies Rooted in the Past

Antonina Tsvetkova
Faculty of Logistics, Molde University College, Molde, Norway

Alexandra Middleton
Oulu Business School, University of Oulu, Finland

Introduction

Contemporary supply chain management (SCM) is often indicated by such integral parts as outsourcing and integration processes that ensure firms' operational performance. At the same time, introducing the sustainability concept in core business functions of the supply chain enables firms to extend their performance beyond traditional processes and achieve a more competitive advantage in the market (Ansari and Kant, 2017). Sustainable SCM has been considered a new era of incorporating economic, environmental, and social responsibilities into business processes. Understanding these three distinct responsibilities and their interrelationships is crucial (Pagell and Wu, 2009; Mani et al., 2016; Tsvetkova, 2020). However, a major challenge for firms is still to manage sustainability along the supply chain, which involves interdependent actors that can influence one another's performance and actions.

Further, the SCM literature represents a wide range of studies that illustrate supply chains forced to adopt new and/or costly practices that may have dramatically negative and quite uncertain consequences when building a more sustainable supply chain. Ever-increasing attention has been paid to so-called green technologies in order to reduce environmental and social harm (Green et al., 2012). Further, much research deals with environmental performance and focuses on various operationalizations of practices, where supply chain issues are only secondarily addressed (Seuring and Müller, 2008; Quarshie et al., 2016). Also, the understanding of sustainable development is often one-dimensional and limited to environmental improvements, neglecting the social dimension (Seuring and Müller, 2008). In the CCTS supply chain context, research has focused on resilience perspectives, from infrastructure and environment standpoints (Gabrielli et al., 2022). So, extant research offers a

DOI: 10.4324/9781003218043-10

somewhat limited insight into how to create a cost-effective and economically viable supply chain that produces no harm or may even have a positive or regenerative effect on social and environmental systems (Pagell and Shevchenko, 2014). To address these shortcomings of sustainable SCM literature, our study aims to explore *how SCM facilitates the implementation and further institutionalization of the world's sustainability and climate strategies in the North Sea, with subsequent application in the Arctic Ocean.*

In an effort to understand the role of SCM in sustainable issues, we investigate the implementation of a carbon capture, transport, and storage (CCTS) project in the Norwegian seabed. This project sets the long-term objective of restoring climate-resilient carbon cycles to achieve sustainable development. These types of projects have been considered a new solution for the decarbonization of different industrial sectors to reduce CO_2 emissions and thereby limit global warming. Instead of being released into the atmosphere, CO_2 as hydrate gets sequestrated and stored under the seabed, mostly in offshore depleted oil and gas reservoirs. In Norway, such practices have been in place since 1996, when CO_2 from produced gas was removed and injected in the Sleipner area, with 19 million tonnes of CO_2 stored by 2020 (Equinor, 2022). However, some researchers point out that this solution can pose the risk of carbon dioxide re-emission from the ocean sinks. Further, CO_2 dissolution into the ocean can result in ocean acidification and an alteration of ocean chemistry that is detrimental to marine ecosystems (Zheng et al., 2020). The most significant change is the shift toward transportation of captured $CO_{2,}$ which brings more complex supply chain operations and additional risks related to shipping activities.

This study presents an empirical case of the development and implementation of "Longship", a full-scale carbon capture and storage (CCS) project that will demonstrate the capture of CO_2 from industrial sources, as well as transport and storage in the Norwegian continental seabed. The project sets the long-term objective of restoring sustainable and climate-resilient carbon cycles and receives substantial financial support from the Norwegian government (Norwegian Government, 2022). The case is noteworthy due to its pioneering nature. Specific regulation of carbon capture transportation and storage for implementing such sustainable and climate-resilient projects is still evolving. Moreover, there is no functioning framework for the evaluation of material financial, environmental, and social risks for the stakeholders involved, e.g., coastal communities and Indigenous Peoples. The project is relevant as a demonstration of the potential of CCTS-reliant supply chains to contribute to climate mitigation strategies as part of the Paris Agreement. It is assumed that outcomes from the "Longship" project will be utilized in developing further CCTS initiatives that do not rely on government support. In the Arctic context, the "Polaris" carbon storage project off the coast of northern Norway aims to store more than 100 million tonnes of CO_2 (Reuters, 2020; Horisont Energi, 2022). Hence, the knowledge about the sustainability aspects of CCTS supply chains is of great importance for evaluating the feasibility of these operations in the Arctic.

In our study, we attempt to show the dynamics of the circulation of sustainable and climate-resilient strategies and how they are institutionalized into existing practice through supply chain operations. Previous research is not so concerned with how meanings and actions change when companies face a choice of supply chain strategy (Tsvetkova and Gammelgaard, 2018). We follow Jepperson (1991) in our perception of institutionalization, which is the process whereby social activity becomes institutionalized and, eventually, is more or less taken for granted. Once fully institutionalized, ideas can survive across generations, accepted as the definitive behavior (Tolbert and Zucker, 1996). At the same time, the institutionalization process is cyclical, as "institutions emerge, diffuse, change, die, and, are replaced by new institutions" (Haunschild and Chandler, 2008, p. 630). Moreover, actors – e.g., competitors, suppliers, regulators, and consumers (Greenwood et al., 2002) – in such a heterogeneous environment as SCM act as drivers for the relentless promotion of institutionalization processes.

In the section that follows, we provide a literature review on sustainable SCM. Then, we present our methodology. In the fourth section, we present our findings. Finally, the chapter ends with concluding remarks.

Sustainable Supply Chain Management Literature

In this section, we provide an overview of the literature on sustainable supply chain management to identify the gaps between theory and practice. Sustainable SCM has gained increased attention in the academic community and has been specifically defined in numerous ways. In our study, we mainly adhere to the definition given by Carter and Rogers (2008, p. 368), which combines the desired performance with the actors' interests and is formulated as "the strategic, transparent integration and achievement of an organization's social, environmental and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains". This means that the voluntary integration of environmental and social considerations has to be applied by all supply chain partners to effectively and efficiently manage the material, information, and capital flows. Further, it is expected that a dimension of corporate socially responsible behavior is also encouraged (Lu et al., 2007; Pagell et al., 2008).

Over the past two decades, an increasing number of studies have addressed different challenges and issues in building more sustainable supply chains and management. Several recent literature reviews pointed out that previous studies have primarily focused on integrating environmental concerns about minimizing environmental impact, decreasing CO_2 emissions, and reducing fuel and energy consumption (Seuring and Müller, 2008; Quarshie et al., 2016; Ansari and Kant, 2017). This gave rise to the implementation of "green" SCM practices (see Jabbour et al., 2015). In contrast, social issues on the route to sustainability have rarely been addressed in SCM studies, as emphasized by many scholars (Seuring and Müller, 2008; Mani et al., 2016; Tsvetkova, 2020). Instead, social sustainability has been narrowed down to environmental issues regarding the possible adverse effects of pollution on human health, safety, and quality of life (Tsvetkova, 2020), as well as the product and process measures to ensure the safety and welfare of people in the chain (Mani et al., 2015).

Further, a large number of studies identified the impact of external drivers on organizations' efforts. External pressures, including contextual and institutional ones, encourage firms that govern the supply chain to adopt and implement sustainable supply chain practices (Seuring and Müller, 2008). Firms have to ensure and increase their external legitimization, to fit socially constructed systems of norms, beliefs, values, and institutions. Regulatory pressure and institutional constraints considerably impact firms' operational performance, by obliging them to adopt sustainable SCM practices. While some regulations may bring negative effects like penalties and fines, others may have positive impacts like environmental programs, partnerships, grants, and governmental support that encourage firms to undertake proactive environmental strategies and green initiatives (Ageron et al., 2012). In addition to various institutional drivers and pressures, researchers point to the impact of market mechanisms and conditions that can incentivize organizations' decisions to adopt sustainable practices at different levels. Not to be overlooked is also reputation related to sustainability that can not only enhance organizations' competitive advantage but also change organizational behavior to exceed accepted standards and thereby generate new business opportunities with other companies, e.g., suppliers and customers (Ageron et al., 2012).

Environmental and social issues, or forms of social sustainability, vary across different geographical locations and contextual settings (Huq et al., 2014; Mani et al., 2016; Tsvetkova, 2020). Implementing sustainable practices and strategies defines the nature of the interaction between the supply chain and the context or the external environment where these initiatives are applied. These interactions may uncover "unexpected results" and "unintended consequences" of the deployment of particular strategies (see Tsvetkova and Gammelgaard, 2018). Without simultaneously addressing environmental, social, and economic issues, our understanding of sustainability becomes insufficient to create truly sustainable supply chains (Pagell and Shevchenko, 2014); that, in turn, creates difficulty in measuring advances in sustainable supply chain practices (Davidson, 2011). Although scholarly attention to social issues has grown in recent years (see Tsvetkova, 2020, Tsvetkova, 2021a), some literature reviews still indicate a need for more studies to develop better scales for measuring the social impact of various supply chains (Rajeev et al., 2017).

Method

We apply a single qualitative case study approach to understand the dynamics of sustainable and climate-resilient strategies in a particular setting (Eisenhardt, 1989) from bounded real-world settings (Barratt et al., 2011), specifically the role of SCM under the implementation of a CCTS project in the Norwegian seabed. We selected "Northern Lights" (part of the "Longship" project), which is responsible for the transportation of the liquefied CO_2 by ship from the respective pick-up points to the receiving terminal located in Norway for subsequent storage in the seabed. The project involves several major stakeholders, including industrial enterprises, e.g., a cement producer, a waste incineration/energy recovery plant, and a fertilizer factory, and several oil companies, with the close involvement of the Norwegian government. Although there are great ambitions to rapidly increase the tons of CO_2 to be captured and to attract even more industrial enterprises in the near future, the implementation process is accompanied by a significant lack of a legislative framework for the legal CO_2 transportation definition to cover transportation by ships. So, this study has a dual unit of analysis, where the organizations are considered to be the unit of analysis for identifying the drivers for emerging new sustainable practices, while the supply chain – as an inter-organizational field characterized by heterogeneity of goals, motives, demands, and principles of managing – is the unit for understanding the impact of supply chain operations on the stakeholders' behavior and actions.

Eight semi-structured individual interviews were conducted between 2021 and 2022. As Yin (1994) recommended using multiple sources of empirical evidence to ensure triangulation, we interviewed a variety of actors within CCTS projects and other critical stakeholders. It was helpful to provide insights from various perspectives. We mainly used the snowball technique, with participants suggesting additional respondents for our study. Interview questions were developed based on the literature reviews and contained open questions for discussion but did not limit the respondents' scope and thinking. The interview data was supplemented by archival materials, including academic papers, legal documents, government reports, EU and national strategies' papers that helped understand the institutional environment and drivers behind the emergence of CCTS initiatives, the role of SCM, key issues, and stakeholders involved. That was helpful in establishing a chain of evidence and reinforcing triangulation (Yin, 1994), thereby increasing the data's internal consistency and the validity of our research findings (Voss et al., 2002). To better code and categorize our data, we used NVivo software, which allowed us to assign attributes and explore relationships in different logistics operations.

Carbon Capture, Transport, and Storage (CCTS) as Part of Green Transition

CCTS projects are viewed as a solution to mitigating greenhouse gas (GHG) emissions as part of Nationally Defined Contributions according to the Paris

Agreement (Paris Agreement, 2015). Emissions of carbon dioxide can be reduced through the reduction of energy intensity, carbon intensity, and carbon sequestration (Yamasaki 2003). Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. It is one method of reducing the amount of carbon dioxide in the atmosphere, with the goal of reducing global climate change. Carbon sequestration can be either biotic or geological. Biotic carbon sequestration refers to carbon stored in vegetation, soils, woody products, and aquatic environments. Biologic sequestration advocates hope to remove CO_2 from the atmosphere by encouraging the growth of plants, especially trees. Geologic carbon sequestration is a technique for storing carbon dioxide in deep geologic formations to prevent it from being released into the atmosphere and contributing to global warming as a greenhouse gas (Duncan and Morrissey, 2011); for an illustration of the technology, see Figure 10.1. Therefore, CCS is a form of geologic carbon sequestration. The technology for sequestration must ensure long-term safety, stability, and environmental acceptance (Zheng et al., 2020).

The long-term storage of anthropogenic CO_2 in deep-sea sediments, using the existing offshore infrastructure, has been proposed. At the same time, the multiphysics process of CO_2 injection, postinjection fate, and subseabed disposal feasibility under different geological and operational conditions have not

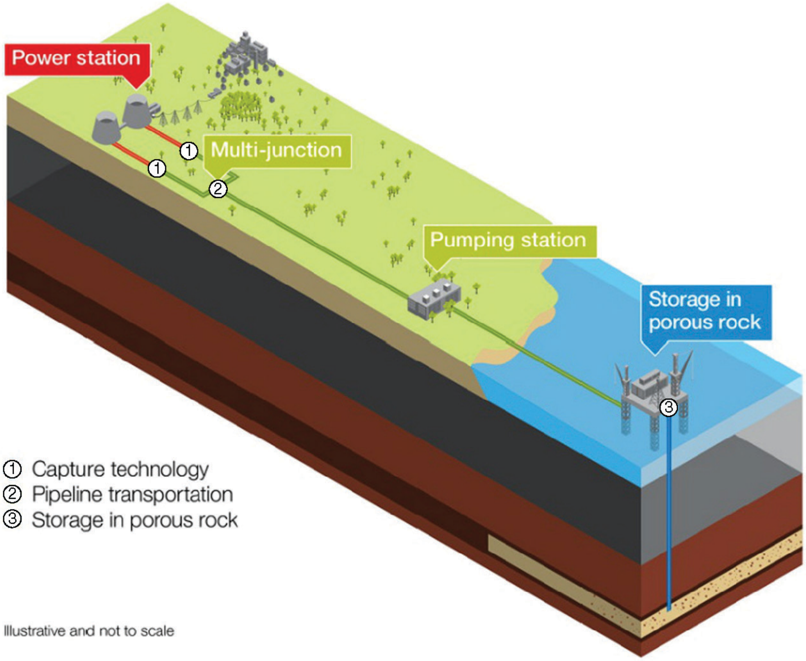

Figure 10.1 Geological storage of CO_2 (*Source*: OSPAR Commission, Quality Status Report 2010, https://qsr 2010.ospar.org/en/index.html).

been well studied. Teng and Zhang (2018) find that, in a deep-sea setting, CO_2 sequestration in intact marine sediments is generally safe and permanent. At the same time, CCS entails several hazards (loss of containment of carbon dioxide, explosive decompression, cold, toxic scale, ignition, etc.) that need to be considered (Wilday et al., 2011).

Typically, CO_2 can be stored in depleted oil and gas fields because these reservoirs have suitable sealing caps, porosity, permeability, etc., as shown by their ability to store oil and gas for a long time before discovery and development. Enhanced oil recovery (EOR) uses CO_2 as a displacement agent to produce oil that cannot be produced by natural field pressure or water flooding. Depending on the reservoir, oil properties, and existing infrastructure, this may make CO_2 storage more economical. EOR technologies are mature, and many commercial projects have been completed. However, due to marginal economics, almost all of these use low-cost, naturally occurring CO_2 (that is, CO_2 that was previously underground), with only a few using anthropogenic sources of CO_2 (Zheng et al., 2020).

The difference between CCS and CCTS is the addition of transportation of CO_2 to the supply chain operations. While previously only locally produced CO_2 was captured and stored, the inclusion of transportation brings the possibility of transboundary shipment of CO_2. After CO_2 capture, the captured gas is purified and compressed (usually to a supercritical state) to generate a transportable stream of concentrated gas. In the United States, pipelines are the most frequent technique for delivering carbon dioxide. CO_2 can also be transported worldwide by ship. Marine tankers transport liquefied natural gas and liquefied petroleum gases like propane and butane globally. Some marine tankers transport CO_2, although demand is low. No large-scale CO_2 transport system via vessels (millions of metric tons per year, e.g.) is running. However, the European Union has proposed implementing just such an idea. Hence, marine tanker prices for CO_2 shipping are uncertain as it stands (US Congressional Research Service, 2022).

Most road maps that address keeping global warming below 2°C include CCS. According to the International Energy Agency (IEA), CCS alone could reduce global CO_2 emissions by nearly 19% by 2050 (IEA, 2022). Moreover, the IEA forecasts that 100 CCS projects will be required by 2020 and more than 3,000 by 2050 if CCS is to completely contribute to the least expensive technology portfolio for CO_2 mitigation. As early as the 2009 IEA publication, *Technology Roadmap: Carbon Capture and Storage*, it was recommended that international legal barriers to global CCS deployment be removed by 2012, including the ban on transboundary CO_2 transfer under the London Protocol (IEA, 2011). It took about ten years to remove these legal obstacles, which was only done in 2019, with an amendment to the London Protocol. The latest 2022 Intergovernmental Panel on Climate Change (IPCC) report, "Mitigation of Climate Change", states that geological CO_2 storage capacity is estimated to be 1,000 gigatonnes, which is greater than the CO_2 storage needed until 2100 to limit global warming to 1.5°C. Global rates of CCS deployment are now substantially below those in simulated paths that limit global warming to 1.5°C or 2°C. According to the IPCC, these hurdles could be reduced by enabling factors such as governmental instruments, increased public support, and technical innovation (IPCC, 2022). Moreover, countries are integrating climate change measures into national policies, strategies and planning, as part of adherence to the UN Sustainable Development Goals.

The Global CCS Institute maintains a database of all active and planned CCS facilities. In 2022, there were 29 fully operational CCS facilities worldwide (GCCI, 2022). The first facilities that are going to be involved in the transportation aspect of CCTS are the Norwegian ones, that is, Northern Lights as part of the Longship project and the future Polaris project in the Barents Sea.

Institutional Drivers as Prerequisites for CCS and CCTS Projects Origination

London Protocol

For many years, industrial pollutants, including radioactive waste, were dumped in the oceans. In the 1970s, the practice became governed by an international treaty with the purpose of standardizing procedures and prohibiting actions that could cause marine contamination (Sjoeblom and Linsley, 1994). The international treaty, the "Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972" or the "London Convention", has been in effect since 1975. Its goal is to improve effective control of all marine pollution sources and avoid pollution from waste dumping. However, the London Protocol of 1996, which aimed to protect the marine environment more effectively and prevent waste disposal into the ocean, was modernized and finally replaced the Convention. The London Protocol expressly prohibited incineration at sea and the export of wastes and other matters for the purpose of ocean dumping. Dumping is forbidden under the Protocol, except for specified waste or other items mentioned in Annex I, which include dredging material, fish waste, and inert, inorganic geological material.

In 2006, the United Kingdom, Norway, and others proposed amendments to Annex I of the London Protocol to add CO_2 streams from carbon capture processes for storage to the list of wastes or other matter that may be considered for dumping and thus to regulate "carbon-dioxide streams from CO_2 capture processes for sequestration" (London Protocol, 2006). Thus, since 2006, the London Protocol has regulated the injection of CO_2 waste streams into subseabed geological formations for permanent isolation and safe carbon dioxide (CO_2) storage beneath the seabed.

Hence, initially, no export and transport of CO_2 was allowed. Then, the Netherlands and Norway proposed a resolution at the Protocol's October 2019 meeting. A Resolution authorizing the interim application of an amendment to Article 6 of the Protocol to allow CO_2 export for subseabed storage was adopted between contracting parties. This removed the last significant international legal impediment to carbon capture and storage (CCS), enabling CO_2 to be exported globally for offshore storage (Dixon and Birchenough, 2021). Parties would then be able to "provisionally apply" the 2009 amendment, allowing "cross-border transport of CO_2 for geological storage without breaching international commitments" (Dixon and Birchenough, 2021). It should be noted that the observer from Greenpeace International and the observer from the Advisory Committee on the Protection of the Sea (ACOPS) both raised concerns over the protocol amendment (IEAGHG, 2021). On its website, ACOPS mentions that

> *this resolution was framed as a necessary removal of a barrier to CO_2 removal which has been highlighted by the IPCC (Intergovernmental Panel on Climate Change) as one of the necessary solutions.*
>
> *(ACOPS, 2022)*

The Chair of the London Protocol further emphasized the necessity of a focus on CO_2 source reduction and control, as well as the sharing of information on projects and agreements resulting from the provisional application. Countries that intend to export or import CO_2 for storage are now required to inform the International Maritime Organization of any agreements or arrangements.

OSPAR Commission

OSPAR (named because of the original Oslo and Paris Conventions) is the mechanism by which 15 governments[1] and the EU cooperate to protect the marine environment of the North-East Atlantic. Following its study on ocean acidification in 2006, the OSPAR Commission amended the Convention's Annexes to allow carbon dioxide storage in geological formations beneath the seabed. According to OSPAR, capturing CO_2 at the source and storing it in subsea geological formations could aid in the long-term mitigation of climate change. The ultimate purpose of CO_2 storage is to ensure long-term containment in geological formations while minimizing substantial adverse effects on the marine environment, human health, and other legitimate users of the maritime area. Therefore, OSPAR has approved a decision (OSPAR Decision 2007/02) to ensure the safe storage of CO_2 streams in geological formations, as well as risk assessment and management guidelines for CO_2 stream storage in geological formations (OSPAR Agreement 2007–12). In addition, offshore oil and gas infrastructure, such as wells and pipelines, exists in the OSPAR maritime area and could be adapted for CO_2 transport and storage. At the moment, the only functioning CCS projects in the OSPAR Maritime Area are in Norway's Sleipner and Snøhvit. Sleipner started operations in 1996 and Snøhvit in 2008. Both projects include separating and capturing CO_2 from produced natural gas, and both inject CO_2 into saline formations (Bankes, 2020).

So, the London Protocol of 1996 and the amendments in the OSPAR Convention marked significant legal changes, which in turn made the implementation and promotion of CCS and CCTS projects possible and fully legitimate.

EU Legal Strategies toward Climate Adaptation

European Green Deal

From a legislative viewpoint, in 2009, the EU introduced Directive 2009/31/EC on the geological storage of CO_2 (so-called CCS Directive), which created the legal basis for the geological storage of CO_2 to address climate change. The Commission works closely with Member State authorities to implement the CCS Directive, enabling exchanges, producing guidance materials, and adopting Commission Opinions on draft storage licenses.

In 2019, the European Green Deal introduced a package of measures ranging from reducing greenhouse gas emissions to investing in cutting-edge research and innovation to preserving Europe's natural environment. Climate and resource front-runners are needed in the EU industry to develop the first commercial implementations of breakthrough technology in major industrial sectors by 2030. Priority areas include clean hydrogen, fuel cells, and other alternative fuels, energy storage, and carbon capture, storage, and utilization (Communication from the Commission, 2019).

The EU Green Deal includes the following parts: European Climate Law; European Climate Pact, to engage citizens and all parts of society in climate action; 2030 Climate Target, to further reduce net greenhouse gas emissions by at least 55% by 2030; and the New EU Strategy on Climate Adaptation, to help make the EU more resilient. European Climate Law states that

> *solutions that are based on carbon capture and storage (CCS) and carbon capture and use (CCU) technologies can play a role in decarbonization, especially for the mitigation of process emissions in industry, for the Member States that choose this technology.*
>
> *(European Climate Law, 2021)*

The EU 2030 Climate Target Plan sets a more ambitious and cost-effective path to achieving climate neutrality by 2050. CCS is viewed as an essential part of the Climate Target plan.

> *In order to further reduce emissions from industry in line with the higher climate target for 2030, major changes need to be made in the way industry consumes energy and produces its products notably via increased material and energy efficiency, greater material recirculation, new production processes and carbon capture technologies.*
>
> *(Climate Target Plan, 2020)*

The New EU Strategy on Climate Adaptation 2021 views that "in coastal and marine areas, nature-based solutions will enhance coastal defense and reduce risk of algal blooms. Simultaneously, they will provide benefits such as carbon sequestration, tourism opportunities, and biodiversity conservation and restoration" (The New EU Strategy on Adaptation to Climate Change, 2021). The EU will seek mutually beneficial alliances and ensure an international level playing field regarding new sustainable technologies, such as renewable hydrogen, advanced solar and wind, batteries, and carbon capture, as well as critical raw materials for these technologies, such as rare earths. The EU's position as the world's largest trading block provides significant opportunities in this respect (Stepping up Europe's 2030 climate ambition, 2020). As seen from these initiatives, the EU supports CCS through the European Green Deal (2019) legislation package and views it as part of a climate change solution.

Role of the EU Taxonomy

EU taxonomy, introduced in 2020, represents a classification system that includes economically sustainable activities (EU Taxonomy, 2020). It might help the EU increase sustainable investment and achieve the EU Green deal. The EU taxonomy defines sustainable economic activities for enterprises, investors, and regulators. Under the Taxonomy Regulation, the Commission was required to define technical screening criteria for each environmental objective by delegated acts, in order to generate the actual list of environmentally sustainable activities. needed. Notably, CCTS is included in the directory of activities that are listed under climate adaptation and climate mitigation objectives; see Table 10.1 (Commission Delegated Regulation (EU) 2021/2139 2021).

Translating CCTS Technologies into Actions and Objects: Longship Project in Norway

Norway has ambitious goals regarding the Paris Agreement, that is, Norway's Nationally Determined Contribution under the Paris Agreement is to reduce emissions by at least 40%, compared to 1990 levels, by 2030. Norway will cooperate with Iceland and the EU to fulfill their respective emission reduction targets under the Paris Agreement (Meld. St. 13 (2020–2021). Norway has established policies and strategies to minimize or eliminate greenhouse gas emissions. The polluter-pays idea underpins Norwegian climate policy. CO_2 taxes on mineral oil and petrol were imposed in 1991 to cost-efficiently control greenhouse gas emissions, and, in 2010, CO_2 tariffs were imposed on natural gas and liquefied petroleum gas (Meld. St. 13 (2020–2021).

Table 10.1 Role of EU taxonomy in CCTS (compiled by the authors)

Activity	*Substantial contribution criteria*
Transport of CO_2	**1.** The CO_2 transported from the installation where captured to the injection point does not lead to CO_2 leakages above 0.5 % of the mass of CO_2 transported. **2.** The CO_2 is delivered to a permanent CO_2 storage site that meets the criteria for underground geological storage of CO_2 set out in Section 5.12 of this Annex or to other transport modalities which lead to a permanent CO_2 storage site that meet those criteria. **3.** Appropriate leak detection systems are applied and a monitoring plan is in place, with the report verified by an independent third party. **4.** The activity may include the installation of assets that increase flexibility and improve the management of an existing network.
Underground permanent geological storage of CO_2	**1.** Characterization and assessment of the potential storage complex and surrounding area, or exploration within the meaning of Article 3, point (8), of Directive 2009/31/EC of the European Parliament and of the Council (224), is carried out in order to establish whether the geological formation is suitable for use as a CO_2 storage site. **2.** For operation of underground geological CO_2 storage sites, including closure and post-closure obligations: appropriate leakage detection systems are implemented to prevent release during operation; a monitoring plan of the injection facilities, the storage complex, and, where applicable, the surrounding environment, is in place, with the regular reports checked by the competent national authority. **3.** For the exploration and operation of storage sites within the Union, the activity complies with Directive 2009/31/EC. For the exploration and operation of storage sites in third countries, the activity complies with ISO 27914:2017(225) for geological storage of CO_2.

Norway became a forerunner in terms of CCS technology when it commissioned the world's first offshore CCS project, "Sleipner", in 1996. More than a million tonnes of CO_2 have been stored in the Utsira formation below "Sleipner" every year since then. In the "Snøhvit" CCS project, CO_2 has been separated from raw natural gas at the onshore liquefied natural gas (LNG) plant at Melkøya and transported and stored offshore, since 2008. Analysis of legal framework development for CCTS demonstrates that Norway led the change for allowing the transboundary shipment of CO_2. The Norwegian Parliament authorized the Longship capture, transport, and storage of CO_2

project in the state budget for 2021. The project will cost NOK 25.1 billion, which is approximately \$2.49 billion (www.regjeringen.no). The Norwegian government approved a decision to cover approximately two-thirds, and the industry will cover approximately one-third of the costs in the project's first phase. Part of the Longship project is the Northern Lights CCTS project which has been supported by the Norwegian government with NOK 14.2 billion, which equals \$1.63 billion (www.regjeringen.no). Actually, an essential premise for the state is the industrial partners' self-interest in CCS projects. However, as highlighted by one of our respondents, there are several barriers to commercial CCS investments:

> *Business companies don't have a tendency to invest in technology with uncertain future market potential. And policymakers cannot commit to a technology they do not know. We can say it can be a sort of deadlock for future development.*

It is also worth emphasizing that one of the primary project goals defined by the government is to demonstrate that full-scale CCS is feasible and safe, and to reduce the cost of future CCS projects through learning curve effects and economies of scale (Killingland et al., 2020). As a result of this, sentiment for investment by business companies should increase. As a representative of Northern Lights stated:

> *There are a lot of challenges first related to the fact that this is still a new concept. We sometimes feel like test pilots because we develop new contracts and new ships and have to deal with a market that doesn't exist. There is little or no operational experience in this area...uh, there is a lot of risk management that needs to be done... The cost focus and structure are something that we need to pay attention to because CCS in Europe will only be successful if we manage to keep the costs down.*

Longship involves capturing CO_2 from industrial sources in the Oslo Fjord region (cement and waste-to-energy) and transporting liquid CO_2 from these industrial capture facilities to an onshore terminal on the west coast of Norway. The CO_2 will then be transferred by pipeline to an offshore storage facility in the North Sea for permanent storage. Northern Lights is responsible for the project's shipping and storage requirements (see Figure 10.2).

As part of Longship, the Norwegian government's large-scale CCS initiative, Northern Lights is responsible for building and operating CO_2 transportation and storage facilities accessible to third parties. It will be the world's first open-source, cross-border CO_2 transit and storage infrastructure network, and it will allow businesses across Europe to store their CO_2 underground. Halfway through 2024, the first phase of the project will be finished, with a capacity of up to 1.5 million tonnes of CO_2 per year (Northern Lights, 2021).

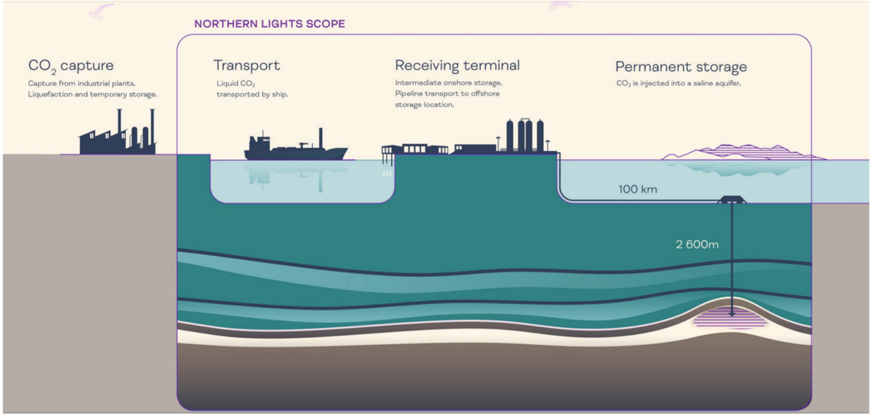

Figure 10.2 Longship project (*Source*: Northern Lights).

Currently, two CO_2 emitters – the Norcem cement plant in Brevik and the waste recovery plant in Oslo (Fortum Oslo Varme) – are the key first customers that will capture and provide intermediate storage for CO_2 in liquid form in dedicated tanks on existing quay facilities. Both emitters plan to capture 400,000 tonnes of CO_2 per year for transport and permanent storage: a total of 800,000 tonnes of CO_2 per year (Northern Lights, 2021).

The Northern Lights project builds on the experience that three owner companies have from their various CCS operations across the world. The completely innovative component that has never been applied before is a ship-based transportation system. Previous projects like the Snøhvit CCS storage project used a direct link between the emission source, which is the LNG facility in Hammerfest, and the storage facility. So, the value and supply chain in Northern Lights is unusual because it is based on transporting CO_2 using two ships. However, the shipping solution has not been covered by the provisions of the CO_2 Storage Regulations. This follows from the fact that the capture of CO_2 by industrial sources is not subject to these rules, which define "facility" as follows:

> *Installations, plants and other equipment for exploitation of subsea reservoirs for storage of CO_2, but excluding supply and utility vessels or vessels that transport CO_2 in bulk. Facility also includes pipelines and cables unless otherwise determined.*
>
> *(Regulations, 2020)*

The transport ships, of cargo size 7,500 m^3 (8,000 tones CO_2) and 130m length, carry cold (–26°C), pressurized 15 barg and liquid CO_2 from capture players to a receiving and intermediate storage facility on land in western Norway.

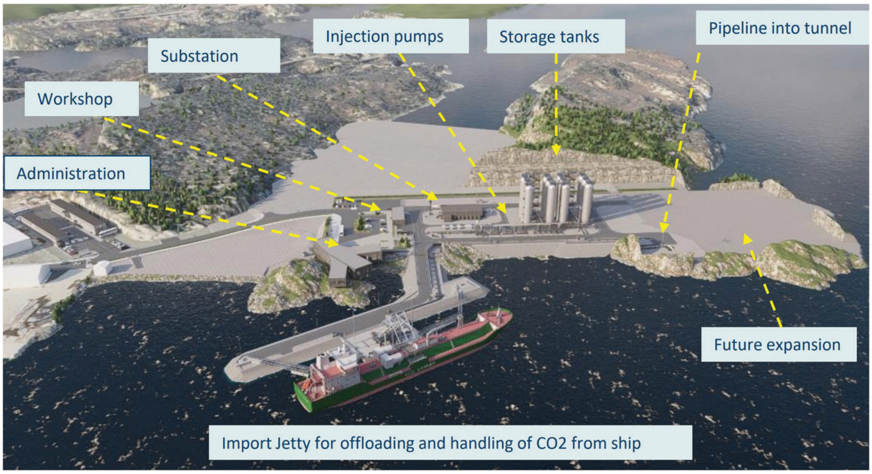

Figure 10.3 Receiving terminal (*Source*: Northern Lights).

Offloading CO_2 will involve the aid of offloading arms (capacity of 800 m^3/hour). Cold and liquid CO_2 is stored intermediately before it is pumped 100 kilometers through an export pipeline for injection and permanent storage 1,000–3,300 meters under the seabed on the continental shelf: to be precise, in one or more new injection wells in suitable geological reservoirs in the Troll field located in the North Sea (see Figures 10.2 and 10.3). As a representative of the Northern Lights project explained:

> *It matters a lot for large industrial emitters, as they can be located anywhere and can still utilize this technology. They don't need to be located close to storage resources. That is important. For instance, many big emission sources in Norway are in the southeastern part of Norway, like the Norcem cement plant and Oslo Fortum Varme (the largest district heating supplier). That means these types of large emission sources will have access to* CO_2 *storage despite being hundreds of kilometers, maybe thousands in some instances, away from the storage complex. Building a pipeline from these remote locations to where the storage facilities are available on the western side of Norway would be extremely expensive and not feasible for several reasons.*

It is assumed that CO_2 transport is a key component in connecting industrial emitters in Europe to suitable and safe CO_2 storage sites such as the one operated by Northern Lights in the North Sea (see Figure 10.4). Many of these European emitters are located far away from storage resources, extremely limiting access to them. While storage capacity is unevenly distributed across Europe, Norway has approximately one-third of the European overall storage

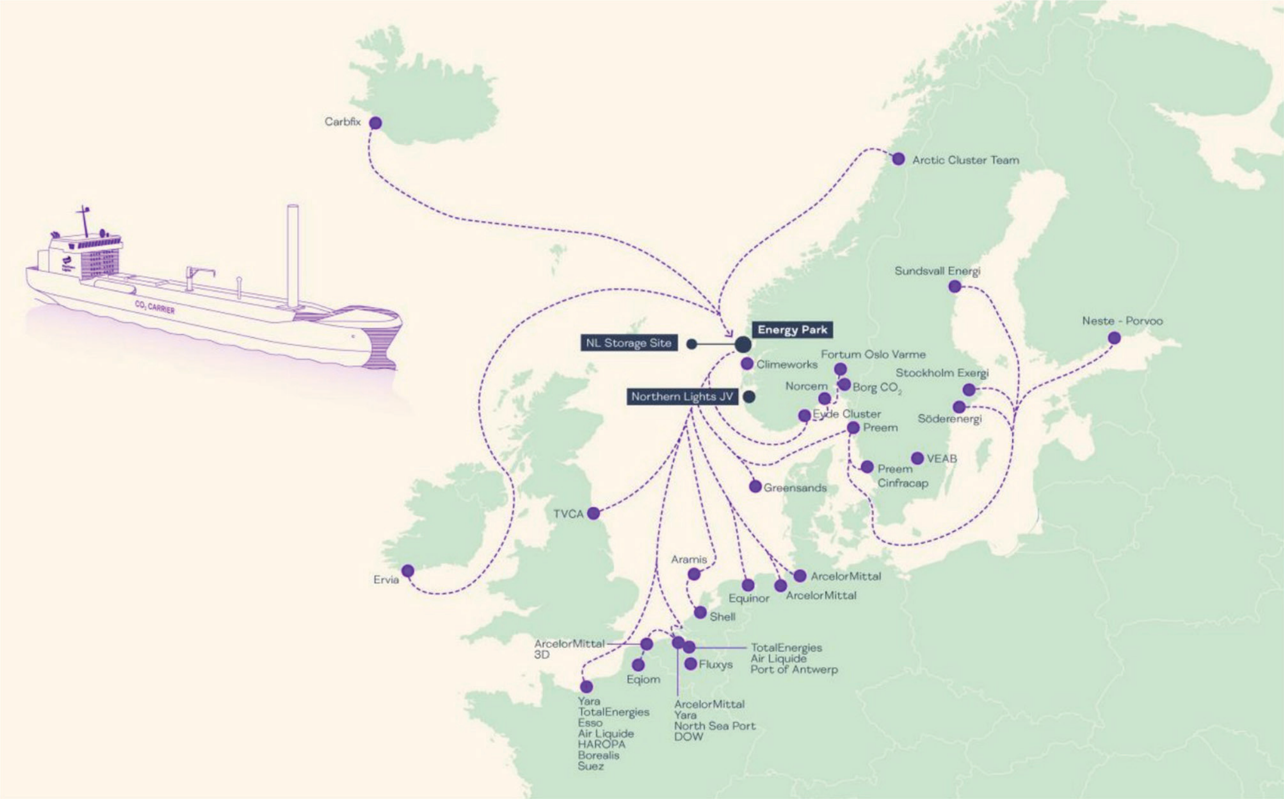

Figure 10.4 Potential CO_2 market (*Source*: Northern Lights).

capacity because of the geological characteristics of the Norwegian continental shelf. The sectors that the main focus is on include cement, chemicals/refineries, waste incineration, biofuel/bioenergy, direct air capture and steel, which have different levels of experience and maturity with respect to CCS projects. For example, chemical refineries are expected to be ready in 2025–2026, and the cement industry was initially expected by 2026–2028, but is going to be ready in 2024. Many of these emission sources that are big industrial facilities have relatively small overall emissions that could not necessarily defend making such an investment on their own. So, an intention to build large emission hubs as many large emitters concentrate around the port area can hardly be feasible in Europe in the nearest decade. It would be expensive to use the CO_2 pipeline in Norway. As a representative of Northern Lights stated:

> *The shipping solution, first of all, provides flexibility for the emitters across Europe, meaning that they don't need to commit to one storage operator. But they can actually also ask for more storage capacity to be developed across Europe, which is between storage operators. In such a way, we're creating a CO_2 market. It will help create competition among storage operators that will be important in terms of price development and capacity development overall over time.*

In pushing full-scale CCS projects, shipping is considered a scalable CO_2 transport solution that is well-suited to sailing distances in Europe. Developing a flexible shipping solution as part of the world's first cross-border CO_2 transport and storage network that helps overcome challenges and issues for European industrial emitters, "Northern Lights" seems to contribute to the development of a new market for CO_2 storage.

The background to why large industrial emitters can become interested in CCS is linked to the European Emission Trading Scheme (EU ETS). Industrial businesses have to pay for the CO_2 that is emitted. The ETS price has been fluctuating; for instance, on 25 December 2021, the ETS price was €98.97, and on 11 May 2022, it was €87.52. It is expected that the price may go up to €100 or higher by 2030. However, if they can utilize CCTS technology like "Northern Lights", they will be emission-free. As a "Northern Lights" representative explained:

> *I suppose the EU's goal is to reduce emissions by 55%. So that means many of these industries are not able to decarbonize without engaging in CCS. The cement industry, for example, cannot use solar or wind power in order to reduce their overall emissions. Although this industry is responsible for between 6 and 8% of global emissions, the emissions have nothing to do with energy use. It happens since the limestone used in cement production naturally contains CO_2, which is released in the operational cycle. I mean, many large industrial emitters will always have CO_2 emissions and cannot get rid of them in any other way. We also need to capture CO_2 from the air or use biogenic or bioenergy with CCS in order to reach our climate goals.*

At the same time, another respondent objected to this opinion:

> *Scientists have repeatedly proven that only trees can actually absorb huge amounts of CO_2. This is a natural technology and also very cheap. Why invest such huge injections in new industrial objects, like capture facilities, which also can put a negative strain on nature?*

It is worth adding that the European Commission highlighted the need to geologically store between 3,600 million tons of CO_2 per year by 2050. For instance, the Northern Lights project is able to store 1.5 million tons of CO_2 per year; in the future, the volume can be increased to 5–7 million tons of CO_2 per year. According to several of our respondents, the EU's goals require more storage capacity and more CCS projects like Northern Lights. The ambition of the actors involved is to keep costs leveled down and continue innovating to make technologies affordable for industrial emitters across Europe. Thereby, it is important to reach a balance between the cost level and the tariff level, so that the overall costs for transport and storage components are below 100 euros. But now, there is still a need for subsidies and incentives from the European Union and national governments in implementing CCS projects.

One of the biggest concerns is the safety of such projects, for both marine life and nearby coasts. Under Article 195 of United Nations Convention on the Law of the Sea (UNCLOS), states must not transform a type of pollution into another type of pollution or shift pollution from one area to another. It is assumed that, if carbon dioxide, which is essentially a source of atmospheric pollution, is placed on the seabed, and these technologies do not create a new source of pollution, then this is an acceptable solution. However, several of our respondents emphasized that only preliminary safety assessments are available at the time of the ongoing construction of the "Northern Lights" infrastructure facilities. The official project reports identify a risk of potential migration and leakage routes for CO_2 that can theoretically occur through geological strata and faults or via wells (Northern Lights, 2019; 2021). As a representative of "Northern Lights" informed us:

> *Leakage is obviously a very important thing to avoid altogether. The CO_2 storage complex is a well 2,600 meters deep on the seabed. What we are looking for in the storage complex – and what we have when we identified this particular storage complex – is a saline aquifer. So, it's basically a sandstone formation. This sandstone formation is very porous and has excellent properties for storage of CO_2. Above the storage complex is a primary seal. It's a caprock of shale, 75 meters thick. Drillers have long known that gas is released only when shale beds are penetrated, but the pores in the rocks are so small that they hold onto any gas tightly. It's the same principle for foiling mass. We have modelled CO_2 migration, and our analysis showed the migration will happen over thousands of years. Potentially, while leaking, CO_2 might reach*

> *an area where it will become trapped again. So, we predict this is a safe storage complex.... [...] Actually, we are liable for the region, the Norwegian authorities and the European Commission. I mean if CO_2 leaks out, we need to pay the equivalent of the ETS price at the time of leakage, and that's a huge cost.*

Another respondent representing an environmental organization expressed doubt:

> *This is more like a patch in the context of climate change decisions. And most likely for some short period. Indeed, this is necessary. But no one can say that such initiatives are absolutely safe and that all risks are foreseen. Everyone just hopes that it is safe.*

Concluding Remarks

In our chapter, the implementation of CCTS projects, including future projects in the Arctic seabed, has been described from the perspective of the SCM's role in implementing new environmental and climate-resistant strategies. The idea of the "Longship" CCTS project in Norway is rooted in the past, as a consequence of quite long technological experience with carbon capture and storage since 1996. Through its translation into actions and large industrial objects, the idea manifested itself as a strategic continuation, under pressure from the EU and Norway's initiatives and regulatory amendments in favor of green technologies, causing organizational and institutional change. Of greatest interest is that the "idea" of the Longship project has only been made feasible by the transport component and management of CO_2 supply chains, which has proved to be innovative.

CCTS projects are viewed as a breakthrough in developing climate-resilient carbon cycles and are specifically implemented as an effective mitigation solution to climate change. However, there is a critical need to analyze whether the effect is sustainable, especially since it is argued in the literature that our present knowledge is not sufficient to create truly sustainable supply chain practices (Pagell and Shevchenko, 2014). For this purpose, we attempt to look at the possibilities for the deployment of CCTS in terms of three aspects of sustainability: economic, environmental, and social.

Weber (2021) argues that, while there are no legal hurdles to transferring CO_2 by ship in principle, international and European law are not yet prepared to accept CO_2 transit by ship. First, the approach for circumventing the Article 6 barrier of the London Protocol reflects what has been politically feasible, not what is legally desirable. Second, considering the future Fund for the Convention on Hazardous and Toxic Substances, the article contends that CCS is a particular circumstance and that specific concessions are justified. However, evaluation of compliance with Articles 195 and 196 of the United Nations Convention on the Law of the Sea (UNCLOS) when implementing

CCTS projects is paramount. According to Article 195 of UNCLOS, "Duty not to transfer damage or hazards or transform one type of pollution into another", in order to prevent, reduce, and control pollution of the marine environment, States shall act in such a way as not to transfer, directly or indirectly, damage or hazards from one area to another or transform one type of pollution into another (UNCLOS, 1982). Article 196 of UNCLOS concerns the use of new technologies and the introduction of new species; in the context of the adoption of new technology and transboundary shipping of CO_2, it becomes increasingly important to adhere to this article, whereby

> *States shall take all measures necessary to prevent, reduce and control pollution of the marine environment resulting from the use of technologies under their jurisdiction or control, or the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto.*

This indicates that regulatory mechanisms and pressure from the EU are focusing on the development of so-called green technologies. In contrast, UNCLOS cautions that such mega-industrial projects can have unexpected adverse effects on the environment. These CCTS projects can be very dangerous for the environment and require guaranteed, reliable technologies for safe and cost-effective CO_2 supply chain operations. Therefore, this finding is consistent with the findings of Tsvetkova and Gammelgaard's (2018) study that institutional mechanisms and factors may play a role in how supply chain strategies evolve and that such strategies are not (only) objective, rational processes of goal-setting and activity planning.

The need for long-distance transportation and the lack of existing infrastructure, e.g., CO_2 storage facilities, mean significant investments and large costs. The decision to create a carbon market by increasing the price of CO_2 emissions is twofold. On the one hand, this creates financial guarantee incentives by involving a large number of industry stakeholders. On the other hand, it can appear that this does not stimulate CO_2 emitters to reduce CO_2 emissions by setting environmentally friendly devices, e.g., distillatory filters. There is also a growing concern among decision-makers and strategists about the negative environmental and social effects of the fast-paced industrial growth of CCTS projects. The negative environmental and social aspects are overlooked in the narrative that promotes the benefits of CCTS. In 2022, over 500 organizations across the United States and Canada expressed grave concerns regarding the U.S. and Canadian governments' support for CO_2 carbon capture and storage and carbon capture and sequestration due to its negative impact on coastal communities, Indigenous Peoples, and the diverting of funding from transitioning to renewable energy solutions (CIEL, 2022).

Further, it remains unclear whether such rapid implementation of CCTS is more likely to be accepted or rejected by society in the future. Given the wide range of technological options and the resulting societal implications, the phenomenon of such sustainable initiatives also appears to be non-trivial. Moreover, a methodological concept for analyzing CO_2 leakage and safety in the case of potential accidents is still lacking, even though the project owners have vast experience, and some scientific research provides a starting background. This represents a difference from the debate in perceptions of the societal benefits of CCTS. We suppose that the population may expect safeguarding or even increasing economic performance in their local environment with the use of CCTS. It is worth adding that previous research findings illustrate that societal benefits have either the same or slightly higher explanatory power for CCS acceptance than societal risks (Kraeusel and Möst, 2012). In light of this, the study also contributes to the literature on how institutional drivers and political ambitions influence public value-creation for residents in response to social needs (see Tsvetkova, 2021b). Whether this is also valid for the implementation and subsequent application of CCTS in the Arctic Ocean remains to be investigated.

Note

1 Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and United Kingdom.

References

ACOPS (2022), Advisory Committee on the Protection of the Sea: A Network to SEA the Future. Available at: www.acops.org.uk/london-convention-and-its-protocol-on-the-dumping-of-waste-at-sea/ (Accessed 22 August 2022).

Ageron, B., Gunasekaran, A., and Spalanzanic, A. (2012), "Sustainable supply management: An empirical study", *International Journal of Production Economics,* Vol. 140, No. 1, pp. 168–182.

Ansari, Z.N. and Kant, R. (2017), "A state-of-art literature review reflecting 15 years of focus on sustainable supply chain management", *Journal of Cleaner Production,* Vol. 142, pp. 2524–2543.

Bankes, N. (2020), "Carbon capture and storage and the law of the sea", in Johansen, E., Busch, S.V., and Jakobsen, I.U. (Eds.), *The Law of the Sea and Climate Change: Solutions and Constraints,* pp. 160–183. Cambridge: Cambridge University Press.

Barratt, M., Choi, T.Y., and Li, M. (2011), "Qualitative case studies in operations management: Trends, research outcomes, and future research implications", *Journal of Operations Management,* Vol. 29, No. 4, pp. 329–342.

Carter, C.R. and Rogers, D.S. (2008), "A framework of sustainable supply chain management: Moving toward new theory", *International Journal of Physical Distribution & Logistics Management,* Vol. 38, No. 5, pp. 360–387.

CIEL (2022), Over 500 Organizations Call on Policymakers to Reject Carbon Capture and Storage as a False Solution. Available at: www.ciel.org/organizations-demand-policymakers-reject-carbon-capture-and-storage/

Climate Target Plan (2020), Available at: www.eea.europa.eu/highlights/eu-achieves-20-20-20 (Accessed: 26 November 2022).

Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives (Text with EEA relevance). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32021R2139 (Accessed 11 May 2022).

Davidson, K.M. (2011), "Reporting systems for sustainability: What are they measuring?", *Social Indicators Research,* Vol. 100, No. 2, pp. 351–365.

Dixon, T. and Birchenough, A. (2021, March), "Exporting CO_2 for offshore storage – The London Protocol's export amendment", in *Proceedings of the 15th Greenhouse Gas Control Technologies Conference* (pp. 15–18).

Duncan, D.W. and Morrissey, E.A. (2011), *The Concept of Geologic Carbon Sequestration*. US Department of the Interior, US Geological Survey.

Eisenhardt, K. (1989), "Building theories from case study research", *Academy of Management Review,* Vol. 14, Issue 4, pp. 532–550.

Equinor (2022), Sleipner area. Available at: www.equinor.com/energy/sleipner (Accessed 10 November 2022).

European Climate Law (2021), *Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law').* Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021R1119 (Accessed 28 November 2022).

The European Green Deal (2019). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN (Accessed 10 May 2022).

European Green Deal (2019). Available at: https://climate.ec.europa.eu/eu-action/european-green-deal_en (Accessed 28 June 2022).

EU Taxonomy (2020), EU taxonomy for sustainable activities. Available at: https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en (Accessed 10 November 2022).

Gabrielli, P., Campos, J., Becattini, V., Mazzotti, M., and Sansavini, G. (2022), "Optimization and assessment of carbon capture, transport and storage supply chains for industrial sectors: The cost of resilience", *International Journal of Greenhouse Gas Control*, Vol. 121, p. 103797.

GCCI (2022), Global CCI Institute. Available at: www.globalccsinstitute.com/ (Accessed 7 June 2022).

Green, K.W., Zelbst, P.J., Meacham, J., and Bhadauria, V.S. (2012), "Green supply chain management practices: Impact on performance", *Supply Chain Management: An International Journal,* Vol. 17, No. 3, pp. 290–305.

Greenwood, R., Suddaby, R., and Hinings, C.R. (2002), "Theorizing change: The role of professional associations in the transformation of institutionalized fields," *Academy of Management Journal,* Vol. 45, No. 1, pp. 58–80.

Haunschild, P. and Chandler, D. (2008), "Institutional-level learning: Learning as a source of institutional change", in Greenwood, R., Oliver, C., Sahlin, K., and

Suddaby, R. (Eds.), *The SAGE Handbook of Organizational Institutionalism,* Thousand Oaks, CA: Sage Publications.

Horisont Energi (2022), Carbon storage license in Barents Sea awarded. www.horisontenergi.no/carbon-storage-license-in-barents-sea-awarded/ (Accessed 17 May 2022).

Huq, F.A., Stevenson, M., and Zorzini, M. (2014), "Social sustainability in developing country suppliers: An exploratory study in the ready/made garments industry of Bangladesh", *International Journal of Operations & Production Management,* Vol. 34, No. 5, pp. 610–638.

IEA (2011), "Carbon capture and storage and the London Protocol: Options for enabling transboundary CO_2 transfer", *IEA Energy Papers,* No. 2011/15, Paris: OECD Publishing, https://doi.org/10.1787/5kg3n27pfv30-en.

IEA (2022), CCUS in Clean Energy Transitions. Available at: www.iea.org/reports/ccus-in-clean-energy-transitions (Accessed 20 December 2022).

IEAGHG (2021), Exporting CO_2 for Offshore Storage – The London Protocol's Export Amendment and Associated Guidelines and Guidance. Available at: www.club-co2.fr/files/2021/04/IEAGHG-2021-TR02-Exporting-CO2-for-Offshore-Storage-The-London-Protocol-s-Export-Amendment-and-Associated-Guidelines-and-Guidance.pdf (Accessed 27 November 2022).

IPCC (2022), *Climate Change 2022: Mitigation of Climate Change*. Available at: https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf (Accessed 25 August 2022).

Jabbour, A.B.L.D.S., Frascareli, F.C.D.O., and Jabbour, C.J.C. (2015), "Green supply chain management and firms' performance: Understanding potential relationships and the role of green sourcing and some other green practices", *Resources, Conservation and Recycling,* Vol. 104, Part B, pp. 366–374.

Jepperson, R.L. (1991), "Institutions, institutional effects, and institutionalism", in DiMaggio, P.J. and Powell, W.W. (Eds.), *The New Institutionalism in Organizational Analysis,* Chicago, IL: University of Chicago Press.

Killingland, M., Boge, M.K., and Magneschi, G. (2020), "Potential for reduced costs for carbon capture, transport and storage value chains (CCS)", *Project Report No. 2019–1092*, Gassnova SF, Porsgrunn. Available at: https://ccsnorway.com/app/uploads/sites/6/2020/07/Report-Cost-reduction-curves-for-CCS-Gassnova-version-2b-1.pdf

Kraeusel, J. and Möst, D. (2012), "Carbon capture and storage on its way to large-scale deployment: Social acceptance and willingness to pay in Germany", *Energy Policy,* Vol. 49, pp. 642–651.

London Protocol (2006), Resolution LP. 1 (1) on the amendment to include CO_2 sequestration in sub--seabed geological formations in annex 1 to the London Protocol [LC 28/15, Annex 6 (Adopted on 2 November 2006)]. Available at: www.imo.org/blast/blastDataHelper. asp.

Lu, L.Y.Y., Wu, C.H., and, Kuo, T.C. (2007), "Environmental principles applicable to green supplier evaluation by using multi-objective decision analysis", *International Journal of Production Research,* Vol. 45, pp. 4317–4331.

Mani, V., Agrawal, R., Gunasekaran, A., Papadopoulos, T., Dubey, R., and Childe, S.J. (2016), "Social sustainability in the supply chain: Construct development and measurement validation", *Ecological Indicators,* Vol. 71, pp. 270–279.

Mani, V., Agrawal, R., and Sharma, V. (2015), "Supply chain social sustainability: A comparative case analysis in Indian manufacturing industries", *Procedia – Social and Behavioral Sciences,* Vol. 189, pp. 234–251.

Meld. St. 13 (2020–2021) Report to the Storting (white paper) Norway's Climate Action Plan for 2021–2030.

Northern Lights (2019), Available at: www.equinor.com/energy/northern-lights (Accessed 28 December 2022).

Northern Lights (2021), *Annual Report,* Available at: https://norlights.com/wp-content/uploads/2022/04/Northern-Lights-Annual-report-2021.pdf (Accessed 18 January 2023).

Norwegian Government (2022), Questions and answers about the Longship project. Available at: www.regjeringen.no/en/topics/energy/landingssider/ny-side/sporsmal-og-svar-om-langskip-prosjektet/id2863902/?expand=factbox2863906 (Accessed 15 December 2022).

OSPAR Decision 2007/02 on the Storage of Carbon Dioxide Streams in Geological Formations. Available at: www.ospar.org/documents?v=32643 (Accessed 25 November 2022).

Pagell, M., Krause, D., and Klassen, R. (2008), "Sustainable supply chain management: Theory and practice", *Journal of Supply Chain Management,* Vol. 44, No. 1, p. 85.

Pagell, M. and Shevchenko, A. (2014), "Why research in sustainable supply chain management should have no future", *Journal of Supply Chain Management,* Vol. 50, No. 1, pp. 44–55.

Pagell, M. and Wu, Z. (2009), "Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars", *Journal of Supply Chain Management,* Vol. 45, No. 2, pp. 37–56.

Paris Agreement (2015) Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T.I.A.S. No. 16-1104.

Quarshie, A.M., Salmi, A., and Leuschner, R. (2016), "Sustainability and corporate social responsibility in supply chains: The state of research in supply chain management and business ethics journals", *Journal of Purchasing & Supply Management,* Vol. 22, pp. 82–97.

Rajeev, A., Pati, R.K., Padhia, S.S., and Govindan, K. (2017), "Evolution of sustainability in supply chain management: A literature review", *Journal of Cleaner Production,* Vol. 162, pp. 299–314.

Regulations (2020), Regulations related to safety and working environment for transport and injection of CO_2 on the Continental shelf (CO_2 Safety Regulations), Available at: www.ptil.no/contentassets/f18375b7184d4cd68fc1c733b318b3dc/co2-sikkerhetsforskriften_e.pdf

Reuters (2020), Hughes joins Norwegian Arctic carbon storage project. Available at: www.reuters.com/article/us-baker-hughes-horisont-energi-ccs-idUKKBN2BF1A6 (Accessed 22 June 2021).

Seuring, S. and Müller, M. (2008), "From a literature review to a conceptual framework for sustainable supply chain management", *Journal of Cleaner Production,* Vol. 16, No. 15, pp. 1699–1710.

Sjoeblom, K.L. and Linsley, G. (1994), "Sea disposal of radioactive wastes: The London Convention 1972", *IAEA Bulletin,* Vol. 36(2), pp.12–16.

Stepping up Europe's 2030 climate ambition (2020). Investing in a climate-neutral future for the benefit of our people, Available at: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52020DC0562 (Accessed 28 October 2022).

Teng, Y. and Zhang, D. (2018), "Long-term viability of carbon sequestration in deep-sea sediments", *Science Advances,* Vol. 4, No. 7, pp. 6588. https://doi.org/10.1126/sciadv.aao6588.

The New EU Strategy on Adaptation to Climate Change (2021), Available at: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52019DC0640 (Accessed 16 October 2022).

Tolbert, P.S. and Zucker L.G. (1996), "Institutional theory", in Clegg, S.R., Hardy, C. and Nord, W.R. (Eds.), *The Handbook of Organization Studies,* London: Sage Publications.

Tsvetkova, A. (2020), "Social responsibility practice of the evolving nature in the sustainable development of Arctic maritime operations", in Pongrácz, E., Pavlov, V. and Hänninen, N. (Eds.), *Arctic Marine Sustainability: Arctic Maritime Businesses and the Resilience of the Marine Environment,* Springer: Polar Sciences.

Tsvetkova, A. (2021a), "Human actions in supply chain management: The interplay of institutional work and institutional logics in the Russian Arctic", *International Journal of Physical Distribution & Logistics Management,* Vol. 51, No. 8, pp. 837–858.

Tsvetkova, A. (2021b), "New public management and public value: A good match? A case of one maternity ward in Norway", in Strømmen-Bakhtiar, A. and Timoshenko, K. (Eds.), *Revisiting New Public Management and Its Effects: Experiences from a Norwegian Context,* pp. 41–64, Münster, Germany: Waxmann Verlag GmbH.

Tsvetkova, A. and Gammelgaard, B. (2018), "The idea of transport independence in the Russian Arctic: A Scandinavian institutional approach to understanding supply chain strategy", *International Journal of Physical Distribution and Logistics Management,* Vol. 48 No. 9, pp. 913–930.

UNCLOS (1982), United Nations Convention on the Law of the Sea. Available at: www.un.org/depts/los/convention_agreements/texts/unclos/part12.htm

US Congresional Research Service (2022), Carbon Capture and Sequestration (CCS) in the United States. https://sgp.fas.org/crs/misc/R44902.pdf

Voss, C., Tsikriktsis, N., and Frohlich, M. (2002), "Case research in operations management", *International Journal of Operational & Production Management,* Vol. 22, No. 2, pp. 195–219.

Weber, V. (2021), "Are we ready for the ship transport of CO_2 for CCS? Crude solutions from international and European law", *Review of European, Comparative & International Environmental Law*, Vol. 30, No. 3, pp. 387–395.

Wilday, J., Wardman, M., Johnson, M., and Haines, M. (2011), "Hazards from carbon dioxide capture, transport and storage", *Process Safety and Environmental Protection,* Vol. 89, No. 6, pp. 482–491.

Yamasaki, A. (2003), "An overview of CO_2 mitigation options for global warming – emphasizing CO_2 sequestration options", *Journal of Chemical Engineering of Japan*, Vol. 36, No. 4, pp. 361–375.

Yin, R. (1994), *Case Study Research: Design and Methods, Applied Social Research Methods Series.* Vol. 5, Thousand Oaks, CA: Sage.

Zheng, J., Chong, Z.R., Qureshi, M.F., and Linga, P. (2020), "Carbon dioxide sequestration via gas hydrates: A potential pathway toward decarbonization", *Energy & Fuels*, Vol. 34, No. 9, pp. 10529–10546.