Social Acceptance of Hydrogen in the Norwegian Maritime Sector: Challenges and Experiences from an Industrial Perspective

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Master Thesis in Climate Change Management

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Preface

This thesis is a part of the master's program in Climate Change Management at the Department of Environmental Sciences, Faculty of Engineering and Science at the Western Norway University of Applied Sciences in Sogndal.

After conducting a quantitative-based bachelor's degree and a thesis related to thermoelectricity, I wanted to explore a different scientific approach. Hydrogen is something that always has been interesting to me, and besides the technological aspect I did not possess a lot of information about it. Therefore, when being posed with the opportunity to conduct a study based on social acceptance of hydrogen I did not stutter. Furthermore, hydrogen seems to be at a critical stage with regards to development, and as a result a study based on interviews with key actors in the transition towards hydrogen seemed sublime.

I would like to thank all the participating interviewees for being willing to contribute to this cause. Furthermore, I would to thank all the people inviting me to online seminars and workshops so that I could better engage in the topic. Without the help of the interviewees I would not have been able to conduct nor finish this thesis.

A special thanks to my supervisors Bente Johnsen Rygg and Geoffrey Sean Gilpsin both working at Department of Environmental Sciences, Faculty of Engineering and Science at the Western Norway University of Applied Sciences in Sogndal. Thanks for always helping me out in stressful times, and for your constant aid and constructive criticism.

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Abstract

Studying social acceptance is vital in order for new innovations to succeed. This study investigates the social acceptance viewed from the perspective of individuals already integrated in the transition towards hydrogen as a zero-energy emission carrier in the Norwegian maritime sector. Currently, feasibility studies of hydrogen-based maritime vessels are plentiful, yet there is a clear lack of studies related to social acceptance. Through extensive literature review, document analysis and interviews this report discovers the thoughts of five individuals with close ties to hydrogen in Norway, such as politicians and employees working with hydrogen production. Furthermore, this study links findings towards theory regarding social acceptance as proposed by Wüstenhagen et al. (2007) and Sovacool and Ratan (2012) in order to explore the current potential for success. The results indicate an overall positivity towards this technology, yet the interview subjects pose concerns that cannot be ignored, such as lack of funding, fear of safety, sufficient supply and demand, lack of political frame work and overall social acceptance of the technology. Thus the results indicate areas where actions are needed to improve social acceptance of this technology when looking at the factors proposed by Wüstenhagen et al. (2007) and Sovacool and Ratan (2012). Despite needing improvement in some areas, Norway seems to be on a good path towards implementing this technology, if, proposed and planned measures are instigated and advanced. The country is at a make or break point, where failure to improve aspects such as funding and political frame work, will likely reduce overall social acceptance which in turn will lead to the demise of this technology.

Sammendrag på norsk

Å forske på sosialaksept er avgjørende for å lykkes med nye teknologiske utviklinger. Dette studiet undersøker sosialaksepten blant personer med tett tilknytting til overgangen mot hydrogen som en nullutslipps energibærer i den norske maritime sektor. Per dags dato finnes det en rekke studier relatert til muligheten for hydrogenteknologiske løsninger, men det er en klar mangel på studier relatert til sosialaksept. Ved hjelp av litteraturgjennomgang, dokumentanalyse og intervju undersøker denne rapporten tankene og opplevelsene til fem personer med tett tilknytting til hydrogen i Norge, som politikere og arbeidstakere involvert med hydrogen produksjon. I tillegg sammenlikner dette studiet resultater og funn med teori som omhandler sosialaksept basert på studiene av Wüstenhagen et al. (2007) og Sovacool and Ratan (2012) for å undersøke suksesspotensiale til denne teknologien. Resultatene viser en tydelig positivitet for denne teknologien, men viser også mange vanskeligheter, som mangel på økonomisk støtte, frykt for sikkerhet, tilstrekkelig tilbud og etterspørsel, mangel på politisk rammeverk, og mangel på generell sosialaksept av denne teknologien. Videre indikerer resultatene områder hvor grep må tas for å forbedre sosialaksepten av denne teknologien basert på faktorene gitt av Wüstenhagen et al. (2007) og Sovacool and Ratan (2012). Selv om det kreves forbedring på visse områder er Norge på god vei til å implementere denne teknologien, viss, foreslåtte og planlagte mål blir implementert og utviklet. Landet er på et bristepunkt, og viss man ikke forbedrer visse aspekter som økonomisk støtte og politisk rammeverk, vil det resultere i redusert sosialaksept som vil lede til fallet av denne teknologien.

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1. Introduction

In order to abide by the Paris Agreement, emissions need to be reduced, and as a result the frequently disputed energy carrier, hydrogen has once again become a matter of contention. Hydrogen has a long history that spans back to the 19th century with the introduction of fuel cells (Andújar & Segura, 2009; Crabtree & Dresselhaus, 2008). In short, a fuel cell is a battery where hydrogen and air are supplied in order to produce a current. Though often used in fuel cells, the element is quite versatile and has many application areas in which it has been tried such as airships, cars, busses, planes, fertilizer production and petroleum refining (Andújar & Segura, 2009; h2tools.org, 2016; Pratt et al., 2013). Though the element has become quite relevant in fertilizer production and petroleum refining it has not yet succeeded on a larger scale as an energy carrier in cars, busses, planes nor maritime vessels. Often hydrogen may be disregarded as a viable energy carrier much due to the maturity and superiority of fossil fuels and the skepticism towards this newer energy carrier.

The Hindenburg accident in 1937 is often what people may associate and think of when they hear the word hydrogen. At the time of the incident, airships were already heavily developed with the first airship being introduced in 1852 (Liao & Pasternak, 2009). The Hindenburg airship was known as a Zeppelin type airship which was designed to utilize helium as the floating element, however, this element was scarce and expensive, and hydrogen, which was cheaper and more abundant was chosen as a suitable replacement (Dumas et al., 2012; Liao & Pasternak, 2009). The Hindenburg accident was not the first fatal airship crash, yet it has become the most famous one. A crucial factor causing the Hindenburg to become such a monumental part of hydrogen history is because it was filmed and thus provided live footage of the disaster. Although 62 passengers survived, previous airship accidents had not been documented in the same way and it is therefore likely that this inspired a shift towards other means of travel, as people posed skepticism towards airship travel (DiLisi, 2017). Nevertheless, other factors such as the increasing popularity of plane travel might also have affected this shift in travel preference (Bejan et al., 2014).

The Hindenburg disaster set of a massive shift in travel preference and shows why it is important to investigate social acceptance of new innovations as it is important in order for them to succeed. Shortly described, social acceptance is often defined as a mainly positive attitude towards a technology or a measure (Batel et al., 2013). The aspect of social acceptance of renewable innovations was largely ignore up until the 21st century (Wüstenhagen et al., 2007), yet has become of increasing concern and labeled as a key factor in advancing and implementing renewable energy innovations. Hydrogen is considered a renewable energy solution, where recent research focus on utilizing the element in fuel cells (Andújar & Segura, 2009; Edwards et al., 2008).

The fuel cell technology is considered mature, because it has been tested as an alternative energy carrier, in Norway, for quite some time. Projects such as the Hydrogen Road in Norway (HyNor) that started in 2003 and ran until 2012, aimed to facilitate and coordinate the introduction of hydrogen as an energy carrier in Norway (Sataøen, 2008). Originally, fueling stations related to this project was owned by Statoil (now Equinor) though they abandoned the project in 2011 as they claimed it was too expensive and not economically feasible. Following their abandonment of the project, Hyop AS gained control over the fueling stations up until 2019 when the company went bankrupt. The last years before going bankrupt the company merely survived on government incentives and due to electric cars being favored and few customers at their stations, Hyop AS simply ran out of money and had to declare bankruptcy (e24.no, 2019; hyop.no, 2019). Other companies such as Uno-X Hydrogen also tried to provide fueling stations for fuel cell based personal cars, yet despite cooperating with the Norwegian government, they were not successful. However, Uno X Hydrogen were likely affected by another factor than just economic loss. In 2019, one of their fueling stations located in Sandvika exploded. The accident, caused by a wrongly installed valve (Jensen, 2019), caused two people to sustain minor injuries. Though hydrogen car sales had not flourished prior to this incident, purchases had been steadily increasing from 2013 up until 2019 (Hydrogen.no, 2019), where they effectively stopped. This may have been caused by skepticism towards this type of fuel in combination with the sudden lack of availability of the fuel. Other reasons such as the increasing and well-established infrastructure surrounding electric cars may have caused people to favor this option as it is simply easier to re-fuel. These factors therefore, give another indication why it is important to investigate social acceptance of hydrogen technology.

Despite many unsuccessful projects the Norwegian government, alongside companies, are still interested in developing and utilizing the hydrogen fuel cell technology. The energy carrier is slowly becoming an option in the Norwegian maritime industry, much due to the climate goals posed by the Norwegian government, where several pilot projects are in place or planned (AOHC et al., 2019; Ødegård, 2021). In addition, there is little infrastructure for both electric and hydrogen vessels and therefore there exists a great window of opportunity to advance hydrogen and take it to the next level. Nevertheless, this does not change the fact that it is an alien technology for most, and it needs to be accepted into society, just like battery innovations eventually have been (Ingeborgrud & Ryghaug, 2019). Furthermore, Norway is gifted with large amounts of clean renewable energy and as a result hydrogen can be produced in an environmentally friendly manner (NMPE & NMCE, 2019; nve.no, 2020). In addition, when hydrogen is utilized in a fuel cell it creates no direct nor indirect emission, the only by-products are water, heat and air (Alaswad et al., 2016; Andújar & Segura, 2009). Therefore, Norway are keen on developing and utilizing this technology due to the vast amount of green energy that can be utilized in the production of hydrogen. Other places in the world, many countries rely on electricity from non-renewable sources, such as coal, and therefore do not have the same prerequisites as Norway when it comes to environmentally friendly production (ourworldindata.com, 2020).

Hydrogen can be produced in several ways, where the three main options are grey, green and blue hydrogen. Grey hydrogen is often defined as the production of hydrogen utilizing fossil fuels such as coal, oil or natural gas. The process brings about extreme emissions due to the fact that all the CO_2 created in the process is directly emitted to the atmosphere. Grey hydrogen is currently the most common hydrogen production method and is mainly preferred due to its lower production price compared to other hydrogen types. Blue hydrogen is essentially the same as grey hydrogen, the major difference is that the CO_2 produced in the process is captured or separated in some way, thus eliminating the direct emission to the atmosphere. The CO_2 is then often transported and returned to its origin, which in Norway means it is stored underneath the seabed surface. Lastly, of the main hydrogen production forms we have green hydrogen. This type of hydrogen is produced through water electrolysis with electricity supplied from renewable sources, which prevents any unnecessary CO_2 emissions. Green is therefore often described as the ideal production form moving forward into the future, though the most expensive (Giovannini, 2020; Røkke, 2020; Yu et al., 2021). Undoubtedly, choice of hydrogen-type will alter social acceptance.

Successful implementation of hydrogen seems like it has many obstacles to overcome and to better understand social acceptance of this technology one can use the development of wind power in Norway as an analogy. Like wind power, hydrogen production will demand a lot of area and nature intervention. Though, the size of the structures of hydrogen production facilities will vary, they will likely be lower and concentrated in more urban areas than windmills (Roberts, 2019; SINTEF & NTNU, 2019). However, if Norway were to capitalize on the untapped potential of hydropower (Sundseth et al., 2019) for hydrogen production a number of smaller nature interventions would be needed. These interventions would be in close proximity to water sources which in turn are located in nature thus likely affecting social acceptance of them. In addition, due to the characteristics of hydrogen, safety zones would be needed (NMPE & NMCE, 2019), preventing people from hiking or conducting other recreational activities close to the production site.

It is evident that hydrogen technology has a turbulent history in Norway, where several projects have been tried, yet ultimately failed. Nevertheless, there seems to be a window of opportunity in implementing the fuel cell technology in maritime vessels. Norway possess great prerequisites for this technology as environmentally friendly green hydrogen can be produced through water electrolysis, yet, skepticism caused by previous accidents like the Hindenburg and Sandvika explosions creates a need for social acceptance studies of this technology. This thesis aims to investigate the societal acceptance of hydrogen technology in maritime vessels in Norway viewed from the perspective of people already integrated in this industry. Through interviews with different key people in combination with existing literature on the subject, this thesis aims to better understand social issues related to hydrogen fuel cell technology in maritime vessels.

Though this study aims to explore difficulties in implementing hydrogen in the maritime sector with regards to social acceptance, the process is already underway. Several pilot projects such as Vestfjorden (Fonneløp, 2020; Norum et al., 2020) are planned, and some are already implemented to some extent. Upscaling the technology will likely be the next point on the agenda after pilot projects. With increased usage of this technology, it will in a larger sense affect society and therefore studies regarding acceptance are currently vital and desperately needed.

The following sections will present some theory and already existing knowledge on social acceptance in combination with the hydrogen framework in Norway. Several studies and previous research will be presented which in turn will be utilized in sections *Results,* and *Discussion* of this thesis.

2. Theory

Social acceptance studies of renewable innovations has historically not been a major focus in any scientific field (Wüstenhagen et al., 2007). However, after realizing that social acceptance of new innovations was vital, it became increasingly more popular and has now become an important issue which is frequently addressed (Batel et al., 2013; Mallett, 2007; Stigka et al., 2014; Wüstenhagen et al., 2007). Renewable energy innovations were not diffused into society easily nor immediately upon introduction (Negro et al., 2012). Nevertheless, through trial and error in combination with better understanding of the importance of social acceptance, renewable innovations have become important in several parts of the world, especially in Norway (Ciriminna et al., 2016; Hitzeroth & Megerle, 2013; Mallett, 2007). Hydrogen has not yet diffused into society as it is still a fairly new renewable innovation, at least regarding usage in maritime vessels. Therefore, social acceptance studies are relevant and vital in order to help hydrogen succeed in diffusing into the Norwegian society. Failure to correctly understand the social acceptance surrounding hydrogen in Norway may ultimately halt the expansion. Ideally one wishes to advance this technology due to the overall positive environmental impact and sustainability of this technology and studies regarding social acceptance are therefore critical at this stage of the implementation process.

The subsequent segments aim to provide an overview of theory surrounding social acceptance. This thesis mainly focuses on two separate papers that are commonly used for describing social acceptance. The first study was conducted by Wüstenhagen et al. (2007) and explains the relationship of three factors and social acceptance. The other study conducted by Sovacool and Ratan (2012) further expands on the factors proposed by Wüstenhagen et al. (2007) and conducts a more deep dive into them. All the factors which are important for these studies are explained below where the aspects proposed by Wüstenhagen et al. (2007) are listed first followed by the elements identified by Sovacool and Ratan (2012).

2.1 Theory Regarding Social Acceptance

When studying social acceptance of new renewable innovations, three main factors have become apparent. These factors are often identified as socio-political acceptance, community acceptance and market acceptance (Wüstenhagen et al., 2007). Socio-political acceptance is often described as the general acceptance in society and more specifically the processes around the implementation of new technologies such as policies and laws. According to Wüstenhagen et al. (2007) there are several aspects that indicate a high acceptance of renewable technology and politics. Such positive attitudes have led policymakers to believe that social acceptance is not an issue (Bell et al., 2005; Bell et al., 2013) and as a result many of the obstacles in successful implementation of projects are linked to lack of social acceptance. For hydrogen it seems important that there is a clear framework on the technology which makes it predictable, easy and stable for people and companies to invest. If the framework is unstable in combination with lack of cooperation between national and local authorities it may lead to unnecessary obstacles.

The second factor, community acceptance, is often defined as the division of advantages and disadvantages amongst the population. Counties and the inhabitants may often get the short end of the stick, as they have to implement the hydrogen infrastructure locally. This results in them experiencing the noise of the production, the visual pollution, effects on the ecosystem and limitation of recreational area. In addition, they have to live in close proximity to this heavily explosive element which many may not idealize. Furthermore, the advantages may not affect them directly. Though they will experience the positive environmental effects in the form of reduced emission, they will likely not see the economic benefit as that will be pocketed by government and companies to further advance their positions. Thus, many people may think that hydrogen is a solid alternative and are not concerned with explosive tendencies and other downsides until it is proposed close to their home. Then they will receive most of the negative side effects whereas others, companies and government, experience prosperity. Ultimately, this may cause issues if the government plans hydrogen production in one area and expects no pushback, but in reality, when trying to implement it or after implementation, people start to protest. A phenomenon often used to describe community acceptance is known as *not in my back yard* (NIMBY), which explains a general positivity to climate friendly innovations, but an opposition when it is implemented into their community (Stigka et al., 2014). However, an opposite belief to the NIMBY phenomenon known as *please in my back yard* (PIMBY) has been identified by (Stigka et al., 2014) which occurs when new projects are regarded as beneficial to the community. This may occur due to a number of reasons such as a local source of income and job creation locally.

Finally, market acceptance explains the investment willingness in the proposed technology as well as the availability of grants, funding or loans. This factor explains the process of the market adaptation of an innovation. Physical supply and demand is often an issue related to this factor of social acceptance. More specifically, there is often a demand for large amounts of green energy but there lacks acceptance to build the corresponding needed infrastructure. For hydrogen advancements in Norway this may be relevant as certain areas are better suited for hydrogen production. As a result, certain parts of the countries would act as suppliers to the rest which may be viewed as an unfair distribution of advantages and disadvantages. Though socio-political acceptance, community acceptance and market acceptance cover large aspects of social acceptance, other elements influence these factors as well. As a result, a study conducted by Sovacool and Ratan (2012) addressed these three main factors and the elements affecting them.

The newer social acceptance theory study conducted by Sovacool and Ratan (2012) took the ideas proposed by Wüstenhagen (2007) to the next level. Rather than just explaining it by the three factors: socio-political acceptance, community acceptance and market acceptance, the study proposes nine sub-factors that they mean are relevant when studying social acceptance. Therefore, when studying new innovations, such has hydrogen-based vessels, these preliminary factors may give a good indication to what extent the technology will be accepted. The paper describes the nine sub-factors as listed below:

1. Strong institutional capacity (socio-political) → Countries exhibit support at the national level through ministries and/or departments of energy with specific programs or sectors dedicated to renewable energy.
2. Political commitment (socio-political) → Political figures make promoting renewable energy a highly visible topic.
3. Favorable legal and regulatory frameworks (socio-political) → Laws and regulation facilitate easy entry into the renewable energy market. National interconnections standards exist, and change happens in a predictable and transparent matter.
4. Competitive installation and production cost (market) → Renewable energy technologies can propose a competitive rate compared to other technologies.
5. Mechanisms for information and feedback (market) → Investors and producers/users have reliable information about renewable energy policies, prices and opportunities.
6. Access to financing (market) → Producers, manufacturers and users have access to domestic sources of low-cost financing and/or can benefit from specific government financing schemes.
7. Prolific community/individual ownership and use (community) → Renewable energy systems tend to be installed, owned and/or used locally.
8. Participatory project siting (community) → People and communities are involved in the decision to site or permit renewable energy facilities near them.
9. Recognition of externalities or positive public image (community) → Community members are generally aware of the environmental impact of conventional energy and the benefits of renewables, cultivating a strong public image.

The study conducted by Sovacool and Ratan (2012) based its findings on all these sub-factors in four different countries in order to determine their validity. Through countless interviews with key actors in several different renewable projects the study concluded that the more of the sub-factors the country met, the more renewable innovations were present and established in the country. Thus, for hydrogen to succeed as a potential zero emission energy-carrier in the Norwegian maritime sector, it should meet as many of these factors as possible. To what extent these factors are achieved in Norway will be further handled in section *Discussion*.

3. Previous Research and Current State of Knowledge

Hydrogen is at the moment not major player at the Norwegian market, and little infrastructure surrounding it exists. Most of the hydrogen demand stems from production of ammonia and methanol at Herøya and Tjeldbergodden, and according to a report conducted by the Norwegian government, by 2030 this production site will still represent about 75% of the demand for hydrogen in Norway (NMPE & NMCE, 2019). The report has also conducted estimates for how much hydrogen the different sectors will require by 2030. *Figure 1* shows the estimation division in the form of a pie chart.

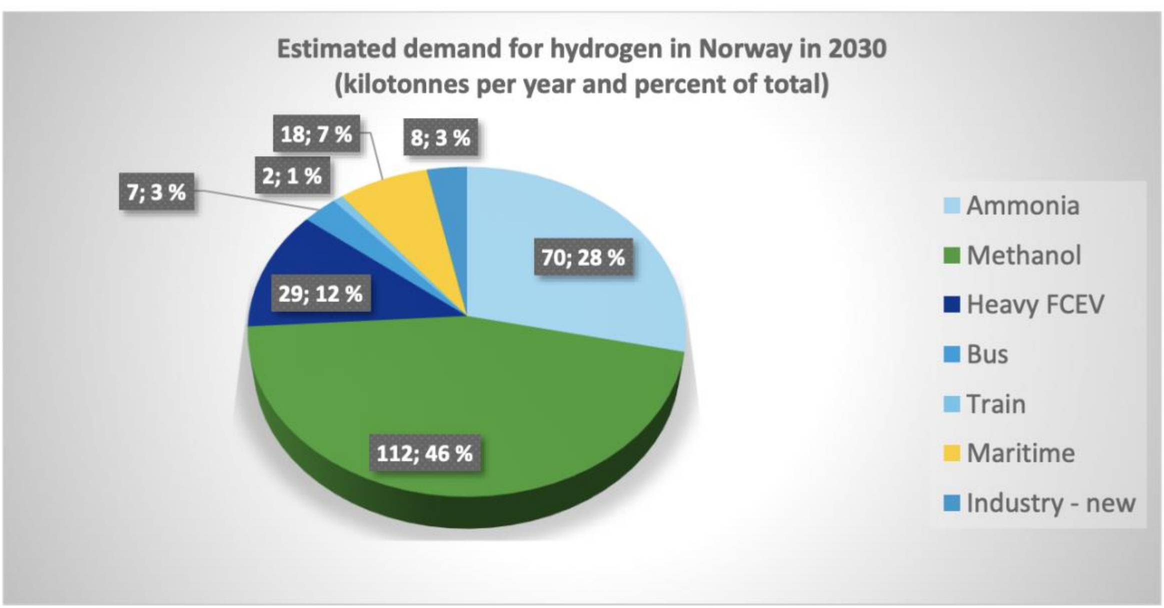

Figure 1: The figure, taken from Synthesis Report on Hydrogen (NMPE & NMCE, 2019) shows the estimated division of required hydrogen by each sector both in tons and percentages by the year 2030.

Looking at *Figure 1,* it is evident, though not specifically written with strict goals and deadlines, that the Norwegian government aims to increase the usage of hydrogen in the maritime sector as they estimate that it will require seven percent of all hydrogen produced. Though only covering a small amount of the total hydrogen-budget, this is a good start which may demand more of the element, based on the performance of the pilot projects. These pilot projects are further presented in another segment of this chapter. If the project is successful more vessels will likely convert to hydrogen-based solutions and thus demand more hydrogen, which in turn will create a more viable, and larger industry (Grueger et al., 2019). This will in turn likely demand more area in addition to infrastructural changes and thus might further bring about issues regarding social acceptance (Tröndle et al., 2020).

3.1 Norwegian Framework on Hydrogen

The Norwegian government has proposed a hydrogen strategy for the entire country that covers more than just maritime hydrogen. Though other sections may be interesting, they do not directly apply to this thesis and therefore the maritime hydrogen section will be of focus. The government has created an action plan (NMPE & NMCE, 2019, 2020) for green shipping with goals and deadlines for certain milestones. The highlights of this action plan condensed into a list of bullet points:

- Inspire further green growth and competitiveness in the Norwegian maritime industry.
- Follow up resolutions to introduce zero-emission vessels in the world heritage fjords no later than 2026.
- Extend the requirements set for the heritage fjords to all other fjords.
- Ensure that Norwegian Maritime Authority and Norwegian Coastal Administration have the capacity and skills to handle new innovations in green shipping and are equipped to develop regulations for the use of hydrogen in the maritime sector.
- Consider implementing zero or low emission options for ferries and high-speed services wherever possible (NMPE & NMCE, 2020).

Looking at the condensed list of bullet points it is evident that the plan is rather vague and does not give detailed information regarding the subject. It has some hard dates such as 2026 were heritage fjords have to be emission free, however, the other points merely set out wishes and not requirements. Due to the nature of the phrasing of these points, there is no real accountability held by the government if they are not achieved. Thus, making it look like Norway is trying hard to convert to different energy carries, whereas the reality is that harsher measures could be introduced as was stated by Pedersen (2020). In addition, the framework does not address new safety measures for the proposed pilot projects, but rather bases it of what the liquified natural gas technology utilizes (dsb.no, 2018).

3.2 Hydrogen infrastructure

Maritime hydrogen infrastructure is currently lacking or underdeveloped in Norway, though a hydrogen road-map is being planned and developed (Regjeringen.no, 2020c). In addition, several private actors have researched this topic and suggest and assume that five main bunkering stations will be in place by 2030. The suggested stations will likely be located in Bergen, Ålesund, Tromsø, Kristiansund and Stavanger as there is already large maritime traffic to these areas and they are well suited to act as fueling stations (AOHC et al., 2019). In addition, smaller stations are required in areas where vessels have fixed routes, such as ferries, where they will have a local fueling station. These more decentralized fueling locations will likely affect the corresponding communities and thus gives another indication as to why studies of social acceptance are vital.

Feasibility studies of hydrogen infrastructure in a larger sense exist in plentiful numbers. In this thesis I want to highlight two of the studies which propose opposing thoughts on the matter. The first study, conducted by Van de Graaf et al. (2020), advocates that a hydrogen road map is essential if one is to meet the climate goals posed in the Paris Agreement. The study continues by encouraging a cooperation between national hydrogen road maps in order to create an international road map that would create jobs, economic benefits and reduce emissions. However, Van de Graaf et al. (2020) poses concern that it is very unlikely that one can achieve such a road map, both internationally and nationally, without at least the aid of blue hydrogen.

On the other hand, a different study conducted by Caglayan et al. (2021) proposes opposing thoughts and findings. The study concludes that a fully renewable energy supply system in combination with hydrogen infrastructure is feasible in Europe. Nordic countries, who possess cheap and clean electricity, can produce green hydrogen and supply it sufficiently throughout Europe, or maybe even internationally. Furthermore, the study advocates that the more producers in one regional space would offer cheaper electricity and in turn reduce the economic cost of the technology per annum. In other words, centralized green hydrogen production is beneficial both for environment and the economy.

3.3 Maritime Hydrogen-Based Pilot Projects

Currently, there are two main hydrogen-based maritime projects that are frequently addressed in Norway, namely the Vestfjorden project located in Nordland, and the Hjelmeland-Nesvik-Skipavik project (hereby referred to as the Jøsenfjorden project) located in Rogaland. Both projects are based on hydrogen solutions (AOHC et al., 2019; Fonneløp, 2020; Norum et al., 2020), though the Jøsenfjorden project will be introduced this year, 2021, whereas the Vestfjorden project has been postponed from original release date in 2024 until 2025. The Jøsenfjorden project has already implemented a fully electric vessel on this stretch earlier this year (2021) with the hydrogen-based vessel set to be introduced later this year. The electric ferry will be able to be upgraded to a hydrogen-based solution at a later stage if Norled, the proprietors, wishes to do so (Norled, 2021). The new hydrogen-based vessel will itself need approximately 73 tons of hydrogen and will replace 365 thousand liters of diesel per annum (AOHC et al., 2019). However, the ferry crosses the fjord in 13 minutes now compared to the previous 11 minutes which in turn decreases the amount of departures per day. Such side effects indicate another reason why social acceptance is important as this new technology alters the everyday life of people dependent on this ferry.

The other pilot project set forth by the Norwegian government is the case of hydrogen implementation in Vestfjorden. Though further into the future than the Jøsenfjorden project, it will be quite more demanding, both planning wise and technologically wise. The longest stretch on this route is alone, 88 kilometers, and the longest ferry stretch in Norway. Moving from the Jøsenfjorden project to the Vestfjorden project one goes from minutes of crossing, to hours (e24.no, 2020; Norled, 2020). In theory, if one can implement hydrogen on the longest ferry stretch in Norway, one should be able to implement it on nearly, if not, all other stretches. Though not yet implemented the subject is addressed in journals such as Ryengen (2021) and newspaper articles such as dn.no (2020) and (Syvertsen, 2020). These journal articles and newspaper articles possess one common denominator which is an overall positivity to such projects, though they advocate that heavier measures are needed. However, other articles (Norum et al., 2020) highlight skeptics, where one of them is the mayor in the municipality of Røst, where the Vestfjorden project is located.

3.4 Funding for Hydrogen Technology in Norway

Investment and funding of new technologies are important for the innovations to advance and diffuse into society (Fonneløp, 2020; Johnston et al., 2005). Historically, the Norwegian government has provided loans or grants for hydrogen projects, although mainly for land-based transport (NMPE & NMCE, 2020). With the increasing focus on implementing the fuel cell technology in maritime vessels, the government has recently granted funding for 13 hydrogen-based projects (forskningsrådet.no, 2021). The Norwegian government agreed on providing 150 million NOK to the above-mentioned projects, though, this includes other emission-reducing projects (Regjeringen.no, 2020a, 2020b). In addition to this support the Norwegian government approved a strengthening of the Enova fund by two billion NOK, in order for them to better enable future hydrogen-based projects. Enova is a government-owned enterprise who work for the transitioning to a zero-emission society. Because new renewable innovations often are expensive and difficult to establish, Enova provides funding for projects that would likely not be possible without it (enova.no, 2021).

3.5 Efficiency of Fuel Cells

Producing green hydrogen is the best option to reduce emissions and creates the most environmentally friendly hydrogen possible, however, it is quite energy demanding (Gielen et al., 2019). The process utilizes water and electricity in order to produce hydrogen with an efficiency of less than 70% (Alaswad et al., 2016; Barbir, 2005). Other studies have found that the efficiency could be higher, although this would require significantly higher temperatures (Haseli, 2018; Zhang et al., 2010). Though the maximum efficiency of water electrolysis may vary, the main issue with the technology is that one receives a lot less energy out than what is put into the system. Furthermore, the hydrogen produced during the water electrolysis process needs to be used as an energy carrier in another system, fuel cells. The fuel cell technology then converts the hydrogen into electrical energy that powers the vessel engine, which also is prone to energy losses (Van Biert et al., 2016; Xing et al., 2021). However, the efficiency of the hydrogen engine is often estimated to be higher than conventional combustion engines such as diesel. Fuel cell technology engines display an efficiency rate between 40-65% whereas diesel engines obtain a rate in between 25-45%, based on their size (forskning.no, 2019; SINTEF & NTNU, 2019; Welaya et al., 2011). Though, throughout the entire production chain, hydrogen fuel cells have less overall efficiency of the entire system. The aspect of receiving a lot less energy out than what is put in, is likely something that will affect social acceptance.

4. Methods

This chapter and its related paragraphs aim to describe how this thesis was carried out. The section will describe why qualitative method was chosen and furthermore how examination of literature was conducted. In addition, this part will explain how interviewees were chosen and contacted in addition to what interview format was utilized and the following advantages and disadvantages of this. Furthermore, this segment will describe how the interviews were recorded, transcribed and analyzed. Lastly this section will discuss the validity and reliability of this study based on the chosen interviewees and methods, finishing off with a sub-section related to ethics.

4.1 Qualitative Method

Qualitative research is often based on collecting and analyzing non-numerical data such as text, video or audio, in order to better understand a concept, experiences or opinions (Fossey et al., 2002). This method is good for collecting in-depth insights into a given problem or generate a new one. There are many ways to conduct a qualitative study, but the general denominator is flexibility (Seale, 1999). Qualitative researchers are often describing themselves as instruments because observations and interpretations are seen from the perspective of the researcher. This method is often considered to try and preserve the voice and perspective of the participants and possess a number of strong suits (Brinkmann & Kvale, 2005). Qualitative studies are often flexible, provide detailed information of the experiences of people, collects data in a natural setting and provide new ideas through open ended responses. However this method also brings about negative issues (King et al., 1994) such as subjectivity of the researcher, limited sample size in combination with being labor-intensive (Bandari, 2020).

Due to the nature of this particular research, qualitative method was chosen in order to provide the best results. The main focus of this thesis is to investigate the general social acceptance of maritime hydrogen in Norway, viewed from the perspective of individuals with close relations to the industry. Through a qualitative study of social acceptance one can discover personal experiences and thoughts of the individuals, such as problems they have faced during their time in this industry. In addition, this approach will hopefully lead to a nuanced view of actions the interviewees think are needed for the industry to succeed.

With qualitative method, and more specifically interviews, it is difficult to gain a representative overview (Arksey & Knight, 1999), especially when the chosen interviews have close relations to the subject matter. Yet, the goal of this study was to emphasize the perspective of these individuals and the social acceptance of maritime hydrogen technology will be seen from their point of view.

4.2 Examining Literature

Examining literature is a reliable source to gain an overview of current knowledge on a certain subject which in turn may give one extensive insights into gaps of knowledge, methods and identifying relevant theories (McCombes, 2021). Furthermore, in addition to providing an extensive overview of the subject it provides rational information to better argue for the choice of exploring the research statements. Additionally, this form of examination provides information and insight into the bigger picture, and how the proposed problem statements fits into the global scheme (Rewhorn, 2018).

This approach was conducted during this thesis to identify gaps of knowledge and provide trustworthy information on the subject as stated above. Though not many social acceptance studies have been conducted on maritime hydrogen technology in Norway, several acceptance studies of other renewable innovations exist and served as inspiration. Furthermore, this method provided essential insights to the long history of hydrogen, not only in Norway, but across the globe. Though a general idea of the research statement existed before the literature examination, it was reformed and finalized based on information gather through this method.

4.3 Interviewees

Locating the appropriate interviewees is essential when conducting a study or dissertation based on qualitative method through interviews. After reading background information and examining literature for weeks, I was invited to several online seminars and workshops on hydrogen related to Norway, hosted on either Zoom or Teams. Through these sessions more information regarding subject was gathered and many potential candidates for this thesis became apparent. Therefore, after a number of attended workshops, I reached out to one individual through email, asking for suggestions as to whom I could interview. I quickly received a response and started contacting proposed interviewees where some agreed to an interview, others did not respond, and a few proposed other individuals better suited for this type of interview. After reaching out to ten individuals asking if they could participate, five agreed to an interview. The original thought when conducting these interviews was not to anonymize the subjects, however, some of the interviews preferred to be anonymized and subsequently none of the subjects are named. However, in order to provide some insights to their positions, a short description of their employment can be seen below.

Subject A: Individual whom closely works with calculation and feasibility of maritime hydrogen technology.

Subject B: Individual whom closely works with planned hydrogen production and distribution.

Subject C: Individual employed in Norled, working on the Hjelmeland-Nesvik-Skipavik stretch.

Subject D: Individual responsible for planning certain maritime hydrogen projects.

Subject E: Individual whom has been a key political figure in transition towards hydrogen in the Norwegian maritime sector.

These individuals were chosen as they likely have different experiences and thoughts on the subject and would therefore provide nuanced views. This group represent everything from politicians in the decision-making process to the individual calculating the feasibility of hydrogen and how to best utilize it in maritime vessels. In addition, individuals producing, and supplementing hydrogen will be represented as well as an employee on a proposed hydrogen vessel. Lastly the group would gain views from a person responsible for planning possible routes and options on maritime vessels in Norway. Though representative of different cornerstones of the subject on maritime hydrogen, the chosen interviewees are yet a small group and may already possess some bias regarding their thoughts on the matter. Nevertheless, for this given thesis the interview subjects made up an excellent versatile selection who could provide different, important views on social acceptance of hydrogen in the Norwegian maritime sector.

4.4 Semi-Structured Interview

Many different interview types can be considered when conducting a study or dissertation anchored in qualitative method. Based on the purpose of this thesis, semi-structured interviews were chosen to be the best fit. Utilizing this technique allows the interviewer to gain the views and thoughts of the interviewee and yet guide the individual through the process in order to gain answers to the key subjects without affecting their responses in a subjective matter. In addition, this method somewhat limits the interviewee to go off topic and the interview guide aids in the process of keeping the conversation going (Arksey & Knight, 1999).

Though qualitative studies and semi-structured interviews have their advantages they also possess flaws. Some interviewees may provide socially desirable responses in which they answer what they think the interviewer want to hear. Additionally, responses may sometimes be difficult to interpret the right way, and the interviewer might analyze responses in an unintended way (King et al., 1994). However, interviews also escape the limits of rigidly defined tools and models and therefore can facilitate a more streamlined flow of knowledge, as answers are not refined to categories set out by the researcher. Moreover, this method is also more flexible and enables the investigator to adjust questions during the interview and follow up to gain more thorough answers. Finally, semi-structured interviews are one of the few ways to approach value laden and subjective problems according to Sovacool and Ratan (2012). In a sense all these aspects of semi-structured interviews are favored for this thesis as the interviewee can supply information on the issue in a streamlined and easy manner. Moreover, it allows me as an interviewer to follow up on specific topics posed by the interviewee. Lastly, the interviewee may have a certain relationship to hydrogen already and thus this method allows me to approach this value laden subject in a suitable manner.

Though semi structured interviews are excellent at providing thoughts on similar issues through the interview guide, this thesis decided to develop separate interview guides based on the relationship of the interviewee to maritime hydrogen in Norway. This choice was made due to the different connection the subjects had to hydrogen as they ranged from political figures to first officers on ferries. Nevertheless, the core of the interview guide was the same, but rather more political related questions were aimed at the political figure and more physical implementation related questions were addressed to the first officer.

4.5 Interview guide

The main purpose of the interview guide was to serve as tool in order to remember questions and help provide a streamlined conversation. In addition, the interview guide served as useful aid in an unfamiliar and possibly stressful situation. The essence of the interview guide was mainly the same, however, some questions varied based on the connection the subject had to the transition. The main focus was to investigate the thoughts and possible issues they had encountered in this transition and how they perceived the overall acceptance amongst the public. Additional questions regarding political framework and laws were aimed at certain individuals who possessed knowledge and experience about this. An example of one interview guide can be seen in *Appendix: A.* Moving on with the interviews, they were all conducted in Norwegian as all the interviewees were native speakers and conducting it in English would possibly cause a stressful environment.

The interview guide was largely based on gaps that was found when reading background information where previous social acceptance studies about renewable innovations served as inspiration. In addition, issues related to the stagnation of wind power in Norway also served as valid and essential background information when creating the interview guide. Furthermore, reports about the technological aspect of hydrogen such as Barbir (2005), Mazloomi and Gomes (2012) and Alaswad et al. (2016) aided in the process of repeating and familiarizing myself with the technology. Lastly, reports and articles about previous hydrogen projects in Norway provided important and useful inspiration to questions that could be addressed to the interviewees (hyop.no, 2019; Jensen, 2019; NMPE & NMCE, 2020; Sataøen, 2008). In conclusion, the main literature used for developing this interview guide, is the above-mentioned journal articles and documents.

4.6 Interviews

Each interview was conducted online on either teams or zoom and lasted approximately 20 to 30 minutes. To better analyze the answer and better engage in the interview with follow up question, the interviews were recorded. In order to avoid sensitive issues, such as recording video, a separate third-party program BlackHole was utilized in combination with QuickTime player in order to only record audio. Before conducting the interviews, each participant was sent a consent form which shortly explained the project and what they agreed to by participating in the interview. In addition, the form gave them the opportunity to withdraw at any given time, though none practiced this option.

Each interview started with a greeting as well as a short explanation of the thesis before I asked one last time for permission to record the conversation. After re-confirming that they agreed to being recorded, the interview started with me asking them to elaborate on how they became involved with the hydrogen sector. After this question the interviews went in different directions as the individuals addressed different questions in their responses. Therefore, follow up questions based on their answers caused the separate interviews to follow different paths, yet the essence still remained the same. Conducting these interviews online went remarkable, yet one cannot determine with certainty if they would have gone differently if they were conducted in person. However, due to safety concerns and the ongoing pandemic, all interviews were conducted online in order to minimize risk.

At the end of the interview, the subjects were all asked to elaborate on their thoughts about hydrogen as a potential zero-emission energy carrier in the Norwegian maritime sector in order to determine their overall reaction to this transition. For all the interviews this further emphasized what they had previously mentioned in the interviews and served as a natural ending point to the session. The audio file was then saved according to NSD guidelines as a preparation for the process of transcribing.

The Cambridge online dictionary defines the word transcribe as: *to record something written, spoken, or played by writing it down* (dictionary.cambridge.org, 2021). This process which turns speech into text is a helpful strategy when one is to analyze the interviews. The plan was to transcribe the interviews in periods when other work related to the thesis seemed overwhelming and thus the transcription process had no real structure. This method of description worked for me exceptionally well. The transcription process took a long time where interviews in which the individual provided short answers in-between questions were the most time consuming.

The transcribing left out unnecessary words which were used by the subjects when thinking and creating natural pauses. As previously mentioned, the interviews were conducted in Norwegian and were transcribed as such. Direct quotes from the interviews were translated to the best of my ability when utilized in this thesis and I strived to provide the subjective meaning and essence of each individual when doing so. As a result, the quotes should not be affected by the translation process.

4.7 Analysis

This paper chose to utilize one of the most popular analyzation forms, namely thematic coding when analyzing the transcribed interviews. This method is based on finding similar information from all the interviews and group them. This provides an excellent overview of what the thoughts and experiences of the subjects are on the same issue (Gibbs, 2007). This method was chosen for this thesis as the factors defining social acceptance acted as good categories in which the findings could be grouped.

The transcribed interviews in this thesis were thoroughly analyzed and read several times in order to understand fully what the interviewee had said. This process started immediately after all the interviews were transcribed, as this process can take a long time and is important for the thesis. The essence of the interviews was gathered and grouped in the manner of the three factors of social acceptance theory, namely, socio-political acceptance, community acceptance and market acceptance. The main findings were as a result easily adopted into the result section of this thesis in the form of direct quotes.

Direct quotes were used with context as without it might twist the meaning of the words and alter the essence of what the interviewees said. To minimize misconception this thesis has tried to explain the background of the person, backed up with some information about the issue at hand in order to avoid misinterpretation of the answers of the interviewee.

4.8 Validity, reliability and representation

Validity in qualitative research has no exact given definition, but rather encompasses a larger set of factors. Shortly explained, validity may be explained as the correctness of the actions of the researcher with regards to the tools and processes utilized and the resulting data collected. In other words, whether or not the research question is valid for the desired outcome, the methodology is appropriate in answering the research statements, the sampling and data analysis is valid and lastly the results and conclusion are coherent and valid for the sample and context (Leung, 2015; Whittemore et al., 2001) .

In this thesis the problem statement has been developed in manner which enables the following methodology to coincide and answer it. For results it was somewhat unclear if they would answer the problem statement as one cannot determine this before conducting the study, nevertheless, the results have been able to answer the problem statement to sufficient lengths. However, if what the interviewees said is correct, accurate and truthful is not something I can answer, yet, based on their position and employment I would assume it is. In addition, the validity of the answers may be weakened if the interviewee or interviewer are not well enough educated on the subject in question and thus interpreted incorrectly.

Reliability in qualitative studies, much like validity, does not have an exact given definition. Reliability is often used to describe the consistency of a study. If someone were to conduct the same study it should yield the same results, however, for qualitative studies variability is tolerated to some extent according to Leung (2015).

For this thesis different factors may have affected the reliability of the study. For instance, I as an interviewer may have asked leading questions which in turn has caused the subject to not express themselves as they would have normally. Furthermore, they might have given answer they thought the interviewer wanted to achieve as well as being wrongly interpreted by me as stated by King et al. (1994). Nevertheless, the questions were constructed in such a way that the interviewee would understand I merely wanted to investigate the issue and was therefore not looking for specific answers. In addition, recordings of the conversation and transcription of them ensures that every thought expressed by the subject is untampered with.

Lastly, with regards to the representativeness of this thesis, it does not represent the average citizen, nor is it the point. This thesis aimed to investigate the social acceptance viewed from the perspective of people already integrated in the Norwegian maritime hydrogen sector and that is what has been done. If the challenges proposed by these individuals can be related to other environments related to maritime hydrogen in the future is somewhat questionable due to many factors such as geographical location and access to electricity amongst others. Yet the political framework and incentives are the same across the country, although assuming the case would be the same at the global scheme is unrealistic.

4.9 Ethics

When conducting qualitative studies, it is important to be aware of the ethical aspect with regards to sensitive information. Therefore, before starting the interview process, an application was submitted to the Norwegian Center for Research Data (NSD) in order to get approval to carry on with this study. The interview guide was enclosed with the application as well as description of the project and what information I would be using from the interviewees. Due to the nature of the study not relying on sensitive data, the approval to conduct the study came rather quickly. Nevertheless, a submission form, based on recommendations by NSD was created and sent to all the subjects who had agreed to an interview. They were informed that they could at any point cancel the interview, also after it had happened, though no one utilized this option. All signed documents were stored, according to NSD guidelines and will be deleted upon finishing this thesis.

Furthermore, all quotes and data stemming from the subjects have been anonymized and made untraceable. Though there exists a short description of the subjects in another section, this should be rather vague and merely provide information on their relationship to hydrogen, and as a result should be untraceable. The quotes and information gained through the interviews are not tampered with and merely translated from Norwegian where sayings are as stated by the subjects.

5. Results

In order to create a coherent and well understood result section the below paragraphs will be structured with basis in theory about social acceptance. More specifically this section will present the interviews key findings related to one of the three factors, socio-political acceptance, community acceptance and market acceptance. Rather than grouping the results based on the nine sub-factors proposed by Sovacool and Ratan (2012) the results are sorted based on the factors highlighted by Wüstenhagen et al. (2007). This is done as they somehow encompass the other nine sub-factors and thus created a more coherent and easy read section. The in-depth look through discussion will rather utilize the nine sub-factors in the section, *Discussion*. In addition, a separate section on the thoughts surrounding green, gray and blue hydrogen is shortly presented. To maintain the interviewees´ wish to appear anonymous the individuals will be referred to as *subject A, B, C, D* and *E* as stated in the section, *Methods.* Furthermore, this segment will mainly present the key findings in a grouped manner whereas discussion and argumentation will be handled the section, *Discussion.*

5.1 Findings Related to Market Acceptance

Market acceptance, as previously mentioned, is defined as the willingness to invest in the technology. The main issue related to this aspect of social acceptance is the economic cost of hydrogen technology. An individual working closely with calculation of different aspects of hydrogen says:

> *Currently, hydrogen technology is about four times more expensive than marine diesel and therefore it is difficult to create a market. Subject A*

Hydrogen does not only have high fuel prices; the infrastructural requirements is also an expensive technology to implement, though with research and development trends, the technology may become less expensive. Nevertheless, currently, the investment costs are still immense, especially if one bases the production facilities on renewable solutions. An individual working at a hydrogen production facility claim:

> *I think it is expensive to establish a facility (…) It is such a large investment, so we are dependent on signing long enough contracts in order to become profitable. It is often a challenge that companies wants to sign a contract lasting say three years, whereas we want it to be ten years. Subject B.*

In addition to large investment and production cost of this zero-emission energy carrier, production through water electrolysis may cause concern that electricity prices will spike and thus negatively affect consumers. The individual working closely with hydrogen production further states as follows:

> *Not necessarily lack of supply (electricity), but rather how much energy that is used and one has to expand the electricity grid which in turn will result in more expensive energy (…) this is something that often causes headlines even though it is just a balancing in the market. Subject B.*

Other than advancing the technology, bringing down cost through supplementary options exists. One possible solution is to utilize the untapped potential of small hydropower plants which are located too far away from the electricity grid. Instead of connecting it to the grid one would simply utilize the energy locally to produce hydrogen. A former political figure who had great influence on hydrogen politics advocates:

> *Most people are often skeptical because of the vast amount of electricity that is needed for production and storage, one loses a lot of energy. So, my suggestion was to utilize a local river without letting the electricity enter the grid and thus save money and such. (…) my thought was to transport it across the fjord to the maritime base where it could be utilized. Subject E.*

Though such solutions would help minimize cost, the economical investment and production cost is likely to shrink when the technology becomes mature as has happened with other technologies such as solar power. One employee working closely with hydrogen production says the following:

> *(…) the prices of electrolyzers have dropped significantly the past years (…) Subject B.*

Therefore, looking at creating a hydrogen infrastructure may be expensive, yet it may prove economically beneficial in the long-run once the technology is better understood and developed which in turn would create cheaper production methods. An individual working on the stretch where a new hydrogen vessel will be introduced states:

> *We mostly think about the environment, it is at least not for economic reasons in the start, however, the end goal is economical gain. (…) We would never try this solution if we thought it would not be economically beneficial. Subject C.*

Nevertheless, green hydrogen production will always demand significant amounts of energy and the production line will always contain more energy losses than conventional fossil fuels as well as electric solutions. Therefore, hydrogen is currently an expensive technology that may become more inexpensive through research and development, yet it will be more expensive than battery solutions, at least from a pure fuel related perspective. An individual who works closely with hydrogen and battery solutions articulates:

> *There is sort of a bottom line that lays in the production chain. If one uses an electric current into a battery one has the price of the electricity, however, with hydrogen one has a chain that gradually becomes more expensive. Therefore, one will likely never be competitive with battery driven systems, but one can probably become competitive regarding price with diesel solutions, at least bio-diesel. It will likely depend on the fees. Nevertheless, one has a "floor" in hydrogen production which one cannot avoid. Subject D.*

Batteries have diffused into society better than current hydrogen technology has. Theoretically, batteries will always bring about less energy losses because of the energy being directly utilized in the form of electricity. Hydrogen, on the other hand, has to go through a number of transitions which all bring about losses. Funding of this technology in order to help minimize energy losses is essential, however, it may be an issue. In order to advance the technology and minimize energy losses and maximize capital gain, funding is needed. The interviewee working closely with the technological and infrastructural aspect of hydrogen articulates:

> *There has not been a lot of funding financial support for hydrogen technology, though this has been somewhat increased in the past years, though not sufficiently. Subject D.*

Related to the market acceptance, a major issue is the price of hydrogen and a lack of sufficient funding. Though the technology will bring about environmental gain, the interviewees advocate that when the technology is advanced, the economic gain will increase. Potential for utilizing untapped hydrogen is also posed by *Subject E* in order to reduce some of the economic cost.

5.2 Findings Related to Community Acceptance

Community acceptance is one of the other key factors related to social acceptance theory, and as mentioned previously is the overall acceptance of communities or inhabitants. Furthermore, it also explains the relationship of gains versus losses. Communities may be opposed to new infrastructure surrounding hydrogen as they do not experience a positive change, only negative in the form of environmental intervention as well as concern for safety. The individual working closely with hydrogen production says:

There are a lot of people who are concerned with the safety aspect, especially after the explosion in Sandvika, it is not something I notice a lot, but when you tell people you work with hydrogen, a lot of people bring up this incident. So, this can be a challenge. Otherwise I also experience a lot of positive attitudes. Subject B.

Hydrogen has explosive tendencies, but if it is treated the correct way it is completely safe, yet it is an unexperienced technology, at least in maritime vessels, and for most people it is new, and alien. Therefore, when incidents do occur the media usually covers it extensively. As a result, inhabitants and communities that are not familiar with this technology may label this technology as dangerous. One of the interviewees who works with production and distribution of hydrogen highlights another issue with safety and community acceptance:

So, it is about safety a lot as well, if people label hydrogen as an unsafe energy-carrier it does not really help if we contradict them and say the opposite. Subject B.

Furthermore, as mentioned in the introduction, previous incidents like the Hindenburg may affect the overall acceptance of this technology. The former politician who has played a key role in implementation of hydrogen technology in the maritime sector says:

There are people who are afraid of an explosion. And it is likely a little bit because of the airship that exploded amongst other things. But it is evident if petrol and diesel technology was invented today one would never be allowed to use it in a car, it is extremely dangerous. Subject E.

Stronger established technologies are not critiqued in the same way as newer renewable innovations, often because one is more accustomed to them. Newer renewable innovations may struggle to diffuse into society due to a number of reasons and as a result are fragile. The individual who works closely with the technological aspect as well as the infrastructural aspect of hydrogen claims:

Currently the technology is very fragile, so there is not a lot required before thing changes. There was a tv-article where they claimed that hydrogen contributed to increased greenhouse gas emissions. That causes people to question was this not supposed to be the solution? That is one side, and then you have the other which is that new energy-carriers cannot survive many incidents. The social acceptance decreases quite rapidly. It is incredible what we allow regarding fossil fuels, especially with regards to gasoline which is quite explosive as well. (…) It is mostly because it is new one has an issue with it. It is not more dangerous it is unfamiliar which is a disadvantage. One has to be extremely careful when one starts a hydrogen project that nothing will go wrong and as a result the technology development stagnates. Subject D.

Despite concern for safety and other better-established technologies, another issue that may also be brought up when studying social acceptance of maritime hydrogen is the issue of nature intervention and area required for the infrastructure. As previously mentioned, wind power implementation has stagnated in Norway, much due to heavy social pushback. Therefore, lessons may be taken from the wind power sector of Norway with aspect to community acceptance and concerns and potential issues may be studied before implementation happens on a larger scale. Preliminary studies are vital in the successful implementation of renewable innovations and the individual working at the hydrogen production site says:

I remember when I visited NVE when I was studying, and they had developed a map for wind power in Norway which upon being published was immediately removed. In reality they had just mapped the potential and possible locations for wind power. However, this was seen by the public as places where we were going to build wind turbines and there were massive uproars. In the end it was a lot of wasted work. For Hydrogen it would be preferable to have a hydrogen-map and a better framework before companies are allowed to expand. Subject B.

Community acceptance is an important factor of the bigger picture of social acceptance. Concerns about safety due to previous accident like the Hindenburg and Sandvika, are evident and causes the technology to advance slowly. Extreme precautions need to be taken when researching the technology and there is little room for error as the media utilized any opportunity to portray new innovations poorly. Effects seen from the lack of social acceptance of the wind power industry in Norway will be unfavorable, if it same were to happen with the hydrogen technology, according to the interviewees.

5.3 Socio-Political Acceptance

Lastly, of the social acceptance main sub factors, is the socio-political acceptance, which is often described as the general acceptance in society and more specifically the processes around the implementation of new technologies such as policies and laws. As mentioned in the theory section of this report, the Norwegian framework on maritime hydrogen is somewhat lacking without clear goals just merely wishes. The five individuals interviewed highlighted or mentioned matters related to the political aspect of the hydrogen transition in the Norwegian maritime sector. The former political figure heavily involved in this transition tells about difficulties experienced in this process:

> *(…) mainly it was a problem that it (hydrogen technology) was viewed as the future and not now, but after this obstacle was overcome there were many people who wanted it. (…) Then it is also to discover that even though one has told 100 people about it does not mean it spreads easily. People forget. So, repeating and repeating was a challenge. Also, one has to be available at all times in order to not slow down the process. In addition, constantly changing politicians was a major obstacle. Subject E*

A constant change of politicians who have different views on hydrogen technology may cause the process to slow down and make the process more difficult. In addition, lack of government funding may halt the process to some extent as the technology is expensive to develop and use. The individual working with hydrogen infrastructure and calculations further expands on this issue:

> *There are, some projects, where the government has said that hydrogen should be tested, on ferries for instance. Other than that, there has not been a lot of government funding for*

> *hydrogen, though this is slightly and slowly increasing. (…) There exists government ambition on hydrogen, but not funding and demands for the technology. Subject D*

Though there has been a lack of government funding in the past for maritime hydrogen, as stated by *Subject D* this has started to slightly increase. In 2020 the Norwegian government devoted 150 million Norwegian kroners to new projects regarding hydrogen, though this funding is not only related to maritime hydrogen, but all hydrogen projects in Norway. Other than funding, the individual who works with hydrogen production highlights another issue and explains:

> *There is not a very well-developed framework, there are companies that expand even though there is a lack of laws that say how and where you can build with regards to safety zones and such. One bases it on LNG (liquified natural gas) laws and safety zones, and hydrogen and LNG are not the same. So here one should be a bit more forward thinking and have developed a better framework, and not just say "yes" to development. Subject B*

Currently there does not exist a framework related to usage and storage of hydrogen on maritime vessels and as a result brings about regulatory challenges. A temporary measure causes the Norwegian Maritime Authority to approve potential hydrogen vessels based on previous laws developed for fuels with ignition point of 60 degrees Celsius or less. Though the risk analysis and approval process in general is extensive, it is not developed for hydrogen technology but rather LNG technology. The individual working on the stretch where a new hydrogen vessel will be implemented explains:

> *(…) you have to have an IGF-certificate just like the one you need for LNG ferries. (…) currently, there is no extra certificate needed, and I think that the IGF-certificate is sufficient, it covers the essentials with regards to hydrogen. However, I think specific certificates should be developed for hydrogen, though mainly to show that we are serious about the safety of our passengers and employees. Subject C*

Despite lacking regulatory framework on maritime hydrogen, one of the interviewees raises another concern that the individual feel is vital for hydrogen technology to become successful in the Norwegian maritime sector. The person, who is heavily involved in calculating every aspect of hydrogen technology explains as follows:

> *Incentives, such as the ones given to electric cars in Norway should also be implemented for hydrogen-based maritime vessels. Reduce taxes on the technology and also increase taxes and costs for other technologies such as diesel. (…) also, establish possibilities to take classes related to hydrogen in the schools, starting from a young age. This will provide more knowledge and as a result the technology may advance in a better manner. Subject A*

Past waves of hydrogen have not translated into sufficient government support, neither with regards to policy nor investment aid. The expansion of hydrogen value chains brings about dilemmas and difficult trade-offs. Further investment into the technology is needed in order to bring down costs, yet it may be risky in the absence of an assured supply and demand. This highlights a responsibility by the Norwegian government, where a proper framework as well as incentives favoring hydrogen are needed in order for people to invest in the technology and helping it succeed.

5.4 Green, Blue and Gray Hydrogen

Other than linking the interviewees answers to community acceptance, market acceptance and socio-political acceptance, another key subject frequently addressed by the interviewees was the aspect of the different types of hydrogen. The production form of hydrogen will alter social acceptance of the technology. The different forms bring about different challenges, yet issues of area usage, environmental impact, economic gain and safety, are some of the aspects will be related to social acceptance. The individual working closely with hydrogen infrastructure and technology articulates:

> *(…) we want it (hydrogen) to be green, yet it is rare that one has too much green hydrogen, so supplementing with other types are probably necessary, at least in the start. If one*

moves over to relying on blue and gray hydrogen it is sort of pointless. However, utilizing it to create a technological shift is fine, if the end goal is green. Although we have to be careful if we start this way and standardize blue and gray hydrogen and then we do not bother switching. Subject D

Green hydrogen should be the end goal if the purpose of the technology is to reduce emission and abide by the Paris Agreement. Temporary measures utilizing other production forms can serve as a temporary solution, but, for overall reduction of emissions green hydrogen is the solution. The individual working closely with calculation of all aspects of hydrogen says:

(…) establish a market, gray-, blue- or green hydrogen, it does not matter what type. One needs to create a market for this technology and then the coming years after the implementation, say 10 years, we need to make sure that at least gray is phased out and we only use blue and green in the future, preferably green although I think this is unrealistic. Subject A

Green hydrogen should be the end goal though, according to the two above-mentioned interviewees. Their respective quotes emphasize that the change from blue or grey hydrogen infrastructure needs to be done and one cannot settle and halt the transition if one starts of on one either blue or grey hydrogen. However, not all the interviewees feel this way and the former political figure heavily involved with hydrogen claims:

I do not think that there is any point in starting with something else than what is the end goal. The investment costs are very big so there is no point in sort of transitioning twice. Subject E.

The interviewee above, has close ties to Florø, which possess large amounts of energy that are stuck in the area due to high costs or not opportunities to transfer it to other parts of the country. An individual working with potential hydrogen production and distribution, who also has close relations to Florø, claims:

(…) I think producing green hydrogen locally, and use it like us, where it is produced at a base with a lot of traffic is smart. (…) there is a significant number of vessels who come to

the base and I think it is a very relevant place to have green hydrogen production because the transport aspect of hydrogen demands a lot of energy. Subject B.

Nevertheless, there exists a consensus that the end goal should be green hydrogen, whilst there is somewhat disagreement at what stage it should be implemented. The individual working at the ferry stretch where a new hydrogen ferry will be implemented advocates:

I hope that it (hydrogen) will be produced environmentally friendly in Norway with Norwegian workers, creating Norwegian jobs. However, I think we just need to start in one place. If it is necessary with import in the start, I do not think we should focus too much on it. There will always be a need for a starting phase where we are dependent on others who are better technological adapted than us. Sort of like with the oil, we got some help before we managed on our own, and I think that can be the case for hydrogen as well. Subject C.

Choice of hydrogen will affect social acceptance of this technology, yet it is difficult to say if it is directly linked to either of the factors, socio-political acceptance, community acceptance and market acceptance. The production form will likely cover several of these elements. Price of green hydrogen may ultimately affect market acceptance in the form of it being expensive, yet as well affect community acceptance if capitalizing on untapped hydropower in remote areas. Blue or grey, on the other hand may affect market acceptance in a more positive way due to it being cheaper. Yet it may also affect community acceptance as it is a poor replacement for current technology which is not that much more environmentally friendly.

6. Discussion

This section will take a more in-depth look at the theory of social acceptance, more specifically discuss the nine factors of social acceptance developed by Sovacool and Ratan (2012) and relate them to findings through the interviews and previous research. These factors are intertwined and as a result may cover aspects across the sectors of socio-political acceptance, community acceptance and market acceptance in some cases. After discussion of the nine factors of social acceptance, thoughts regarding green, blue and gray hydrogen are further explored and discussed. In addition, this section will address the issue of relating maritime hydrogen to the lessons learned from the wind power industry in Norway.

6.1 Looking at Maritime Hydrogen through the Nine Factors of Social Acceptance Theory

Previously, in this thesis, the nine sub-factors of social acceptance developed by Sovacool and Ratan (2012) were listed and shortly explained. The list consisted of three socio-political factors, three market acceptance factors and lastly three community acceptance factors. The first socio-political factor is related to support at the national level through measures such as government developed or supported research work. In its country, Norway exhibits support at a national level with the implementation of hydrogen in the Jøsenfjorden project, as well as by providing reports such as *Production of Hydrogen in Norway* (NMPE & NMCE, 2019) and *Production of Hydrogen at Small Hydropower Installations* (Sundseth et al., 2019). These projects and reports are all government funded and will therefore aid in the acceptance rate of the technology according to Sovacool and Ratan (2012). Furthermore, Norway, has as mentioned in the section *Results* given increasingly larger amounts of funding for hydrogen related projects, although not only for maritime hydrogen projects. Nevertheless, this is likely to increase the ability of the technology to diffuse into society. Although, the increasing funding is not solely related to maritime hydrogen, a project that has ambition on implementing hydrogen is the Vestfjorden project (Fonneløp, 2020; Norum et al., 2020). Such projects prove that the Norwegian government are serious about implementation of hydrogen technology and as a result strengthens the first socio-political factor proposed by Sovacool and Ratan (2012). This claim can be further backed up by the answers gained through the interviews as the subjects highlight these pilot projects and express a positive attitude towards them. In addition, *Subject D* advocated that if one could successfully achieve hydrogen-based vessels in Vestfjorden one could implement it anywhere. In addition, *Subject C,* who will be working at the Jøsenfjorden pilot project stretch, advocates that the crew frequently talk about this issue. The individual further explained that they all regard this call for hydrogen-solutions in maritime vessel as positive and hope it will transpire throughout society.

Continuing, the second socio-political factor says that political figures should promote the topic openly and actively. The subject of hydrogen is frequently addressed positively by politicians, such as the Prime Minister, Erna Solberg (Falnes & Skårdalsmo, 2020). Yet, there exists several articles in different newspapers (dn.no, 2020; Syvertsen, 2020) and journals (Ryengen, 2021) that claim the promoting is not sufficient enough, and one needs to discuss the matter more frequently and openly. In addition, projects like Vestfjorden bring about skepticism locally, where the mayor in Røst municipality advocates that they had a poor experience with the implementations of LNG based ferries in 2013, and therefore she is skeptical (Norum et al., 2020). Skepticism from key political figures, like the mayor, may transpire throughout the local community and thus affect the acceptance of the technology. People living in Røst municipality probably has closer ties to their mayor than the Norwegian government and thus her perception and thoughts on the issue will likely affect them more. Such incidents can be related to what an individual working with hydrogen project advocated in the section *Results,* where the interviewee advocated that if people label hydrogen as unsafe, it does not really matter that people working with it and fighting for the implementation of it says otherwise. Nevertheless, one could advocate that political promotion of hydrogen, which is the second socio-political factor is achieved. Although there are skeptic politicians, the prime minister and many of her supporting political figures endorse this technology which is an essential part for this factor.

However, the Norwegian political framework has been criticized for being unfavorable and in desperate need of improvement as advocated in the article written by Ryengen (2021) in the journal *Teknisk Ukeblad.* Such claims can directly be linked to the third socio-political factor which states that a country possesses favorable regulative and legal framework for new proposed technologies. Previously, in this thesis the findings from the Norwegian maritime strategy were highlighted, though not discussed. Currently, the strategy is lacking and does not provide many hard goals nor dates for achieving these goals. It merely proposes wishes like, Norway wish to become a large actor in the maritime hydrogen sector, and the country wants to become more environmentally friendly through hydrogen utilization (NMPE & NMCE, 2020). *The Norwegian Hydrogen Strategy* (2020) has been further criticized by another piece written in the journal *Teknisk Ukeblad* by Ole Petter Pedersen (2020) who describes the hydrogen strategy report as *a status report disguised as hydrogen strategy.* The report is further critiqued for lacking a set of accountability and measurable indicators of where we are heading. In addition, the piece advocates that one is looking at hydrogen technology the wrong way. It claims one has to understand that it is not only about the climate goals that need to be met, it is rather about the possibilities of another industry after the oil reserves are drained. Thus, this gives a strong indication, that this specific factor related to social acceptance could be immensely improved, for instance by developing a proper hydrogen road-map for the maritime sector. However, it may seem like the Norwegian government already strives to improve this aspect where a road-map for hydrogen is already discussed and planned implemented in the coming years (Regjeringen.no, 2020c). The claims set forth in these reports are further backed up by answers given by the interviewees. Especially, *Subject B* calls for a need for a proper hydrogen road-map and claims this is essential in order to increase social acceptance. Nevertheless, the individual possess concern that one has to be careful when bringing it to the public in order for them to not misunderstand the purpose the road-map. In addition, the first officer of Norled calls for a proper hydrogen certificate rather than a utilizing the IGF-certificate developed for LNG-vessels. Such steps will help improve social acceptance as the public will then see that the government is taking this issue seriously. Thus, with a little more work and execution of proposed measures this factor would be improved and aid social acceptance of the technology.

Moving on to the next section of sub-factors, market acceptance, one starts off with the issue of competitive pricing compared to other technologies. Unfortunately, due to hydrogens inexperience in maritime vessels the investment cost versus the return is abysmal. Hydrogen is still an extremely expensive technology, which becomes radically more expensive if one is to use green hydrogen (AOHC et al., 2019). As a result, it is highly unlikely that hydrogen will be able to compete financially with more conventional fuels such as diesel or liquified natural gas (LNG) (Mazloomi & Gomes, 2012). Therefore, when implementing hydrogen, one has to advocate that though the price is high at the moment, it will become significantly less expensive when the technology matures and is implemented on a larger scale as was seen with other technologies such as solar power (Ciriminna et al., 2016; Sovacool & Ratan, 2012). Examples of economic advances can already be seen in the hydrogen industry with the reduction in price and improvements of the electrolyzer, as was shown in the result section where the individual working with hydrogen production advocated that the prices of electrolyzers had dropped significantly the past year due to technological developments.

Reduction in price to advance the technology is further backed up by the report conducted by Grueger et al. (2019) which also states that through technological advancements and innovation they have found different pathways to reduce hydrogen production costs as well. This may further amplify the belief that production cost will decrease as one becomes more familiar with the technology, which in turn will increase social acceptance. However, given the current circumstances, hydrogen is not capable of being price competitive with other technologies and thus this factor can be considered as in need of improvement. The lack of achievement of this factor is further backed up by the what *Subject A* explained, which was that currently hydrogen technology is about four times more expensive that maritime diesel. Nevertheless, it is important to note that it likely will become more price competitive with other technologies once the hydrogen infrastructure becomes better and technological advancements are achieved.

The second factor surrounding market acceptance claims that producers and users possess reliable information about renewable energy polices, prices and opportunities. In Norway, there is a considerable amount of reports (NMPE & NMCE, 2019, 2020; Sataøen, 2008) that indicate the true potential of hydrogen. However, as mentioned in the previous paragraphs such reports have been heavily criticized for lacking clear goals and plans. Therefore, even though such reports are in existence, they should be improved, yet, one can advocate that this point is achieved to some extent, considering the availability of the reports. In addition, these reports highlight the price of hydrogen production in Norway as well as explains the current energy policies in the country. Though many of the energy policies are not directly related to hydrogen, it still serves as a good indication of what part of the future hydrogen will play. Thus, investors, producers and consumers can easily obtain detailed information about hydrogen if needed and as a result, one can argue that this sub factor is accomplished. Though, as advocated earlier, they should probably be improved in order to make sure this factor is further accomplished. In other words, the reports should not just be easily accessible, they should become more thorough and detailed, with more hard goals and deadlines. Such claims can be further backed up by the interviews, especially when looking at the information articulated by *Subject B*. The interviewee highlights that if not a proper hydrogen framework is created one might encounter problems with social acceptance. When expanding the technology producers and consumers need reliable information about this technology and a proper hydrogen framework would help with this.

Lastly, for the market acceptance factor is the access to financing, which in short means producers, manufacturers and consumers possibilities to gain grants, funding, loans or exploitation of government financing schemes. In Norway, there exists opportunities to gain financing from the government or other organizations such as Enova (forskningsrådet.no, 2021; Regjeringen.no, 2020a), though it is not always easy to receive such financing. However, it is important to note that during the last few years, the government has significantly increased their funding for hydrogen related projects and continue to do so (Regjeringen.no, 2020a, 2020b). Yet, there seems to be somewhat of a problem with funding especially when considering what the interviewee working closely with hydrogen production highlighted previously. The individual advocated that the support had been experienced to be somewhat strange and they only funded certain parts of their projects. However, this is something they had been criticized for and as a result the interviewee utter that this might change in the future. The individual further stated that they received a grant to expand their production sites from Enova, though not funding for the electrolyzer. This highlights an issue where the Norwegian government could and maybe should improve. Funding new technology innovations is a key factor in order to mature the technology and reduce the cost. The study conducted by Johnston et al. (2005) found that hydrogen could have advanced significantly more if governments had prioritized funding for this innovation. In addition, the report claims that lack of funding in turn will bankrupt small hydrogen-related businesses and halt the technological advancements. This was mainly because the technology could not advance without financial aid and thus could not become economically beneficial. Such findings argue against the accomplishment of this factor, and for Norway it seems like an area where it could greatly improve. Although it is important to highlight that funding for hydrogen-related technologies have greatly increased in the last years and if this trend continues, one is on the right track on accomplishing this aspect which in turn will increase social acceptance.

The last set of factors regarding social acceptance are all related to the issue of community acceptance. The first sub factor addresses the issue of ownership of the renewable innovation, and states that renewable energy systems are often installed and used locally. When looking at hydrogen through this perspective one can argue that it will likely be less relevant than for other renewable innovations. Though there exists a potential for utilizing untapped hydropower for the production of hydrogen as stated by Sundseth et al. (2019) most hydrogen production occurs at larger sites with a longer history of hydrogen production such as Tjeldbergodden and Herøya (NMPE & NMCE, 2019). The companies operating here already have routines and knowhow of treating explosive elements, thus making these places ideal. However, these production sites are not mainly based on green-hydrogen and thus, if the untapped hydropower is utilized for hydrogen production this factor may become significantly more relevant. If larger companies start to cause nature intervention in order to create production sites and the community does not see the gain, issues will likely occur. The communities will therefore likely be affected by this intervention, in the form of reduced recreation area, noise and such, and in return they will not see an economic benefit. Companies establishing will likely export the gains other places and thus the community may feel like they receive all the negative aspects of the expansion and does not see any gain. As a result, strong individual connection and ownership of the technology is likely lacking if untapped hydrogen power is to be used for hydrogen production. Such issues can be resolved if one looks at the information gained through the interviews, where *Subject B* and

Subject E both highlight possibilities to produce green hydrogen at certain places in Norway where there already is an energy surplus. These areas already have good relationships to the production sites, where many local inhabitants work, and thus provides a better connection and ownership of the technology.

Another factor related to community acceptance advocates that it is important for the locals to be involved in the siting of potential production sites. However, due to the characteristics of hydrogen, namely the explosiveness, this will likely be difficult. Though the framework of hydrogen is still based on LNG production, specific measures are still in place and requirements need to be fulfilled (dsb.no, 2018). As a result, it is difficult for municipalities, or individuals to affect the siting process, as many conditions need to be fulfilled for the production facilities. One of the major safety measures stated by The Norwegian Directorate of Civil Protection (DSB) concerns safety zones. In short, production sites require certain safety zones, where it will be prohibited to build structures in the future. Essentially these zones are areas DSB deems unsafe to live in. These safety zones are often large but depend on the size of the production site. Obviously, communities can proclaim their thoughts on where sitings should occur, yet, due to the many safety regulations, this is largely a decision that has to be taken by companies and the government officials. Though locals may not have a large say in the production site, the areas in which proposed maritime hydrogen-vessels will operate may be a different scenario. Currently, there are a few hydrogen-based pilot projects implemented in Norway. These are projects planned or implemented, often based of off Norwegian government decisions, where communities have little effect. Especially, the planned Vestfjord project did not address the local communities before planning the implementation, the government merely stated that this is a necessary project to advance the technology (Fonneløp, 2020; Norum et al., 2020). Therefore, in conclusion, local communities may have an opportunity in the future to affect planned hydrogen projects and their area of operation, though, currently this is not the case as the Norwegian government feels forced pilot projects are necessary to mature the technology. In the future, however, this might change once the technology becomes more established.

The last factor related to community acceptance describes the awareness of the positives of renewable energy innovations and downsides of conventional energy. As previously, the

Norwegian government promotes renewable solutions, such as hydrogen, quite frequently and describes why it is needed and the positive aspects of this technology through countless reports and news articles (Falnes & Skårdalsmo, 2020; NMPE & NMCE, 2020; Ryengen, 2021). However, for hydrogen technology many may understand the environmental gain from this technology, yet they are skeptical because it is alien and explosive. Though frequently labeled as environmentally friendly and an overall good technology there are skeptics displaying their dissatisfaction with the technology, often in the form of comments on internet articles. In addition, articles online often include the perspective of a skeptic in order for the reader to gain a nuanced perspective on the situation such as the article by Norum (2020). However, most articles published are positively laden and this aspect of social acceptance can be considered accomplished. Furthermore, all the interviewees advocate that they experience a largely positive attitude towards this technology, though they always encounter some skeptics. In addition, according to the interviews it seems like the understanding of the technology is not the major issue. People understand the positive sides, yet, it is the safety the interviewees highlight as the most common issue or skepticism they encounter.

6.2 Thoughts Surrounding Green, Gray or Blue Hydrogen

In the result section it was highlighted that the choice of the hydrogen type was one of the points where the interviewees disputed the most yet it is an intricate part of the findings which spans across many of the subfactors proposed by Sovacool and Ratan (2012). Choice of type of hydrogen will likely affect social acceptance of the technology. Increased production of blue or gray hydrogen would create more jobs when scaling up the production and require more employees to transport hydrogen to given locations. Green hydrogen would also create more jobs and the need for transport (in most scenarios, though not all), however, unlike blue or gray hydrogen it has the benefit of probably gaining more public support due to it being environmentally friendly. Nevertheless, it may be critiqued by the public and lose social acceptance due to it currently being a more expensive solution and people not seeing the bigger picture might oppose this. For the opposite reason gray and blue hydrogen may gain public support for being inexpensive but lose support as it is not environmentally friendly. *Subject B and Subject E* actively said that starting with something else than green hydrogen seemed pointless. The other three, though not fully in agreement, said they obviously wished for the cleanest form of hydrogen, yet it is unlikely to utilize it from the start. *Subject D* used biogas as an example of comparison, where the individual stated that hydrogen maybe is a bit similar to the biogas technology. Not in a purely physical way, but rather how one supplemented natural gas when there was a lack of biogas. This can also be done for hydrogen where when there are insufficient amounts, one supplements with other forms of hydrogen.

Hydrogen demand is likely to increase in the future according to the report posted in a collaboration study by the Norwegian Ministry of Petroleum Energy and the Norwegian Ministry of Climate and Environment (2019). Based on the findings in this study, it is unlikely that one can transform an industry to solely rely on a green hydrogen production in the start. Especially for Norway as currently, blue hydrogen is currently the most common production form (AOHC et al., 2019; NMPE & NMCE, 2019). Obviously transitioning to green hydrogen is the best environmental solution as blue hydrogen production still brings about emission, but they are just captured and stored where they are not emitted to the atmosphere. Thus, one can understand why all the interviewees wish to utilize green hydrogen in the end, yet some individuals are more skeptical saying it is not feasible in the start, simply one has to overcome other obstacles first. However, it is important to highlight that the individuals most positive towards utilizing green hydrogen from the start are closely linked to the community of Florø, and thus justifies their belief to start with green hydrogen as they possess the advantage of an energy surplus. In conclusion the beliefs of *Subject B* and *Subject E* coincides well with what Caglayan et al. (2021) found in their report that a centralized green hydrogen infrastructure is feasible. What is maybe a bit different regarding the study and their belief is the transportation aspect. *Subject B* and *Subject E* propose a production site in which hydrogen is fueled and used directly by vessels from the base, whereas the report conducted by Caglayan et al. (2021) proposes a centralized production site where transportation is required to deliver hydrogen to the necessary places. Thus, the solution proposed by *Subject B* and *Subject E* should be considered better as one eliminates the transport aspect of the element which is both time consuming and energy demanding, which both are aspects that affect social acceptance negatively. In other words, the latter solution proposed by the interviewees should be prioritized where feasible in order to secure better capital gain which in turn may positively impact social acceptance.

The answers and thoughts given by *Subject A, Subject C* and *Subject D* contradicts with what Caglayan et al. (2021) found and rather coincides with what the report conducted by Van de Graaf et al. (2020). As previously mentioned, the report concludes that creating a hydrogen infrastructure is not feasible without the aid of at least blue hydrogen. The answers given by the latter interviews match what the report found, however, it is important to mention that the report said it is not possible to rely on green hydrogen from the start and blue hydrogen is needed to create the infrastructure. The answers given by *Subject A, Subject C* and *Subject D* do not indicate that it is not possible to start off with green hydrogen, the answers merely highlight that they are okay with starting off with a cheaper form of hydrogen and then transition towards green hydrogen once feasible. Though it is difficult to say what is the correct solution, the most logical thing to assume would be starting off on blue hydrogen is favorable as it is cheaper, although not as environmentally friendly as green hydrogen. Ideally one would start off with the most environmentally friendly solution, namely green hydrogen.

6.3 Looking at Hydrogen with Experience from Wind Power

Comparing hydrogen innovations to the wind power revolution that happened a few years ago may provide essential information and lessons regarding the implementation of hydrogen technology. Wind power production had the fate of being heavily critiqued after it was implemented on a large scale, and thus making it hard to counteract. Though, wind power expansion has somewhat halted, one will not remove already implemented infrastructure related to these projects. Thus, for hydrogen technology, it is important to educate the public and conduct studies like this in order to look into possible social barriers before implementing it. The individual who works closely with calculating all aspects of hydrogen technology advocated that we need to highlight the positive aspects of the technology and create opportunities to learn about it from a young age, focusing on the pilot projects and learn from them before scaling up. Opportunities to be well-educated on the matter will alter social acceptance in a positive way, as one understands the technology better and what benefits it brings about.

Undoubtedly new issue will arise when implementing hydrogen technology on a larger scale, but by conducting careful research one may be able to reduce the amount of pushback when actually implementing the technology. As was stated by the individual working closely with hydrogen production who claimed that Norway needs a hydrogen road-map before companies expand further. The potential of wind power posted by NVE (2009) was quickly misunderstood as places where it was planned wind power parks, when they were merely mapping the potential. Learning from this, one should be careful when displaying a possible future road-map for hydrogen to the public as to avoid ending up in the same situation. In the end a road-map for hydrogen will increase social acceptance if presented in a correct manner.

Continuing, one might also draw lessons from wind power with regards to required space needed for production facilities. As mentioned previously, wind power has been largely criticized for the required space for these structures. Hydrogen production sites will also demand some space though not as tall as wind power. Thus, one has to be prepared for pushback from the public if one is to build new production sites for hydrogen. Especially when looking at the untapped potential of smaller water resources (Sundseth et al., 2019), one is likely to receive pushback as this would directly impact the nature and maybe force people away from their recreational area in some way or another. Therefore, separate studies as well as frequent information flow between companies, government and the public needs to be extensive in proposed areas to minimize pushback and as a result maximize acceptance. Though this is one solution, it is also possible to expand or centralize hydrogen production to facilities already capable of such, namely Florø, Tjeldbergodden and Herøya. This will likely not affect social acceptance as much, as these sites are already capable or already producing. An issue with this proposed measure would be the transport of hydrogen to areas it is needed, as it is both difficult, energy demanding and costly. Summing up, one should learn from the failures of wind power in Norway and introduce hydrogen technology in a more responsible way with a main goal of undisputed social acceptance.

7. Conclusion

This thesis set out with the main goal of exploring social acceptance viewed from the perspective of individuals already integrated in the current transition towards zero-emission energy carriers, more specifically hydrogen solutions. In addition, this thesis aimed to investigate the results and link them to theory surrounding social acceptance, namely three main sub factors, community acceptance, market acceptance and socio-political acceptance. Furthermore, this thesis aimed to discuss the further nine subfactors linked to the previous three main sub factors in order to explore the current state of social acceptance of hydrogen technology viewed from the perspective of the interviewees. Increasing number of factors met increases the likelihood of diffusion into society as proposed in the research conducted by Sovacool and Ratan (2012).

Throughout this research period it has become evident that the overall acceptance regarding hydrogen technology in maritime vessels in Norway viewed from the perspective of the interviewees, is quite high, though they realize there are room for improvement. One should expect this for individuals already integrated in this transition process whom also spend large amounts of time working with hydrogen. Several issues were brought to life throughout interviews and extensive literature research, however, the most apparent one addressed in all the interviews is the issue of safety. This issue is closely related to the community acceptance aspect of hydrogen technology and one can conclude that this is the most flawed and unachieved factor regarding maritime hydrogen-solutions in Norway. It has become apparent that currently, the local inhabitants will likely perceive the technology as mostly negative due to the vast number of issues it brings about with a gain they cannot physically see, namely environmental friendliness. Furthermore, the technology is currently extremely expensive and advancements through research and development are needed to reduce costs and make it cost-competitive in order to increase market acceptance. The increasing trend of government funding should continue in order to further advance the technology and improve social-political acceptance which in turn would better enable the technology to diffuse into society.

In addition, better political framework is needed, mainly in the form of the planned hydrogen road-map which would further boost diffusion into society and likely increase overall social acceptance. However, Norwegian politicians, such as the prime minister are currently promoting the issue and continuously trying to improve the political aspect of this technology. Nevertheless, there exists skeptics, some who hold key positions in pilot project areas, such as Vestfjorden. Though skeptics are always likely to exist, important political figures in the country advocate for this technology and currently it seems like the overall acceptance viewed from the perspective of people integrated in this industry, is more prominent than the skeptics. Looking deeper into the theory regarding social acceptance, namely the factors developed by Sovacool and Ratan (2012) it is evident that Norway, currently meets a number of these factors when looking at previous research and information gained through the interviews. Nevertheless, room for improvement is needed in order to better help the technology diffuse into society and become cost competitive with current day technology.

No clear conclusion can be drawn regarding which type of hydrogen is to be used, though undoubtedly all proposed hydrogen production forms will affect social acceptance. Different reports, documents and the answers received through the interviews all imply different scenarios, and one cannot determine which will be the best solution regarding social acceptance. Undoubtedly, green hydrogen is the best solution when looking at environmental impact, yet, other types of hydrogen may be needed when insufficient amounts of green hydrogen are produced in Norway. Nevertheless, it is important to remember that blue hydrogen is currently the main type in Norway, as well as the cheapest to produce and would therefore likely affect social acceptance the least when purely looking at required area and nature intervention in combination with economic cost. Nevertheless, blue hydrogen may lose social acceptance as it is less environmentally friendly than green hydrogen in addition to merely hiding the emissions rather than dealing with them directly.

This thesis set out with an aim of investigating the social acceptance of maritime hydrogen technology in Norway, viewed from the perspective of people already integrated in this industry. Norway as ha turbulent history with hydrogen, yet, the country is keen on developing the hydrogen fuel cell technology. Due to the climate goals posed by the government and the little infrastructure for both electric and hydrogen vessels in the maritime sector, there exist a clear window of opportunity to advance this technology and diffuse it into society. With hydrogen pilot projects slowly appearing in the sector, it is a key place in the transitioning process to investigate social acceptance viewed from key individuals. This thesis found, based on previous research and interviews, that hydrogen technology is on a viable path to become a relevant option in the Norwegian maritime industry when looking at the factors set forth by Wüstenhagen et al. (2007) and Sovacool and Ratan (2012). However, in order to ensure that the technology diffuses successfully, further improvements are needed. Creating a proper political frame work and laws, further increased funding, and education regarding safety are some of the aspects which will result in increased social acceptance, if further improved. The actions we take now, will be determent of whether or not the technology can gain sufficient social acceptance, and as a result succeed.

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9. Appendix A

Example of interview guide in Norwegian:

Intervjuguide

1. Kan du fortelle litt om hvordan du ble involvert med din bedrift?
    a. Hvorfor er det fokus på hydrogen?
    b. Hvor stor andel av bedriften omhandler hydrogen?
    c. Hvor på verdikjeden ville du satt bedriften?
2. Kan du fortelle/utdype litt om prosjektene du er involvert i nå?
3. Hvilke hoved utfordringer har bedriften?
    a. Praktisk
    b. Politisk
    c. Økonomisk
    d. Sosialt
    e. Hvordan finner du nødvendig kompetanse til bedriften?
4. Er det noen utfordringer relater til produksjonen og lagringen av hydrogen?
5. Hvilke viktige faktorer har påvirket prosjektet?
    a. Hvordan fikk dere støtte?
    b. Økonomisk?
    c. Politisk?
6. Hva er nødvendig for at firmaer (arbeidstakere involvert i hydrogen produksjon) skal se på hydrogen som et trygt alternativ den maritime industrien?
    a. Hvordan påvirker det innbyggerne som lever i nærhet av produksjons-området?
7. Tidligere studier har vist at synsforurensing forårsaket av vindmøller spiller en stor rolle med tanke på samfunsaksept, kan dette bli tilfellet for hydrogen?
8. Sagafjordbase planlegger å kombinere hydrogen-produksjon med land-baserte oppdrettsanlegget.
    a. Kan dette bli implementert andre steder som vil produsere hydrogen i fremtiden?
    b. Er det andre alternativer til land-baserte oppdrettsanlegg som kan kombineres med hydrogen produksjon?
9. Har du noen tanker om Grønn vs. Blå hydrogen?
    a. Norsk produksjon vs. Import?
    b. Forsyningssikkerhet?
10. Hvilken rolle tror du hydrogen vil ha i den norske maritime sektoren i fremtiden?