Master Thesis

Energy, Environment, and Society

"A look at Norway's Energy Future: Can jobs be retained during the green transition?"

Universitetet i Stavanger

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Stavanger, June 2021

MASTER DEGREE IN

Energy, Environment and Society

Candidate Number: 4816
Semester: Spring 2021
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Master Thesis Title: A look at Norway's Energy Future: Can jobs be retained during the green transition?
Subject Words/Key Words: Renewable Energy Climate Change Green transition
Page Numbers: 74 Stavanger, 10.06.2021

Summary

This thesis investigates the energy future of Norway. The Norwegian government has set goals to reduce greenhouse gas emissions. This could affect the energy landscape in Norway significantly. A transition towards low carbon and renewable energy technologies will affect the economy in Norway, and jobs in the oil and gas industry will be lost. This thesis investigates possible renewable energy technologies that can retain jobs from the oil and gas industry during the transition. Interviews with oil and gas industry workers have been done to hear what they think about the upcoming transition and the possible shift into the renewable energy industry. Policies from the different ministries of the Norwegian government have also supplemented the thesis.

The research into the different energy technologies, interviews with oil and gas industry workers, and the policies presented by the government all point in the same direction. Biofuels, offshore wind, and carbon capture and storage (CCS) are technologies that will be important in Norway's energy future both in cutting emissions and retaining jobs. Hydrogen and geothermal energy were found to be possible technologies for the future based on the research and interviews. According to research, policies, and interviews with oil and gas industry workers, pumped hydro energy storage (PHES) with Norway as a green battery will also play a part in Norway's energy future. However, this will not transfer as many jobs from the oil and gas industry as the other technologies mentioned.

In terms of policy, it seems Norway will continue to invest in, produce and explore oil and gas options in the future. This will happen simultaneously as they invest in greener energy technologies, suggesting that even more oil and gas will be exported from Norway in the future. This also tells us that the transition away from oil and gas will be slow and that the oil and gas industry jobs will be safe for decades to come unless policies change.

Table of Contents

List of figures

Abbreviations

CAES	Compressed Air Energy Storage
CCS	Carbon Capture and Storage
CO2	Carbon Dioxide
ETS	Emission Trading System
EU	European Union
FSVP	Floating Solar Photovoltaics
HES	Hydrogen Energy Storage
HVDC	High Voltage Direct Current
kVA	Kilo Volt Amps
kW	Kilo Watt
MLP	Multi-Level Perspective
nM3	Normal Meter Cubed
PHES	Pumped Hydro Energy Storage
PR	Public Relations
PV	Photovoltaic
TW	Terawatt
UN	United Nations

1. Introduction

In 2015 the Paris Agreement was introduced, and the United Nations (UN) member countries decided to take up the fight against climate change together. (Streck et al., 2016). The agreement's primary goal is to reduce global warming to well below 2°C of the pre-industrial average (Streck et al., 2016). The economy of Norway today is highly based on fossil fuel-based energy companies and service companies that deliver products to those companies. With the way the world is moving, many of those companies may go out of business unless they adapt and find new sources of income. Either the environmental focus will limit the amount of fossil fuel produced, or the fossil fuel available will eventually decrease. (Safiee et al., 2009). Norway needs a new source of income that can secure the economy and the job market for when that happens. In 2017 approximately 225 000 people worked in the oil and gas industry in Norway (Ministry of Petroleum and Energy, 2020). For a country with a population of just over five million, that is quite a large part of the job market.

This thesis will investigate what kind of new energy technologies Norway could rely on in the future in terms of jobs and investigate what professionals in the oil and gas industry in Norway think about that future. The oil and gas industry significantly influences policymaking as it is the most significant driver of Norway's economy (Ministry of Petroleum and Energy, 2020). When it comes to energy technologies, Norway, as a green battery for parts of Europe through pumped hydro energy storage (PHES), was the starting point. Still, several other energy storage technologies and renewable energy technologies have been investigated as well. If or when the world will have to rely mostly on renewable energy technologies, there will be a great need to store the energy because of the intermittency of these technologies (Henden et al., 2016). Therefore, energy storage technologies will play a part in this thesis. Norway is currently increasing its wind power capabilities. If this continues, it could free up some of the hydropower used for storage and the green battery for Europe concept (Graabak et al., 2018). The renewable energy sources that Norway transitions to will most likely be based heavily on which ones can create the most jobs. The public opinion has a large effect on policy and what gets done, therefore there must be job opportunities for the public to back a transition.

For many European countries like Germany, UK, The Netherlands, etc., the Paris Agreement means increased renewable energy production. Germany, for example, has set a goal of increasing renewables to 60% of their total energy production by 2050. (Gullberg et al., 2014). They are doing this by making renewables cheaper through benefits like feed-in tariffs. (Moe, 2015). Their focus will be solar and wind, which gives them some challenges. Peak hours for both wind and solar are generally during the day, which means that there will be a surplus of energy produced during this time, and there will not be enough energy production during the evening/night. (Henden et al., 2016). The intermittency in energy production means that the surplus of energy produced will need to be stored effectively, sustainable, and safe. The storage possibilities to consider are using countries like Norway as a PHES battery, as well as "compressed air, large-scale hydrogen storage, and more decentralized battery-based storage within a smart grid system…" (Gullberg et al., 2014, p. 218). Storing clean energy would mean less use of fossil fuel as a baseload to fill in the gaps in the fluctuating energy production. Norway as a PHES battery would be helpful to reach the environmental goals of the Paris Agreement from 2015. Reducing CO2 emissions by using Norway to store green energy from other countries, and not just Germany, would make this goal more reachable.

1.1 Current Status in Norway

Norway is in a unique position when it comes to energy. The main export from Norway is oil and gas, which has created tremendous wealth and security. Most oil and gas produced Norway exports because its energy needs are almost entirely met through hydropower (Gullberg et al., 2014). The mix of wealth, security, and the fact that the energy needs are already met by renewable energy has caused many of the new renewable energy technologies to meet resistance and doubt among politicians and the public (Ministry of Petroleum and Energy, 2020). Norway is also a tiny country compared to many other countries globally. People often say that there is no point in Norway trying to invest more in greener technologies as it will not affect the big picture. People are also afraid that a shift away from oil and gas will cost many people their jobs and careers. This thesis will look into where the energy jobs of the future can be found in Norway.

Topics like PHES and windmills have sparked heated debates and discussions in Norway. In light of this, asking the people in the oil and gas industry instead of just hearing the opinions of regular people would be a good indication of where the future might be heading. The main actors in the large energy industry often have a considerable influence over policy making. They will have a part to play in the road forward in the transitions that are coming, whether they like it or not. This thesis will also try to capture important actors' and professionals' thoughts and feelings in energy-related industries on the coming transitions in Norway. Interviews with them have been conducted to seek out their opinions on what the energy future in Norway should look like when the focus on fossil fuels diminishes due to the lack of new oil and gas discoveries or the pollution and damage it causes. This thesis will also explore any differences in the outlook on the transition in different age groups. If the younger generation has a different view than the older, this could indicate what is to come as the older generation retires. Norway's policy on retaining jobs and transferring talent and knowledge from oil and gas to renewable energy will also be investigated in this thesis. This will give insights into any differences or similarities in the policies compared to the workers' thoughts in the oil and gas industry.

1.2 Constraints

The constraint on resources and time limits the scope of this thesis to a feasible size. It effected how deeply certain subjects were investigated as well as how many interviews and surveys were done. This thesis is about the future of the Norwegian energy mix and exports and the economy and jobs connected to it. Only workers in oil and gas companies and oil and gas service companies in Stavanger, Norway was interviewed due to access and the time constraint.

1.3 Structure of the Thesis

The thesis consists of 11 chapters. Chapter two is a literature review explaining what literature was used as well as what gaps are found in the literature that this thesis has tried to fill in. Chapter three explains the research questions which lay the starting point of the thesis and is what the report will give an answer to. The fourth chapter goes into the research strategy of the thesis. Chapter six explains the methods used during the research and writing of this thesis. It includes methods for empirical research, interview methods, as well as data collection, reduction, and analysis. Chapter six explains the theoretical framework used in the analysis of the results found. The MLP and transition pathways is the main framework explained in the theory chapter. Chapter seven is the presentation of the different policies in Norway that relates to the research questions and the overall scope of this thesis.

Chapter eight gives history, background and current status on the different low carbon and renewable energy technologies analyzed in this thesis. They are also related to how they will fit

Norway in this section. Chapter nine presents the results and findings from the interviews done with the oil and gas industry workers form the two different age groups. The 10th chapter discusses the findings from the different section and goes more into depth on what these findings mean and how they relate to the research questions. Chapter 11 is the concluding chapter where the thesis is wrapped up and the final findings and answers are presented.

2. Literature Review

A few articles and books have been written on most of the relevant renewable energy technologies and how they have been or could be implemented in Norway. However, not many reports say anything about which technologies would be the best to invest in to replace fossil fuels. Furthermore, little has been investigated about what relevant actors in the fossil fuel industry think and feel about the energy transition. To start researching renewable energy technologies book by Coley (2008), *Energy and Climate Change*, was used to get a basic and introductory insight and overview of the different energy technologies. Norway as PHES has been in discussion for some years now so there are a few articles written about it. However, they are primarily focused on the political and social feasibility from the Norwegian and German standpoints. The articles say that it would be possible for European cooperation if the people accept it and no country comes out much worse than others (Gullberg, 2013; Gullberg et al., 2014; Moe, 2015).

The paper by Graabak & Korpås (2016) asses the latest news regarding balancing wind and solar power with Nordic hydropower in Europe. It looks at the need for it, the possible future developments, the consequences of different options, and what changes this would bring to the operations of the Nordic energy system. Graabak et al. (2017) look at the impact PHES will have on the existing hydropower system in which Norway relies on today. The more technical aspect of how different energy storage technologies, including PHES, work (Mahlia et al., 2014) had some excellent insights and techno-economic performance analysis of various hybrid renewable energy systems with different storage options (Awan et al., 2018).

The focus of this thesis is the future of energy in Norway and Norway as a PHES battery for Europe could be a big part of that future. The article by Henden et al. (2016) focuses on the economic feasibility of Norway as a PHES battery for Europe. The report finds that for PHES to be economically feasible, the transmission capabilities between Norway and Europe would have to increase by a significant amount. It also finds that it would be better to use the existing flexibility of the hydropower plants and build little to no new pumped storage. A Reuters news article by Karagiannopoulos (2018) was used for information on the high electricity prices caused by the dry climate of 2019.

Information on the Paris agreement, which has helped spark these energy transitions, was found in the article by Streck et al. (2016). Some information on the state of fossil fuels and their future was seen in Shafiee (2016). McCright (2011) had some insights into how the existing energy regime sometimes present skewed facts to fit their own agenda. For some practical operational strategy related to electricity price Connolly et al., (2011) was helpful. Endegnanew et al., (2013) provided interesting information on the frequency in the Nordic power system. The articles from Smil (2016) and Sovacool (2016) both provide some historical insights on previous energy transitions and their duration, which was useful for the thesis and its research design. Geels (2002) also has some historical insight, but in the form of a transition set in the framework of the multi-level perspective.

For the research strategy part, the great work on social research by Blaikie (2010) was very helpful in figuring out which research strategies to use and, in general, to guide the entire research design. Together with Yin (2018), it also helped determine which research strategies to not use for this thesis. They outline the different types of research strategies well, which helped when choosing the one that fit and did not fit the study. The information on the theoretical framework the multi-level perspective (MLP) was found in several books and articles (Geels, 2004; Geels, 2011: Geels, 2014: Grin et al., 2010). The book by Grin, Rotmans, & Schot (2010) also provided the theoretical framework of the transition pathways for the theoretical section. Blaikie (2010) and Yin (2018) were also important in data collection, reduction, and analysis of the research design. Meadowcroft (2011) engages in the politics of sustainable transitions applicable both in the PHES transition and the related renewable energy transitions. Van De Graf and Sovacool (2020) helped by defining the categories that the different energy technologies could be put into. It helped with dividing sections in the interview so that it was easier to have a clear plan with it. It also had information on the different barriers that energy technologies face, which was used in both the interview and the thesis in general.

Energy policy in Norway was investigated through the websites of a few different government ministries. Mainly the Ministry of Climate and Environment (2020) and the Ministry of Petroleum and Energy (2020) were used as they had the most relevant information for this thesis. It said some about the current status of different technologies as well as the plan forward for the oil and gas industry. It did however have some contradictions between the two ministries as discussed in the policy section later. There was little to no information on how these policies would create or retain jobs, which is one of the main focuses of this report.

3. Research Questions

The main goal of this thesis is to investigate the possible energy technologies that could replace fossil fuels as the primary energy technology that can support the economy and retain jobs and talent from the oil and gas industry in Norway. The potential of the different technologies will be investigated to see which would be the best fit. The thesis will also explore what energy needs Norway needs to fill if Norway use more of their hydroelectric capacity for the PHES battery. It will investigate what other green energy technologies are out that could be an option for Norway in the future. The energy policies have been looked into, and oil and gas workers in two different age groups have been interviewed to get their perspectives on the transition towards renewable energy.

"Research questions are needed to define the scope and the nature of the research." (Blaikie, 2010, p. 59). The research questions and the wording of these questions are essential when determining what will be studied and how it will be studied. (Blaikie, 2010). There are three different types of research questions, "why" questions, "what" questions, and "how" questions. (Blaikie, 2010). These correspond with the three main research categories, description, explanation/understanding, and change. This is done to make the selection of research strategies in the next section more manageable.

Here are the research questions that will guide the thesis:

1. What should replace oil and gas as the primary energy investment in Norway to secure jobs according to relevant actors in the oil and gas industry and current policy?
2. What are the similarities and differences between the workers' outlook in the oil and gas industry and current policies on the energy transition?

3. Which renewable energy technologies are available and could be good options for Norway in the future?

4. Research Strategy

To answer the research questions presented in this paper, both an inductive research strategy and a retrodictive research strategy have been used. Although these questions can be answered and researched in several ways, these are the strategies that were followed in this study. Case study was excluded because it explains "how" or "why" some phenomena work. (Yin, 2018). This thesis will try to figure out what energy technology options can be viable replacements for oil and gas in terms of retaining jobs and talent, so it does not quite fit. The deductive research strategy was not chosen as it aims to find an association between two concepts by using a theory that can be tested for relevance. (Blaikie, 2010). There are no two concepts in the research questions that we need to find an association between. The abductive research strategy was tossed around for a while as it could be used for this thesis, but the others were eventually chosen as they fit the research questions better. The primary research for this thesis was done by conducting surveys and interviews as well as mainly researching peer-reviewed articles for information on different renewable energy technologies and their fit for Norway.

4.1 Inductive Research Strategy

For questions one and two, the inductive research strategy should be a good fit to answer them. "The aim of the Inductive research strategy is to establish limited generalizations about the distribution of, and patterns of association amongst, observed or measured characteristics of individuals and social phenomena." (Blaikie, 2010, p. 82). An overview of the possible answers to the research questions with the available data will be given through the inductive research strategy. Data will be collected, and generalizations are drawn from it. (Blaikie, 2010). The reason for the inductive strategy for questions one and two are that they are typical "what" questions, which the inductive strategy is perfect for. (Blaikie, 2010). For question three, it will be to find general information on different renewable energy technologies and see how they would fit Norway.

Information on how renewable energy technologies work and their current state is fundamental inductive research. Question one will possibly need a bit more digging into the research to find which renewable energy technology should be Norway's main focus according to the relevant actors and policy. Interviews with the relevant actors give data on characteristics and patterns among the oil and gas industry workers from which descriptions can be produced. This can again be related to the research questions. There are three main sections in this thesis, technology section, interviews with oil and gas industry workers, and energy policy in Norway section. All of these sections were again divided into categories of society, economy, and technology, as well as barriers and specific categories for the technologies drawn from Van De Graf and Sovacool (2020). This was done to help establish limitations and find patterns within the inductive research method.

4.2 Retroductive Research Strategy

For research question three, more of a combination of the inductive and retroductive strategy will be needed to dig deeper into the underlying mechanisms that can answer the questions. (Blaikie, 2010). "The aim of Retroductive research strategy is to discover underlying mechanisms that, in particular contexts, explain observed regularities." (Blaikie, 2010, p. 87). This thesis includes a large section with history and description of different low-carbon and renewable energy technologies. This was research to build context, lay the groundwork for the interviews, and highlight Norway's different options. The research into these technologies also gave insight into what the literature might say is a good fit for Norway, which compares the interview answers.

5. Methods

For this thesis, some of the focus has been on qualitative research like government websites, peer-reviewed articles, and academic books. The rest have been doing interviews to find the information needed to try and answer the research questions regarding the oil and gas industry workers. The interview data have been gathered through semi-structured interviews with different actors within the oil and gas industry. With university access, there is a lot of information available on both renewable energy technologies and theoretical frameworks and other subjects used to answer the research questions. Some news articles were also used from independent and reliable news sources. Books and articles on the theoretical framework of the MLP and the transition pathways were essential in guiding the study and keeping it from getting off track. The book by Blaikie (2010) was necessary for the method of doing the research design and was used as the project progressed and when additional research was needed. The time dimension of the study will be cross-sectional but might include some historical data for specific purposes. (Blaikie, 2010). The history of low carbon and renewable energy technologies is one example of historical data being used in this thesis. This used several sources to back up claims made, where possible, to validate the facts further. Some of these ideas and technologies are still new, especially in relation to Norway which means there will be some instances where only one source is used. The section with history and information about the different available low carbon and renewable energy technologies was included to give background on the technologies and set up the interviews and give context to the data and answers gathered there. It also allowed for some presentation of what the literature says about the current and future projects regarding these technologies in Norway.

Information on energy policies in Norway were found on government websites. In addition, the ministries have their own web pages, and this is where information on the current policies and focus of the different ministries were found. It also gave some additional insights into other parts of the thesis.

5.1 Interview Methods

The interviews were done with people working in the oil and gas industry as their views on renewable energy transitions are lacking in the literature found. The literature on transitions and renewable energy technologies is mostly from experts within renewable energy or transitions. There is not much on what the workers in the fossil fuel industry have to say on the issue. The interviewees were selected based on age groupings, five interviews were done with workers between the age of 25 and 40, and five interviews were done with workers between the age of 50 and 65. This was done to get a broader scope of the different opinions and thoughts of different age groups. The age differences also allowed for analysis of differences in answers between the age groups to see if the younger or older group was more open to the renewable energy transition and the transition to renewable energy technologies. As the younger group's jobs are more at risk as the energy transition will most likely happen after the older group has retired, it was essential to see if the younger group was willing to switch jobs during the transition. The interviews conducted were semi-structured interviews.

> The semi-structured interview involves prepared questioning guided by identified themes in a consistent and systematic manner interposed with probes designed to elicit more elaborate responses. Thus, the focus is on the interview guide incorporating a series of broad themes to be covered during the interview to help direct the conversation toward the topics and issues about which the interviewers want to learn (Qu & Duman, 2011, p. 246).

The semi-structured interview was chosen as it fit the theme and goal of this thesis. It is a qualitative research method that gives the interviewees some freedom to elaborate and answer follow-up questions to make their opinions clear without going off-topic. The semi-structured interview also gives the interviewer more freedom when it comes to the interview guide as it can vary from very scripted to more open (Qu & Duman, 2011). This made structuring the interview to fit the theme and goal of the thesis reasonably simple. However, because of the COVID-19 pandemic, it proved difficult and unnecessary to conduct all of the interviews in person. Therefore, some interviewees were simply sent the interview questions, making it more of a survey format (See appendix 1). This, in return, made follow-up questions and clarifications more complex than first expected.

The snowball or chain sampling approach was used when finding people within the oil and gas industry. The snowball approach is an approach where a few interviewees help the researcher with more contacts within who fit the criteria needed for the study (Moy, 2008). For example, a few preexisting contacts in the industry like family members or friends were reached out to first. They had contacts that were referred to as fitting for the age and job characteristics needed in the study. To avoid all the red tape that follows gathering personal information, the interviewees will remain anonymous in the presentation of their answers. Only their age was asked of them as that was important for the age groups.

5.2 Methodological Framework

Three categories were shaped with help from Van De Graaf & Sovacool (2020). The categories were social, economic, and technological aspects of the renewable energy transition in Norway and the renewable energy technologies analyzed in this thesis. Their text also had some excellent categories in which to put the different energy technologies and barriers the technologies might face. These were all used to get more structure and simplify analyzing and comparing the answers, technologies, and policy. The interviewees were also given these categories to get the full scope of the goal of the interviews and the study. These are the categories used to place the state of the different technologies.

> **Typically available** describes the traditional systems already used around the world to provide energy services, many of them fossil fueled.
> **Currently available best practice** represents the most advanced commercially available climate mitigation technologies that are cost-effective and widespread today.
>
> **State-of-the-art feasible technologies** are defined as the best performing technologies being prototyped and demonstrated that are technically feasible but have not yet been proven and indeed may not yet be cost-competitive.
>
> **Frontier or breakthrough technologies** are those that could perhaps someday result in significant emissions reductions but are not yet even being piloted or trialed.
>
> (Van De Graaf & Sovacool, 2020, p. 144).

These categories also made it easier to compare the answers from the interviews to the information from the literature and the policies from the Norwegian ministries. The barriers used from the Van De Graaf and Sovacool (2020) text were cost-effectiveness barriers, policy and regulatory barriers, and sociocultural barriers. The interviewees were asked to place the renewable energy technologies in these categories above to see if their answers differed and if they had different answers in what the best options for Norway are moving forward. The barriers were also asked about in the same way to see if the different interviewees saw different barriers to the transition away from oil and gas towards more low carbon and renewable energy technologies.

The societal, economic, and technological categories were also used to analyze the different energy technologies, the energy policy in Norway, and the interview questions. These categories were used to have a clear connection between the three main sections. It also allowed for more straightforward discussion, comparison, and analysis between the similarities and differences of the sections. The barriers and the categories referring to the state of the different technologies were also applied to the other section. However, not all had literature or documents that could answer or place the categories.

5.3 Data, Data Collection, and Data Reduction and Analysis

Social research data can be divided into three types of data, primary, secondary, and tertiary. (Blaikie, 2010). Primary data is data collected firsthand, like interviews, surveys, etc. (Blaikie, 2010). Secondary data is data collected by someone else for a specific purpose, like a research project or a government census. (Blaikie, 2010). Tertiary data is data that has been analyzed and presented as a result or finding by a researcher or scholar. (Blaikie, 2010). As mentioned in the methods section, qualitative data such as peer-reviewed articles and books found through the university library resources were primarily used in this thesis. Using keywords or phrases like "pumped hydro energy storage Norway" or "renewable energy Norway" and similar searches for the other renewable energy technologies, some articles, and sources were found. This created an excellent place to start gathering data. After that, the searches got more into detail, searching for articles regarding specific renewable energy technologies and other subjects that could prove to be helpful. Data like this is primarily secondary or tertiary data. Some books and articles were gathered from previous university classes, especially for the research strategy and the theoretical sections. This gave extra confidence in the sincerity of the data and information of the materials. This again is secondary or tertiary data sources. The interviews done were primary data and were collected through in-person interviews and interviews in survey form sent to the interviewees.

5.4 Data and Ethics

When doing research, it is always essential to have reliable data to back up ideas and arguments. Most of the data is thoroughly checked and vetted by looking at the references they have and how many people have cited the article. The author's background is checked to make sure they are qualified to be writing and publishing on the subject. This is done because it is essential to avoid using articles with an agenda, and results and findings have been skewed to fit the authors' motives. When collecting the data, it is crucial to see the difference between what Bortolotti (2008) calls good and bad science. Especially in the energy industry, some American companies (existing regimes) have created think tanks that pay scientists and policymakers to do "bad" science to get the public to question the impact that fossil fuels have on the environment. (McCright, 2011). They do this by misrepresenting the data in ways that make it fit their agenda.

(McCright, 2011). One of the interviewees suggested that a good student would read the book *Inconvenient Facts* written by Gregory Wrightstone. This book says warmer climates are good for humanity and that it is not affected by human behavior. After searching this author's credentials, one could see that he was a board member at The Heartland Institute and a fellow at the Cornwall Alliance. These are both well-known climate change deniers and skeptical groups. This shows that it is important to look at the scientific author's background when researching renewable energy, PHES, and other climate change related technologies. This also goes into the data sources' reliability and validity, which will be discussed further in the next section.

5.5 Data Reduction and Analysis

The data reduction technique of coding was used as this is the most obvious process for quantitative research. (Blaikie, 2010). All the data and articles collected were put into the codebook program NVivo to organize the data effectively. When doing research, it can often be hard to keep all the information organized, which makes it easy to find back to specific points you might be interested in. The NVivo codebook is a good tool to categorize articles and paragraphs by keywords or themes that you chose yourself. It was used to categorize the articles by chapter in the thesis. There were keywords or short summaries added to the articles to remember better what they contained when needed for more information. The reliability and validity of the research design rely on the reliability and validity of the data used. Reliability is when the study can be repeated, and others can find the same results. (Yin, 2018). Although different researchers can come up with different conclusions based on the same data, the reference list and quotations should give them the chance to find the same conclusions somewhat. Background checks of the author and their sources, as mentioned earlier, will also help to ensure the reliability of the data used for the research design. Validity means whether or not the findings of the research study can be generalized. (Yin, 2018). The inductive strategy, which is used for two of the research questions, aims to give limited generalizations on the subject. (Blaikie, 2010). So that is covered well as far as the validity of the research study goes. As for the data used for the research design, most of it can be generalized in some shape or form. However, even some of the subject makes for pretty narrow and specific generalizations.

6. Theory

The transition to other energy technologies for Norway is a long-term and complex socio-technical transition. There are many moving parts with both local, domestic and international considerations to factor in. The transitions will affect the Norwegian industries, politics, economy, and society differently. Because of all these moving parts, the multi-level perspective (MLP) was chosen as it is a good theoretical framework for transitions of this nature. It is a good fit for transition studies. Scholars have also developed it to bridge science and technology studies and evolutionary economics. (Grin et al., 2010; Geels, 2011). This fits well with this thesis as it deals with economic and technological sustainable transitions. To work with the MLP, the framework of the transition pathways was used to complement it. The transition to new energy technologies is caused by and could cause several other transitions with different pathways. This framework will help separate and highlight the differences of the transitions and explain how they could happen in Norway's energy future.

6.1 The Multi-level Perspective (MLP)

The Norwegian transition away from oil and gas production and towards more renewable energy technologies will cause a shift on many levels in Norway and the countries we cooperate with. It will affect the local, national, and international economies, politics, job markets, industries, etc. Therefore, the multi-level perspective (MLP) will be used as the main theoretical framework for this paper. "The MLP views transitions as non-linear processes that results from the interplay of developments at three analytical levels: niches (the locus for radical innovations), socio-technical regimes (the locus of established practices and associated rules that stabilize existing systems), and an exogenous sociotechnical landscape." (Geels 2011, p. 26). The niches in this scenario will be renewable energy technologies that could be a future option for Norway to focus on. "Niches are 'protected spaces' such as R&D laboratories, subsidized demonstration projects, or small market niches where users have special demands and are willing to support emerging innovations." (Geels, 2011, p. 27). The socio-technical regimes are the already existing energy industries like hydroelectric energy in Norway and the existing oil and gas industry that will be affected by the transition. "The socio-technical regime forms the 'deep structure' that accounts for the stability of an existing socio-technical system." (Geels, 2011, p. 27; Geels, 2004). The sociotechnical landscape is the political and social landscape that has been put under pressure by the Paris Agreement of 2015 and the overall greener thinking by most of the public in Norway and the rest of the world. This has caused pressure, resulting in more renewable energy technologies, which has caused the need for intermittent energy to be stored. “The sociotechnical landscape is the wider context, which influences niche and regime dynamics.” (Geels, 2011, p. 28).

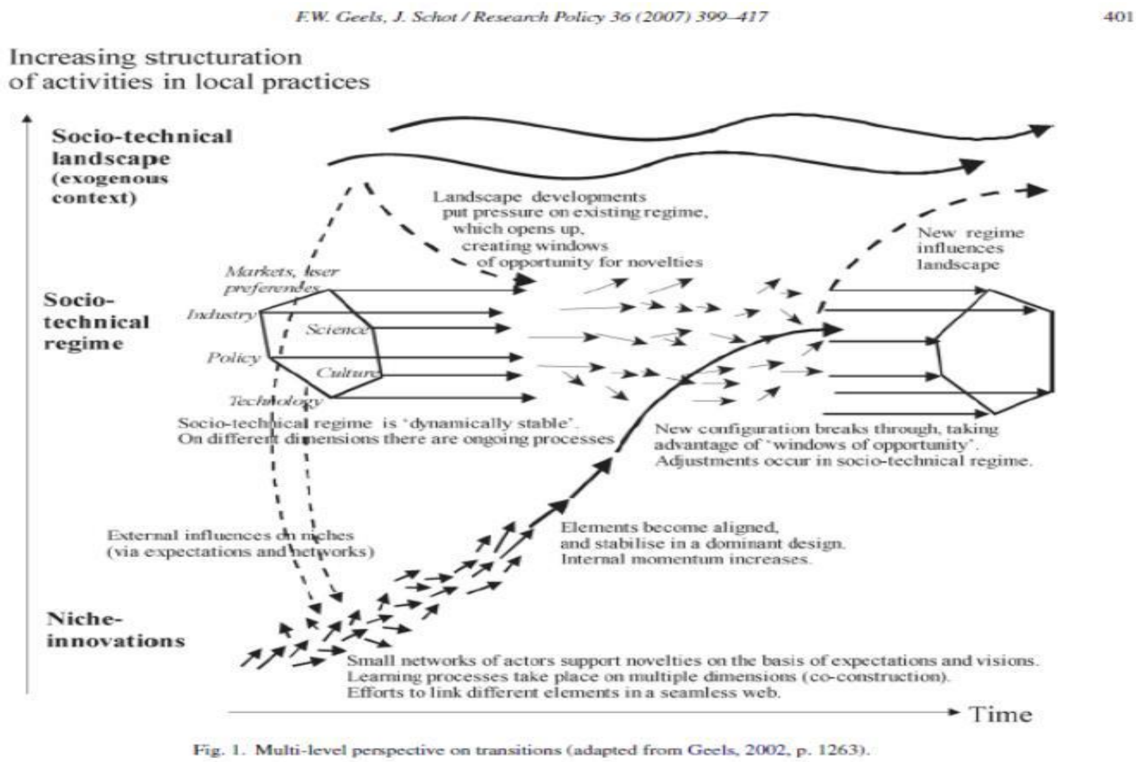

Figure 1- The Muli-Level Perspective (Geels,2002).

6.2 Transition Pathways

The underlying cause of the shift in the primary energy technology in Norway is several transitions towards the more intermittent renewable energy technologies as the world is trying to move away from fossil fuels to combat climate change. Most of them have been caused by the world's environmental problems and the subsequent goals created in the Paris agreement of 2015. These transitions and the transition Norway needs to go through can be explained by the transition pathways theory that builds on the MLP. There are four main types of transition pathways. Grin et al. (2010) defines them in the following manner:

> Transformation Path: if there is a moderate landscape pressure (disruptive change) at a moment when niche-innovations have not yet been sufficiently developed, then regime

actors will respond by modifying the direction of development paths and innovation activities. (p. 57).

De-alignment and re-alignment path: if landscape change is divergent, large and sudden (avalanche change), then increasing regime problems may cause regime actors to lose faith. This leads to de-alignment and erosion of the regime. If niche-innovations are not sufficiently developed, then there is no clear substitute. This creates space for the emergence of multiple niche-innovations that co-exist and compete for attention and resources. Eventually, one niche-innovation becomes dominant, forming the core for re-alignment of a new regime. (p. 63)

Technological substitution: if there is much landscape pressure (specific shock, avalanche change, or disruptive change) at a moment when niche-innovations have developed sufficiently, the latter will break through and replace the existing regime. (p. 68).

Reconfiguration pathway: symbiotic innovations, which developed in niches, are initially adopted in the regime to solve local problems. They subsequently trigger further adjustments in basic architecture of the regime. (p. 72).

In the case of transitioning towards other technologies that are more renewable and moving away from oil and gas, it seems to be following the technological substitution pathway. There is pressure from the public, the environmental challenges, and the Paris agreement to change. The niche innovations like wind and solar power have developed sufficiently and are therefore ready to break through and take the place of fossil fuel-produced energy. In the case of Norway, becoming a PHES battery for Europe looks most like a reconfiguration pathway. As hydroelectric power was first developed to solve local needs, it can be reconfigured to solve a broader need for energy storage instead of just production. One can also argue for the de-alignment and re-alignment pathway for PHES. There are several other options for large-scale energy storage like "compressed air, large-scale hydrogen storage and more decentralized battery-based storage within a smart grid system…" (Gullberg et al., 2014, p. 218). As the transformation has not yet been done or even begun, it is primarily speculative for now. As for now, those are the ones it seems that they will follow. The focus on job creation to make up for lost jobs from oil and gas during the transition could affect both the renewable energy technology selected and the transition pathway it follows. The likely scenario could be that existing regimes and actors in the oil and gas industry will transform themselves from and oil and gas company to a renewable energy company. This would follow a technological substitution pathway within the companies themselves, and a reconfiguration pathway for the landscape as a whole.

7. Energy Policy in Norway

Norway has set a goal of reducing greenhouse gas emissions by 50-55 percent by 2030 based on 1990 levels. (Ministry of Climate and Environment, 2020). The Ministry of Climate and Environment (2020) wishes to accomplish these goals through several actions. Firstly, they want the actors who emit the gases to pay high carbon taxes and other penalties for doing so. “It should be expensive to emit greenhouse gases in Norway.” (Ministry of Climate and Environment, 2020). Over 80 % of the greenhouse gas emissions in Norway are taxed or a part of the European quota system EU-ETS (Ministry of Climate and Environment, 2020). In 2020 Norway banned the use of mineral oil for heating of buildings. (Ministry of Climate and Environment, 2020). According to the Ministry of Climate and Environment (2020), the government in Norway is focusing heavily on climate-friendly options in the transport section. Norway is already doing well in electrifying the private transport section and has the most electric cars per capita (Ministry of Climate and Environment, 2020). Norway is also one of the leading countries in low or carbon-free solutions for ships and ferries (Ministry of Climate and Environment, 2020).

There has been much debate regarding policies on renewable energy in Norway, especially when it comes to onshore wind. The government has recently changed its policies on this topic because of the public's criticism (Ministry of Petroleum and Energy, 2020). They seem to have focused more on offshore wind, which is what the worker in the oil and gas industry think Norway should focus on as well as we will go into more in the results and discussion of the interviews. As for retaining jobs and talent from the oil and gas industry during the transition to more renewable and low carbon energy options, it seems that the policy of the Norwegian government is to have the current regime and actors use their market share and power to invest and transition to more green technologies (Ministry of Climate and Environment, 2020). The talent and jobs will remain in the companies as they transition into new technologies and away from oil and gas. The transition will have the support of a few different research and investment entities that focus on helping renewable energy projects (Ministry of Climate and Environment). This is signaling that the cost-effectiveness barrier of these technologies is being lowered. Many industries have also created roadmaps on cutting emissions while maintaining growth and creating jobs in the future (Ministry of Climate and Environment, 2020). The Ministry of Climate and Environment (2020) policy emphasizes that the green transition needs to be a global cooperation effort with common goals and shared knowledge and guidelines.

The MLP gives an interesting analysis of these policies that Norway now has. There seems to be a goal that policy and industry the existing socio-technical regime will work together to reach the technological substitution pathway where oil and gas are replaced by the renewable energy niche innovations that are fully developed. However, even though the Ministry of Climate and Environment (2020) is talking about the green transition and how important it is, the Ministry of Petroleum and Energy (2020) is calling the oil and gas industry "the most important industry in Norway." It promises further exploration from new oil and gas fields in Norway. They contradict the Ministry of Climate and Environment (2020) and its promise of the green transition. These contradicting policies and the increased regulations around onshore wind can be seen as policy and regulatory barriers described by Van De Graf and Sovacool (2020). These are barriers that renewable energy technologies will need to overcome to break through and become a part of the socio-technical landscape in the MLP. The policies that grant further exploration and longevity in the oil and gas industry could cause a barrier within energy companies. If they are allowed to continue and find new oil fields, this might be more profitable, and all plans to transition to renewable energy technologies might be scrapped or shelved because of it.

The Ministry of Petroleum and Energy (2020) puts oil and gas and hydropower in the typically available category of Van De Graf and Sovacool (2020) categories. They describe them as having laid the groundwork for Norway's economic boom and energy security for many decades. Advanced biofuels, CCS, and offshore wind are presented as the next step as there have been several projects among these technologies. (Ministry of Petroleum and Energy, 2020). These projects signal that these technologies could fall into the state-of-the-art feasible technology of the best available practice category as they are being invested in and tested. CCS is more in the state-of-the-art feasible technology practice at is still not greenlit and not in use worldwide yet.

Biofuels and offshore wind would fall into the best available practice as they are renewable energy resources that have had projects started and operational and are in use worldwide (Ministry of Petroleum and Energy, 2020). It could also be seen as a signal that these technologies will be where the energy jobs of the future will be found. Biofuels, wind power, CCS and hydropower are the low-carbon and renewable energy technologies that the Norwegian ministries focus most on. There are several other technologies that could be a good fit for Norway in the future based on both natural resources and the talent and knowledge transfer from the oil and gas industry.

8. Renewable and Low Carbon Energy Technologies: Background and fit for Norway

This chapter of the thesis presents some of the different renewable energy technologies that could fit the future energy mix in Norway. The various technologies have also been put into the potential pathways of the MLP, as well as the categories presented by Van De Graf and Sovacool (2020). The findings will be discussed further in the discussion chapter later. This chapter is a general overview, history, and background of the energy technologies are given and a current or future fit for Norway. The policy section gave us an insight into the renewable energy technologies that Norway are already investing in today, but there are several other options to consider. Getting the insight from the oil and gas industry n these technologies will provide a better understanding of where the future might be headed, and also which technologies will retain most jobs. This chapter will lay the groundwork for that. The technologies in this chapter were chosen as they are all viable options that could be a good fit for Norway (Coley, 2008).

8.1 Norway as a Battery- PHES

Using moving water as an energy provider has been done for thousands of years worldwide (Coley, 2008). It started by just using the water as irrigations to water the fields. Later it became the main driver of corn grinding mills, first in a vertical-axis design and then in a horizontal axis geared system (Coley, 2008). This horizontal design is the basis of most current modern hydropower plants (Coley, 2008). Hydropower is created when the water in the hydrologic cycle is utilized. The hydrologic cycle is the natural evaporation and transportation of large water masses to a higher elevation with a considerable gain in potential energy as it rises (Coley, 2008).

Rain or snowfall leads to form streams, lakes, and rivers that flow back down to lower levels (Coley, 2008). Hydropower is created by interrupting this flow back down briefly in order to utilize some of the energy of the moving water (Coley, 2008). Norway's geography provides a large number of natural lakes and rivers to use for hydropower production. Norway has the most hydro pump storage capacity in Europe, with about 50% of the capacity available in Europe (Gullberg et al., 2014; Henden et al., 2016).

Hydropower can be effectively used to balance and support intermittent renewable energy-based grids, and this is what Norway could do for parts of Europe (Graabak et al., 2018). During hours of low demand and high energy production, the excess energy can be used to pump the water back up to the higher levels so that it can be stored there to be used later when needed (Figure 1) (Graabak et al 2018; Nikolaidis & Poullikkas, 2017). The process described is essentially how PHES works. With Norway's natural resources and already built-out hydropower capabilities, it is one of the most promising solutions for the variability problems of the increase of renewable energy in the energy mix. The PHES process can be over 70% effective, and maximum generation in hydropower plants can be reached in seconds, making them suitable for balancing grids (Coley, 2008). The capacity of the hydropower reservoirs in Norway represents about half of the hydro storage capacity in Europe (Graabak et al., 2018). There is currently a lack of pumped storage capabilities in the existing hydro power plants, although increasing this would give even more flexibility in the grid (Graabak et al., 2018). If this were combined with the plans of building more solar and wind power, there would be less need for average hydro power production in Norway, and it can be used to support other countries with stabilizing their grids (Graabak et al., 2018).

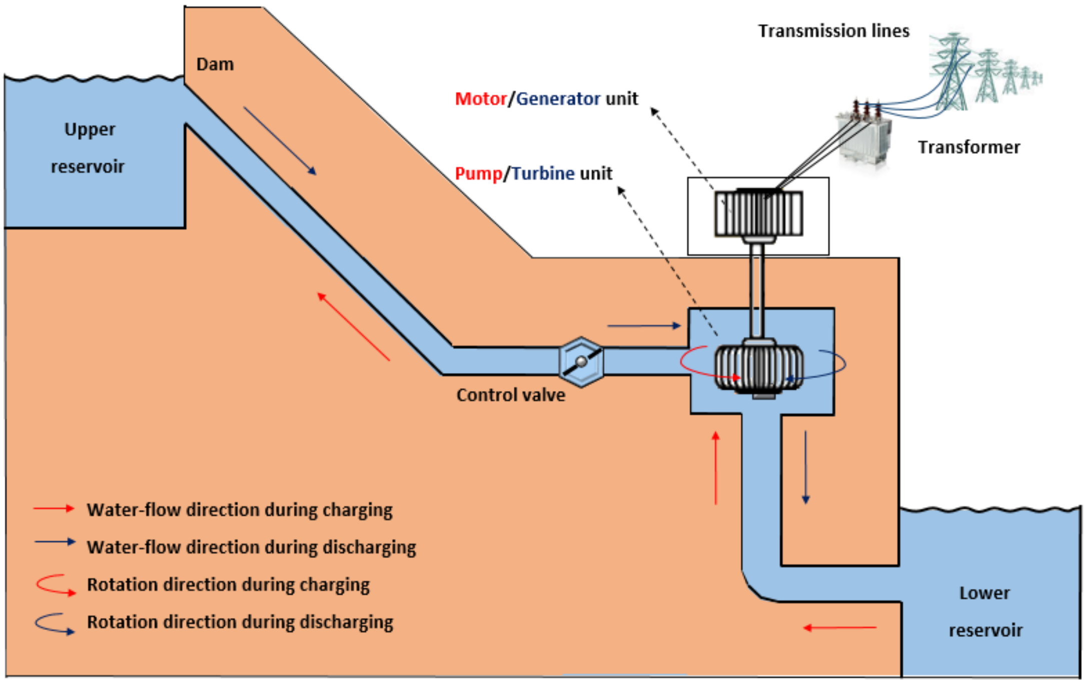

Figure 2- Pumped Hydro Energy Storage mechanisms (Nikolaidis & Poullikkas, 2017).

Some new hydroelectric projects in Norway have been abandoned as they have proven not to be profitable. (Gullberg, 2013). However, that is for new projects that have not yet been built, using existing hydroelectric plants, and expanding and increasing efficiency in these seem to be most promising. (Henden et al., 2016). Becoming a PHES battery also means that Norway will need more renewable energy if they use most of the hydroelectric capacity for energy storage. That is why other renewable possibilities for Norway will also be investigated in this study. Solar and wind power would be explored the most in this regard. With the dry summer, Norway had last year (2018), the price of electricity hit a record high as there was less water available in the water reservoirs of the hydroelectric facilities (Karagiannopoulos, 2018). Suppose Norway were to combine it with solar power either domestically or internationally. In that case, they could use the solar power produced when there is dry weather to pump more water into the hydroelectric facilities by using the surplus of energy produced in the peak solar hours. This would make it easier to keep a more stable price on electricity and give higher energy security (Graabak et al., 2016).

Building new hydropower plants can have many negative impacts like resettling people, loss of natural habitats and species, impact on wildlife and people close to dam, etc. (Coley, 2008).

However, Norway would not need to build any new dams for hydropower plants in order to become a green battery for parts of Europe. To make the PHES battery plan economically viable the electricity transmission capabilities between the candidate countries need to increase (Henden et al., 2016). The fluctuating energy prices caused by weather and growing demand will also influence whether it is economically viable. (Henden et al., 2016). Pumped hydro energy storage has the largest storage capacity compared to other options. (Mahlia et al., 2014). The way pumped hydro storage works is, "The energy is stored by pumping water uphill using peak-off electricity and then letting the water move downhill and driving the generator to produce electricity for power grid when needed." (Mahlia et al., 2014).

For countries like Germany, cooperation with Norway would be very beneficial as it would solve one of their most challenging problems regarding the change to more renewable energy sources (Energiewende) (Gullberg et al., 2014). For Norway, there are two sides to cooperation like that. On one side, there could be an economic benefit for the Norwegian energy industry, as well as helping with the decarbonization on the European continent (Gullberg et al., 2014). On the other side, there will be a need for new grids and power lines that will visually damage the environment. The Norwegian electricity consumption is also already fully met by hydroelectricity (95-99%), which means Norway does not need cooperation (Gullberg et al., 2014). Norway would either need to expand the hydroelectric capacity or invest in more wind and solar power to meet the demand of both the hydro pump storage for other countries and the domestic electricity demand. If all of this causes the electricity prices to rise so that the costs are transferred to the consumer, they will have difficulty getting these plans through (Gullberg, 2013). Investing in new hydro pumped storage facilities is also risky as it is hard to predict if there will be any profits because of the fluctuating electricity prices (Connolly et al., 2011).

If we use the MLP as a guide, the transition to PHES could be seen as a reconfiguration pathway. In the PHES scenario, we might see that new renewable energy technologies like wind and solar are being used more and more, which causes the current hydropower regime to adopt them into their regime by being the balancing power of their intermittency. The current regime will benefit by staying relevant, and efficiency will increase as the water stores can be refilled with excess energy from the new technologies in the regime. Looking at PHES by using Van De Graf and Sovacool's (2020) categories, it could be seen as a mix between state-of-the-art feasible technology and the currently available best practice. The pumped storage part is the state-of-the-art feasible technology as it is not yet cost-effective and is still in the testing phase. The hydropower part is the best practice part as it is a renewable energy source that has proven cost-effective and is used worldwide.

8.2 Hydrogen Energy Storage

Hydrogen energy storage is a form of chemical energy storage that converts electrical energy to chemical energy, most often a fuel type, like hydrogen in this instance (Acar, 2018). This type of energy storage has become popular as it is pretty efficient, and distribution and transport are more accessible than other forms of stored energy (Acar, 2018). The most common type of hydrogen energy storage is water electrolysis, where water is split into hydrogen and oxygen by electric energy (see figure 3) (Acar, 2018). The hydrogen can then be stored in gas, liquid, or solid form (Acar, 2018).

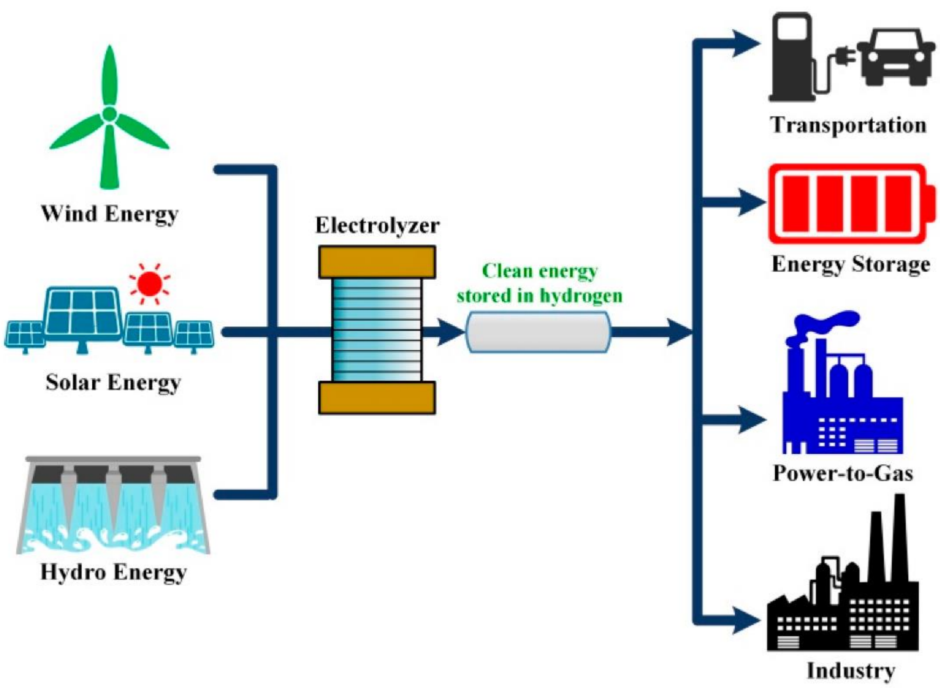

Figure 3- Hydrogen Energy overview (Yodwong et al., 2020).

Hydrogen energy storage is something Norway already has done a great deal of investing and testing in. The first-ever full-scale hydrogen energy storage plant combined with wind power was completed in 2004 in Utsira, a small island in Norway (Astasio, 2016). The goal of the pilot project was to make this island self-sufficient and only powered by renewable energy. It successfully provided ten households with electricity for several years without any problems (Astasio, 2016). “This plant included two 600 kW wind turbines, one connected to the external grid and the other to a stand-alone system, a 5 kW flywheel and a 100 kVA master synchronous machine to balance voltage and frequency, as well as a 10 Nm3/h electrolyzer with a peak load of 48 kW. Hydrogen is compressed by a 5-kW compressor and stored at a 200 bar pressure in a 2400 Nm3 pressure vessel.

Moreover, a 55-kW hydrogen internal combustion engine and a 10-kW fuel cell were installed.” (Astasio, pg. 5, 2016). This pilot project shows that wind power with hydrogen storage is a good combination and is exceptionally well suited for remote locations. The energy could be provided locally without the need for a connection to a local grid.

This technology is a good fit for Norway as they are currently investing in offshore wind. They have a significant coastline with plenty of access to water for the electrolysis. If Norway wants to use more of their hydro power to be a battery for Europe, the wind power and HES plant technology will be a good choice for local energy production. Norway has many remote locations with a widespread population, making the HES combined with wind power a good fit as the grid would be more local. Hydrogen has also been seen as many as a viable replacement as a fuel for transportation (Coley, 2008). This, combined with hydrogen storage, could create a renewable carbon-free society, or the “hydrogen economy” as it is also known (Coley, 2008). In theory, it is a great idea, although some challenges still need to be addressed. Hydrogen is only liquid at – 253 C, and there would be a need for large amounts of renewable energy produced to meet demands (Coley, 2008). Norway has also already seen a shift in the transport sector, although not towards hydrogen vehicles but electric vehicles. In 2015 the market share for electric vehicles had reached 17,1 % (Figenbaum, 2017).

Since Norway has not implemented HES in any significant way, it is hard to place the transition within the MLP. More research and development and lower costs could easily fit the technological substitution pathway if it is ready when the oil and gas industry starts to regress. However, if HES is implemented in a more local way like the test at Utsira first and then starts being used on a larger scale, it will follow the reconfiguration pathway of the MLP. If we look at Van De Graf and Sovacool's (2020) categories, HES storage would fit the category of a state-of-the-art feasible technology in Norway. It is demonstrated as technically feasible but is still lacking in the cost-effectiveness area.

8.3 Compressed Air Energy Storage

Compressed air energy storage (CAES) is large-scale physical energy storage that, like PHES and HES, can help solve grid connections and the intermittency problems a more renewable energy-based energy mix would present (Zhou, 2019). Traditional CAES technology has five main components, compressors, compressed air storage, combustion chambers, expanders, and generators/motors (Nikolaidis & Poullikkas, 2017; Zhou, 2019). First, the system stores energy by compressing air into the compressed air storage. Then, the system releases that energy by passing it through a combustion chamber and burning it with a mix of fuel to create high pressure and temperature air, which in the expander works to output electricity (Nikolaidis & Poullikkas, 2017; Zhou, 2019). Many of the older technologies emit some greenhouse gases due to the mix with fuels to heat up the air, but some newer technologies do not need the fuel to heat the air (Nikolaidis & Poullikkas, 2017).

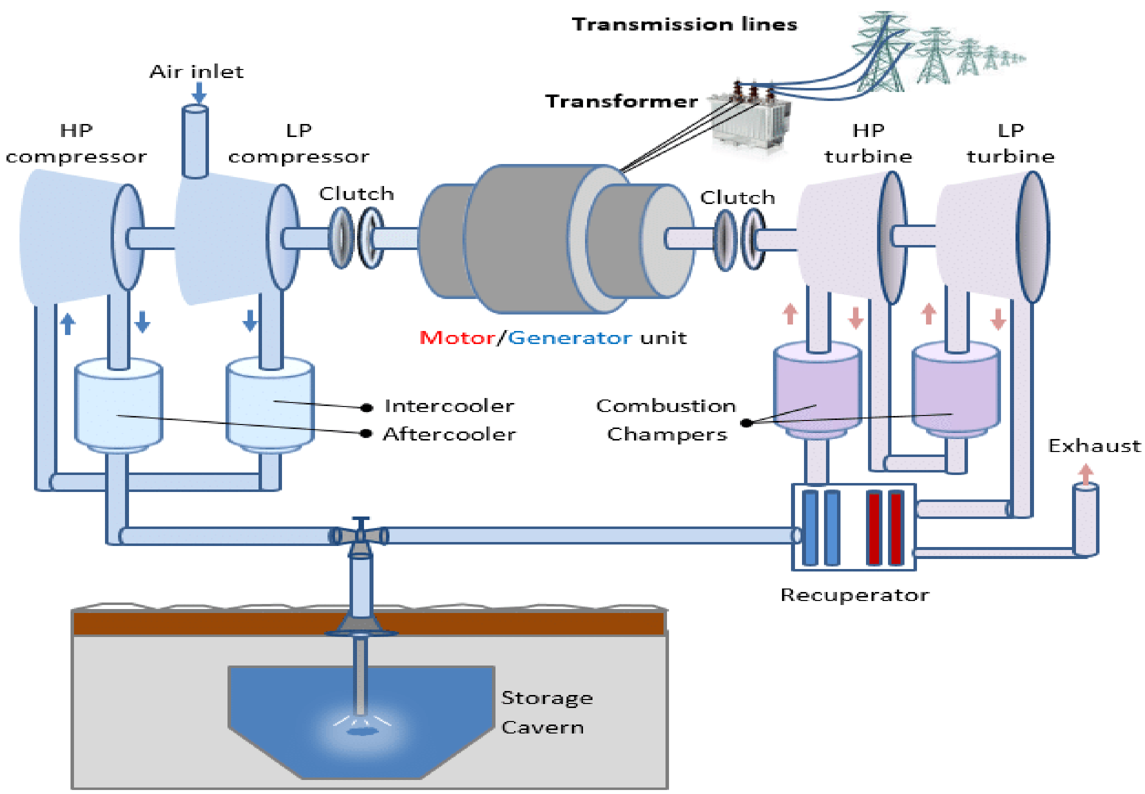

Figure 4- Compressed Air Energy Storage (Nikolaidis & Poullikkas, 2017).

CAES could be argued as a state-of-the-art feasible technology within Van De Graf and Sovacool's (2020) categories. However, it has been demonstrated as technically feasible but is not yet widely used as it is not yet cost-effective enough to break through.

8.4 CCS

New energy technologies are not the only options in combatting the increasing emissions of greenhouse gases. Carbon capture and storage (CCS) is a technology that captures carbon dioxide and stores it so that it is not released into the air. There are three general phases in CCS, capture, transport, and storage (Brun et al., 2019). There are three leading technologies for capture, post-combustion, or flue gas separation often called oxy-fuel combustion and pre-combustion (Brun et al., 2019; Coley, 2008). Post-combustion capture is often done chemically where the carbon dioxide is absorbed by bonding with a liquid solvent forming new compounds. After that, it is sent to a regenerator, where the carbon dioxide is removed using steam (Brun et al., 2019; Coley, 2008). Oxy-fuel combustion is used by using only pure oxygen for the combustion, making the end result only carbon dioxide and water (Brun et al., 2019; Coley, 2008). Water is easily condensed, leaving nearly pure carbon dioxide for storage; however, this process is energy consuming at close to 15% of the power plants' final output (Coley, 2008). Pre-combustion capture is done by coal gasification, where carbon monoxide and hydrogen are produced (Coley, 2008). The carbon monoxide is then reacted with water to produce carbon dioxide for storage and hydrogen for gas turbine or transport fuel (Coley, 2008). After capture, the carbon dioxide gas is often compressed into a liquid for more accessible transport and storage (Brun et al., 2019; Coley, 2008).

CCS is worth looking into for Norway. The deep fjords and several old offshore oil fields can come in handy for places to store captured carbon dioxide. The least technological method of CCS is planting trees. However, some interesting new technologies and methods have made their way onto the CCS scene (Coley, 2008). Norway has been using CCS in some shape or form for decades at their offshore platforms. However, a much larger scale is needed to make a significant impact (Brun et al., 2019). Geological storage could be interesting for Norway. It is a technology that has already been used for quite some time to dispose of so-called “acid gas,” which is residues from oil and gas production (Coley, 2008). However, it is mainly used to push more oil and gas out, and the gas is often released into the air upon decommissioning the oil field (Coley, 2008). With a slight modification and leaving very little oil behind, this technology could be retrofitted to store the gas permanently (Coley, 2008). With its vast offshore oil fields, Norway should investigate this as an expansion option for CCS (Brun et al., 2019; Lothe et al., 2019).

Another storage method that should be considered is oceanic storage. This is where the carbon

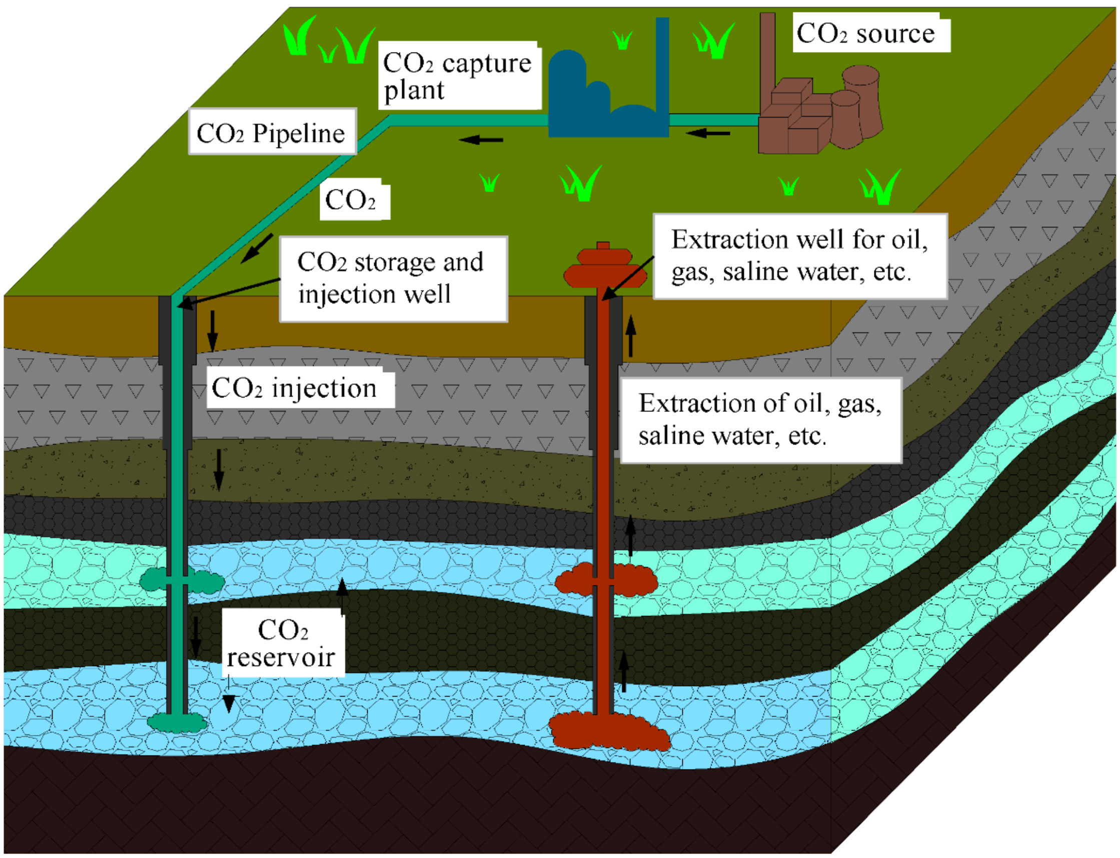

Figure 5- Carbon Capture and Storage example (Li et al., 2020).

dioxide is either stored or dissolved in the ocean (Coley, 2008). If it is injected at depths between 1-3 km, it will dissolve in the water, and this is not as bad as it sounds as the ocean will absorb about 80% of the carbon dioxide in the air, although it would take a few thousand years (Coley, 2008). Dissolving it in the ocean will speed up that process without altering the concentration of the ocean much, although it is still unsure how much effect this small change will have on the wildlife in the ocean (Coley, 2008). The oceanic storage option is to store in below depths of 3 km. Here, carbon dioxide will simply form lakes on the bottom and stay there (Coley, 2008). These technologies could be interesting for Norway to investigate in the future, although the public might have some strong opinions once “dumping” stuff into the ocean is brought up.

Therefore, the expansion of geological storage in depleted oil wells offshore should be the first option Norway should explore in CCS. According to the Ministry of Climate and Environment (2020), several CCS projects in Norway are just waiting for the government to greenlight them to start building.

The MLP, in terms of CCS, could end up following the technological substitution pathway within the same regime with the same relevant actors. If CCS is implemented in Norway, it will most likely be operated and run by the existing companies in the oil and gas industry. Therefore, it is more like a technological addition to the existing technologies within the oil and gas industry. As many of the other renewable energy technologies presented in this thesis, CCS falls into the category of a state-of-the-art feasible technology within the categories presented by Van De Graf and Sovacool (2020). This is because it has been tested and proven technically feasible but is too expensive to break through the cost-effectiveness barrier.

8.5 Onshore and offshore wind power

There is over 10 TW found in the winds of the world today, more than enough to cover the world's primary energy needs (Coley, 2008). The energy is kinetic and comes from sunlight. Wind power is one of the most popular and promising renewable energies in the world today (Coley, 2008). Wind power has been used for thousands of years, and the technology is simple even today, much more straightforward than solar PVs, for example (Coley, 2008). In the early days, wind power was used to raise water for irrigation, grind corn, and propel boats (Coley, 2008). The name "windmills" came from horizontal axis machines used for grinding grain (Coley, 2008). Today most windmills use the wind to drive a turbine which then produces electricity. They are often built several at a time in the same area. Some wind farms, as they are called, can have up to 1000 windmills (Coley, 2008).

In Norway, windmills have caused quite a debate. As Norway has its energy needs met by hydropower, many people question the need to build and invest in domestic windmills. However, that is a good argument if one wants to meet future needs. If Norway wants to become an exporter of clean energy by being a green battery for Europe or other ways, more clean energy production is needed. One option that seems more favorable to people is offshore windmills. Although more expensive to install and maintain, the output of offshore windmills is higher, and the environmental impact lower than onshore windmills. Offshore windmills will also utilize a knowledge transfer from offshore oil rig operations, which will be important in securing jobs for the workers in the oil and gas sector as Norway transitions more towards green energy. There are a few different types of offshore windmills to consider. These vary mainly by if they are floating windmills or not. In the figure, one can see some of the different methods for securing the windmills offshore.

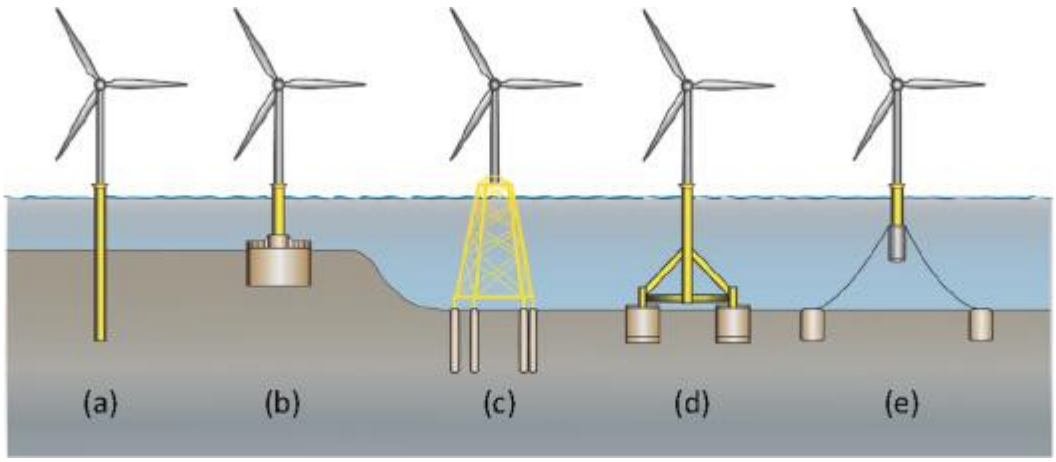

Figure 6- Offshore windmill options (Kaynia, 2019).

Norway has also invested in offshore wind power projects in other countries. This is also a good option, as it helps other countries become greener, and Norway can profit from the technology exchange.

8.5 Solar Power

In less than one hour, the earth's surface receives enough solar energy to provide the world's primary energy needs for an entire year (Coley, 2008; Van De Graaf & Sovacool, 2020). This is, of course spread out over the entire surface of the earth, and it would be impossible to harness all of it, but it gives a perspective of the potential of solar energy. Throughout history, the sun has been used as an energy source in many ways, and there are several kinds of technologies in use for harnessing the energy on sunlight (Coley, 2008). The simplest form of solar power is called passive solar heating and lets the sun heat a large surface that can absorb the energy in for heat and slowly release it back. For this, a large window and fabrics that can absorb the energy are needed (Coley, 2008). However, active solar technology is where a separate solar collector is heating a fluid to utilize the sun's energy (Coley, 2008). This can again be done through several different technologies and methods. The main idea in most of them are using the sun to heat up the air (Trombe wall) or to heat water (solar water heating) or another fluid (heat pumps) in order to use it as a heat sour for inside heating (Coley, 2008). Water heating is done at low temperatures for heating or high temperatures for electricity production (Coley, 2008). Low-temperature water heating is often done with a flat plate with a black absorber or transparent cover with tubes of water flowing through, increasing the temperature up to 50 C (Coley, 2008). High-temperature solar water heating is done by concentrating the sunlight on a tube or point using reflectors. This turns the water into steam, driving a turbine that produces electricity (Coley, 2008). These types of technology might not work that well in the wintertime in Norway as it gets pretty cold and the sun is low. However, there is one type of solar power technology that is more interesting for Norway.

When they hear solar power, the most common technology people think of when they hear solar power is probably solar photovoltaics (PV). With the increase in efficiency and decrease in price over the last few decades, it has, together with wind, become one of the most promising technologies for use in the increasing need for renewable energy (Lee et al., 2020). Solar PVs are not all the same, and there are some different types, but they all work in just about the same way, light hits the PV, and the crystalline lattice inside reacts with it and releases electrons (Coley, 2008). The thing that makes solar PVs an exciting option is that they can be placed nearly anywhere and close to an energy need. They are less noticeable than windmills, and they are quiet, which are some of the main complaints against windmills in Norway. Many solar PVs are more effective when it is cold, which means they could work in Norway even during the winter. It has already been in use for quite some time in cabins around the country. Cabins generally do not use much electricity to cover the basic needs of a small solar PV on the roof or wall. If Norway is to become a green battery for Europe through hydropower, then solar PVs could be a good resource for domestic energy use. The Tesla solar roof launched a few years ago is an exciting technology that could do well in Norway. They are already the leading country in the number of Tesla vehicles per capita in the world. This roof looks like a regular roof, lasts longer, and produces electricity through solar PVs in the roof (Tullo, 2016). It is also connected to a large battery so that the excess energy produced during the day is stored for when the sun goes down (Tullo, 2016).

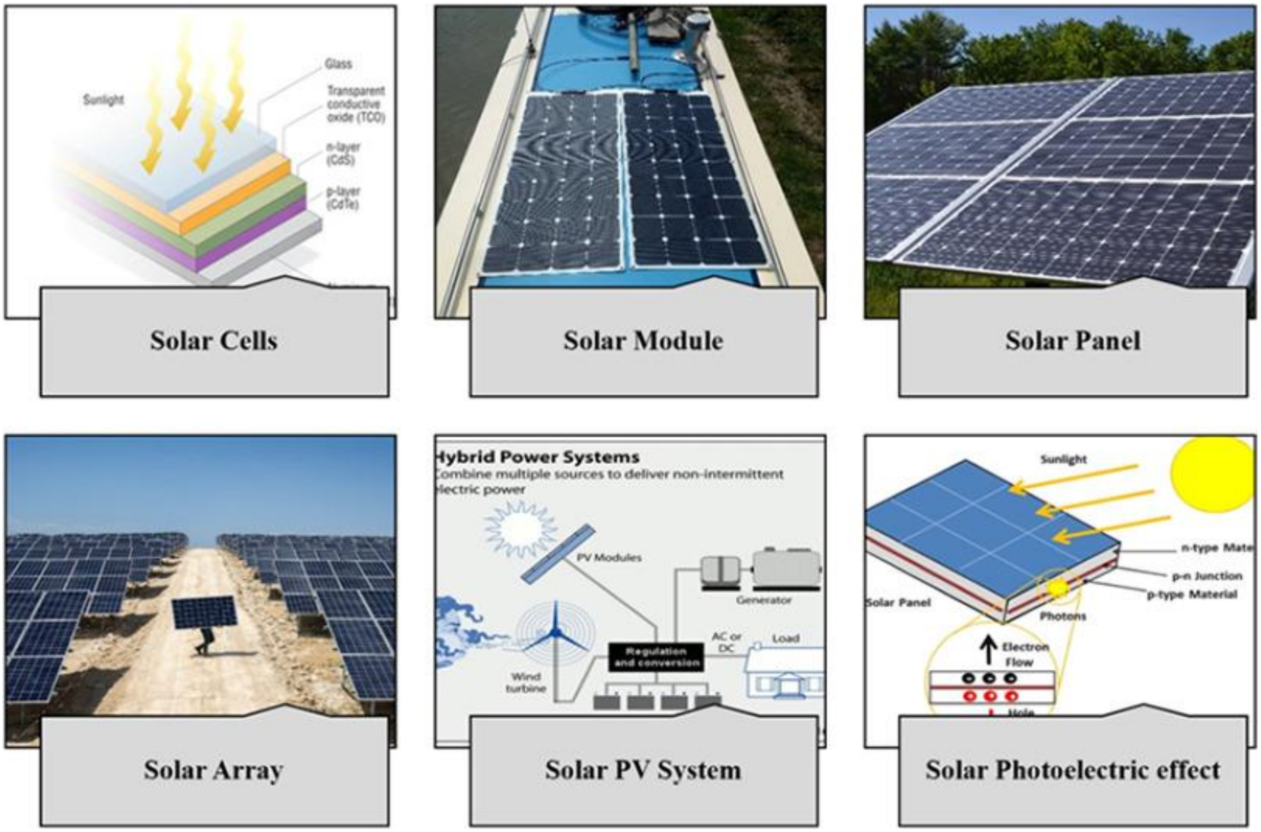

Figure 7- Solar Power examples (Rabaia et al., 2021).

Floating solar photovoltaics (FSVP) is an interesting new idea for renewable energy. Using it on the large bodies of waters made by the dams of hydro power plants would help reduce the water's evaporation and create more energy for the plant, which is already connected to the grid (Lee et al., 2020). Furthermore, using FSVP reduces the need for a standard land area which can be vital for other uses and more expensive (Lee et al., 2020). Using a hybrid system with FSVP and hydropower, one can optimize the usage by using only solar during the day if that produces enough. If not, solar power can be supplemented with hydropower when solar is not enough (Lee et al., 2020). Although this technology might not work as efficiently in Norway as in other countries because many hydropower plants in Norway have smaller water surfaces and less sun exposure, especially in the winter months, it could still be worth looking into. It would certainly be a good investment opportunity for Norway in other countries with a more suitable climate and larges bodies of water dammed up.

8.6 Geothermal

Norway has been utilizing shallow geothermal energy for quite some time, but there has been little to no activity within the deep geothermal energy production (Gjølberg, 2011). Deep geothermal energy comes from the radioactive decay of isotopes deep within the earth and the cooling of the earth's core (Coley, 2008; Gjølberg, 2011). The Geothermal energy emitted from inside the earth is almost three times the world's energy requirement, but unfortunately, the power density is low, and much is lost on its way to the surface (Coley, 2008). The heat flows also vary in different locations, primarily based on the thickness and type of the earth layers in that area (Gjølberg, 2011). Nevertheless, a country like Norway could use deep geothermal energy, especially for heating during the winter. The expansion of the deep geothermal energy industry would need geologists and engineers, which could come from the oil industry as many aspects of the processes are similar.

There are three main types of deep geothermal technologies and resources, wet rocks, hot dry rocks, and hot fractured rocks (Coley, 2008; Gjølberg, 2011). Wet rocks are a natural aquifer. Here, the water and steam are trapped geologically, much like oil and gas often is (Coley, 2008). The water comes from rainfall that has drained down into the aquifer and been heater up by the hot rocks deep below the surface (Coley, 2008). To access the aquifer, a hole is drilled. If the steam is hot enough, it goes directly through a turbine to produce electricity. If it is not hot enough, it goes through a heat exchanger with a fluid with a lower boiling point which is then turned into steam and sent through a turbine to produce electricity (Coley, 2008; Gjølberg, 2011).

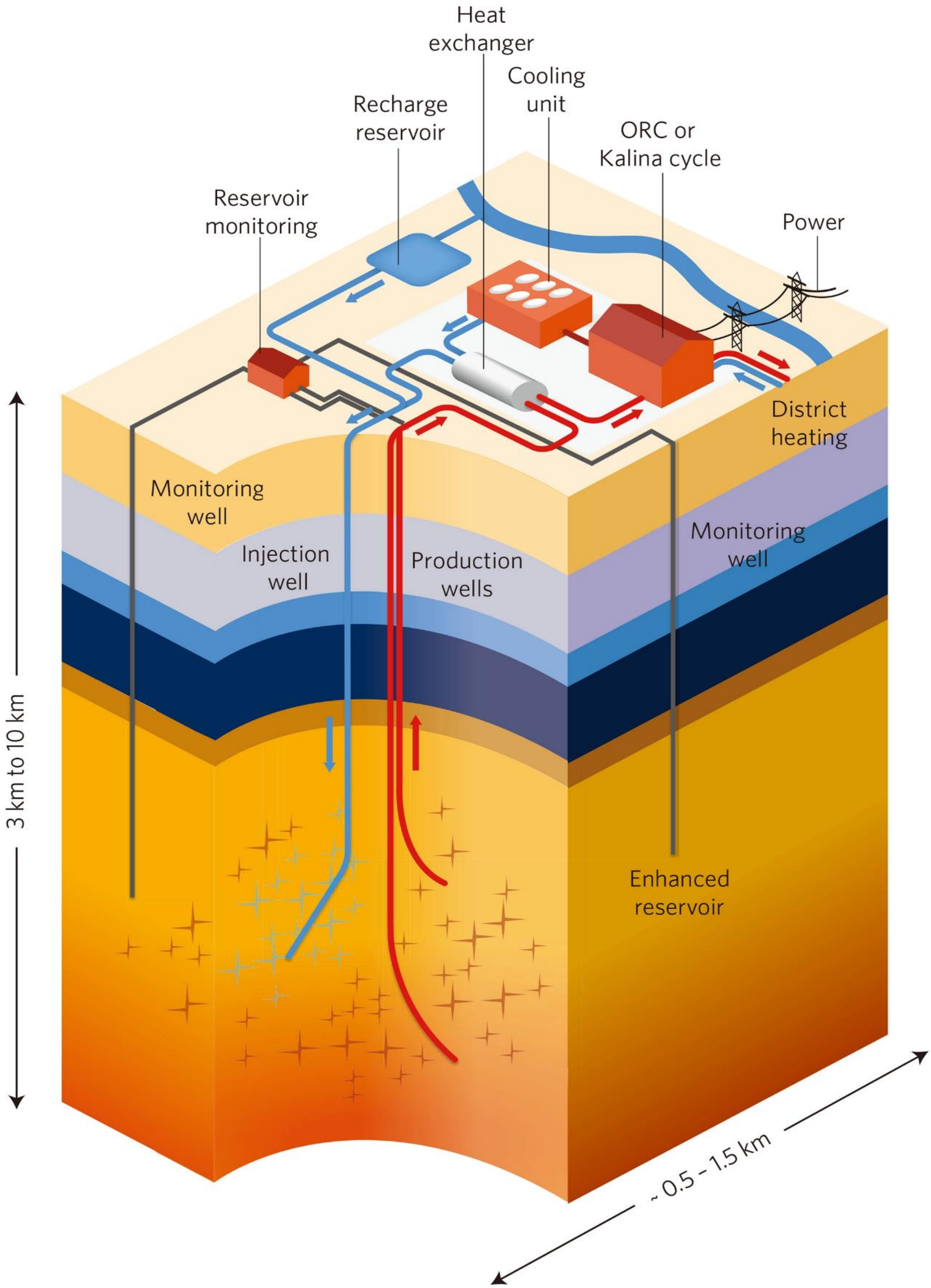

Figure 8- Geothermal Energy overview (Huang, 2012).

Finally, a reinjection well is also drilled to repeat the process repeatedly to fully utilize the deep geothermal energy (Coley, 2008). Hot dry rocks work similarly, only here there is no natural occurrence of steam and water, so the reinjection well is drilled not only to reinject but to inject the first water (Coley, 2008; Gjølberg, 2011). Next, the water is sent down to the heated rocks and funneled down through the fractures. If there are no fractures, this is where hot fractured rocks come in. They are fractured using high pressure from the water (Coley, 2008; Gjølberg, 2011).

8.7 Biomass

The use of biomass can be traced back over 250 000 years to when humans started creating fires for heating and cooking purposes (Coley, 2008). It was the primary energy source in the world, together with waterpower, until the industrial revolution and fossil fuels took over (Coley, 2008). In simple terms, biomass can produce energy in three main ways. It can be burned to run a steam generator or be turned into either oil or gas for transportation fuel or burned for heating (Coley, 2008). Liquid biofuels can be a cleaner alternative to fossil fuels when there is an increasing need for liquid fuels as they are already very integrated into society today (Karmee, 2015). However, growing crops just for biofuel use has sparked debate as it could cause land and water shortage for growing food crops. A prospect for the future could be biofuels from food waste (Karmee, 2015).

Approximately 1.3 billion tons of food waste is thrown out worldwide every year (Karmee, 2015). This waste that is currently not used for anything could produce large amounts of useable liquid biofuels. Most biofuels today are made from edible feedstocks, which account for around 80-90% of the cost of biofuels (Karmee, 2015). Those costs could be removed by using food waste for biofuel production. Although producing biofuels can also be expensive as the technology and research are still in early stages. Most food waste ends up the landfills, where they cause further air and odor pollution (Karmee, 2015). In order to collect the food waste, people would need to become better at recycling and sorting their waste. Many countries have started to use biofuels as a substitute for diesel and gasoline. Certain biofuels can also be used as a blend with traditional fossil fuels like diesel and gasoline (Karmee, 2015). The rising economies in Asia will further increase the food waste available (Karmee, 2015), which is a further sign that biofuels from food waste could be an essential part of the future of liquid biofuels and liquid fuels in general.

Like most of the world, Norway has a long history of using biomass as an energy source. However, unlike many other industrialized countries, many people still use biomass as a heat source. Fireplaces can be found in many Norwegian homes and cabins and are used as an additional heat source during the winter. Norway has also created climate-friendly biogas and fertilizer out of food waste for some years now (Valseth & Solberg, 2016). Biofuels for transportation could be a suitable replacement for fossil fuels. It could potentially utilize many of the same transportation and storage systems already in place, like gas stations, fuel trucks, pipelines, and more. According to the Ministry of Climate and Environment (2020), several facilities up and running are producing liquid biofuels in Norway already, and more projects are in the making. It is one of the only renewable energy sources that can directly replace fossil fuels. This transition would follow the technological substitution pathway of the MLP. The substitute technology (biofuels) has been sufficiently developed, and a shock to the current regime could cause a substitution to the technology (fuel). Biomass could follow a different pathway in other energy sectors, hard to say which before it happens.

8.8 Wave and Tidal Power

Norway has a long coastline and many fjords, which would be well suited to utilize the potential of wave and tidal power. The coastline is 2500km when measured in a straight line along the coast, but if all the islands and fjords are included, it is an impressive 83,000km long (Grabbe et al., 2009). Wave power, like wind power, is an indirect form of solar power (Coley, 2008). Water has a higher density than air which means that waves have a higher energy density than wind, reaching 70kW per meter of wave at some locations. (Coley, 2008). There are many different technologies available (see figure 3), some are far from shore, and some are closer (Coley, 2008). Wave power could be considered a state-of-the-art feasible technology based on Van De Graaf and Sovacool's (2020) categories as it has been tested and proven but is not yet cost-effective. Wave power could follow either the transformation pathway or the reconfiguration pathway of the MLP. However, as it is not yet implemented in the Norwegian energy mix on any large scale, it is hard to say which pathway it will follow.

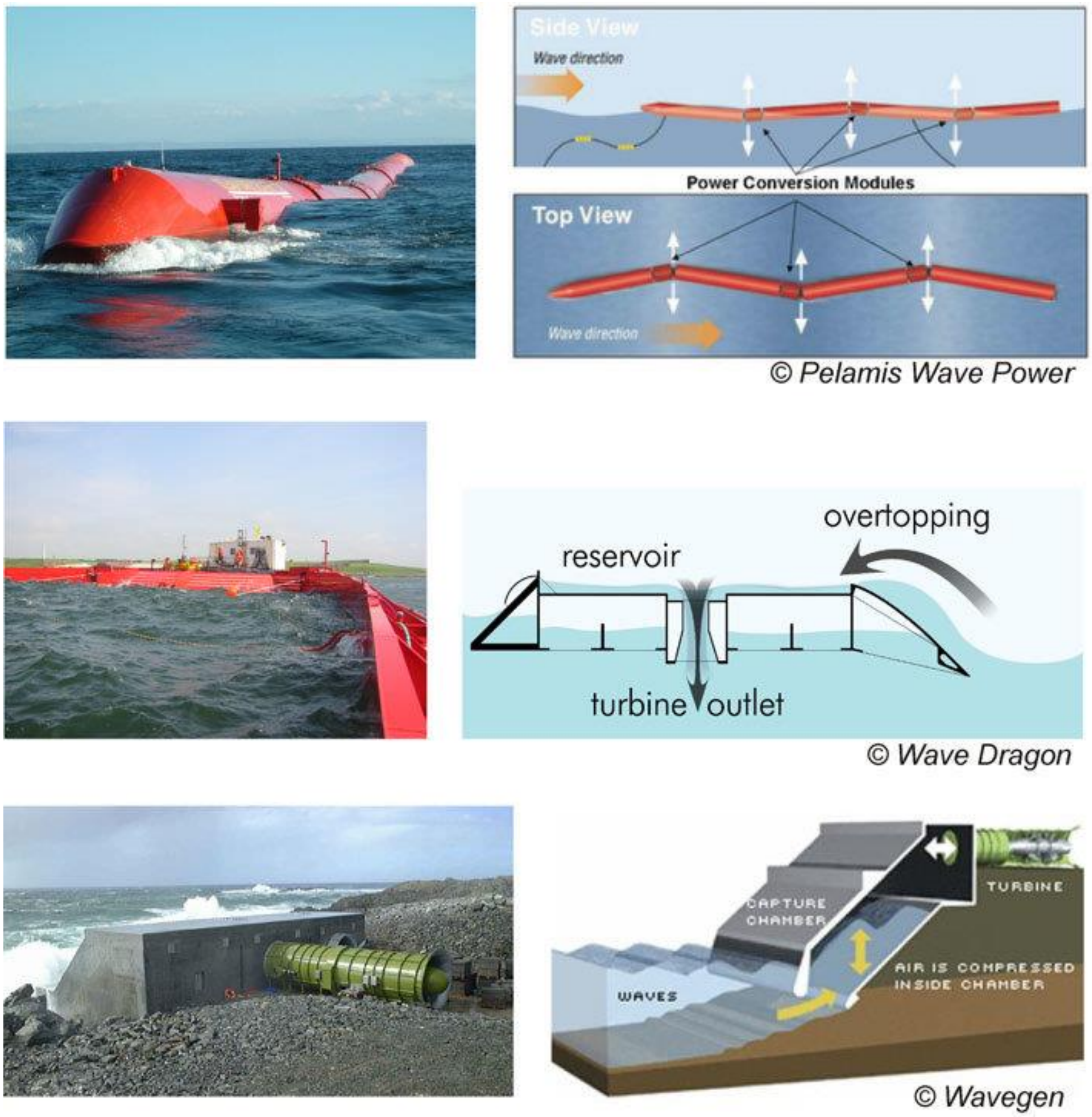

Figure 9- Wave Power options (Water, 2021).

The rise and fall of water in the ocean represent the drag of the moon and sun, and there are large amounts of potential energy stored in these shifts (Coley, 2008). The tidal shift produces energy by storing the water when it rises and then releasing it back through a turbine when the water levels fall (Coley, 2008). A different way to utilize the energy of the tides is to have turbines installed underwater to take advantage of the tidal streams caused by the rise and fall of the water. Strong tidal currents are common in Norway because the tidal range increases with latitude (Grabbe et al., 2009). The most powerful tidal currents in Norway can reach surface speeds of up to 5 m/s (Grabbe et al., 2009). Although tidal power is intermittent, it is highly predictable as the rise and fall can be predicted and calculated easily (Grabbe et al., 2009). Hydropower can again be used to mitigate intermittency. The abundance of knowledge from the offshore oil and gas industry can help with the construction and operation of tidal power plants (Grabbe et al., 2009). Tidal power is the same as wave power. It could be considered a state-of-the-art feasible technology based on Van De Graaf and Sovacool (2020) categories as it has been tested and proven but is not yet as cost-effective as other options. Tidal power could also follow either the transformation pathway or the reconfiguration pathway of the MLP. However, until it is a more significant part of the energy mix, it is hard to say which transformation pathway it fits.

8.9 The electric highway, a connected Europe

In 2009 European governments committed to reducing their emissions of greenhouse gases by 80% by 2050 (Pierri et al., 2017). As both Norway and other European countries attempt transitions to more renewable energy to meet the goals and promises their governments made, the problem of transporting the electricity emerges (Pierri et al., 2017). Although fossil fuels were transported before combustion on ships, trucks, railroads, or pipelines, this will not work for renewable energy as the electricity is produced right away. Therefore, there is a need for larger gird and connectivity within the countries and between countries (Pierri et al., 2017).

For Norway, these plans for interconnectivity in Europe could be an opportunity to become a green battery for Europe a reality. It could make Norway the most reliable energy provider to the countries that eventually might run mostly on intermittent renewable energy. The NORD.LINK (High Voltage Direct Current) cable between Norway and Germany became the longest HVDC connection in Europe in 2020 (Pierri et al., 2017). Testing started in 2021, and it will be a good indicator if the green battery idea could be feasible (NordLink). The idea is for Germany to provide renewable energy to Norway in the dry seasons and when they have an excess of it, and Norway supplies Germany with hydropower when Germany needs it (NordLink). Even if the green battery idea does not come to fruition, a more interconnected Europe will still give Norway opportunities to sell the excess renewable energy they will have if they keep investing in it.

9. Interview Results

This section of the thesis will present the results of the interviews and surveys done with professionals in the oil and gas industry. All the questions and info sheet given to the interviewees can be found in Appendix 1. There were five interviewees between the ages of 25-40, these are referred to as Young Worker #1-5 in the results. There were five interviewees between the ages of 50-65, these are referred to as Old Worker 1-5# in the results.

9.1 Societal Questions

The opening question of all the interviews asked them if they thought that young adults starting the oil and gas industry in Norway today would have a place to work until retirement. They all had somewhat the same answers to this question. In their opinion, there would only be a few of those starting in the oil and gas industry in Norway today who would be able to work there until retirement. The reason for this was also mostly the same among the interviewees. They all mentioned that the high startup cost for new platforms and oil exploration would not be cost-effective with the lower oil prices and the cost competitiveness of renewable and low carbon energy options. One of the younger interviewees also mentioned that there would be a need for people to work on the decommissioning of the platforms and production wells.

> Some will, but I think most of them will not. The larger fields developed in later years (i.e. Johan Sverdrup) will probably have production for another 30+ years. Most of the investments here are already made and the breakeven costs of the production are pretty low and internationally competitive. There are also several thousand wells that need to be permanently plugged and abandoned and many platforms that will need to be decommissioned and remove. So this will also provide some work. (Young Worker #1).

A few older interviewees said that many would still have a job in the oil and gas industry because the future energy demand will be so high that oil and gas will still have a significant role in the energy mix. “Yes, but fewer than today. This is based on the world’s energy demand in the future. Oil & gas is needed in many years to come.” (Old Worker #1). It would not be practical or realistic to think that all fossil fuels can be replaced with renewable energy within the next 40 years, another of the older interviewees said. Another point of view from an older interviewee was that she thought that most of the oil and gas industry workers will have a job in the same company. However, their focus will be more on greener energy solutions rather than just oil and gas. It was also mentioned that there could be less of a need for workers because of the decrease in offshore operations and because many tasks will become more automated. One of the young interviewees said that since Norway has a leading role in low emissions during oil and gas production, they will be relevant longer than other countries as the oil and gas would be more attractive to buyers. These answers show already at the first question that there are slight differences in the thoughts of the young and the old workers in the oil and gas industry.

The second question asked which renewable energy technologies would be the best option for Norway to retain jobs from the oil and gas industry. It also asked to place these technologies in the categories mentioned earlier. The answers given were remarkably similar here. Everyone said that no technology alone could cover it all and that Norway should explore several renewable options. The interviewees answered many of the same technologies with a few differences regarding the technology that would retain most jobs. Offshore wind was unanimous as much of the current offshore experience and talent could be transferred from oil and gas. One interviewee from the young age group said that the different environment of working offshore compared to onshore is an essential experience that offshore workers from oil and gas could bring to offshore wind.

> I think offshore wind power is a great option that can utilize much of the workforce that would have worked on offshore oil rigs. When thinking of job security, it's important to think outside of the typical petroleum engineer who works at an operator company. There are oil service companies whose fates are intertwined with those of the operator companies, and there are the countless offshore workers who do anything from painting to cleaning to construction. If we were to find a way to employ these workers who have expertise working offshore (which is extremely valuable as it is a completely different environment than working onshore), we could save the most jobs in the energy transition. Since wind is relatively clean and Norway has vast space in their sector of the North Sea, I think this would be their best option for job security. (Young Worker #2).

The same could then also be said for offshore CCS, although the interviewee did not mention that. CCS was, however, a favorite and mentioned by almost everyone as a good option for knowledge and talent transfer from the oil and gas industry. The arguments here were that the old offshore wells could be used, and if new sites needed to be drilled, then the technology and know-how would have many similarities with the drilling for oil and gas. Expanding and improving current hydropower capabilities and introducing PHES to these was mentioned by many as an excellent technology to focus on alongside offshore wind and CCS. Many used the argument that Norway knows these technologies well, and it would be good to focus on strengths like that. Geothermal energy was another technology that more than one person chose as a good opportunity for Norway in the future. “Energy storage, CCS, offshore wind/wave power, solar power and geothermal energy will likely all play a role during phases of transformation and future energy supply.” (Old Worker #2). Some who talked about geothermal energy highlighted the fact that the oil and gas companies could transition to this as they have experience drilling wells and managing reservoirs that deep geothermal energy requires. Solar power was only mentioned by a few interviewees. As for the placing of the technologies into categories, not everyone answered that part. Those who did said that offshore wind and hydropower are a mix of typically available and best practice, while CCS is more a frontier or breakthrough technology. PHES was described as a part of hydropower that was on the brink of becoming best practice.

The third question asked if they could see any societal challenges in Norway that could hinder the transition away from oil and gas and towards low carbon and renewable energy technologies. There were many different answers to this question as many seemed to overlook or misunderstand the word societal. However, there were some similarities in the answers in both age groups as well. One of the main societal challenges pointed out in the answers is that society is afraid of job loss. They fear that moving towards more renewable energy and away from oil and gas threatens their job security.

> A lot of people in Norway work in the oil and gas industry, or in industries dependent on the oil and gas industry. Many seem to be against renewable energy mainly because it will take their job away. Norway has one of the highest standards of living in the world, and much of this can be attributed to the oil and gas industry. It needs to be communicated better that renewable energy will also provide jobs for people. (Young Worker #1).

The high standard of living in Norway is pointed out as one of the leading factors of this fear. One of the younger interviewees said that, the older generation needs to stop worshipping oil and gas and the money it brings in. She says that there was a time before oil where Norway did other things. Those things were not as profitable, but now Norway can use the wealth and power gained to invest in more renewable energy that can become profitable in the future. Public opinion is another societal challenge that is brought up among the responses to this question. Norway has seen significant criticism on many of the onshore wind projects from the public. The problems have been that windmills are being built in nature, visually scarring it, or too close to where people live, which causes noise pollution and other disruptions to people's daily lives. One of the older age group interviewees said that the only solution to this problem was to stop investing and building onshore windmills entirely. The willingness to invest in research and development for renewable and low carbon energy technologies is also mentioned as a societal challenge, although the willingness to invest have gone up in recent years. Regulatory incentives and tax breaks are also touched on in some responses, in this context they think it is a challenge not having them or enough of them so that renewable energy technologies could compete when it comes to cost. This is where some have gone more into regulatory of economic challenges rather than societal ones.

The next question asked was if they saw renewable energy technologies being hindered by any regulatory or policy barriers as the oil and gas industry greatly influences this. There was a wide range of different responses here. Some of the above 40 group interviewees said that wind power had too few regulations and taxes. It should be taxed the same as oil and gas, and that the lack of regulations had caused further outrage among the public as some of the onshore wind projects built larger windmills and took up large spaces than it said in the plans. Especially onshore wind was highlighted as needing more regulation, in their opinion.

> Today I believe the government has totally failed in the wind energy regulation (onshore). The companies that own these windmills should be taxed the same way the oil and gas business is. That will hinder more windmills onshore, which is a good thing. Also windmills offshore needs to be regulated with high taxes. (Old Worker #3).

Others said that policies were not hindering renewable energy technologies, but they might need some help as the transition is moving slowly. Some interviewees pointed out that the large focus on oil and gas in Norway could have focused on other areas, like hydropower expansion. One person highlighted that the CO2 taxation had not increased the CCS research and development as hoped. A few of the younger interviewees said that since the state still owns parts of some of the oil and gas companies, they favor policies and regulations that are profitable for those companies. They said that the policies should become even stricter to force the companies to go green. Here we see an interesting difference between the age groups. The older focused primarily on how the new renewable technologies should be regulated and taxed the same as oil and gas. In contrast, the younger group focused more on helping renewable technologies by either lowering the regulations and taxes on them or increasing regulations on oil and gas-related operations even further.

The fifth question asked in the interview was is they see any sociocultural barriers to the new low carbon and renewable energy technologies that could replace oil and gas. Sociocultural barriers in this sense were explained as specific cultural norms and traditions in Norway that could affect the transition. The answers here from the above 40 years old group all had certain similarities. Everyone highlighted that the love of our nature could be a barrier to specific technologies that could interfere with this. Onshore wind was again mentioned as Norway has had some recent heated debates on this issue. “The best example is the wind power on land versus the interference with nature (and farmers).” (Old Worker #1). Almost everyone in that age group also talked about how people in Norway are very comfortable with today's situation and do not want to risk losing or changing their wealth and high living standards. One also highlighted that Norwegians do not like change, and untested energy technologies will meet opposition. The younger age group also mentioned the wealth created. “Money talks,” Young Worker #4 said, saying he did not think there were any cultural barriers, and the most profitable energy technology would win. “As long as the technology is well developed and proved to be efficient, I think we will manage to adapt.” (Young Worker #3).

The sixth question and the last of the societal part of the interview focused on misinformation. It asked if they felt that Norwegians are misinformed or underinformed about the damages that fossil fuels cause or opportunities involved with new renewable energy technologies. Again, most of the older age group were on the same page in many aspects. They all said that the media was too black and white or extreme with how they presented certain things. This makes the public naïve and somewhat misinformed in the sense that they think that the oil and gas industry in Norway should be shut down because of climate change. “Yes, there is a lot of misinformation and oversimplification. Belief and ideology are favored over open and honest professional debate, illustrating that politics and research is a bad combination." (Old Worker #4). They feel the media should have more facts and realistic approaches to presenting the challenges and options that lie ahead. It seems from their answers that they understand change is needed, but they argue that it will take time and that oil and especially gas will be a part of the energy mix for years to come. Change takes time. Many of them said the media needs to present less extreme and dividing headlines and stories so that change can happen more efficiently with everyone being on the same page. Another said that he felt like belief and ideology were favored over open and honest professional debate and that research and politics are not a good combination. The younger age group had some different answers to this. One interviewee said that Norway has a high percentage of people who believe climate change is only partially or not caused by human activities. Although he said that it seems like a clear divide in age where those over 50 years old often do not want to know or don't care, many believe that renewables will not create any jobs or revenue. One of the younger interviewees mentioned Equinor as an example of someone spreading misinformation. They talk about all the good they are doing now and how they are becoming environmentally friendly now. If you look at what they are actually doing, most of their investments are still in oil and gas, although they do not like to talk about them. Young Worker #3 said: "Lack of technological background/education in both politics and media is something I see as a big disadvantage."

9.2 Economic Questions

The first question in the economic section asked how long they thought it would take before Norway is relying on and investing more in renewable energy than oil and gas. The answers varied a bit, with ten years being the shortest and 50+ years being the longest time they thought it would take.

> That is dependent on the developing countries and how much help is received from the industrial countries, and the worlds understanding of the pollution of how rapid the change will occur. My best guess is between 20-30 years. In Europe, this change will go faster. (Old Worker #1).

Many also said that they think we will be investing more in renewables early but that it will take some time for the investments to build the infrastructure needed to rely more on renewable energy than oil and gas. Two people said they thought it would take 50+ years, one from each age group. There was no clear divide between the age groups in this question. “I think we still need 10-20 years to develop the technology and also change our mindsets.” (Young Worker #3). Most of the answers were around 20-30 years, with one that said ten years and those two that said 50+.

The next question in the economic part asked what Norway’s best move would be when it comes to investing more in renewable energy but at the same time retaining the talent and jobs from the oil and gas industry. There was an interesting mix of answers to this question. One of the older interviewees thought that changing the education would be the best way to go.

> Start by changing the focus in the education. Stop having pure oil and gas education and start to include all energy technologies. That way the young people starting on the oil and gas business, have something to fall back on when times change. (Old Worker #3).

Most of the other interviewees from the older age group mentioned many of the same energy technologies. CCS and offshore wind parks were the two most popular as they felt that these technologies would have the most use of knowledge transfer from Norway’s offshore oil and gas industry. Another said that upgrading hydropower, building and installing geothermal heat pumps, building and installing solar power, and investing in energy-saving technologies was the best for Norway moving forward. One of the younger age group interviewees said that Norway should diversify among a wide range of renewable energy technologies as no one technology could replace the economic impact oil and gas has had on the Norwegian economy. Some of the technologies mentioned in the answer as suitable investments for Norway were battery production and aluminum (used in electric vehicles) production using green energy. This was because of the increased demand for electric vehicles seen in Norway over the last few decades. One of the other young interviewees said that the oil and gas companies should transition to renewable energy technologies themselves. They already have a talented workforce and the financial backbone to get things done.

> The best thing is for large oil corporations to transition their own companies to renewable energy companies. This is already happening (it makes the most financial sense for the companies), and it gives a great opportunity for the current knowledge and talent base employed at those companies to learn how they can transition their expertise into the new energy industry. (Young Worker #2).

Some of the other young respondents said the same as the older age group by mentioning CCS and offshore wind as promising technologies for retaining jobs and talent.

The third question in the economic section asked what some of the most important economic challenges that Norway must overcome to have renewable energy replace oil and gas as the primary energy technology. This question also provided a wide range of different answers. The only thing that almost every interviewee mentioned was that the renewable energy technologies need to become cost-effective, and the R&D and startup costs need to become lower, or the Norwegian government needs to create incentives to lower these barriers.

> Replace oil & gas is difficult based on the value creation and number of jobs. The oil & gas will be with us far into the future and we need to phase out oil & gas related jobs over to green energy sustainable jobs. The economic challenge is the large investment that is needed up front in R&D, maybe decades prior to the technologies being cost effective and creating positive value. (Old Worker #1).

Another one of the interviewees from the older age group had an interesting answer saying that Norway needs to think outside the energy box and maybe invest more in fisheries and farming etc. Especially since Norway's energy needs are currently met by hydropower, there is no pressing need to invest in more energy technologies, hence the thinking outside the energy box perspective. One answer said that Norway needs to tax renewable energy companies need to be taxed the same as oil and gas as it is a good income for Norway. One answer from the older group said that, the younger generation needs to accept a lower standard of living and lower pensions as renewable energies will not make enough money for the standards of living today. On the other end of the scale, another answer was that Norway needed to lower taxes on renewable energy companies to incentivize and speed up the process. Most of the younger age group mentioned that the technologies need to be cost-effective and make financial sense, whether through lowering costs of the technologies or by government funding and lower taxes. "It needs to be financially sustainable to keep the workforce and deliver returns on investment." (Young Worker #5).

The last question in the economic section was focused on the cost-effectiveness barrier of renewable energy technologies. It asked which of the technologies were most affected by this barrier and which are on the brink of breaking through it. Here, there were similarities and differences in the answers as most had several renewable energy technologies that they mentioned for both parts of the question. CCS was mentioned by many as one of the technologies suffering from the cost-effectiveness barrier. Especially the interviewees in the older age group talked about CSS in the first part of the question. PHES is also one of the energy technologies that the older age group thinks is suffering from the cost-effectiveness barrier. “I think PHES, and CCS opportunities are suffering, Wind (+wave) may soon breakthrough.” (Old Worker #2). The argument here was the full-scale testing that is needed for it. One technology that both age groups mentioned was green hydrogen. The argument here was that the world already uses much hydrogen that comes from natural gas, but if green hydrogen becomes more cost-effective, it could easily replace it as there are systems in place for it. “Hydrogen, offshore wind and CCS. Solar power and onshore wind I see having potential for breaking through.” (Young Worker #5). Hydrogen energy storage was also mentioned as one technology that could be on the brink of breaking through the cost-effectiveness barrier. A few of the older interviewees mention large-scale wind power and wave power as technologies that are on the brink of breaking through, in their opinion.

9.3 Technology Questions

The first question in the technology section asked what some of the technological challenges and barriers that Norway needs to overcome for renewable energy to become the main focus in the energy sector. This being a difficult question to answer, the answers varied quite a bit. Many of them stated the cost of the technologies as the main barrier. This goes more toward the economic part rather than technological. Cross-industry cooperation and engagement were mentioned, so more technology and information sharing are exciting for speeding up the transition. “More cross-industry focus and engagement is essential.” (Old Worker #2). One of the young interviewees said that many renewable energy technologies have a short life, some under 50 years, so there is a need to figure out how to handle renew or discard them when they are no longer usable. More research and time were also mentioned by many in both age groups.

The next question in the technology section asked if PHES in Norway is the best available practice to replace oil and gas as the primary energy technology. Most of the answers here were a yes or a partial yes. “Yes. It will build on our existing water/electricity technology.” (Old Worker #3). It seems to be a consensus among the interviewees that PHES will play a large part in the future Norwegian energy mix. The answers are based on the large capacity Norway already has for hydropower and that maximizing and expanding on it will be easier since much of the technology is already there. Most think that PHES combined with other renewable energy technologies could replace oil and gas in Norway. One of the younger respondents pressed the importance of cooperation between countries to solve the upcoming energy challenges. Countries who have a specific advantage within an energy technology naturally like Norway does with hydropower need to do their part to share that so that it can benefit everyone in the most efficient way possible. “Yes, this might be the thing we have available today. Then we could provide Europe with electricity instead of gas.” (Young Worker #1). One in each age group said that PHES was not a good idea as it was too expensive and Norway should focus on other renewable energy technologies.

The last question of the technology part and the interview was that the interviewees were asked to pick three energy technologies that they believe have the best chance of becoming a technology in the typically available category. For the young age group, the most mentioned technologies were PHES, wind power, solar power, and CCS, with one mention of geothermal. “Geothermal energy, solar power, carbon capture and storage.” (Young Worker #3). The older age group also mentioned the same technologies but with a few more saying geothermal and one also mentioning hydrogen energy storage. “PHES, CCS, Geothermal energy” (Old Worker #3).

10. Discussion

This section of the thesis will discuss the findings from the three previous chapters. It will look into different scenarios that the results could create. The las part of this chapter sums up all the discussions and compares some of the results from the different sections.

10.1 Technologies: How does it look?

This thesis has presented several renewable and low carbon energy technology options that could help replace the oil and gas industry as the primary industry in Norway. Some of the technologies, like wind power, are already being invested in and built in Norway. Other technologies have been widely tested but not gotten further than that, primarily because of the cost-effectiveness barrier. One of these technologies alone will not be able to fill the gap that oil and gas will leave in Norway in terms of economic gains and job creation. Norway will likely need to invest and focus on at least three technologies to fill that gap. There could be a need for more than three renewable and low carbon technologies, and for which three or more, the answer is a bit more unclear. It all depends on which direction the government and companies take, and it depends on which technologies breakthrough the cost-effectiveness barrier first.

For the transition to speed up, one of three things needs to happen, it seems. Either the research and development of the technologies need to speed up to lower the costs to make them more attractive for widespread use. The second option is for the energy companies that now rely primarily on oil and gas to start investing more in renewable energy technology. They have the money and the profits to make it happen even if the costs are still higher than the traditional energy technologies. We have in Norway seen Equinor, who even changed names from Statoil, have started investing more in renewable energy sources, although some have dubbed their name change and green investing a PR stunt. However, there is hope that it is just the start for Equinor, and if successful other companies could follow suit in transitioning to more renewable and low carbon energy technologies. The last path to more green technologies is that the government highly subsidizes and lowers the cost barriers of starting production and installing these renewable and low carbon energy technologies in Norway. However, this will lessen the profits for Norway as a country, so there could be some opposition here.

By putting the different technologies into the categories from Van De Graf and Sovacool (2020), we see that many technologies find themselves in the same category, the state-of-the-art feasible technology category. This is because they have all been tested and are being used in some parts of the world, but they have yet to become a mainstream energy technology in Norway because mainly of the high costs connected to them. Add the fact that Norway is one of the wealthiest countries in the world where people love nature and have most of their domestic energy use already covered by hydropower makes implementing new energy technologies into nature quite the challenge (Gullberg et al., 2014). There always pushback from the public with new projects, and therefore the politicians know they cannot push too hard.

The NORD.LINK cable testing done by Statnett (2020) can be a make or break for PHES in Norway. If the testing and project are deemed successful, more could follow, and PHES could be fast-tracked. On the other hand, it could mean the end of large-scale PHES investing in Norway if it is unsuccessful. It will be interesting to see how it goes as an investment in PHES could give room for other renewable energy technologies that have to make up for the lost energy production using Norway's hydropower resources for PHES instead of domestic use.

10.2 Views from the Oil and Gas Industry

The interviews had some expected aspects and some surprising ones, especially looking at the answers from some of the different age groups we looked into. As one might expect, the 50–65-year-old age group was more conservative in many of their answers regarding the transition to more renewable energy technologies in Norway. The first question asked about if people starting work in the oil and gas industry today would have a job until retirement. There was a small divide between the young and old age group. The younger ones typically argued that there would be far fewer jobs available, while some said that there would be the same amount. However, the companies will have changed to more renewable energy technologies. These answers are positive in the transition perspective of someone who works in the oil and gas industry. It shows that they are expecting and prepared to transition themselves and might be working either a different job or in the same job but with renewable or low carbon energy technologies in the future. On the other hand, even many in the older age group said that they thought there would be fewer jobs in the future and that not everyone will have a place to work. Although some did say that everyone will be needed as oil and gas will be a large part of the energy mix in the future. Overall, the younger oil and gas workers seem to have a more positive attitude towards a transition related to their jobs.

It would be foolish to think that one renewable energy technology alone could replace the oil and gas industry in Norway when it comes to job creation. The workers from the oil and gas industry interviewed for this thesis agreed with that, and most of them said at least three different ones together are needed to fill the gap that oil and gas would leave in terms of jobs if and when it is scaled back. When it comes to which technologies it should be in terms of retaining jobs and talent from the oil and gas industry, the answers were interesting. All of the interviewees mentioned offshore wind since the offshore operational knowledge could be transferred from Norway's offshore oil and gas operations. This makes sense any way you look at it. CCS was another mentioned by many. Again it makes sense as it will let the oil and gas production and exploration continue if the CO2 can be stored. It also transfers knowledge and talent by needing drilling and storing underground, where many of the same technologies and expertise when drilling for oil and gas will be needed. There is also the possibility of storing it in empty oil wells, which Norway will have more and more offshore. Some talked about PHES as a good opportunity. It was unclear if they meant in general or as a way to retain talent and jobs. If it was, there is not much of a transfer here. The pumped part can have some similarities, although water is easier to work with than oil and gas, and oil and gas flow upward naturally while the water will need to be pumped up using electricity. A few also mentioned geothermal energy, which has some apparent similarities that make retaining jobs and talent easier. There is a need for geologists to locate the best sources for heat. Drilling and managing wells fit right into many of the operations of oil and gas companies today. This is something more oil and gas companies should look into for future energy options in Norway. As for the differences in age groups here, nothing stuck out. They all had a variety of different and similar answers.

From the answers to the third question about societal challenges connected to the transition to more renewable energy technologies, it is clear that the job loss and the loss of the high standard of living that the Norwegian population has grown accustomed to is the main challenge according to the workers in the oil and gas industry. Suppose Norway can keep the same high living standards by retaining the jobs connected to the oil and gas industry. In that case, the fear and challenges of transitioning to renewable energy technologies could diminish. The other societal challenge that the interviewees mostly agreed on was the public opinion on new renewable energy projects. It seems that because of the comfortable situation that Norway's economy finds itself in, people do not like change, especially things that interfere with nature. The debate around the onshore windmills shows that. One can argue that some of the onshore wind projects might have been too hastily done and lacked proper thinking beforehand. There is likely a place for onshore wind in Norway, although some of the older oil and gas workers strongly disagree. The placement of these wind projects needs to be carefully selected to not interfere with nature or populations.

The policy and regulatory barriers question showed a more significant divide between the age groups. Many of the older oil and gas industry workers wanted renewable energy companies and technologies to be taxed and regulated the same as oil and gas in order for Norway to profit more from them. Meaning they wanted more regulations and fewer incentives on renewable energy technologies, especially onshore wind, as again it has caused outrage and heated debate in many cases. The younger age group seemed more open to renewable energy getting tax breaks and other incentives to make them more cost-competitive and speed up the process. Some also said that even stricter regulations and taxes needed to be put on oil and gas companies to push them more towards greener technologies, so that means doubling down by making renewable energy projects cheaper and making oil and gas projects more expensive same time. This is a positive development, at least if you are on the side for more renewable energy at a faster pace in Norway.

Many of the answers to the different questions had similarities, and the same subjects were brought up often. The same goes for the question of the sociocultural barrier, where again, the love of nature and the high standards of living the oil and gas dominated economy has produced could be seen as a barrier for new renewable energy technologies in Norway. The younger age group also seems to be on the same page regarding the wealth that oil and gas have created being a barrier to the transition. There seems to be a need for proof that the transition to renewable energy technologies will create and retain jobs and a profitable economy for people to become comfortable with the idea of transitioning away from oil and gas as the main driver for the Norwegian economy.

Many of the interviewees from the oil and gas related industry had a lot to say about misinformation. The older age group focused many of their answers around the media portraying extremities and painting a black and white picture of the situation. The media has been under much scrutiny lately, especially with regards to politics in the USA. The fact that newspapers measure their success through how many clicks they get online has not helped the situation either, as dramatic headlines or stories gather more attention. The interviewees seem to be onto something here when they claim that the media creates more of a divide. In order to make a transition to renewable energy more successful, there is a need for more people to be on the same page. The younger group said they thought it was worse before the oil and gas companies created their own “science” to prove that human activities were not causing climate change. However, it was interesting that one of the older interviewees suggested that any good student would read the book Inconvenient Facts written by Gregory Wrightstone, a board member of The Heartland Institute and a member of the Cornwall Alliance. Two think tanks that are well-known climate deniers and are surrounded with controversy because of it. So one can argue that the misinformation is still alive and well on the subject of the cause of climate change.

To start the economic section, the question about when Norway will start investing and relying more on fossil fuels may have been a little misleading as the answers here varied quite a bit. Mentioning both investing and relying on simultaneously could have caused confusion as they will most likely differ a bit timewise. Some did give answers to both investing and relying and said that we will be investing more earlier than we will be relying on renewable energy more than fossil fuels. Some of the answers were a bit worrying if you are rooting for a faster energy transition as there were two in the younger group and one in the older who said that they thought it would take 50+ years before we were relying more on renewable energy than fossil fuels in regard to the economy in Norway. A few of the younger interviewees said that they believed Norway would be investing more in renewables within 5 years and relying more on it after that when the investments have panned out. This is a much more positive view, and it is interesting to see how different outlooks these oil and gas industry workers have on the way the energy industry is going. The rest of the interviewees had what you might think of, like a more realistic timeline with how things are looking when they said 20-30 years.

The next question in the economic section was admittedly very similar to the one in the societal section regarding which technologies would be best to focus on to retain the knowledge and talent base from the oil and gas industry. Although it was meant to be from a more investing and economic standpoint, it is hard to say if that came across well enough in the interviews for those answering survey forms. There were some interesting new answers despite the similarities in the question. The answer regarding the education needing to change to attract more students and give them more flexibility for the future was exciting. We have seen the number of applicants to oil and gas-related education fall over the last decade. A more combined energy education with renewable energy technologies and oil and gas technologies on the education plan could help both companies and the country transition from oil and gas to renewable energy when the time comes. It could secure the remaining future of oil and gas without jeopardizing the students' future careers that are not needed for the oil and gas part as it is transitioned out. Like CCS and geothermal, the other technologies mentioned have already been discussed as viable options for knowledge and talent transfer. The one interviewee that mentioned solar power must have thought in a more general way that Norway should invest in it, as there is no obvious way this can transfer knowledge and talent from the oil and gas industry. This was admittedly one of the faults of conducting most of the interviews in survey form by sending them the question rather than asking in person. This gave a lack of clarification if they misunderstood the question. Luckily, most of the respondents did understand the questions, so it was more realizing that some of the outliers were just misunderstanding the question.

The economic challenges question came with some not-so-surprising answers. Many new renewable energy technologies cannot currently compete with the current actors in the Norwegian energy industry because of cost. The startup costs are too high and the possible revenue too low for most of the technologies. Add the public's fear of change to the status quo and preserve nature to that, and it seems like a tall task to get things going in many aspects. The response from one of the older interviewees saying that, the younger generation needs to accept a lower standard of living if we are to transition away from oil and gas was interesting and goes into the fear of change discussed earlier. This means that they believe that the new technologies and other things Norway might pursue will not be as economically successful as the oil and gas industry has been. This could be true but is also a bit “glass half empty” view on the situation, with the suitable investments and focus, who can cay what Norway can and cannot accomplish. The two opposing viewpoints regarding the economic incentives on renewable energy were also interesting. The older age group thinks it should be taxed the same as oil and gas because this means more money for Norway. However, the younger group wants to see more tax breaks and benefits to speed up the transition to more renewable energy technologies. This is the problem in a nutshell. If we give tax breaks and incentives, there will be less income from it, and that might cause public opposition. On the other hand, it will be too expensive to invest in and build if there are no incentives.

CCS can be thought of as the poster child for the cost-effectiveness barrier, and the interviewees agree. It was the one technology that most brought up when asked the question regarding the cost-effectiveness barrier. CCS is a great idea that would enable us to use oil and gas for decades to come as it will reduce the emissions significantly and entirely if effective enough. For Norway who has an economy that depends on the profits from exporting oil and gas, it could be the key to securing the economy for future generations. Green hydrogen to replace the hydrogen from oil and gas was also an interesting idea that the interviewees mentioned. If it could pass the cost-effectiveness barrier, the implementation should be easy and could even help retain jobs from the oil and gas industry and could be one of the keys to energy storage when the time comes. PHES was also brought up in the cost-effectiveness barrier technologies answers from the interviewees. It indeed is suffering from the cost-effectiveness barrier, especially when it comes to the expensive interconnectors needed between Norway and other European countries for it to be feasible. The electricity grid as a whole needs to be expanded as well to handle the increased flow. This will probably be needed anyway as more and more of the transportation sector are going electric.

The technology section of the interview seemed again to confuse in terms of what the question asked. The technological barriers question had many pointing back to the cost of the projects and the technologies which was more the same as in the economic part. One good answer was given, and it was the one about more cooperation and engagement between industries. The world's problem will need tremendous cooperation and information sharing across industries, and the sooner this starts, the better. The oil and gas industry has been operating in several different climates and locations and has a wealth of information that can be helpful for the renewable energy sector. PHES seems to be an idea that many workers in the oil and gas industry support, especially among the younger age group. This is again promising that the younger generation of oil and gas employees are more open to new technologies than the older generation. Although it is unclear how this will translate into jobs and talent transfer from the oil and gas industry.

10.3 Discussion of Norwegian Energy Policy

By looking at the policies of the different ministries in Norway, we see a slight but understandable contradiction. Especially between the Ministry of Petroleum and Energy and the Ministry of Climate and Environment. Norway has a clear goal of cutting emissions and is planning for the green change as they call it, yet they also promise continued search for new oil and gas fields. This seems to be done to please both sides of the oil and gas versus low carbon and renewable energy debate. Norway’s economy is highly reliant on the oil and gas industry, and not promising continued search and production for oil and gas would upset many people and companies. We can see a correlation here to the answers from many of the interviewees who said that oil and gas will still be a large part of the energy mix in the future. It seems that the policies in Norway are on the same page as they continue to explore oil and gas options and invest in greener technologies simultaneously.

With all the focus of the Ministry of Climate and Environment (2020) on reducing emissions and electrifying the transport section and on biofuels, even more of the oil and gas produced will be exported. Other countries might not have the same pace as Norway when it comes to using renewable energy for heating, electricity, and transport and will still need oil and gas. With these policies, Norway is continuing its if we do not burn it here, it is not our problem approach. With around 225 000 people working in the oil and gas industry in 2017, it is natural for the government to protect this industry and make promises about the future (Ministry of Petroleum and Energy, 2020). However, there is no mention of a planned end date for further exploration or production of oil and gas in Norway. That could be costly if the predictions of the oil and gas needs in the future are lower than expected.

On the other side, we find the Ministry of Climate and Environment who seems to be doing what they can to reach Norway's goals and agreements. Many plans and projects in the works promote the importance of low carbon and renewable energy options (Ministry of Climate and Environment, 2020). CCS could help with the problem that further exploration of oil and gas could cause and allow Norway to continue with oil and gas if all emissions are captured and stored securely. This will also create jobs for people from the oil and gas industry.

10.4 What does this mean?

To reach the goals of the Paris Agreement from 2015, every country should do their part, especially those who have the economy and resources to be a leader within the energy transition. It seems clear now that there are many viable renewable energy technology options available for Norway to pursue in the future if oil and gas are scaled back. CCS, geothermal energy, and offshore wind have been brought up as good technologies to invest in as the knowledge and talent transfer from the oil and gas industry could limit the loss of jobs and a faster transition away from oil and gas. The problem seems to be the cost-effectiveness of these technologies as well as the fear of change among the public in Norway. As mentioned, Norway has its current energy needs nearly covered by hydropower (95-99%) and has a robust economy and welfare from oil and gas export (Gullberg et al., 2014). These things are something they seem reluctant to risk by investing more in renewable energy technologies and less in oil and gas.

The split policies of the different ministries in the Norwegian government are not making it clear in which direction Norway will go either. It seems like the oil and gas workers, especially the younger ones, are open to a change to more renewable energy technologies if they have a job to go to and their way of life is not changed too much. The low carbon and renewable energy technologies are there, many of them tested and proven as well. Now the government needs to take a clear stand and start investing and working to lower the costs to get the renewable energy ball rolling. Misinformation has been highlighted through interviews, and it seems that the media has a job to do as well. There are too many dramatic headlines and articles stirring up a divide rather than presenting the situation as is and bringing people together to solve it. Renewable energy technologies will create jobs as well and that needs to be better communicated. The transition will not be instant, and the scaling back of oil and gas will go slowly, but it needs to start in in Norway as well to reach the goals set by the Paris Agreement in 2015.

PHES might not transfer many jobs from the oil and gas sector, but it could be an essential economic driver for Norway and open for other renewable technologies. When the world becomes more electrified, more cooperation between nations and Norway should utilize their unique hydropower position to be the baseload for this in the future. Geothermal and offshore wind energy could supply Norway with the electricity lost to PHES and Norway as a green battery. This will create many jobs where workers with relevant oil and gas industry expertise can be brought in.

11. Concluding Remarks

The goal of this thesis has been to investigate what energy options for Norway are in the future, with the focus on retaining jobs and talent from the oil and gas industry. The findings are based on literature research on existing technologies and policies, secondary data, as wells are primary data in the form of surveys and interviews.

There is several technology options Norway could choose for their future energy investments. The ones that will give the most significant job opportunities for the oil and gas industry workers are offshore wind, CCS, and geothermal energy. They have several characteristics and operations that match those of oil and gas productions in Norway. The interviews and surveys done with workers in the oil and gas industry reveal that they recognize the coming transition and believe there will be less need for workers in the oil and gas industry. The younger generation of oil and gas workers are open to shifting to renewable energy if needed. The older generation of oil and gas workers see a transition coming but believe it will be slow and that there will still be a significant need for oil and gas far into the future. The findings from the energy policies in Norway backs up the views from the older generation as the Ministry of Petroleum and Energy (2020) promises continued exploration and production of oil and gas far into the future. Policies from the Ministry of Climate and Environment (2020) are working to reach the emission goals set as well as investing in low-carbon and renewable technologies. This tells us that Norway's energy future will focus both on continued exploration and production of oil and gas and investing heavily in green options. With this approach job, shortages should not be a problem.

Many of the renewable energy technologies that exist today are held back by the cost-effectiveness barrier. It is hard to gain public and governmental support for projects that will cost more than they can bring in. This is especially true for Norway as its energy needs are covered by hydropower as well as export of oil and gas drives the economy (Gullberg, et al 2014; Ministry of Petroleum and Energy, 2020). The testing of the NORD.LINK cable by Statnett (2020) running from Norway to Germany will indicate how feasible PHES is and could be a make-or-break test of this technology. It will not transfer jobs directly from the oil and gas industry but would make room for renewable energy technologies that will.

From an economic standpoint, it seems that Norway's future is secure, and there will be jobs for everyone in the oil and gas industry in the foreseeable future as it stands now. If the government's energy policies stay the same as they are now, there will be no need to create many jobs through renewable energy technologies. However, suppose the pressure of climate change and a looming climate crisis push policies away from oil and gas and towards renewable energy. In that case, there will be a need to create jobs for those who lose theirs in the oil and gas industry.

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Appendix 1

University of Stavanger

Master Thesis Interview/Survey

University of Stavanger

Thank you for participating in this study. This interview is a part of a master thesis that is exploring the energy technology options that Norway has in the future. The world is moving in a new direction and oil and gas will either be phased out because of pollution and climate change, or we will simply run out of oil and gas. Norway's economy is heavily reliant on oil and gas, that needs to change in order to secure a stable economic future. When it comes to renewable energy technologies, we have heard a lot form the experts and people who work with renewable energy, but there is a lack of opinions from the people working in the oil and gas industry. Norway has a large workforce in oil and gas, and we need to secure their future and knowledge as we transition towards greener energy technologies. The goal of this interview is to hear from people working in the oil and gas industry and get their thoughts and opinions on the best way forward in order to transition in a way that does no leave anyone behind without a place to work.

For this study we will be using the categories below to analyze the potential of different renewable and low carbon alternatives to replace oil and gas as the main energy industry in Norway. Some of these will be referred to in the questions asked so please take some time to get to know them. You will also find an information sheet on some of the renewable and low carbon energy alternatives that are being considered in this study.

- **Typically available** describes the traditional systems already used around the world to provide energy services, many of them fossil fueled.

- **Currently available best practice** represents the most advanced commercially available climate mitigation technologies that are cost-effective and widespread today.

- **State-of-the-art feasible technologies** are defined as the best performing technologies being prototyped and demonstrated that are technically feasible but have not yet been proven and indeed may not yet be cost-competitive.

- **Frontier or breakthrough technologies** are those that could perhaps some day result in significant emissions reductions but are not yet even being piloted or trialed.

(Van De Graaf & Sovacool, 2020, p. 144).

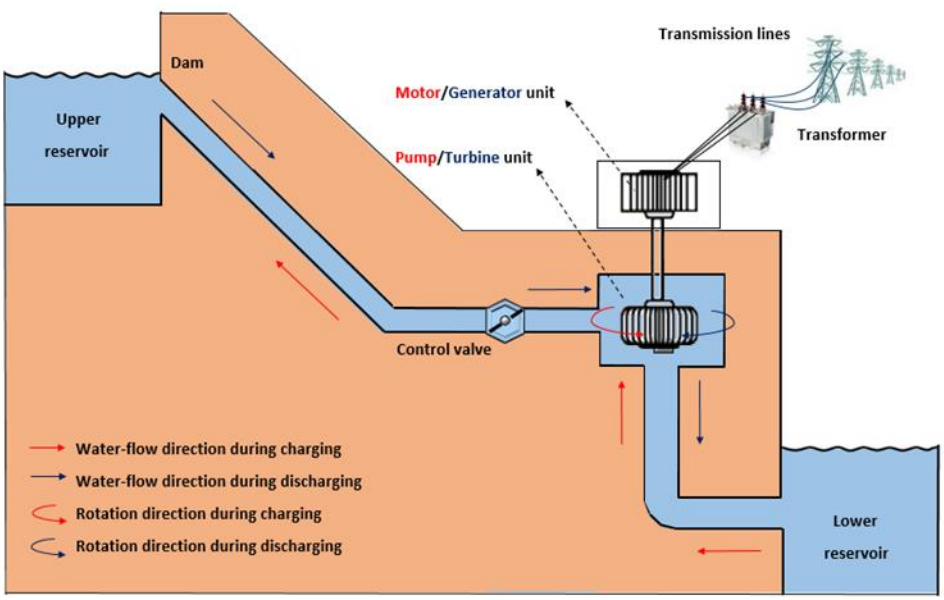
Information Sheet for Interviewees:

Hydrogen Energy Storage

Hydrogen energy storage is a form of chemical energy storage where electrical energy is converted to chemical energy, most often a type of fuel, like hydrogen in this instance (Acar, 2018). This type of energy storage has become popular as it is quite efficient, and distribution and transport are easier than other forms of stored energy (Acar, 2018). The most common type of hydrogen energy storage is water electrolysis where water is split into hydrogen and oxygen by electric energy (Acar, 2018). The hydrogen can then be stored in gas, liquid, or solid form (Acar, 2018).

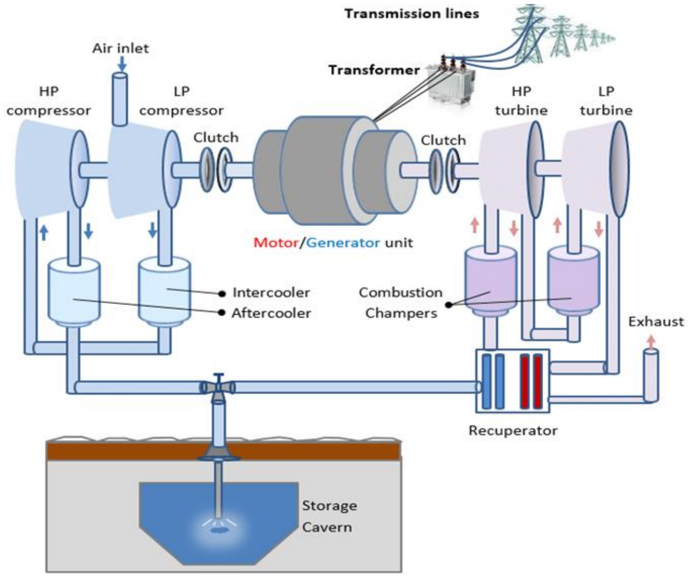
Pumped Hydro Energy Storage (PHES)

Hydropower can be effectively used to balance and support intermittent renewable energy based grids, and this is what Norway could do for parts of Europe (Graabak, et al, 2018). During hours of low demand and high energy production the excess energy can be used to pump the water back up to the higher levels, so that it can be stored there to be used later when needed.



Compressed Air Energy Storage

Compressed air energy storage (CAES) is a large-scale physical energy storage which like PHES and HES can help solving the problems with grid connections and the intermittency problems a more renewable energy based energy mix would present.



CCS

New energy technologies are not the only options in combatting the increasing emissions of greenhouse gases. Carbon capture and storage (CCS) is technology that captures the carbon dioxide and stores it so that it is not released into the air. There are three general phases in CCS, capture, transport, and storage

Onshore and offshore wind power

There is over 10 TW found in the winds of the world today, more than enough to cover the world's primary energy needs (Coley, 2008). The energy is kinetic energy and comes from sunlight, wind power is one of the most popular and promising renewable energies in the world today

Solar Power

The most common technology people think of when they hear solar power is probably solar photovoltaics (PV). With the increase in efficiency and decrease in price over the last few decades, it has together with wind become one of the most promising technologies for use in the increasing need for renewable energy

Geothermal Energy

Norway has been utilizing shallow geothermal energy for quite some time, but there has been little to no activity within the deep geothermal energy production (Gjølberg, 2011). Deep geothermal energy comes from the radioactive decay of isotopes deep within the earth and the cooling of the earth's core (Coley, 2008; Gjølberg, 2011).

Biomass

In simple terms biomass can produce energy in three main ways, it can be burned to run a steam generator, or it can be turned into either oil or gas for transportation fuel or to burn (Coley, 2008). Liquid biofuels can be a cleaner alternative to fossil fuels in a time where there is increasing needs for liquid fuels as they are already very integrated in society today (Karmee, 2016).

Interview Questions:

Age:

Societal: Going beyond typically available technologies.

Do you think professionals starting in the industry at 24–25-years of age today will have a place to work until retirement in the oil and gas industry in Norway? Why/why not?

In your opinion, what renewable energy technology would be the best option for Norway in terms of retaining jobs and job security in the future? In which of the categories introduced does this technology fall?

What are some of the societal challenges that need to be overcome before renewable energy can replace the oil and gas industry as an employer and producer of wealth in Norway?

Norway has been good at breaking down policy and regulatory barriers for renewable energy technologies, the high increase in electric vehicles because of favorable policies is a good example. The oil and gas industry still has a big influence on policy and regulations, do you see any of the renewable energy technologies being hindered by policy and regulatory barriers?

Sociocultural barriers consist of country specific norms and traditions that might be a barrier to new technologies, can you think of any cultural barriers in Norway that may conflict with creating a new energy industry that can replace oil/gas?

Misinformation is also a sociocultural barrier; do you feel Norwegians are misinformed or underinformed about both the damages of fossil fuels and the and opportunities involved with new renewable energy technologies?

Economic: Between State-of-the-art feasible technologies and Currently available best practice

The energy world is changing, it is moving towards more investments in renewable energy. How long do you think it will take before we are investing and relying more on renewable energy than oil and gas?

What do you think will be the best move for Norway in terms of energy investment and technology regarding the goal of keeping the knowledge and talent base we have in the oil and gas industry?

What are some of the most important economic challenges that need to be overcome before renewable energy can become the main energy technology in Norway and replace oil and gas?

The cost-effectiveness barrier is a barrier that is very much applicable when it comes to renewable energy companies. If they can’t compete with existing technologies in terms of cost, investors and consumers will not be interested. Which of the renewable energy technologies are suffering the most from this barrier, and which might be on the brink of breaking through it?

Technology: From frontier or breakthrough technologies to Typically available systems

What are some of the technological challenges and barriers that need to be overcome before renewable energy can become the main energy technology in Norway?

Norway as a green battery for Europe through pumped hydro energy storage (PHES) is an interesting idea that has been talked about for some time. Do you think it is our best available practice we have today as a possible replacement for oil and gas in the energy industry? Why/why not?

Regarding energy innovation, different technologies are currently in different categories as described in the introduction. Which three of these energy technologies have the highest potential to see a breakthrough in a way that they become a typically available technology? Pumped hydro energy storage (green battery), solar power, wind power, hydrogen energy storage, compressed air energy storage, geothermal energy, Carbon capture and storage, biomass.

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