Managing Open Radical Sustainable Innovation

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Preface

I started first semester in Master of Business Administration (MBA) back in 2016, when I was working on a major oil & gas development project as part of a pre-operations team. The main reason that the MBA program caught my attention was that the program was running a course called "International Contracts" which focused on shipping and offshore contracts, which was very much related to the project I was involved in at the time.

I did not have an aim to complete the whole MBA program when I started on the program, but as time emerged and the courses that followed were indeed interesting and relevant, I found myself attending these courses semester by semester. The fact that the program was also quite flexible, made it easy to take a break in between semesters if work or private life did not facilitate attending such a course.

Throughout the program, I found particular three courses of interest: International Contracts, Strategy and Business Development, and Leadership, Digitalization and Change Management. These courses were closely linked to the work environment I was part of at that time, whereas one example was a shipping company, that I was part of, had merged with several other companies and was undergoing a major change during the one-year period I was there. This process touched upon several elements from the Strategy and Business Development course, and the Leadership, Digitalization and Change Management course.

Since 2016, I've worked in five different organizations in the energy sector: from shipping companies and oil & gas service providers to an oil & gas E&P (Exploration and Production) company which I'm part of today. A common denominator for all these organizations, I've been part of, have been a world that is changing fast; from oil & gas crisis in 2014, climate change, pandemic and now an energy crisis due to the ongoing war in Ukraine, these organizations are constantly putting their strategy and change management in the front seat to make sure their organization can withstand these changes and continue to grow.

As part of the marine department of an oil & gas E&P company today, we have a strong focus and commitment on sustainability with regards to the vessels we use today, and how we can meet the climate targets in accordance with the Paris Agreement, which is targeting a reduction in carbon intensity of international shipping, as an average across international shipping, to be reduced by at least 40% by 2030. In addition, the Norwegian government have, through their Hurdal declaration in 2021, declared a zero-emission strategy for all offshore supply vessels on the Norwegian Continental Shelf within 2030.

To achieve such, new technology and innovations would need to be implemented on these vessels, and as part of this thesis I wanted to focus on how an organization, like an E&P company, should obtain, integrate and possibly commercialize such a radical transformation through focusing on innovation strategy across the eco-system.

I would like to thank my supervisor, Tor Helge Aas, for great guidance and support throughout the work with this thesis.
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1 Introduction

In 2000, the Lisbon summit set a strategic goal that the European Union should by 2010, "become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion" (Lisbon European Council, 2000).

As an inspiration to this summit, Louis Lengrand published an innovation paper in 2003, where he further explored how this goal could be achieved through "innovation and its relation to policy and policymaking" (Lengrand, 2003).
Lengrand states that "regulatory reform can achieve increased effectiveness and thereby help to solve challenging economic and social problems", whereas he refers to the "third generation innovation policy" as at the heart of each policy area where the common aim is "to maximize the chances that regulatory reform will support innovation objectives, rather than run the risk of impeding or undermining them" (Lengrand, 2003).

To achieve this, Legrand talks about two sorts of knowledge: "knowledge about (the changing nature of) innovation processes and innovation policy" and "knowledge about (the rationale and reform processes underway in) the specific policy areas".
And even if such knowledge is achieved to outline the basics of a "third generation innovation policy", Lengand still states that a "a serious effort to articulate and fuse the bodies of knowledge that need to be brought together to add depth to this is still required" (Lengrand, 2003).

Fast forward to 12 December 2015, such a regulatory reform took shape when the Paris Agreement was signed as a legally binding international treaty on climate change. The treaty stated, among other things, a "vision of fully realizing technology development and transfer for both improving resilience to climate change and reducing GHG emissions" (United Nations Climate Change (UNCC), 2015).

As a follow up to this agreement, the United Nations published a brief on technological innovation for the Paris Agreement in 2017, which stated that there is "a pressing need to accelerate and strengthen technological innovation so that it can deliver environmentally and socially sound, cost-effective and better-performing climate technologies on a larger and more widespread scale. But there is no 'one size fits all' approach. Different innovation approaches are needed "(The Technology Executive Committee (TEC), 2017, pg.4).

The brief further stated that to "enhance the implementation of nationally determined contributions, national adaptation plans and mid-century strategies, the Technology Executive Committee recommends that the Conference of the Parties (COP) encourage Parties" to, among others, "create an inclusive innovation process that involves all key stakeholders, facilitating the incorporation of diverse and relevant expertise, knowledge and views and generating awareness of the benefits and impacts" (The Technology Executive Committee (TEC), 2017, pg.4).

To summarize, these sustainable innovations processes are often political driven by setting new legislation and requirements to the various stakeholders in an eco-system to cut their emissions, such as the oil & gas sector, and this again sets the stakeholders in a position where they must manage new radical sustainable innovations to achieve such.

Having introduced the drive, need and demand for new radical sustainable innovations, it's also crucial to understand this in conjunction with the principal theory surrounding open, radical and sustainable innovation.

Chesbrough (2003) launched the open innovation model in 2003 where he stated that "at its root, open innovation is based on a landscape of abundant knowledge, which must be used readily if it is to provide value for the company that created it. However, an organization should not restrict the knowledge that it uncovers in its research to its internal market pathways, nor should those internal pathways necessarily be constrained to bringing only the company's internal knowledge to market" (Chesbrough, 2003, pg.4).

An interesting digression is that Huizingh, E. K. (2011) predicted that one should not be surprised that the term would fade away the next decade, however in the context that it would not dissipate but simply be integrated into innovation management as no organization could afford not to include open innovation.

How could then such an innovation model be relevant towards the challenges various eco systems are facing today, such as climate changes?
Gupta et al (2016) argues that "the openness of knowledge system at community level facilitates emergence of open and reciprocal innovations for dealing with climatic, institutional and market risks", and also further states that "when systems become open, search cost for inclusive innovation will automatically come down and the knowledge system will also become more symmetrical and inclusive" (Gupta et al, 2016, pg. 1-2).

With the climate changes at hand over the last few decades and with the rapid need for new technology innovation, it may be argued that the traditional open innovation is insufficient. How can stakeholders (firms) in the various ecosystems efficiently manage such radical transformations?
Peschl et al (2010) points to the crisis at hand with climates changes, financial crisis, poverty etc., and claims "that prevailing innovation and design processes have shortcomings and do not allow to meet the demands and needs of stakeholders, although those procedures are claimed participatory design or open innovation", and argues that another approach is required; "the need for radical innovation in a specific sense" (Pesch et al, 2011, pg. 1).

As called for in the Paris Agreement to handle climate changes, several sustainable development goals have been defined such as "finance, technology and capacity-building support" (United Nations Climate Change (UNCC), 2015).
In this aspect, Boons et al (2012) further points out that "sustainable development requires radical and systemic innovations" (Boons et al, 2012, pg. 1).

To systemize such a technological innovation, a specific workflow should be established by a relevant stakeholder in an eco-system. Within the inbound open innovation, as defined by Dahlander & Gann (2010), West & Bogers (2014) further discussed such a workflow whereas they introduced a four-phased process model: Obtaining, Interaction, Integrating and Commercializing. Within these processes, the stakeholder would need to identify and integrate external knowledge and resources to drive a successful innovation.

To succeed in such a radical sustainable innovation, it would be beneficial to understand what kind of knowledge and type of resources are required, and how we could ensure the flow of these across these processes.

It's also important to gain an understanding of what kind of gaps and barriers could potentially affect a radical sustainable innovation.

Peschl et al (2010) discusses the importance of bridging such gap, arguing that "one of the key problems for radical innovation lies in bridging the gap between the following two poles:

(i) bringing forth something which is both radically new and game changing and
(ii) at the same time – can be somehow related and connected to existing knowledge, experiences, products, services, etc." (Peschl et al, 2010, pg.3).

Sandberg & Aarikka-Stenroos (2014) have also tried to systemize the barriers to radical innovation and points out that these barriers "seem to be a complex, multifaceted phenomenon on which our understanding remains limited". In their research, they have systemized and identified several barriers such as insufficient resources, technological turbulence, lack of competence etc.

They also address the eco-system and network surrounding these radical innovations, whereas they point out "an undeveloped network and ecosystem have the widest influence" to such barriers, and that "they vary according to the characteristics of firms, markets, and along the innovation process" (Sandberg & Aarikka-Stenroos, 2014, pg.1).
This is further addressed by Szimigin & Canning (2014), whereas they state that "in business and management literature, networks and network competence are recognized as critical to change, including radical innovation" (Szimigin & Canning, 2014, pg. 26).
As their research were focusing on the funeral industry, Szimigin & Canning (2014) also points out that "the investigation demonstrates the role of relationship networks and more specifically the importance of network competence of actors in bringing radical sustainable innovations to market", and that "further research should build on this by examining network competence and radical sustainable innovation in other business fields." (Szimigin & Canning, 2014, pg. 25).

Masucci et al (2020) focuses on alignment of various incentives in a business ecosystem (specifically oil & gas), but also concludes that there is a gap in their effectiveness and states that "future research should explore alternative mechanisms to align incentives among ecosystem actors and their effectiveness in different contexts." (Masucci et al, 2020, pg.13).

West & Bogers (2014) also concludes with regards to open innovation that there is still "major gaps on how such innovation is integrated and ultimately commercialized", and as such it "remains unclear how external innovations travel from the outside to a commercial product through the firm's business model and to what extent it requires distinct innovation strategies" (West & Bogers, 2014, pg.828). This means that three of their phases with regards to external innovation; Interaction, Integration and Commercialization, still remains somewhat unexplored within the science community.

Aarikka-Stenroos & Lehtimäki (2014) have also examined the commercialization of a radical innovation, which is identified by Story et al (2009) as one of the competencies in radical innovation. They claim that there is a research gap in the market preparation which seems to be crucial for innovation success. It is also interesting to note that they also identified an overlap and interaction between commercialization and front-end R&D (typically the process between obtaining and integrating), and that these early decisions also impacted other activities (Aarikka-Stenroos & Lehtimäki, 2014, pg.1383)

As I've addressed above, there is seemingly a gap in the open radical innovation literature, specifically from the Interaction to the Commercializing process, and, as pointed out by Peschl et al (2010), there is also a gap in bridging new radical knowledge together with existing knowledge and experience.

The UN brief, TEC brief # 10 (2017), mentions the pressing need to introduce new technology innovation, whereas Boons et al (2012) emphasizes that such developments will require radical and systemic innovation.

Looking at today's research, I believe there is a need to achieve a better understanding of how knowledge and resources are shared and flow across the various stakeholders in an eco-system when introducing a new radical sustainable innovation, specifically from the integration phase to the commercialization, and how these stakeholders are interacting. And there is a matter of urgency to achieve such an understanding as there is a pressing need to successfully introduce new radical technology in various eco-systems to be able to meet the commitments as set forth in the Paris Agreement.

Also, within the business eco-systems today, there are various initiatives to accelerate these developments, for instance as touch upon in Masucci et al (2020) research, where they looked at five different outsourced innovation projects for a firm within an oil & gas eco-system to conduct their research.

They have looked specifically on "how firms can orchestrate outbound open innovation strategically to accelerate technological progress among the firms they collaborate with", using an oil & gas major company and their key-providers as a case (Masucci et al, 2020, pg.1), and as a case in this research I will look more specifically into an oil & gas eco-system. In such an eco-system today, there is a vast focus on decarbonizing this industry, which is contributing to the introduction of new radical technology such as capturing CO_2 and reinjecting it to subsea oil & gas reservoirs (Longship Project, 2022).
Though this eco-system by large in general represents well-established firms with developed networks, introduction of new radical innovation may also introduce new undeveloped networks such as new joint ventures between stakeholders, for instance the Northern Lights JV between Shell, Equinor and Total, as part of the Longship Project (Longship Project, 2022). With this in mind, the bottlenecks in the ecosystem, as addressed by Masucci et al (2020), should be carefully considered in conjunction with the relevant barriers to radical innovation, as discussed earlier.

As part of my research, I would like to further research some of these gaps identified in a similar eco-system related to the flow of resources and knowledge between the stakeholders, where such innovations are driven by the climate challenges at hand and where there is a need to manage these radical sustainable innovations.

The Research Question I will address in this paper is:

How is knowledge and resources from external stakeholders in an industrial ecosystem obtained, integrated and commercialized in an open radical sustainable innovation process?

I would like to look closer on how we can use an open radical innovation strategy together in an ecosystem, and how knowledge and resources between the stakeholders can make a transformation, such as a radical sustainable innovation process, successful, using a specific case as elaborated in chapter 3.2.

This study will use a specific case in an oil & gas eco system to research how the knowledge and resources are obtained, integrated and commercialized across the relevant stakeholders to succeed in introducing a new radical innovation.
The focus will be the process from obtaining the innovation to potentially commercializing the innovation at hand, and how these stakeholders are interacting.
The theory will go more in depth in the relevant literature linked to open radical sustainable innovation with regards to external resources between stakeholders, how to manage a network, the relevant clusters and business models in the eco system and the theory surrounding open radical innovation.

The case for the thesis will deal with the introduction of a new radical technological innovation on offshore supply vessels used in an oil & gas eco-system on the Norwegian Continental Shelf (NCS), namely the introduction of Carbon Capture and Storage (CCS) technology.

The study is based on a qualitative approach in interviewing the relevant stakeholders such as oil & gas E&P companies, relevant ship owner and relevant technology firms.
The interviews are based on the Interview Guide as per attachment 8.1, which are analyzed with focus on the theory at hand and how this is applied in the specific case and potential other findings.

2 Theory

2.1 Open Innovation

As touch upon earlier, the introduction of new technology calls for an open innovative strategy to succeed in such an implementation.
This is also underlined by Carlos Moedas in his report "Science, Research and Innovation performance of the EU" (2016), where he states that we need open innovation to capitalize on the results of European research an innovation, meaning creating the correct ecosystem, increasing investment and taking more companies and regions into the knowledge economy.

To achieve this capitalization the firm in a specific eco-system needs to establish relationships with other organizations, as defined by Perez Perez & Sanchez (2002).
Such a relationship would form a network that would need to be managed between the stakeholders in such a network.

How can then such relationships and networks be managed to achieve a flow of knowledge and access to resources that the organization does not have itself?
Gulati (1998) refers to alliance formations where he emphasizes that "the creation of an alliance is an important strategic action, yet the cumulation of such alliances also constitutes a social network. Given our limited understanding of the dynamics of networks, alliances provide a unique arena in which action and structure are closely interconnected and the dynamic coevolution of networks can be examined." (Gulati, 1998, pg. 311)

As such an alliance formation should also be seen to achieve the knowledge and resources, such as technology and financing, that the organization doesn't necessarily have itself, and also a means to reduce and/or spread associated risk.

Additionally, Gulati et al (2000) also discusses strategic networks which builds on the alliance formation research but also emphasizes efficient use of resources, information access and control and how "network dynamics can influence the returns that different actors can extract from the strategic networks of which they are a part" (Gulati et al, 2000, pg.212).

As part of this thesis, I want to examine further how these dynamics are affected when introducing new radical sustainable innovation processes. The innovation perspective is linked by Pittaway et al (2004) together with the network management theory I've addressed above, where they summarize research on networking and innovation and find "that benefits of networking as identified in the literature include: risk sharing; obtaining access to new markets and technologies; speeding products to market; pooling complementary skills; safeguarding property rights when complete or contingent contracts are not possible; and acting as a key vehicle for obtaining access to external knowledge." But he also points to that networks may fail due "to inter-firm conflict, displacement, lack of scale, external disruption and lack of infrastructure." (Pittaway et al., 2004, pg. 137).

As such, organizations in such innovative network should carefully consider their network competence to achieve support in the different innovation stages, as touched upon by Szimigin & Canning (2014), where they state that "as part of their network competence, managers must judge which parties could undertake networking on their behalf (or indeed with them) to gain support at the different innovation stages. As part of this network competence, managers also need to assess the contribution that other individuals or organisations make to the innovation process." (Szimigin & Canning, 2014, pg. 25).

Identifying and establishing such networks should be seen as crucial to succeed with an open innovative strategy.
Chesbrough et al. (2006) defines open innovation as the "use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively."

They also emphasize the importance of a flow of knowledge in a network and argues that "at its root, open innovation assumes that useful knowledge is widely distributed, and that even the most capable R&D organizations must identify, connect to, and leverage external knowledge sources as a core process in innovation." (Chesbrough et al, 2006, pg. 3).
Also, Vanhaverbeke (2006) claims that "inter-organizational relations and networking are crucial dimensions of open innovation" and that they are an important part of the open innovation framework "when external ideas are insourced to create value in a firms current business or when internal ideas are taken to the market through external channels, outside a firms current business (Vanhaverbeke, 2006, pg. 7)

Dahlander & Gann (2010) introduces four types of open innovation; Revealing, Selling, Sourcing and Acquiring, whereas sourcing and acquiring falls under the inbound open innovation, which Chesbrough & Crowther (2006) refers to as "the practice of leveraging the discoveries of others: companies need not and indeed should no rely exclusively on their own R&D" (Chesbrough & Crowther, 2006, pg. 229).

	Inbound innovation	Outbound innovation
Pecuniary	Acquiring	Selling
Non-pecuniary	Sourcing	Revealing

Figure 1: Structure of different forms of openness. (Dahlander & Gann, 2010, pg. 702)

Chesbrough & Crowther (2006) discusses further that outbound open innovation (revealing and selling) suggests companies should source external organizations with business models whom may be better suited to commercialize a given technology than utilizing internal resources to the market.

This is an interesting discussion as West & Bogers (2014) in their research are discussing the inbound open innovation when determining their process model for leveraging external sources of innovation with focus on sourcing and acquiring innovation from external sources.

Could a combination of outbound and inbound open innovation be considered in the process model, specifically for the commercialization phase?

Gassmann & Enkel (2004) defines this combination as a third addition to the outbound and inbound innovation, a coupled process where they emphasize the importance of giving and taking between complementary stakeholders in an alliance to achieve success.

Hung & Chiang's (2010) research, limited to Taiwanese tech companies, focuses on such combination of integrating its internal technology with external knowledge, to develop new and more complex products and technology to then create value again for their customers. They argue that organizations that actively seeks external resources and knowledge to strengthen their own business, and chooses to sell their new technology to a partner to commercialize and realize the idea, may "outperform their counterparts who chooses to do otherwise" (Hung & Chiang, 2010, pg. 260)

However, West & Bogers refers to Chesbrough (2003) and claims that if the goal of a business model is value capture and creation, then research on inbound innovation is more representative than the outbound innovation, as it also represents more research and literature than the latter (West & Rogers, 2014, pg. 823).
This is also supported by Chesbrough & Bogers (2013), where they highlight that most research and literature is surrounding the inbound innovation, whereas the outbound and coupled innovation is less understood (Chesbrough & Bogers, 2013, pg. 13)

But West & Bogers also emphasize that though their research sample has consistently established the value creation and potential of external source, more research on the value capture from such sources, specifically considering the performance benefits of such sourcing, is needed (West & Bogers, 2014, pg. 823-824).

As touched upon earlier in the introduction, West & Bogers identified four phases to leverage external sources in an inbound open innovation process: obtaining, integrating, commercialization and interaction.

West & Bogers emphasizes that "obtaining the innovation source" is the part of the process model that has been the most researched and also is the phase that matches the early open innovation research (Chesbrough, 2003) and also is the phase that can be easily observed and measured.
For the interaction phase, they discuss the importance of cocreation processes and engagement of external networks and communities, but also raises the need for more research on the exact motivation for the external collaborators, specifically when they are driven by non-pecuniary motivations (Sourcing and Revealing) (West & Rogers, 2014, pg. 825).

This could be an interesting perspective to explore within this paper as the non-pecuniary may be a central element when introducing risks associated with new radical technology, as outlined in the case of this thesis.

As for integrating the innovations, West & Bogers (2014) discusses the capability to absorb external knowledge (absorptive capacity), which has been considerably researched, measured by internal R&D investments, as a complement to utilize external innovation, but points out that more research on substitution effects is needed (West & Bogers, 2014, pg. 824).

Rothaermel & Alexandre (2009) further claims that a higher level of absorptive capacity will allow a firm to capture the benefits more fully.
They also claim that an organization that sources all their technology internally is likely not to enhance their performances due to the increased risk. On the opposite, they also state that if an organization only relies on external technology, this may have a competitive disadvantage and lead to "inability to capture the returns to innovation" (Rothaermel & Alexandre, 2009, pg. 759).

As such, they state that there is a need to balance and combine internal and external sources of knowledge of both known and new technology to have a positive performance implication.
To structure this technology sourcing and organization performance, they developed an exploration-exploitation framework, as seen in figure 3.
As for new technology (quadrant III and IV), they refer to the term exploration as to source for new technology, and for known technology (quadrant I and II), they refer to the term exploitation (Rothaermel & Alexandre, 2009, pg. 760).

Yet again, Rothaermel & Alexandre emphasizes the importance of maintaining a balance, also between the exploration and exploitation dimension, to enhance the organizations performance, and also point out that "although higher levels of absorptive capacity allow managers to take advantage of ambidexterity in technology sourcing, maintaining a balance between internal and external technology becomes a much more important task at higher levels of absorptive capacity because the penalties in terms of performance loss due to an imbalance in technology sourcing strategy are much more pronounced". (Rothaermel & Alexandre, 2009, pg. 775-776).

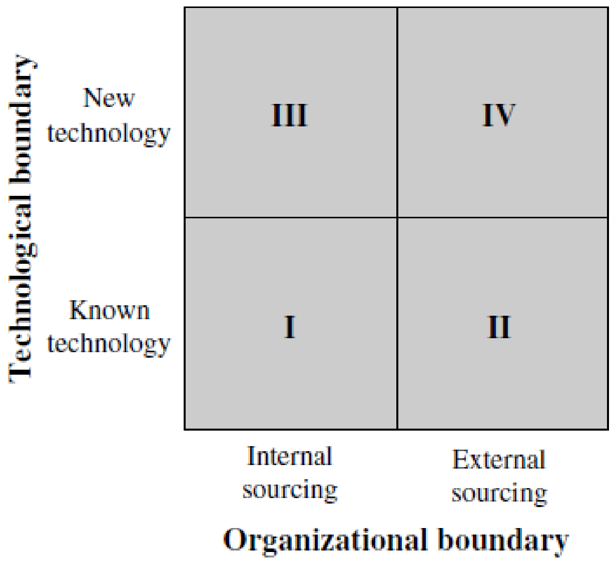

Figure 2: Types of Exploitation and Exploration Along Technological and Organizational Boundaries. (Rothaermel & Alexandre, 2009, pg. 760)

But there is also a consideration with regards to the organizational culture to be able to absorb such knowledge, and West & Bogers (2014) also highlights this and the need for more research. They point out specifically the need to identify if the culture facilitates integration rather than reducing the interest in the same through R&D investments (West & Bogers, 2014, pg. 822).
These process stages for leveraging external sources will be further analyzed with focus on the flow of knowledge and resources when introducing a new sustainable radical innovation.

Gupta et al (2016) argues further that "the conventional understanding of open innovation theory is highly inadequate for dealing with emerging challenges in leveraging contingent conditions of climate risks, asymmetry of knowledge and power and lack of reciprocity and responsibility among the formal and informal actors. To deal with the greater complexity and need for higher frugality and circularity (McDonough and Braungart 2009), the open innovation theory will need substantial evolution in the direction indicated in the paper. The degree of openness among different actors in different domains and at different levels in the society may influence the strategies for harnessing the power of co-creation and network management for distributed knowledge system."

To further broaden the theories surrounding conventional open innovation as we deal with these emerging challenges as highlighted by Gupta et al (2016), I'll discuss the theory concerning radical and sustainable innovation, before establishing a theoretical framework based on these theories, to further address the case and research problem at hand.

2.2 Radical Innovation

I've discussed the theory around open innovation, but to shed some light on my research problem I also need to look further beyond open innovation, into the radical innovation literature.

There is far from an agreed formal definition of radical innovation between researchers, which is also pointed out by McDermott & O'Connor (2002).
They define a radical innovation as a product that involves the "development or application of significantly new technologies or ideas into markets that are either non-existing or require dramatic behavior changes to existing markets" (McDermott & O'Connor, 2002, pg. 424). O'Connor & Ayers (2005) defines in their research radical innovation as a commercialization of products and technologies that may impact the market and the organization, and also points to the correlation that such imposes high risk and high uncertainty to the organization, which is then required to develop their competencies in technology, market and organization (O'Connor & Ayers. 2005, pg. 24)

According to Bers et al, radical innovation gives rise to new technological revolutions, but these innovations are often disruptive which results in lengthy cycles from technical breakthrough to actual commercialization. As such, they claim there is a need to accelerate the innovation process to be able to manage it within today's society's economic and political time horizon (Bers et al, 2009, pg. 165-166).

From their research, they discovered three main lessons to ensure a successful radical innovation; the innovation should start from a major crisis or opportunity, it needs to proceed along a technical life cycle, and it needs to build on prior achievements.

From those three lessons it's interesting to note that from a technology life cycle view, they point out that radical innovation cannot be rushed, which would seem a bit contradictory considering the aim of the research if to accelerate the process. However, they point out that the key to acceleration is not to find "shortcuts around the life cycle but to understand how it unfolds and find ways to manage it on a better planned and informed basis" (Bers et al, 2009, pg. 167). In other words, they claim that the key to accelerate the innovation is to build on latter knowledge and resources and as such their methodology is built on "rapid information retrieval, pattern recognition, and knowledge management" (Bers et al, 2009, pg. 169).

Sandberg & Aarikka-Stenroos (2014) have further tried to systemize the barriers to radical innovation to try to get a better understanding of what makes this innovation so complex and difficult. Based on the various literature within radical innovation, they've identified several barriers, whereas some of these can be seen in context with the above research by Bers et al (2009).
Firstly Sandberg & Aarikka-Stenroos divides the barriers into internal and external barriers. Among the external barriers, they point at resistance from among other customers, governments etc. Bers et al also discusses this as a challenge as companies are likely to focus on "safer, surer, less costly and nearer term-bets" alternatives rather than a radical innovation that would most likely stretch beyond the time horizon of their own interest and without guaranteeing their benefits nor success.

As for the internal barriers, Sandberg & Aarikka-Stenroos discusses, among other, the lack of competence and insufficient resources, and under the lack of competences they specifically

touch upon the lack of acceleration and commercialization competences, which is the main topic of the research of Bers et al (2009).
Bers et al has developed a ten-step process upfront of the process to identify and manage "vast amounts of intelligence, mobilizing a value network of multiple stakeholders and conducting multiple small-scale experiments and developmental activities" (Bers et al, 2009, pg. 176).

Could then such a tool or a similar approach be a way to mitigate some of the barriers identified by Sandberg & Aarikka-Stenroos, such as to avoid narrow focus on meeting needs of current customers, challenges in utilizing the innovations potential in building an effective business model and the difficulties in finding the correct partner and how to cooperate with them?
This could be an interesting tread to analyze further when looking into the method and case in section 3.

One of the internal barriers highlighted by Sandberg & Aarikka-Stenroos is the lack of competence and resources. Zhou & Li (2009) have researched how internal knowledge sharing can affect radical innovation, and have among other concluded that "a firm with a deep knowledge base is better able to achieve radical innovation through enhanced market knowledge acquisition rather than internal knowledge sharing". By this they emphasize the importance of a balance between the existing knowledge base and the way an organization integrates its knowledge (Zhou & Li, 2009, pg. 1098).

As for the internal resources in an organization involved in a radical innovation, Stringer (2000) argues where such a network or alliance is established apart from the organizations existing business, they tend to treat their own internal resources as they were external resources, with various success involving radical innovations (Stringer, 2000, pg. 81).

As to establishing a value network, it is also suggested by Pittaway et al (2004) that there is a direct relationship between type of networking activity and innovation type (radical or incremental), as they found that organizations less willing to take risk would typically connect their innovation activities and network relationships to customers as knowledge of clients demand would reduce their risk of failure (Pittaway et al, 2004, pg. 150).
Incremental innovation is in a simple term defined as an ongoing improvement to product, process and service (Bhaskaran, 2006, pg.67)

Seen in light of Sandberg & Aarikka-Stenroos' (2014) findings in their research regarding barriers to radical innovation, a direct relationship, as discussed above, seems supported as they have shown that "external barriers related to customer resistance and an undeveloped network and ecosystem and the internal barrier related to restrictive mindset seem to be important during the entire innovation process for most firms, whereas the importance of other barriers differ for particular firms, markets, or activities" (Sandberg & Aarikka-Stenroos, 2014, pg.1303).

How can then such barriers be overcome considering such a relation between networking and radical innovation?
A central element could be the organization structure of those stakeholders involved in the radical innovation.

Green & Cluey (2014) refers to organic organizations who are more likely to innovate as they are more informal, flexible and open to risk-taking than a so-called mechanistic organizations, which are more formal, inflexible and bureaucratic (Green & Cluey, 2014, pg. 1344).

That said, there are still challenges for both types of organizations to cater for radical innovation. The mechanistic organization should strive to “engineer informal, flexible and creative spaces within which people can innovate”, whilst Green & Cluey also points out that innovations can’t exist without some level of formal organization. Hence this leaves the challenge for an organic organization to “develop systems and structures to support innovation without restricting it”.
However, they also point out that if one is to develop radical innovation this would require more than an informal structure, and points to Story et al (2010) research whereas they found that “radical innovation is typically built on interactions across organizational functions and divisions and is often the result of intraorganizational networks and collaborations” (Green & Cluey, 2014, pg. 1344).

As organizational structure may appear as one consideration to manage networking and achieve successful radical innovation, the organizational culture may seem more vital, as Green & Cluey states that “we need to turn our attention from structure to culture and to explore the effects of radical innovation rather than its causes”, as they refer to previous researches that points out that organizational culture needs to consider their history, presence and future to achieve a holistic understanding (Green & Cluey, 2014, pg. 1344).
Büschens et al (2013) has looked further into the behavioral approach when organizing radical innovation. They point at various types of organizational cultures, but argue specifically for a developmental culture that “emphasizes flexibility, external orientation and growth as an organizational end” (Büschgens et al, 2013, pg. 142). They further claim that such culture reinforces an autonomous motivation as it interacts with idea generation.
As earlier discussed, if there is a direct relation between networking and radical innovation, such culture building should be considered across the whole network involved in a radical innovation.

Story et al (2010) also points to that a successful radical innovation is “increasingly linked with relationships and networks”, but that how exactly they support in such an innovation is less clear (Story et al, 2010, pg. 952).
They have identified four main competences that is required to launch a successful radical innovation which they define as discovery, incubation, acceleration, and commercialization.
In short, they describe these competences as follows:
Discovery – behaviors and activities that identify, create and elaborate opportunities for radical innovation.
Incubation – developing the radical opportunity into a business proposal.
Acceleration – Maturing the technology, commercializing the product and developing production capability in preparation to expand sales.
Commercialization – Full-scale launch of the product.

They also point at two specific skillsets across these competences: experimentation and exploration.
For the discovery phase, they emphasize that this competence facilitates the exploration and considering radical innovation, the particular importance of communicating and elaborating on such an idea and opportunity, whereas such would also pose a challenge, as the various stakeholders may not be able to understand the full potential.

For the incubation, they also point at experimentation as an important skillset, both technical and market, as this competence should develop an understanding of the application and market to form a concise concept or prototype.
Both experimentation and exploration are emphasized as key skills for the acceleration competence, as experimenting would typically entail working with customers to develop the product further, whilst using the exploitative skills to build infrastructure, manufacture capabilities and business processes.
For the latter competence, commercialization, the exploitative skill is highlighted to manage production, supply, marketing and sales capabilities, and last but not least, stimulate the market demand (Story et al, 2010, pg. 953-954).

As discussed earlier, the literature has still gaps on how these innovations are integrated and finally commercialized.
Aarikka-Stenroos & Lehtimäki (2014) have further examined the commercialization of radical innovation, and has developed a dynamic process model of such commercialization which flows between three main activities: strategic marketing decision making, market creation and preparation, and sales creation and development (Aarikka-Stenroos & Lehtimäki ,2014, pg. 1372).

As they see this process complicated by conflicting challenges, they've identified six major commercialization challenges which the stakeholders may face:

- Choosing a feasible strategy in conditions of uncertainty
- Understanding the benefits of innovation from the customers perspective
- Creating credibility
- Acquiring support from the stakeholders and the ecosystem
- Overcoming adopting barriers
- Creating sales

2.3 Sustainable Innovation

Sustainability has become an important part in all aspects globally, whereas organizations define their own sustainability goals and strategies often driven by governmental incentives as part of their commitment to the Paris accord (2015).
Sustainability was defined in 1987 by the United Nations Brundtland Commission as "meeting the needs to the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987).

Together with the organization's sustainability goals, strategies and development, comes also the need for sustainable innovations.
Sustainable innovation is in such regard defined by Boons et al (2012) as a "process where sustainability considerations (environmental, social, and financial) are integrated into company systems from idea generation through to research and development (R&D) and commercialization" (Boons et al, 2012, pg. 3).

Radical and incremental innovations are closely linked to the sustainable development organizations are undergoing today, whereas earlier discussed, Boons et al (2012) argues that sustainable development requires radical innovation, and Adams et al (2016) discusses the need to turn focus on incremental changes to product innovation to become more sustainable oriented (Adams et al, 2016, pg.180-181)
As with open and radical innovation literature, Medeiros et al (2014) also argues for integration of knowledge and resources and writes that "considering inter-functional collaboration, Byrne and Polonsky (2001) identified that synergy among different sectors must happen not only internally, but also among the stakeholders involved in environmentally sustainable product development and delivery processes" (Medeiros et al, 2014, pg. 81).

Likewise, Oksanen & Hautamäki (2015) also calls out for a cross-functional cooperation between all partners and shareholders, especially between firms, universities, venture capitalists and other financiers, municipalities and citizens to facilitate for sustainable innovation (Oksanen & Hautamäki, 2015, pg. 23).

Peschl et al (2010) points to a radical innovation in a specific sense, whereas the innovation has the quality of being "ontological sustainable in the following sense: due to the fact that they develop out of the ontological core of the innovation-object they are a "natural", yet radically new, development of qualities which have been present in an undiscovered, yet latent manner" (Peschl et al, 2010, pg.3).
To be able to realize and implement a profound sustainable innovation, they refer to an empirically tested innovation process, LEAP, which is a process in seven phases, organized in workshops, over a period of four to eight months.
These workshops between the stakeholders are referred to as Learning to see, Dialogue on the innovation fields, Emergent Design etc. The stakeholders may also be involved, as part of this process, in other organizational matters involving innovation, such as communication strategy, management approval etc. (Peschl et al, 2010, pg.4).

As LEAP would represent a specific initiated innovation process, a more profoundly choice and concept of business models may also affect the success rate of the sustainable innovation, as Boons et al (2012) states that such innovations could be more effective created and studied if built on business models. They argue that the business models have a "potential to bridge the gap between the radical and systemic sustainable innovation and firm strategies, including the issue of economic performance at several levels" (Boons et al, 2012, pg. 3).

In this aspect, a business model is defined by Boons et al (2012) as the "way in which a firm combines a value proposition with supply chain management, the interface with customers and a revenue model" (Boons et al, 2012, pg. 5)

Further in their study, they point at three important aspects in the business model that is key to sustainable innovation:

- Value proposition – relationship between the stakeholders should not be built around a service or product, but on the exchange of value. For sustainability, the focus of value would typically be between economic, social and ecological value.
- Value creation – the activities in an organization should be embedded across all stakeholders involved in the innovation, technically and socially. Specifically, if importance the interface between the stakeholders and supply chain activities.
- Revenue model – all the stakeholders should have a fair balance of costs and rewards.

As part of the value creation between stakeholders, may the transfer of knowledge be an important part in managing a sustainable innovation.
Adams & Comber (2013) are in their research discussing what kind of knowledge transfer is required across small- and medium-sized enterprises (SMEs) to improve resource efficiency to manage a sustainable innovation. They also discuss the absorptive capacity, as highlighted by Rothaermel & Alexandre (2009), to facilitate knowledge transfer and resource efficiency, whereas they divide them into four categories:

- Ignorance of key issues.
- Awareness of key issues.
- Knowledge and understanding of key issues and solutions.
- Implementation of key issues and solutions.

They claim that the higher the absorptive capacity of the SME are, the more effective the knowledge transfer leading to better integration of sustainable innovation into their strategies (Adams & Comber, 2013, pg. 5-6).

Further they've identified three main pillars that are required to be in place for a successful knowledge transfer:

- Linkages to sources of external knowledge
- External culture that supports resource efficiency
- Internal culture that can integrate and adjust to new ideas.

These findings are also interesting in the light of Green & Clueys (2015) research who calls for a need to turn the attention from structure to culture.

Lv et al (2018) discusses the uncertainties around sustainable innovation, and the need for resilience in an organization, which should be seen as the ability to survive in a turbulent business environment. Across their review of the resilience research, they've identified two integral parts that the resilience consists of; stability and adaptability, whereas they define stability as the ability to withstand stress hence avoid a loss of function when dealing with environmental turbulence, and adaptability as the ability to adjust to environmental changes, i.e. seize opportunities and create new fundamental systems (Lv et al, 2018, pg. 2-3).

They've connected these two definitions to the three dimensions; culture, leadership and team, and established a set of criteria to establish a framework to understand stability and adaptability in an innovation process, as shown on the figure below.

Dimension	Stability	Adaptability
Culture	A consistent, stable, and inherited culture. Outperforming repeated work with scrupulousness.	A creative atmosphere. Encouraging new ideas and innovative behavior.
Leadership	Systematic strategy plan. Path-dependence and rule-following.	Dynamic and flexible strategy. Allowance of various trajectories in parallel and a high tolerance of uncertainty.
Team	A stable organizational structure. Standardization, routines, and institutionalization.	An organic organizational structure. Authorization, openness, and improvisation.

Figure 3: Criteria for understanding stability and adaptability in innovation processes. (Lv et al, 2018, pg. 5).

Lv et al (2018) argues that the stability- and adaptability-oriented activities are complementary rather than contradictory, but that managers and leaders need to "balance the regular and creative activities in order to find out the most beneficial resource allocation on the behalf of the whole organization". They point to this as a challenge as managers often are perplex as to how many resources should be allocated to these activities, and that an optimal ratio is non-existing (Lv et al, 2018, pg. 19-20).
Medeiros et al (2013) identifies also four main critical success factors to achieve a successful environmentally sustainable product innovation:

- Market, law and regulation knowledge
- Inter-functional collaboration (as touched upon in the start of this chapter)
- Innovation-orientated learning
- R&D investments

Across these factors, they've identified in their literature several variables that influence these factors. The main differences they've identified from traditional product innovation is the (Medeiros et al, 2013, pg. 83-84):

- need to know regulation and environmental laws as well as policies concerning financial and information incentives oriented to green innovation practices.
- adoption of appropriate methods for developing environmentally sustainable products, as well as research in cleaner technologies are important variables for innovation success.
- innovation-oriented learning is a factor specific for the success of environmentally sustainable products, involving the synergy of tacit knowledge and theoretical models.

Chen (2016) has also researched important factors to succeed in sustainable innovation, and has in his empirical study identified three main aspects; knowledge innovation capability, production innovation capability and market innovation capability (Chen. 2016, pg. 1).

The interaction phase as described by West and Bogers (2014), is also discussed by Geissdorfer et al (2018) with regards to sustainable innovations where they define a sustainable business model as "simplified representations of the value proposition, value creation and delivery, and value capture elements and the interactions between these elements within an organizational unit" (Geissdorfer et al, 2018, pg. 402).
A challenge they point to for innovations towards a sustainable business model, is the need for engagement in extensive interactions between the various external stakeholders, and that such require extra attention and efforts (Geissdorfer et al, 2018, pg. 408)

2.4 Analysis Framework

As I've discussed the theory surrounding open, radical and sustainable innovation, the next step is to establish a summary of some of these theories and processes together in a framework to guide my study, as I further analyze the case to understand how the relevant stakeholders have approached their innovation, and what kind of knowledge, competences and resources that can be identified beyond the theories.

Have the stakeholders also had a conscious relation on how to handle and identify resources and knowledge across the innovation process, considering the applicable theory?
These are also central elements to analyze as I attempt to identify how resources and knowledge are obtained, integrated and commercialized across the stakeholders to successfully implement such an innovation.

As a core in the applicable inbound open innovation theory, lies West & Bogers four-phase process model, as shown in figure 4. This would be the foundation of my analysis framework, as I analyze each process with focus on the knowledge and resources utilized and shared across the innovation.

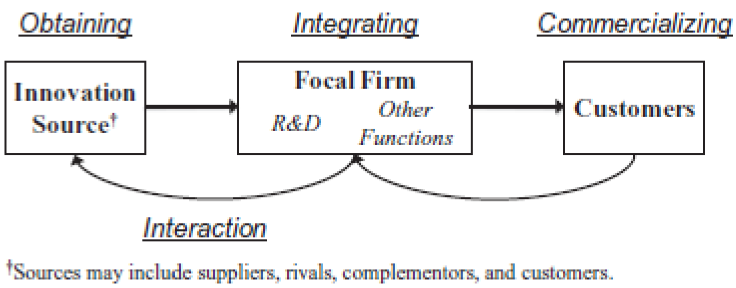

Figure 4: Four-phase Process Model for Leveraging External Sources of Innovation. (West & Bogers, 2014, pg. 816)

Another element in the analysis is to gain an understanding of how they manage the network in their innovation process, as this should be seen in conjunction with the interaction phase in an inbound open innovation process as defined by West & Bogers.
The analysis will focus on the inbound innovation process, though some of the stakeholders in the sample may also have an outbound focus, which may be natural to discuss.

In the innovation process itself, key aspects, but not limited to, from West & Bogers to analyze are:

- Which stakeholders are involved and how they were identified?
- What kind of requirements to knowledge and resources and how these are utilized and organized in the innovation?
- How the innovation process has been integrated into each organization?
- How can the innovation be commercialized?

This analytic framework has set the basis for the interview guide and the subsequent analysis conducted in section 3.3.

3 Method

3.1 Choice of Method

The nature of the research question at hand is of an explorative nature, hence it is natural to focus on qualitative methods when determining how data and information should be collected to build further on the theory discussed previously and try to shed light and find answers to the research question at hand.

As such, interviews with various stakeholders in the same ecosystem involved in an innovation process have been conducted as further outlined in this chapter.

3.2 Sample

3.2.1 The Case – Carbon Capture & Storage technology on existing Offshore Supply Vessels

The newly elected government, formed by the Labor Party and Centre Party in autumn 2021, declared in their governing platform (Hurdalsplatformen, 2021) a requirement that all offshore supply vessels in the Norwegian Petroleum sector should have in place a low-emission solution by 2025, and achieve zero-emission by 2030.

Though a lot of initiatives were already in place for offshore supply vessels (OSVs) such as battery packages and LNG (Liquid Natural Gas) fuel (Möhring, 2017), this has accelerated the need to find a near zero-emission solution for these kinds of vessels within 2030.

The oil & gas E&P companies on the Norwegian Continental Shelf (NCS) acknowledges their responsibility in finding such a solution, and are exploring several options such as ammonia, together with various ship owners (Lunde, 2021). And there are other innovations emerging for shipping, such as hydrogen (Bahtic, 2021) and carbon capture (Chambers, 2022)

But these initiatives are all representing new technology and innovations that would introduce additional costs and uncharted risks. Most of the same OSV ship owners have also been under pressure the last years due to a major downturn in the oil & gas industry from 2014 and has merely started to recover after the market has improved (Kvale & Nilsen, 2022) but are still struggling with debts (Underhaug & Korableva, 2021, p. 97-99).

It would therefore be reasonable to assume that such an investment of introducing new technology would be difficult for some of these OSV ship owners to bear by themselves, also considering the resources and knowledge available to them internally.
As such, the establishment of an innovation network between the various stakeholders to, among other, share the risks and manage the required knowledge and resource, may be of an outmost importance to succeed in a radical sustainable innovation.

The E&P organizations on the NCS should, as a major stakeholder, carefully consider their role and strategy if the aim is to introduce such a new radical innovation and technology in a successful and sustainable manner, which leads us to the research problem of this thesis.

As part of this thesis, an innovation case will be used as a base to elucidate the research problem at hand. As mentioned previously, there are a lot of innovation initiatives related to cutting emissions for the shipping industry, but for this thesis, the case will focus on implementation and management of retrofitting on-board carbon capture & storage (CCS) technology on existing offshore supply vessels, operating in the NCS.
To succeed in such an implementation, it is key for a shipowner to obtain and integrate external resources and knowledge, hence such a case would be relevant to shed light on the research question at hand.

During the data collection, it was discovered that one of the OSV ship owner was involved in a specific innovation initiative for usage of on-board CCS on offshore supply vessels, and there are also several other similar initiatives within CCS in the shipping industry, such as implementing this technology on gas/chemical carriers, where also data was collected from. Part of this case is hence to map the interest the OSV shipowners have towards such technology, the feasibility of it on an OSV, their knowledge and competence to succeed in such an innovation process, specifically towards the theory at hand, and what they believe is required to succeed in such an innovation. And are some of these ship owners already planning or in process of implementing CCS on their vessels?

As a benchmark and to get a more in depth and wider perspective on the research problem, I will involve other stakeholders that may not be directly involved in the eco-system in the case, but that are already involved in CCS innovation in the maritime industry, to understand how they are solving and handling their innovation process.

I will also investigate two organizations in the eco-system that have and are exploring alliance formation and strategic innovative networks, whereas one is an E&P company that has established several alliances with strategic partners for their project execution and operation. and secondly, a newly established joint venture between three major E&P companies, where the aim is to deliver carbon storage service as part of a governmental initiated carbon capture and storage project.

The eco-system in the case is the oil & gas business on the Norwegian continental shelf, and for the reader to further understand that part of eco-system relevant to the case and the role of the stakeholders, an overview is given below. The stakeholders may also be involved in other eco-systems, such as the CCS provider, deep-sea shipowner and class society.
The white boxes indicate stakeholders where no informants were identified or interviewed.
The case itself will focus on the OSV shipowner and the flow of external knowledge and resources required for them to succeed with an innovation, such as on-board CCS.

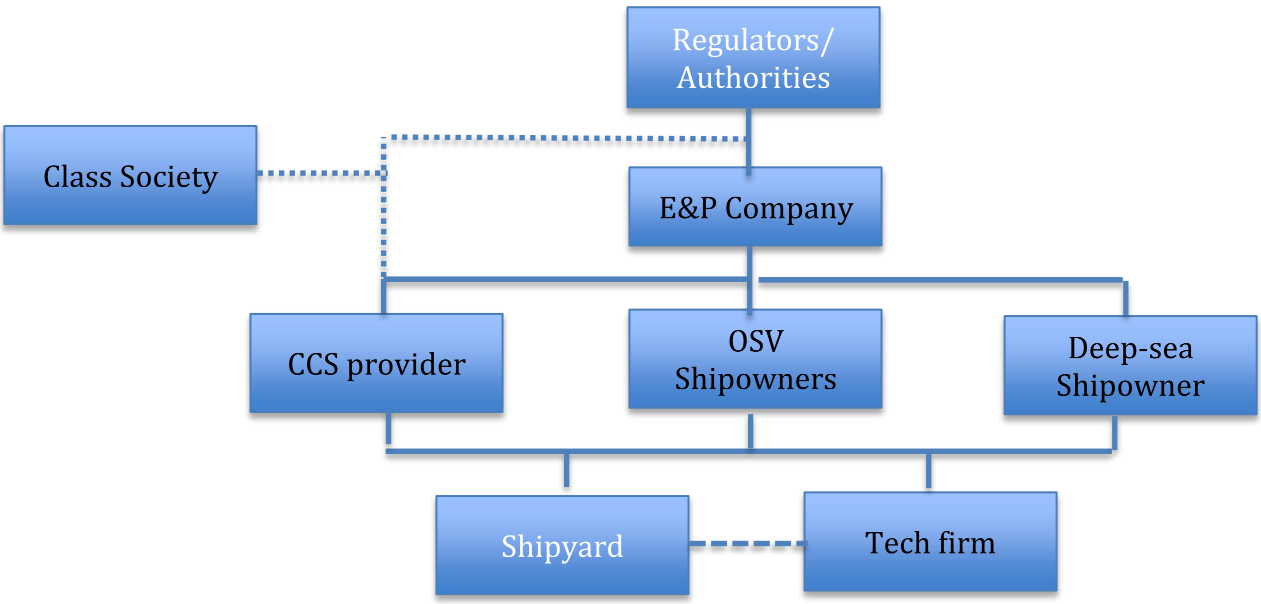

Figure 5: Part of the industrial eco system of the oil & gas business and its stakeholders in the NCS

3.2.2 Informants

For reference, an overview of the various informants is established below, whereas the Informant number will be used further throughout the thesis.

Informant #	Stakeholder	Role
Informant 1	OSV shipowner (involved in CCS)	Operation
Informant 2	OSV shipowner	Management
Informant 3	Technology firm	Management
Informant 4	E&P company – R&D	Support
Informant 5	E&P company - Operation	Management
Informant 6	Service provider CCS	Commercial
Informant 7	Classification Society	Support
Informant 8	Deep-sea shipowner	Management

Table 1: Overview of informants

As for each informant's relevance and consideration to the case, this is further outlined in the sub-chapters.

3.2.2.1 OSV shipowner (informant 1 & 2)

Two shipowners, who operates offshore supply vessels on the Norwegian Continental Shelf (NCS), have been interviewed to collect data and information related to the thesis' research problem.

Both are involved in sustainable innovation projects for their vessels, such as installing battery packages and introducing ammonia fuel cells to power their vessels, instead of conventional diesel engines.

One of the informants was also directly involved in a study of the use of carbon capture technology on offshore supply vessels operating on the NCS.

3.2.2.2 Technology firm (informant 3)

A major technology firm, who delivers carbon capture technology and who has been involved in such projects related to shipping and vessels have also been interviewed. They are also involved in research and development when it comes to the possibility of utilizing carbon capture on offshore vessels.

The informant headed up a local branch office in Norway that specialized in exhaust gas cleaning (EGC), and is, among other, a major provider of exhaust gas scrubbers for ships. From 2018 they also started R&D into carbon capture technology for ships, based on their experience with exhaust gas cleaning.

3.2.2.3 E&P company (informant 4 & 5)

As E&P companies on the NCS would be considered a significant stakeholder in this eco-system, it would also be vital to involve such an organization when collecting data and information to the research problem, especially how such a stakeholder would involve themselves in such an innovation, considering incentivization and business models.

The informants or the associated E&P company were not directly involved in any carbon capture project, but they were central in the organization with regards to R&D, acquiring of new technology and project execution.
Informant 5 was head of an alliance structure, who also had background from concept development and technology in the company. The alliance structure was formed between three integrated partners (resources from two suppliers and the E&P company) within a specialized field whereas their main responsibility was to support various projects from concept select to final delivery, which also could involve use of new technology. They have delivered 14 projects to date, and was currently involved in 7 ongoing projects. They could also be involved in the concept development phase, but on a support and advise basis (no formal responsibility).
Informant 4 was part of the E&P company's concept development & technology department, and hence was involved in the whole innovation process, from obtaining it to potentially commercializing it, or operationalizing it, as the informant referred to.

3.2.2.4 Service provider of CCS (informant 6)

To manage the whole value chain in a shipping eco system with carbon capture technology on offshore supply vessels, the case also touches on the utilization part and how the vessels can discharge the captured carbon, and if at all, there is a commercialization probability in such an innovation.

A joint venture between three major E&P companies have been established to develop such a value chain from collecting CO2 across various areas on the European continent, and to

discharge such at designated purpose-built terminals for re-injection to CO2 wells offshore or utilized in other ways (commercialized?)
As such, this JV has also been interviewed who may be a stakeholder in such an eco system as a service provider where such carbon may be discharged and stored.

3.2.2.5 Classification Society (informant 7)

An important aspect in introducing any new technology to the shipping industry, is the involvement of the relevant classification society. As to carbon capture technology on ships, the class society interviewed in this thesis, had already been involved in such projects, and were already working on developing new guidelines and standards for ship-owner to meet, who were exploring the possibilities of introducing such technology.

The informant was also leading a working group together with several ship owners, E&P company, technology firm and maritime authorities in a feasibility study for on board CCS for deep sea shipping.

3.2.2.6 Deep-sea Shipowner in process of or using CCS (informant 8)

As the case is focusing on the introduction of carbon capture technology on vessels, a third shipowner who operates gas and chemical carriers world-wide, and who is involved and in progress of introducing such technology on their vessels, have been interviewed to gain a better understanding on this innovation process.

3.2.3 Secondary data

Secondary data has also been considered to verify some of the data collected during the qualitative interviews. This data has, however, not provided any additional findings.
The following secondary data was collected:

- Sustainability report 2022 for deep sea shipowner (informant 8)
- Sustainability report 2022 for OSV shipowner (informant 1)
- Parts of funding application to Green Platform initiative for OSV shipowner (informant 1)

The reports have not been included, so as to secure the anonymity of the informants and stakeholders.

3.3 Qualitative interviews

The interviews have been carried out and recorded over MS Teams after the consent from the various interviewees, and an overview of each informant interviewed is shown in section 3.2.2.
Each interview was done for approx. one hour each and was carried out as per the interview guide in attachment 8.1. The interview guide is largely based on the analysis framework with focus on West & Bogers four-phase process model, as described in section 2.4.

The guide is structured in three stakeholder groups: Vessel Owner/Operator, Technology, CCS service provider & class society, and E&P company.
Each section starts with an open question to the informant, which is followed by one or several follow up questions.

The questions are largely based on West & Bogers theory, but considering also other theories surrounding open, radical and sustainable innovation, such as importance of successful interaction and cooperation between stakeholders in a developed network. Is the organization informal and flexible, or more formal and inflexible? Does the network come across as matured and developed, and how is the mindset? How is competence and resources shared across the network, and access to external knowledge and resources? Are sufficient stakeholders and partners involved (customers, tech firms etc.)? How is risk sharing and access to new markets managed?

These are important elements to gain an understanding of in how they manage their innovation network.

3.4 Analysis

The data collected was analyzed against the theory and four-phase process model by West & Bogers (2014), as shown in figure 4.
For each process, it was analyzed how the various informants had considered knowledge and resources they deemed required in the innovation process they were involved in, and if any relevant theory had been applied or considered in their processes, and if there was a pattern across the various informant interviewed related to how knowledge and resources were considered.

3.4.1 Obtaining the Knowledge and its Technical Feasibility

Part of the analysis was also to identify how external knowledge could be obtained for such innovation and if the technology was at all feasible to obtain on offshore supply vessels.

From the data collected, the focus was to understand how the informants had identified external sources of knowledge, and how this process had been, mainly compared to the theory by West & Bogers (2014), but also potential other aspect of relevant theory as discussed in section 2.
Though the focus was the innovation process for the OSV shipowner (informant 1) involved with CCS, it was also of interest to compare the data between the informants and how other stakeholders in the eco system approached a process of obtaining external knowledge.

3.4.2 Interacting and Integrating Stakeholders

Though all the interviewees were involved in various inbound open innovations, both sustainable and radical, but not necessarily carbon capture technology on offshore supply vessels, it was important to analyze their innovation experience towards the theory from West & Bogers. If they had for instance identified or practiced any other aspects around interaction and integration with the stakeholders they been involved with, and what they emphasized as important in succeeding with their innovation in that part of the phase, and also how they had managed their innovation network.
It was also important to analyze how each organization was organized; where they informal and flexible or more formal and inflexible? And how they managed risk sharing and access to new markets.

3.4.3 Commercializing the Innovation

As West & Bogers points out, there is little research on this area, and the commercialization aspect surrounding the carbon capture technology on offshore supply vessels is uncertain.
The JV / service provider of the carbon capture technology could provide the most knowledge around such possibility of utilizing captured carbon, but, such a possibility is still immature.

Another aspect of the commercialization would also be any governmental incentives and/or penalties and if any E&P organizations would consider such technology for offshore supply vessels to be able win contracts.

3.4.4 Knowledge & Resources

Across the various phases, it was also important to analyze how the stakeholders considered the need for flow of knowledge and resources between them, to gain an understanding and potential answer to the research problem.
For instance, how do the interviewees consider the need to share external knowledge and resources in their innovation project? And what kind of resources and knowledge do they require in their innovation projects? Do they have sufficient internal knowledge and resources?

These aspects have also been carefully analyzed for each interview.

3.5 Justification and Ethical challenges

The participants who have been interviewed in this thesis have been anonymized to ensure an open and transparent process in collecting information and data. The data collected has also been handled as per GDPR (General Data Protection Regulation) requirements and registered with SIKT (Norwegian Agency for Shared Services in Education and Research)

As the author of this thesis has a background in the industrial eco-system related to the case it has also been carefully considered that the interviewees have no direct relationship or identified interest with the author that could influence their answer.

4 Findings

4.1 Obtaining

West & Bogers points to two important steps when obtaining knowledge (West & Bogers, 2014, pg. 819):

1. Find external sources of knowledge.
2. Integrate this knowledge into the firm.

As for the onboard CCS technology, the findings suggested that it was the deep-sea ship owner that had come the furthest in this innovation process, as according to informant 8, they have had a collaboration with the interviewed technology firm (informant 3) since 2011. According to informant 3, the technology firm had developed, together with the deep-se shipowner, exhaust gas cleaning system (EGCS) which could capture SOx (sulphid oxides), NOx (nitrogen oxides) and PM (Particulate Matter) to meet the regulations as set forth by the IMO (MARPOL Annex VI, 2019).

Informant 3 explained that the EGCS had been commercialized by the tech firm, which basically constituted most of their revenue, while what they "were currently working on was carbon capture". This they had started to look at in 2018 as to how they could further develop the EGCS innovation to capture CO2 on ships as they saw emission "legislation would be only become more and more stringent, first with sulfide and then more on particles and NOx, and eventually CO2".
To obtain more knowledge on such technology, informant 3 explained that they had "connected with various academic environments related to the carbon capture technology itself" (such as different universities, SINTEF (Selskapet for industriell og teknisk forskning ved Norges tekniske høgskole) as they already obtained knowledge how to integrate such a technology on a vessel.
It was also expressed that they considered themselves as having "a more informal and practical approach than some of these environments, but needed to gain a basic understanding of the theory and learnings around CCS technology" to absorb such knowledge and competence.

The findings indicated that the branch office of the technology firm possessed robust internal resources and knowledge with an internal R&D department with less than ten employees, with a flat organization structure. Despite such, it was also expressed challenges in utilizing relevant resources and knowledge within the firm, though externally from the branch office. There was not an issue in obtaining internal resources and knowledge from the firm, but rather to source the correct resources and knowledge they required, and to integrate these into their existing team, as informant 3 emphasized that "despite high level of internal engineering capacity, it could still be a challenge to find the right people in a large international organization. Though internal resources would be made available, they may not have the right competency or understand the culture".
As an example, informant 3 mentioned the commercialization phase and when they were upscaling their EGCS solution in increasing production, that they experienced inefficiency as they had "to utilize a lot of time on training and integrating those internal resources into their team".

Informant 3 expressed that the carbon capture technology for use on offshore supply vessel was matured, but that further detailed engineering would be required to retrofit such technology on existing supply vessels, together with relevant shipowner and shipyard. The CO2 capture process would also require heat generation, which they considered an abundance of for an offshore supply vessel as half of the energy from engines/fuel is just disposed of through cooling water and exhaust funnel.

Both informant 1 and informant 3 pointed to the challenge of disposing of the captured CO2, as it would be mixed with an amino solvent to capture the gas. This could be potentially treated on board (separating the fluid and CO2) or sent ashore to a treatment plant, though both informants realized such facilities are not currently in place in this eco-system.

The findings indicated that both ship owners involved in CCS, had a traditional shipping organization with main focus on the operation of their vessels and no separate R&D department or resources working specifically on new technology. However, according to informant 8, they "had actively participated in research programs at academic environments such as NTNU (Norges teknisk-naturvitenskapelige universitet) and SINTEF (Selskapet for industriell og teknisk forskning ved Norges tekniske høgskole)".
Informant 8 had also a substantial academic background with regards to research on marine engine combustion technology, which according to this informant was not a typical resource or knowledge to find internally in a traditional shipping company which than gave this ship owner an advantage when obtaining this new technology in collaboration with the tech firm and engine makers.
The findings suggested as such that part of the CCS technology innovation had been innovated by that individual.

According to informant 8, a supplier alone would have difficulties in developing and implementing such a CCS system without the ship owner integrated in the project as the system itself introduces intrusive impact to other integral ship systems, such as waste heat recovery which is required for CCS.
The informant also emphasized that they had "no strategy in acquiring this technology, but to enable this technology with external knowledge and resources to give them a competitive advantage when the emission regulations come into play".

The findings suggested that a barrier to obtain the innovation and to mitigate the risk for the ship owner was the investment cost. Both shipowners (informant 1 and 8) saw it time-consuming and resource demanding to obtain funding for such an innovation, and they had applied from the likes of Norwegian NOx fund (NOx-fondet, 2023), Enova (Enova, 2023), Innovation Norway (Innovasjon Norge, 2023) and the Green Platform Initiative (The Research Council of Norway, 2023).
According to informant 8, they were now back with an application with Enova, where they were still waiting for a decision but have had positive feedback so far.
Regardless, they considered that they still had to take a large amount of the investment and risk themselves, but they also saw a huge potential and upside if they would succeed with the first vessel using CCS. Compared to alternative fuels such as hydrogen and ammonia, which informant 8 indicated could have a fuel cost increase of up to 300%, the CCS technology would cap at a 30% increase according to their studies so far.

As for informant 1 & 2, they emphasized that they rely on external sources of innovation and do not have a strategy to obtain nor commercialize new innovations internally.

As for the case at hand, the informant 2 pointed out that there is a barrier when they “operate such vessels world-wide as there is currently no direct shipping legislation from IMO that is driving the need for new green technology in a large scale on a world-wide basis” such as the Norwegian government proclaimed to achieve zero-emission by 2030 for OSVs on the NCS. According to informant 1, they operated their vessels mainly in the NCS, i.e., in the eco system, outlined in the case in section 3.2. As for the aim to achieve zero-emission by 2030, their impression was that “no one is really ascertain how such can be achieved where even no clear guidelines from the Norwegian government or Norwegian Maritime Directorate have been given”.

Both informant 1 & 2 indicated that the investments and associated risks are difficult to be born by the ship owners independently, even with internally management support, and the cooperation with certain stakeholders in this eco-system had been challenging when it comes to new technology and to meet the pronounced target of achieving zero emission by 2030. They emphasized that the main driver should come from the E&P companies to implement such green technology, but their experience to date was that they as ship owners were very little involved, if at all, in any such initiatives.

Informant 1 also indicated little involvement when E&P companies were deciding which technology to obtain for the OSVs they were using, and that there was a lack of flow of communication with regards to choice of concept.
The findings suggested that the E&P companies in the NCS also did not seem aligned on how they wanted to achieve net zero emission for OSVs by 2030, and informant 1 expressed a difference in the organization cultures across the E&P companies, particular on the ability to absorb their knowledge and experience as ship owners.
The findings also indicated that it would be difficult for the ship owners to select the technology concept themselves as they saw a risk in having a vessel that potentially no customers would want to use.

Both informants were adamant that they would not have the resources to drive this alone without involving the customer where the investment needs to be born by the E&P company, which sets a barrier. They also indicated some reluctance in sharing such risk between stakeholders.
For instance, informant 2 suggested that in their battery projects where they seek support from the likes of Enova (Enova, 2023), they were starting to see that such support was getting increasingly more difficult to obtain. And they were not in a position to budget for such improvement, though some of the E&P companies did contribute with a higher day rate where for instance such batteries were installed.
The findings suggested that without these drivers and incentives, the ship owners would not be able to make such an investment.

They also saw a lot of risks with a lot of new unproven technology emerging, for instance green hydrogen and ammonia, and as such they considered dual fuel technology important to limit risk towards just one type of fuel.

Informant 1 indicated that the ammonia project was primarily customer driven where they had made one of their vessels available for the project. They had no internal resources tied to this, other than that they were informed of the innovation process where a tech firm was currently developing and testing such engines and fuel cells.

As for the CCS technology, informant 1 explained that this was more “an internal driven innovation” where they had obtained the innovation source from the deep-sea ship owner and tech firm interviewed in this thesis, whereas they are reliant on that external knowledge and resources. They were still in a progress of bringing these innovations into their organization as such technology had not been utilized on OSVs yet, and though the technology itself was considered mature, it was “less mature than for deep sea vessels as the interface and feasibility for OSV needed to be studied”.

The findings indicated that both these informants suggested that the stakeholders should seek a common technology across, and not have individual ship owners driving their own separate innovations with different technologies. They proposed that a standard should be agreed, and expressed that the Norwegian Continental Shelf could be ideal to achieve this, if the E&P companies in this eco-system could come together and drive this development for offshore supply vessels. Informant 1 also indicated that “long term contracts would be required to support ship owners, for instance 10 years”.

So how are the E&P companies on the NCS obtaining their innovations and knowledge?

When speaking to both the E&P company (informant 4 & 5) and the classification society (informant 7), they both referred to the Technical Readiness Level (TRL), ref. attachment 8.2, of the technology as an important tool in the process from obtaining technology to commercialize it, or operationalize it as informant 5 also referred to, as they had an operational focus to the innovation, and not the commercialization itself, as this was the incentive for the supplier.

The findings suggested that the E&P company were not involved in any on-board CCS technology for the OSV’s they were using, but had a robust concept development and technology focus.
Informant 5, who was tasked to work with technology across the whole organization, explained that they are the ones owning the process in identifying new technology, pre-qualify and the implementation of it.
In addition, they were also responsible for the E&P company technology strategy.

The findings indicated that it was mostly external R&D projects where they cooperated with suppliers and academic and research environments, and internal projects were mostly related to data handling and performance.
Informant 5 emphasized that their “strategy is to work with suppliers and have a flat, flexible and lean organization on technology internally that is able to work across business units in the organization, and not a vertical technology department with a CTO on top as intention is to utilize external knowledge and resources”.

Informant 5 also suggested that their control of risk and opportunities “follows indirectly by their principles of maturity of the technology and the size of the project, meaning the overweight of the projects should not represent the very early phase projects but also not the over-mature projects that are already ready for implementation”.
They would also weigh them on the timeline (majority 3-5 year, but larger and/or higher risk projects could typically have a longer timeline), i.e. likely timeline to commercialize the project.

The E&P company had an alliance structure with some of these key suppliers, whereas informant 4 were involved in one of these alliances.
The informant explained that they were involved early in a concept development phase to provide input, though they had no formal decision-making in that early phase.

The findings suggested that their alliance partners could also be involved in certain innovation initiatives related to sustainability, where the E&P company would also contribute financially. These initiatives could be driven by the alliance between partners, i.e. not involving concept development and technology in the E&P company.
According to informant 4, the alliance "often saw that there is typically a good dialogue between supplier, tech environments and customer, where technology is funded and developed. But that it often ended up with technology not being used, as the operational part of the organization deemed it too high risk to take the technology into use".

From their aspect, it's important to build confidence in the technology over time and consider TRL (technology readiness level). The TRL would not be the best model to weigh risk and cost considering that the risk is typically with E&P company, and not the suppliers, and could be a barrier against new tech. However, the suppliers in the alliance showed a better understanding of this risk than suppliers outside the alliance.

A part of the stakeholders is also the classification society which typical support the likes of tech firm and ship owner when obtaining new technology.
The findings showed that they had mostly internal knowledge and resources, but some cooperation with research institutes and vendors. According to informant 7, they saw a challenge that there was a lack of external knowledge with regards to alternative fuel, but for CCS they were working with companies that had experience with land-based CCS and how to assess that risk. Informant 7 indicated that the "CCS technology itself was proven, with a TRL of 6 or 7, whilst the CCS handling and offload part would probably represent a less mature phase with a TRL of 4 or 5".

4.2 Integrating

According to West & Bogers, obtaining the knowledge is only half the battle, and in order to profit from knowledge, the external knowledge must be integrated into the firm's innovation activities (West & Bogers, 2014, pg. 821).

As to the case studied, findings showed that both ship owners who were involved in implementing on board CCS (deep-sea and OSV) did not possess any internal R&D department and the internal R&D activities were limited whereas the CCS innovation was more or less individual driven with few internal resources.
According to informant 1, the OSV ship owner was still early in the obtaining phase where they were trying to facilitate a feasibility study with the tech firm and a shipyard, whereas they had approached an E&P company for further funding and investment.
If they could go ahead with such a feasibility study, the informant advised that the technology firm and a shipyard, could produce design and drawings of a CCS system on board an OSV, and calculate CAPEX and impact to OPEX of the vessel, with a theoretical calculation of how much CO2 that can be captured, whereas the informant indicated that they "realistically could capture 70-80% of the CO2, and remaining, if using bio-fuel, they believe possible to achieve net zero."

The findings indicated a potential barrier of a risk of resistance from the shipyard when introducing new technology as the deep-sea ship owner, the technology firm and the CCS service provider had experienced such in the past, for instance when new exhaust gas cleaning solutions were introduced, where informants 3 and 8 were involved.
Informant 6 suggested that the "traditional shipyard don't typically like risk, but focus on low margin, high turnover and standardized design", and they saw that the yard "didn't really take into account the lifetime cost of vessel, including attributions to a low OPEX". they had found it difficult to find a shipyard during the tender phase that was willing to use engineering resources (considering new technology impacting design), as they were reliant on external knowledge and resources from engineering companies to do feasibility studies for their upscaled CO2 vessels.

However, informant 3 emphasized that they do see a "different environment and attitude from various shipyards when it came to CCS considering the drive and requirements for reducing emissions, but also as CCS introduced a less design change than introducing new fuel technology like ammonia or methanol".

Informant 8 explained that they carefully considered yard in such an innovation aspect, and that they had shortlisted 5-6 pre-qualified shipyards in Europe and the Far East.
Specifically for the CCS innovation they were selectively looking at a yard that had previously experience in retrofitting exhaust gas cleaning system on their vessels.
According to the informant, they saw it as an "incentive for the yard to be the first to do a CCS retrofit as such can be used for marketing purposes".
Other findings also supported this, as informant 6 explained that they saw a few shipyards who "saw market opportunities in a potential emerging market with this new technology as the technology itself would be owned by the shipyard or their subcontractors", as the CCS service provider would not take any incentives for the design.

According to informant 6 the shipyards were to a "large extent an assembly yard, and they would typically outsource the majority of engineering to subcontractors, for instance the cargo handling system, which was one of the key innovations" for their vessels, but emphasized that it would be a "commercial challenge if they intervened with the subcontractors as that responsibility would lie with the shipyard as a turnkey provider of the complete vessel". Findings indicated that they would engage with vendors who were responsible for delivering critical deliverables to the vessel, such as the cargo handling system.
Informant 8 suggested, based on their lesson learned on new technology, that they would "interact more with the various key suppliers to ensure correct deliverable, even though the work scope was outsourced to the shipyard (yard supply)".

Informant 8 was also adamant that the shipyard needs to be involved early to ensure that they "understand the work scope and integration, and to avoid a dispute around the responsibility once the vessel is in the yard", where the yard would need to "detail the physical location of the system, based on the P&I (piping & instrumentation) drawings issued by supplier and ship owner".
A high grade of flexibility and risk sharing was required, according to informant 8, where it was emphasized that "written contracts and commitments in every detail would stagnate the progress in an innovation process, resulting in the innovation not being realized".

This was also pointed out by informant 3 where they emphasized the importance of "involvement of the customer who should be interested in a successful innovation and who is willing to find solutions during the innovation process." In a radical innovation, they also point out that in an innovation process such as CCS, it should not be "over-designed with all eventualities as that could introduce a significant cost". The informant saw it as vital to install the system that was designed and fit for its purpose, test it and then optimize the technology. According to the informant, it's more difficult to remove elements than add them once the system is installed onboard.
In other words, the findings suggested that a too complex, and consequently costly, innovation, could be a potential barrier to a successful innovation process.

Informant 3 referred to different internal business models where some parts delivered a specific complete product, whilst other parts of the organization had a more complex system focus, such as with CCS technology, where several parts and equipment were delivered and the integration and installation was dependent on a collaboration between the various stakeholders where the design would vary from project to project, such as the tech firm, ship owner and ship yard if retrofitting a CCS system on supply vessel.

According to informant 3, the tech firm would rely on external resources and knowledge, such as ship design firms, to integrate a CCS system to an existing vessel, whereas the tech firm would typically be involved in the basic design development but would not involve themselves significantly in the detailed engineering phase, as "experience showed such phase was best handled between the shipyard and the ship owner".

As to integrate their innovation in collaboration with the shipyard, informant 3 explained that some shipyards in the Far East did not hold such innovations between the stakeholders confidential, and they could shortly after discovering that local competitors were suddenly in possession of their technology. As such, the tech firm was careful in sharing too much information and engineering drawings with the shipyard to protect their value creation. To control this barrier and ensure a successful flow in this innovation process, the informant emphasized the importance of having their own representative locally in the shipyard, and also pointed out that it is "easier to protect their innovation in a retrofit project compared to a newbuild vessel", as this could potentially involve shipyard in other geographical areas than Far East, where they saw it as a particular challenge to protect such confidentiality.

The findings indicated a focus on capturing learnings, as informant 8 explained that they had been collecting lesson learned thorough out since 2011 when started with exhaust gas scrubber system, and had seen for instance that an additional engineer was required as more equipment had been introduced on board.
Another learning was the importance of "involving their crew early and get their understanding of the technology, to build their confidence and knowledge".
According to informant 6, they were contractually committed to ensure all their lesson learned were registered continuously in the project they are involved in, i.e. facilitating rapid information retrieval.

Findings also showed that the E&P company experience challenges when it came to capture learnings from innovation processes. According to informant 5, they used an implementation plan that would typically cover the innovation process from TRL 1 to TRL 7 (see attachment 8.2), whereas requirements would be defined when TRL 7 was met and what kind of further actions had to be done at this level, including lesson learnt. The challenge was that the

“project would potentially already be disbursed at this level”, so whom to share the lesson learnt with and how to capture it?
Often, they saw that such learnings were not captured. To counteract this, they had, according to informant 5, a quarterly review “focusing on status of each project and had formalized a project close-out report where it was detailed what had been achieved and a roadmap (next steps) to further implementation”. This had been “implanted to have systematic or structured way of capturing learnings”.

From the shipyard perspective it was not identified during the data collection what kind of internal R&D resources they possess, but it’s likely to assume that such would vary depending on the business model of the shipyard. For instance, yards like VARD Group (Vard, 2023) and Ulstein Group (Ulstein, 2023) who have an innovative branding with new ship designs etc. could possess strong internal R&D resources, whilst a typical repair or assembly yard could have a limited R&D resources and portfolio, as also indicated by the samples.

The finding showed that the classification society would typically approve the design on the vessel and support the other stakeholders in assuring quality and analyzing the risks involved when introducing new technology.
According to informant 3, they were progressing with the approval in principle for the on-board CCS with the classification society on their vessel, and did not see this as a risk or barrier to the innovation process.
The classification society had, as indicated by informant 7, also initiated a work group to do a feasibility study in using different types of CCS technology on various types of deep-sea vessels. The work group comprised of stakeholders of a different eco-system than the case, from shipowners, E&P companies, tech firms and shipyards.
According to the informant, the class society possessed to a “large extend internal knowledge and resources for such an innovation process, both from a cooperate (finance, strategy, ESG reporting etc.) as well as the technology aspect”, where they had for “instance a technology center with extensive marine engine knowledge, and where supplier was directly involved in innovating new technology”.

Findings suggested that the footprint and integration of a CCS system can be a challenge for an OSV. Though, according to informant 7, they saw benefits with a short operation profile and high capture rate.

An important stakeholder in the eco system is the E&P companies, and their approach to how they integrate external sources of innovation., and both informant 4 & 5 emphasized the “importance of integrating with suppliers”.

Findings showed that the E&P company would normally be approached by a supplier who presented them with new innovation and technology. But informant 5 also indicated that there could also be an internal identification for improvement, where they would approach key suppliers, and “ask what kind of solutions they have in place that could reduce such cost”, and as such “suppliers were involved from day 1, with a project lead in the E&P company whom own and is responsible for the delivery, and also had some technology resources that may be involved 100% or on ad-hoc basis. In addition, would the relevant technical authority be involved in the work scope, risk analysis and pre-qualification plans”.

According to informant 5, the integration would "vary depending on the supplier, where some of them are experienced with extensive internal resources and knowledge" to carry out their innovation process, where they drive the process with little involvement from the E&P company other than they are typically setting functional requirements.
While other suppliers would need a "more integrated approach where it's a more an integral development process" between them, where resources and knowledge are shared.

It was insinuated by informant 5, that minor suppliers "may have adequate internal resources and knowledge, but that on occasions it was identified that they didn't have good enough processes in place when it came to handling of technology and risk, and how to meet specific requirement" related to the oil and gas business in the NCS. On those occasions the informant explained that they would need to integrate their knowledge and resources to mitigate that risk and ensure they would be able to meet those requirements.

According to informant 4, the E&P alliance had a "high focus on sharing and transferring knowledge and resources between the integrated alliance partners with a flat, but somewhat asset acentric structure, and also had facilitated for a shared office for the alliance".
The two suppliers formed predominantly around 75% of the alliance structure, as this was where the main knowledge and competence within their specialized field would lie.
The remaining 25% from the E&P company was mainly to integrate the knowledge and competence from the E&Ps existing assets, and to interact with these based on the project activity and need. In addition, this part of the alliance would form certain specifications, requirements, design basis etc. which would traditionally fall under an E&P responsibility as an operator for their assets.
The informant emphasized the importance of sitting together, and especially during Covid when the alliance sat apart from each other, they saw "challenges in the flow of information and knowledge in the alliance, especially considering innovation and creativity activities related to the projects".
The alliance also had incentives in place to ensure the alliance was working towards the same goal, and to avoid such silo structure, where each partner could focus on their own gains and losses. One of the alliance's purposes was to especially "counteract such focus to avoid delays and/or unforeseen changes/costs".

Findings showed that historically there had been limited sharing of new technology across the various BUs (business units) and Assets in the E&P company, where projects had been initiated on an individual basis without identifying needs across the organization. Also, informant 4 highlighted the challenge that lesson learned between projects were not shared and interacted before the project was completed, which could typically take 2-4 years, as "after 4 years, it would probably already be too late to capture those learnings".

The finding suggested that an innovation process in the E&P company had typically run separate from the BUs up to TRL 4, as to where the integration would take place with the relevant parts of the organization.
However, a typical barrier that informant 5 highlighted, was that they had "developed a technology innovation without integrating sufficiently with the end-users which resulted in that the assets didn't see a use for it and hence the innovation process failed at TRL 4". The technology may have been "sufficiently developed and proven, but there was simply no need for it".

According to informant 4, traditionally an E&P company without an alliance structure would have a "large engineering department filling up and, in some cases, duplicating the knowledge and resources lying with the suppliers", but this had not been the strategy of the alliance, where such skills should lie on the suppliers. This had resulted in less man-hours and less cost during the various projects".
With such a strategy, they had not experienced any additional risks, but changed a focus from control of suppliers on regular basis to interaction with them on a daily basis.
Their experience, since implementing this alliance, had shown an increased predictability and confidence related to cost and schedule for each project executed.

4.3 Commercialization

To commercialize the knowledge, West & Bogers (2014) discusses the importance of aligning the business model with the choice of innovation and the commercialization strategy.

Findings suggested that the stakeholders in this case would typically have a different commercialization strategy to each other for such an innovation. For instance, the tech firm would have its value creation when selling the product (outbound), whilst the shipowners and E&P company would capture its value in a potential cost reduction (considering CO2 tax and other incentives) and through creating differentiation (vessels with CCS could obtain a competitive advantage if less emissions with less cost than other alternatives).

For the sake of this study, the focus will be the commercialization potential for the shipowner and E&P company if CCS is fitted to an OSV operating in the NCS.
But I will also touch on the findings related to the other stakeholders interviewed and their business model and strategy to an innovation as CCS.

In a CCUS (Carbon Capture, Utilization & Storage) aspect, findings showed that the Utilization part of this value chain could also release a commercialization potential, as the CO2 waste captured on board could be sold on as a product (synthetic fuel, black carbon etc.) instead of storage (subsea re-injection etc.), in a "circular economy" which was mentioned by informant 3 and 7.

Informant 8 mentioned differentiation, despite an externally sourced innovation, as the informant was adamant that the CCS would give "an advantage over competitors exploring alternative fuel technology considering the fuel cost difference between the two technologies. As findings indicated that they were one of the first ship owners looking at onboard CCS, the informant also believed this would give them a "head start compared to the competitors".
The informant expressed that they had "very good response from their customers so far as to introduce onboard CCS technology" on their vessels, whereas they had in place Letter of Intent (LOI) with customers for long term contracts.

Findings showed that there were still some uncertainties on how this would be handled commercially with the charterers/customers, such as who would own the emission/CO2 waste and who would take the cost to capture the CO2. Considering the complexity and integration with other ship systems, the informant was adamant that the equipment itself would need to be owned by the ship owner.
For the CO2 waste, it was according to the informant two options; either it would occur as an additional cost, or it could be utilized and sold. The utilization part was considered "still

immature, but saw a large potential, as CO_2 reception facilities and hubs are emerging in large port". In line with this, it was mentioned a potential in CO_2 utilization such as "synthetic fuel and artificial fertilizer as these reception facilities would emerge".

As previously mentioned, the ship owner had not strategy in place to acquire and commercialize the technology, but according to informant 8, they considered that it "could be a discussion with the supplier if the innovation would be a success", as part of the design had been developed by them.
The informant emphasized again that the main importance for them was "up-scaling and installing this on all their vessels to differentiate themselves and give them an advantage over the competition".
The main barrier informant 8 considered for the CCS was of "technical nature and to secure sufficient funding to see the innovation process" through.
Findings indicated that neither of the ship owners involved in CCS had not had much focus on the CCS value chain.

Informant 1 argued that incentives from relevant E&P companies in this eco system needed to be in place for them to progress with such new sustainable innovation.
Informant 2 also pointed out that the risk needs to be more equally shared between ship owner and E&P company, as they "don't have the capability to bear most of such risk or cost". For instance, a "3-year contract incentive to install ammonia technology would still represent a significant risk" for the ship owner, as they could risk "other customers would not be interested in the vessel" considering additional cost and risks with ammonia.
As such, the findings suggested that incentives should typically be potential for long-term contracts in addition to a compensation in day rate of the vessel.

Informant 1 also considered onboard CCS as less potential risk than alternative fuel solutions, as it would "likely involve less intrusive integration to the ship systems than the options, hence it could more easily be removed if required".

Discussing the CCS value chain in the NCS, informant 1 was clear that their study and responsibility would "limit itself to the vessel, and that the E&P companies would need to bear the risk to handle the treated CO_2 from the OSV to onshore facilities". The findings showed that the design basis would be to collect the CO_2 in small IBCs (intermediate bulk containers) on board which could easily be lifted off when the vessel was in port.

It also mentioned by the informant that they were familiar with "initiatives related to transport and storage of CO_2 where some of the E&P companies in NCS were involved, and such could be a viable option" for their CO_2 waste, but to "develop such a business model and value chain, they did not possess the resources nor knowledge", and emphasized this "should be owned by the E&P companies in the eco-system, as the emissions should also belong to them when the vessels are on their charter".
Findings showed that the resources of the ship owner would be limited to follow up the on-board CCS project with shipyard and technology firm.
As for the utilization part, informant 1 considered it likely that the "CO_2 would go to storage and reinjection to dedicated CO_2 wells".

Findings suggested that the barriers and key aspects to succeed with the innovation could be the will to invest and own the value chain, i.e., facilities to handle and receive CO_2, and to identify CO_2 handling cost and potential business model (identify upsides and incentives).

Speaking to informant 6, it was pointed out that the “main challenge is to make the value chain work”, where their main focus was to commercialize the carbon transportation and storage business by transporting CO_2 from customers shore terminals to permanent well injection storage. To succeed in such, it was emphasized the importance of “upscaling the volume of CO_2 being transported and stored”.
To achieve such, the informant referred to “carrot and stick, where the carrot would typically be governmental subsidies (for instance the inflation reduction act (Inflation Reduction Act, 2022) in the US and the future CBAM (European Commission, 2023) in Europe), whilst the stick would represent penalties through CO_2 taxation and EU ETS (EU ETS, 2022)”. Regardless, the informant considered it a “matter of time before it would simply represent a compliance issue”.

Findings indicated a potential barrier for onboard CCS for an OSV, as it would represent low volumes and hence higher costs, and according to informant 6 they were “not in a position to handle such low volumes of CO_2”, as their reception facilities were “only facilitated for large carriers where the CO_2 would be re-injected for storage in a subsea well”.
The informant indicated that on a long-term basis they “hoped a community could arise around the reception facilities to potential utilize CO_2, in addition to storage”, and mentioned they’ve had “interest from companies who wanted to develop business like bio-fuel and direct air-capture”, and as part of this, “truck receiving facilities could also merge, which could potentially be a CO_2 handling solution for OSVs with CCS technology”.

The findings also suggested a potential barrier related to the Carbon intensity indicator (CII) and its rating (IMO, 2023), as it presently didn’t cover carbon capture for vessels when calculating the rating, which would result in rating getting worse and being penalized for having CCS on board. According to informant 7, “The Norwegian and Korean authorities were working towards IMO to get this included” and they “had gotten positive feedback so far, and considered it likely that this would be included from June 2023”.
Findings indicated that this would be an important incentive for ship owners to use CCS to decarbonize their fleet.

Informant 7 also pointed to the commercialization barrier related to CCS, where it was seen as “unclear who owns the downstream (CO_2 handling and storage) and exactly what cost would be involved for the full life cycle”.
Findings showed that early studies had indicated “an estimate 30-40% extra in CAPEX for on board CCS, whilst fuel cost and maintenance (OPEX) would represent roughly a 20% increase”. For the whole CCS value chain, they indicated a “rough cost of 250 $/t CO_2”.

The findings suggested that the “CCS technology itself was proven, with the capturing system on a TRL 6 or 7, whilst the CCS handling and storage was seen less immature with a TRL of 4 or 5”.
Another risk informant 7 mentioned, was the lack of definition by international and local laws, and that their “work and studies were largely based on risk-based assessments without having the full understanding of how the legislation would appear”. But this could be “easier managed in a small eco-system with less stakeholders to get a local legislation in place that would be fit for purpose, compared to a global aspect”.

It was also pointed out by the informant that the main driver at the moment would be to "penalize and incentivize to motivate stakeholders to capture and store CO2, and that the CCS value chain and waste handling was still an unknown and potential barrier".

According to informant 3, they saw that there were several market opportunities within CCS, especially onshore, but had considered "their core competence and expertise was to install such system on ships, and that this was where they could differentiate themselves in a competitive market".

Informant 3 considered the commercialization aspect for the ship owner to have two main drivers:

- Economic incentives, such as an increase of the Norwegian CO2 tax and competitive cost of CCS technology vs fuel alternatives such as ammonia, hydrogen and methanol. Inclusion of CCS in CII would be an important factor.
- Cost savings as most infrastructure for fuel exists if continue using carbon-based fuel types, with exception of reception facilities of CO2.

Considering commercialization for their own part with regards to CCS, the informant saw a potential challenge to upscaling as this would demand an increase of resources and capabilities in their organization.

Findings showed that the E&P company was not part of any carbon capture innovation in this eco-system but was involved in several technology innovations, and that their strategy on commercialization was to support suppliers and strengthen their own competitiveness through strengthening their suppliers and their competitiveness.

According to informant 5, patents and commercialization of a product itself was not part of the strategy, but there "would be an agreement in place to ensure their user rights, as they would want to avoid being part of a larger system delivery".
In principle in an innovation process, they would try to cover the investment cost from the supplier, as the risk sharing should go both ways and to ensure there is a commitment from the supplier to see the innovation through. But there would be no business model in place for the E&P company to earn directly of the innovation, and they would want to motivate the suppliers in increasing the volume for a successful innovation, as this would increase it's robustness and further development of the product.

Informant 5 saw typically a too large gap between R&D completion until the asset started using the technology, where typically operational aspects could be missed out, as a barrier to commercialization/operationalization
To counteract such, the informant meant "operational experience earlier in the R&D development could minimize such a gap, and that the end goal should be more clearly defined from day 1".

As for collaboration across the E&P companies in the eco-system, the informant expressed that this was something they "tried to do in various projects when introducing new technology and innovation processes".
An alternative was also Offshore Norge (Offshore Norge, 2023), which is an employer and industry organization for companies with activities related with the NCS, though "experience had shown that innovation processes that way can be cumbersome and time consuming".

4.4 Interaction

When utilizing external sources of innovations, West & Bogers (2014) refers to interaction mechanisms between the stakeholders which span across their four-phase process model (figure 1).
These mechanisms would include feedback, reciprocal interactions with cocreation partners and integration with external innovation networks and communities (West & Bogers, 2014, pg. 824).

Several of the informants raised the need to effective capture learnings, where for instance the CCUS service provider has even a contractual commitment in their innovation process to register and feedback their learnings as the innovation progressed.
Other stakeholders mentioned the challenge of receiving such feedback and learnings in due time to capture them, for instance as discussed with the E&P alliance team when taking in use new technology.
As for the case itself, the OSV shipowner also argues that one of the upsides of the CCS technology they are considering is that they can establish feedback loops from the technology firm and deep-sea ship owner that are already progressing with that technology.
As such, one can argue that the innovation case would not represent only a linear approach, but more a hybrid innovation process, containing feedback loops.

Findings showed that both the deep-sea shipowner and the technology firm accented their collaboration with universities and research societies when developing the CCS technology. In addition, they had also established a close collaboration between themselves, where the tech firm could be considered the innovation creator whilst the deep-sea ship owner would be considered the firm seeking the innovation.

According to informant 1, the OSV shipowner considering CCS also discussed such collaboration, but such interaction had been limited as they were still early in the innovation process.
As for the other OSV shipowner and E&P company they had, according to informant 2, established processes, such as committees, where such collaboration between themselves and relevant suppliers were facilitated.
Bot these informants however raised the challenge that often the E&P companies in the eco-system did not involve and interact with them sufficiently when evolving new technology that would affect their vessels.

Lastly, West & Bogers (2014) discusses the interaction between networks and communities in an open innovation process.
The stakeholders involved in the onboard CCS had established research and academic networks, but it was yet to determine if such would have an effect in any regional innovation process, and if the innovation process itself would be a commercial success.
Informant 5 in the E&P company expressed a lot of focus on participation and collaboration in networks to try to affect their innovation processes, even between other E&P companies in the eco-system. However, some of the informants from the ship owner side expressed a lack of or insufficient involvement between E&P companies and themselves when E&P companies were sourcing and determining new technology involving offshore supply vessels in the NCS.

4.5 Summary

Key findings:

- The carbon capture technology was linked to existing knowledge according to informant 3.
- The findings suggested that the OSV shipowner had sourced external knowledge based on the innovation process done by the deep-sea shipowner and tech firm to date but was lacking the complete knowledge if such would be feasible for a supply vessel.
- The findings indicated barriers to commercialization such as investment cost for shipowner to implement on board CCS and area of operation.
- Lack of interaction, knowledge and risk sharing between stakeholders in the eco-system was suggested by the findings.
- The findings showed potential resistance from shipyard when integrating external knowledge and new technology.
- A high grade of flexibility and risk sharing was required between stakeholders to succeed in a radical sustainable innovation process according to informant 3 and 8.
- Findings indicated that neither of the ship owners involved in CCS had obtained knowledge or focused on the CCS value chain, and it was unclear how CO2 could be transported and stored in the eco-system.

5 Discussion

5.1 Theoretical implications

5.1.1 Obtaining

The sample indicated that there is a positive correlation in achieving a successful innovation process when there is a link to existing technology, which is also discussed by Peschl et al (2010) whereas they emphasized the importance of bridging the gap between a radical innovation, but yet something that is "related and connected to existing knowledge, experiences, products, services, etc." (Peschl et al, 2010, pg.3).

As to sourcing a new external radical sustainable knowledge this may suggest that to ensure an advantage to achieve a successful innovation process, such obtained new knowledge should somehow be linked to an existing source of knowledge or resource (product, service etc.).

It could therefore be argued that if such a gap exists, it could be less likely for the sustainable radical innovation to succeed. This should however be verified by collecting more data from additional samples.

West & Bogers talks about enabling and filtering innovation from external sources whereas its particular the second key mechanism that applies in this case in establishing tools and processes for external stakeholders to share innovations (West & Bogers, 2014, pg. 820).
The data and findings suggested that such tools and processes were established with academic environments to absorb new knowledge and competence. However, the sample showed, as there was a connection to the existing knowledge, that this limited the amount of knowledge that was absorbed from these environments.
This may support the importance of minimizing and bridging this gap between new knowledge and existing.

Acceleration is considered a key aspect in a radical innovation process, and Bers et al (2009) discusses that the key to such is to build on latter knowledge and resources. Though the sample showed that the new knowledge was built on latter knowledge, it did not indicate that this facilitated any acceleration to the process. One can therefore argue that the focus on acceleration may not be that crucial to succeed in such an innovation. This also contradicts Sandberg & Aarikka-Stenroos (2014) where they point to lack of acceleration and commercialization competences as a barrier to a successful radical innovation process.

West & Bogers (2014) also calls for more research when it comes to individuals as sources of innovation. This should also be seen as a source of existing knowledge as the sample showed a specific individual that had contributed to developing new technology in a radical sustainable innovation process. As such, it can also be argued there that such further research should be done to understand the impact such individuals may have in bridging a knowledge gap.

Proposition 1:
A new sustainable and radical knowledge should be connected to existing knowledge and experience to bridge the gap between a new radical innovation and an existing technology, to succeed in a new sustainable radical innovation process.

5.1.2 Integrating

Resistance towards integrating a new sustainable radical knowledge is highlighted by Sandberg & Aarikka-Stenroos (2014) and Bers et al (2009) as a barrier when introducing a new radical knowledge.

The sample also showed that there was a potential risk of resistance from certain stakeholders when integrating new knowledge.
However, it can be argued that such resistance may be reduced if the stakeholder in question has previous experience in integration new sustainable radical knowledge.
It can be discussed if the matter of previous experience is also a matter of building an organizational culture to build confidence when integrating new knowledge.
West & Bogers (2014) also discusses the importance of organizational culture and the need for cultural changes to successfully utilize an innovation from external sources and to avoid tendencies as "not invented here" (West & Bogers, 2014, pg. 821).

If the stakeholder has knowledge and experience from previous sustainable radical innovation, it may be argued that there is a prerequisite in place that facilitates an acceleration of such radical knowledge. But this could be limited to the innovation itself and not the innovations value chain, and as the sample showed, some stakeholders who have traditionally a low absorptive capacity, as per West and Bogers hypothesis, they are less likely to use innovations from external sources (West & Bogers, 2014, pg. 821). In that light, the choice of suppliers that possess such latter knowledge and have a high level of absorptive capacity could be crucial for a successful innovation.

The type and complexity of the knowledge and innovation being integrated can also be a factor considering the risk of resistance. The sample showed that it was considered less likely with resistance compared to more complex knowledge, also as the innovation introduced a lesser change to the product.
However, to also counteract the tendency of "not invented here", as West & Bogers points to, the acquiring stakeholder should also consider a close interaction with the outbound stakeholder and utilize and integrate its resources when integrating new sustainable radical knowledge.
Such balance to combine internal and external sources of knowledge is also discussed by Rothaermel & Alexandre (2009 theory where they claim such is required to achieve a positive performance implication.

Masucci et al (2020) points out in their research the importance of retaining control of knowledge in a novel innovation to incentivize suppliers to adopt and unlock value from it. "Our findings suggest that the possibility of exerting strong control over the IP of novel technologies expedites the hub firm's pursuit of their external exploitation by enabling deployers to extract value from them. By pointing to control over IP as a mechanism to align the activities and incentives of different ecosystem actors, our study contributes to shed further light on the link between appropriability and OI in ecosystem settings" (Masucci et al, 2020, pg.12)

On the contrary, retaining such control of the knowledge may also result in resistance from certain stakeholders. By giving suppliers access to and potential ownership to the knowledge, it may incentivize them as it could give them a competitive advantage over other competitors. Though the flip coin of such, could be that the stakeholder in an inbound innovation process would naturally have some different interests, and for instance protective over their new knowledge. In such aspect, the organizational culture of the stakeholders involved should be carefully considered.

Though focusing on integrating external knowledge is an important aspect in an inbound open innovation process, it is likewise important to focus on how this external knowledge is integrated internally, especially in a larger organization. The ability to integrate external knowledge is also reliant on the internal resources in the various internal departments, and there is likewise a risk of the bias of "not invented here" between the various departments internally as to the external sources. To counteract this, relevant departments should be actively integrated to ensure ownership of the new radical knowledge is obtained across the organization. In such a way one is not only integrating the external knowledge in the innovation department, but also trying to involve other internal departments in the integration phase, to counteract the "not invented here" tendency, though in a bit different internal aspect than described by West & Bogers.

West & Bogers also addresses the substitution effects where firms with strong internal innovation resources are less likely to have interest in external innovations.
Such substitution effects were also found in the sample, and it shows that in the inbound process the stakeholder sees less value of the external sources of knowledge, despite there might be a need to absorb some external knowledge.

Proposition 2:
There is a potential barrier and resistance when integrating new sustainable radical innovation, however such resistance may be reduced if the stakeholder has knowledge and experience from previous sustainable radical innovations.

5.1.3 Commercialization

West & Bogers (2014) talks about measures of value creation and capture.
In the value creation, they point to that evidence shows that firms are reliant on external sources of knowledge to create value using externally sourced innovation.
The evidence from the sample showed that this is the case here as well between the relevant stakeholders, however though external sources of knowledge for the innovation itself is obtained, there seems to be an uncertainty and lack of knowledge of what type of external knowledge is required to succeed in a value chain that is not developed yet for a new radical sustainable innovation.

When obtaining and integrating new radical sustainable knowledge, there is a risk that the value chain of such innovation is also immature. Such a barrier can be complex to handle as it may involve several stakeholders with different interests and capabilities, and such an immature value chain can demand significant resources and costs.
It can also be argued that the focus on the value creation is not sufficient in the early stage of the inbound innovation process (obtaining and integration), where a typical focus would be first and foremost to get the knowledge integrated and the innovation to work, without understanding the knowledge required on how the entire value chain will function.

Across the analytical framework of Aarikka-Stenroos & Lehtimäki (2014), it is also interesting to note that they recognize that the stakeholders' features may shape the commercialization process, i.e. stakeholders in a solid financial position are better placed to cover cost and ensure the required resources are in place (Aarikka-Stenroos & Lehtimäki ,2014, pg. 1374).

To obtain such external knowledge of the value chain to succeed in the commercialization, evidence for the sample indicates that closer cooperation and interaction between the stakeholders would be required to succeed in the commercialization.

According to Boons et al (2012), "the link of international competitiveness to sustainable business models resides in two key actors in the innovation system that drives many of the competitiveness factors. These two actors are entrepreneurs and governments seeking to establish markets for sustainable innovations that start at the national level but seek diffusion to the global level. Thus, competitiveness is dependent on the ability of governments to design and implement appropriate policies and framework conditions to support entrepreneurs to implement new sustainable business models with new technologies and services." (Boons et al, 2012, pg. 5).
Such drive, as governmental incentives and/or penalties, seems vital to a sustainable radical innovation that could represent a potential significant cost increase, not only considering the investment cost but also related to operation cost, as the innovation itself may be more drive by sustainable and environmental purposes rather than financial purposes. And as such, the innovation and values chain may be reliant on such conditions to facilitate a successful commercialization.

As for the value capture, West & Bogers (2014) discusses how external sources of knowledge can improve profit by reducing cost or increasing prices. They also discuss the differentiation and how internally sourced unique knowledge compared to externally sourced knowledge could impact such differentiation and competitive advantage.
A sustainable radical innovation is likely to have a cost increase, as discussed above, and potentially reduce the profit. The main drive could be to meet future demands and regulations from governments, regulators and customers. There could be a realistic reduction of cost if for instance an innovation would reduce emissions sufficiently to avoid a future substantial emission tax.

Proposition 3
There is uncertainty of how external sources of knowledge will create value in an immature value chain for a sustainable radical innovation.

5.1.4 Interaction

Geissdorfer et al (2018) discusses the importance of engagement in extensive interactions between stakeholders in a sustainable innovation process.
Evidence from the sample suggests also that there is room for improvement between the stakeholders in interacting with each other in the obtaining and integration phase in a radical sustainable innovation process. To succeed in these phases, the stakeholders should perhaps focus more on how the resources and knowledge across can be more integrated, i.e. shared offices, common processes, budgets etc.

It can also be argued that the risk sharing between the stakeholders in a radical sustainable innovation can be unclear, and that such should be clarified between relevant stakeholders to avoid a conflict of interest and to ensure the correct incentives and motivation are in place, especially when considering the commercialization of the innovation. For a radical sustainable innovation, typical long-term incentives as the innovation can represent uncertainty should be considered to reduce any risk for relevant stakeholders.
As discussed in the commercialization above, it is also of importance to interact and understand the whole value chain of the innovation between the stakeholders when evaluating the risk sharing between them.

As understanding the structure and management of the innovation network and communities is of importance, likewise is it to gain an understanding of how they consider the organizational culture within their respective organizations and network, with emphasize on flexibility, external orientation and growth.
Green & Cluey (2014) point out that our attention should shift from structure to culture, to explore the effects of radical innovation rather than its causes.
However, for a radical sustainable innovation it is perhaps more important to focus on the flexibility and adaptability between the stakeholders as important factors to ensure the innovation process does not stagnate.
Such is also argued by Büschens et al (2013) as important aspects in a developmental culture that "emphasizes flexibility, external orientation and growth as an organizational end" (Büschgens et al, 2013, pg. 142).

West & Bogers (2014) discusses a firm-to-firm collaboration in a community, but it's interesting to note that it's indicated that such a collaboration between stakeholders in a radical sustainable innovation is indicated as more efficient in a network rather than through a community.
Could the motivation for the firms differ between the two?
It's pointed out by West & Bogers (2014) that more research is required on the motivation of external collaborators, especially considering non-profit motivations.

As for the feedback mechanisms, West & Bogers (2014) discusses models that include feedback loops, and the need for "probe and learn".
In a radical sustainable innovation, such feedback mechanisms should be facilitated in means of ensuring that lessons learned are continuously registered and shared across the stakeholders involved in the innovation process. In that way, one is also facilitating rapid information retrieval, as discussed by Bers et al (2009).
West & Bogers (2014) talks about a dyadic cocreation in a reciprocal innovation process, where a "reciprocal exchange of knowledge in cocreation and other collaborative innovation process" would take place outside the firm (West & Bogers, 2014, pg. 824). Such cocreation of knowledge and collaboration is also of importance when obtaining external knowledge and such would typically involve collaboration between relevant stakeholders and academic institutes, such as universities and research societies, as the sample here has also shown.

Choice and concept of business models as identified by Boons et al (2012) is also an important aspect to consider in achieving a successful innovation, and as earlier mentioned, the business model for the sample seems unexplored as the stakeholders have merely focused on the technical challenges of the innovation at hand, and not the value chain.

Proposition 4:
There is insufficient interaction and risk sharing between the stakeholders to succeed in a radical sustainable innovation when obtaining, integrating and commercializing new external sustainable radical knowledge.

5.2 Practical implications

5.2.1 Technical implications

An open, radical, sustainable innovation may have benefits in succeeding if external source of knowledge is connected to existing knowledge. The sample showed that the technology had been developed and, in some respects, proven, but was yet to be installed and tested, including a feasibility study that was yet to be completed.

However, a significant technical challenge in an eco-system for a radical sustainable innovation may be to explore, understand and determine the value chain for such an innovation, as new technology could require a new and more complex infrastructure, which could demand significant resources and funding from relevant stakeholders.

5.2.2 Financial and Governance implications

For a radical sustainable innovation to succeed it seems crucial that governmental incentives/penalties are in place, and/or funding from stakeholders who are in such a financial position.

As discussed earlier, if there is a lack of interaction between stakeholders in a radical sustainable innovation, this may result in an uncertainty in the eco-system on the investments required to make the innovation successful, such as the value chain and infrastructure required in place for a new technology. The lack of interaction may also prevent a unified approach between stakeholders in identifying a suitable sustainable radical innovation for an eco-system, i.e. may result in silo thinking.

On an executive level, the stakeholders involved in a radical sustainable innovation should consider establishing work groups or other business models, such as joint ventures, to enable and understand technical challenges and feasibility, value chains, conflict of interests, risk sharing and potential business models.
This could again counteract the lack of interaction between the stakeholders. Such a work group should also focus on how to facilitate a high grade of flexibility without triggering commercial and contractual discussions, but ensure incentives and differentiation are in place to drive the innovation process.

Stakeholders involved in a radical sustainable innovation needs to carefully consider the costs, both investment costs (CAPEX) and operational costs (OPEX) related to a radical sustainable innovation, as the sample showed example of an increase from 20-30% to 300% depending on the technology chosen.
The investment cost could also vary significantly depending on the technology.
The market and eco-system, and potential new markets, for the innovation should also be considered as this may significantly affect the success of a radical sustainable innovation.

There are several aspects a management should consider before managing a radical sustainable innovation.

- In which market and eco-system the radical sustainable innovation process will take place, and possible consequences such innovation may have to other market and eco-systems.
- Identifying a business model for the innovation in the eco-system involving relevant stakeholders, identifying value chain, risk sharing, infrastructure etc.
- The technical feasibility of the technology and how mature it is.
- Choice and management of suppliers/contractors involved in the new technology.
- Which regulatory and governmental drivers are in place, such as governmental incentives and/or penalties.

5.3 Limitations and further research

The various stakeholders interviewed may also have a different perspective to the case at hand considering the four-phase process model by West and Bogers. For instance, the technology firm would look at the innovation commercialized once the technology is installed on the vessel, whilst the vessel operator and/or E&P company may focus on the ability to commercialize the disposal of CO_2.
As to the inbound innovation, there were informants (like the technology firm) that would have a typical outbound focus as well due to the nature of their business (to develop and sell innovating products and systems), which had to be taken into consideration.

The analysis has considered the various aspects, whereas the main focus has been the commercialization aspect from the ship owner and E&P company.

The number of informants could have been increased to ensure broader data collection. Such as data from only one E&P company in the eco system was collected, due to resource and time constraints. It would have been favorable to include one or two more E&P company samples.
Throughout the interviews, it also became apparent that an informant representing a shipyard sample would have given the thesis a more thorough database.

The sample should have also included more cases to retrieve a wider data collection to answer the research question at hand.

West & Bogers (2014) discusses that there are still major gaps from an innovation is integrated and finally commercialized. The findings in this thesis as well indicated that more research is required, as for instance indicated by informant 5 where they often saw that new technology in the E&P company often failed at TRL 4.
The case for the thesis also indicated uncertainty for the integration and commercialization phase as feasibility for CCS technology on an OSV was not yet determined, and also the value chain was not mature, and it was uncertain how such an infrastructure would be established.

Geissdoerfer et al (2018) also calls for more research on sustainable business models and on the challenges it faces and why there is low implementation success rate. Such further research is also supported by the findings, where an implementation of a CCS value chain and how collaboration and interaction between the relevant stakeholders needs to be identified and established.

6 Conclusion

How is knowledge and resources from external stakeholders in an industrial ecosystem obtained, integrated and commercialized in an open radical sustainable innovation process?

The sample and findings showed that when obtaining the knowledge there was a focus on that the radical sustainable innovation was linked to existing knowledge, as this would give more confidence to a successful innovation process.
The stakeholders are typically reliant on external knowledge and resources from suppliers in the eco-system and academic environments, and there could be a potential lack of understanding within a complex technology organization where a concrete competence and experience is required to process a radical sustainable innovation.

Between the obtaining and integration phase, the stakeholder should consider to early involve suppliers/sub-contractors to facilitate open knowledge sharing between the stakeholders to identify how the knowledge and resources can be integrated in the innovation process.
The stakeholder should also consider having dedicated resources to manage the innovation with the supplier/sub-contractors, especially when moving into the integration phase.

Secondly, the stakeholder should source what kind of knowledge and resources that is required for the innovation to create value to commercialize, as a radical sustainable innovation may impose significant requirements to value chains and infrastructure.

Conclusively, the stakeholder should consider establishing work groups, forums, joint ventures or similar, to ensure interaction between the stakeholders throughout the four-stage innovation process can flow uninterrupted between them to ensure continuous learning, knowledge sharing, risk sharing and use of resources.

7 Litterature

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8 Attachments

8.1 Interview Guide

Vessel Owner / Operator	
Open questions	**Follow up questions**
Introduction – who you are and what you do in the organization?	Main mandate and goal?
What does sustainability mean today for the organization?	How is the organization focusing on sustainability today for vessels used in their business? How does the organization consider itself; informal/flexible vs formal/inflexible?
What are the thoughts around achieving near-zero emission (by 2030 for offshore supply vessels)?	What kind of strategy is in place and what are the possibilities for investment? Are there any such investments / projects today?
How does the organization consider risks and opportunities with regards to new technology?	What type of barriers do you see? How do you consider the use of knowledge and resources if to introduce such new technology? How would you use internal sources and would external sources (knowledge/resource) be required? Are you involved in any innovation process or plan to be? How is risk sharing and access to new markets considered and managed?
How would you seek and obtain such external sources?	What kind of knowledge and resource would be required need/demand? How did you find partners if already in an innovation process /project?
How would such an innovation process be integrated in your organization?	Would you structure your organization differently? How? How would you integrate external knowledge/resources, and what type of knowledge and resources would be needed?

	How would tasks be done by internal sources? Any thoughts around the ability to absorb the external knowledge?
How would you interact with other stakeholders in such an innovation process (network/clusters)	Are there stakeholders in existing network/clusters you would involve? Partly or fully involved?
How could such innovation process / new technology be commercialized?	What type of barriers do you see to commercialize? What markets and opportunities do you see? Any specific business model?
How do you define your organization culture and how is this supported?	What do you believe is important to promote in your culture? Any particular elements related to an innovation process?
How does the organization consider CCS technology and has this been considered for their vessels?	Any strategy aspects from the organization related to CCS? How would the organization consider risks/opportunity specific towards CCS? What would be the drivers to implement such technology? Incentives from government?
What kind of process would need to be implemented to introduce such technology?	What do you see as the key aspects to succeed with such innovation? What do you see are the barriers? Have latter knowledge and experience been considered to facilitate rapid information retrieval and lesson learned (acceleration)?
Any other operational aspects to CCS?	OPEX/CAPEX? Logistics etc.? Commercialization (Utilization (CCUS))? Business model?
How do the organization see the future for their vessels 10 years from now considering the demand for sustainability?	

Technology, service provider of CCUS and class society	
Open questions	**Follow up questions**
Introduction – who you are and what you do in the organization?	Main mandate and goal?
What does sustainability mean today for the organization?	How is the organization focusing on sustainability today towards shipping and vessels for their business? How does the organization consider itself; informal/flexible vs formal/inflexible?
What are the thoughts around supporting near-zero emission (by 2030 for offshore supply vessels)?	What kind of strategy is in place and what are the possibilities for investment? Are there any such investments / projects today?
How does the organization consider risks and opportunities with regards to new technology / carbon capture?	What type of barriers do you see? How do you consider the use of knowledge and resources if to introduce such new technology? How would you use internal sources, and would external sources (knowledge/resource) be required? Are you involved in any innovation process or plan to be? How is risk sharing and access to new markets considered and managed?
How would you seek and obtain such external sources?	What kind of knowledge and resource would be required need/demand? How did you find partners if already in an innovation process /project?
How would such an innovation process be integrated in your organization?	Would you structure your organization differently? How? How would you integrate external knowledge/resources, and what type of knowledge and resources would be needed? How would tasks be done by internal sources?

	Any thoughts around the ability to absorb the external knowledge?
How would you interact with other stakeholders in such an innovation process (network/clusters)	Are there stakeholders in existing network/clusters you would involve? Partly or fully involved?
How could such innovation process / new technology be commercialized?	What type of barriers do you see to commercialize? What markets and opportunities do you see? Any specific business model?
How do you define your organization culture and how is this supported?	What do you believe is important to promote in your culture? Any particular elements related to an innovation process?
How does the organization consider CCS technology and are they involved in any such projects related to shipping?	Any strategy aspects from the organization related to CCS? How would the organization consider risks/opportunity specific towards CCS? Is it technically feasible for a supply vessel and what would the cost aspect be? Is it achievable to gain zero emission with such technology? What would be the drivers to implement such technology? Incentives from the government?
What kind of process would need to be implemented to introduce such technology?	What do you see as the key aspects to succeed with such innovation? What do you see are the barriers? Have latter knowledge and experience been considered to facilitate rapid information retrieval and lesson learned (acceleration)?
Any other operational aspects to CCS?	OPEX/CAPEX? Logistics etc.? Commercialization (Utilization (CCUS))? Business model?
How do the organization see the future pf CCS technology and the use of this for ships, especially, offshore supply vessels	

E&P Organisation	
Open questions	**Follow up questions**
Introduction – who you are and what you do in the organization?	Main mandate and goal?
What does sustainability mean today for the organization?	How is the organization focusing on sustainability today for vessels used in their business? How does the organization consider itself; informal/flexible vs formal/inflexible?
What are the thoughts around green transition / achieving near-zero emission (by 2030 for offshore supply vessels) in the alliances?	What kind of strategy is in place and what are the possibilities for investment? Is there any experience in choice of type of strategies when introducing such transformation in the organization? Are there any such investments / projects today? How is the organization focusing on sustainability today for vessels used in their business?
How does the organization consider risks and opportunities with regards to new technology?	What type of barriers to you see? How do you consider the use of knowledge and resources if to introduce such new technology? How would you use internal sources and would external sources (knowledge/resource) be required? Are you involved in any innovation process or plan to be?
How would you seek and obtain such external sources?	What kind of knowledge and resource would be required need/demand? How did you find partners if already in an innovation process /project?
How would such an innovation process be integrated in your organization?	Would you structure your organization differently? How?

	How would you integrate external knowledge/resources, and what type of knowledge and resources would be needed? How would tasks be done by internal sources? Any thoughts around the ability to absorb the external knowledge
How would you interact with other stakeholders in such an innovation process (network/clusters)	Are there stakeholders in existing network/clusters you would involve? Partly or fully involved?
How could such innovation process / new technology be commercialized?	What type of barriers do you see to commercialize? What markets and opportunities do you see? Any specific business model?
How do you define your organization culture and how is this supported?	What do you believe is important to promote in your culture? Any particular elements related to an innovation process?
How does the organization consider CCS technology and are you aware or involved in any such initiatives or projects?	How does the organization consider CCS technology and how is the organizations positioning itself with regards to such implementation , if relevant? Any support/incentives considered? Any strategy aspects from the organization related to CCS? How would the organization consider risks/opportunity specific towards CCS? What would be the drivers to implement such technology? Incentives from government?
What kind of process would need to be implemented to introduce such technology?	What do you see as the key aspects to succeed with such innovation? What do you see are the barriers? Has the organization any such experience? Have latter knowledge and experience been considered to facilitate rapid information retrieval and lesson learned (acceleration)?
Any other operational aspects to CCS?	OPEX/CAPEX?

	Logistics etc.? Commercialization (Utilization (CCUS))? Business model?
How do the organization see the future of CCS technology and the use of this for ships, especially, offshore supply vessels	

8.2 Technical Readiness Level (TRL), API standard (API, 2009)

Phase	TRL	Development stage	Development stage definition
System validation	7	**Field proven** Production system field proven	• Production unit integrated into intended operating system, installed and operating in the same environment and operating conditions for more than 10% of its design life with acceptable reliability, demonstrating low risk of early life failures.
	6	**System installed** Production system installed and tested	• Complies with all requirements of TRL 5. • Production unit or full-scale prototype built and integrated into intended operating system. • Full interface and functional test programme performed in intended or closely simulated environment and operated for less than three years. • New technology equipment may require additional support for first 12 to 18 months of operation.
Technology validation	5	**System tested** Production system interface tested	• Complies with all requirements of TRL 4. • Designed and built as production unit or full-scale prototype and integrated into intended operating system with full interface and functional test, but not usually in intended field environment.
	4	**Environment tested** Preproduction system environment tested	• Complies with all requirements of TRL 3. • Designed and built as a production unit or full-scale prototype and put through qualification programme in simulated environment (e.g. hyperbaric chamber to simulate pressure) or actual intended environment (e.g. subsea environment) but not installed or operating. • Reliability testing is limited to demonstrating that prototype function and performance criteria can be complied within the intended operating condition and external environment.
	3	**Prototype tested** System function, performance and reliability tested	• Prototype built and put through generic functional and performance tests. • Reliability tests are performed in relevant laboratory testing environment, including reliability growth tests, accelerated life tests and robust design development test programme. • Tests are performed without integration into broader system. • The extent of application compliance requirements are assessed and potential benefits and risks are demonstrated.
Concept validation	2	**Validated concept** Experimental proof of concept using physical model tests	• Concept design or novel features of design validated by physical model, system mock-up or dummy, and functionally tested in laboratory environment. • No design history. No environmental tests. • Materials testing and reliability testing performed on key parts or components in testing laboratory prior to prototype construction.
	1	**Demonstrated concept** Proof of concept as desk study or R&D experimentation	• No design history. • Essentially desk study not involving physical models but may include R&D experimentation. • Technology concept and/or application formulated. • Concept and functionality proven by analysis or reference to features common with/to existing technology.
	0	**Unproven concept** Basic research and development (R&D) in papers	• Basic scientific/engineering principles observed and reported in papers. • No analysis or testing completed available. • No design history.

8.3 Reflections

I started my executive MBA study back in autumn of 2016, when they launched the course International Contracts. The interest sparked as I was at the time involved in various contracts in relation to an offshore project I was engaged in.

The course was run by two experienced lawyers with backgrounds from shipping and oil & gas industry, and the quality of the lectures and course exceeded my expectations as they had a practical approach to the theory and were engaged story tellers.
In addition, the students had a broad background and experience with an age range from twenties to sixties, giving the lectures an extra dimension as the lecturers would be often challenged on some of their statements creating a dynamic interaction in the classroom.

Initially, I intended only to attend this course, but as it was very giving and interesting, I decided to consider more courses.

The next course was strategic management and business development, where the lecturer was a professor from the University. Though he had good insight and knowledge, I felt it was missing a more practical approach which maybe an external resource could have offered. And considering it's a substantial tuition fee, I'd say there also was an expectation among the students that external resources also were to be brought into the lecturer.

In Autumn 2017, project management was offered as a course, which also suited my current work situation being involved in a major offshore project.
This time an external lecturer was brought in, but unfortunately the quality of lecturers was not to expectations. I only attended two out of three gatherings due to my work situation, but for the last gathering the initial lecturer had been removed after complaints from the students as the curriculum was not covered. During the last gathering, I guess we managed to get up to speed, and successfully completed the exam by the end of the semester.

For my part, I took a semester break, as work and travelling did not allow me to study in addition. The next course I took was Leadership, digitalization and change management in autumn 2018. This was a very well-organized course with a skillful and professional lecturer in change management, which I understood was engaged in the University on ad hoc basis. In addition, they had engaged several external lecturers which gave the course a lot of extra value and increased the quality.

The following semester I attended Financial Management in decision-making, which was also run by a professor at the University. Considering the nature of the subject and the curriculum, it seemed sufficient that this was run using the Universities own resources.

After another semester break, I attended Design and management of value chains spring of 2020, which again was hosted by an external lecturer, who was very professional and full of knowledge. The last part of those gatherings was done remotely, due to the Covid pandemic that broke out. Despite this, the learning outcomes were good and valuable.

Having done all six courses, I didn't really have time nor motivation to start with a Master thesis. I would also need to set aside savings to fund the thesis, which was not really a priority at the time.

However, when I started with a new employer in September 2021, I was offered a sponsorship to complete my thesis, which gave me the final boost to see the whole MBA program through.

For me, it has been crucial to have the flexibility of the program with a full-time job and family on the side. Any queries or requests have been efficiently handled by the University and they were always very accommodating to solve any challenges at hand.

Despite challenges to some of the courses, it’s been uplifting to see that the program has only improved since I started it back in 2016, and I would highly recommend it to anyone that is motivated for more academic knowledge with a practical and experience approach.