MASTER'S THESIS

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Future Outlooks for Natural Gas and Blue Hydrogen in the Norwegian Arctic

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Preface and Acknowledgements

This master thesis is conducted as part of my Master of Science in Global Management at Nord University. The thesis is written the spring of 2022 and is a requirement for specializing in the field of global management. The idea of studying natural gas and blue hydrogens future outlooks of the Norwegian Arctic was a result of an interest of the author, combined with its relevance for the Global Management degree. I hope that my research can help build knowledge for others as well, for factors important for future investment in the Barents Sea.

This thesis is written under supervision of Dr. June Borge Doornich. I would like to thank her for guidance and support during my thesis process. Her knowledge and inputs have helped a lot in forming my thesis. I would also like to thank my contributors to interviews as they have helped me retrieve fruitful information about the arctic energy climate for my analysis.

18th of May 2022

Summary

The Barents Sea gas at the Norwegian Continental Shelf (NCS) accounts for almost 2 percent of the total global petroleum production, while more than 60 percent of the estimated total undiscovered resources on the NCS is expected to be found under the seabed of the Barents Sea. This thesis explores the need for natural gas & blue hydrogen (based on natural gas) from the arctic in the future Norwegian arctic energy outlook.

In this study, I investigate factors that influences the future outlooks of natural gas and blue hydrogen in the Norwegian Arctic. I analyze relevant reports and articles along with conducted interviews to find out what drivers and barriers are connected to Norwegian Arctic natural gas and blue hydrogens relevance in the future energy outlook. With the use of the Three Horizon framework, I identify how the future is divided into three different horizons from the current state of play to emerging futures. To understand the future outlooks of the Norwegian arctic I conducted a literature review and found that there have been few research articles previously exploring the topic. However, the three-horizon framework has been used in similar future outlooks in other studies. The interview within this thesis is conducted with key actors in the arctic energy climate as well as researchers within the field of blue hydrogen, this was done to strengthen the understanding and reliability of the thesis.

My findings indicate that there is a high need for low-cost stable options such as Norwegian arctic natural gas in the current energy picture, and that there is high relevance for a future market for Norwegian blue hydrogen as a transition fuel towards a green hydrogen driven long-term future. The most important factors for the future outlook is access to enough arctic gas, technological advancement within carbon capture and storage, and climate-factors such as reduction of methane leakages from natural gas. The Norwegian arctic gas has the potential to be a greener alternative for the future, with the use of the Three-horizon framework I try to explain how the future outlook could end up being.

1.0 Introduction

The Arctic region is expected to hold 22 percent of the world's undiscovered, technically recoverable resources (Nordregio, 2019). The region is already in fruitful exploration and development in about half of the arctic basins, including the West Barents Sea. The Barents Sea gas at the Norwegian Continental Shelf (NCS) accounts for almost 2 percent of the total global petroleum production, while more than 60 percent of the estimated total undiscovered resources on the NCS is expected to be found under the seabed of the Barents Sea (NPD, 2020).

Natural gas is gas created through decomposition and transformation of organic matter underneath the seabed and Norway is today one of the main exporters of natural gas to Europe. Snøhvit the worlds northernmost natural gas production facility located in the south Barents Sea cools down natural gas to liquefied natural gas (LNG) and exports high amounts of stable energy to the EU.

This area of natural gas develops opportunities to start producing blue hydrogen and ammonia through market leading initiatives such as Barents Blue project which was in 2021 granted 482 million NOK towards production of low-emission ammonia (Bye, 2021), the project lead by Horisont Energi is a joint project with major arctic involved businesses Equinor & Vår Energi producing the world's first and largest blue ammonia plant with close to zero emissions. A daily production of the plant is 600 tons of hydrogen frozen down to liquid and converted to 3000 tons ammonia for transportation purposes, with a yearly production of 1 million tons of blue ammonia, with 2 million tons of CO2 for storage within the Barents Sea (Enova, 2021). There is high momentum behind blue ammonia and hydrogen within the Norwegian Arctic region. Although, globally blue hydrogen is at an early stage mostly within research and development.

Blue Hydrogen is similar to the traditional and most commonly used grey hydrogen production based that is on the processing of natural gas with reforming technologies, however blue hydrogen uses carbon capture and storage technologies to avoid CO_2 from reaching the atmosphere by storing it under the seabed. A focus on blue hydrogen production for the green transition in energy can increase the need for the gas resources both undiscovered and discovered in the Barents Sea.

Norway has good conditions to adapt blue hydrogen in fields where they already have well-built natural gas infrastructure (Regjeringen, 2020, pp. 7). Along with the long industrial experience from the entire hydrogen value chain that Norway has. This puts Norway in an excellent position for an increasing hydrogen market.

The opportunity that is presented to Norway by delivering clean energy in the form of blue hydrogen to the European market is highly influenced by the policies created by the EU affecting natural gas production in the Norwegian arctic waters.

Green hydrogen a technology that is produced via electrolysis processes based on the use of renewables to power the process making the production of hydrogen emission-free, is envisioned by the EU as part of the solution. However, technological maturity along with costs sets boundaries for large-scale development of green hydrogen both globally and in the Arctic region.

There are several challenges connected to both natural gas and blue hydrogen. Technological maturity, emissions from natural gas creating issues of climate change in a critical arctic region and stranded resources.

Although there are positive prospects for natural gas and blue hydrogen development in the Barents Sea there are several challenges the Norwegian arctic faces connected to this development. Technological maturity of blue hydrogen and Carbon Capture and Storage. The Arctic region is at a tipping point of a severe meltdown. The worlds dependence on energy resources has drawn the Arctic to an unprecedented crisis point due to climate change. The climate change is the biggest treat the Arctic is facing right now. The temperature in the Arctic is increasing three times faster than the rest of the planet.

Arctic human made climate change is proven with many key indicators that imply the criticality. Decline in sea ice thickness, temperature increase, thawing of the arctic permafrost and rapid changes of the arctic ecosystems are some of the indicators proving the actuality of human made climate change in the Arctic (Arctic Council, 2021). Therefor it is critical that we find ways to adopt to the negatively changing arctic with innovations and technologies that can give us opportunities to increase energy production while decreasing emissions.

On the basis of expectations of future demand for both blue hydrogen and natural gas in the Norwegian Barents Sea. Along with the worlds increase in population with simultaneous increase in demand for clean energy whilst being on a tipping point of a climate crisis I investigate the factors that pushes or pulls policymakers from natural gas and blue hydrogen.

In my thesis I use three strategic horizons framework as a methodology, the framework stems from the UK Foresight Program's Intelligent Infrastructures (Sharpe & Hodgson, 2006). The methodology is used in my thesis to predict the future horizon of natural gas and blue hydrogen in the Barents Sea. The framework explores the future by making first assumptions explicit, then exploring the emerging changes connecting the present with the future. Three horizons have proven useful as a conceptual model in creating possible and desired futures (Curry & Hodgson, 2008). Connecting the expert interviews along with collected reports and relevant articles I create a basis of three horizons to explain a possible future of the natural gas and hydrogen in the Barents Sea.

The existing Melkøya plant at Hammerfest, opening of Johan Castberg field along with other finds in the south Barents Sea such as Wisting proves that there are quality gas resources and possibilities for application of blue hydrogen in the Norwegian Barents Sea. Therefore, I have chosen to write the thesis with the following purpose. To investigate the future outlooks for Norwegian arctic blue hydrogen and natural gas towards 2050 and beyond. Secondly, to foresee the future arctic energy climate on the basis of social actors associated with the green transition in the Barents Sea. Lastly, to build an understanding of the forces helping and inhibiting blue hydrogen and natural gas as relevant resources in the future from the present. These forces will be presented by the three following (1) forces for natural gas (2) Forces for climate (3) forces for blue hydrogen. The forces work as a broader analysis to what factors are drivers and barriers for future development of the resources.

1.1 Research Question

Therefor on the basis of what is stated above I have chosen to write my master thesis with the following research question: What are the future outlooks for natural gas and blue hydrogen in the Norwegian Arctic? Through this project I want to contribute to a deeper understanding of the opportunities the future holds for the Norwegian Arctic region within the field of natural gas and blue hydrogen. This thesis can also work as a tool in decision making for stakeholders within the Barents Sea South region, when searching for future outlooks.

1.2 Discoveries

In this thesis I have discovered that the need for natural gas extends beyond 2050 and with promising carbon capture technologies and low leakages of unburned fugitive methane Arctic Norwegian resources have a possibility to be at the forefront of clean energy development. In addition, the development of blue hydrogen as a transition fuel for future use of green hydrogen is critical in a phase where cost and technological maturity are barriers for green hydrogen. The ultimate goal of producing hydrogen however, according to interviewed social actors in the Arctic should always be to create a green hydrogen system that is technologically mature enough to run without subsidies, cost-effectively and competitively with other hydrogen technologies such as blue hydrogen.

In the following chapters I explain the theoretical framework (three horizons framework) of the thesis, followed by an extensive view of the chosen methodology. Next, I use an empirical analysis where I present the major forces affecting future outlooks these contain technical explanations for relevant technologies in the fields of natural gas and blue hydrogen such as CCS and explain the issues of unburned fugitive methane. I show different forms of gas and hydrogen to better understand the resource as well as the possibilities for the future. Furthermore, I look at the implications that production of natural gas and blue hydrogen has for the Norwegian Arctic and the Barents Sea region. Before I lift the major forces to a more abstract level through the empirical discussion, to argue their influence and explain what drives the future of blue hydrogen and natural gas in the arctic. The last part of this thesis includes a summary of the analysis and discussion along with the concluding thoughts.

2.0 Theoretical Framework

This section's purpose is to lay down the theoretical framework used in this master thesis, which will contribute to forming of the analysis at the end of the thesis. Firstly, I introduce strategical horizons as a framework to help understand how it is applicable to my thesis. Secondly, I explain the three different horizons and how they can be applied to the present and future of natural gas and blue hydrogen in the Barents Sea. Thirdly, I examine the horizons as analytical models. Next, I show how the framework is relevant by showing how it has been used previously as an analytical model to foresee the future of energy and lastly, I explain how this framework is used in my thesis.

2.1 Future horizons

The framework applied in this thesis is the Three Horizons framework by Sharpe & Hodgson (2006), the framework connects the present with the future by identifying possible divergent futures. By looking at the history as well as the possibilities of the future you can create knowledge on what is a possible outcome for the future. Three horizons have been a useful as a conceptual model as a tool in aiding people to consider current assumptions as well as emerging changes, desired and possible futures. As a conceptual model it is under constant growth, and sizeable case studies exist already within the framework. It has previously been used in the as a tool to understand sustainable energy transitions based on social community-based movements (Seyfang & Haxeltine, 2010) and as a foresight tool to predict future scenarios for transportation towards a far future (Banister & Hickman, 2013).

As an adaptable future tool, the three horizons can be used in various ways, and it is important to figure out when to use it. Firstly, it can be used as a simple introduction to futures thinking, working as a way for participants in the horizon tool to make use of their know-how tacit knowledge and basic assumptions for an issue. Further these are used for short-, medium- and long-term change, and how these changes react to different impacts (Sharpe & Hodgson, 2006).

The framework presents three different horizons, which works as patterns to understand the emerging future. An established 1st horizon helps give way over time to an emerging 3rd horizon, with the help of a transitional activity in the 2nd horizon (Sharpe et. al., 2016).

2.2 The three horizons

Horizon one (H1) or the horizon of maintaining core business, is according to McKinsey an action-based horizon, which is mainly focused on the short-term development of a business or issue. As a society we tend to rely on stability as a pattern to everyday business life, this is the starting point of the three-horizon framework and an understanding that this pattern is losing its fit with the emerging conditions is important in H1 stage (Growth Tribe, 2019). Meaning that the H1 stage is a declining stage, however with the transitional help of H2 stage, H1 can turn into H3 which will be explained later as an emerging stage (Sharpe et. al., 2016).

In this thesis products such as natural gas and carbon capture and storage technologies can be included in the 1st horizon, since it is a continuous optimization of an existing technology as natural gas is, while still keeping the core which is natural gas.

The third horizon (H3) or the horizon of transformative emerging changes is built on ideas of the future and visions of the desired future. The mindset of this stage is visionary. The H3 will be the long-term successor of H1 with the help of H2. It builds and grows on fringes from the existing H1 system. In the 3rd horizon I develop ways of meeting new emerging conditions and possibilities. However, some dominant patterns will emerge in H3 as well, in development of H3 all views of the future will be present and contested (Sharpe et. al., 2016).

Examples of the third horizon in this master thesis could be the full implementation of green hydrogen in the Barents Sea, as it is in the early stages both in technological maturity and towards cost. However, this should always be the goal of the future. In addition to full implementation of green hydrogen in the Barents Sea comes phasing out fossil fuels, or full electrification

Lastly, the second horizon (H2) is the actions made to resist or to adapt to change, or to build upon change. The focus in this horizon is to manage change, and mindsets of H2 is entrepreneurial. This stage consists of transitional activities and innovation, as a response to the changing landscape that is between H1 and H3. The H2 stage is predominant in how it provides disruptions to the radical H3 systems. In addition, the second horizon (H2+) innovations can help the H1 systems to evolve and facilitate for H3 to emerge. In the stage of H2 many of the new innovations will fail and further fall back into the H1 part of the system, by only contributing to change that is marginal to the transition towards H3. An example of H2 systems in this master thesis is the use of blue hydrogen as a transition fuel towards green hydrogen, it has the possibility to work as a transitional tool while costs are reduced in the H3 stage which focuses on green hydrogen.

2.3 The horizons interaction

The table below provides an understanding as to how the different horizons interact with each other; the chart is a good way to visualize how the mindsets of the different horizons needs to collaborate to create an innovative playing field.

From this Horizon…	To this Horizon…	(-) Perspective	(+) Perspective
H1	H1	Competitors. Beat it or control.	Useful infrastructure. Potential allies in lobbying for shared activities
	H2	Monitor (Parasite of potential investments)	Source of new ideas. Shows what can be done. Advancement.
	H3	Irrelevant. Ignore. Challenges H1 dominance.	Future hope. Important for the far future. Possible renewal.
H2	H1	Slowing progress.	Not challenging H1 role, relates to my life more than H1.
	H2	Competitor for resources	Arena of action. Source of support and scale to support.
	H3	Impractical	Allies in momentum (Creation stage).
H3	H1	Barrier to progress.	Inspirational. Source of ideas. Skills that can be redeployed – to scale.
	H2	Misusing the vision of H3.	Changes scope of what is possible. Important ally.
	H3	Vision competitors.	Brings deeper issues into play.

Table 1. The different views the various stages of the three-horizon model have on each other. Based on text from Ian Page (Sharpe et. al., 2016).

Being aware of all aspects of the horizon model helps relieve tension and conflict between the horizons. Meaning that those who are in H1 are important for the daily life, however, they stand by a greater responsibility for transparency and accountability (Sharpe et. al., 2016). H1 often regard H3 as overly visionary, although it is important for H1 to see H3 as important for future development of the field.

The meaning with understanding the different mindsets is to understand that all parts of the horizon model need to advance in order for the current system to continue and advance, the future will not be resourced if there is no action towards the future needs, regretting to do so will collapse the existing systems (Sharpe et. al., 2016).

2.4 Horizon Methodology

As an adaptable future tool, the three horizons can be used in various ways, and it is important to figure out when to use it and how. Firstly, it can be used as a simple introduction to futures thinking, working as a way for participants in the horizon tool to make use of their know-how tacit knowledge and basic assumptions for an issue. Further these are used for short-, medium- and long-term change, and how these changes react to different impacts (Sharpe & Hodgson, 2006).

Next the three horizons tool can be used when we are sense making trends as well as explaining emerging changes. One of the areas where this framework is stands out is where it helps make complex situations more easily understandable, the idea is that the three horizons can be explained in a short amount of time, and different groups can add to the horizon to create deeper understanding. Doing so means reviewing emerging changes, data on trends and potential impacts the 3H has. The possibility to sort overlapping changes and sort their criticality as well as their maturity (Sharpe & Hodgson, 2006). Sense making as such puts us in a position as third-party observers, by standing on the outside looking in we are led towards a more impartial worldview setting aside our own values and preferences. Through sense making you are able to explore relevant pathways to solutions combining what you already know with what is unknown.

After applying sensemaking the 3H can be applied as a strategic conversation and a visionary action tool. In strategic conversation we bring a group discussion into the picture, in this step it is important to acknowledge all voices in the discussion. This leads to a stronger recognition of validity from all participants which then again leads to a more productive conversation, use of this method is effective when you have participants of all three horizons within the strategic group discussion. The 1st horizon giving fruitful insight to the 3rd and vice versa. From sensemaking and strategic conversation we build the framework through visionary action, creating an understanding of where our journey is going. By clarifying the relationship between the different horizons, the three H framework simplifies the visionary action.

The 3H framework can also work as a provider for internal structure to scenario narratives. Since the framework often represent overlapping and competing timelines it can be used as narrative backbone of change patterns in given scenarios (Sharpe & Hodgson, 2006). Lastly, the 3H can be used to generate innovations, by using the 3rd horizon changes to challenge assumptions of the 1st horizon. We can use these challenges, and conflicts that emerge in the 2nd horizon. This means that the 2nd horizon is presented as an opportunity to discard the old and take practical steps towards something new and innovative, with the use of emerging changes as a building tool (Sharpe & Hodgson, 2006).

In more recent research within the field of energy and energy development the framework has worked as a tool to forecast energy scenarios of Southeast Asia. It was applied in this study to understand issues arising from the current energy usage and the desirable future energy visions of the region (Silberglitt & Kimmel, 2015). It was also used as a tool in roadmaps for the transition towards zero carbon solutions in a built environment in Australia, along with other relevant studies on achieving major innovative sustainable transitions (e.g., see Dixon et. al. 2013; Newton 2007).

In my thesis the 3H is applied with short to long term change in the natural gas and blue hydrogen in the Barents Sea, as well as the impacts of technological advancement/maturity, emissions of CO_2 and CH_4, climate change and regulations for the future of resources in the Barents Sea. I am applying sensemaking to create impartial worldview of the future, before using both strategic conversation with relevant stakeholders in the Barents Sea to understand the various areas of the future horizon and lastly the use of visionary action to make sense of where the journey of natural gas and blue hydrogen is going in the future Barents Sea.

Further the Three Horizon framework is applicable for my thesis when reviewing data on trends from relevant stakeholders in the Barents Sea, as well as comments on emerging changes both from relevant secondary data such as reports and relevant research, or primary data such as interviews where comments are made directly on the emerging changes of the Barents Sea towards the far future.

3.0 Methodology

The purpose of this chapter is to provide the applied methodology selected to answer my research question. In the following chapter I elaborate on the research philosophy this thesis is founded on. I then explain my research design, approach, and strategy. Before I show the data collection methods as well as the sample with technique and size. Next, I introduce the interviews as qualitative data. Lastly, I approve the validity and reliability of the conducted research. By elaboration I will show the rationales of the methodology in this research.

3.1 Research Philosophy, design & approach

Research philosophy, design and approach will be explained in this subchapter. I show how the researchers worldview affects his/her contribution to the research question looking at positivism versus constructivism and how these are connected to standpoints of epistemology, ontology, and axiology. Further, I look at qualitative methodology and lastly, I look at the chosen approach for research in this thesis and the different types of approaches for research.

3.1.1 Research Philosophy

Research philosophy refers to the researcher's belief and assumptions regarding how knowledge develops for the researcher (Saunders, Lewis, & Thornhill, 2016). Whether or not it is a conscious choice, it reflects my view as a researcher on the world and how this plays a role in my research. This will further contribute to how the research question and method is understood for further exploration of the research.

To understand research philosophy, it is important to acknowledge positivism versus constructivism. The view on how our knowledge develops, known in philosophy as Positivism developed by Comte (1830-42) the ontology of positivism explains how phenomena that exist outside of ourselves exist independently of our interpretation, by applying the correct methods in positivism these phenomena's can be observed, experimented on, and lastly understood. Epistemological positivism is considered dualist and objectivist, by this it is believed that no one can be completely objective. To be completely objective means to separate your personal beliefs and experiences from the observed phenomena. Dualistic view deals with the mind versus body as two distinct modes of beings (Higgins, 1956).

Constructivism on the other hand deals with the construction of reality and knowledge in a different way than positivism. Contrary to positivism that looks at 1 reality and objective knowledge, constructivism looks at the interplay of forces that brings reality into existence. The general understanding of ontology in constructivism is relativist, leading to many different realities that coexist together in the context they are part of. Constructivists agree that realities differ from different individuals, since realities are constructed within different communities, societies, and various other forces. Reality constructed in a constructivist way claims that the interaction between people construct reality. Further, epistemology within constructivism is understood in a relativist way. This means that a meaning is not valid equally, new meanings that different people bring into existence strengthens our knowledge on the world. In the research process constructivist can take many different paths, however it is commonly agreed that subjective values and experience play on knowledge in the research process (Fosnot & Perry, 2005).

Saunders et. al. (2016) distinguishes between three various research philosophies. Epistemology, Ontology and Axiology. An epistemological question looks at the knowledge that appears when an individual conducts research. Such research philosophy is done through critical thinking about how we know what we know and critically looking at what knowledge can be considered acceptable. Further an ontological approach to research is conducted through assumptions made on what we know as our reality, this means that the researcher will try to understand the reality that emerges when understanding a research question. Lastly axiology deals with the consciousness of research participants values, these further affect the values of the research process.

Furthermore, Saunders et. al. (2016) looks at subjective approaches, this is a belief system that revolves around social reality being created by social actors to a greater or lesser extent. Subjective epistemological research is concerned with opinions, narratives, and attributed meanings through adaptation of humanities and arts. Secondly, ontological subjectivists are searching for the outcome of a research process to be constructed socially by various research participants, including the researcher themselves. Ontological subjectivists also with this accepts multiple realities. Lastly, axiological subjectivists understand and acknowledge the fact that they are reviewing and using the data they are retrieving from the research process, therefor they cannot detach their values from their research. Axiologists therefor spend time on reflecting and questioning their values openly, this is included in their research methods.

My approach to this article is the use of Sharpe and Hodgson’s (2006) framework that connects factors of the present to the future by using three different horizons. Henceforth, I am applying constructivist approach to my article. This means that I believe that there are multiple realities that help explain my question at hand, I understand the question in a relativistic way. The different people interviewed and new knowledge that appears during my research strengthens my knowledge on the world.

Further, my choice of selecting appropriate people to interview, both from the world of science as well as appropriate businesses reflects on the subjectivist knowledge and knowledge creation. This means that I believe that the social reality is explained by both scientists in the relevant field & businesses connected as the social actors. I also acknowledge that there are multiple realities to my research phenomena.

3.1.2 Research Design

Saunders et. al. (2016) explains research design as a critical phase in research. And at the front of this phase is whether or not to select qualitative or quantitative methodology for research. Choosing between the two there needs to be an understanding of the need for textual or numerical data to best apply to the purpose of this study (Williams, 2007). A quantitative research method focuses on what is measurable and the relationship between variables explained numerically, this is done by using statistical as well as graphical chosen techniques (Saunders et. al., 2016) examples of this can be the use of statistical programs such as SPSS to gather statistics from the collected data. Contrary, qualitative research method focuses on the textual data. This means that it explains the research problem by looking at the relationship between meanings within the research, analytical processes and data collection techniques are used in order to create a conceptual framework for qualitative research. The analytical part of the qualitative research creates the framework for the article.

Not only does Saunders (2016) urge the importance of selecting qualitative or quantitative framework, but they also focus on the researcher's consciousness towards creating a research design that is explanatory as well as descriptive & exploratory. This consciousness is proven in how researchers build questions, to further aim for how they are supposed to be collecting & analyzing their data. According to Saunders (2016) there are three different approaches to the early stages of a study that needs to be understood: Descriptive, explanatory & exploratory.

Descriptive approach is explained by the researcher being well-informed on the topic beforehand (Saunders et. al., 2016). This means that the researcher can foresee events in a structural manner, the questions in this approach are done simple and straight forward. Next, we have the explanatory approach. Using this approach means that the researcher is using causal relationships and applying them in different situations to explain a problem (Saunders et. al., 2016). The explorative approach works as a more pliable approach, this allows for the researcher to go into new directions as new data &/or knowledge appears. The focal point of this approach is to ask open questions that is meant to reveal what is really happening, using this information the researcher explains the problem and develops an understanding.

My research focuses on the future Barents Sea and what the future outlook for natural gas and blue hydrogen is. I am interested in the future picture, while understanding the problem by seeing social realities of important social actors in the industries. Therefore, I see it fit to use a qualitative approach to this study, as it's a future scenario that is better understood by the textual data. Additionally, I have selected an explorative approach to my qualitative research. I believe that asking my interviewees open questions allows for them to answer more freely and open for an explorative understanding of the future picture. This will give me the opportunity to obtain a comprehensive understanding of the different actor's reality of the problem. In addition, I believe that the explorative approach is applicable because it allows for me to move in a different direction should new information occur in interviews.

3.1.3 Research Approach

Not only is it important to decide on design and philosophy when it comes to research, it is also important to decide which approach to select when it comes to drawing conclusions from the collected research. Saunders (2016) divides research approach into three sections: deduction, abduction, and induction.

Deductive approaches deal with the drawing of conclusions from a set of premises that are logical. The conclusion of the problem is deemed as true when all the premises are true (Ketokivi & Mantere, 2010). Research processes where the researcher starts in advance with reading academic literature, before designing the research strategy is considered a deductive approach (Saunders et. al., 2016).

Secondly, we have the inductive approach. Here the researcher draws conclusions from empirical observations made (Ketokivi & Mantere, 2010). In these research practices the focus is on the collection of data to explain a phenomenon, from this there is a creation of a framework or a theory.

Lastly, we have the abductive approach. This approach is explained as a combination of the above mentioned deductive and inductive. Conclusions is created from observation, these lay premises for either the whole or parts of the theory. In addition, data collection is conducted to further identify and explore the problem at hand. Using this combination approach the researcher can explore new theories or further develop existing ones (Saunders et. al., 2016).

My research is constructed on the basis of social actors and their social realities and how they are understood by me, observations as well as the data collection is used to draw conclusions and create new theories on the future development through forces that affect the natural gas and blue hydrogen in the Barents Sea. Therefor I have applied an abductive approach to my research. In addition, I base my analysis on the theoretical framework of Sharpe & Hodgson (2006) that takes different forces into account while looking at the present as well as the future through the three horizons.

3.1.4 Research Strategy

According to Denzin & Lincoln (2011) a research strategy is defined as a plan where the researcher answers underlying figures and research questions as methodological links between both philosophy and data collection methods.

In direct connection to my research question, I used case study as the research strategy

The case study strategy deals with analysis intensively of an individual unit (this can be a person or an environment) by stressing the impact the developmental factors have in relation to the environment (Denzin & Lincoln, 2011). Case studies are understood as focusing on an *"individual unit"* with what Robert Stake (2008, pp. 119-120) calls a *"bounded system"*. When choosing a case study, you are not making a clear conscious methodical choice as to what is to be studied. The studied individual units may be understood in various ways, both qualitatively and quantitatively, hermeneutically, or analytically or by a mix of the methods. Case studies stress the development over time, this means that a case needs to be seen as a whole through both concrete and interrelated events that happen during the research period (Denzin & Lincoln 2011, pp. 301).

Through intensive in-depth research of a real-life setting the researcher tries to obtain empirical decisions that further leads to development of a theory (Eisenhardt & Graebner, 2007). The use of the case study is applied when understanding a detailed examination of a phenomenon. However, a case study is not applicable when trying to obtain an understanding the broader aspects, more so it is applied in the preliminary stages because it provides a hypothesis. This can be further investigated systematically through a higher number of cases.

Case studies can be divided into single case studies and multiple case studies according to Yin (2014). Single case studies are applicable in cases where the problem faced is unique or extreme, often times single case studies are used when studying a phenomenon that has not been explored by many before. Multiple case studies on the other hand are used on research where generalization is the goal. In addition, case studies can be both embedded or holistic, this means you can study a case as a whole entity or focus on parts of the case to understand the bigger picture (Yin, 2014).

Connected to research strategy I have chosen to apply case studies. To understand how the forces affect the future outlook for natural gas and blue hydrogen in the Barents Sea I look at reports and what is done previously in similar cases, to compare how the future outcome may look. In addition, this study is done using a single-case study, since the applied framework of Sharpe & Hodgson (2006) of the three horizons along with an understanding of what forces affect blue hydrogen and natural gas is unique and has not been explored by too many scientists before. However, I have seen the framework applied in cases of future energy outlooks in other regions before, as mentioned in the theory chapter above. Therefor this study takes an embedded approach where different parts of the natural gas and blue hydrogen technology, market demand and climate are considered as sub-units to create holistic research of the question at hand.

3.2 Qualitative methodology

Qualitative research as opposed to quantitative research, search for meaning in the world through the use of non-numeric data. This means that you collect data through people's opinions or expertise to try to understand what these people think.

When choosing qualitative research method, it is important to identify your research question, identify the appropriate methodology to answer the question. Further you collect the data, before this data is analyzed and lastly you show your research findings (Busetto et. al., 2020).

In my thesis I have chosen qualitative methodology to answer my research question, the reasoning behind this is because I am researching an outlook of the future climate of the arctic region. In my opinion the best way to understand this outlook is to comprehend how the social actors of the region think about the future of the region, since the actors of the region are familiar with how changes have happened previously and are familiar with the region, they are in my opinion the most suited people to create such an outlook with.

3.3 Data Collection

Saunders and colleagues (2016) divide data collection into two time-horizons, longitudinal and cross-section time horizon. Longitudinal are repeated over a longer period of time, while cross-section based is on a shorter time frame. My research will be conducted over a time cross-section-based time horizon since interviews are conducted over a short time period. The main reasoning behind this is the time frame given in my master thesis. Further I see this method as interesting for my thesis and article because it gives an indicator of the energy picture as it is at this very moment as well as the possible ways that the energy picture might develop based on the knowledge of important actors in the Barents Sea.

3.2.1 Samples selection

As a researcher it is important to select the magnitude of the sample size, defining the sample size helps the researcher get the best possible answer to the question at hand (Saunders et. al., 2016). Because there is a limited amount of time, resources, and access I think it is important to be precise in selection of the population for research, this practice is called target population. The practice helps narrow down the population to make the process of samples simpler. Keeping this in mind one must remember that as a researcher the goal is to remember the research question when picking the target population (Saunders et. al., 2016).

In my research I have chosen a population that holds deep expertise in the energy environment related to natural gas and hydrogen in the Barents Sea. I found it research question specific to focus on both blue hydrogen and natural gas in the early stages of choosing population, in addition I have selected a population that is directly connected to the research question in a way, either as a business professional or a researcher. Furthermore, my article-based thesis is supposed to work as both knowledge and a value for any business faced with the issues of valuing or devaluing the role of natural gas and blue hydrogen for the future Barents Sea.

3.2.2. Probability & non-probability sampling

When selecting the target population, it can either be done with probability or with non-probability sampling according to Saunders (2016). The probability technique of sampling assures that the sample is selected from a random subset of participants. Each member of the random participants has an equal chance of being selected as participants as the target population. However, in non-probability sampling the researcher selects its target population using selective judgment rather than a randomized subset of participants. Popular non-probability sampling techniques include the snowballing method, this method helps researcher find participants that are difficult to locate by using research participants to find new relevant participants. Researchers often use this technique when the sample size is smaller and more difficult to locate.

The specific technique used for choosing a sample otherwise known as sample technique, explains how one goes about choosing the specific sample of respondents to research (Saunders et. al., 2016). In non-probability sampling methods, there are several ways of sampling techniques that can be chosen to best select a representative sample.

In my thesis I have chosen to go with the purposive sampling technique, which allows the researcher to choose the sample purposefully that he/she thinks is best suited to answer the research question (Saunders et. al., 2016). This method is effective when working with smaller sample sizes such as the sample size in this thesis (Hopkin et. al., 2015).

I have also used snowballing sampling method in finding relevant interviewees, starting from a broader energy cluster in Northern Norway, ending up amongst researchers in the field. My aim through this method is to provide an in-depth understanding of the field, whilst having the research pull me in different directions as new knowledge appears. To create a holistic view of the problem at hand, I have chosen to get various insights on the topic from various actors.

3.2.3 Sample size

In non-probability sampling methods, there are no set rules for sample sizes (Saunders et. al., 2016). However, it is important to assure that the sample reflects directly upon the research question. To make sure that the research question is answered correctly as well as thinking about what is credible and useful for concluding the article as well as what is possible with the availability of resources given. These factors are kept in mind when conducting both structured and semi-structured interviews.

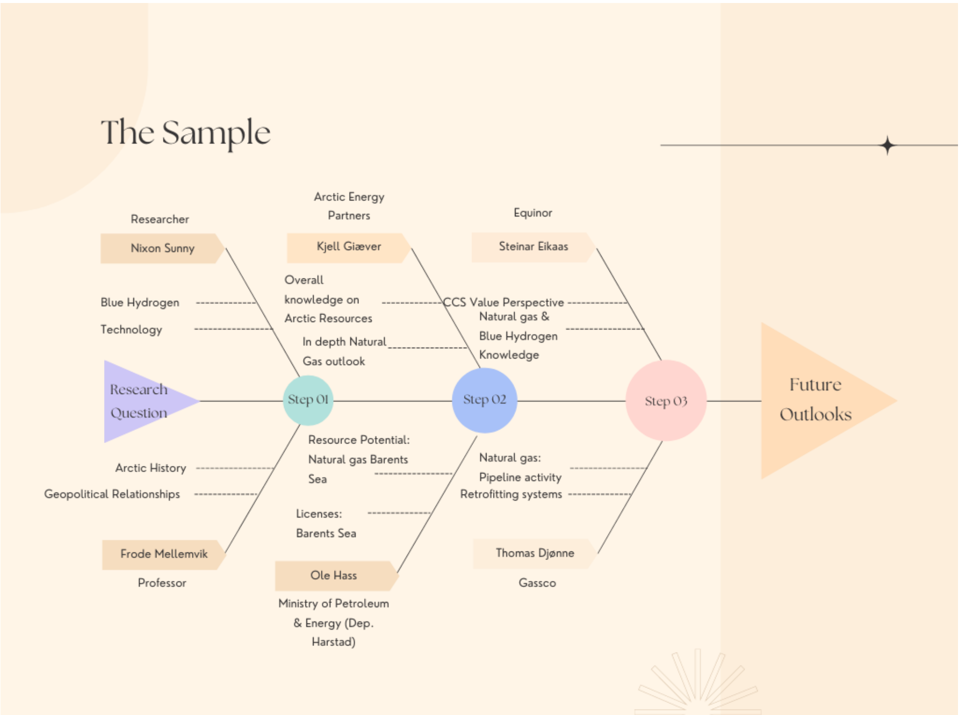
My sample is selected in cooperation with my thesis advisor and my contact person at the northern Norwegian energy cluster Arctic Energy Partners. Since my contact person Kjell Giæver at Arctic Energy Partners has great knowledge on the energy picture of the arctic it was a conscious choice to select him to help find the appropriate sample for this thesis. Through a couple of meetings, I was able to set up the first set of interviewees, as a result of the sampling meetings I managed to set up an interview with Steinar Eikaas from Equinor, Thomas Djønne from Gassco and lastly Ole Hass from the Ministry of Petroleum and Energy department Harstad. Further from there the Snowballing method was used to reach even more people relevant to the research question. Meanwhile I focused on finding appropriate researchers to interview that had studies on the field of natural gas and blue hydrogen.

Although my sample is small, I have selected a sample that has a wide knowledge and that are large actors within the Arctic energy climate or has wide knowledge on either blue hydrogen or natural gas. I selected a small sample with a focus on a few “heavy hitters” to strengthen my thesis.

My approach is focused on finding people connected to the transition, while talking to researchers with a critical view on the aspect of climate change connected to the use of both natural gas and blue hydrogen.

3.2.4. The sample

The diagram below shows the selected sample for this thesis. The diagram shows the different knowledge I have gathered from interviews with the various actors to build the future outlooks. Each interviewee contributed to various expertise that is important as an understanding of the future outlook for natural gas and blue hydrogen in the arctic. Interviews were done in three stages, selected in order to build knowledge for each interview, for a better interview. Each of the selected interviewees are powerful actors within the field of natural gas and hydrogen, whilst researchers contribute to the deeper technical knowledge needed for a holistic understanding. The following sample is:



3.2.5 Interview

When selecting interview type I can select between two types of data sources, these are primary and secondary sources (Saunders et. al., 2016). Primary sources are data that is collected from the source directly and is of direct use for the research project, whilst secondary data is data for other use that is applicable for the project. My project uses this data in forms of research articles connected to topics of the article, reports, and specific documents on policies from the EU, blue hydrogen development in Norway and Arctic Report Cards. Documents have also been provided to me by my contact person at Arctic Energy Partners as well as, researchers where I have specifically asked for articles during interviews.

Throughout my studies at Nord University in Global Management along with the process of this research I have built a strong knowledge on the relevant actors in the Arctic, through participating seminars such as the High North Conference and being from the North of Norway I have an insight on the important actors and deep knowledge on the energy picture of the Norwegian Arctic. Therefor I have the needed knowledge myself to help select relevant interview objects needed for the thesis along with the awareness of important reports needed to strengthen the thesis.

The rest of the secondary data is collected by me through sources such as Scopus and Google Scholar. These have worked as a fundamental understandings of the energy systems blue hydrogen and natural gas, as well as understanding the effects of climate change in the Barents Sea due to production of natural gas and its criticality. However, the main data in this research project is gathered from primary data sources, which in this case is conducted interviews.

Interviews are seen as imperative sources of information, especially in the case of case-based studies (Yin, 2014). In this matter there are three different ways of conducting an interview according to Saunders (2016). These three types are: semi-structured, structured and unstructured interviews. Semi structured interviews are conducted in a matter where the topic and key questions are covered, but there is an informative style to the interviews. The semi structured interview is based on follow-up questions, while new information can drag the researcher in different directions depending on the actor being interviewed. Structured interviews on the other hand have a set structure to the interview, it has pre-defined questions to go through in the interview. These interviews are often conducted in quantitative research. Lastly, we have unstructured interviews, the aim of such interviews is for the respondent to speak as freely as possible on a set topic.

In my research I have decided that the most appropriate way to conduct interviews to gather data for my analysis is to choose semi-structured interviews. Before interviews I send out a series of questions that are suited to the person that is being interviews. These vary from the interviewee. The questions sent beforehand are open questions that allow for the interviews to be open where the respondent can share his beliefs and meanings freely, while I add follow-up questions to push the interview in the direction, I need it to go.

Conducting interviews

Pre-interview I made sure I had spent enough time studying the relevant theory, while both gathering and understanding the secondary data so that I was well prepared for follow up questions on the various topics. This also helped understand new information as it appeared in the different interviews. Before conducting interviews, I sent the respondents a form to fill out for permission to record audio during the interviews, in addition to permission to use their name in the research. This ensures the flow of the interviews. Further the interviews were transcribed, for the ability to use the data in the analysis.

All of the interviews were conducted over video conferencing such as teams or zoom. The reason behind this interview type is mainly for practicality for the respondents. The respondents are from all over Norway, and the interviews are from 30 minutes to 1 hour. In such interviews there can be a concern for loss of visual body language, however I did not experience this to be an issue when conducting my interviews. Interviews are conducted both in English and in Norwegian, depending on the language of the interviewee to ensure that the maximum of information is extracted from the respondents in the most fluent way. Post interview, I had to transcribe the conducted interviews from the audio recordings.

Data analysis

I have chosen the categorical data analysis as most appropriate for my thesis. This way of analyzing data groups variables into a set of mutually exclusive ordered or unordered categories (Watson, 2014). Categorical data analysis uses variables to organize observations into different groups. In general, this is done with groups that have fewer than 20 as a variable (Imrey & Koch, 2005).

When analyzing my data, I have selected relevant research articles along with reports that are published within the field of energy and climate. Articles are gathered through the use of Scholar and Scopus and analyzed by searching for relevance to future outlooks of the Arctic.

Relevant reports are selected through my own intensive research within the field of blue hydrogen and natural gas. Examples of selected reports are IEA energy outlooks, Barents Blue, Hydrogen Backbone Initiative, Norwegian State reports, Gassco & Rystad Energy analysis of future energy development in Norway. These form the basis of my analysis Further I have structured my interview questions into sections, which makes it easier to analyze the data collected through interviews. Outliers as questions that appeared within interviews are seen as important because they bring a new knowledge into the research, although questions are analyzed towards relevance of the research question.

3.3. Evaluation of the selected methodology

When evaluating the methodology, I have selected for this thesis it is important to look at two aspects: Validity and reliability

3.3.1. Validity

Validity in a project is about securing the quality of the phenom that is being researched as well as the quality of the research itself (Morse et. al., 2002). The phenom under research here is the future outlook of Natural gas and blue hydrogen in the Arctic. In my study I will have a look at the external and internal validity of my research.

3.3.1.1 Internal validity

Internal validity deals with how the researcher can create a causal relationship between two different variables (Saunders et. al., 2016). In my study this is represented where the respondents of interviews have an emotional connection to the group that they represent. Businesses such as Equinor or Gassco are affected by their line of work. However, all of the respondents are selected on the basis of their knowledge of energy systems and the Barents Sea resources. As explained in the sample section, my respondents reflect upon different areas of the future arctic energy with various backgrounds that reflects their answers.

In my research I have applied triangulation, by basing it on secondary data and early unstructured interviews. It helps identify key issues early on for building of primary data. This helps overcome the weakness that is in the use of only one method such as observation or questionnaires (Saunders et. al., 2016). However, it is important to remember that 6 interviews are not entirely enough to give a fully understandable picture.

3.3.1.2 External Validity

External validity regards to how the study's findings can be generalized to other settings or groups (Saunders et. al., 2016). This is applicable to my research question as to What forces and what are the future horizons of natural gas and blue hydrogen in the Barents Sea. The findings in this study are generalized findings that suits other settings. Even though my research is specific to the Norwegian arctic region it can be used by companies acting in the arctic dealing with implementation of business choices that use natural gas or blue hydrogen. In addition, it addresses the issue of unburned fugitive methane, capture rates of CCS and the natural gas bottleneck of Melkøya that causes stranded resources of natural gas in the Barents Sea, these can all be used as an understanding of the future energy picture of the Norwegian Barents Sea. This is why I believe that my study will have value for companies that are involved in energy development in the future arctic. However, this study revolves around interpretive future horizon, which is not based on forecasting but combining the competing images to explain the future. Therefor I will not be able to provide a complete picture as it does not predict the future fully accurately, I think it would be beneficial to monitor the changes in relation to this study.

3.3.2 Ethical Issues

Research ethics or ethical issues is referred to by Saunders and colleagues (2016) as behavioral standards that provide guidance to researchers conduct in relation to the participants of the research or others that may be affected by the research. The Norwegian National Research Ethics Committee divides research ethics into 6 different subcategories: Research, society, and ethics (i), respect for individuals (ii), respect for groups and institutions (iii), the research community (iv), commissioned research (v), dissemination of research (vi). I will mainly focus on explaining respect for individuals, research, society, and ethics.

3.3.3 Respect for individuals

Respect for individuals deals with the human dignity and personal integrity connected to individuals linked to the research. As a researcher in a study, you are responsible for the protection of individuals integrity, individual freedom and self-determination, privacy and family life and safeguarding of harm. The privacy includes the processing of personal data. This means that the research needs to account for considerations connected to data protection, this includes storage of data for protectional purposes (Norwegian National Research Committee Ethics, 2022). In my research I have assured respect for individuals by assuring them of what the data will be used for, in addition my research is registered in NSD for privacy and data protection. I have made use of names and some workplaces to strengthen the research as to understand where individuals' standpoints are coming from, however some workplaces are made anonymous. All interviewees had to sign a consent form to be part of the research as a measurement to secure respect for individuals. All data is also deleted after the project end date. By giving informed consent the participators understand and accept the implications of their participation, this is also in regard to privacy related issues (Diener & Crandall, 1978). However, participants are also informed that they can withdraw from the research at any point. I have avoided to push for answers and have experience little constraints from participants when answering questions within interviews

3.3.4 Research, Society & Ethics

Scientific, ethical & norms help regulate the responsibility of research, although research also has a social responsibility. In my research this social responsibility is to deliver research-based knowledge on natural gas and hydrogen in the Arctic. Qualifying as good and responsible research includes assessing both the good and undesirable consequences. In this research I look at the negatives connected to the criticality of the Arctic as well as the possibilities of the future if there is to be blue hydrogen and natural gas production from the Arctic in the future.

4.0. Empirical Analysis

In this chapter I present and discuss major driving forces that is regarded as barriers or drivers for the future outlook of natural gas and blue hydrogen in the Norwegian Barents Sea. The empirical analysis is founded on the empirical data collected from both research articles, industry reports and interviews with experts on the topic and within the Norwegian arctic region. I argue for three driving forces that can push or pull future prospects in the Norwegian Arctic.

The following three driving forces affecting future outlooks of natural gas and blue hydrogen in the Barents Sea. The three forces are: (1) natural gas, emissions & technology (2) Blue hydrogen, emissions & technology (3) climate. Driving forces are explained as something that has the power to make something happen (Cambridge University Press, n.d.) which in the case of this master thesis is the forces that has the power to affect the future outlooks for natural gas and blue hydrogen in the Arctic.

4.1. Force 1: Technology & Emissions of Natural Gas

We refer to natural gas as dry gas, wet gas, liquefied natural gas (LNG) and shale gas. Natural gas is used as an umbrella term for gas that is produced through decomposition and transformation of organic matter. Gas may be composed by a number of different chemicals, which has different sets of characteristics. Most of these chemicals are composed of either hydrogen or atoms of carbon, this is why they are called hydrocarbons (Equinor, 2022).

4.1.1. Dry gas

Dry gas is gas that has no form of condensate or liquid hydrocarbons, or gas that has the liquid hydrocarbons removed. The gas-to-oil ratio of dry gas exceeds 100,000 STB (Schlumberger, 2022). It mainly consists of methane and in some instances ethane with small amounts of heavy hydrocarbons and CO_2. This type of gas is typically transported in pipelines to customers (Equinor, 2022).

4.1.2. Wet gas

Wet gas regards gas that is heavier in contents of heavy hydrocarbons, it also contains less methane than dry gas with less than 85% of it being methane. It therefor contains more ethane and more complex hydrocarbons (Schlumberger, 2022). Under pressure and normal temperature, the wet gas will be one part liquid one part gas. From the stage of wet gas, you can produce dry gas by extracting the liquids from wet gas, by separating and splitting the gas, and it can be sold as butane, ethane, propane and more (Equinor, 2022).

4.1.3. Liquified Natural Gas

Liquified natural gas, or LNG is natural gas turned into liquid by freezing it down at cryogenic temperatures (-162C). These processes occur under pressure near the atmospheric pressure and under extremely low temperatures. If gas pipelines are unavailable as transport options, such as areas like the jungle or remote regions offshore, the gas is turned liquified by freezing it to transport it and sell it. LNG is transported in large tanker ships to customers (Equinor, 2022).

4.1.4 Shale Gas

Natural gas found in Shale, a finely graded, sedimentary rock formed of mud, clay and other minerals such as quartz and calcite. A shale that has thermally matured can produce economically quantities of natural gas (Schlumberger, 2022). Americans have been aware of the gas contains in shale since 1940 but have been unable to extract it due to lacking mature technology, now however this technology exists. This causes extraction of natural gas from shale which makes it possible to extract large amounts of natural gas at low costs (Equinor, 2022).

4.2 Discussion of Future Horizons for Natural Gas: Why Natural Gas?

Natural gas as a fuel is in the EU considered a favorable fossil fuel due to its lower rate of CO_2 emissions to the atmosphere, in fact natural gas has approximately half of the emissions of CO_2 compared to other fossil fuels. Therefor natural gas has been considered important as a transition fuel towards the net zero 2050 future. The word transition fuel in the context of this article means to substitute a fuel that is more CO_2 heavy such as oil or coal with a less taxing fuel such as natural gas (Smil, 2015).

Natural gas role in the future energy market could be considered to be bridging the gap between fossil fuels and zero carbon technologies is only temporary due to natural gas emissions of CO_2, however there is possibilities of becoming near zero emissions with the use of carbon capture and storage technology in the future as this technology matures further.

There are conflicting views on natural gas and how it affects the path towards net zero, some claim that natural gas is an important driver for renewable energy development by working as a synergy with coming renewables by balancing the intermittent energy outputs (Dupont & Oberthür, 2012). While also working as a provider for stable energy in peak hours (Van Foreest, 2010). The other end shows skepticism towards the dependency of fossil fuels created with a continuation or increase in production of natural gas. Further investments in the fossil fuel industry might end up delaying the overall green transition and slow the emission mitigation efforts in the longer picture (Safari et. al. 2019).

4.2.1. Transition fuel: Direct effects

To further understand drivers and barriers for further use of natural gas in the future energy picture towards net zero 2050, we need to understand natural gas and its effects as a transition fuel. To understand this, I look at the direct effects of natural gas.

For direct effects I am looking at natural gas and its potential to help aid the renewables in various areas. Both previously mentioned assisting factors such as aiding renewable technologies in its progression and replacement of other more polluting fossil fuels are direct effects of natural gas. Important renewable technology for the future such as wind and solar power are reliant on nature to provide its energy, therefor called intermittent energy (Van Foreest, 2010). Solar is reliant on sunlight in order to produce solar energy, which in the case of the arctic can be in issue in winter months with less sunlight. Same goes for wind power which is fully reliant on wind to produce energy. Solutions to such issues can be solved with storage of energy through grid electricity innovations as well as through energy carriers that are considered sustainable, however this technology is presently lacking both economically, technologically, and commercially.

Furthermore, looking at economic difficulties for renewables, the present high cost of renewables also makes it less favorable. Therefore, natural gas can partake in the transition towards net zero by being a cost-efficient option that is more favorable and less pollutant than other fossil fuels, at the same time it has the possibility to become near zero emitting coupled with CCS technologies. These are the direct positive effects natural gas has on the transition, both providing secure stable energy for renewables

4.2.2. Natural Gas in The Arctic & the EU region

The Norwegian Arctic oil and gas production is fairly young compared to the rest of Norway’s production. Even though the Norwegian sea and the Barents Sea was opened for exploration activities in 1980 it was not until 1997 that the first field “Norne” was in production. Further it took ten more years until the first gas discovery was made at Snøhvit in Hammerfest. Today there is 8 discoveries with 4 different production areas: Norne, Snøhvit, Goliat & Skarv (Equinor, 2022). The gas discovery at Snøhvit has had many positive repercussions for the Hammerfest community, local businesses as well as sales revenue and profitability for the Hammerfest community has increased after Snøhvit compared to the rest of Finnmark (Klaussen, 2015). Norway is also the second largest exporter of natural gas to Europe according to Eurostat (see table below).

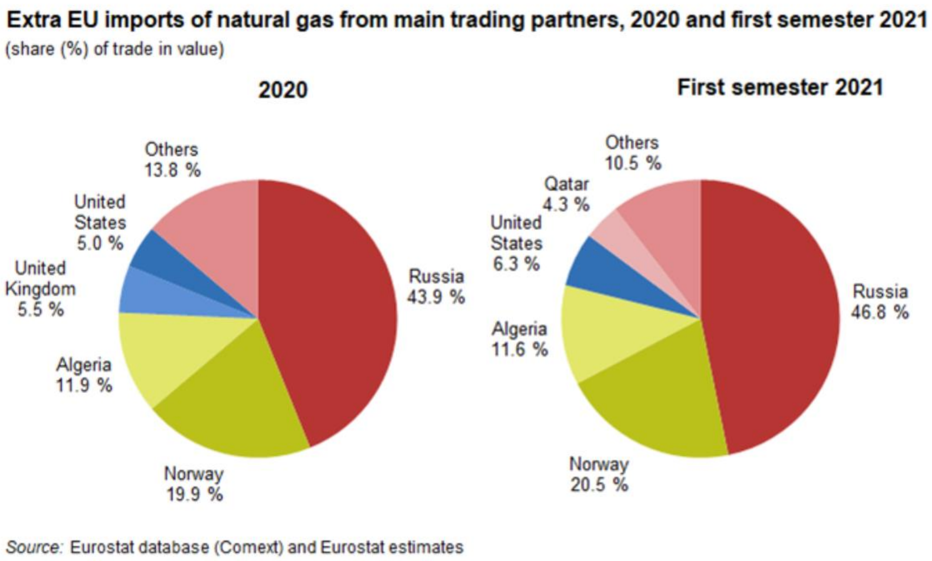


Table 2. EU imports of natural gas from trading partners, Norway second largest according to Eurostat (2021).

All fields on the Norwegian continental shelf contain different amounts of natural gas, in early stages of Norwegian production gas was sold through long-term contracts for the entire operation of the field. Gas now is sold through various markets, most commonly spot price, but also, through long-term contracts and directly to end users (Equinor, 2022).

Furthermore, Norwegian gas transport is transported through an extensive network of pipelines, in fact the world's largest network of gas pipelines, with a distance of over 8000 km (Equinor, 2022). These pipelines connect the Norwegian gas on the continental shelf to landing points in Great Britain, Germany, France, and Belgium. These large infrastructures have knock-on effects for future production of blue hydrogen as there are possibilities to build on existing gas networks within the Arctic.

4.2.3. Climate & Natural Gas in The Arctic

Norway is underway with agreements with the EU towards 2030 on climate goals, the companies that are subject to climate quotas are planning to reduce its emissions in line with European goals towards 2050. Through European quota systems the emissions are supposed to lower every year so that European climate goals as well as the Paris Agreement is met by Norway.

Looking towards natural gas and its role in the future arctic it is clear that natural gas will contribute to some of the solution with its previously mentioned cost effectivity. With low emissions from gas production in the Norwegian Arctic, the gas is competitive in the future low carbon energy mix. While the world is at a point where there has not been more coal produced, close to 8000 million tons a year (International Energy Agency, 2020), along with population increase in Asia and Africa the need for cheap, reliable energy sources has never been higher. This leads to one of the major global challenges the world faces when it comes to climate change, the decrease of coal production with less CO_2 heavy energy forms. Therefor it is possible that Norwegian produced arctic natural gas can play a role in the future energy mix towards net zero in 2050.

However, it is important to understand the effects natural gas has on the climate, especially in a critical region such as the arctic. With emissions of both CO_2 and CH_4 natural gas causes environmental and safety issues that is important to address.

4.3 Force 2: Climate change in the Norwegian Arctic (Barents Sea)

To understand the reasoning behind inhibiting gas production which will have importance for future blue hydrogen & natural gas production in the arctic, it is important to understand the criticality of climate change in the Norwegian arctic.

The arctic climate differs from other climates around the world mainly because of the sunlight. Above the Norwegian arctic circle, the sun disappears during the winter months, this leads to dark and cold winters. However, during the summer months, the arctic experiences sunlight around the clock. Areas of the arctic has experienced some of the most rapid growth of climate change, in fact the arctic is warming at twice the rate of the rest of the world (National Oceanic and Atmospheric Administration, 2021). This comes with implications such as increases of temperature, melting of the sea ice and thawing of the arctic tundra (Hanna et. al. 2020). The reasoning behind the rapid warming of the arctic is mainly because of the albedo effect, when melting of snow and ice exposes a darker surface of this increases the energy of the sun in these areas hence warming up the arctic faster than the rest of the world (NPI, 2022).

4.3.1 Greenhouse gasses & potentials of global warming

Greenhouse gasses (GHG) absorb infrared radiation, in this process it traps heat whilst making the planet warmer. The most important GHG emitted into the atmosphere directly by humans are carbon-dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorine containing halogenated substances such as PFC, NF, SF (United States Environmental Protection Agency, 2019). My focus is on the emitted CO_2 and CH_4 since it is directly connected to the warming of the arctic due to production of natural gas and future production of blue hydrogen.

Such gasses emitted to the atmosphere contribute to global warming both directly and indirectly. Directly through the gasses themselves absorbing radiation, whilst indirectly radiative forcing happens through chemical transformation of a substance produce other G_HG. This is when gas has an influence on other atmospheric lifetimes or when gas effects atmospheric processes that alter the balances of radiation on earth, explained above in the albedo effect. The indirect effects of CO_2 in the atmosphere are seen in soil and plant structures and can have big impacts on the ecosystems by stimulating photosynthesis and reducing loss of water in the future (University of Southampton, 2016)

In connection to emission contributions the IPCC has made a concept to compare gasses ability to trap heat in the atmosphere relative to other another gas, this concept is called global warming potential or GWP for short.

4.3.2 Sea Ice

The overall inevident increase in temperature in the arctic both from natural and manmade drivers of climate change has led to a decades long decline of sea ice in the Norwegian arctic. Older, thicker sea ice that covers the central arctic oceans is now almost entirely gone; sea ice levels of April 2021 is the lowest since the start of the records in 2010 (National Oceanic and Atmospheric Administration, 2021). The loss of sea ice has enabled shipping and extraction of resources to happen further into the arctic and for longer periods of time, resulting in higher pollution numbers and disruption to the biodiversity of the arctic oceans. The decrease affects the climate as well as the weather. Studies suggest that the decline of sea ice in the arctic increase circulation patterns this resembles the negative effects of the Arctic Oscillations and the North Atlantic Oscillations in the winter months (Vihma, 2014).

Not only does it have effect on the winter months but thinning of the arctic sea ice also leads to a stronger summer ice-albedo effect. The thinner ice also has an effect on the summer months when it comes to vulnerability towards a hard summer retreat through anomalous atmospheric forcing. Totality of warming has negative knock-on effects for the possibility future cold winters that could give opportunities for the ice to recover temporarily.

4.3.3. Arctic Ecosystems

In addition, we see effects on the arctic ecosystems due to activity in the Barents Sea, who causes different species both land and sea to end up on the endangered list. An example is the polar bears who according to WWF Arctic Program is expected to decrease by 30% within 2050 (WWF, 2022).

In addition to causing harm to life of indigenous people on land near the Barents Sea shores by preventing access to food and making hunting & fishing grounds more hazardous (National Oceanic and Atmospheric Administration, 2020).

Ecosystems rely on the success of initiatives such as the Paris Agreement for it to prosper towards 2050 and into the future. Cooperation across borders along with proactive companies in the transition can help turn tides for ecosystems in the arctic.

4.3.4 Permafrost

The highest increase of temperature is expected to happen over sea level. Permafrost, which is soil that holds below zero degrees Celsius for at least two years, covers today about one fourth of the entire northern hemisphere and can be up to 100 meters in thickness. With an increase in temperature of the arctic, this soil will thaw with the increase in temperature creating subsequent consequences loss of permafrost formations, increase in GHG, landslides and subsidence (Stemland & Johansen, 2021).

Natural gas productions effect on thawing of the permafrost is connected to increase of GHG’s such as methane, importance must be set on reducing emissions that are thawing the permafrost by reducing thawing we are also avoiding the sub-permafrost methane released from the thawing process, this is often overlooked when researching the positive climatic feedback of the region (Birchall et. al., 2021).

4.4. Discussion of Future Horizons for Arctic Climate: Natural gas effect on the arctic climate

To understand the future of blue hydrogen as well as natural gas it is important to understand the role of natural gas in blue hydrogen, especially connected natural gas effect on the climate. This will give a better understanding as to what inhibitors exists for the organs such as the EU to set boundaries for natural gas production which will be important for the future blue hydrogen production and infrastructure in the Barents Sea in the future horizon.

WWF urges the vulnerability of the Arctic climate and the response rate for spills that is a possibility when searching for natural gas resources in the Barents Sea. The lacking infrastructure and the given remoteness of the arctic makes responses slower than other areas of the world. In addition to the short summers in the arctic which makes damages to the arctic climate more critical, and recovery rates of ecosystems much slower than the rest of the world (WWF, 2022).

However, it is important to remember that production of natural gas is of a global character, most production of natural gas is mainly done outside of the arctic. Norway is mainly involved in the extraction and transportation of gas, specifically LNG from Melkøya.

"All oil and gas production in any case is of global character. This means that the local footprint within the South Barents Sea of Norway is no different than in any other offshore oil and gas production in other regions of the world. When discovering natural gas you make one discovery, you either make both an oil and a gas discovery, or in some instances you make pure gas discoveries, in that case there is no danger of oil spills." (Respondent: Kjell Giæver)

The most urgent form of effect on the arctic climate that needs to be dealt with is the emissions from natural gas production in the form of carbon dioxide emissions and unburned fugitive methane, a need for focus within technological maturity within the carbon capture and storage technology is important to deal with the emissions of carbon dioxide in such a critical region as the Norwegian Arctic region is.

In dealing with the critical climate changes the Norwegian arctic is facing it is important for large companies to take a proactive role within the climate issues we are facing:

"It is important that we embrace the energy transformation that is happening in Europe and that we want to be part of the solutions. This means that we do not push to sell our gas as we always have but act proactively by using natural gas to create blue hydrogen or blue ammonia. Acting early financially in the early stages will help mature such projects, it is important that we take this role both as a nation and as large companies." (Respondent: Steinar Eikaas)

"We are dedicated to obtaining the sustainability of gas and in that we acknowledge that the system must be both competitive and developed in the right direction towards sustainability. We now see in Europe that we are facing a climate situation that is demanding. We are approaching net zero targets towards 2050 that are demanding. We need to see how gas can

contribute to this green shift, it's everything from the gas having a role in one way or the other, either as a flexible source of energy needed along with the renewables, or modified gas production to make it emission-free, examples could be to use it for blue hydrogen/ammonia in the future." (Respondent: Thomas Djønne)

Acknowledgment of the issues at hand that is climate change as well as positioning in the future energy market seems like a high priority amongst the companies acting within the Arctic Energy market as well as companies within the gas activities.

4.4.1 Black Carbons effect on climate change in the arctic

Black Carbon (BC) is considered the second most contributor to climate change, second to CO_2 emissions. BC are particles that absorbs heavy amounts of sunlight and creates the black color of soot. The darker the soot the more warming it works. It is created both naturally and through production of fossil fuels, biomass, and biofuels. The darker soot is usually created from burning of fossil fuels compared to burning of biomass (Qi & Wang, 2019).

Reducing CO_2 is considered the key to solving the climate change crisis both globally and in the arctic. However, the emitted CO_2 has long atmospheric lifetimes, so it will take several decades for the emitted CO_2 to stabilize. Therefor it is important to also look towards reducing BC in the Arctic as it only has atmospheric lifetime of one to four weeks, this will give more immediate effects to the rapidly changing environment in the Norwegian arctic (Center for Climate & Energy Solutions, 2010). Examples of ways to reduce BC in natural gas production in the Norwegian arctic is reduction of gas flaring. Gas flaring in natural gas is the process of releasing pressure when producing gas, it is used as a safety measure to manage unpredictability within the large pressure variations that occurs when burning excess gas. However, in Norway gas flaring is only permitted when necessary for safety reasons, and overall rates of gas flaring in Norway is amongst the lowest of all gas exporting countries (Norsk Petroleum, 2022).

4.4.2 Shipping and natural gas extraction & its role on the climate

Shipping and petroleum extraction of the present globally lead to both cooling and warming, whereas in the arctic region such activities is leading to warming in the future arctic. These future results depend on factors such as sea ice melting as well as various economic factors. It will therefore be deemed as important to reduce CO_2 & CH_4 emissions as it seen as the key to an effective climate policy and will be seen from an EU perspective as highly important to avoid both CO_2 and CH_4 emissions towards 2050. Monitoring the changes of the arctic composition in the future, as well as heightened focus on mitigation will be important measurements for the arctic (Law, 2017). Not only does an increase of shipping and extraction of resources lead to warming, but it also shows an increase of more garbage, plastics and hazardous materials illegally discarded into the arctic oceans (National Oceanic and Atmospheric Administration, 2021).

Such worries have increased the interests of the EU in the arctic causing them to set guidelines for member countries to prevent the worsening of climate change in the arctic. Examples of guidelines to companies to which economic activities are sustainable is the EU Taxonomy classification system. The system is a classification system for establishing sustainable economic activities, it helps companies, policymakers, and investors in understanding which economic activities can be considered environmentally sustainable for the future (European Commission, 2022).

4.4.3 Adaptation to future production of natural gas and blue hydrogen and the future arctic?

To tackle the challenges of the future arctic climate change while producing natural gas and future blue hydrogen we need to identify the magnitude of emissions from the natural gas sector as well as emissions from transportation and various technologies. Understanding that both CO_2 and CH_4 emissions needs to be reduced in order to slow down negative outcomes for the future arctic climate. Not only is the arctic climate vulnerable to changes but also the society, biology and ecological systems, physical and chemical processes in the arctic nature is subject to climate change. Therefor the emitting industries have to adapt – This requires several strategic approaches especially from the natural gas industry.

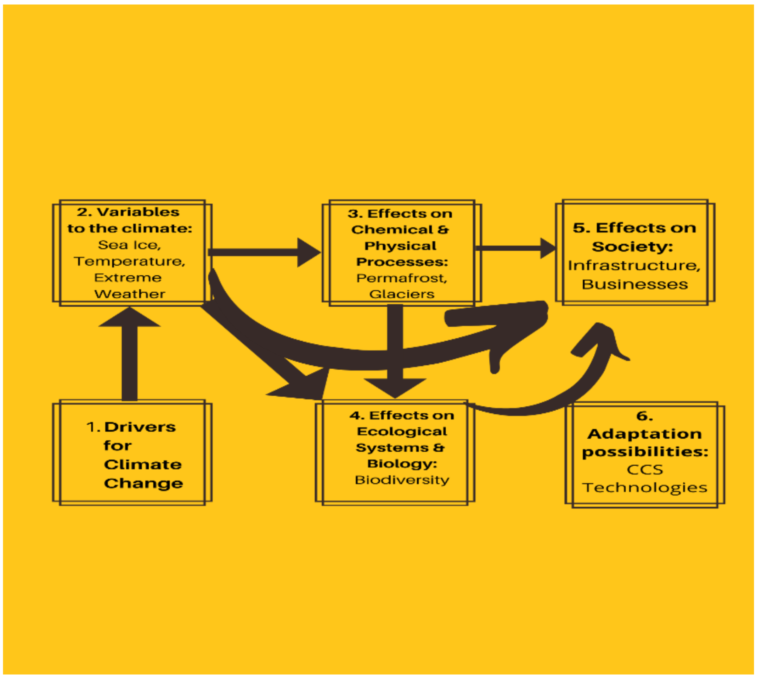


Figure 1. Drivers, effects, and adaptation of climate change in the arctic (Created by the author with drivers and effects from this chapter).

When changes happen to both ecosystems and climate the society has to adapt to these changes, such adaptation varies on the magnitude of the changes. It is difficult to predict the changes of the future, therefor there will be a variety of countering adaptation strategies that can be implemented for societies of the arctic. The overall magnitude of these changes is difficult to predict, however it is important to consider the possibility of anticipated effects and to prepare accordingly (NPI, 2010).

4.4.4. Emissions from Blue Hydrogen in the future arctic

Emissions from the Blue Hydrogen sector in the future arctic is both methane and carbon dioxide emissions. The latter one is the mostly focused on emissions, however in later research there has been focus on the unburned fugitive methane gas released from production of Blue Hydrogen. Methane is a more potent warming agent than carbon dioxide, if both are compared mass-to-mass, methane as a warming agent is more than 100 times as powerful as carbon dioxide. Therefor methane needs to be considered as an important emission to monitor in the future production of Blue Hydrogen in the future (Howarth & Jacobson, 2021).

To account for the totality of emissions from blue hydrogen production we need to account for several processes of production. Firstly, we have the emissions from the steam methane reforming process after carbon capture is completed. Secondly, the energy needed for heat and pressure to drive the SMR process. Thirdly, the emissions from needed electricity to drive the carbon and capture equipment, this process is often not accounted for in calculations of total emissions from blue hydrogen. Lastly, there is the indirect upstream activities needed to produce and transport natural gas. Henceforth, the sum of all these factors makes up for the total emissions from production of blue hydrogen (Howarth & Jacobson, 2021).

However, we will have to remember that all forms of hydrogen production including green hydrogen will emit some greenhouse gasses over its total life cycle. Therefore, removal of GHG will be needed to comply with strict regulations towards net zero. It will be seen as important for the EU to apply policies and regulations on emissions, while facilitating for an increase in production of natural gas for blue hydrogen to have a part in the future energy picture.

4.5 Force 3: Technological maturity and emissions from Blue Hydrogen

Next force deals with hydrogen, it begins to explain hydrogen and its production, before I explain blue hydrogen. Further, I go through the current and future demand followed by a discussion of emissions of methane from hydrogen as well as the resource availability connected to hydrogen.

In this section of the article, I show hydrogen as a future energy carrier in the coming low-carbon energy picture. This is to provide an understanding of the relevance of hydrogen as an energy carrier. This section’s purpose is to understand blue hydrogens drivers and barriers towards the future.

4.5.1 Hydrogen and production

Hydrogen is the first chemical element on the periodic table and is delivered from water and plays an important role for all life on earth. It is used to create both fertilizers and ammonia which can be used to further create other commodities. In the current energy picture hydrogen is used in the industry in oil refining and in creation of synthetic nitrogen fertilizer (Howarth & Jacobson, 2021). Since Hydrogen is extremely energy dense it has the possibility to play an important role in sectors such as transport, aviation, energy, construction and in countries which rely on natural gas for heating it has the possibility to replace such heating systems (Gardarsdottir & Sundseth, 2021).

Therefor Hydrogen is considered one of the most important energy carriers in the future decarbonized energy picture (Howarth & Jacobson, 2021), being an energy carrier means that it needs to be produced from another source of energy. Hydrogen is considered one of the solutions to replace fossil fuels in the future (Gondal et. al. 2018). Since hydrogen as an energy carrier, it emits no environmental harming CO_2 emissions when consumed in either fuel cells or turbines. In spite the environmental positive effects of hydrogen the production phases of hydrogen however have different implications.

Hydrogen can be produced at or near its point of use, in large facilities and then delivered to the point of use or in intermediate size facilities located in close proximity to the point of use (Wang et. al., 2020). Hydrogen can be produced in several different processes. First by using thermochemical processes, this process uses heat and chemical reactions to release hydrogen from organic materials such as fossil fuels and biomass. Next, we have electrolytic, where water is split into hydrogen and oxygen. Lastly, we have photolytic and biological, this is created with solar energy and bacteria that creates hydrogen itself.

We have five main labels of Hydrogen; I will introduce three of them with a focus on blue hydrogen. The first and most used today, is grey hydrogen which is produced from natural gas using reactions made with hydrocarbons such as methane. Natural gas contains methane, this can be used to produce hydrogen by thermochemical processes called steam methane reforming (SMR) or autothermal reforming (ATR). The difference between the two processes is how heat is formed to activate endothermic steam reactions. In SMR the catalyst is kept in tubes that are heated by external heaters and in ATR the heating process is done by using a portion of the natural gas to raise temperature before it comes in contact with the catalyst. These processes come with negative outcomes for carbon dioxide emissions (Kahn et. al. 2021).

Next, we have green hydrogen, which is produced through a process where clean renewable energy (Wind, Solar, Biomass etc.) is used in an electrolysis process where water is split and broken down to hydrogen and oxygen, hydrogen is stored, and oxygen mainly goes into the air. For green hydrogen there are three main technologies (i) polymer electrolyte membrane electrolysis, PEMEC. (ii) Alkaline water electrolysis, AEC and lastly (iii) solid oxide electrolysis, SOEC. Both AEC and PEMEC are matured technologies while SOEC is yet to be commercialized (Kahn et. al. 2021).

Lastly, and the focus point of this article is blue hydrogen. Blue hydrogen, like grey hydrogen also uses natural gas, however in this process carbon capture and storage is used to eliminate carbon dioxide emissions. The advantage of using this method for producing hydrogen is the fact that natural gas is cheap, cleaner than coal and easy to move in pipelines or through the use of LNG carriers. Blue hydrogen takes use of production methods of grey hydrogen, either steam methane reforming or autothermal reforming (Noussan et. al., 2021). It is important to understand that the color coding of hydrogen is just labels, the hydrogen itself is the same.

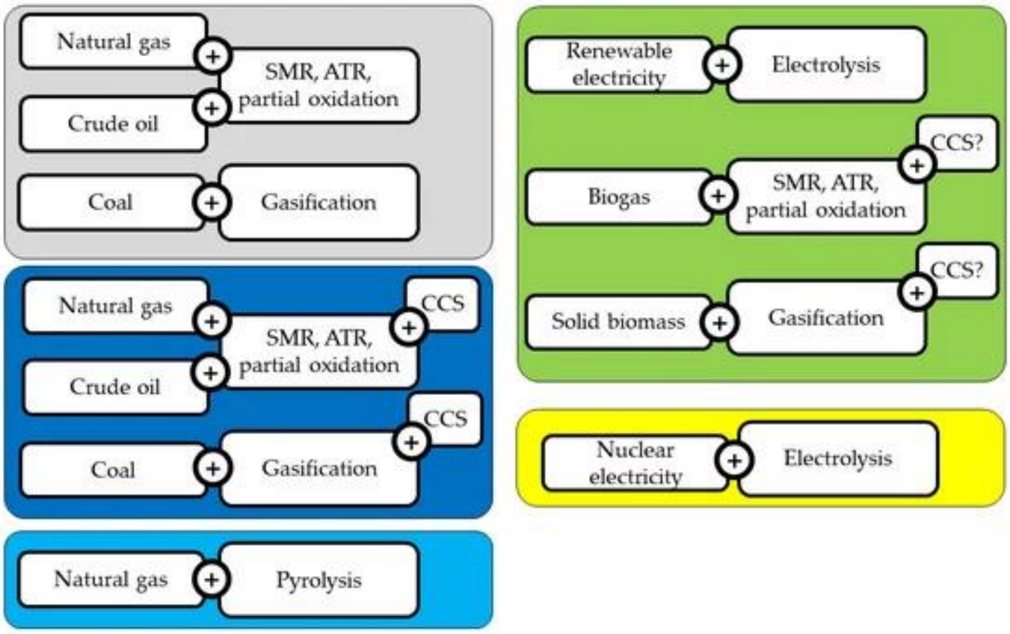


Figure 2. Five labels for creating hydrogen. SMR: Steam Methane Reforming, ATR: Autothermal Reforming, CCS: Carbon Capture and Storage. (Noussan et. al. 2021)

All these different pathways to hydrogen have different implications, which creates both limitations and opportunities for Hydrogen. In these cases, it is important to mention that the choice of solution depends on other aspects related to the geopolitical choices connected to the national strategies by availability of certain resources. Since Norway inhabits large resources of gas both discovered and undiscovered for the future in the South Barents Sea the countries production of blue hydrogen is feasible for the future. Furthermore, cross-border trading of hydrogen because of the need for decarbonization globally leads to a promising future for hydrogen and is possible to help reshape the global energy politics in the future (Noussan et. al. 2021).

4.6. Blue Hydrogen

Considering blue hydrogen in the transition towards climate neutrality will be important as it works as an alternative to make use of immense resources of natural gas while moving towards climate neutrality. This connects to Norway's future if the country is to remain as a world-leading country in the energy sector. Creating both a domestic and international market and infrastructure for hydrogen production will be important for the future of Norwegian energy production (Gardarsdottir & Sundseth, 2021).

Blue hydrogen is based off the idea that current production processes can be coupled with CCS technologies to eliminate unwanted GHG emissions to the environment. This approach is considered less costly than green hydrogen, hence why it is deemed as important for the future as the world transitions into a low carbon future. However, it is important to remember that CSS technologies are in the early stages and may face technical barriers in later stages.

In addition to the advantage of cost, blue hydrogen also has the ability to continue building on the principles of the commonly used grey hydrogen. This can be performed by using existing plants and adding CCS technology to benefit from the existing infrastructure. However, there needs to be measurements to secure safe storage of CO_2. In many instances an additional facility is needed to the generation facility, which may not already be in place.

When defining blue hydrogen there exists no standard definition as to how much CO_2 should be captured to consider it blue hydrogen instead of grey. Studies shows a range of capture from 70-95 % captured. On the other hand, questions have been raised in previous articles towards the unburned fugitive methane which is released when creating blue hydrogen in upstream phases, this ultimately raises the awareness as to how green blue hydrogen is. However, minimization of such factors is possible in countries with low emissions in production such as Norway, the UK, and the Netherlands. These countries have methane levels below 0,5%, compared to articles stating an emission level of over 2% (Bauer et. al. 2021).

4.7. Current Hydrogen demand

Since blue hydrogen is at a maturing stage, we tend to look for future demand scenarios for Hydrogen, and this article is based on future forces for hydrogen and natural gas. However, it is important to monitor present demand for Hydrogen in order to understand if there is demand for hydrogen in the future. IEA released a statement in 2019 on the rise of demand for Hydrogen, where we have seen a threefold increase since 1975. Also, the number of countries that support hydrogen is on the rise, this includes policies that support further investment into RND for Hydrogen. Such policies are promising for the future of Norwegian blue hydrogen, as it is in its early stages (International Energy Agency, 2019).

Furthermore the 2020 demand for hydrogen was at 90 megatons, with 70 megatons used as pure hydrogen and less than 20 of the 90 used as hydrogen mixed with carbon gasses in steel or methanol production, almost all of the demand consisted of refinery and industrial uses of hydrogen, large scale operations. As we see in the table below by IEA the current 2020-2030 demand is based on hydrogen from fossil fuels. With the hope for hydrogen based on electrolysis to take over 80mt of the market within the year 2030, and an increase from 0,71Mt to 55Mt of Hydrogen with CCS in the short future (International Energy Agency, 2019)

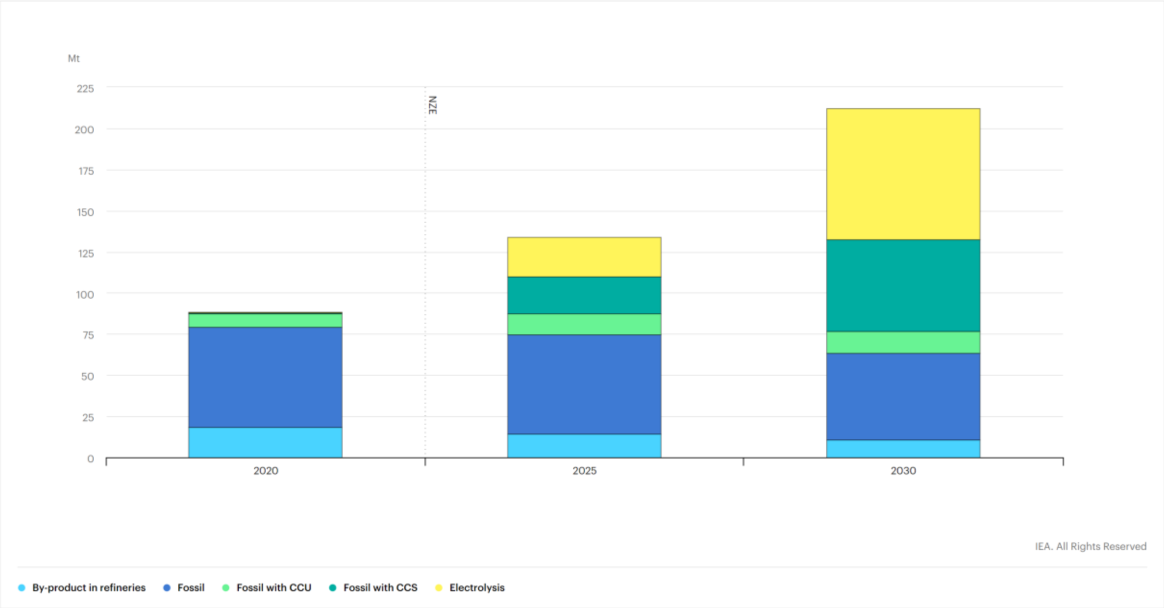


Table 3. International Energy Agency look on demand for Hydrogen by production technology. Outlook 2020-2030 (International Energy Agency, 2019).

If we take a look at the areas of use for hydrogen towards 2030 according to IEA, it is clear that the demand for hydrogen for refineries and industry will continue to dominate the market demand towards 2030. While grid injection to natural gas grids and ammonia for fuel will be introduced in 2025 and continue to affect the market in the future years, both with a production volume of 51 Mt for grid injection and 18 Mt for ammonia as fuel (International Energy Agency, 2019).

Companies are within early stage of blue hydrogen (Global CCS Institute, 2021), the research and development phase of entering blue hydrogen. So there needs to be a focus on developing projects to explore the need for hydrogen, and different methods to retrofit existing systems to further develop the infrastructure around blue hydrogen.

“We are within the research and development at the moment and there we have a number of collaborations related to this. We have a "joint industry project", where we look at the possibility of blue hydrogen in the future, where could this be relevant? And how do we get

hydrogen to the markets. In such a setting, Gasscos role could be linked to reuse of infrastructure, can existing pipelines be used to export hydrogen? Can hydrogen be added to the mix? This would be a place where Gassco could contribute (Respondent: Thomas Djønne).”

4.8. Discussion of Future Horizons for Blue Hydrogen

In the following chapter I take a look at discussion topics relevant to the future horizons formed in the analysis chapter. I show the resource availability for blue hydrogen along with the question, can blue hydrogen be used as a transition fuel? Further I show blue hydrogens role in the future energy markets according to reports.

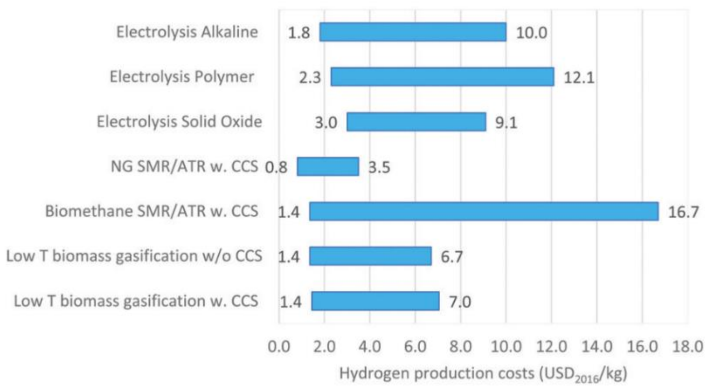
4.8.1. Resource availability, Blue Hydrogen as a transition fuel?

If we look at natural gas with CO_2 capture and storage and its current resource availability it is considered as sufficient, as well as the resource availability 2050 it is considered that blue hydrogen will have sufficient resources. While if we take a look at all electrolysis processes there is limited resources available, this changes towards 2050 where electrolysis processes are considered to have sufficient resources in 2050 (International Energy Agency, 2019).

Moving towards the Paris agreement it is clear that CO_2 emitting production is being prohibited, therefor it is not surprising that most new hydrogen projects planned are projects involving natural gas reforming with carbon capture and storage technology for large scale projects and electrolysis for smaller scale projects. There are issues related to electrolysis presently, the main issue is availability of low-carbon electricity, as well as very high costs related to green alternatives. In the future it is expected that such high costs of green energy are to decrease due to technological development as well as economy of scale (International Energy Agency, 2019). However, the mentioned issue of renewable electricity seems to become an issue for the future as well.

In 2020 the total amount of solar and wind energy was at 10% of the global electricity production, this is projected to raise to 50% within the year 2040, with the major role being played by fossil fuels still (International Energy Agency, 2019). This will affect the ability of electrolysis to tackle large scale projects in the future. Therefor blue hydrogen must be seen as a transition fuel, in transitioning towards a fully renewable hydrogen production. If we look at the tables below, we see that the natural gas steam methane reforming produced hydrogen with CCS has the lowest range for production costs, which is promising for the future of blue hydrogen. Not only does it have the lowest cost range, but it also proves promising when we look at the lifecycle impacts as it is close to the GHG footprint of renewables if certain conditions are met. Firstly, there is a need for advanced reforming technologies such as autothermal reforming (ATR) with CO_2 removal rates approaching 100%. Secondly, keeping methane emissions to a minimum throughout the entire production and supply chain in connected to the European standards (International Energy Agency, 2021).

The future of blue hydrogen also depends heavily on the availability of CO_2 infrastructure connected to storage and transport. Measures both domestically as well as in the EU needs to be set to facilitate for the future of CCS, which will be critical for blue hydrogen advancement towards net zero 2050.



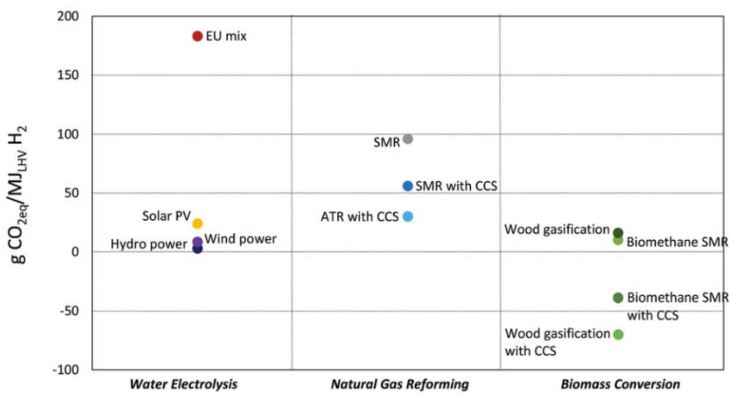


Table 4 & 5. Hydrogen Production Costs, from Electrolysis, Natural gas steam methane reforming or autothermal reforming and biomethane with SMR or ATR (5). CO_2 emissions from Hydrogen produced from water electrolysis, natural gas reforming and biomass conversion (International Energy Agency, 2021).

4.8.2 Blue Hydrogens role in the Future Norwegian Barents Sea

A Sintef report clarifies the role of hydrogen from natural gas coupled with CCS technology. According to the report blue hydrogen will produce a turnover of 220 billion NOK, and from 25000 to 30000 employed in the industry within the year 2050 (Reigstad et. al., 2019). The importance of implementing both blue hydrogen and CCS technologies in the Norwegian arctic becomes more evident when looking at numbers of CO_2 emitted in Nordland County in Norway, Nordland County emits 1,5-2million tons of CO_2 pr. Year from the processing industry. This industry has a goal of reaching net zero withing 2050, while the need for production increases. Such goals will need a strategy for handling CO_2, there is a need for advancement in the CCS technology along with the use of renewables and other new energy sources such as blue hydrogen (Regjeringen, 2020)

5.0. Empirical Discussion

In the following chapter I show my empirical findings that develop an empirical discussion retrieved from interviews conducted with my chosen sample. As described in the methodology chapter my sampling technique included a discussion with my supervisor Dr. June B. Doornich and CEO of Arctic Energy Partners Kjell Giæver. Since Kjell Giæver has a great knowledge as an energy cluster amongst the important actors in the Barents Sea both in Natural Gas and Blue Hydrogen, it was appropriate to use him to find a good representative sample along with my knowledge on important actors in the Arctic climate.

5.1. Discussion about forces: Climate

The respondents to questions of climate are varied, both researchers and representative businesses have their take on how climate is a force that affects the future energy climate in the Barents Sea while having a take on the future outlooks of the Barents Sea.

My respondents agree on the criticality of reducing emissions of methane from the natural gas production, this urgency is also proven in the blue hydrogen production. The emissions from unburned fugitive methane leakages have the possibility to unlock irreversible effects for the climate. The need for an international regulation underpins how we source our methane leakage. Creating a certain standard to adhere helps clarifying what targets could be set by various players in the industries. Setting very clear standards on emissions is a clear point.

"To adopt something like a twin track approach where you have both green and blue hydrogen simultaneously developed based on the strategic asset, but over time gradually tightening the emissions standards. Accounting for the wider scope at the system to incorporate methane leakages in that standard as well, if you did that you would start out with the system that will allow a broader range of participants to compete and then you would have to force technology innovation by gradually tightening that emission standards. This is something that which we are recommending, and which is going into the discussions at the moment (Respondent: Nixon Sunny)."

This is a possible approach going into the future considering the criticality of measuring both CO_2 and CH_4. However, both researchers and businesses agree that the standard from Norway overall is very good compared to other countries. Norwegian companies have good transparency when it comes to emissions and are among the best in the world when it comes to keeping low rates of emissions from methane. Previous 2021 article by Howarth & Jacobson (How green is actually blue hydrogen) shows numbers (Study conducted in the

United States) that are proportionally higher than what is the reality of Norwegian emissions of methane. US 197 million tons, 80% (EPA, 2020) of this is from the natural gas sector compared to Norway's 0.018 million tons from the oil and gas sector (SSB, 2019).

5.2. Discussion about forces: Technology & emissions

Both researchers and businesses touched on the subject of technology when it comes to the future of blue hydrogen and natural gas. In a few interviews there was a heavy emphasis on the capture rates of CCS, as this has been a discussion in literature previously.

5.2.1. Are 95% and above capture rates possible for CCS?

Capture rates of 95% and above is technically viable, there is no practical engineering limiting you from going 95% and above. However, it is a question of how much energy is to be used to be able to go above 95%. Since there is a need for more energy to produce higher capture rates there is a possibility that going higher than 95 would do more harm than good.

"Sometimes it might have an effect on environmental best case scenarios as well, it might not be the best for you to capture 99% worth of CO_2, because in order to capture more CO_2 you need to use more fuel, and if this fuel for example comes with methane emissions, then if you use more fuel then you have to counteract and think is the extra 3-4% worth it? Literature on that is still a bit hazy, the point is there is no fundamental limitation there (Respondent: Nixon Sunny)."

This also includes a cost tradeoff; the cost has a flat and acceptable growth of cost reaching 95%. However, when going above 95 the cost grows exponentially along with being ineffective. An alternative strategy explained is to introduce biogas into the mix to account for the remaining 5%.

CCS can be an applicable technology with high capture rates as it matures in the future energy picture. Researchers agree that maturity is needed as the CCS is still in its early stages. As used in previous literature we see underperforming systems, as the technology is yet to mature, however this should not be used as a deterrent. We will see underperforming systems in the process of finding our way to higher capture rates and technological maturity.

5.2.3 CCS Value Perspective

To understand why companies would want to use CCS, I want to show the profitability. Profitability of CCS is mainly built up by 2 elements. The first element is regarded as economical profitability. With an ETS of 100 EUR it will be possible for companies to be able to run their CCS systems with profitability without subsidies. To get a better understanding of how close the ETS is to reaching 100EUR, we can examine the price increase of ETS since the start of the Northern Lights CCS project, where the price was at 5EUR at the beginning of the project, now it is at 70-90 EUR. In order to run this profitable there is a need to run CCS through pipelines instead of ships, and to scale up CCS more than it is at this time. However, the willingness to pay for clean energy is often times higher than the taxes.

This brings us to the second area of profitability for CCS, the social profitability element. This will be proven when businesses have a choice of paying taxes to emit CO_2 or make the choice to capture and store their own CO_2, they can provide a social profitable element to their business. If faced with the opportunity to capture and store their own CO_2, they retrieve added value to their company by bragging rights from being sustainable. Doing so can help companies attract more employees, strengthen their reputation, and ask for higher prices for goods that are produced with carbon capture and storage technologies.

"You can compare the value concept of having your own captured carbon to buying eggs from free range hens (Respondent: Steinar Eikaas)."

5.3. Future horizon for: Norwegian Arctic blue hydrogen

All respondents have responded on the role of either both or one of the two, researchers and businesses have different perspectives on the role of blue hydrogen and natural gas towards 2050 and beyond.

5.3.1. Blue Hydrogen as a transition fuel in a Norwegian perspective?

Questioning the position of blue hydrogen is understood as important as the EU keeps its main focus on green hydrogen. The EU goal towards 2030 is to reach 10 million tons of green hydrogen, while the total blue & green hydrogen in 2021 was at 0,5 Mt (European Commission, 2021).

Therefore, blue hydrogen is considered as an important transition fuel towards 2050, as the world transitions from blue to green. Politically there is a higher momentum to green hydrogen, this is making sense from a diversification standpoint as well as the need for financial backing that is needed within the high-cost green hydrogen.

The primary reason to not do green is from a cost standpoint, therefor we will see different roles for blue and green hydrogen in the future energy market. It is favorable with use of blue hydrogen because scale favors it, it applies to industrial demand because it is stable compared to intermittent energy sources used within green hydrogen. However, there are areas where green hydrogen can play an important role, therefore we need to see the cooperation between the two resources green and blue hydrogen instead of asking the question "Green versus Blue".

"Blue hydrogen, although scale favors it there is a lot going for it, it might be better suited for industrial demand because you do not need to ramp it up and down. You do not need to worry too much about storage in the system. In hydrogen storage you might need small buffers, but this is ultimately what you will need because the industry basically uses hydrogen base load demand, they just run their assets out with max utilization, throughout that time frame. Whereas if you were trying to meet the demand where people are involved then you have to cater it to what people do at nighttime, what people do at daytime: Transport, heating, power, use all of these will require a lot of storage and infrastructure, maybe in those instances it would make a lot of sense to apply a hybrid approach (Respondent: Nixon Sunny)."

In addition, blue and green hydrogen varies in applicability in regard to what region you are looking at. With regions such as Norway it would be more reasonable to consider blue hydrogen based on its resources of natural gas, and other regions that have a high access to renewables it would be less reasonable to consider blue hydrogen:

"Nobody really wants to have blue hydrogen, it is just that if you were to have it at scale or to produce hydrogen at scale, then there really is no clear way to get it. Green simply is not going to deliver it, firstly at the price point, secondly at the scale. So, the question is, this is something that we have to live with if we go down that picture (Respondent: Nixon Sunny)."

However, there is a need for a transition phase, how long this transition phase can be difficult to predict. A transition phase can be 50 years from now, it does not seem like green hydrogen or green ammonia will have started to dominate the market within 2050. Therefor it is the blue solutions of hydrogen that needs to play an important role in the coming years towards 2050. We might even see blue hydrogen dominance in the coming 40-50 years.

As for Norway's role in the transition there will be a shorter way to decarbonize and create projects such as blue hydrogen and blue ammoniac since Norway already have existing infrastructure that can be retrofitted to fit blue hydrogen production. Additionally, the amount of natural gas resources along with existing accepted project Barents Blue focusing on the production of Blue Ammonia in the Norwegian arctic makes it a favorable area for development of blue hydrogen. It will be important in the transition phase for Norway to maintain a proactive role. With the new clean energy comes higher costs and for Norway's energy system having one of the world's lowest cost disadvantages when it comes to clean energy, it will set them in a position to tackle the transition very well. When looking at the Barents Sea in particular, this is a region where the need for dissemination of the value of resources is critical. The bottleneck created by underexplored resources creates an issue where if there is an exploration of natural gas, the possibility to extract does not happen until 40-50 years later. This creates an issue where companies do not want to search for natural gas.

"The fact that the gas we have underexplored in the Barents Sea today is a resource not a problem will prove easier to explain nowadays with the energy situation that is now (Respondent: Steinar Eikaas)."

This can possibly work as a barrier for blue hydrogen production from the Barents Sea, as the time aspect connected to extracting new resources may have natural gas resources locked in its primary use instead of being applicable as use for blue hydrogen. However, this can be changed with an increased focus on hydrogen from the EU, taxation of natural gas or statements made on the overall use of natural gas.

5.4. Future horizon for: Norwegian Arctic natural gas

The basis of this chapter is derived from reports on natural gas as well as interviews conducted upon the future of natural gas in the Barents Sea towards 2050 and beyond. Findings are related to the forces that drives or works as a barrier for future development of natural gas in the Norwegian Arctic region. The amounts of gas exported through pipelines are enormous and the demand is high for natural gas in the present energy market, Gassco who delivers and develops pipelines solution on the NCS:

"Deliver more than 100 billion standard cubic meters of gas yearly; this is around nine times of the Norwegian Hydropower. This means that there are enormous amounts of energy exported to Europe (Respondent: Thomas Djønne)."

This proves that the market for natural gas presently is high, and that natural gas is highly relevant as a resource in the coming years.

5.4.1. Biomethane to replace natural gas?

While the STEPS scenario of IEA claims that natural gas is expected to rise substantially towards 2050 because of the need for natural gas to replace coal in the future energy picture

(International Energy Agency, 2019). There are reports stating that biomethane has the ability to replace natural gas in the medium to long future (Wang, 2020). Because of its chemical identity to natural gas, it has possibilities for transportation similar to natural gas, and similar usages. However, the use of Biomethane has two significant differences to natural gas. The first being since it is captured from decaying materials it removes the issue of fugitive unburned methane emissions, in addition biomethane releases only carbon that is circulating in the air beforehand whilst natural gas releases carbon that otherwise would've remained locked underground. Further, the benefit of being able to be produced in far more locations than natural gas, avoiding the future reliant on gas reserves (Baraniuk, 2022).

Although it seems promising, there is still the issue of costs linked to biomethane as it is for green hydrogen. To avoid this issue in the future if biomethane is to replace natural gas there is a need for scale-up within production of biomethane. Additional policies are required in order to speed up the transition (Wouters, 2020). Further there are issues connected to scale when considering biomethane at a large scale as natural gas is. Comparable there are major differences connected to scale.

5.4.2. Triple stranded resources in the Barents Sea

The demand for gas on a global scale is high presently, the need for low-cost energy resources such as natural gas is high in alignment with the growing population. However, during my research I have discovered that many resources are stranded. I qualify these resources as stranded, double stranded and a new term developed during this study, triple-stranded resources. Stranded resources, or resources that are explored but assets gas companies are unable to sell are considered stranded. These stranded resources are possibilities for Norway in the future if they can be extracted as the demand is existing within the EU region for natural gas, and will only increase with the need for replacing coal in the future:

"In the Barents Sea these resources accounts for around 50bcm, with such resources available there is possibilities for the Arctic region to become a more mature gas province. A mature gas province with more platforms, pipelines, ships, terminals can increase the capacity and lower the stranded assets. As of right now the Norwegian arctic region is not a mature gas region, since there is only one gas field running at Hammerfest, and this field is running at maximum capacity. Therefor when there are new discoveries in the Barents Sea, there are no places for the gas to be transported and it is left underground as discovered but stranded (Respondent: Kjell Giæver)."

The Barents Sea is complicated when it comes to assets as the criticality of the Arctic climate demands structured planning before extraction. There are areas of the North Barents Sea where there is believed to be enormous resources of natural gas, however this gas has not been discovered yet, there is no infrastructure to extract it and there are regulations prohibiting exploration in the area of the North Barents Sea. The above-mentioned aspect is what I classify as triple-stranded resources. These resources need utilization if there is to be future large market for natural gas and blue hydrogen from the Norwegian Arctic. The demand for natural gas strengthens the need for North Barents Sea resources.

Remembering that the resources within the Barents Sea North are located far from land is important when understanding the issues of extraction from the now closed Barents Sea North. However, there are drivers to making discoveries in this part of the Barents Sea connected to the magnitude of the findings:

"The resources are very far from land and what is perhaps the most important driver if you were to develop these resources, is that you find large enough discoveries to be able to financially defend a new development. We completely lack infrastructure in these areas, and that is a prerequisite. So theoretically if the discovery was large enough to be able to defend the development financially then it would be possible. And that would in a way be a springboard further to be able to develop other smaller discoveries that are nearby (Respondent: Ole Hass)."

The resources within the Barents Sea North can be seen as critical if there is to be a development of blue hydrogen or with the increase in need for natural gas continues. Therefor there should be a focus on discovering what resources lie underneath the seabed in the Barents Sea North. Norway is in a good position to extract these resources in a sustainable manner and make use of the needed possible natural gas resources that exists in the Barents Sea North.

Issues of lacking infrastructure makes extraction and transportation of these resources highly complicated, therefore the discoveries that are made needs to be big enough for infrastructure to be put in place to extract these resources with financial gain. The interest of the Norwegian State of the Arctic resources is to increase the value potential of the resources within the Arctic region; therefore, it would be valuable to connect small discoveries to the larger discoveries and connect them to an infrastructure ultimately.

5.4.3. Climate regimes might end up favoring natural gas

Mentioned in 2015 by Nord University "Climate regimes might end up favoring natural gas in the future", my question evolved around how this statement held ground in 2022 for the arctic gas and climate debate. My findings are that the statement is even more precise in 2022, the need for energy now is higher than it was in 2015:

"The issues of climate change of today does not automatically mean that we need to stop using natural gas, as it can be a solution for the future such as in the exploration of important minerals for the transition along with an important driver for the blue hydrogen. In addition to being a great alternative to coal (Respondent: Frode Mellemvik)"

We have had technological breakthroughs such as the CCS technology advancement that puts natural gas in an even better position than it was in 2015. Where additional thought processes behind the need for natural gas in the future is the belief that natural gas will aid the extraction of important minerals needed for the green transition in creation of batteries and other important technology found in the Barents Sea region.

Climate regimes might favor natural gas when looking at the other possible solutions, at the same prices, examples of such solutions include coal. Where there is higher need for cheap energy, in such instances natural gas is a more viable solution for the climate when compared to coal.

This concurring energy crisis sparks the need for such low-cost energy, costs of both natural gas and coal including ETS is critical when selecting which energy source applicable in which region, in poorer areas the focus has been on upscaling coal production which further leads to major emissions. If you look at the table below you can see that the cost of natural gas from January 2021 to January 2022 compared to the cost of coal it is clear as to why coal is still relevant in poorer regions. These lower costs of coal make it possible to open old coal mines, and makes coal production profitable, whilst high gas prices left spot price electricity at high numbers.

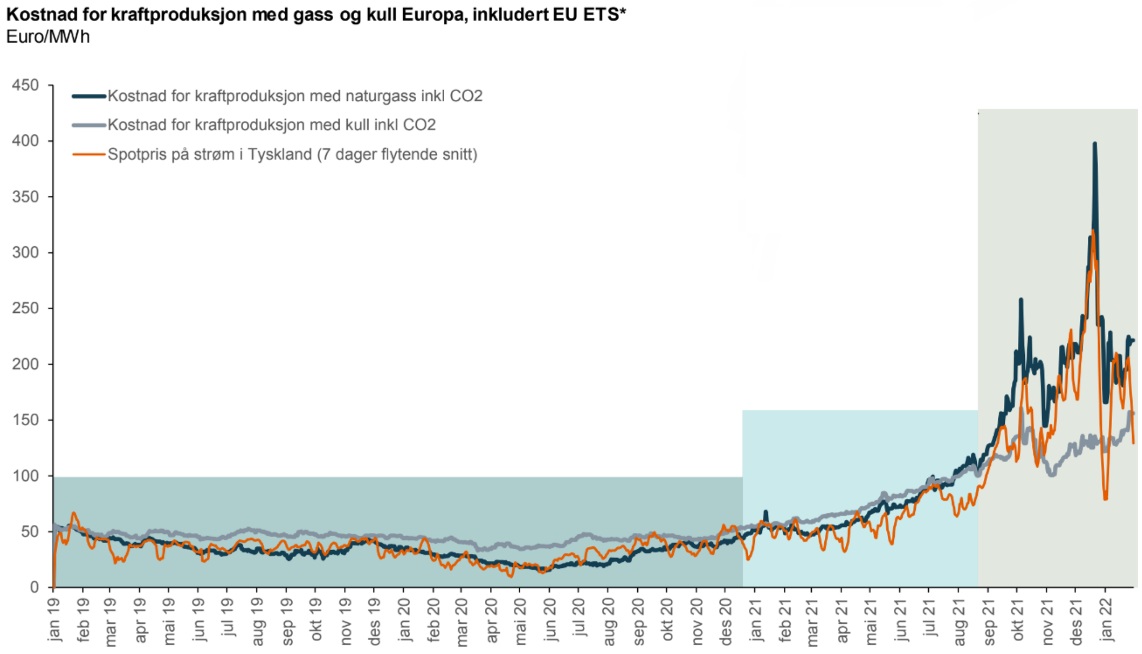


Table 6. Estimated production cost of Natural gas & coal in Europe, including EU ETS (Rystad Energy Analysis, 2022).

Due to the increase in coal production and increase of natural gas cost the overall emissions from the power sector were higher in 2021 than in 2020, while gas had a decrease in production of 2%, coal had an increase of 18% leading to higher emission rates. The increase from 490 TWh to 579 or an increase of around 90 TWh in the coal sector equates to 17 Bcm if it were to be covered with natural gas, if gas had the capacity to deliver these numbers there would have been a decrease of 55 million tons of emissions in 2021, this equates to more than the total emissions from Norway in 2021 (Rystad Energy, 2022).

Not only is there issue of cost a barrier for natural gas, one of the main barriers to natural gas from the Norwegian Barents Sea is having enough natural gas to supply the demand. capabilities of Melkøya in Hammerfest which is the only natural gas producing plant in the Arctic at the moment is running at max capacity in extraction of resources:

"One of the main barriers for natural gas is the access to natural gas. There is still not enough gas to deliver the wanted rates needed to fulfil market demands towards 2050, this creates an imbalance in the energy market as we see presently (Respondent: Kjell Giæver)."

This imbalance can be regulated with an increase for exploration of natural gas within the Barents Sea South and also in the future exploration of the resources within the Barents Sea North. What proves difficult with production running at full capacity is the ability to readjust to the changing energy climate, while securing predictable gas to Europe aligned with demand.

"The focus now is to supply high/secure and predictable gas/energy to Europe, this will apply in the coming years. The question is also how fast one can manage to readjust, how fast one can expand capacity on wind to get the alternatives up and running (Respondent: Thomas Djønne)."

My findings prove that natural gas major barriers go beyond the issues of climate change this is verified through various interviews conducted, the need for energy creates a need for a continuation of a stable energy sources such as natural gas. However, emission reductions are possible through the use of natural gas to replace the increasing use of CO_2 heavy coal, this is setting natural gas in a good position for the future outlook of the future Norwegian arctic.

6.0. Summary of discussion

The summary of discussion of the thesis evolves around the three-horizon framework by Sharpe and Hodgson (2006). The future of the natural gas and blue hydrogen in the Barents Sea is explored through the three horizons to create a future outlook. The forces that affect this transition helps understand which direction the Norwegian arctic resources are taking. In the section below I show a summary of the discussion above that helps portray the future outlook from the first to the third horizon, present to far future. By understanding the forces that drive the transitional phases I build the future outlook.

6.1. Driving Forces: Technology for Blue Hydrogen & Natural Gas

Technological advancement is a force considered for both blue hydrogen and natural gas in this thesis, it mainly deals with three important areas of technology: Blue Hydrogen at large scale and high volumes from the Barents Sea, application of CCS technologies at scale and at a price point where its seen as valuable and lastly the reduction of unburned fugitive methane emissions.

The forces that drive blue hydrogen in the Barents Sea in the future picture is seen throughout this thesis as development of technology, making it possible to consistently capture 95% of the released CO_2 from production leading to blue hydrogen at large scale and high volumes being a favorable option as an energy vector. The amounts of existing resources in the Norwegian Barents Sea region makes blue hydrogen a possible option for a low-carbon arctic solution, however, there needs to be a heightened focus on exploration of resources as well as extraction of known resources as the need for available gas is increasing along with the need for clean energy.

The role of blue hydrogen if hydrogen will be the focus of the existing century will be important as a transitional fuel towards green hydrogen as a favorable long-term option, technology will be the decider to whether or not green hydrogen can mature enough to provide hydrogen at large scale. At this point of time the only viable option to provide secure, large scale low-cost hydrogen is the application of blue hydrogen. For the technology to be well developed at scale there is a need for technological advancement within CCS as well as low emission rates on unburned fugitive methane. The numbers we see in Norway at the present time 0,018 million tons (SSB, 2019) is low and highly acceptable compared to competing nations such as the United States 197 million tons (EPA, 2020) & Russia 31 million tons (Gazprom, 2020), therefor blue hydrogen produced in the Norwegian Barents Sea through projects such as Barents Blue with the technologies and infrastructure existing seems like a favorable option.

6.2. Forces: Natural gas

Natural gas has drivers within the technological advancement along with the growing population with increasing need for stable, low-cost energy alternatives. Not only does natural gas provide stable energy with low emissions of CO_2 but it also works as a flexible source coupled with renewables in the green transition. Further there is a need to replace CO_2 heavy coal with natural gas, this is why climate regimes might end up favoring the use of natural gas from the Arctic region. The Norwegian arctic is highly competitive with low emission rates of both carbon dioxide and methane within the natural gas industry.

Technological advancement especially within the carbon capture and storage for natural gas in the Arctic is an important driving force, being able to provide the needed stable energy with as high as 95% capture rates of CO_2 will keep natural gas relevant for the foreseeable future. This opens the need for more resources and the mentioned triple stranded resources of the North Barents Sea will need utilization to match the growing need for natural gas as a primary energy source and within the production of new technologies such as blue hydrogen.

There are possible competitors to natural gas within energy such as biomethane, but this market is at very small scales presently. However, if biomethane matures technologically this could be a barrier for natural gas markets with zero emissions. The clearest barrier for natural gas is in fact the access to high enough volumes of natural gas combined with the high demand for natural gas. Especially from the Arctic region where high amounts of resources are stranded, double stranded and even triple stranded while demand only increases.

6.3. Forces: Climate

Climate is seen as the strongest barrier to production of both natural gas and the future of blue hydrogen, in a critical region as the arctic there is not room for an increase in temperature higher than what is calculated in the Paris Agreement. The force of climate is the most powerful inhibitor to further production of natural gas and blue hydrogen, if production is completed with high numbers of emissions.

Ecosystems are changing, sea ice levels declining, and permafrost is thawing releasing higher amounts of CH_4. Urgency needs to be set on reducing greenhouse gasses from natural gas and blue hydrogen production to avoid unlocking effects to the Arctic that are possibly irreversible.

The previously mentioned technologies of carbon capture and storage is the solution to reduce emissions from natural gas close to zero which will be an opportunity for further sustainable production of an important energy source as natural gas is for the global market and Norwegian economy while being in an existing world of climate change. This is clarified especially with the increase of coal production in population heavy countries such as China and India, natural gas has opportunities to reduce these emissions drastically by being a cost-effective, lower emission option to replace coal in these countries and evidently lowering the effects of climate change.

As it is seen through reports and interviews throughout this thesis there is a strong emphasis on the climate perspective throughout Norwegian companies acting proactively in the Barents Sea. Taking such a role towards climate change is considered important amongst critical players in the Arctic, this does not mean the discontinuation of natural gas in the arctic, but proactivity towards lowering emissions and improving technology for secure and sustainable energy solutions for the Norwegian arctic future.

6.4. The first horizon

Present forces are affecting the first horizon which is evolving around the current state of play of the energy horizon in Barents Sea. In the 1st horizon I look at the assumptions of the current picture connected to production and future technologies that can affect the duration of the current state of play. The 1st horizon also deals with a look at the current market, whether or not there is promises for the present market. What is taken for granted in the current state?

Throughout this thesis I discovered that the current state of play is evolved around production of natural gas mainly through Melkøya, however there is bottlenecks and stranded resources that inhibits Norway from filling the full potential of need for natural gas to main importers such as the EU.

The first horizon has flaws connected to the emissions from natural gas which is an inhibiting force that ultimately can lead to negative outcomes for climate change in the Arctic. However, there is hope for the Barents Sea natural gas, as technology works as a driving force to reduce emissions of both CO_2 and CH_4. Further I discovered that Norwegian natural gas compares in a cleaner manner to its competitors with lower numbers of emissions of carbon dioxide and methane, along with the current need for low-cost energy the current state of play will be at play for a longer period than we have foreseen earlier.

While researching the first horizon I have seen the first horizon with natural gas has a lot of promises as the energy transition including natural gas is lasting over the year 2050. One of the important driving forces being the possibility to replace CO_2 heavy coal makes natural gas one of the mainstays in the global energy transition as a low-cost carbon dioxide limiting solution, therefor on the background of my research natural gas will be the main factor on the way to climate neutrality.

6.5. The second horizon

The second horizon evolving around the transformational forces that drives the green transition. Further the second horizon evolves around innovations and works as a method to replace the old with practical steps of emerging changes. In my thesis understood as the blue hydrogen technologies and the application and development of early-stage carbon capture and storage solutions.

The need for energy vectors such as blue hydrogen is to be critical if we are to rely on hydrogen in the future. Since blue hydrogen plays a role in large scale hydrogen production by being both low cost and a reliable non-intermittent energy source that provide secure energy that is more flexible in the short to medium future.

Blue hydrogen while not being a wanted long-term energy solution, is a needed energy transitional solution while green energy gains enough momentum to be competitive, this may also happen with the use of taxation systems creating a better playing field for green hydrogen. As all interviewees agree, the main goal should always be green hydrogen. However, there is a long way to go with technological advancement for green to be reliable enough, therefor the transitional phase of the three horizons is dominated by blue hydrogen. It is a promising technology that combines the well-developed infrastructure of natural gas, builds on the existing infrastructure, and coupled with carbon capture and storage technologies captures near 100% of the CO_2 leaving blue hydrogen as an important energy vector for the future.

The price of ETS is approaching an area where it is profitable to capture CO_2, therefor I can see parts of 2^{nd} horizon forming as a transitional innovative phase. Companies in the 2^{nd} horizon will have a heightened focus on proving that they can handle CO_2 on their own as well as emerging companies in the blue hydrogen sector. The Barents Sea with enormous, discovered resources have opportunities to create production built on the existing infrastructure of the Arctic. We can expect natural gas to continue to play a large role within the second horizon as the role blue hydrogen plays automatically sparks the demand for high numbers of natural gas produced.

6.6 The third horizon

In the final horizon I show what emerging changes are developing as completely new paradigms in the energy picture of the Norwegian Barents Sea. Further we try to understand what new issues has worries for the foreseeable long term future horizon, and what the visionary social actors of the regions are saying. The first completely new paradigm in the Barents Sea energy picture in my thesis is seen as the full-scale development of green hydrogen. This includes a low-cost green hydrogen option, which will lead to the possibility of zero emission solutions. In the 3rd horizon there has been development to mature technology of green hydrogen, especially for cost efficiency and the storage of green energy, an example of this can be lightweight batteries. EU's policies drive the need for green hydrogen solutions within the Arctic, the three central climate targets within the 1st and 2nd horizon by the EU: Lower natural gas consume, increased hydrogen production and tightening in carbon taxes creates strong relevance for development of green hydrogen projects within the 3rd horizon as an emerging change.

Although green hydrogen as a technology already exist it is seen as the 3rd horizon because it is small scale, and at very small volumes at this present. The energy market is dominated by fossil fuels, and because of the growing need for energy, the future of green hydrogen is seen as the far future or the 3rd horizon. The issues that worry the new future is the possible override of the 1,5 degrees target set, because the need for low-cost alternatives have been in play for a long time it can be difficult to avoid going above 1,5. These worries needs to be met by technology advancement both for green hydrogen, but also for existing technologies such as blue hydrogen.

Focus should be set on the (+) perspectives mentioned in chapter 2.3. The horizons interaction in order to succeed in a cooperative transition. This collaboration has the possibility to create an innovative playing field for all actors optimizing all resources to its full potential both technologically and by climate standards.

6.7. The Three Horizon Model

Figure 3. Three horizon framework by Sharpe & Hodgson (2008).

7.0. Conclusion

This thesis applies the Three Horizon framework whilst looking at the future outlook of the resource's natural gas and blue hydrogen for the Norwegian Arctic. By establishing a relationship between the driving forces as well as the barriers that affects the progress, I have discovered that the need for natural gas towards 2050 is high and that the technological advancement made within CCS technology as well as the ability natural gas has to aid renewables in being flexible and replace other CO_2 heavy polluting resources such as coal puts natural gas from the Norwegian Arctic in a very favorable place towards the future energy outlook. The existing pipeline infrastructure having the lowest rates of emissions of all gas exporting regions because of low gas flaring rates and higher shares of electrified fields. These low emission rates from Norwegian Arctic gas coupled with future carbon capture and storage sets natural gas from Norway & the Norwegian Arctic on the path as a mainstay in the global low-carbon future. Additionally, the growing populations need for a stable energy source that is low-cost favors natural gas from the Norwegian Arctic in the foreseeable future.

Blue hydrogen from the Norwegian Arctic is possible with the resources existing in the Barents Sea South and North both discovered and undiscovered and coupled with new and existing technologies such as retrofitting pipelines for transport sets Norway in the driving seat for possible transportation and production of blue hydrogen. As a country Norway is in an excellent position to continue with natural gas production and future blue hydrogen production with high amounts of resources, low emission rates, high technological advancement within critical areas such as CCS-technologies, methane leakage avoidance & electrification processes that favors Norway as a greener natural gas producing country while the market for natural gas exists.

Throughout this research blue hydrogen has proven to be an important transition fuel to focus on because of its stability in large-scale operations, this is needed in the early phase of development of green hydrogen. However, green hydrogen should be seen as the ultimate solution in the future, developing technological maturity for the possibility for low-cost green hydrogen solutions, whilst having blue hydrogen as a solution for industrial purposes and other large-scale operations still.

The forces that affect natural gas and blue hydrogen towards 2050 is seen through my research as access to enough natural gas to supply demand, technological maturity of CCS and blue hydrogen, emission reducing activities for unburned fugitive methane and replacement of coal with natural gas. The social actors within the arctic climate agree that natural gas will be a strong driver for the green energy transition being low-cost and preferably as a fossil fuel with the lowest emissions. In addition, there is a common agreement amongst social interviewed actors that the Norwegian Arctic region has good conditions for development of blue hydrogen in the future, with actual projects such as Barents Blue being the largest and first blue ammonia project, the Norwegian Arctic will be in the forefront of the Hydrogen future for the EU.

In a scenario where 100% of gas demand to the power sector disappears there would still be a need for gas to Europe that is higher than what was exported from Norway in 2021 around 120 Bcm. This means that even with drastic changes to the gas demand there will still be a need for Norwegian pipeline gas to supply the remaining demand.

Both natural gas and blue hydrogen have in my opinion very bright outlooks for the future and should be seen as highly valuable if technological advancement is made to avoid emissions that can possibly unlock irreversible effects in the critical Arctic region and create damages of global character. Keeping in mind that converting blue hydrogen to gas is an energy extensive process, losing large amounts of energy in the process, therefor we should always strive to find ways to make it more energy efficient or alternatives to blue hydrogen that has a higher energy efficiency. Considering this we need to remember that the energy loss within blue hydrogen is lower than with use of green electrolysis processes producing green hydrogen, again favoring blue hydrogen as a transition fuel. 147 years ago in 1874 the French novelist Jules Verne believed that one day we would be able to use water as an energy source to replace the issues of coal use, today 147 years later Norway is the best suitable country to be at the forefront of the process of blue hydrogen for the future.

7.1. Recommendations

During my thesis period I have come across some interesting personal suggestions to further research to this topic. Firstly, it is important to keep in mind that this thesis has a limited number of participants, due to restrictions of time and resources in the project. Therefor I believe that interviewing a larger base would provide interesting new information about the topic.

Further research as blue hydrogen develops can also be interesting to continue to monitor, and as the world is in a changing situation in regard to the concurring war in Ukraine it is interesting to see how fast of an energy transition the world will be able to take, including the

Norwegian Arctic resources and the possibility of opening for discoveries within the resource rich Barents Sea North. It would additionally be interesting to see the impact of extraction of resources within the Barents Sea North calculated, if carbon capture and storage solutions are added into the calculations.

Lastly, I would like to see a study conducted on the possibility for production of nuclear energy from the arctic region and how this compares to the production of natural gas. Nuclear energy has the possibility to create stable electricity prices with minimal encroachment of the nature.

Further the recommendation to reach successful use of natural gas & blue hydrogen towards 2050 is:

A heightened focus on CCS technologies, mature CCS enough for stable capture rates of 95%, this strengthens natural gas as a resource as a mature CCS technology helps avoid emissions while keeping a stable energy source such as natural gas in the energy mix. Further there needs to be a heightened focus on developing new technologies and standards for measuring emissions of unburned fugitive methane leakages, creating such standards makes it easier for companies to monitor and avoid high rates of methane leakage. In addition, it will be important to clarify to the global audience that natural gas from the Norwegian Arctic is favorable with low emission rates and companies with transparent business ethics.

If natural gas is to come from the arctic, we need more research and development to understand the resources within the Barents Sea North, these resources can be important if we are to replace coal with natural gas in the coming years. This research and development are also important amongst the pipeline companies for blue hydrogen, by exploring the possibility of retrofitting systems to transportation of future blue hydrogen from the arctic, companies are not only exploring opportunities for their own financial gain, but also for future infrastructural development. Lastly, I recommend developing production of blue hydrogen within the Arctic. Since costs are close to equal with producing blue hydrogen in Norway or elsewhere in the world, there should be a focus set on creating production of blue hydrogen within Norway. Doing so can create ripple effects for a clean energy hub within Norway, preferably within the Norwegian Arctic.

7.2 Limitations

Due to the time frame of the project, I have limitations from going into some other important aspects of this future outlook. The Arctic has a very close geographical connection to the

European market, this strengthens the Arctic gas from Norway, this is not mentioned in detail within this thesis. This gives Norway a competitive advantage over other gas exporting regions to the EU. Further, I have not touched on the production phase of liquid ammonia, where there is a need for a cryogenic process, there are large competitive advantages to producing this in Arctic cold climates because of the freezing process and maintaining the cold, this has not been mentioned in this thesis. Lastly, there is only within the Northern Norwegian region where there is excess of renewables, when the need for blue hydrogen to be a fully emission free process there is a need for excess of renewables therefor the Norwegian arctic is again a favorable place to produce blue hydrogen, this is not researched in this thesis.

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9.0. Appendix

Example of Norwegian Interview Guide:

Naturgass sitt potensiale mot 2050 og utover?

Blått Hydrogen sin framtid i Barentshavet, muligheter for produksjon av Blått Hydrogen i Arktis?

Låste ressurser ved Melkøya? Kan ressurser fra Barentshavet dekke mer av den Europeiske Etterspørselen, eller vil det ta for lang tid å få tak i disse ressursene?

Ditt syn på klimautfordringer i Norske Barentshavet knyttet mot Naturgass & framtidens produksjon av Blått Hydrogen?

I min oppgave så snakker vi om tre horisonter for framtiden (Se bilde under), hvor vil du plassere det som skjer nå i de tre horisonter?

HORISONT 1: Den Nåværende Status

HORISONT 2: En Interessant "Transition" Ide

HORISONT 3: Kommende endringer

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