Høgskulen på Vestlandet

MASTER'S THESIS

Climate Change and Climate Risk Perception among Actors in the Norwegian Renewable Energy Sector

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CLIMATE CHANGE AND CLIMATE RISK PERCEPTION AMONG ACTORS IN THE NORWEGIAN RENEWABLE ENERGY SECTOR

Master thesis in Climate Change Management

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This thesis is a part of the master's program in Climate Change Management (Plan legging for klimaendringer) at the Department of Environmental Sciences, Faculty of Engineering and Science at the Western Norway University of Applied Sciences. The author(s) is responsible for the methods used, the results that are presented, and the conclusions in the thesis.

Preface

This thesis entitled "Climate Change and climate risk perception among actors in the Norwegian renewable energy sector" has been prepared in partial fulfillment of the requirements for the degree of M.Sc. (Climate Change Management) in the academic year 2021-2023. This thesis corresponds to 30 ECTS credits in the study program at Western Norway University of Applied Science (Høgskulen på Vestlandet).

My study is a part of the ongoing research project "Creating sustainable renewable energy futures with low climate risks" (SusRenew) funded by the Norwegian Research Council and led by Western Norway Research Institute. For the completion of my thesis, I used the primary data collected through a survey that I helped develop. Once the data was collected, primary data analysis was my sole responsibility.

I was born and raised in Nepal, a developing country that is thriving to develop sustainably and then I got an opportunity to come to Norway to pursue my master's degree for 2 years at HVL. I was motivated to participate in this study because I wanted to deepen my understanding of the Norwegian renewable energy sector and reflect upon the context of Nepal with better learning experiences.

Overall, it was a success for me as I moved forward in my learning curve given that I was able to apply and re-learn what I had learned from the earlier classes.

Acknowledgment

My work is the result of the perseverance and diligent efforts of many others who encouraged me at every turn. I simply wish to dedicate appreciation to all those who helped me accomplish my thesis along with making the most of the educational opportunity.

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Then I would also like to take a moment to thank the department that made my 2 years of master's degree full of learning and new exposure, which is hard to imagine anywhere else, all the professors from the faculty. These two years were all about exposure, adapting to unfamiliar places, and lots of learning and living with beautiful experiences.

I would also like to share my gratitude towards my colleagues and dear friends from Nepal, who always provided a warm and welcoming environment to be around and were incredibly supportive if I had any difficulties. Communicating with them for talks or for doubts made 2 years' journey lively and less difficult.

Finally, I would like to thank my parents and family members of mine for always being understanding and supportive. Thanking my mother and sister is never enough who believed in me, without them my journey would have been impossible to imagine. Also, I would like to share my huge gratitude to Suvin for always cheering me up and providing me with all the support and guidance which shaped me better as a student and human being.

And I would like to thank myself for holding tight everything together and moving forward on this topsy-turvy ride filled with experiences and mindfulness.

Abstract

This master's thesis aims to analyse the perception of actors in the Norwegian renewable energy sector about climate risk and the consequences of climate change on the renewable energy sector. Climate risks have highly influenced the current and past energy systems showing a high concern in the discourse on climate change and energy transition (Aall et al., 2022). Many works of literature have been cited as studies of climate change and risk perception focused on general or specific risks with farming, mining, environment (Carlton & Jacobson, 2013a; Eitzinger et al., 2018). But studies exploring climate change and climate risk associated with energy systems are rare, a situation which is also the case in Norway. Therefore, this research is about climate risk perception, aiming at the level of concern, time factor for the seriousness of the issue, weightage on societal factors, and climate factors as determinants of the consequences of climate change on the renewable energy sector.

To address this research agenda, a quantitative method is employed with a matrix 7-point Likert scale survey question on various dimensions. Data is collected through an online survey and analysed using the SPSS program.

The research findings show that Norwegian actors in the renewable energy sector have high concerns about climate risk and believe they are already experiencing the consequences of climate change in the energy sector. Awareness of climate risks among the respondents in the energy sector is observed to be two-dimensional, in the sense that climate risk is a sum effect of climate change (i.e., climate hazards) and societal change (i.e., climate vulnerability). The study also shows that there are no significant differences among actors in the production and distribution sub-sectors of the renewable energy sector regarding the perception of climate risk.

Overall, this research aims to enhance knowledge about the ongoing conversion to renewable energy and the need for climate change adaptation by examining the perceptions of climate risks among representatives of Norwegian actors in the renewable industry sector. Thus, this thesis will hopefully contribute to better and more informed decision-making and policy formulation within sustainable energy development.

Samandrag på norsk

Denne masteroppgaven tar sikte på å analysere aktører i norsk fornybar energisektors oppfatning av klimarisiko og konsekvensene av klimaendringer på fornybar energisektoren. Klimarisiko har sterkt påvirket dagens og tidligere energisystemer, og viser stor bekymring i diskursen om klimaendringer og energiomstilling (Aall et al., 2022). Mange studier har blitt sitert som studier av klimaendringer og risikopersepsjon fokusert på generelle eller spesifikke risikoer med jordbruk, gruvedrift, miljø (Carlton & Jacobson, 2013a; Eitzinger et al., 2018). Men studier som utforsker klimaendringer og klimarisiko knyttet til energisystemer er sjeldne, noe som også er tilfelle i Norge. Derfor fokuserer denne forskningen på klimarisikooppfatning hovedsakelig bekymringsnivået, tidsfaktoren for problemets alvor, vekting på sosiale faktorer og klimafaktorer som bestemmende faktorer for konsekvenser av klimaendringer på fornybar energisektoren.

For å adressere disse forskningsagendaene, brukes en kvantitativ metode med en matrise 7-punkts Likert-skala spørreundersøkelse på ulike dimensjoner. Studien fokuserer på norske aktører innen fornybar energi, inkludert produsenter og distributører, politiske aktører og nettoperatører i ulike roller. Data samles inn gjennom en nettbasert spørreundersøkelse og analyseres gjennom SPSS-programmet.

Forskningsfunnene viser at norske aktører i fornybar energisektoren har høye bekymringer for klimarisiko, inkludert deres tro på at de opplever konsekvensene av klimaendringer i energisektoren nå. Bevisstheten til aktører i energisektoren er observert å være todimensjonal, det vil si å være en summeffekt av at bade klimaet og samfunnet endrer seg. Studien viser videre at det er ingen signifikante forskjeller mellom aktører i produksjons- og distribusjonsdelsektorene i fornybar energisektoren når det gjelder oppfatningen av klimarisiko.

Samlet sett har denne forskningen som mål å øke kunnskapen innen fornybar energi og klimaendringer ved å undersøke oppfatningen og bekymringene til norske aktører i industrien om mulige negative konsekvensene på fornybare energisystemer. Dermed bidrar denne oppgaven forhåpentligvis til mer informert beslutningstaking og politikkutforming innen bærekraftig energiutvikling.

Acronyms and Abbreviations

ADB: Asian Development Bank

AR: Assessment Report

CF: Climate Factors

CO_2: Carbon Dioxide

EU: European Union

GHG: Greenhouse gas

IEA: International Energy Agency

IRENA: International Renewable Energy Agency

IPCC: Intergovernmental Panel on Climate Change

m/s: meter per second

Mt: Megaton

NCCS: Norwegian Centre for Climate Services

NVE: The Norwegian Water Resources and Energy Directorate

RCP: Representative Concentration Pathways

TWh: Terawatt hour

UNFCC: United Nations Federation for Convention on Climate Change

UNISDR: United Nations International Strategy for Disaster Reduction

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1 Introduction

One of the most urgent challenges of our day is climate change, which has the potential to have a major impact on humans, the environment, and different sectors. Even though climate change is a worldwide issue, various areas and stakeholders within certain regions endure its effects in varying ways. The most discussed problem in energy systems is climate change. According to the Intergovernmental Panel on climate change (IPCC), there is a strong urgency to cut greenhouse gas emissions and make it net zero by the end of this century. The main strategy for achieving this goal is to transform society from today's dependence on fossil energy to a renewable energy sector.

However, several studies have shown that climate change has huge impacts on bioenergy, hydropower, and wind energy systems also affecting energy demand patterns (Cronin et al., 2018; Ebinger & Vergara, 2011; Gernaat et al., 2021). Changes in precipitation, temperature increases, changes in wind patterns, and natural hazards have affected energy production and distribution systems. A result from 220 studies looking at the impact of climate change on energy systems globally showed an increase in cooling demand and a decrease in heating demand as well as a decrease in hydropower and thermal energy (Yalew et al., 2020). Also, the uncertainties in weather pattern make it difficult to quantify the impacts on energy systems in a specific way. However, the uncertainties brought by climate change led to a high-performance gap for grid integration and a drop of around 16% in power supply reliability because of extreme weather events (Perera et al., 2020). With the growing concerns about climate change among policymakers worldwide, there is an issue of risk analysis and communication, also showing that future climate policies and decisions rely on the perceptions of climate change risks (Pidgeon, 2012). Renewable energy sources are being considered as a solution to reducing fossil fuels however have huge technical and economic barriers followed by several regulatory policies barriers (Olabi & Abdelkareem, 2022). Climate risks have highly influenced the current and past energy systems showing a high concern in the discourse on climate change and energy transition (Aall et al., 2022). The paper review and investigates the existing literature and semi-structured interviews with policy actors in Norway and share the findings that this topic has a huge knowledge gap and needs more research.

Studies regarding climate change and risk perception focus either on overall risks or specific risks in sectors like farming and mining or environmental risks (Carlton & Jacobson, 2013; Eitzinger et al., 2018). Furthermore, studies exploring climate change and climate risk associated with energy systems are rare also in Norway. Therefore, the first step in bridging this gap will be to analyse how Norwegian actors in the energy sector perceive climate change and climate risk.

1.1 Study Background

Climate change is undoubtedly a severe and abiding issue facing the world. Excessive emissions of greenhouse gases (GHG) will cause variations in solar radiation, temperature, and precipitation pattern. IPCC special report defines risk as, “The potential for adverse consequences from a climate-related hazard due to the relationship between hazard, vulnerability, and exposure for human and natural systems” (IPCC, 2022). When it comes to the exposure of the affected system to climate risk, it refers to the potential or likelihood of being exposed to different hazards as an impact of climate change.

The long-term temperature goal set in the Paris Agreement as a global response to climate change, assures the goal of limiting the global temperature rise to below 2 degrees Celsius further putting efforts to limit the rise to 1.5 degrees Celsius (UNFCCC, 2015). The share of renewable energy in the energy supply needs to exceed 60% by 2050 so that the 1.5- 2 C goal of the Paris Agreement will be achieved (Gielen et al., 2019). In alignment with this, the Commission from the EU (European Union) as a part of the European Green Deal raised the 2030 Greenhouse gas emission reduction target to at least 55% compared to 1990 (2030 Climate & Energy Framework, n.d). The key targets for 2030 include at least 40% cuts in greenhouse gas emissions from 1990 levels, and at least 32% share for renewable energy. Aligned with the goals of the Paris Agreement, the Climate action plan of Norway has put its target of reducing greenhouse gas emissions by 50% and up to 55% by 2030 and a long-term target of reducing them by 90% and up to 95% by 2050 (Norwegian Ministry of Climate and Environment, 2021). Norway reassessed its emission reduction target as a response to a call from the 2021 climate summit and enhanced its target to cut emissions by at least 55% compared to 1990 levels. The Norwegian energy system must go through a substantial and rapid transformation in energy to meet the goals set aligned with the Paris Agreement.

1.2 The Energy System in Norway

Norway could be viewed as an 'energy superpower' in the sense that domestic energy production of renewable and non-renewable (mostly oil and gas) energy by far (a factor of 10) exceeds domestic consumption of energy, and trade energy export exceeds by a factor of 20 trade energy imports (cf. Table 1).

	TWh (2021)
Production [1]	**2486**
Trade- Imports	129
Trade- Exports	2281
Consumption [2]	**223**
Manufacturing and mining	79
Transport	54
Household	48
Others [3]	**42**

1. Production of primary energy products such as crude oil, natural gas, hydropower
2. Final energy consumption
3. Commerce and public services, agriculture, and fishing

Table 1: Supply and use of energy in Norway, Energy balance (Source: Statistics Norway,2022)

Norway has 1690 Hydropower plants contributing to 88% of the total production capacity. 53 Wind farms in Norway contribute to 10% of Norwegian production capacity while the remaining 2% comes from other sources of production including thermal, solar, bioenergy, waste, oil, and coal (Electricity Production - Energifakta Norge, 2021). Norway has a total production of 2486 TWh of energy in 2021. With hydropower dominating production, Norway has the highest renewable energy production shares in Europe. Norway exports major portions of its energy while imports are lesser (Statistics Norway, 2022).

Consumption in Norway in 2020 was 211 TWh where major consumption was in manufacturing and mining (69 TWh) followed by transport (52 TWh), Household (46 TWh), public services (33 TWh), and others including commerce, agriculture, and fishing (12 TWh).

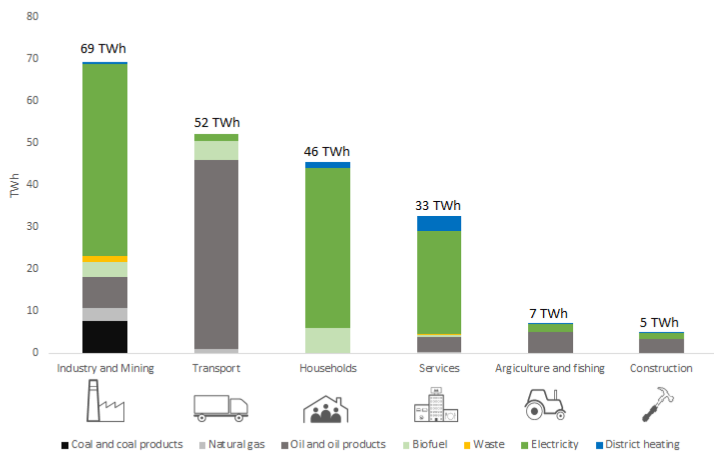

Figure 1: Final energy consumption in Norway split by energy carrier. Total in 2020: 211 TWh. (Source: Statistics Norway, 2022)

Norway together with Sweden, Denmark, and Finland are the parts of the Joint Nordic power market integrated into the European power market via interconnectors to the United Kingdom, Germany, the Baltic states, Poland, the Netherlands, and Russia. The interconnection connects 24 countries and covers 90% of European electricity consumption. Statnett (system operator of the Norwegian power system) is responsible for maintaining a balance of the power system, development and operation of cross-border interconnections, and power exchange with other countries. 25.5 TWh was exported and 8.1 TWh was imported in 2021 through interconnectors with Norway.

*Figure 2: Import, eksport og nettoeksport, 2000-2020 (*The Power Market - Energifakta Norge*, 2022)*

GHG emissions fell by 9% in 19 years from 2000-2019 in Norway. Norway also has commitments of reducing GHG emissions by at least 50% and towards 55% by 2030 as compared to 1990 levels under the Paris Agreement. A total of 71% of the total emission equivalent to 36Mt CO_2 were emitted from the energy sector in 2019. Oil and gas extraction with 25% share, transport with 24%, fuel combustion in the industry with 7%, buildings with 6%, industrial process with 18%, agriculture with 9%, and another emission with 9% were all emissions from the energy sector (International Energy Agency, 2022., p. 35). Although there have been efforts in reducing GHG emissions, the effects of climate change in Norway have been visible more than before. Norway has seen a rise in precipitation and a decrease in the duration of snow cover. There are also many glaciers shrinking while the sea level is rising. Patterns of flood has also changed in Norway while many places have observed longer summer and shorter winter. The weather stations in all parts of Norway have shown that the average temperature has risen by 1 degree Celsius since 1990 and 0.5 degree Celsius in the past 15 years (Norway's Climate Action Plan, 2021). Also, according to the Norwegian Centre for Climate Services, NCCS report- the average winter temperature in Svalbard has increased by 7 degrees Celsius since 1971. While climate change is being considered a huge threat to the globe and Norway being its part, Energy transition has been taken as a key area to tackle climate change.

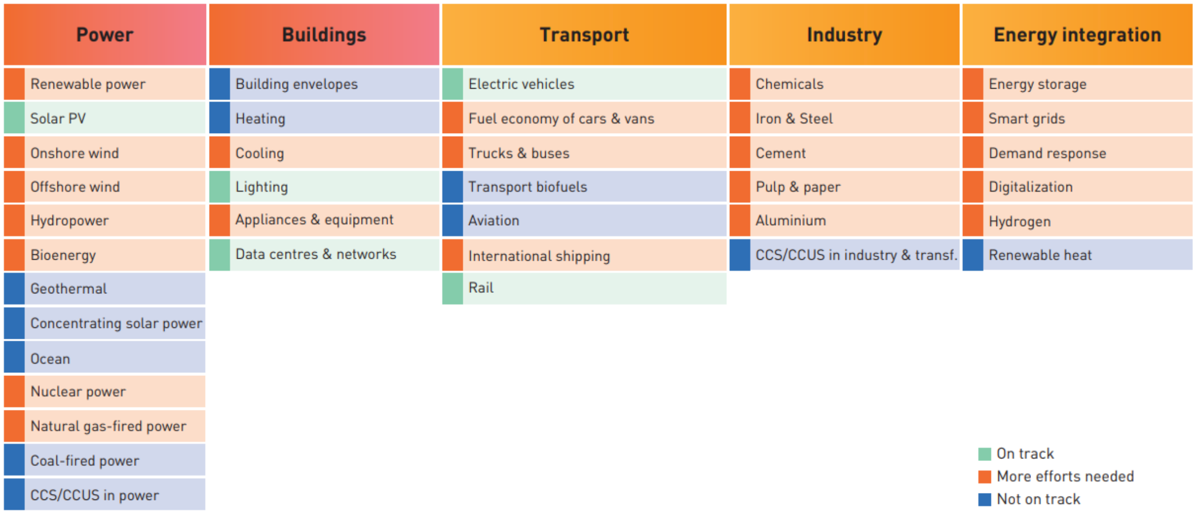

Figure 3: Technology areas that are important for the green transition (Adapted from IEA Tracking Clean Energy Progress 2019 by the Research Council of Norway)

Major technology areas that are important for the green transition are the power sector, buildings, transport, industry, and energy integration. However, there have been limited studies on the impacts of climate change on the energy sector. Even though climate change is acknowledged as a serious worldwide concern, little is known about how participants in the Norwegian energy sector perceive climate risk and the effects of their beliefs on the move toward a system powered entirely by renewable energy.

1.3 Projections of Climate Change in Norway 2100

The report "Climate in Norway 2100" provides a projection on future climate through the 21st century, mostly based on global climate projections from the 5th Assessment report of the IPCC. The report is based on three scenarios for GHG emissions called Representative Concentration Pathways (RCPs): RCP8.5- business as usual, RCP4.5-reductions after 2040, and RCP2.5- drastic cuts from 2020.

Considering the reference period as 1971- 2000, the annual temperature for Norway will increase by 2.7 degree Celsius for RCP4.5 and by 4.5 degrees Celsius for RCP8.5 until the end of the century. The mean annual temperature for Norway (1971-200) was +1.3 degrees Celsius. From 1900- 2014 annual temperature increased by 1 degree Celsius in spring and winter (Climate in Norway 2100, 2017).

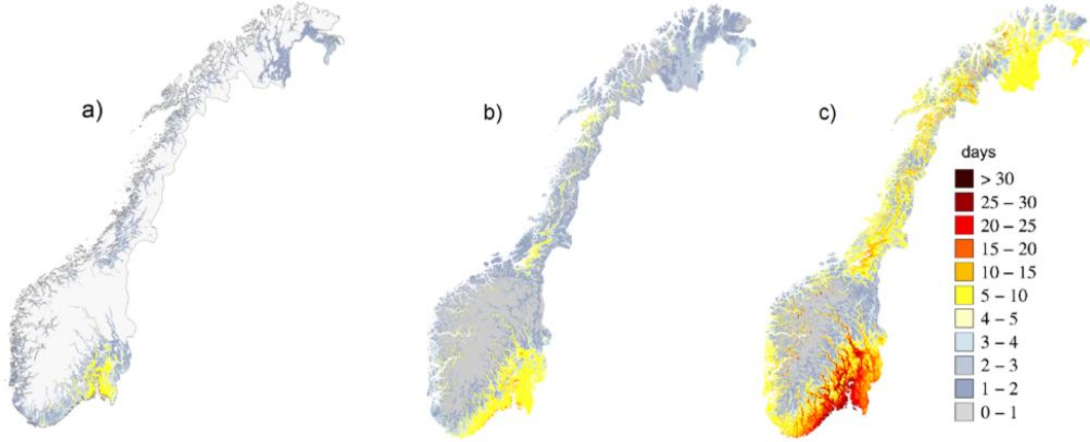

Figure 4: Number of days with daily mean temperature above 20 °C in a) 1971-2000, and according to median projections for b) RCP4.5 and c) RCP8.5 by the end of the century (Adapted from Climate in Norway 2100, 2017)

Days with a mean temperature above 20 degrees Celsius are regarded as warm days. Figure 4 a) shows very few warm days per year. As the mean temperature is projected to increase, the number of warm days per year is also going to increase. There will be around 30 warmer days for RCP8.5, and more areas will experience ten warm days for RCP4.5 in the eastern region of Norway by the end of the century.

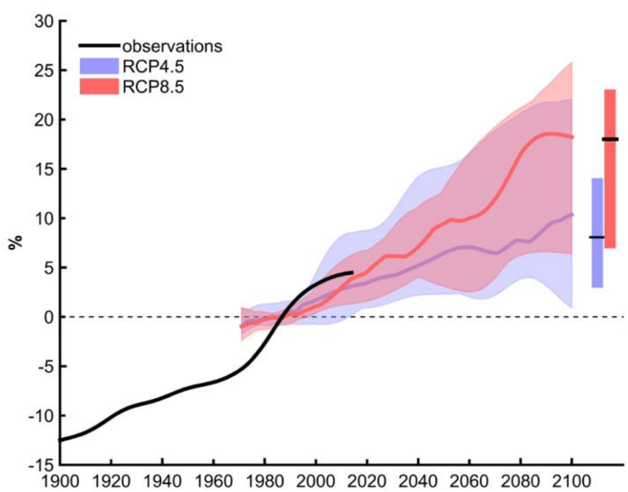

Figure 5: Annual precipitation over Norway as deviation (%) from the period 1971-2000. The black curve represents observations (1900-2014), and red and blue curved lines show median values for the ensemble of ten RCM simulations for emission scenarios RCP8.5 and RCP4.5 (Adapted from Climate in Norway 2100, 2017).

Annual precipitation is projected to have a huge deviation from the reference period 1970-2000. At the end of the century, the mean rainfall for RCP8.5 is projected to increase by 18% compared to the base year 1900. While the frequency of heavy rainfall as well as intensity has increased in the past few years, for RCP8.5, the rainfall days are projected to be doubled.

Snowfall is related to the temperature as well as precipitation. As the temperature rise and a change in precipitation is expected, the number of days of annual snowfall is going to decrease. Based on RCP4.5, several days with snow cover could be less by 1-5 months while RCP8.5 could have 1-7 months less by the end of the century.

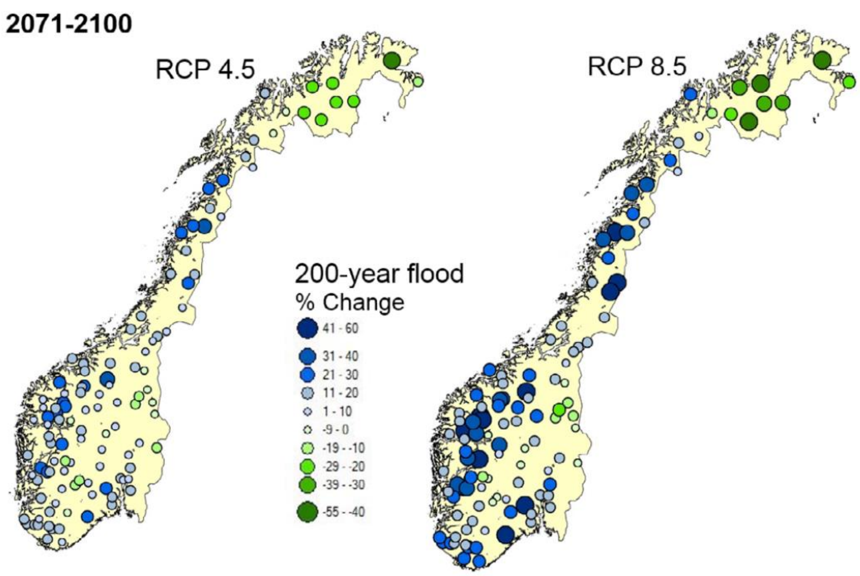

Figure 6: Percentage change in the 200-year flood for medium (RCP4.5) and high (RCP8.5) emissions. Green indicates a reduction and blue an increase in flood magnitude (Adapted from Climate in Norway 2100, 2017).

Climate change effects on floods are complex to project due to uncertainties of hydrological events. However, many areas are expected to have more than a 30% change in the flood magnitude from the base year 1900. Only the northern area is going to have a reduction in flood magnitude in both scenarios.

It will equally trigger different disasters like avalanches, landslides, reduction in snow ice, and increase in sea level. Although the projections have limitations due to different uncertainties and factors in climate, the assessment already gives an idea of how climate change brings extreme weather conditions in Norway.

1.4 Climate Risk

The definition of climate risk is revised by a group of authors and Bureau members during the preparation of IPCC`s Special Reports of the Sixth Assessment Cycle for better use in various contexts. They have defined climate risk as the potential of unfavourable effects on ecological as well as human systems considering that climate change and hazards may result from the effects of climate change and human response to it. The negative effects might include the people’s lives, health, well-being, socioeconomic and cultural assets, and infrastructure and ecosystem services and species Climate risks usually arise from the dynamic relationship between climate-related hazards and exposure and susceptibility of the affected ecological systems (Reisinger et al., 2020).

Further, the climate-related risk is divided into two main categories: Physical risk (risk related to the physical impacts of climate change) and Transition risk (risk related to a lower carbon economy) (Task Force on Climate-related Financial Disclosure 2017). In what follows, I will use the term "climate risks" as a synonym for the term "physical climate risks".

Furthermore, we refer to the definition by IPCC which defines physical climate risk as the sum effect of climate hazards, exposure, and vulnerability (Reisinger et al., 2020). Hazards incorporate different climate indices like temperature, and precipitations well as weather-related natural disasters like flooding, landslides, and avalanches.

Exposure, on the other hand, refers to the values or policy goals that have the risk of being negatively affected by those hazards. Some exposures include the security of energy supply to the consumers, affordable energy, etc. (See Figure 7).

While hazards pertain to climate change, vulnerability extends the scope to encompass societal change. Vulnerability thus covers various aspects of societal changes that can make society more susceptible to the impacts of climate change.

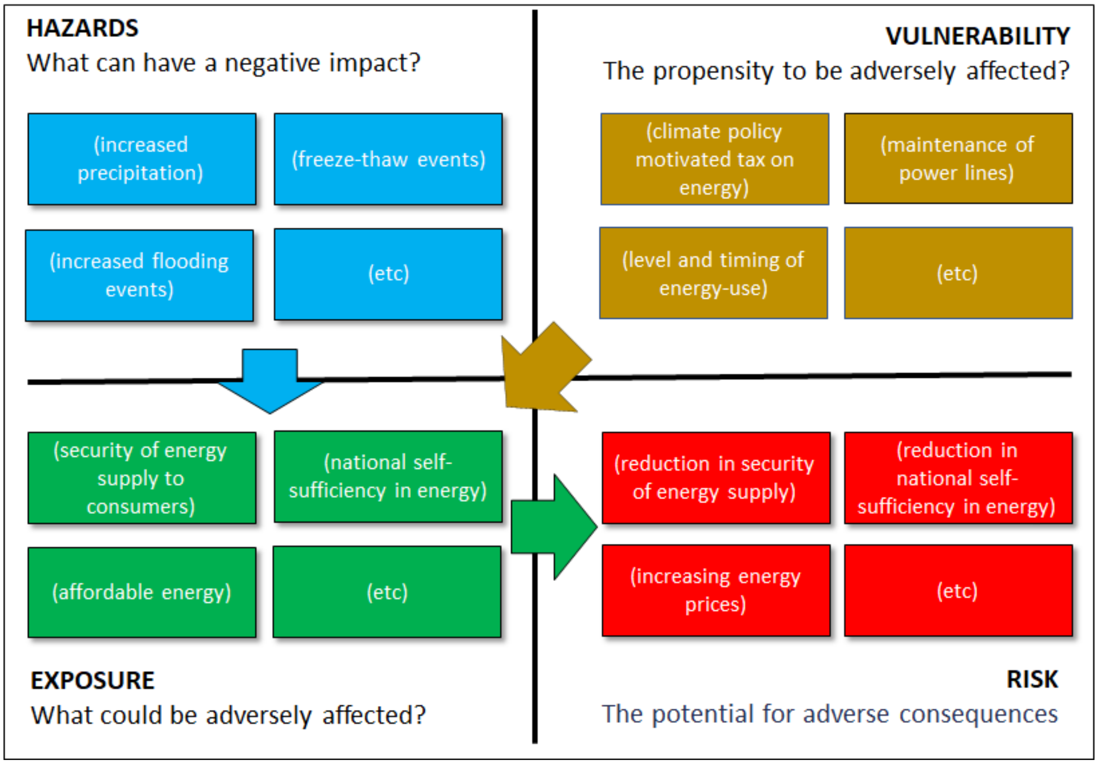

Figure 7: Climate risk as the interaction between vulnerability, exposure, and hazards (Adapted from Reisinger 2020)

In the case of the energy system, examples of vulnerabilities include resources for maintenance of the power grid, resources for grid upgrades, the extent of domestic power demand, international climate requirements, etc. If hazards, exposure, vulnerability, and societal change are considered for the study, there can be important learning on the complex dynamics between climate change and the energy system.

1.5 Research Aim and Research Questions

To create effective initiatives and approaches to addressing the issues associated with climate change, it is crucial to comprehend how participants in the energy sector perceive climate change and climate risk. It is important to know how actors in the Norwegian Energy sector perceive climate change and it is also important to provide a good insight and strengthen the communication among stakeholders in the energy sector, policymakers, and other relevant actors to make further investments in sustainable energy options, decision-making processes, and strategic planning. Therefore, my research will investigate the perception of the Norwegian actors on the level of climate risk and its degree of concern specifically in the renewable energy sector.

Finding the answers to the following research questions will serve as the primary driving force for the study's direction in this area of research:

1. Do Norwegian actors in the renewable energy sector have high concerns about climate risk?
2. Do Norwegian actors in the renewable energy sector think they are experiencing the consequences of climate change in the energy sector now?
3. Is the awareness of actors in the energy sector one-dimensional (on just climate change) or two-dimensional (also on climate vulnerability, i.e., societal change)?
4. What kind of weightage do they emphasize when it comes to climate factors and societal factors as a determinant of consequences of climate change on renewable energy?
5. Are there any significant differences among actors in the production and distribution sub-sectors of the renewable energy sector regarding the perception of climate risk?

Arguments- taken from (Aall et al., 2022.)

- The existing literature shows that the Norwegian actors in the Energy sector think that the consequences of climate change are not visible at present. Still, there are certain experiences of extreme weather events so it could be interesting to know if there are changes in their perception.
- Considering that risk perception is a multidimensional area and can be shaped by varied factors, it is important to know the degree of emphasis given by actors in the Norwegian energy sector on societal factors as well as climate factors i.e., a higher understanding of climate change vulnerabilities and societal factor as a context in changing climate.
- In the few kinds of literature produced previously, the actors mostly prioritize climate factors as a determinant of climate change but is it the same case now? How much value or attention do they provide to societal factors nowadays?
- The energy sector as a system is complex. Hence, it is important to see how the perception of climate risk varies within the different working groups in the energy sector, namely producers and distributors.

1.6 Thesis Structure

My thesis is structured into six chapters where I have explained my research and answered my research questions. Below is a summary of the chapters included in my research.

Chapter One gives the study's background with climate risk to establish the significance of this research, its aims, and the study's shortcomings based on the Norwegian energy sector.

Chapter two reviews the available literature to investigate climate risk in depth, to find out what perception already exists towards climate risk, what is lacking, and how this research fits in the bigger picture bringing to create a piece of new knowledge in terms of perception of actors in the Norwegian energy sector on climate risk.

Chapter three elaborates on the research methodology used in the research and the notion of using a quantitative research method, the overall study design, and its limitations. Methods of statistical analysis, such as descriptive and inferential statistics, will follow this.

Chapter four explains the results of the survey and any significant findings from the responses will be presented.

Chapter five gives insights from data analysis and discusses how the results relate to the research objectives.

Chapter six concludes the study by presenting the results based on the research question. Finally, highlights the research's flaws to provide references for future research in the field.

2 Literature Review

The production and distribution subsector of renewable energy in Norway is a vital area to act against climate change and energy transition. Therefore, it is important to understand the perception of Norwegian actors regarding the consequences of climate change on the production and distribution of renewable energy in Norway to address the concern posed by climate change. This literature review aims to study and synthesize existing research on this area and identify gaps in knowledge and provide a base for further study on the perception of actors in the Norwegian Energy sector. The review is organized into the following sections: 2.1. Climate change and climate risks, 2.2 Consequences of climate change on energy production, energy distribution, and energy demands, 2.3. Factors influencing climate risk perception, 2.4. Climate risk perception on renewable energy systems.

2.1 Climate Change and Climate Risk Perception

We have become more aware of the serious hazards that climate change poses to our ecosystems. Higher temperatures, rising sea levels, more intense rainstorms, droughts, and heat waves are all potential results of climate change.

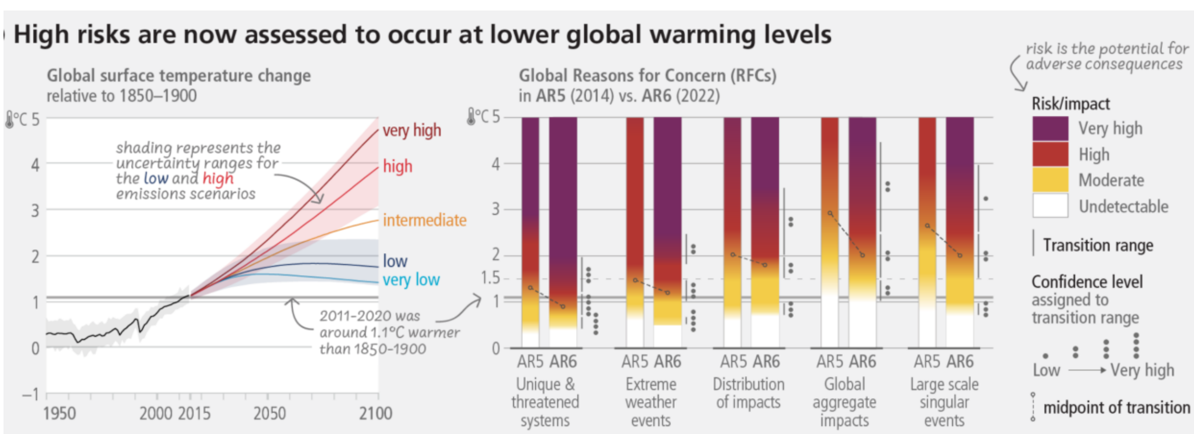

Figure 8: Projection of Global surface temperature change (Adapted from IPCC-AR6 Synthesis Report, 2023)

Climate change has caused variations in the sea levels due to which coastal areas around the globe are having catastrophic effects. It is expected that if adaptation measures are not taken, climate change would result in 0.2-4.6% of the global population flooding every year in 2100 under 25-123 cm of global average rise in sea level (Hinkel et al., 2014). Over the past century extreme sea levels have risen primarily due to the corresponding increase in the mean sea levels, the variation of extreme sea levels is correlated with the nodal tidal cycle and seasonal variations (Weisse et al., 2014). A study also reflects that the rapid rise in the sea level since the 1970s is due to the simultaneous effect of thermal expansion and greater loss of Greenland's ice (Frederikse et al., 2020).

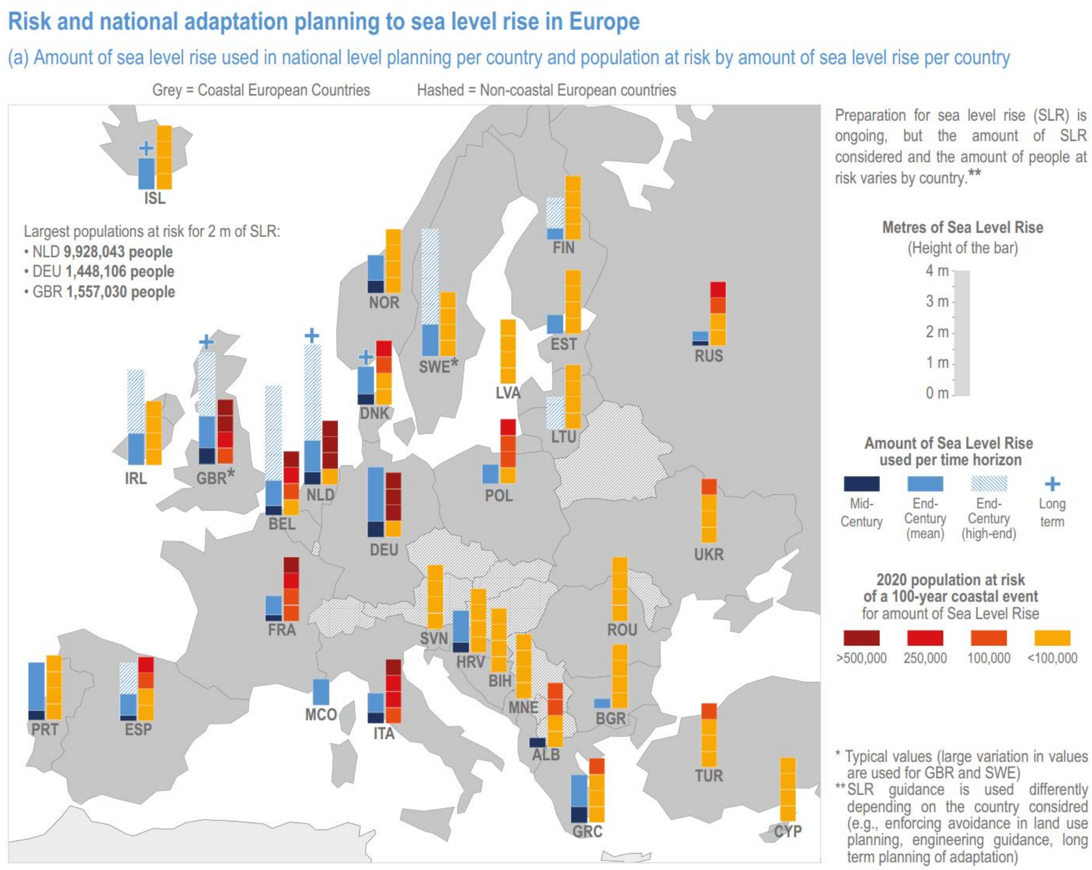

Figure 9: Amount of sea level rise per country (Adapted from IPCC, Climate Change 2022: Impacts, Adaptation, and Vulnerability)

Climate risks appear regionally. Thus, it is necessary to comprehend the direct effects of physical climate risk within the context of a geographically defined region. Both within and between nations, there are variations. Physical climate risk is constantly shifting or non-stationary as the Earth's temperature rises. Due to the physical inertia of the geophysical system, additional warmth is "locked in" over the upcoming decade.

"Cities in many nations have started to assume responsibility for finding, analysing, and evaluating local risks brought on by climate change. For local governments, civic society, and private businesses, the complexity of the job at hand poses several institutional challenges" (Fünfgeld & Schmid, 2010). The need to address security risks linked to climate change through cooperation and communication is becoming increasingly evident among policymakers, researchers, and the public (SIPRI 2023).

The willing cooperation of the intended beneficiaries is frequently a prerequisite for policies to encourage adaptation to climate risks. The implementation of the policies will fail if the beneficiaries disagree with the decision-makers and program managers regarding the necessity of adaptation or the efficacy of the actions they are being requested to take (Patt & Schröter, 2008). Cities and their communities need to be more resilient and ready to face the threats head-on to lessen the risk and effect of these threats and improve their citizens' safety and welfare.

However, perspectives on the threat presented by climate change and support for adaptation measures differ significantly across nations. Thus, there is an urgent need to examine the attitudes toward climate change adaptation as well as beliefs and risk perceptions related to the possible impacts of climate change in this nation. Due to various national contexts and varying exposure to climate hazards, different countries will have different climate change adaptation policies. Sea level rise, changes to the biosphere, an increase in the number and severity of extreme weather events, and the emergence of hazards that have not previously been encountered locally are some examples of these (e.g., forest fires in areas where these have not previously posed a risk, diseases that formerly thrived in warmer climates becoming more prevalent). Furthermore, second-order effects like supply chain disruption brought on by climate change in other regions of the globe could present more intricate and additional country-specific risks (Taylor et al., 2014).

2.2 Consequences of climate change on the renewable energy sector

Compared to many other economically and environmentally important natural systems and sectors, such as ecosystems, agriculture, water resources, human health, and tourism, the vulnerability of the energy system to climate change, its potential effects, and available adaptation strategies have received less attention over the years. Moreover, this is not to forget that two-thirds of greenhouse gas (GHG) emissions come from the energy sector, so the IPCC strongly urges a transformation of the global energy system that includes a massive uptake of renewable energy sources and gradually rising energy efficiency (Tollefson, 2018). Most climate impact analyses in the energy industry have concentrated on energy consumption (*Electricity Market Report 2023 – Analysis - IEA*, n.d.).

Energy sources are going to be affected by climate change. Figure 10 shows a projection of climate risks for major energy supply in Europe: It provides an overview of risks under 1.5°C, 2°C, and >3°C GWL.

Figure 10: Projected climate-change risks for energy supply in Europe for major sources and under 1.5°C, 2°C and >3°C GWL (Adapted from IPCC, Climate Change 2022: Impacts, Adaptation, and Vulnerability)

The complete industry, including fuel mining or production, fuel transportation to power plants, energy production, high voltage transmission through grid networks, and low voltage distribution to consumers, is anticipated to be impacted by climate change. Climate change will also affect customer end-use demand and the growth patterns of energy loads. The complex and cascading effects of climate change on power systems can influence water and transportation and vice versa.

2.2.1 Consequences of climate change on the energy production subsector

Changing climatic conditions significantly impact energy production, especially renewable energy production. The availability of water resources and the seasonal pattern of the hydrological cycle are key factors in Hydropower generation. Climate change affects the hydropower endowments in those areas where snowmelt is a factor in the annual water cycle, and the glaciers are affected by higher temperatures (Mideksa & Kallbekken, 2010a). Schaffer has mentioned in his paper, studies that have shown that glaciers in Chacaltaya in Bolivia have their size reduced and hence affecting the hydropower generation in those areas reducing the hydropower endowments (Schaeffer et al., 2012a). A study focused on a model-based approach with geo-references of 5991 hydropower stations to analyse the possible effects of global change on Europe's hydropower potential summarized the increase in 15-30% hydropower potential in Scandinavia and northern Russia while a decrease of 20-50% in Portugal and Spain and Ukraine, Bulgaria, and Turkey (Lehner et al., 2005). Aligned with the study, there are projections for Norway (See Figure 11). that show an 11-17% increase in the annual inflow to the hydropower generation system resulting in an increase of 9-20% in energy generation from the hydropower simulations (Chernet et al., 2013). MARKAL Norway model was used in a similar study to project hydro resources with and without impacts of climate change where there seems additional 5-20 TWh per year hydro potential from climate change concerning 159 TWh projection as Base without the impact of climate change (Seljom et al., 2011).

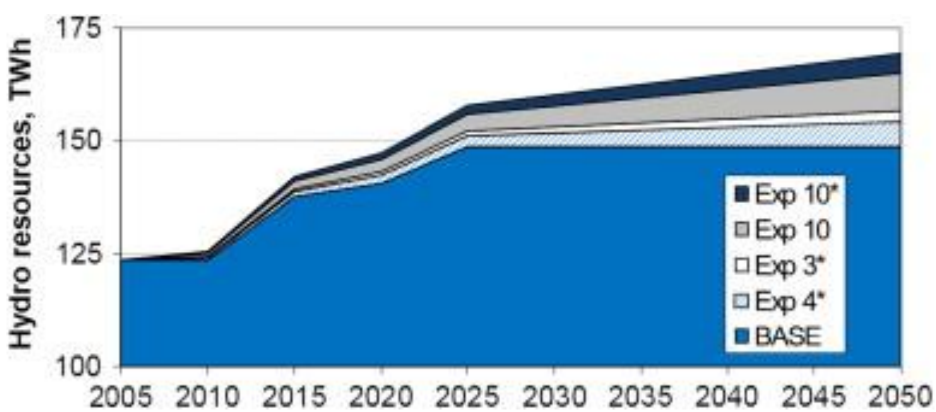

Figure 11: Projected hydro-resources with and without the impact of climate change (TWh per year) Source: (Seljom et al., 2011)

Wind power also one of the major renewable energy sources in the world as well as in Norway is hugely affected by climate change. Wind power generation depends on the geographical distribution and inter- (intra-) annual variability of wind speed, wind indices, and energy density but there have been very few studies to assume the increase or decrease of those factors under climate change scenarios (Pryor & Barthelmie, 2010). Extreme wind speed and gusts and icing issues are contributing as a primary factor to the life cycle of wind power plants. A case study simulation from Brazil with IPCC A2 and B2 scenarios based on HadCM3 general circulation model shows that the wind power generation in Brazil will not be negatively impacted by Global climate change but have positive potential over time. However, taking the limitations of large uncertainties associated with the GCC models and changing scenarios, the findings of the case study were suggested only as a possibility instead of projections (Pereira de Lucena et al., 2010). Simulation from an investigation in the North Atlantic on the North Sea shows that offshore wind farms produce 3-9% growth due to increased wind speed as the effect of climate change scenario (Sood et al., 2006). Also, researchers from Northern Europe predict the decline in icing frequency and sea ice while increasing the wind energy resource and extreme wind speeds benefitting the wind power (Pryor & Barthelmie, 2010). There is also a similar study in Scandinavia using different climate change projections where they report a decrease in time of icing by 5-100% showing that wind turbines will gain efficiency due to climate change (Laakso et al., 2006). Other studies in Scandinavia have also shown the effects of climate change and mostly the uncertainties of climate change on wind power production (Russo et al., 2022; Yang et al., 2022). But the literature on such in Norway has been limited and it is therefore difficult to look at the projections of wind power under the impacts of climate change, specifically in Norway.

2.2.2 Consequences of climate change on the energy distribution subsector

Climate change affects not only the generation of energy but also the transmission and distribution. Climate change bringing extreme winds, ice loads, avalanches, floods, landslides, and lightning strikes may cause transmission and distribution lines failures. A study in California has shown a decrease in the capacity of fully loaded transmission lines due to an increase in temperature (Sathaye et al., 2013). There will be more transmission losses due to the increase in temperature. Some studies describe the effects of climate change on transmission networks as power line sagging and a decrease in carrying capacity, but the studies do not include quantitative methods (Eskeland et al., 2008). A quantitative analysis of climate projection from the regional climate model in the UK projects an increase in lightning and solar heat faults and flooding faults in the transmission system in the UK (McColl et al., 2012). In a book published on climate Impacts on Energy systems: Key issues for the energy sector, there are mentions about thousands of kilometers of transmission lines will be exposed to wind gusts, icing, storms, landslides, Rock Falls, and erosions. distribution systems are also exposed to factors induced due to meteorological reasons like falling trees (*Climate Impacts on Energy Systems: Key Issues for Energy Sector Adaptation - Jane O. Ebinger - Google Books*, n.d.). A report published by Asian Development Bank (ADB) mentions that Wind speed and storms wind damages overhead lines causing a 20% capacity increase for every m/s rise in wind speed, a 1% rise in temperature de- rates transformer by 1% load, resistance of overhead and underground wires rises by approximately 0.4% and 4.5 cm sagging of overhead lines per 1-degree Celsius rise in temperature. Drought can reduce the underground cable capacity by 29%, while flooding can cause up to 100% loss of local supply (Asian Development Bank, 2012; Varianou Mikellidou et al., 2018). A study on 30 cities in Sweden under 13 climate change scenarios using a stochastic robust optimization method show a drop of up to 16% in power supply reliability due to extreme weather conditions (Perera et al., 2020b). Studies are limited in the effects of climate change on transmission and distribution systems globally while there have not been studies about the area in the case of Norway.

2.2.3 Consequences of climate change on energy demand

Several studies and simulations on the potential impacts of climate change on energy demands indicate reduced heating demand and increased cooling demand (Dolinar et al., 2010; Isaac & van Vuuren, 2009; Mideksa & Kallbekken, 2010b; Schaeffer et al., 2012b). A transient systems simulation in Slovenia using climate change scenario predictions of temperature rise (+1 degree Celsius and +3 degree Celsius) and solar radiation increase (+3% and +6%) shows a decrease in heating demand from 16-25% in the sub-alpine region but still insignificant on Mediterranean region and increase in cooling demand by 6 times in Subalpine region and 2 times in Mediterranean region (Dolinar et al., 2010). An econometric multivariate regression model study in Massachusetts, USA predicted a 2.1% and 1.2% increase in per capita residential and commercial buildings energy consumption (Amato et al., 2005). Under A2 and B2 IPCC SRES emission scenario, four cities in Switzerland will have heating degree days reduced by 13 -87% and cooling degree days increasing up to 20 times, similarly under a scenario in the next 50 years with a temperature rise +1 degree Celsius and +3 degree Celsius 2 cities in Slovenia will have heating degree days reduced by 14 - 32% and cooling degree days increase up to 418% (Christenson et al., 2006; Dolinar et al., 2010). A study analysed 11 studies showing an increase in peak load from 0.4- 4.6% for a 1-degree Celsius rise in temperature and parallel 15 studies showing an increase in energy demand from 0.5-8.5% for a 1-degree Celsius rise in temperature (Santamouris et al., 2015). In the global scenario, there is a change in energy demand due to the rise in temperature as the effect of climate change. But the demand would also hugely depend on the intensity of warming. There was a prediction of a decrease in global heating demand by more than 30% and an increase in global cooling demand by 70%, but the net change of demand due to climate change is low, and economic factors play a role in it (Isaac & van Vuuren, 2009).

The energy demand also depends on different regions using electricity for different purposes as well as changes in heating and cooling degree days. About 27% of Europe's residential energy use is for cooling and heating; however, Norway is different as more than 80% of buildings use electricity for heating purposes (Mideksa & Kallbekken, 2010b). There is extremely limited study on the impacts of climate change on energy demands in Norway. 10 climate experiments based on 5 different global models and 6 emission scenarios found that the demand for space heating decreased by 9% for experiment 3, 11% for experiment 10, and 13% for experiment 4 in 2050 while using Soldat calculations and found a decrease in heat demand by 13-17% for experiment 10 (Seljom et al., 2011). There is a similar pattern to be defined as a U shape in the heating and cooling energy demand for a rise in temperature in Norway.

2.3 Factors Influencing climate risk perceptions.

Perception of climate risks comes as a combination of direct experience, news and media sources, and societal construction (Akerlof et al., 2013). While if people have experienced any form of global warming, it heightens risk perception among people. Risk perceptions are, however, overly complex, and multidimensional area. Helgeson has suggested four dimensions of climate risk perception as demographic, cognitive, experiential, and sociocultural factors (Helgeson et. al., 2012). Some research shows that people correctly perceive changes in long-term climatic conditions. Psychological factors are the dominant determining factor in risk perception of climate change. According to Rosa, human perception allows a gap in the existence of real-world threats and subjective judgments of those threats and therefore is unique (Rosa, 2003). Climate risk perception differs in people in different geography have access to different information sources about climate change and their pattern of media use (Metag et al., 2017; S. L. D. Van Linden et al., 2015). Risk Perception of Climate change can be determined by cognitive factors- mostly knowledge about cause and impact, experiential factors- emotion and personal experience of extreme weather conditions, sociocultural influences- defined by societal norms and values of the community, and socio-demographic factors (Van Der Linden et al., 2015).

Indeed, it is evident that the world's different climate-related policies need to be revised to increase their level of ambition. Research by the International Renewable Energy Agency (IRENA) demonstrates that energy efficiency and renewable energy solutions when implemented quickly together can achieve over 90% of the energy-related carbon dioxide (CO2) emission reductions needed to meet nationally pledged climate goals. To truly have an effect, though, this calls for a global strategy that involves all spheres of society, including communities, regions, and governments in addition to numerous other stakeholders in both the public and private sectors (IRENA 2019).

2.4 Climate risk perception on energy systems.

Although all the mentioned above show the impacts of climate change on the energy system itself, very less effort is put into the studies on the knowledge of relevant stakeholders in the energy sectors of Norway towards climate risk in the energy sector. Climate change is a huge topic of research but there is limited knowledge of public perception of its impact. Research in the UK with empirical analysis shows that energy security is a concern for the UK public, with dependence on fossil being the most concern and disruption of energy supply being the least area of concern and concern varies with the context of the climate change scenario (Demski et al., 2014). A study of climate risk perception in agriculture is available where one of the studies shows that

Midwestern US farmers have major concerns about longer dry periods and droughts, also that there was strong agreement with the hypothesis of a positive correlation between human belief caused climate change and perceived climate risk (Mase et al., 2017). People have more belief when they experience global warming. Some studies suggest that individuals who perceive climate change as a huge issue are more likely to express their interest to invest in renewable energy. Also, people with better knowledge and understanding of renewable energy are more likely to share their interest in investment in renewable energy.

The data collected from around 1000 respondents per country for each tear surveyed (European Commission, 2017) showed that more than 70% of them perceive that climate change is a profoundly severe problem (See Figure 12).

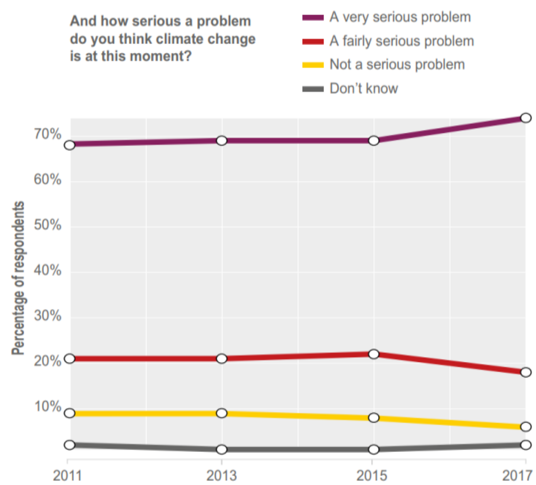

Figure 12: Perceived seriousness of climate change (Adapted from European Commission 2017)

The existing literature shows that the Norwegian actors in the Energy sector think that the consequences of climate change are not visible at present time but there are certain experiences of extreme weather events so it could be interesting to know if there are changes in their perception. Considering that risk perception is a multidimensional area and can be shaped by several factors, it is important to know the degree of emphasis given by actors in the Norwegian energy sector on societal factors as well as climate factors i.e., higher understanding of climate change vulnerabilities, and societal factor as a context in changing climate. In the few kinds of literature produced previously, the actors mostly prioritize climate factors as a determinant of climate change, but is the same case now? How much value or attention do they provide to societal factors nowadays? The energy sector as a system is complex. Hence, it is important to see how the belief of climate risk varies within the different working groups in the energy sector, namely producers and distributors (Aall et al., 2022).

However, climate impact assessment for energy systems is a comparatively new area of research, and methodological approaches keep on increasing extending the knowledge in this area. There is little knowledge on this subject, and the knowledge that does exist has several flaws after reviewing policy and study literature and speaking with important energy policy actors in Norway. The way that climate risks are typically discussed ignores climate vulnerabilities brought on by the ongoing energy transition and instead projects future climate onto the present energy system (Aall et al., 2022). Most policy players agree that a future energy system dependent on renewable resources will primarily gain advantages from climate change and reduce rather than increase climate risks. Increasing the ability to produce renewable energy is essential for reducing climate change, according to a special study on renewable energy sources and climate change by the IPCC (Moomaw et al. 2011). By 2050, the share of renewable energy in the total primary energy supply must surpass 60% to meet the 1.5°–2° aim of the Paris Agreement (Gielen et al., 2019b). It is obvious that climate change has a big hurdle for energy transition, but stakeholders' beliefs vary on the urgency. Varied factors including economic considerations, environmental concerns, societal factors, and political factors play a role in forming stakeholders' perceptions of climate risk.

The policy and institutional frameworks In Norway also have a key role in shaping the perception of different actors in the production and distribution of renewable energy sectors in Norway. Norway places second in the world for the share of primary energy. With the highest global share of electric cars, Norway is also at the forefront of the transition to electric vehicles (Saele & Petersen, 2018). Norwegian Water Resources and Energy Directorate [Norges Vassdrags-og Energidirektorat (NVE)] published a special report in 2019 on the impact of climate on the inflow of hydropower in Norway with the analysis of current hydropower system in light with the future climate. In reports first summary it is mentioned that the inflow has increased more quickly in recent decades than projected by climate change models (NVE, 2019). This viewpoint finds that current capabilities will be sufficient to meet future demand which is optimistic, and this might influence policy incentives and regulations on different investors in renewable energy sector in Norway differently. As a result, the various actions in renewable energy sector could potentially take on new dimensions with the changing climate.

This literature review has offered a detailed analysis of the prior research although extremely limited on the perceptions of Norwegian actors about the effects of climate change on the nation's production and distribution subsector of renewable energy sources. It has highlighted the importance of understanding diverse viewpoints including the energy sector professionals, communities, and policymakers. There has been limited study among which the study of climate risk perception in Norway has been only on other sectors than energy. Further study of the perception of climate risk in the energy sector will be guided by major research gaps that have been shown to contribute to creating effective policies and strategies for Norway's transition to a sustainable energy future.

3 Methods

This chapter explains the methodological approach used in this research to analyse the perception of actors in the Norwegian renewable energy sector toward climate risk. In the following, I will describe the chosen research design, then go on to present the method used for data collection and analysis of my data.

3.1 Research Design

This thesis is a part of the ongoing project "Creating sustainable energy future with low climate risks" (SusRenew) led by Western Norway Research Institute and has 5 more research partners. For the completion of my thesis, I used the primary data used in this project, in which I also made contribution during various stages of development. This research used a quantitative method for a comprehensive exploration of research questions mentioned in Chapter 1.5.

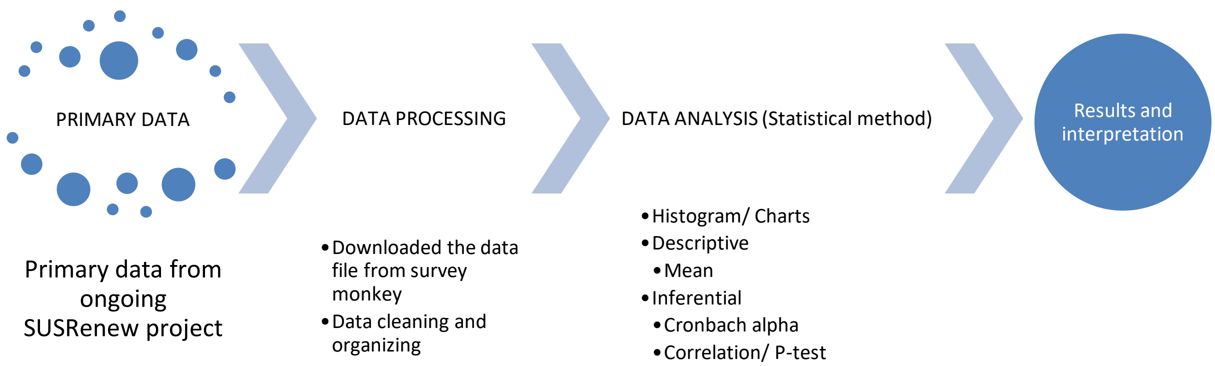

Figure 13: Methodology for this thesis

3.2 Sampling of Respondents

Participants for the survey were selected such that they are actively involved in the production and/or distribution of energy in the renewable energy sector of Norway, mostly by being part of the planning of such activities. Also, the participants were selected based on whether they had responsibility for assessing questions concerning the possible consequences of variation in relevant climate factors. Thus, the study applied a purposive sampling technique. The actual recruitment of informants was done by researchers at Western Norway Research Institute, but I was also involved in the discussions surrounding the recruitment. In practical terms, the recruitment took place through a form of snowball technique, where the researchers called representatives of various renewable energy companies and asked for tips for relevant informants within the company that was contacted and tips for other companies (preferably with suggestions for contact persons) that might be interested in taking part in the survey. The sample includes actors from relevant stakeholders within production or distribution, some from Statnett (transmission). The sample size taken for this thesis is 48.

3.3 Data Collection

3.3.1 Primary data

A structured survey questionnaire was developed, primarily by researchers at Western Norway Research Institute – but also by including me in discussions about the design of the questionnaire, to analyse the climate risk perception of Norwegian actors in the renewable energy sector. The questionnaire includes items that measure the level of concern, perception of their company's effort, climate factors, and societal factors as determinants of the consequences of climate change on the renewable energy sector. All questions measure on a matrix 7-point Likert scale, ranging from strongly disagree to strongly agree. In addition to that the profile of the participants in the energy sub-sector group and their roles are collected. Likert scale was used because it is easy to use for respondents, quantification of the opinions and behaviours is possible, it is more reliable and valid, and it has been widely used in survey research.

The Likert scale used for this survey is.

Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree

Very negative	Negative	Neutral	Positive	Very positive	Do not know

The survey was administered online, using the Survey Monkey tool, and it ensures anonymity and confidentiality of responses.

3.3.2 Secondary data

Different reports were studied to understand the theoretical content of the research. Some of the important studies are listed down. Government report: Energikommisjonens rapport 2023, Norway 2022 energy policy review (IEA), Synthesis Report of the IPCC Sixth Assessment Report (AR6), Report to the Sorting (green paper): Norway's Climate Action Plan for 2021–2030. The relevant literatures were used for the discussions.

3.4 Data Analysis

Data collected from the survey were analysed using proper statistical tools and techniques. The data were cleaned and organized before analysis. The data were summarized with descriptive statistics and checked for response bias. Inferential statistics were used to draw conclusions and make inferences about the population based on the sample data. Excel and SPSS (Statistical Program for Societal Sciences) were used for the descriptive and inferential analysis of the information in the survey.

- Descriptive statistics such as frequency distribution, mean, and standard deviation were calculated in SPSS to summarize the quantitative survey data.
- Reliability tests using Cronbach's Alpha were done to test the degree of consistency within the groups of the matrix of the Likert scale.
- Q-Q plot was plotted for the group of matrix questions to analyse if the data were normally distributed.
- Inferential statistics, including analysis of variance (ANOVA), was conducted to find any significant differences in perception of climate risk being positive among actors in the different subsectors of the renewable energy sector as the data was normally distributed.
- Inferential statistics, including an independent sample test was conducted to show any significant differences in perception of climate risk being negative as well as societal factors among actors in the different subsectors of the renewable energy sector as the data was not normally distributed.

- Mann-Whitney U test was done to analyse if there exists any significant difference in how actors in energy production and energy distribution perceive on overall consequences of climate change on energy systems.

Detail tables for the respective tests done through SPSS are shared in the Appendix B.

3.5 Ethical consideration

Participants were informed about the study's purpose and their rights, including voluntary participation as well as that their information will be confidential. Data are stored securely and reported which does not allow individual participants to be identified. Ethical approval from NSD was applied before conducting the research. The case number is 220686.

3.6 Limitations of the Data and the Analysis

There were a few limitations to this method.

- The complexity of the Norwegian energy sector system (ownership of companies and shares) limited the choice of the respondents and their reachability. This complexity could have potentially limited the sample size and representation of the survey respondents. Hence, the findings may not fully capture the perspectives of all relevant stakeholders in the energy sector.
- The scope of this survey was limited to a specific geographical region (Norway). Therefore, the findings will not be directly applicable to other regions. The survey is focused on the renewable energy sector and limited the knowledge across other sectors.
- There is always a chance for response biases as it is a self-reported survey. Respondents might have supplied inaccurate or incomplete information due to numerous factors like societal desirability, misunderstanding of survey questions, and recall bias. There are also chances that some respondents tend to agree with survey statements without thoroughly considering their responses. These biases can affect the validity of findings, potentially leading to a skewed understanding of the study.

4 Results and Analysis

In this section I will present and summarize the results of the survey, focusing on presenting a clear overview of climate change and climate risk perception among actors in the energy sector (significance of data and any relationship that may infer to any specific trends) to answer my research questions which are previously mentioned. In the following part of this section, the descriptive statistics will be presented briefly, to present the overall perception of specific contents of the survey question. The inferential statistics findings will be further followed to present any specific inferences or trends seen in the response data. In addition, the themes of specific survey questions will be presented, which will directly guide me in answering my research question.

4.1 Summary of Respondents

This study studies the perception of 48 respondents from the Energy sector in Norway where the informants can be a member of more than one of the categories. The respondent is categorized into two main categories namely producers and distributors in terms of the sub-sector of energy. The perception of these actors was studied through the analysis of survey responses collected through online surveys.

Energy sector category

	N	%
Energy Production	20	41.7%
Energy Distribution	25	52.1%
Both production and distribution	3	6.3%

Statistics- Can be member of more than one categories

Area of responsibility	N
Hydropower	15
Wind power	11
energy sources	21
Operation/maintenance	20
Planning	24
Sale	3
Information	3
Marketing	2
Strategy and management	22
Sustainability	15
Other	4

Table 2: Number of respondents in each area (Energy Systems in Norway)

Among a total of 48 respondents, 20 belong to energy producers, 25 to energy distribution, and 3 to both producers and distributers. Among different renewable energy, 15 are from Hydropower, 11 from wind power, and 21 from other energy sources. Among different responsibilities in the energy systems, 20 of them are involved in operation and maintenance, 24 are involved in planning, 22 in strategy and management, 3 in sales, 3 in information, and 2 in marketing. There is diversity in the participants in terms of areas of energy systems and their role in the organization.

4.2 Degree of Concern and Actions

Participants were asked on the timeline that they think Norwegian society will seriously notice the consequences of climate change. Figure 14 shows, that 50% of the participants responded think that Norwegian society is currently experiencing the negative consequences of climate change, 31% think that this will happen in the next decade, while 19% of them think that Norwegian society will not notice the consequences of climate change until 20 years or later. This suggests that most of them believe that climate change is harming energy systems now.

When do you think Norwegian society will seriously notice the negative consequences of climate change?

	N	%
We notice them now	24	50.0%
The next decade	15	31.3%
In 20-50 years	8	16.7%
In more than 50 years	1	2.1%

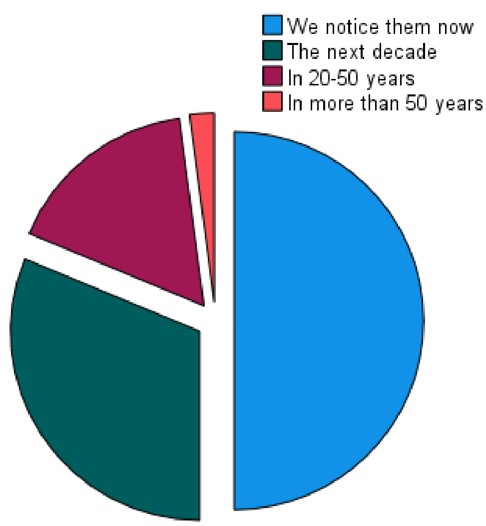

Figure 14: Perception on time for negative consequences of climate change

Furthermore, in response to the question – What do you think the overall consequences of climate change will be for the production and distribution of renewable energy in Norway in the future, (See Figure 15) most participants (20) responded that it will be negative. However, a slightly smaller number of participants (16) responded that the overall consequences will be positive. So, the response is contradictory, and we cannot draw any specific conclusion on the perception of the overall consequences of climate change on the production and distribution subsector of renewable energy in Norway. While two participants believe that it to be positive.

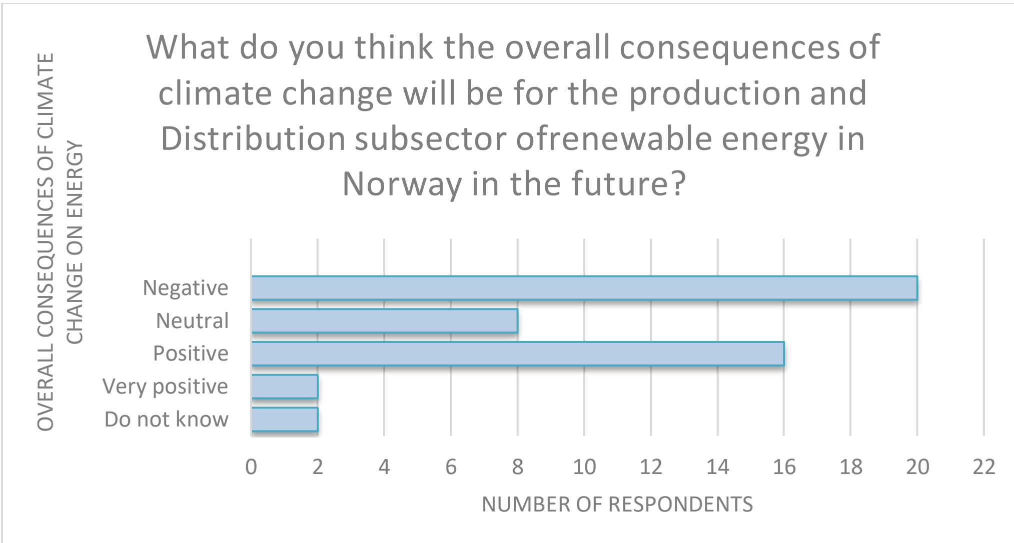

Figure 15: Perception of overall consequences of climate change on the renewable energy sector.

Test Statistics[a]

	What do you think the overall consequences of climate change will be for the production and distribution of renewable energy in Norway in the future? The overall effect will probably be:
Mann-Whitney U	218.000
Wilcoxon W	408.000
Z	-.494
Asymp. Sig. (2-tailed)	.622

a. Grouping Variable: Energy sector category

Table 3: Mann-Whitney U test for Production and Distribution categories

In addition to this, a Mann-Whitney U test was done to analyse (see Table 3) if there exists any significant difference in how actors in energy production and distribution perceive on overall consequences of climate change on energy systems. The test statistics values report Mann/Whitney U: 218, Z-score -0.494 with p value 0.622 (two-tailed) higher than 0.05. It suggests that there is no significant difference between the two groups (Producers and distributors) in terms of their responses.

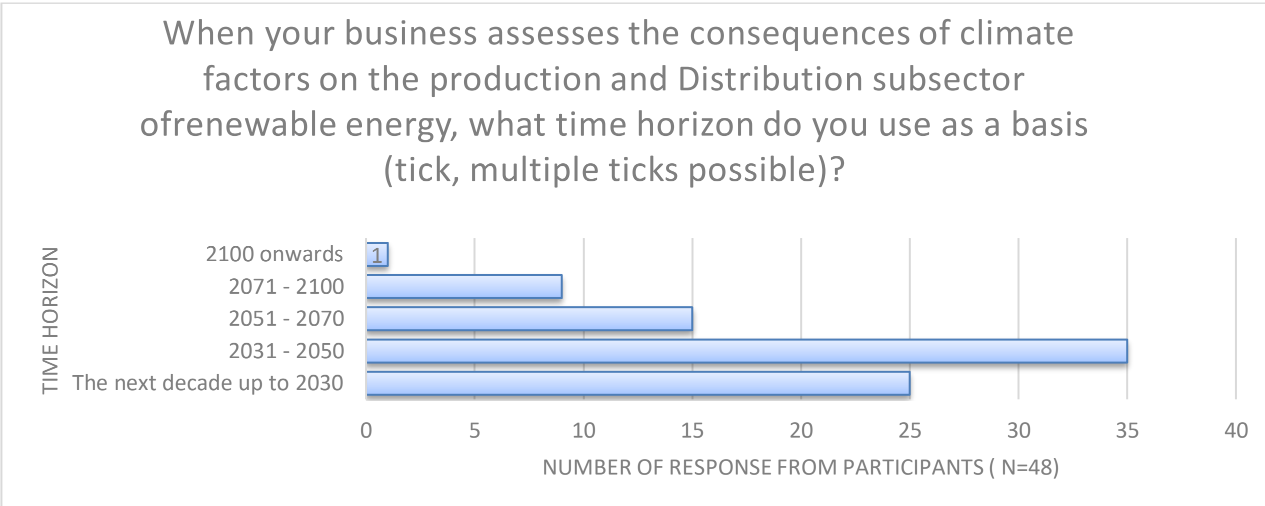

Figure 16: Time Horizon companies use when assessing climate change's impact.

Additionally, results on the time horizon that companies use when assessing the consequences of climate factors were analysed to understand the degree of concern, they show about climate change (See Figure 16). It suggested that most of them only consider the next few decades in their assessment. Among 48 participants, only one participant responded with the 2100 onwards time horizon, 15 participants with the 2051–2070-time horizon and 25 participants shared their assessment time horizon to be in the next decade up to 2030.

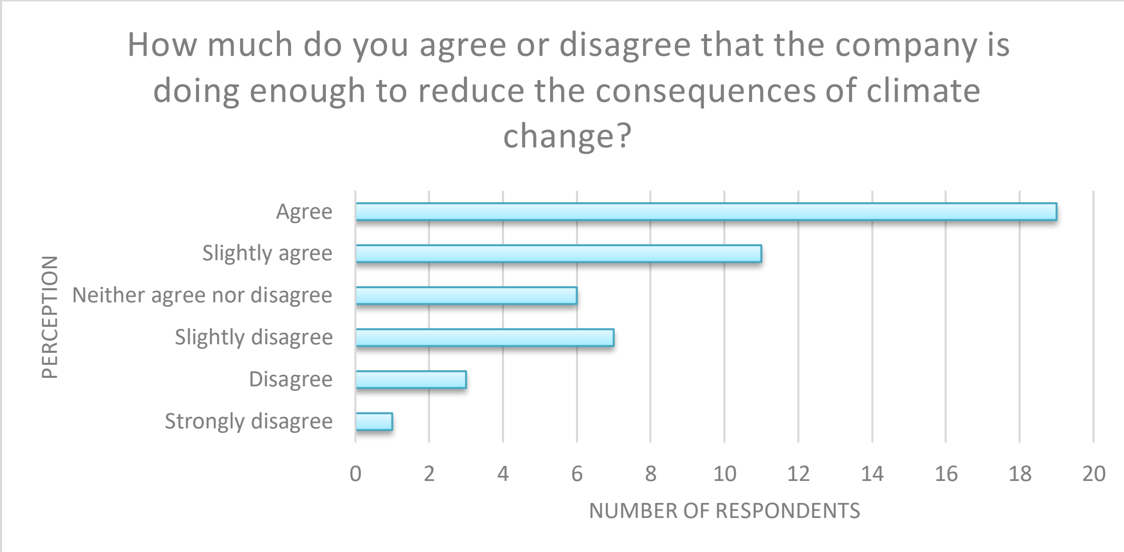

Figure 17: Perception that the company is doing enough to reduce the consequences of climate change.

There was a question about the company's action in reducing the consequences of climate change. From Figure 17, we see that most of their responses were inclined to the agreement (including slightly agree and agree). But still, three respondents disagree, and one strongly disagrees that their company is doing enough to reduce the consequences of climate change showing that some actors believe the company's action is not enough.

4.3 Perception of the consequences of climate change can have positive impacts.

Perception of the consequences of climate change that can have positive impacts on the energy sector was studied by using reliability analysis followed by descriptive analysis. The climate factors considered for this question were – high outdoor temperature, increased precipitation, and varying wind conditions to contribute to the production and distribution of energy in a positive way.

A Cronbach analysis suggested just a moderate level of consistency, Cronbach alpha, a= 0.655.

The mean is 4.05 in a sample of 48 on a 7-point Likert scale representing that the respondent stakeholders in Norwegian Energy sectors perceive that there are some positive consequences on the energy system but very slightly and not convincingly. More respondents perceive that Increased hydropower production can positively impact energy systems, while on average, they neither agree nor disagree that increased bioenergy, increased wind power, and reduced energy use will positively change energy systems. Also, (See Figure 18) they disagree that the strengthened security of supply for electricity will have positive impacts on energy systems.

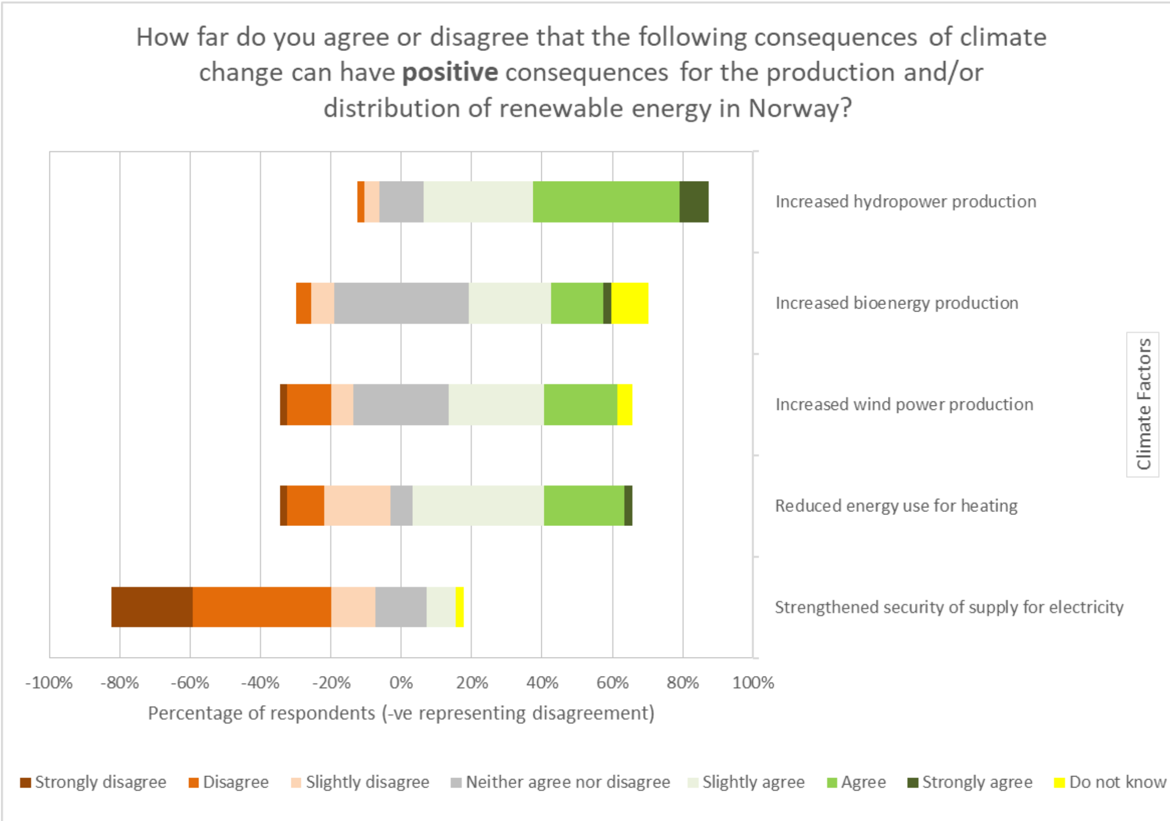

Figure 18: Consequences of climate factors as positive impacts on the production and distribution subsector of renewable energy sectors in Norway

Furthermore, inferential analysis was needed to see if production and distribution sectors have different perceptions of climate factors that can have positive consequences. So, the Normality test was performed to assess the normal distribution of data and find the right test to interpret the results. The normality test shows that the data might follow a normal distribution. However, significance 0.233 ($p > 0.05$) suggests there is no convincing evidence to reject the assumption of normality.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PCR_Climate factors positive	.105	48	.200*	.969	48	.233

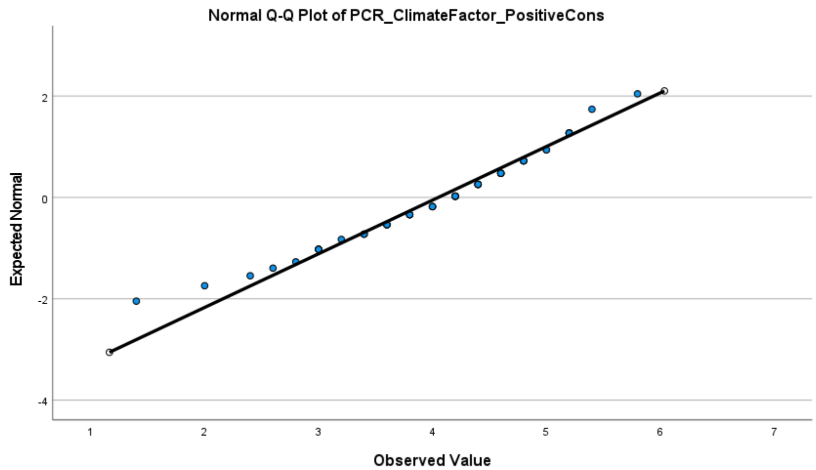

Figure 19: Q-Q plot- Perception of climate risk: Climate factor positive consequences on energy systems in Norway

The Q-Q plot followed the diagonal line, which shows that the data are normally distributed. The observed quantiles align well with the expected quantiles from the theoretical distribution.

As the data was Normally distributed, an ANOVA test was performed to figure out whether there are significant differences between groups (producers and distributors).

ANOVA- PCR_ClimateFactors_PostiveConsequences_EnergySector

PCR_CF_P

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.185	2	.093	.098	.907
Within Groups	41.752	44	.949		
Total	41.937	46			

Groups: Energy Sector (Production and Distribution)

Table 4: ANOVA test between energy sector groups.

In this case, p- value= 0.907 is greater than the significance level of 0.05, showing no significant difference between the actors in the production and distribution sectors on perception that the climate change will have positive consequences on energy sectors.

4.4 Perception of climate factors as determinant of negative consequences of climate change on the energy sector

To analyse the perception of actors in the Norwegian energy sector towards negative consequences on the energy sector, we asked about specific climate factors, such as increased incidence of extreme precipitation, reduced precipitation in the form of rain at sometimes of year, the reduced annual amount of snow, increased flooding, increased landslides and avalanches, more storm surge, more icing on power lines, more lightning and thunder, increased humidity, and sea level rise were considered.

A Cronbach alpha, a= 0.86, suggested a prominent level of internal consistency among the factors, and the responses used to analyse the perception towards negative consequences of climate change on the production and distribution subsector of the renewable energy sector were exceptionally reliable for further analysis.

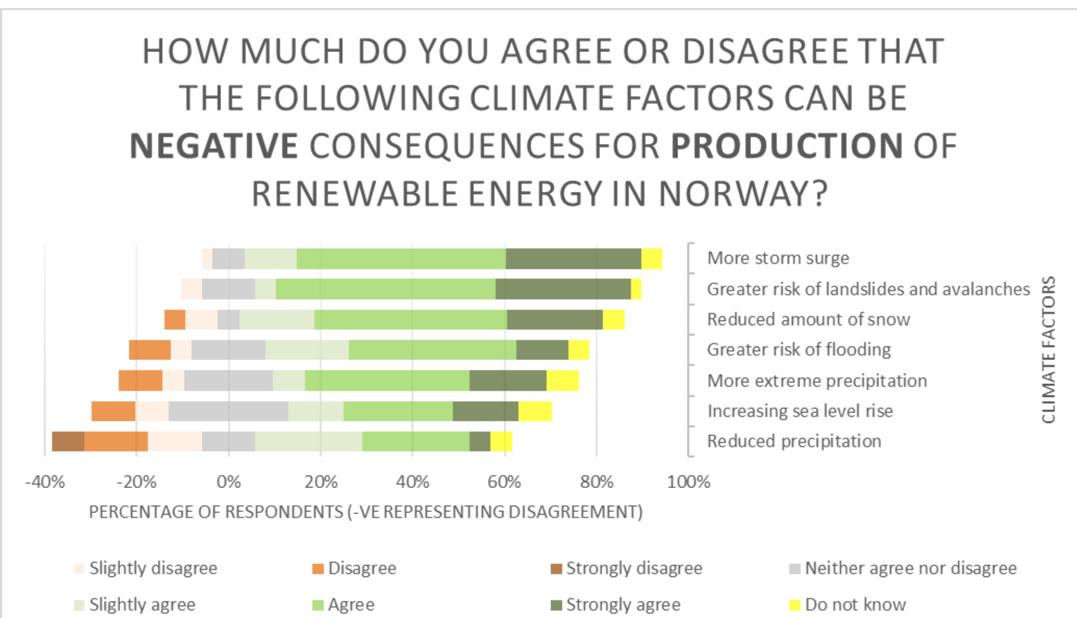

Figure 20: Consequences of climate factors as negative impacts on the Production subsector of renewable energy sectors in Norway

From Figure 20 above, we see that most of them agree that the stated climate factors will have negative consequences on the production subsector of renewable energy. Among different climate factors, more storm surges and greater risk of flood and landslides are perceived to have the most negative impacts on production. This might be because these climate factors are mostly responsible for causing physical harm to the production of hydropower and wind power sectors as well as their infrastructures. Yet, the reasons are to be explored.

To gain more insights, a normality test was performed. From the Shapiro- Wilk test, p-value 0-001 is below the significance level of 0.05 showing against the null hypothesis of normality and suggests that the distribution is significantly different from a normal distribution.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PCR_CF_N_P	.147	42	.023	.838	42	<.001

a. Lilliefors Significance Correction

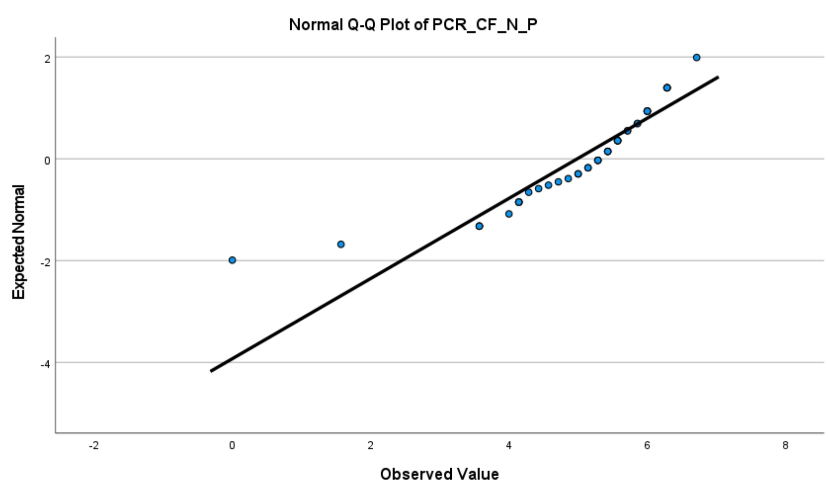

Figure 21: Q-Q plot- Perception of climate risk: Climate factor negative consequences on the Production subsector of renewable energy in Norway

Also, the Q-Q plot suggests the upper U-curve suggesting that the data is not normally distributed. The expected Normal line and observed value do not align on the slope. Thus, the normality test suggests that nonparametric tests can be done to further analyse the data.

An Independent sample test was performed on the energy sector category: Production and distribution.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of PCR_CF_N_P is the same across categories of Energy sector category.	Independent-Samples Kruskal-Wallis Test	.184	Retain the null hypothesis.

[a] The significance level is .050.

[b] Asymptotic significance is displayed.

Table 5: Independent sample test- Climate factors that have negative consequences on the Production subsector of renewable energy in Norway.

Null Hypothesis, H_0: The distribution of perception of climate risk, with climate factors having negative consequences on production is the same across the participants from the production and distribution sectors. p=0.184 is greater than the significance level of 0.05 So, it retains the null hypothesis.

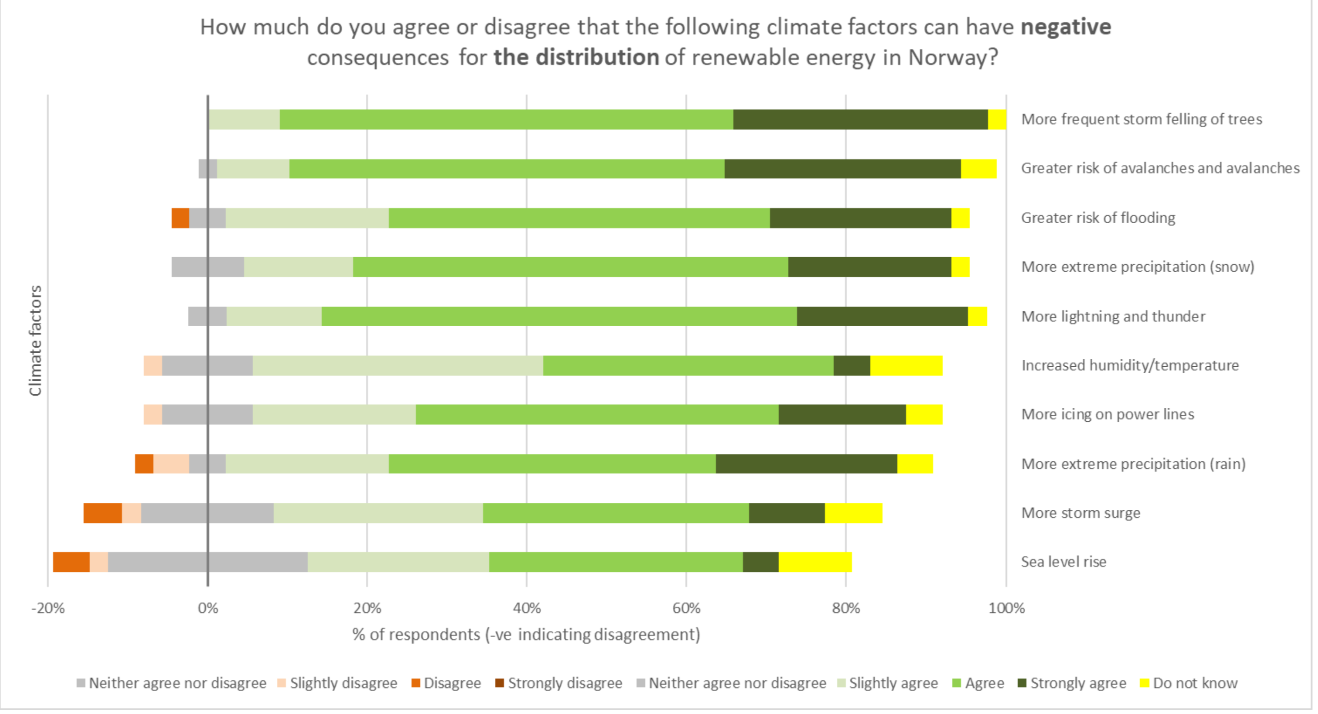

Figure 22: Consequences of climate factors as negative impacts on the Distribution subsector of renewable energy sectors in Norway

Similarly, the analysis of the perception of climate change that can have negative consequences in the case of the distribution sector shows that most of the participants agree that the climate factors with extreme weather conditions will have negative consequences on the distribution infrastructures of the renewable energy sector (See Figure 22).

Also, the mean value of all the factors was more than 4.5 which shows that on average participants agreed that these factors will have negative consequences on the distribution subsector of renewable energy. The mean value of more frequent storms falling down the trees 6.09 suggests that all the participants believe that this weather condition will affect the distribution lines adversely.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Statistic
More extreme precipitation (rain)	44	.00	7.00	5.4318	1.66213
More extreme precipitation (snow)	44	.00	7.00	5.7500	1.22237
Greater risk of flooding	44	.00	7.00	5.7045	1.32208
Greater risk of landslides and avalanches	44	.00	7.00	5.8864	1.46614
More storm surge	42	.00	7.00	4.8095	1.79753
Increasing sea level rise	44	.00	7.00	4.5227	1.83618
More icing on power lines	44	.00	7.00	5.3864	1.52827
More frequent storm felling of trees	44	.00	7.00	6.0909	1.11685
More lightning and thunder	42	.00	7.00	5.8571	1.18056
Increased humidity/temperature regarding rot and material deterioration	44	.00	7.00	4.8409	1.75132

Table 6: Descriptive-Climate factors that can have negative consequences on the Distribution subsector of renewable energy sectors in Norway.

Further analysis of the Normality test suggested that the p-value of 0.001 is less than the significance level of 0.05, hence that the distribution is far from the Normal distribution.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PCR_CF_N_D	.249	40	<.001	.669	40	<.001

[a] Lilliefors Significance Correction

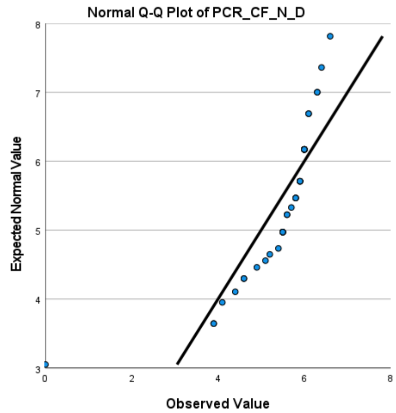

Figure 23: Q-Q Plot Climate Factors that can have negative consequences on the distribution sector.

An Independent sample test was performed on the energy sector category: Production and distribution.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of PCR_CF_N_D is the same across categories of Energy sector category.	Independent-Samples Kruskal-Wallis Test	.296	Retain the null hypothesis.

[a] The significance level is .050.

[b] Asymptotic significance is displayed.

Table 7: Independent sample test- Climate factors that have negative consequences on the distribution subsector of renewable energy in Norway.

Null Hypothesis, H_0: The distribution of perception of climate risk, with climate factors having negative consequences on distribution is the same across the participants from the production and distribution sectors.

p=0.296 is greater than the significance level of 0.05 So, it retains the null hypothesis.

4.5 Emphasis on societal factors as determinants of consequences of climate change in the energy sector

Analysis was done to understand the perception of actors on societal factors as determinants. The following societal factors were considered – resources for maintenance of the power grid, resources for upgrading the power grid, extent of domestic power demand, energy efficiency improvement, foreign power exchange, power demand, and different requirements from international and national bodies. A Cronbach analysis shows an elevated level of consistency, Cronbach alpha, a= 0.92. This indicates that the factors are measuring the same construct and are reliable for data analysis.

From Figure 24 below, on average the response is higher than the central value. Most of the participants responded that they agree with societal factors to be emphasized while looking at the consequences of climate change on renewable energy sectors in Norway.

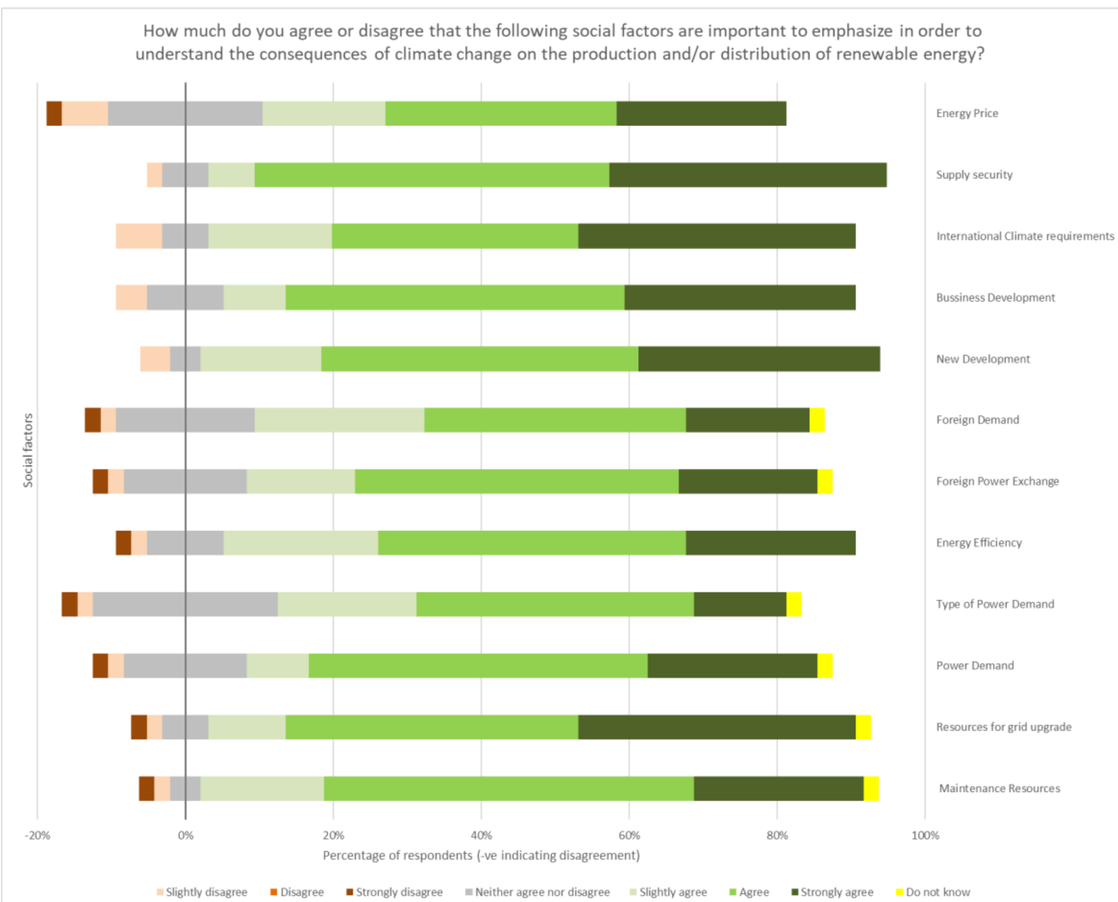

Figure 24: Societal factors that can determine the consequences of climate change on the renewable energy sector in Norway.

Supply security, new development, and international climate requirements are among the societal factors that most of the actors agree on as determinants. With a mean score of 5.65 and a standard deviation, on average, the respondents perceive that it is more important to consider the societal factors mentioned above to understand the consequences of climate change on the energy sector in Norway.

Further, the Normality test on the data shows a p-value of 0.001, less than the significance level of 0.05. The Q-Q plot shows that the expected normal value and observed value are differently aligned and hence not normally distributed (see Figure 25). It suggests that the data is highly skewed, and a non-parametric test can be done for a more conclusive analysis.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PCR_SF	.128	48	.047	.875	48	<.001

a. Lilliefors Significance Correction

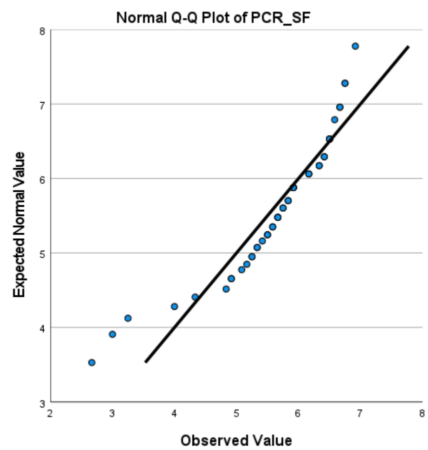

Figure 25: Q-Q Plot-Societal factors as determinant of the consequences of climate change on the production and/or Distribution subsector of renewable energy

For the non-parametric test, an independent sample test was performed on the energy sector category: Production and distribution.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of PCR_SF is the same across categories of Energy sector category.	Independent-Samples Kruskal-Wallis Test	.459	Retain the null hypothesis.

Energy sector category: Producers and distributors

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table 8: Kruskal- Wallis Test Independent sample test- Societal factor determines that climate change has consequences on energy.

Null Hypothesis, H_0: The distribution of perception -societal factors decide climate change consequences on the energy system is the same across the participants from the production and distribution sectors.

p=0.459 is greater than the significance level of 0.05 So, it retains the null hypothesis.

Additionally, responses to the perception of emphasis on climate factors versus societal factors show that more than half of the participants think they give equal importance to societal factors as well as climate factors when they assess the consequences of climate change on the production and/or distribution subsector of renewable energy (see Figure 26). However, three respondents think that they should emphasize only climate change and ten respondents give more weightage to emphasizing societal changes.

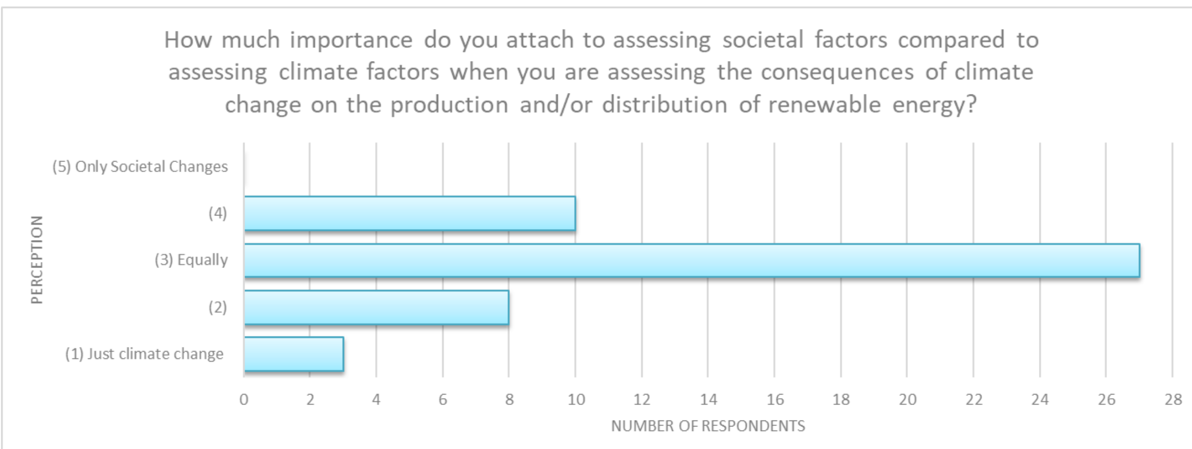

Figure 26: Weightage on Societal factor Vs Climate factor while assessing consequences of climate change on energy systems (N=48)

5 Discussion

The present discussion explores the findings of the analysed survey data about the climate risk perception among actors in the Norwegian renewable energy sector. The thesis aims to provide a comprehensive understanding of how climate change impacts and risks are perceived by key actors of mostly the production and distribution subsector of renewable energy in Norway. Most existing literature supplied the multidimensional nature of climate change impacts that include temperature rise, changing weather patterns, sea level rise, the occurrence of extreme events and their effects on the production of renewable energy, and physical risks on infrastructure. The discussion is based on the findings of the survey, and it supplies valuable insights into the diverse attitudes, and concerns of actors within the renewable energy sector.

Norwegian actors in the renewable energy sector have high concerns about climate risk.

The major finding is that the actors have a high degree of concern about the consequences of climate change in the renewable energy sector. It is clear from the analysis in Chapter 4.2 that more than 40% of participants believe it to have negative consequences. Also, most of the participants responded that they think Norwegian society notices the negative consequences of climate change now. As mentioned in IPCC, 2022, the data collected from around 1000 respondents per country for each year surveyed (European Commission, 2017) showed that more than 70% of them perceive that climate change is a profoundly severe problem. Like the study, most of them think that the Norwegian energy sector has noticed the effect of climate change on the energy sector now.

However, a recent study shows that the Norwegian actors in the Energy sector think that the consequences of climate change are not visible at present (Aall et al., 2022.) So, these results show quite the opposite in the risk. According to the literature review in Chapter 2.3, risk perception is highly influenced by subjective experiences. High energy prices, the war in Ukraine, and its ripple effects on the energy sector in Europe including the energy crisis, which included the experience from 2022 of the effect on renewable energy production of the coincident events of extreme weather events in Europe, drought in Norway, and less wind in the UK, can be a few possible reasons behind the change of perception among actors in Norwegian renewable energy sector. Perception of climate risks comes as a combination of direct experience, news and media sources, and societal construction (Akerlof et al., 2013). While if people have experienced any form of global warming, it heightens risk perception among people.

Even if the actors have shown concerns over climate change in energy sectors, 25 out of 48 participants shared their assessment time horizon to be in the next decade up to 2030. This shows that companies still have very short-term horizon-related beliefs or policies in companies to adapt to the future risk. Only nine participants with the 2071–2100-time horizon, and only one participant with the 2100 onwards time horizon show that most of the companies are just looking at the closest or initial few years that is until the 2050 timeline when assessing the consequences of climate factors on renewable energy. The attitude of actors in the energy sector and the action of the company has some gaps though.

Awareness of actors in the energy sector: one-dimensional (on just climate change) or two-dimensional (also on climate vulnerability, i.e., societal change)

More than half of the participants responded that they give equal importance to societal and climate factors when they assess climate risks. Climate change attitudes and risks are multidimensional and varied based on different individuals. These findings are consistent with the earlier research on climate change and coastal environmental risk perception in Florida (Carlton & Jacobson, 2013b; Devine-Wright & Howes, 2010).

As analysed in chapter 4.5, most of the participants responded that they agree towards societal factors to be emphasized while looking at the consequences of climate change on renewable energy sectors in Norway. Physical climate risk is defined as the sum effect of climate hazards, exposure, and vulnerability (Reisinger et al., 2020). The research findings also point out the importance of societal factors (climate vulnerabilities) while looking at the consequences of climate change on the energy sector. Supply security, resources for maintenance of the grid, and new resource development were identified as societal factors that determine climate change’s consequences on the energy sector. In alignment with the study on determinants and measurement of climate risk perception (S. van der Linden, 2017), societal factors were perceived as equal determinants of climate factors in driving risk perception.

No significant differences among actors in the production and distribution sub-sectors of the renewable energy sector regarding the perception of climate risk.

In addition to this, different actors in the renewable energy sector, production, and distribution do not have different thoughts about the overall consequences of climate change on the energy system. Both stakeholders have aligned attitudes on the overall consequences of climate change being negative on the energy sector in Norway. From the analysis in Chapter 4, there is no significant difference between the two groups in terms of their response. The perception of overall consequences on the energy sector does not significantly differ between the production and distribution categories of the energy sector in Norway.

Also, the ANOVA test indicates that there is no significant difference between the actors in the production sector and distribution sector of renewable energy in their belief that climate factors can have positive impacts on the energy sector.

Independent sample tests also presented that the distribution subsector of perception of climate risk, and societal factors influencing climate change consequences on energy systems is the same across the participants from the production and distribution sector.

Moving forward

According to NVE, Norway has a complicated energy system with the development of significant energy consumers and lately power grid sharing with Sweden, Finland, Denmark, and the rest of Europe. It is crucial to keep a power balance in the common power market and the effect of climate change as perceived by the actors in the renewable energy sector in Norway will highly influence the complex energy systems. It is however filled with uncertainties around the degree of influence of climate change on the common power market.

In addition to this, as the actors also perceive the negative impacts of climate factors like extreme weather conditions on infrastructures of production and distribution subsector of renewable energy, adaptation options like having warning systems in hydropower, monitoring forecast, and river flows, improving electricity interconnections as suggested by IPCC 2022 can be key solutions. Key climate Impacts and adaptation suggested by the ADB report (Asian Development Bank, 2012) like developing improved hydrological forecasting, analysis to estimate projected climate variation, design of robust dams for hydropower, increasing capacity of overhead lines for optimum wind speed, specify more effective cooling for substation and transformers, protect switch boxes and cables from wind and snow weight, increase decentralized energy generation and distribution, etc can be helpful for policymakers knowing that the stakeholders have a concern of climate risk on the renewable energy sector.

As climate change seems to be a huge area of concern to the actors in the Norwegian energy sector, risks, and uncertainties associated with climate change in the renewable energy sectors are going to grow and there exists a necessity for further assessment of their perceptions so that policymakers and stakeholders are well informed towards the decision for sustainable energy transition and come up with mitigating and adaptive measures.

6 Conclusion

In conclusion, this thesis has studied the attitudes, and actions of actors in the Norwegian renewable energy sector concerning climate change, climate risks, and climate change adaptation. The research findings discussed in this thesis have underlined the urgency for a comprehensive understanding of climate risk perception in the renewable energy sector. This study has provided insights into various aspects of risk, and societal and climate factors as determinants of climate risk perspective on the energy sector using a quantitative method. A matrix 7-point Likert scale was used in the survey to understand the multidimensional perspective on the attitudes of the stakeholders.

The results have shown that most actors agree that climate change has negative consequences on the energy sector. In earlier literature, the climate risk was not taken as positive. The difference in this research shows a better picture as this study presents quantitative data on their attitude.

The empirical data obtained for this study has shown that the climate risk perception among actors in the Norwegian renewable energy sector is diverse. Despite most of the stakeholders perceiving climate change as a serious threat to the energy sector now some actors believe climate change is a threat to the energy sector in Norway only after 20 years and more. This shows that certain stakeholders have a prominent level of understanding and concern about the threats associated with climate change, some displaying varied degrees of ambiguity. However, there is no significant difference in actors in the production and distribution of renewable energy areas about the overall consequences of climate change on energy systems.

Furthermore, this thesis has highlighted that stakeholders believe societal factors should be equally emphasized while evaluating the consequences of climate change on renewable energy sectors in Norway. Stakeholders may make informed decisions and create adaptable solutions to combat climate change by cultivating a greater understanding of climate factors and societal factors associated with the energy sector.

However, this thesis brings in the knowledge around extremely limited studies being done on understanding the attitudes of concerned stakeholders within the energy sector while the renewable energy sector is a key to addressing climate change and an undeniable factor in the energy transition in Norway. This thesis also points out the areas of extending research by adding more stakeholders to be part of the research as the sample size in this study n=48 can be a limitation of this study. Also, this thesis is based on the quantitative survey, interviews with the stakeholders, and different qualitative approaches that can bring more perspective to the conversation. Moreover, the complex nature of climate change demands the integration of diverse perspectives, skills, and resources. This can be achieved through collaborations among academia, industries, research institute, government agencies, and policymakers.

In conclusion, this thesis adds some information on climate change and risk perception in Norway’s renewable energy sector. It supplies valuable insights for policymakers and energy businesses by deepening the understanding of the climate factors and societal factors that shape climate risk perception. It is hoped that the findings and suggestions presented in this thesis will contribute to decision-making, support ongoing efforts to add a dimension to how different actors’ attitudes are shaped by different climate factors and address climate change challenges in the Norwegian renewable energy sector and beyond.

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Appendix

APPENDIX A: Survey questionnaire

What is the survey about?

We survey knowledge and views within the energy sector about how expected climate changes towards the year 2100 may affect the production and/or distribution of renewable energy in Norway.

The survey is limited to representatives of businesses that produce and distribute energy in Norway. By renewable energy, we mean energy produced from renewable sources (hydropower, wind power, solar energy, geothermal energy, tidal energy, or bioenergy); i.e. not energy from coal, oil, gas, waste, or nuclear power.

The survey is part of the research project "Creating sustainable renewable energy futures with low climate risks" (SusRenew) funded by the Norwegian Research Council and led by Vestlandsforsking. Projects start in 2023 and last until 2027. The *overarching research question* for SusRenew is: How can the Norwegian renewables sector achieve low-emission targets set by the Norwegian authorities in 2050 and at the same time make the energy system climate-robust?

We base it on the UN climate panel's understanding of the consequences of climate change as a cumulative effect of climate and societal conditions.

Background variables

1. What kind of company do you work for? Enter: ________________
2. What is your job title? Enter: __________________
3. What is your area of responsibility? (Can tick off multiple options):

Alternatives	Yes	No
Energy production		
Energy distribution		
Network provider		
Hydropower		
Wind power		
Other energy sources		
Operation/maintenance		
Planning		
Sale		
Information		
Marketing		
Strategy and management		
Sustainability		
Other (comment)		

SURVEY QUESTIONS:

4. When do you think that Norwegian society will seriously notice the negative consequences of climate change?

We notice them now	The next decade	In 20-50 years	In more than 50 years	Never

5. How far do you agree or disagree that the following consequences of climate change can have **positive** impacts on the production and/or distribution of renewable energy in Norway?

Categories	Strongly disagree	Disagree	Slightly disagree	Neither/ Nor	Slightly agree	Agree	Strongly agree	Do not know
Reduced energy use for heating due to higher outdoor temperatures in Norway								
Increased hydropower production due to increased precipitation								
Increased bioenergy production due to more favourable growing conditions								
Increased wind power production due to more favourable wind conditions								

Improved security of supply for electricity due to generally more favourable climate conditions								
Other suggestions (open field): ____________								

Climate factors that can determine the consequences of climate change:

6. How much do you agree or disagree that the following climate factors can be negative consequences for the production of renewable energy in Norway? If the question is not relevant to your expertise, you can jump down to question 7, which is about distribution. You are welcome to answer both questions (6 and 7)

Climate factors.	Strongly disagree	Disagree	Slightly disagree	Neither/ Nor	Slightly agree	Agree	Strongly agree	Do not know
Extreme precipitation								
Reduced precipitation								
Reduced amount of snow								
Flood risk								
Risk of landslides and avalanches								
Storm surge								
Sea level rise								

Other suggestions (open field):								

7. How much do you agree or disagree that the following climate factors can have negative consequences for the distribution of renewable energy in Norway? If the question is not relevant to your competence, you only need to answer question 6. You are welcome to answer both (6 and 7).

Climate factors.	Strongly disagree	Disagree	Slightly disagree	Neither/ Nor	Slightly agree	Agree	Strongly agree	Do not know
Extreme precipitation (rain)								
Extreme precipitation (snow)								
Greater risk of Flooding								
Greater risk of landslides and avalanches								
More storm surge								
Sea level rise								
More icing on power lines								
More frequent storm felling of trees								
More lightning and thunder								
Increased humidity/temperature								

regarding rot and material deterioration								
Other suggestions (open field):								

8. When your business assesses the consequences of climate factors on the production and distribution of renewable energy, what time horizon do you apply (tick, multiple ticks possible)?

The next decade up to 2030	2031-2050	2051-2070	2071-2100	2100 onwards

9. Societal factors that can determine the consequences of climate change: How much do you agree or disagree that the following societal factors are important to emphasize to understand the consequences of climate change on the production and/or distribution of renewable energy?

Society factors	Strongly disagree	Disagree	Slightly disagree	Neither/ Nor	Slightly agree	Agree	Strongly agree	Do not know
Resources for maintenance of the power grid								
Resources for grid upgrades								
The extent of domestic power demand								

Type of domestic power demand (e.g. electricity versus bioenergy)								
Energy Efficiency among Norwegian power users								
Foreign power exchange								
Foreign power demand								
The authorities' environmental requirements for new power development								
The authorities' requirements for the security of the supply								
Norwegian Authorities' Requirements for business development								
International climate requirements								
The authorities' requirements for the price of energy								
Other community relationships you want to add:								

10. How much emphasis do you place on assessing societal factors (cf. the question above) compared to assessing climate factors (cf. questions 6 and 7) when assessing the consequences of climate change on the production and/or distribution of renewable energy?

1. Just climate change	(2)	(3) Equally	(4)	(5) Only societal changes

11. What do you think the overall consequences of climate change will be for the production and distribution of renewable energy in Norway in the future? The overall effect is likely to be:

Very negative	Negative	Neutral	Positive	Very positive	Do not know

12. To what extent do you agree or disagree that your company is doing enough to reduce the consequences of climate change?

Strongly disagree	Disagree	Slightly disagree	Neither/ Nor	Slightly agree	Agree	Strongly agree

APPENDIX B: Analysis Table

Descriptive Statistics

N	Statistic	48
Minimum	Statistic	2.00
Maximum	Statistic	6.00
Mean	Statistic	3.1250
Std. Deviation	Statistic	1.14157
Skewness	Statistic	.641
	Std. Error	.343

Test Statistics[a]

	What do you think the overall consequences of climate change will be for the production and distribution of renewable energy in Norway in the future? The overall effect will probably be:
Mann-Whitney U	218.000
Wilcoxon W	408.000
Z	-.494
Asymp. Sig. (2-tailed)	.622

a. Grouping Variable: Energy sector category

Table 9: Perception of overall consequences of climate change on the renewable energy sector in Norway (left), Mann-Whitney U test for Production and Distribution categories (right)

Reliability Statistics

Cronbach's Alpha	N of Items
.655	5

Table 10: Cronbach's Alpha test- Climate Factors as Determinants of positive consequences on energy systems

Reliability Statistics

Cronbach's Alpha	N of Items
.860	17

Table 11: Cronbach's Alpha test- Climate Factors as Determinants of negative consequences on energy systems

Reliability Statistics

Cronbach's Alpha	N of Items
.920	12

Table 12: Cronbach's Alpha test- Societal Factors as Determinants of Consequences on energy systems

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Statistic
Reduced energy use for heating due to higher outdoor temperature in Norway	48	1.00	7.00	4.4375	1.45728
Increased hydropower production due to increased precipitation	48	2.00	7.00	5.3125	1.07498
Increased bioenergy production due to more favorable growing conditions	48	.00	7.00	3.9583	1.77402
Increased wind power production due to more favorable wind conditions	48	.00	6.00	4.1458	1.59773
Strengthened security of supply for electricity due to generally more favorable climatic conditions	48	.00	5.00	2.3958	1.28394

Table 13: Climate factors that can have positive consequences for renewable energy sectors in Norway.

	N	Minimum	Maximum	Mean	Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Statistic
More extreme precipitation	43	.00	7.00	5.2791	1.77718
Reduced precipitation	43	.00	7.00	4.0465	1.92667
Reduced amount of snow	44	.00	7.00	4.8409	1.77768
Greater risk of flooding	44	.00	7.00	5.7500	1.41627
Greater risk of landslides and avalanches	44	.00	7.00	5.7045	1.57863
More storm surge	42	.00	7.00	4.7619	2.02195
Increasing sea level rise	42	.00	7.00	4.4762	1.95358 [1]

Table 14: Climate factors that can have negative consequences on the Production subsector of renewable energy sectors in Norway.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Statistic
More extreme precipitation (rain)	44	.00	7.00	5.4318	1.66213
More extreme precipitation (snow)	44	.00	7.00	5.7500	1.22237
Greater risk of flooding	44	.00	7.00	5.7045	1.32208
Greater risk of landslides and avalanches	44	.00	7.00	5.8864	1.46614
More storm surge	42	.00	7.00	4.8095	1.79753
Increasing sea level rise	44	.00	7.00	4.5227	1.83618
More icing on power lines	44	.00	7.00	5.3864	1.52827
More frequent storm felling of trees	44	.00	7.00	6.0909	1.11685
More lightning and thunder	42	.00	7.00	5.8571	1.18056
Increased humidity/temperature regarding rot and material deterioration	44	.00	7.00	4.8409	1.75132

Table 15: Climate factors that can have negative consequences on the Distribution subsector of renewable energy sectors in Norway.

[1] There were four subjective responses that were not relevant, so it was not included in the analysis Table 14