Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Geography

Kristine Katherine Bly

# Enhancing Adaptive Capacity and Resiliency to Glacier Change in Vestland County

Master's thesis in Natural Resources Management
Supervisor: Haakon Lein
Co-supervisor: Irina Rogozhina
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Kunnskap for en bedre verden

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# ABSTRACT

Glacier environments are highly susceptible to the effects of climate change. After glacial advancement during the 1990s, glaciers in Western Norway have retreated at an alarming rate. Glacier loss has an impact on downstream communities and the environment due to changes in water supply, flow regime, and the frequency and magnitude of natural hazards. Subsequently, it also affects those who rely on melt water for hydropower, agriculture, and recreation. In addition to impacting business operations, glacier retreat has profound implications on local identity and culture. As it is widely acknowledged that climate change will continue to have an influence on social and natural systems, it is critical to identify the variables that shape vulnerability.

Building from previous works on vulnerability, this thesis creates and applies the *Localized Social Vulnerability Framework* (LSVF) to identify vulnerabilities and adaptive capacities of local actors experiencing glacial change in six municipalities within Western Norway. The purpose of the LSVF is to examine the four factors driving vulnerability: the environmental impact of glacier change, perceptions, economies and livelihoods, and bridges and barriers to adaptive capacities. This study identifies several factors driving climate vulnerability, including political unwillingness, information and knowledge gaps, and resource limitations. However, there are also clear examples of local actors using adaptive capacities to enhance resilience. This study emphasizes the role of *place* in addressing vulnerability to build climate resilience. Specifically, while glacier melt threatens identity and livelihood, it also has the capacity to mobilize actors to protect their communities from climate impacts. This suggests the importance and complexity of place when investigating the vulnerability of communities experiencing environmental loss.

# SAMMENDRAG

Isbreer og deres miljø er veldig sårbare til effekene av klimaendringene. Etter en kort periode på 1990-tallet hvor isbreene vokste har breene på Vestlandet i Norge trukket seg tilbake i en alarmerende hastighet. Smeltingen av isbreer har påvirker samfunn miljøet i dalene nedenfor da det har en effekt på vanntilførsel, elveløp, frekvensen og mengden natur katastrofer. Dessuten påvirker det de som er avhengige av smeltevann for vannkraft, jordbruk og friluftsliv. I tillegg til næringslivet har tibaketrekkingen av isbreer … konsekvenser for lokal identitet og kultur. At klimaendringene vil fortsette å påvirke det samfunnet og naturen er anerkjent i størrste annlennhet. Derfor er det essensielt å identifisere variablene som former samfunnets og naturens klimasårbarhet.

Basert på tidligere arbeider om sårbarhet ble et *Lokalisert Sosialt Sårbarhets Rammeverk* (LSVF engelsk) utviklet og anvendt i denne oppgaven. Rammeverket ble brukt for å identifisere sårbarheten og tilpasnings kapasiteten til lokale aktører i seks kommuner i Vestland Fylke som blir påvirket av bresmeltingen. Hensikten med LSVF er å undersøke de fire faktorene som driver sårbarhet: miljøpåvirkningen av bresmeltingen, sosiale oppfatninger, økonomi og levebrød, og muligheter og barrierer for tilpasnings kapasiteten. Denne studien har identifisert flere faktorer som driver klimasårbarheten, inkludert politisk uvilje, mangel på informasjon og kunnskap og limiterte ressurser. Likevel var det også klare eksempler på lokale aktører som brukte tilpasnings strategier for å øke motstandsdykigheten mot klimaendrigene. Den foreliggende studien tar for seg *steds* rollen ved å adressere klimasårbaheten for å bygge opp motstandsdyktighet. Mens bresmeltingen er en trussel for identiteten og levebrøded i de rammede kommunene, kan den også bidra til å mobilisere aktører til å beskytte samfunner fra effektene av klimaendringene. Dette understreker viktigheten og kompleksiteten av *sted* når det kommer til sårbarheten til kommunale samfunn som opplever tap av naturmiljøet.

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*To Patrick, Shadow, Belle & Daisy*

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# ABBREVIATIONS

**BEVI**- Built Environment Vulnerability

**CCCCVF**- Comprehensive Contextual Climate Change Vulnerability Framework

**GDP**- Gross Domestic Product

**GHG**- Greenhouse Gas

**GOTHECA**- Glacier Impacts on the Hydrological Systems in Europe and Central Asia

**LSVF**- Localized Social Vulnerability Framework

**ND-GAIN**- Notre Dame Global Adaptation Initiative

**NSD**- Norwegian Centre for Research Data

**NTNU**- Norwegian University of Science and Technology

**NVE**- Norwegian Water Resources and Energy Directorate

**SES**- Social Economic System

**SeVI**- Socioeconomic Vulnerability Index

**SoVI**- Social Vulnerability Index

**UiO**- University of Oslo

**WNRI**- Western Norway Research Institute

# 1 INTRODUCTION

Glacier environments are particularly vulnerable to the effects of climate change. Indeed, since 2000, glaciers have retreated at an alarming rate across the world (Motschmann et al., 2020). Glacial loss impacts downstream communities and the natural environment through changes to water availability, flow regime, and the frequency and magnitude of natural hazards (Motschmann et al., 2020; Jurt et al., 2015). In addition, glacial change impacts individuals who rely on melt water for drinking supplies, hydropower, agriculture, and leisure. Subsequently, changes to the physical environment often have profound cultural effects, since *place* is associated with individual or community identity (Raymond et al., 2010). Thus, the impact of glacier retreat extends beyond physical changes and influences livelihoods, economies, and culture. As it is generally accepted that the effects of climate change will continue to impact social and environmental systems, it is important to identify the factors which drive *vulnerability* (Ford et al., 2018). Specifically, vulnerability research seeks to identify *who*, *what*, *where*, *how*, and *why* communities are impacted by climatic changes (Ford et al., 2018). While vulnerability assesses the factors that make communities susceptible to adversity, *resiliency* refers to the process that links adaptive capacities following disruption (Ford et al., 2018; Norris et al., 2008). An important attribute of resiliency involves embracing change and the new socioeconomic opportunities that often follow. Investigating the vulnerabilities associated with glacier change on communities experiencing loss is critical for successful climate adaptation planning (Motschmann et al., 2020).

According to the *University of Notre Dame's Global Adaptation Initiative* (ND-GAIN), Norway has been ranked the least vulnerable to climate change since rankings began in 1995. This number one spot reflects Norway's favourable northern positioning, as well as the financial ability to respond to climatic impacts (ND-Gain, 2019). Despite being labelled the least vulnerable country to climate change, several adaptation challenges exist including political unwillingness, information and knowledge gaps, and resource limitations. Such adaptation challenges are amplified by notions of climate uncertainty, the invisibility of environmental impacts, and perceptions such as apathy and denial (Lehtonen et al., 2019; Norgaard, 2006; Brechin, 2003; Bulkeley, 2000). Moreover, while the effects of climate change remain largely invisible to many Norwegians, some communities are undergoing rapid environmental change. Specifically, for

individuals living in communities near glaciers, retreat is highly visible and impactful. While these challenges exist in some communities, there are also clear examples of local actors strengthening adaptive capacity and climate resilience. While glacier melt threatens identity and livelihood, it also has the capacity to mobilize actors to protect their communities from climate impacts. Ultimately, the relationship between *place* and climate resilience serves as a major theme throughout this research. Through a qualitative approach, this research investigates how adaptive capacities and resiliency are strengthened by local actors experiencing glacial change in Western Norway. Using a mixture of semi-structured interviews and questionnaire, actors from the following municipalities in Western Norway are included in this thesis research: Kvam, Kvinnherad, Luster, Sogndal, Stryn, and Ullensvang.

## 1.1 Research Motivation

Importantly, this thesis research is in collaboration with the *Glacier Impacts on the Hydrological Systems in Europe and Central Asia* (GOTHECA) project[1]. The aim of the GOTHECA project is to bridge physical and human geography to assess the effects of climate change on glacier systems and communities. Through a combination of qualitative and quantitative methods, this project aims to understand how glacierized regions can better adapt to the effects of climate change. To compliment previous GOTHECA research, I have intended to analyze vulnerability and resilience through a qualitative perspective. Significantly, this is the first GOTHECA project to investigate glacier change through a completely qualitative approach.

As melting glaciers are often represented in the media as a signifier of climate change, it was of personal interest to investigate how local communities are socially and economically affected by such changes. In addition to an interest in the social impacts of climate change, the reasons for conducting this thesis work were: (1) I believe a human geography approach to climate research is incredibly important for understanding *why* and *how* actors chose to react to environmental change; (2) There is a knowledge gap on how continued glacier retreat will impact tourism, hydropower, and agricultural activities in Norway; (3) I wanted to learn how communities are currently adapting to the effects of climate change. Specifically, through identifying and supporting current adaptive capacities, I believe climate resilience is strengthened. Because of this, it is with purpose that this research contributes to future research on climate vulnerability and

[1] Additional information on the GOTHECA project can be found online: https://www.gotheca.com/

resilience in Norway. While these three factors inspired my research, they were also the basis of my thesis questions.

## 1.2 Background on Research Sites

While several glaciated areas in Norway have retreated significantly in the past twenty-years, the municipalities surrounding Jostedalsbreen, Breheimen and Folgefonna National Parks in Vestland County were identified as key study-areas for a variety of reasons. Firstly, previous members of the GOTHECA team had already conducted fieldwork in these areas and established connections with key stakeholders, including NVE, Western Norway Research Institute (Vestlandsforksing) (WNRI), and Statkraft. For the GOTHECA team, these three National Parks were originally classified as areas of interest, since they contained some of the largest glaciers in Norway and Europe. Additionally, new GOTHECA projects in the same study areas were in the process of being established at the same time as this study, which allowed for collaboration during the research and interviewing process. Finally, through literature review, it became evident that many different groups of stakeholders living in the municipalities surrounding the three National Parks relied directly and indirectly on both, the glacier arms, and melt to sustain business operations. As the result of previous and ongoing research in relation to GOTHECA, and the availability of information regarding tourism, hydropower and agricultural operations occurring in Vestland County, the following municipalities were selected as study-sites: Kvam, Kvinnherad, Luster, Sogndal, Stryn, and Ullensvang.

Although several other municipalities within and outside of Vestland County were also identified as areas of interest, including Etne and Lom, conflicting schedules and the unavailability of participants did not permit for the research to be expanded to include these areas. Additionally, it would have been valuable to incorporate municipalities surrounding Jotunheimen into the scope of this study, but due to the time constraints of thesis submission, it was not feasible for this project.

Even though this study aimed to capture a general overview of how changes to the glaciated landscape was impacting key industries and the ability of actors to adapt to such changes, the findings of this research may not be representative of all actors living in this area. Likewise, as qualitative research is often intertwined with social constructionism, it should be noted that the findings in this thesis represented the best interpretation of the data—or the researcher's narrative.

Finally, while this research was situated in Vestland, some of the findings may be transferable to other Norwegian counties, and of interest to Norwegian climate policymakers.

## 1.3 Research Aim and Questions

Using a vulnerability framework, the aim of this research is to investigate how adaptive capacities and resiliency are strengthened by actors living in areas experiencing glacier change. For the purpose of this research, *glacier change* refers to any changes occurring in glacial landscapes. This includes melt, retreat, changes to the frequency and/or magnitude of natural hazards, and precipitation regimes. Building from O'Brien (2007) and Hopkins' (2015) vulnerability scholarship, this research developed and applied the *Localized Social Vulnerability Framework* (LSVF) to glacier change in Western Norway. Through applying the LSVF to glacier change in the six municipalities, the following three research questions are investigated:

1. How does glacier change influence vulnerability in Vestland County?
2. How are retreating glaciers affecting key industries, such as tourism, hydropower, and agriculture in Vestland County?
3. What are the adaptive capacities of actors in relation to glacial change in Vestland County?

## 1.4 Thesis Structure

The following thesis is organized by six chapters. The purpose of this Chapter was to provide context on the research topic, as well as introduce the aim and three research questions.

In Chapter 2, background detail on the six municipalities surrounding Jostedalsbreen, Breheimen, and Folgefonna National Parks are described.

The theoretical concepts and framework utilized during this research is the focus of Chapter 3. Important concepts include social vulnerability, adaptive capacities, and resiliency. While Hopkins' (2015) *Comprehensive Contextual Climate Change Vulnerability Framework* (CCCCVF) provides structure for assessing social vulnerability, it has been adapted and termed the *Localized Social Vulnerability Framework* (LSVF) to better encompass the aim of this thesis work.

In Chapter 4, the qualitative methods used to collect thesis data within the six municipalities is discussed. Specifically, the process of planning and conducting the interviews and online

questionnaire is described in detail. After explaining how data was collected, the data analysis process is reviewed. Finally, this chapter depicts the ethical considerations and limitations of this research.

In Chapter 5, the findings from the online interviews and questionnaire are organized by the four components of the LSVF. First, *the impact of glacial change* focuses on how local actors experience glacier melt and hazards. The following section, *perceptions of glacier change* is presented through two key themes: place attachment, and glacier melt as a signifier of global climate change. Additionally, the *economies and livelihoods* section examine how retreating glaciers are affecting the tourism, hydropower, and agricultural industries. The final section outlines the identified *bridges and barriers to adaptive* capacities. The *bridges* include refocusing the tourism paradox to lessen the carbon footprint of tourists, investing in new business ventures that are adaptable to the changing environment, and creating opportunities or networks for the co-creation of climate knowledge between the municipalities. Alternatively, the uneven dissemination of scientific information and resources, as well as the disconnect between national strategies and localized realities, are revealed as *barriers* impeding the adaptive capacity of local actors.

Finally, Chapter 6 is organized by the three research questions. The first section discusses how glacial melt can result in social and economic vulnerabilities. Afterwards, the impacts of glacier change on tourism, hydropower, and agriculture is assessed. As resilience involves embracing change, new economic opportunities for industry are also presented. In tandem with the third research question, this chapter emphasizes the role of local actors in establishing adaptation measures that can influence climate action at the national level. Finally, it ends with concluding remarks and suggestions for future research.

# 2 BACKGROUND

## 2.1 Introduction to Research Area

This chapter presents background information on the national parks and municipalities appliable to this research. Specifically, as the glaciers exist within and surrounding Jostedalsbreen, Breheimen, and Folgefonna National Parks, this chapter depicts the landscape and tourist activities associated with these three areas (Table 1). Importantly, background information on the municipalities of Luster, Stryn, Kvinnherad, Sogndal, Kvam, and Ullensvang is also provided (Table 2). While additional municipalities surround the Jostedalsbreen, Breheimen and Folgefonna glaciers, it was beyond the scope of this research to collect qualitative data on glacier change from informants living in all eleven municipalities.

## 2.2 National Parks

The following section presents an overview of the three National Parks relevant to this research. Specifically, this section describes the landscape and activities associated with Jostedalsbreen, Breheimen, and Folgefonna National Parks.

### 2.2.1. Jostedalsbreen National Park

Spread between Stryn, Sogndal, Jølster, and Luster Municipalities, Jostedalsbreen is the largest plateau glacier on mainland Europe (Norges nasjonalparker, 2022c). Jostedalsbreen contains approximately fifty glacier arms, including Nigardsbreen, Briksdalsbreen, and Bøyabreen. In 1991, Jostedalsbreen National Park was established to protect the natural assets and cultural landscape of the area. With over twenty-eight glacier arms extending over the edges, Jostedalsbreen National Park is located within Luster, Sogndal, Stryn, Sunnfjord, and Gloppen (Norges nasjonalparker, 2022c). Although half of the National Park is covered by ice, there are also mountains, lush u-shaped valleys, scree slopes, rivers, and waterfalls (Norges nasjonalparker, 2022c). The National Park features a variety of popular tourist destinations involving glacier and mountain activities, such as skiing and glacier hiking. Due to accessibility, Nigardsbreen Nature Reserve, bordering the National Park in Luster, is one of the most visited areas of the Jostedalsbreen glacier (Norges Nasjonalparker, 2022b). Briksdalsbreen, another popular outlet glacier located within the National Park, can be easily accessed by walking, or taking a “troll car”

up. Many glacier arms, including Nigardsbreen and Briksdalsbeen have retreated significantly since 2000 (Hart et al., 2011).

### 2.2.2. Breheimen National Park

Located between the municipalities of Luster, Lom, and Skjåk, Breheimen National Park was established in 2009 to protect the cultural landscape and biodiversity, including reindeer, wolverines, sparrows, and eagles (Norges nasjonalparker, 2022b). The landscape is characterized by glaciers, high mountains, and lush valleys. Tourist activities in the National Park involve hiking, skiing, climbing, and glacier walking. Two visitor centers are found within Breheimen National Park, including the Brehelm Centre, which is located between the National Park and Jostedalsbreen Glacier (Norges nasjonalparker, 2022b). This Center serves as the starting point for many tourist activities in the area.

### 2.2.3 Folgefonna National Park

Situated by the Hardangerfjord in Western Norway, Folgefonna National Park contains the Folgefonna glacier, mountains, fjord arms, valleys, and rivers. Specifically, Folgefonna consists of Midtfonna, Nordfonna, and Sørfonna, as well as several smaller glaciers (Norges nasjonalparker, 2022a). Located within Kvinnherad, Ullensvang and Etne Municiaplities, the National Park was established in 2005 to conserve the biodiversity, economic assets, and the cultural history of the area (Norges nasjonalparker, 2022a). Popular tourist activities involve kayaking, glacier guiding, and summer and winter skiing.

**Overview of National Parks**

| National Park | Area ($km^2$) | Municipalities | Year Established |
|---|---|---|---|
| **Jostedalsbreen** | 1, 314 | Luster, Stryn, Sogndal, Sunnfjord and Gloppen | 1991 |
| **Breheimen** | 1, 691 | Luster, Lom, and Skjåk | 2009 |
| **Folgefonna** | 545 | Kvinnherad, Ullensvang and Etne | 2005 |

**Table 1**: Provides an overview of the three National Parks applicable to this research (Norges nasjonalparker, 2022a).

## 2.3 Research Sites

To provide context on the research sites, this section aims to review the geography, nature, culture and economy of Vestland County and the municipalities of Luster, Sogndal, Stryn, Kvinnherad, Kvam and Ullensvang (Figure 1) (Larger version of map found in Appendix F).

### Map of Research Municipalities

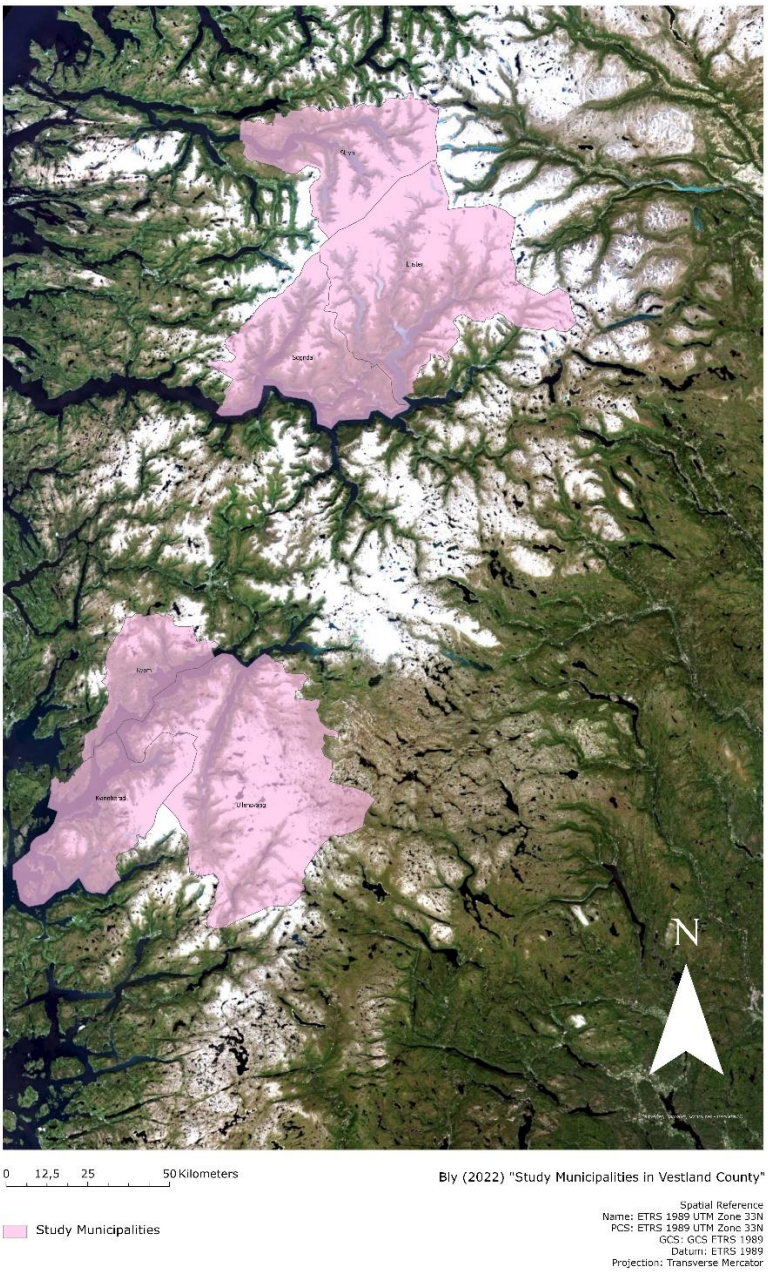


**Figure 1**. Depicts the six municipalities examined for this research.

### 2.3.1 Vestland County

Located in Western Norway, Vestland County is comprised of fourty-three municipalities with a population of approximately 630,000 residents (Vestlandfylke, 2020). While the County contains the second-largest city in Norway, Bergen, numerous small villages are scattered throughout the municipalities. The environmental surroundings comprise of fjords, glaciers, and waterfalls. Besides Jostedalsbreen, Breheimen, and Folgefonna, three additional National Parks are in the County: Jotunheimen, Hallingskarvet, and Handangervidda. (Vestlandfylke, 2020). The economy is reliant on the tourism, fishing and aquaculture, hydropower, aluminum, and agricultural sectors (Hisdal, 2021).

### 2.3.2 Study Municipalities

#### 2.3.2.1 Luster Municipality

Situated at the bottom of the Sognefjord, where Jostedalsbreen, Jotunheimen, and Breheimen National Parks meet is Luster Municipality (Saur, 2021b). Nigardsbreen, a popular glacier arm of Jostedalsbreen, is located within Luster. Although geographically it is one of the largest municipalities in Norway, there are only approximately 5000 inhabitants (Saur, 2021b). Despite the smaller population, there are a variety of public and private institutions within Luster and neighbouring Sogndal. These institutions include the Western Norway Research Institute (WNRI), University College, Norwegian Directorate for IT, and Administration of public roads (Saur, 2021b). Although farming, especially milk, meat, and fruit production was traditionally the primary source of income in Luster, tourism and hydropower have also become vital to the local economy. Specifically, to accommodate domestic and international tourists to the area, a variety of tourism-based businesses exist, including accommodation services, restaurants and cafes, and activity operations. Additionally, two large hydropower plants, *Statkraft Energi* and *Hydro Energi* located in Jostedal and Fortun respectively, generate a large amount of electricity from the glacial fed streams (Saur, 2021a).

#### 2.3.2.2 Sogndal Municipality

The landscape in Sogndal Municipality consists of glaciers, including the popular Bøyabreen glacier, valleys, fjords, and mountains. Since the 1970s, the population of the municipality has steadily increased, where over 12 000 inhabitants mainly reside in areas surrounding the towns of Leikanger, Kaupanger, Balestrand, and Fjærland (Skau, 2022). Important industries in Sogndal

include tourism, agriculture, food and beverage production, and to a smaller extent, hydropower. Tourism activities in Sogndal involve glacier walks, skiing, fjord cruises, and visiting the Kaupanger Stave Church. Moreover, agriculture in Sogndal includes cattle and sheep farming, as well as fruit production (Skau, 2022). The temperate climate allows for a variety of fruit, including berries, apples, apricots, and grapes to be cultivated in the area. While traditionally apricots and grapes could not be grown in Sogndal, the changing climate has allowed for the cultivation of new species (The Nordic Page, 2020). Because of this, *Slinde Vineyard*, the world's northernmost commercial vineyard is set to open in the municipality.

#### 2.3.2.3 Stryn Municipality

Twelve glacier arms, including the popular Briksdalsbreen glacier, connect Stryn Municipality to Jostedalsbreen. In addition to the glaciated environment, the landscape includes mountains, fjords, valleys, lakes, and waterfalls. While the population of permanent inhabitants is approximately 7, 200, this figure drastically increases during the tourist season. Indeed, Stryn is one of Vestland's leading tourism municipalities (Stryn Kommune, 2022). Tourist activities include glacier viewing and walking in Jostedalsbreen National Park, hiking, skiing, and the via ferrata in Leon. Another important industry in Stryn is agriculture, especially milk, livestock, and fruit production (Stryn Kommune, 2022).

#### 2.3.2.4 Kvinnherad Municipality

Situated alongside the Hardangerfjorden and near Folgefonna, Kvinnherad's landscape includes fjords, waterfalls, mountains, and glaciers. Approximately 13, 000 inhabitants reside in Kvinnherad, making it the largest municipality included in this research (Statistisk Sentralbyrå, 2021). While tourism is an important industry, the economy is also reliant on hydropower, including the *Jukla* and *Mauranger* power plants, agriculture, especially dairy cows and sheep, fish farming, and aluminum production (Kvinnherad Kommune, 2021). Popular tourist activities in Kvinnherad involve visiting Folgefonna National Park to partake in glacier or mountain related activities or visiting one of the ski resorts.

#### 2.3.2.5 Kvam Herad

Near the Folgefonna glacier and situated on both, the northern and western side of the Hardangerfjord, Kvam Municipality includes waterfalls, fjords, lush valleys, and mountains. While Kvam has the smallest surface area of the researched municipalities, it has a larger

population than Luster and Stryn, with approximately 8, 500 inhabitants (Kvam Kommune, 2022). In addition, Kvam is a popular place to own a cabin, as it hosts approximately 3000 vacation homes (Vest-Norges, 2017). Specifically, there are several ski resorts and cabins located on *Kvamskogen*, a mountain plateau in the Hardanger region. During the summer season, tourists visit Kvam to see Folgefonna, Steinsdalsfossen Waterfall, cultural landmarks, like the Hardanger Ship Preservation Centre, hike or partake in water activities (Visit Kvam, 2021). Moreover, the economy is also reliant on the agricultural sector, especially livestock and dairy production, as well as aluminum smelting and speedboat manufacturing (Vest-Norges, 2017).

#### 2.3.2.6 Ullensvang Municipality

Like Kvam and Kvinnherad, Ullensvang is also situated in the Hardanger region and consists of fjords, mountains, valleys, waterfalls, and glaciers, including the Buer Valley (Ullensvang Kommune, 2022). Ullensvang has the largest surface area of the six municipalities studied, and has a population of approximately 10, 900 inhabitants (Ullensvang Kommune, 2022). As a part of Folgefonna is located within Ullensvang, tourists visit the area to see the glacier, join a guided glacier hike, ice climb, or ski. Moreover, tourists can visit the summer ski resort to ski or snowboard. Other tourist activities include the fruit orchard trail, visiting the waterfalls in the Husedalen valley or hiking Trolltunga. In addition to tourism, fruit production, especially apples, cherries, plums, and pears is important to the local economy (Ullensvang Kommune, 2022). Other important industries in Ullensvang are fishing and aquaculture, as well as hydropower generation.

**Overview of Study Municipalities**

| Municipality | Area ($km^2$) | Population # (approx.) | Administrative Centre |
|---|---|---|---|
| **Luster** | 2, 700 | 5, 000 (Luster, Kommune, 2021b) | Gaupne |
| **Sogndal** | 1, 257 | 12, 069 (Sogndal Kommune, 2022) | Leikanger |
| **Stryn** | 1, 382 | 7, 207 (Stryn Kommune, 2022) | Stryn |
| **Kvinnherad** | 1, 090 | 13, 017 (Statistisk Sentralbyrå, 2021) | Rosendal |
| **Kvam Herad** | 617 | 8, 500 (Kvam Kommune, 2022) | Norheimsund |
| **Ullensvang** | 3, 236 | 10, 903 (Ullensvang Kommune, 2022) | Odda |

**Table 2**. Presents the surface area ($km^2$), approximate population, and administrative Centre of the six municipalities in Vestland County.

## 2.4 Chapter Summary

The purpose of this chapter was to provide context and describe the three National Parks and key elements of the research municipalities. Key elements, including the location, establishment details, and popular recreational activities, were described for Jostedalsbreen, Breheimen, and Folgefonna National Parks. Additionally, information regarding the geography, nature, local economy, and culture was presented for the municipalities of Luster, Sogndal, Stryn, Kvam, Kvinnherad and Ullensvang. In Chapter 5, the socioeconomic and environmental attributes of the national parks and six municipalities are further presented in relation to glacier change. In the following chapter, the theoretical concepts and framework applied to this research is presented.

# 3 THEORY

## 3.1 Introduction to Theory

This chapter provides an overview of the relevant theoretical concepts, as well as the framework used to organize the research findings. Within the context of climate change literature, this chapter frames *risk*, *hazard*, *adaptive capacity*, and *resiliency* in relation to *vulnerability*. While dichotomies exist within vulnerability research, this thesis is primarily concerned with a *social* perspective of vulnerability. Through adapting Hopkins' *Comprehensive Contextual Climate Change Vulnerability Framework* (CCCCVF), this thesis presents the *Localized Social Vulnerability Framework* (LSVF) as the theoretical framework and methodology.

## 3.2 Framing Vulnerability

Throughout climate change literature, the concept of *vulnerability* is used as a tool to explore the relationship between risk, hazard, and exposure (IPCC, 2014). According to the IPCC (2014), vulnerability is the "propensity or predisposition to be adversely or beneficially affected by climatic changes", where the concepts of *sensitivity* and *adaptive capacity* are explicitly linked. Moreover, *sensitivity* is conceptualized as the "degree to which a system is affected, either adversely or beneficially", whereas *adaptive capacity* involves the "potential of a system, region, or community to adapt" to climatic variability or change (IPCC, 2014). Central to the concept of vulnerability, *exposure* is the degree to which an entity is influenced by an event, process, or phenomenon (Costa & Kropp, 2012; Gallopín, 2006).

To expand beyond the IPCC definition, Gundersen et al. (2016) suggests that adaptive capacity includes the resources and *agency* of actors to successfully respond to climatic events, changes, and processes (p.2). Although a range of definitions exist, this research defines *agency* as an actor's ability to contribute to change by shaping systems or altering behaviour (O'Brien, 2015). Resources and capabilities can include a plethora of tools, including infrastructure, warning systems, policy, and education. Moreover, Berkes (2007) refers to adaptive capacity as the potential of actors to "influence or manage resilience" before change occurs (p. 287). As adaptive capacity entails the ability of communities to respond to change through utilizing available resources, it is a key social construct that can offset, preserve, or intensify risk exposure (Eriksen & Simon, 2016; Kim et al., 2021). Building from Gundersen et al. (2016) and Berkes (2007), this

research defines adaptive capacity as the agency of actors to manage or influence resilience before and after change occurs.

While the IPCC (2014) describes vulnerability in relation to the sensitivity and adaptability of a given system, *social vulnerability* focuses on the range of social and ecological conditions that prevent both, individual actors, and society from adapting to the inequitable impacts of climate change (Hopkins, 2015; O'Brien et al., 2007). The variables that influence social vulnerability range from individual characteristics, such as income, housing, age, race. Additionally, social vulnerability can also be influenced by attributes of regions or communities, including economics, governance, and laws and regulation (Holand et al., 2011). In the context of climate change, social vulnerability entails a multidimensional view of societal interactions, including the socioeconomics, culture, politics, technology and environmental variables of a particular place or area (Gundersen et. al., 2016; O'Brien et al., 2007). Indeed, social vulnerability directly concerns the issues that reduce adaptive capacity and resiliency to cope with climate change or hazards (Costa & Kropp, 2012). Thus, risks, vulnerability, and responses are not independent of wider social changes, but are instead understood in relation to the interactions between different scales, such as *core versus periphery* or *local versus national* (Gundersen et al., 2016). By identifying factors which drive vulnerability, adaptive capacities that enhance resilience can be integrated into existing policy. While many definitions exist, this research defines *vulnerability* as the social and environmental conditions that prevent actors and society from adapting to the effects of climate change (Hopkins, 2015; O'Brien et al., 2007).

## 3.3 Climate Resilience

Adaptive capacity is closely linked with *resiliency*. Turner et al. (2003) characterizes *resiliency* as the response attributes that relate to coping and adapting to climatic changes (p.8075). *Adaptation* is conceptualized as the decision-making process by which actors lessen the negative effects of climate change (Eriksen et al., 2011; Smit & Wandel, 2006). Closely linked to adaptation is *mitigation*, which is defined as any action to prevent or limit the impacts of climate change (Cutter et al., 2008). *Uncertainty* is a key element to adaptive capacity and resilience since the future effects of climate change are unpredictable (Berkes, 2007). However, according to Norris et al. (2008) a resilient society is one that identifies future vulnerabilities and prepares for climatic uncertainties. Thus, climate resilience is a "process" rather than an "outcome" of climatic

consequences (Bergstrand et al., 2015; Norris et al., 2008). Through climate adaptation, Bergstrand et al. (2015) suggests that resilient communities often "grow" by identifying new economic opportunities (p.393). Ultimately, embracing change is central to climate resilience (Bergstrand et al., 2015). For this research, *resilience* is defined as the process of using adaptive capacities to overcome the negative effects of climate change. Significantly, climate resilience includes a network of adaptive capacities, including learning and innovation, local knowledge, economic development, insurance schemes, information and communication, social trust, and place attachment (Amoako, 2018; Leykin et al., 2016; Djalante et al., 2011; Norris et al., 2008). These networks of adaptive capacities are explored in greater detail later in this chapter. The following section presents literature outlining the bridges and barriers to adaptive capacity and resiliency.

## 3.4 Bridges and Barriers to Adaptive Capacity

The adaptive capacity of an area can be assessed through identifying the factors that facilitated (*bridges*) or prevented (*barriers*) climate adaptations (Engle, 2012). Specifically, *bridges* to adaptive capacity are defined as the climate strategies used by local actors to promote resilience, whereas *barriers* are the obstacles that prevent society from adapting to the impacts of climate change (Aguiar et al., 2018). Bridges include community-led adaptation responses, innovative business solutions, and networks that promote knowledge capacity. According to Campos et al. (2016) and Wise et al. (2014) governmental authorities and municipal planners play a large role in promoting bridges to climate adaptation. Because of this, it is important for planners to understand how local conditions can act as barriers to implementing climate solutions (Campos et al., 2016). Barriers to adaptive capacity include the uneven distribution of resources between the cities (core) and remote areas (peripheries), information and knowledge divides, climate uncertainty, and the knowledge-action gap (Aguiar et al., 2018). In climate research, the *knowledge-action* gap refers to the disconnect between scientific information and political or social inaction (O'Brien, 2012). As *inaction* is an obvious barrier to adaptive capacity, several researchers have attempted to explain the knowledge-action gap through invisibility, climate apathy, information gaps, uncertainty, and denial (Lacroix et al., 2019; Lehtonen et al., 2019; Norgaard, 2006; Brechin, 2003; Bulkeley, 2000;).

While it is commonly accepted that knowledge is an important indicator in shaping how actors react to climate change, it is not necessarily clear how knowledge creates engagement (Ford &

Norgaard, 2020). The *invisibility of climate change* refers to how the effects of climate change are very *visible* to actors living in particular places, but largely *invisible* to outsiders living in areas that have not undergone significant change (Lehtonen et al., 2019). Specifically, actors who are directly affected by climate impacts, such as temperature or sea level rise, glacial melt or droughts, are more likely to acknowledge and implement adaptation solutions. Alternatively, those who are far-removed from such challenges, are less likely to change consumption habits or advocate for climate action. Thus, according to Ford & Norgaard (2020) what individuals "know" about climate change is not equal but "filtered through cultural systems assessed by lived experiences" (p.44).

While some authors have argued the effects of climate change remain largely invisible to the general-public due to *apathy*, the disinterest or concern for the inconvenient truths (Blennow & Persson, 2009), others have also suggested the role of *uncertainty* (Brechin, 2003). As it is unknown the extent to which climate change will affect society, politicians and segments of the public often cite uncertainty for inaction (Whitmarsh, 2011). Although it is challenging for the public to access reliable-scientific sources, which can shape apathy or uncertainty, it does not fully explain the knowledge-action gap. Admittedly, Lucas & Davidson (2018) argue the assumption that "public attitudes to climate change can be changed through access to scientific information" has been largely disputed (p.131). Norgaard (2006) demonstrates this through her observations in *Bygdaby*[2], a small village in Western Norway. According to Norgaard (2006), actors living in this village had access to scientific knowledge and were reportedly concerned about climate change. Despite this, actors remained non-responsive to climatic changes. Specifically, although it was suggested by Norgaard (2006) that climate change was visible in Bygdaby, local actors often regarded the effects of climate change as a distant problem. For instance, due to warmer temperatures and a late snowfall, the ski season was largely impacted, and ice fishing was impossible (pp.355-6). Norgaard termed this phenomenon *denial*, which is comprised of individual emotions, cultural norms, and political economy. Specifically, Norgaard refers to *denial* as inaction to information that may seem too difficult to transform into social action (p.352). Ultimately, the process of denial acts as a barrier to climate resilience.

[2] Fictional name

This section described vulnerability, adaptive capacity, resilience, and the bridges and barriers to climate adaptation. The following section defines risk and the identified hazards from this research.

## 3.5 Risk

Within vulnerability literature, several authors have defined risk within the external dimensions of vulnerability (Thomas et al., 2018; Gunderson et al., 2016; Hopkins, 2015; Costa & Kropp, 2012). Specifically, *risk* is the interaction between the likelihood of an event causing harm or loss and the relationship between nature and society (Thomas et al., 2018; Hurlbert & Gupta, 2015). Thomas et al. (2018) highlights the role of culture in shaping risk, since knowledge, previous experience, and values intersect as forms of response or adaptation (pp.8-9). Although culture is an important determinant in the production of risk, risk is also the effect of uncertainty, which is recognized as the incomplete knowledge on what is "known and knowable" (IPCC, 2014). In terms of what is knowable, it is important for actors to be aware of the risks. *Risk awareness* refers to identifying and mitigating threats or hazards (Ivčević et al., 2020).

In the context of climate change, the IPCC's (2021) sixth assessment report (AR6) differentiates between *climate change impact risk* and *climate change response risk*. The IPCC (2021) conceptualizes climate *impact risk* as the potential for adverse effects for social-environmental systems in response to changing climatic conditions. The *social-environment system* (SES) is the larger unit of analysis and can include a population group, geographical region, or economic sector (Füssel, 2007; Gallopín, 2006). Moreover, the IPCC's (2021) definition of impact risk emphasizes the interaction between hazard, exposure, and vulnerability, while acknowledging the variety of values and worldviews that exist between different groups of actors. Alternatively, *response risk* is derived from the inadequate implementation of climate technology, policy, investments or the negative effects of trade-offs and system transitions (IPCC, 2021). While an adaptation strategy may benefit one particular group of actors, the impact of the solution may reduce the livelihood capacity of another group (Eriksen et al., 2011).

## 3.6 Hazard

*Hazard* refers to the potential occurrence of a physical event that can have an undesirable effect on social and environmental systems (IPCC, 2014). Additionally, Costa & Kropp (2012) suggest that hazards represent the function of "probability, predictability, extent, and intensity of the impact" on a region, community, or industry (p.5). However, a hazard only becomes a risk when the environment, people, property, or infrastructure are exposed to the phenomenon (Connelly et al., 2018). As such, snow and glacier related hazards are the result of natural processes, environmental degradation, and intentional human intervention (Leis & Kienberger, 2020). While previous incidents have enabled Norwegian society to better prepare for known risks, a key feature of hazards is their ability to exceed safety measures (Holand et al., 2011). Indeed, an event only becomes a disaster when society is unable to protect vulnerable groups from environmental change (Holand et al., 2011). The glacier related hazards relevant to this research include floods, glacial lake outburst floods (GLOFs), landslides, and wet and dry avalanches. The following section will describe these events in further detail.

### 3.6.1 Floods

*Flooding* occurs when a body of water is unable to be contained by banks, artificial walls, or drainage systems (Luino, 2016). In Western Norway, flooding often occurs after a period of excess snowmelt and rainfall (NVE, 2021). While flooding is a frequent and costly hazard in Norway that can cause significant damage to property, infrastructure and road networks, the phenomenon usually does not lead to the loss of life. Future climate change predictions for Western Norway indicate an increase in precipitation and surface run-off, which could result in floods occurring in greater frequency and magnitude (NCCS, 2017).

### 3.6.2 Glacial Lake Outburst Floods

The phenomenon of *glacial lake outburst flooding* (GLOF) or *Jökulhlaup*, is when a glacial dammed lake reaches a critical threshold and suddenly releases a large volume of sediment and water downstream (Røthe et al., 2019; Khanal et al., 2015). The effects of the flood can be devastating to downstream ecosystems and communities, since the excess water has the potential to destroy habitats, agricultural land and infrastructure, hydropower systems, and threaten human life (Engeset et al., 2005). Since the 18$^{th}$ century, Norway has recorded over twenty GLOF events, but with an increase in mean global temperature it is expected that glaciers across the country will

continue to melt and retreat (Røthe et al., 2019). As a result of increased melt and retreat, GLOFs may occur in greater magnitude and frequency. This can potentially lead to adverse environmental and societal impacts if mitigation and/or adaptation strategies are not in place. In Norway, current GLOF mitigation solutions aimed at reducing the risk of GLOFs include controlling the drainage water through hydropower systems and reservoirs or by creating artificial tunnels, where the water can be slowly released (NVE, 2017). *The Norwegian Water Resources and Energy Directorate* (NVE) is responsible for monitoring and detecting glacier lakes.

### 3.6.3 Landslide

*Landslides* are characterized as the movement of debris, rock, and other elements of the earth down a slope (Devoli et al., 2018). Landslides are often triggered by intense rainfall or snowmelt in mountainous landscapes. Worldwide, landslides pose a serious hazard, causing loss of life, damage to housing settlements, road networks, and other key infrastructure (Devoli et al., 2018). Moreover, in many countries, the frequency of landslides has increased due to population and industry expansion into landslide-prone areas (Devoli et al., 2018). Since 2013, NVE has managed a landslide forecasting and warning system at the national level to mitigate the risk landslides pose to communities and industry.

### 3.6.4 Avalanche

#### 3.6.4.1 Snow Avalanche

*Snow avalanches* are characterized as the interaction between terrain attributes, climatic conditions, and snowpack (Laute & Beylich, 2018). Specifically, snow avalanches are directly connected to the instability of snow cover, which is affected by wind conditions, intense precipitation, and temperature fluctuations (Abermann et al., 2019; Laute & Beylich, 2018). While peak avalanche season generally occurs during the spring season, snow avalanches in Norway can occur at any point from December to June (Laute & Beylich, 2018). Infrastructure, including houses and road connections are especially vulnerable to snow avalanche activity in Western Norway. Utilizing statistical analyzes, Laute & Beylich (2018) predicted an increase in snow avalanche activity along the western side of Jostedalsbreen glacier.

#### 3.6.4.2 Wet-Snow Avalanche

*Slushflows*, a type of wet snow avalanche, are recognized as the rapid mass movement of water-saturated snow, which is released when rain or snowmelt places increased pressure on the

snowpack (Abermann et al., 2019; Hestnes & Jaedicke, 2018). Slushflows are differentiated from other types of dry snow avalanches by their high-water content, low velocity, and flow pattern (Abermann et al., 2019; Hestnes, 1998) Predicting a slushflow avalanche is particularly difficult, as they are triggered spontaneously after rapid melting, rain-on-snow events, or a combination of both (Abermann et al., 2019). Although slushflows occur quite frequently during the autumn and winter in Norway, human activity has only been impacted seven times in the last century, and three times specifically in Western Norway (Hestnes & Jaedicks, 2018).

#### 3.6.4.3 Ice Avalanche or Icefall

*Ice avalanche* is described as the occasional release of fragile masses of ice, which can also include snow, rock, and water (Pralong & Funk, 2006). On the contrary, *icefall* is characterized as the release of smaller pieces of ice, where *calving* entails the shedding of large chunks of ice from a glacier edge (Pralong & Funk, 2006). The destabilization of ice masses are the result of ice and stresses within the fracture zone (Pralong & Funk, 2006). While catastrophic ice avalanches are rare, icefall can occur quite frequently within glaciated landscapes. Both ice avalanches and icefall can pose a major hazard to residents and tourists, and cause damage to infrastructure and transportation networks.

This section defined the hazards appliable to this research including GLOFs, flood events, landslide, avalanche, and icefall. Importantly, these hazards are further discussed in relation to the research municipalities in the Findings Chapter. The following section reviews how vulnerability is assessed within climate research. Additionally, the following section outlines how the *Localized Social Vulnerability Framework* (LSVF) is applied to the context of glacier change in Vestland.

## 3.7 Vulnerability in Climate Change Research

Vulnerability research and assessments began as a pathway to combine climate change impacts and adaptation solutions (Hopkins, 2015). Across spatial scales, theoretical and scientific framings of vulnerability have been applied to a wide range of biophysical, social, and economic contexts (Füssel, 2007). Füssel (2007) suggests four dimensions fundamental to assessing vulnerability: the identified threat or hazard, population group, consequence, and the timeframe (p.157). While vulnerability frameworks and assessments differ due to different scientific framings (quantitative, qualitative or both), the four mentioned dimensions are crucial to describing a vulnerable situation (Füssel, 2007; Metzger et al., 2005). Although this thesis utilized the *Localized Social Vulnerability Framework* (LSVF) to assess vulnerability in Vestland, it is important to note that other interpretations exist and can be complimentary to future research.

### 3.7.1 Alternative to Vulnerability Frameworks

A common approach to vulnerability is the *technical perspective*, which involves mapping and modeling the physical effects of natural hazards (Hopkins, 2015; McLaughlin & Dietz, 2008). As biophysical variables can be measured through GIS and remote sensing, this approach offers a quantifiable basis for measuring vulnerability (McLaughlin & Dietz, 2008). While it is imperative to understand how the physical environment is vulnerable to climate change, this approach often neglects to integrate the social or human components of vulnerability (Hopkins, 2015; McLaughlin & Dietz, 2008).

An alternative approach includes *outcome* or *end-point vulnerability*. According to the outcome vulnerability framework, vulnerability is determined by the adverse effects that exist after adaptation solutions have been implemented, where climate change is regarded as the root problem (Hopkins, 2015; Kelly & Adger, 2000). Through this lens, vulnerability is conceptualized as the *outcome*, where exposure and adaptive capacity are regarded as the *end-point* to moderate the effects of a hazard (Hopkins, 2015). However, such framing places heavy emphasis on the environmental and economic aspects, while excluding the social, cultural, and political attributes of vulnerability. Through this perspective, Hopkins (2015) argues that climate change vulnerability is presented as a "singular or group of events which can be characterized by monetary costs, mortality rates, and ecosystem damage", instead of a wider social issue that encompasses a range of non-quantifiable conditions or stressors (pg.111). Moreover, presenting vulnerability as the

outcome ignores the underlying causes of vulnerability, including the socioeconomic and geopolitical contexts (O'Brien et al., 2007).

#### 3.7.1.1 Quantifying Social Vulnerability in Norway

Cutter et al. (2003) uses the *Social Vulnerability Index* (SoVI) to statistically examine social sensitivity to natural hazards. The SoVI framework measures characteristics that reflect societal vulnerability to environmental threats. Indeed, this approach combines both, outcome, and contextual vulnerability to determine the vulnerability of a place. Two studies applied statistical analysis to social vulnerability in Norway. First, Groven et al. (2006) quantifies the social vulnerability of communities in Northern Norway. To expand on this study, Holand et al. (2011) integrates Cutter's et al. (2003) SoVi and Borden et al. (2007) categorization of social vulnerability and applies it to municipalities throughout Norway. In Holand's et al. statistical analysis, social vulnerability is conceptualized as two distinctive components: socioeconomic vulnerability and the built environment vulnerability. *Socioeconomic vulnerability* (SeVI) is recognized by factors such as living conditions, income level and population structure, whereas the *built environment vulnerability* (BEVI) includes factors like quality of infrastructure, population density, and amount of evacuation routes (Holand et a., 2011).

Although Holland et al. finds municipalities located in the northernmost parts of Norway the most vulnerable to climate change, the findings from the BEVI suggest that the most vulnerable groups live in urban areas and municipalities that are "far into fjord, way up in the valley, and far out in the coast (p.12)." Due to competing definitions of social vulnerability, Holand et al. results are not parallel to Groven et al. findings in Northern Norway. This suggests the complexity of competing definitions of social vulnerability, as well as which variables to include within a vulnerability model (Holand et al., 2011; O'Brien et al., 2007). While such assessments are useful in examining the overall vulnerability of an area, it neglects to account for the inequalities between groups that may heighten or diminish climate risk within a place. In response to approaches that aim to quantify social vulnerability, O'Brien et al. (2007) introduced the *contextual vulnerability framework.*

### 3.7.2 Contextual Vulnerability

O'Brien et al.'s (2007) *contextual vulnerability framework* reimagines vulnerability as the *starting-point,* where climate change variability, adaptation, and societal institutions interact with contextual conditions. *Contextual variables* involve the biophysical, technological, political, cultural, and socio-economics attributes of a defined area (O'Brien, 2007). Through this perspective, climate variability and social structures interact with the local factors that result in unequal risk exposure (Gunderson et al., 2016; O'Brien et al., 2007). In other words, a contextual approach involves investigating the local drivers that create vulnerabilities for different subsets of the population. By identifying the local drivers of vulnerability, O'Brien et al. (2007) suggests that communities can better plan and adapt to climatic impacts. To expand upon O'Brien et al.'s research on vulnerability, Hopkins (2015) creates a framework that aims to assess vulnerability through multiple scales. The following section explores Hopkins' framework in detail.

### 3.7.3 A Contextual Climate Change Vulnerability Framework

To gather a thorough, interdisciplinary understanding of climate change vulnerability, Hopkins (2015) devised the *Comprehensive Contextual Climate Change Vulnerability Framework* (CCCCVF) (Figure 2). Significantly, the CCCCVF aims to capture the wide range of variables that contribute to vulnerability (Hopkins, 2015). A distinctive feature of this assessment is *scalability*, as an industry, community, region, or country can be applied to the CCCCVF. Moreover, the CCCCVF examines the direct impacts, as well as the indirect impacts of internal and external stressors (Hopkins, 2015). Hopkins (2015) emphasizes that within the CCCCVF the "social, biophysical, economic, and political phases are not contained", but instead, "exist spatially and temporally" on an intersecting continuum (p.112). The purpose of this framework is to help inform industry and government policy on factors that can amplify or lessen climate vulnerability (Hopkins, 2015). The following section examines the three internal factors of the CCCCVF in detail.

## Comprehensive Contextual Climate Change Vulnerability Framework

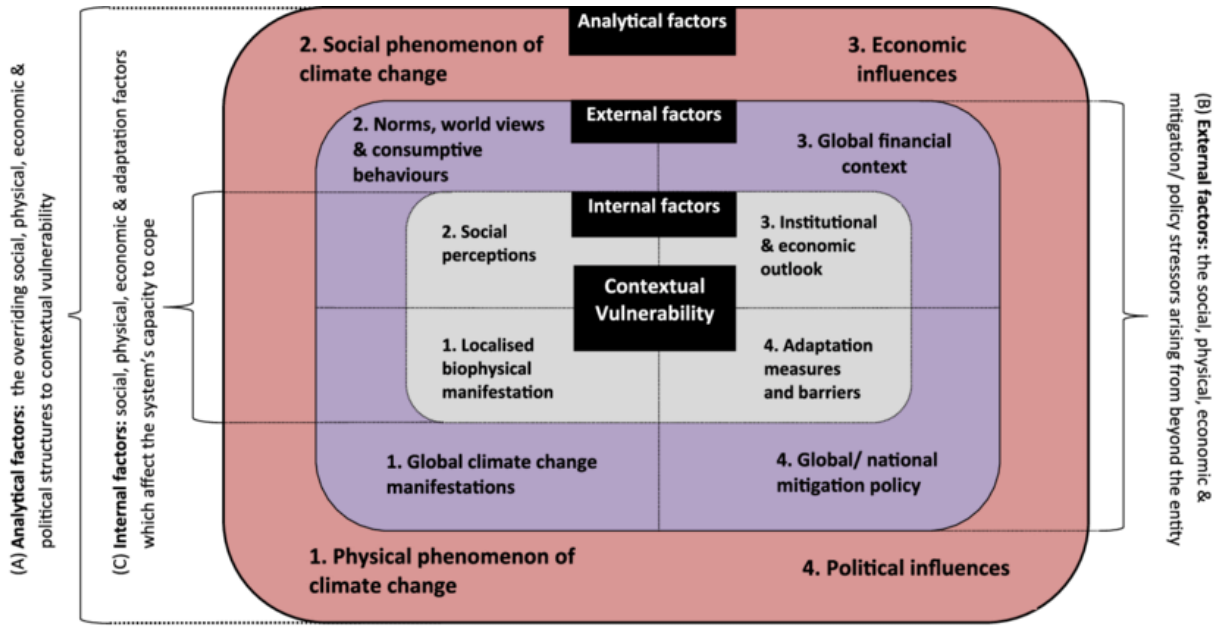


**Figure 2**. Showcases Hopkins' (2015) CCCCVF. The internal factors of contextual vulnerability are organized by analytical, external, and internal factors (p.113). Note: From D. Hopkins, 2015, A Comprehensive Contextual Climate Change Vulnerability Framework, *National Library of Medicine*, 44(2), p.113.

### 3.7.3.1 Analytical Factors (A)

Within the CCVF, the analytical factors include both, the physical and social phenomenon of change, as well as the overriding economic and political influences of contextual vulnerability (Hopkins, 2015). Hopkins (2015) refers to these four components as *overriding* or *broad scale*, since they provide the structure for temporal or spatial analysis. Specifically, the physical phenomenon involves the predicted or identified biophysical effects of climate change on the environment and society (Hopkins, 2015). This includes the direct and indirect impacts of climate change on the global and local scales. Subsequently, the social component is the individual and collective set of beliefs, values, and behaviors which determine understanding of climate change (Hopkins, 2015). While O'Brien's et al. (2007) contextual vulnerability framework combined the social and economic structures of change, Hopkins' (2015) CCVF separates the two interacting influences. Finally, the political influences entail the global, national, and local climate decisions made by governments to mitigate climate change. Thus, the analytical factors present climate

change as the interaction between the biophysical, social, political, and economic contexts (Hopkins, 2015).

#### 3.7.3.2 External Factors (B)

The external factors presented in the CCCCVF connect the analytical scale of analysis with the internal factors (Hopkins, 2015). Füssel (2007) and Hopkins (2015) refer to *external factors* as the stressors that a system is exposed to. Specifically, the external factors in the CCCCVF include global climate change manifestations; worldviews and consumptive behaviors; global financial context; and global/national adaptation policy. As nearly all components of a SES are driven by external factors, it is crucial to understand the factors driving adaptive capacity and vulnerability at the local level (Gundersen et al., 2016). For example, national policies which prioritize the implementation of adaptation solutions in the cities (core) may limit the adaptive capacity of actors living in rural areas (periphery). Moreover, climatic impacts, such as a drought in one region or country, can result in changes to local agricultural productivity in another area (Füssel, 2007). Thus, national decisions made in response to climate change have a direct impact on local communities.

#### 3.7.3.3 Internal Factors (C)

The internal factors within the CCCCVF include the contextual variables that contribute to vulnerability, adaptive capacity, and resilience at the local level. In particular, the internal factors or the *core* which contribute to contextual vulnerability include the *localized biophysical manifestation*, *social perceptions* (understandings), *institutional economic outlook*, and *adaptation measures* and *barriers* (Hopkins, 2015). Each aspect of the core is interacting, where the "complex interactions between the elements require attention" (Hopkins, 2015, p.113). In other words, each internal element *impacts* and is *impacted* by the other elements. For instance, if a change or hazard is not perceived as a threat to the local population, there may be reduced government incentive to invest and implement adaptation measures. Further, if there are costly additional social issues outside of the environmental consequence and limited funding, the ability to invest in new climate solutions may be lessened. Thus, in the context of the CCCCVF to accurately represent vulnerability, the agency of individual and group actors to integrate adaptive capacities must be presented (Hopkins, 2015).

### 3.7.4 Reframing the CCCCVF

Although contextual vulnerability frameworks aim to uncover what and who is vulnerable to climatic impacts, it is argued that the findings are often generalized and offer "multiple points of intervention" that cannot always be addressed (O'Brien et al., 2007, p.84). While this problem exists within some assessments, such arguments are often rooted in technical approaches to vulnerability, where adaptation solutions *only* include the implementation of physical structures to reduce hazard risk (Hopkins, 2015). For instance, while the implementation of technologies, such as structural changes to housing, elevated bridges, flood irrigation methods, and drought resistant seeds reduce risk for certain stakeholders, such adaptations also have the potential to negatively affect others (IPCC, 2021; O'Brien et al., 2007). As the effects of climate change are inequitably distributed between and within populations, a greater focus is required on the adaptive capacities that can mitigate those social differences (Hopkins, 2015).

Though a contextual framing may be regarded as contradictory to outcome framing within vulnerability assessments, this research emphasizes the need for cooperation and integration between the two perspectives. While Hopkins' framework is helpful in distinguishing between the external and internal variables that drive vulnerability, it may be more useful to simplify the framework. Specifically, the use of analytical factors in Hopkins' framework are overcomplicated, while failing to add any significant value to the assessment. In addition, although this research acknowledges that decisions at the global or national scale can drive vulnerability at the local level, it is overly complicated to assess all variables independently. Indeed, while the distinguishing element in the CCCCVF is scalability, examining multiple variables across three different spatial scales can create confusion and fail to present a point of entry to mitigate such vulnerabilities.

To conceptualize how glacier change can drive social vulnerability in Vestland County, this research simplifies Hopkins' CCCCVF by adjusting the scalability of the external and internal factors. Specifically, this modified framework is termed the *Localized Social Vulnerability Framework* (LSVF) (Figure 3). For the purpose of this research, the analytical factors are disregarded entirely from the framework. Although the external factors are removed from the LSVF, it is noted that they are discussed in relation to the internal factors. Moreover, the LSVF has modified the four factors of vulnerability to include: the environmental impact, perceptions, economies and livelihoods, and bridges and barriers to adaptive capacity. While the new

framework builds off the works of Hopkins' (2015) CCCCVF and O'Brien's et al. (2007) contextual vulnerability, it is adapted to the Norwegian context. Significantly, the LSVF assesses social vulnerability to glacier change through the presence of adaptative capacities and resiliency. The following section defines these four components in relation to the research in greater detail.

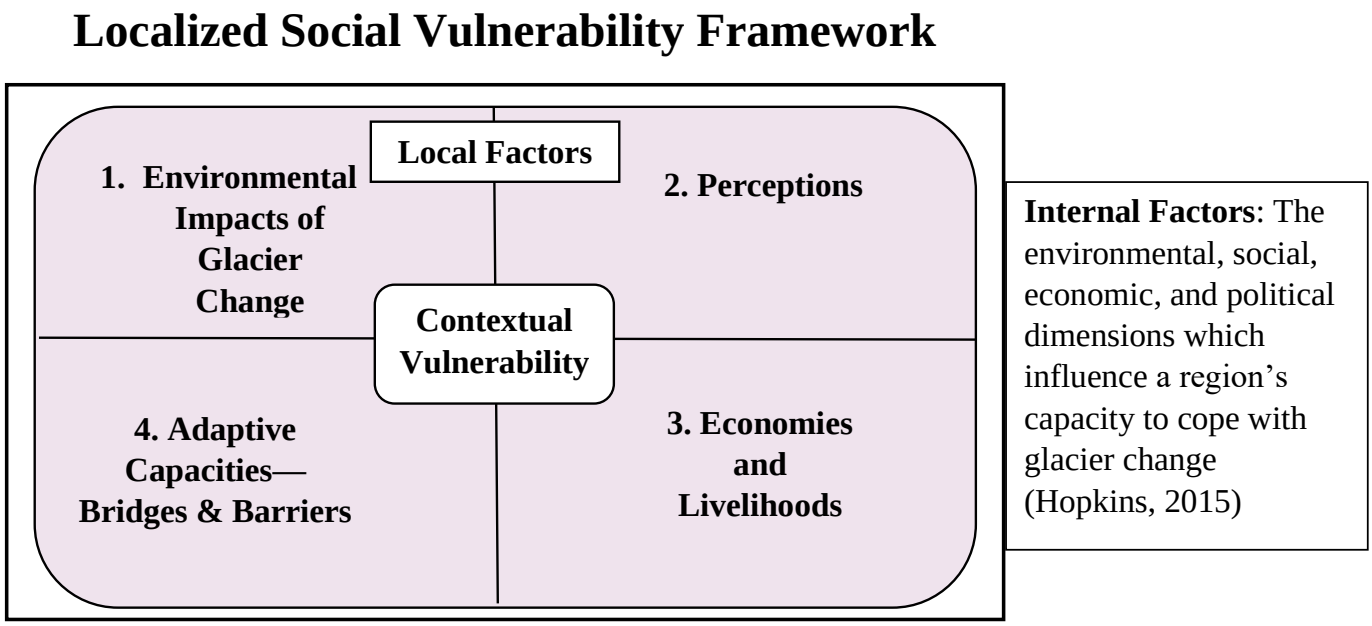


**Figure 3**. Depicts the *Localized Social Vulnerability Framework* (LSVF) adapted from Hopkins' (2015) CCCCVF for this research. The adapted vulnerability draws on the local factors of understanding climate change vulnerability. The local factors of social vulnerability include the environmental impacts of glacial change, perceptions, economies and livelihoods, and bridges and barriers to adaptive capacities. Note: Adapted by Bly (2022) from D. Hopkins, 2015, A Comprehensive Contextual Climate Change Vulnerability Framework, *National Library of Medicine*, 44(2), p.113.

### 3.7.5 Applying the LSVF to Glacier Change

For this research, the *environmental impacts* of glacier change refer to the consequences of melt or natural hazards on local actors. The purpose of examining the environmental impacts is to understand how local actors experience the impact of glacier change within their communities. An important theme when examining environmental change and vulnerability is *risk awareness*. While some authors do not differentiate between risk awareness and perception, this research is strictly defining awareness as hazard risk knowledge (Ivčević et al., 2020).

Subsequently, *perceptions* are defined as the interplay between held values, behaviours, and beliefs (Hopkins, 2015). Since perceptions influence vulnerability, it is important to analyze how local actors within the six municipalities perceive the impacts of glacial change. For this specific study,

*place attachment* and the *visibility/invisibility of climate change* are identified as two key perceptions of glacier change in the study areas. Importantly, place attachment is comprised of both, place identity, and place dependence. *Place identity* refers to the symbolic and cultural connections to *place* that define an individual or community (Raymond et al., 2010). *Place dependence* refers to the degree to which the physical environment supports an intended purpose (Raymond et al., 2010). On the other hand, the visibility/invisibility of climate change refers to how the effects of climate change are *visible* to actors living in certain landscapes, including mountain and glacial areas, but largely *invisible* to outsiders living in areas that have not undergone significant change (Lehtonen et al., 2019). Thus, glacier melt is represented as signifier of climate change for those who witness it.

*Economies and livelihoods* depict how key industries, such as tourism, hydropower, and agriculture are impacted by changes to the glaciated landscape. As climate change can result in new challenges and opportunities for local businesses, this research examines *how* and *if* these three sectors are vulnerable to glacier change. In addition, this research highlights the relationship between the adaptive capacity of these three sectors and their influence in promoting climate resilience. For the purpose of this research, the tourism industry refers to businesses that are dependent on domestic and international visitors to supplement income. Examples of businesses dependent on tourism activities in Vestland include airlines, food and beverage operations, accommodation services, such as cabins and hotels, souvenir shops, and transportation companies. Significantly, the *lifestyle entrepreneur*, actors who are motivated by living a certain lifestyle rather than maximizing profits, are influential in turning environmental challenges into new opportunities (Steiner & Atterton, 2015). The role of the lifestyle entrepreneur in climate adaptation is discussed in further detail in Chapter 5. Alternatively, the hydropower sector involves the actors who work for small- and large-scale hydropower plants. Connected to the hydro companies are the municipalities that rely on the benefit-sharing schemes to boost economic development. Finally, the agricultural industry includes the farms that surround the glaciers in the six municipalities.

Finally, *bridges* to adaptive capacity refer to climate strategies that promote resiliency, whereas *barriers* are the obstacles that prevent society from adapting to the effects of climate change (Aguiar et al., 2018). Specifically, bridges include community-led adaptation responses,

innovative business solutions, and networks that promote the co-creation of climate knowledge. Conversely, barriers to adaptive capacity include the inequitable distribution of resources between the core and periphery, knowledge gaps, and deeply held beliefs that influence how actors think and react to climate change (Aguiar et al., 2018).

It is important to note that even though the four factors of vulnerability are defined and applied independently in the following chapter, they are also interconnected. For instance, the perceptions of governmental authorities influence the climate decisions and policies they make. These decisions can ultimately act as a bridge or barrier to adaptive capacity and resiliency. Alternatively, the environmental impact of glacial melt can influence local economies and livelihoods, since changes to the environment can result in some operations going out of business, whereas others capitalize and take advantage of new opportunities. Nonetheless, the findings from the interviews and survey responses are organized by the LSVF's four components of internal vulnerability in Chapter 5.

## 3.8 Chapter Summary

In this chapter the concept of social vulnerability was discussed to present the need for a greater focus on the contextual variables that drive vulnerability. Additionally, the concepts of risk, hazard, adaptive capacity, and resiliency were defined within conceptual understandings of vulnerability. Moreover, this chapter reviewed the bridges and barriers to adaptive capacity through the notion of place attachment—identity and dependence. This chapter also reviewed Hopkins' (2015) *Comprehensive Contextual Climate Change Vulnerability Framework* (CCCCVF) to showcase the relationship between the external and internal factors in shaping vulnerability. While the CCCCVF is complimentary to quantifiable perspectives on climate change vulnerability, it attempts to assess too many variables over multiple scales. By modifying the CCCCVF, the *Localized Social Vulnerability Framework* (LSVF) was devised for this research. In Chapter 5, the LSVF is applied to the six municipalities in Vestland. However, first, Chapter 4 presents the methods used to plan, collect, and analyze the data for this research.

# 4 RESEARCH METHODS

## 4.1 Introduction to Research Methods

The following chapter reviews the qualitative methods used to prepare, collect, and analyze data from a wide range of participants living or working in Kvinnherad, Kvam, Luster, Stryn, Sogndal, and Ullensvang. Specifically, this chapter describes the process of planning and conducting the online interviews, as well as creating and distributing the online questionnaire. Moreover, this chapter discusses how the data from the interviews and survey responses were organized by themes and analyzed. Lastly, the ethical considerations, such as privacy, anonymity, and confidentiality, and the limitations of this study, including the COVID-19 pandemic and other cultural barriers are explained in detail.

## 4.2 Data Collection

The following section illustrates how the interviews were planned for and conducted during this research. While interview guides were developed during the planning phase, they were continuously adapted to better reflect participant knowledge and research aim. Additionally, designing, publishing, and distributing the online questionnaire to local actors living or working in the six municipalities is described.

### 4.2.1 Interview

An interview is defined as a verbal transaction to gather information or knowledge on a specific phenomenon (Dunn 2016; Jamshed, 2014). To gather qualitative data on the experiences and opinions of local stakeholders, physical and online interviews were arranged with a variety of key actors. To be selected for an interview, participants had to fulfill one or more of the following criteria: (1) lived or worked in one of the municipalities; (2) had insight on the tourism, hydropower, or agriculture sectors within one of the six selected study sites; (3) was at some point in time employed as a municipal or county worker within the study area; or (4) had expert knowledge on the glaciology or geology of Vestland County. As it was important to the research to include different intersections of the population in Vestland County, participants were selected based off stakeholder affiliation. For this research, identified stakeholder groups included: business owners, experts, farmers, municipality or county employees, and other local actors.

Importantly, the "Expert" group included individuals who specialized in glaciology, hydrology or had studied the effects of glacier change on industry or the local communities. For this study, experts included academic researchers employed at a university or research institute, and hydropower specialists who worked for NVE or a Norwegian hydro company. Moreover, the "Farmer" category included any actor who worked on a farm near a glacier in the study area. Further, the "Business Owner" group entailed any actor who owned a business in one of the six municipalities. The "Municipality or County Employee" group involved actors who worked for one of the six municipalities or Vestland County. Finally, the "Other Locals" group included any actor who lived or worked in one of the six municipalities. Noteworthy, while most participants were "local", those who did not work as a government employee, hydro expert, farmer, or business owner were categorized into this group.

To prepare for the interviews, a semi-structured interviewing method was utilized, where question guides were created for each stakeholder group. According to Dunn (2016), the purpose of initiating a semi-structured interview is to create flexibility and allow for participants to share ideas, while also being prepared to redirect the conversation to a new topic when desired (p.158). Throughout the course of the interviewing process, specific questions were reworked or changed to gain deeper insight into the perceived vulnerabilities and benefits of glacier change. For instance, the initial interview guides focused heavily on flooding and the potential consequences it had on stakeholder groups. However, it became evident that some of the questions did not incite participants to share opinions or experiences related to other forms of glacier change, including icefall and avalanches. To encompass diverse opinions on the benefits and consequences of glacier change that were of interest to this study, certain questions were simplified to be more open-ended[3].

#### 4.2.1.1 Interview Participants

During the participant selection process, a combination of convivence sampling, including criterion and snowball was utilized. *Convenience sampling* is a form of non-randomized selection of a target population due to accessibility, feasibility, or willingness to participate in the study (Etikan et al., 2016). As it was not feasible or logistically possible to physically visit the municipalities due to the Covid-19 pandemic, participants were selected by their willingness to be

[3] Interview Guides are found in the appendices.

interviewed. Specifically, *criterion sampling*, a purposeful selection method used to identify participants based off pre-defined criteria (Stratford & Bradshaw, 2016), was utilized to identify stakeholder groups relevant to the study. For this research, pre-determined criteria included actors involved in the business operations related to the glaciated landscape in the National Parks, as well as municipality officials who held positions related to climate planning and policy. In addition, through literature review, it became evident that other projects were also investigating Jostedalsbreen and the impact the glacier has on local society. Through this connection, experts investigating the societal impacts of glacial retreat on tourism, agriculture and hydropower were selected and interviewed for this research project.

Moreover, the *snowball sampling* method involved the recommendation of other potential informants who may be of interest to the study by current participants (Stratford & Bradshaw, 2016). According to Turner (2010), through snowball sampling and extending the research network, researchers can gain access to hard-to-reach populations (p.757). Snowball sampling was applied throughout the course of the research, as many participants shared the contact information of other relevant actors. For example, through snowball sampling, this thesis research was able to capture the perceptions of actors from a variety of different positions, including hydrologists working at a hydropower company, a Vestland County official, National Park workers, and a municipal natural resources manager. While some of these interviewees were identified as potential participants during the planning phase of data collection, this was not the case for all twenty interviews. Thus, snowball sampling played a crucial role in finding relevant participants for this study.

By using criterion and snowball sampling, a total of twenty participants were selected and interviewed for this study (Table 3). Due to Covid-19 and financial feasibility, twelve of the interviews were conducted digitally on *Teams* or *Zoom*. However, eight of the interviews were conducted physically in the study areas and held at participant place of work. Although twenty interviews were conducted, a total of fourty-five potential interview participants were contacted via email. Specifically, emails asking for participation in the study were sent out to local hydropower companies, all six municipality general email addresses, members of published farmer organizations, glacier guiding operations, hotel and camping businesses, museums, National Park employees, and ski and summer ski center companies. Information entailing the purpose and

specifics of the study, privacy, and anonymity rights, as well as how the information would be used by the researcher was also communicated to participants in the introductory email[4]. Because this research promised anonymity, participants were given fictional first names in Chapter 5. A list of the interviewees, including fictional name, job position, stakeholder affiliation, purpose of interview, gender, and date of interview is located on page 34 (Table 3). Additionally, as these populations were classified as-hard-reach due to distance, language barrier, and time constraints, the link to the online questionnaire was included within the email. Following participant consent to be interviewed and recorded, a blend of computer audio recording and note-taking was utilized during the interviews to facilitate future data analysis. Importantly, all meetings were voice recorded on Zoom or Teams and stored securely on the researcher's computer. Dependent on participant schedule and interest in the interview questions, the duration of the interviews varied between thirty minutes to an hour and fifteen minutes.

#### 4.2.1.2 Interview Guides

To ensure participants were asked questions that generated specific information relevant to the research, an interview guide was created prior to conducting the semi-structured interviews. As there were five identified stakeholder groups, a standardized open-ended interview guide was created for each group. While the questions asked often differed within and between stakeholder groups, all questions were organized by the following themes: background, risks, opportunities, and future. In addition, sub-themes were created to better encompass the differences in knowledge and experience between the stakeholder groups. For instance, sub-themes included: flooding and GLOFs, climate management, research and monitoring, the tourist experience, and mitigation technologies or policies. The relevant themes were presented to all participants in an email prior to the interview, as well as at the beginning of the interview session. In two instances, participants asked for the interview guide prior to the interview, which was promptly provided. The interview guides are found in the appendices (A, B, and C).

[4] NSD form is found in Appendix E.

| Subject Name (Fictional) | Subject Occupation | Online or Physical Interview | Sampling Method Cumulative or Snowball | Purpose of Interview | Gender | Date |
|---|---|---|---|---|---|---|
| **Øyvind** | Ski Business Owner | Physical | Cumulative | The purpose of this interview was to learn about how glacier change was affecting the ski and tourist industry. | M | 07/08/21 |
| **Freya** | Camping Business Owner | Physical | Cumulative | The purpose of this interview was to learn about how glacier change was affecting the camping and tourist industry. | F | 07/08/21 |
| **Nils** | Ski Business Owner | Physical | Cumulative | The Purpose of this interview was to learn about how glacier change was affecting the ski and tourist industry. | M | 07/08/21 |
| **Thor** | Farmer | Physical | Cumulative | The purpose of this interview was to learn about how glacier melt, recession and hazards were directly impacting farmers. | M | 10/09/21 |
| **Marius** | Farmer | Physical | Cumulative | The purpose of this interview was to learn about how glacier melt, recession and hazards were directly impacting farmers. | M | 10/09/21 |
| **Anders** | School Principal | Physical | Cumulative | The purpose of this interview was to gain insight into how local actors perceive glacial melt and hazards. | M | 10/09/21 |
| **Pia** | Teacher | Physical | Snowball | The purpose of this interview was to gain insight into how local actors perceive glacial melt and hazards. | F | 10/09/21 |
| **Jan** | Geologist | Physical | Cumulative | The purpose of this interview was to learn about how glacier melt was impacting the region. | M | 10/09/21 |
| **Jørund** | University Researcher | Online | Cumulative | The purpose of this interview was to learn about how glacier change could affect the tourism, hydropower, and agricultural sectors in the future. | M | 09/30/21 |
| **Birgit** | University Researcher | Online | Cumulative | The purpose of this interview was to gain insight into how glacial hazards and retreat impacts the tourism industry. | F | 01/10/21 |
| **Gerhard** | Glacier Guide | Online | Cumulative | The purpose of this interview was to gain insight into how glacier guides and other "lifestyle entrepreneurs" perceive glacier change and whether distinct signs of retreating are noticed within and between seasons. | M | 06/10/21 |
| **Cathrine** | Cryosphere Researcher | Online | Cumulative | The purpose of this interview was to learn what or who was at risk from glacier change and hazards in Vestland County. | F | 08/10/21 |
| **Tom & Rune** | Hydrologists | Online | Snowball | The purpose of this interview was to learn how hydropower companies prepare for hazards and future retreat. | M | 18/10/21 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Johan** | Science Advisor | Online | Snowball | The purpose of this interview was to learn about how institutions like the museum are educating people on glacier change and hazards, as well as how the local community is mitigating glacier risk. | M | 27/10/21 |
| **Live** | Natural Resources Manager | Online | Snowball | The purpose of this interview was to learn how municipalities within Vestland County were adapting to glacier change. | F | 01/11/21 |
| **Ola** | Glaciologist | Online | Snowball | The purpose of this interview was to gain insight into how hydropower could be impacted by glacier change in the future. | M | 10/11/21 |
| **Elin** | National Park Worker | Online | Snowball | The purpose of this interview was to gain information on the National Park management plan, tourism, natural hazards, and personal experience living in the area. | F | 23/11/21 |
| **Wida** | National Park Manager | Online | Snowball | The purpose of this interview was to gain information on the National Park management plan, tourism, natural hazards, and personal experience living in the area. | F | 24/11/21 |
| **Finn** | Municipality Planner | Online | Snowball | The purpose of this interview was to learn how municipalities within Vestland County were adapting to glacier change. | M | 25/11/21 |
| **Katie** | County Climate Advisor | Online | Snowball | The purpose of this interview was to gain information on climate change policy at the county-level. | F | 30/11/21 |

**Table 3**. Presents the participants interviewed during this research[5].

### 4.2.2 Questionnaire

In qualitative research, questionnaires are characterized as a set of predefined open or closed questions that relate to the research objectives of a particular study (McGuirk & O'Neill, 2016). For this study, a mixed method approach was utilized, where a structured online questionnaire was developed in addition to the semi-structured interviews. The purpose of the online questionnaire was to collect data among a larger subset of the population living in the six municipalities. The use and distribution of the questionnaire to actors living in the selected municipalities was especially important for this study, as it was an entry point for individuals who did not want to be interviewed due to the language barrier.

#### 4.2.2.1 Questionnaire Design

Before creating and publishing the online questionnaire, the intended respondent group was identified by reviewing literature on vulnerability, risk, and hazards. The criteria for participating

[5] Fictional names.

in the online questionnaire included living or working in one or more of the selected municipalities. To create an inclusive questionnaire that all locals could participate in, the survey was first, written in English, and then translated by a GOTHECA colleague and published in Norwegian. *Nettskjema*, an online data collection website, developed by the *University of Oslo* (UiO), was used to create the questionnaire. A link to the questionnaire was distributed to participants via email and social media. All questions included in the survey were voluntary.

The survey was available online from October 6th, 2021, to February 6th, 2022, and took approximately fifteen minutes to complete. In total, there were thirty-nine questions, where thirty-three were closed and six were open. As some questions were not applicable to all respondents, open questions following a "no" response would not appear. Before partaking in the questionnaire, participants were provided background information on the researcher, the study topic, and the overarching goals of the inquiry. Additionally, questionnaire participants were provided information regarding privacy and anonymity rights, as well as information on how to contact the *Norwegian Centre for Research Data* (NSD)[6]. Finally, all respondents had to provide consent to participate in the questionnaire before any of the questions appeared. In the event that questionnaire respondents wanted to be interviewed, there was an option to leave their email information. In total, seven respondents asked to be contacted for an interview. Inquiries were sent to all seven respondents, but only one questionnaire respondent was interviewed.

#### 4.2.2.2 Open and Closed Questions

According to Desai & Reimers (2018), *closed-ended questions* tend to require a single or "mouse-press" response, where respondents are given a limited selection of options to choose (p.1426). Although closed questions limit the participants' ability to respond in detail to all questions, they provide a general overview of participant attributes, opinions and experiences that are simple to code and analyze while interpreting the data (McGuirk & O'Neil, 2016; Harris & Brown, 2010). Because of this, closed-ended questions were created and utilized to gather qualitative information on respondent attributes, including residence municipality, occupation, age, and gender (Table 4). Closed questions were also used to attain information on hazards, where participants selected "yes" or "no" to experiencing an event, such as flooding. In the event that the participant selected "no" to an experience or belief, the subsequent open question asking participants to elaborate on the

[6] A copy of the NSD form is in the appendix.

topic would not be presented. Questionnaire responses to several closed-ended questions are presented as categorical and numerical data in Table 3. *Categorical data* refers to qualitative attributes of a particular group, such as occupation and gender (Salkind, 2010). Conversely, *numerical data* involves quantifiable traits like age or amount of time living in a certain location (Salkind, 2010). The purpose of using both approaches on the questionnaire was to gather important information on the respondents for data analysis.

On the contrary, *open-ended questions* are individually constructed, where respondents can provide detailed responses about a given phenomenon (Desai & Reimers, 2018). The purpose of open-ended questions is to provide a space for the coproduction of knowledge between the researcher and respondent (McGuirk & O'Neil, 2016). Within the online questionnaire, six open-ended questions were included. The open-ended questions asked respondents to provide their opinion on glacier change, comment on current climate mitigation and adaptation strategies within their local communities, detail future concerns, and if relevant, state any flooding grievances. Even though the open questions were time-consuming for participants to respond to, and the interpretation of the questions varied, the responses complimented the data collected during the semi-structured interviews. It is important to note that only certain questions from the questionnaire were used during the analysis of this study. This is primarily the result of broadening the research topic from natural hazards to glacial change.

## Questionnaire Respondent Attributes

| VARIABLE | FREQUENCY % |
|---|---|
| **Questionnaire respondents per municipality** | **86 (100%)** |
| Kvinnherad | 6 (7.0) |
| Ullensvang | 12 (14.0) |
| Stryn | 10 (11.6) |
| Luster | 35 (40.7) |
| Sogndal | 5 (5.8) |
| Kvam | 8 (9.3) |
| Other | 10 (11.6) |
| **Gender of Questionnaire Respondents** | **86 (100%)** |
| F | 47 (54.7) |
| M | 39 (45.3) |
| **Age of Questionnaire Respondents** | **86 (100%)** |
| 19-29 | 22 (20.9) |
| 30-39 | 12 (15.2) |
| 40-55 | 34 (39.5) |
| 55-66 | 15 (17.4) |
| 67+ | 3 (3.5) |
| Other | 4 (3.5) |
| **Occupation** | **86 (100%)** |
| Education (professor, teacher, educational assistance) | 9 (10.5) |
| Engineering | 7 (8.1) |
| Farmer | 4 (4.7) |
| Food and Beverage Retail | 3 (3.5) |
| Government Employee (planning, management) | 10 (11.6) |
| Healthcare (medical doctor, therapy, nurse, ambulance) | 9 (10.4) |
| Office (accounting, banking, finance) | 5 (5.8) |
| Outdoor Recreation and Tourism (campground, nature guide, ski) | 10 (11.6) |
| Owner/Manager/Entrepreneur | 4 (4.7) |
| Retired | 6 (7.0) |
| Sales | 3 (3.5) |
| Student | 7 (8.1) |
| Trades (mechanic, hydroelectric technician, carpenter) | 5 (5.8) |
| Other | 4 (4.7) |

**Table 4**. Presents an overview of respondent municipality, gender, age, and occupation.

#### 4.2.2.3 Questionnaire Participants

In tandem with the non-randomized criterion and snowball methods used during the interview process, survey responses were generated using a combination of social media, local newspapers, and email. While it was unknown how many actors viewed the questionnaire, a total of eighty-six participants completed the survey. Although this research attempted to equally represent stakeholders living in all municipalities, some areas were better represented during data collection. For example, nearly one-in-four of the questionnaire respondents lived or worked in Luster, whereas only one-in-ten of the respondents came from Sogndal.

As the digital aspect to this research made it difficult to find local community members to survey, both, an overview of the project, and the questionnaire was posted to a variety of local *Facebook* groups. While the utilization of *Facebook* to collect data presented challenges, such as biased results or the possibility of misrepresenting the population, it was an important point of entry to access respondents in remote areas. The reliance on Facebook to find respondents was emphasized by several interview participants, since it was regarded as the main platform for local actors to discuss community events or buy and sell items. To mitigate the possibility of misrepresenting the actors living in the study-municipalities, questionnaire respondents were also found through emailing local businesses, farmer organizations, and municipality employees. In addition, as respondents were generated from the newspaper publicity. Moreover, the Facebook groups were located through both, interviewee recommendations, and independent research, where the names of certain villages or municipalities were typed into the search box. The Facebook pages used to generate questionnaire responses are described in Table 5.

Through publishing the questionnaire on the local Facebook groups, two separate newspaper organizations, *Grenda* from Kvinnherad, and *Porten* based in Sogn, inquired about the study, and asked to write and publish an article outlining the research objectives. In connection to reporting on the research objectives, both newspaper correspondents provided a generalized overview on the research findings and information describing how local community members could participate in the online questionnaire. Through this publicity, several participants responded to the questionnaire. A link to the Grenda article “Korleis vert menneska påverka av å bu nær ein isbre?”

published on October 21st, 2021, can be retrieved from grenda.no[7]. Alternatively, the Porten article "Kristine (30) frå Canada forskar på korleis isbresmelting påverkar lokalsamfunna i Sogn: – Eit uunngåeleg teikn på klimaendringar" published on October 25th, 2021, can also accessed porten.no[8]. A link to both online newspaper articles can be found in the footnotes. Finally, as previously mentioned, an email was sent out to a variety of local hotel and glacier guiding companies, the six municipalities, and farmer contacts to ask for questionnaire participation. As the survey questions prioritized anonymity, it was unknown how many respondents were generated from cold-emailing.

[7] Access to the October 21st, 2021, *Grenda* article can be retrieved from: https://www.grenda.no/nyhende/korleis-vert-menneska-paverka-av-a-bu-naer-ein-isbre/

[8] Access to the October 25th, 2021, *Porten* article can be retrieved from: https://www.porten.no/indre-sogn-jostedalsbreen-klima/kristine-30-fra-canada-forskar-pa-korleis-isbresmelting-paverkar-lokalsamfunna-i-sogn--eit-uunngaeleg-teikn-pa-klimaendringar/326892

## Facebook Groups

| Facebook Group/Page | Overview of Group | Affiliated Municipalities | # Members (Approx.) | Date Posted |
|---|---|---|---|---|
| **Dette skjer i Kvinnherad** | The purpose of this group is to post events, meetings, and upcoming activities in Kvinnherad. | Kvinnherad | 3,200 | 13-10-21 |
| **Jostedalen Saker, ting og skyss** | The purpose of this group is to provide a space for residents living in Jostedalen to exchange goods and services. | Luster | 955 | 26-01-22 |
| **Kjøp og salg Årdal, Lærdal, Kaupanger, Luster, Sogndal, Leikanger omegn** | The purpose of this group is to create a space for residents of Årdal, Lædal, Kaunpanger, Luster, Sogndal and Leikanger to sell and buy goods. Residents of Stryn are also members of this group. | Luster, Sogndal and Stryn | 13,600 | 13-10-21 |
| **Kva skger i Luster?** | The purpose of this group is to inform residents of Luster on upcoming events. | Luster | 2,800 | 18-10-21 |
| **Kvardagsprat i nye Ullensvang Kommune** | The purpose of this group is to have a platform for residents of Ullensvang to communicate. | Ullensvang | 2,400 | 14-10-21 |
| **Oppslagstavla i Kvam (Hardanger)** | The purpose of this group is to share information about hiking in the environment and mountainous areas surrounding Hardanger. | Ullensvang and Kvam | 5,800 | 18-10-21 |
| **Jostedalsbreen nasjonalparksenter-Besøkssenter nasjonalpark** | The purpose of this page is to provide residents and visitors with information about Jostedalsbreen National Park. | Stryn | 1,970 | 30-09-21 |

**Table 5**: Provides an overview of the Facebook Groups used to find questionnaire respondents.

## 4.3 Data Analysis

Qualitative analysis entails interpreting the data and subsequent themes, in order to develop an understanding of the phenomenon being examined (Cope, 2016; Sargeant, 2012). Following transcription and review of the qualitative data, three processes occurred: deconstruction, interpretation, and reconstruction. Initially after transcribing the voice recordings and reviewing the questionnaire responses, the data was reviewed and then deconstructed by categorizing and coding the descriptions shared by the participants. Both descriptive and analytic codes were utilized to reduce data and generate theory.

*Descriptive codes* represent the themes or relationships that are explicitly stated by informants during data collection (Cope, 2016). Descriptive or in vivo codes that were directly stated from the participants included "sadness" and "worry" when referring to the perceived direct and in direct consequences of climate change on their communities. Analytic codes represented the implicit themes or patterns that were derived from the data, such as "sense of place", and "resiliency." While a preconceived list of codes was established prior to the coding process, a variety of new codes emerged during the review process, which resulted in both, deductive, and inductive coding being used to categorize data. Specifically, initial deductive codes were derived from previous literature on vulnerability, whereas the inductive codes reflected the themes from the data. Following deconstruction, the data was interpreted by comparing the similarities and differences between the codes, categories, and themes. For example, the code "uncertainty" was often associated with other descriptive codes including "worry" and "manageable." The interpretation of "uncertainty" with "worry" and "manageable" suggested that certain participants viewed aspects of glacier change to be negative, while others perceived it to be non-threatening. This binary was often associated with flooding and GLOFs, as some actors considered it to be one of the biggest risks to their community, whereas others regarded it as well-managed. Finally, to organize and minimize the number of codes, categories were created to reflect larger themes. These larger themes included glacial melt and hazards, perceptions, impact on local economy and livelihoods, and adaptive capacities. These larger themes served as the basis for the theoretical framework.

## 4.4 Ethics

Within research, *ethics* are the standards that relate to accurate and relevant knowledge, trustworthiness, human dignity, free and informed consent, and social responsibility (Forskningsetikk, 2019). Moreover, ethics are the reasoning behind researcher actions and how it may impact participants and their communities both, directly and indirectly (Lahman et al., 2010). This research was designed to protect participant privacy and rights, comply with professional and ethical dimensions, and establish trust between the researcher and participants. Despite language and cultural power dynamics being present throughout the research, practicing reflexivity before, during, and after the interview process, as well as being reflective, challenged preconceived bias and expectations. However, due to Covid-19, this research had to rely heavily on online data collection. While it was attempted to gather rich-qualitative data online, the inability to analyze body gestures or emotions further complicated the evident language and cultural barriers.

### 4.4.1 Ethical Dimensions of Online Research

The reliance on online research to collect qualitative data poses a plethora of ethical challenges, such as informed consent, confidentiality, and privacy (Dowling, 2016). Such ethical challenges also needed to be addressed throughout the entirety of this research project. As many online surveys used web hosting services that are unable to safeguard participants' identities, *Nettskjema*, a secure data collection website, was used to collect data via an online questionnaire. Through the utilization of Nettskjema, sensitive personal information was collected and stored in adherence to Norwegian privacy laws. To conduct online interviews, *Zoom* and *Teams* were utilized, where permission was granted from all participants to record the audio conversation. While Zoom and Teams are both secure and accessible video conferencing applications, privacy rights were communicated to all participants.

## 4.4.2. Positionality

*Positionality*, described as the ontological and epistemological assumptions adopted by the researcher within a study, influences how the research is planned for, conducted, interpreted, and presented (Holmes, 2020). Simply, *ontology* refers to preconceived societal beliefs held by the researcher, whereas *epistemology* includes knowledge production and ways of understanding a phenomenon (Holmes, 2020; Winchester & Rofe, 2016). To identify personal positionality, *reflexive practice* can be utilized, which is recognized as the ability for the researcher to

continuously acknowledge the intersectional relationships and preconceived biases that shape knowledge production (Holmes, 2020; Berger, 2013). As this research was derived from an interest in natural hazards and climate change, there was an expectation that the data would reveal certain patterns. This expectation was exacerbated by the research aims of GOTHECA and study of GLOFs. While GLOFs have the potential to disrupt society and harm actors, property, and infrastructure, they were not perceived to be the biggest threat to the stakeholders surveyed and interviewed during this study. Although the preconceived expectation that GLOFs were a serious threat to local actors influenced the study design and initial data collection, the interview guides were reframed to encompass other aspects of glacial change, including the perceived short-and long-term benefits of retreating glaciers. After reframing the interview questions, participant responses described a larger range of challenges and opportunities in relation to glacier melt or hazards. While the initial interview guides limited participant response, other aspects including language and cultural differences also influenced what was spoken about during the interviews.

### 4.4.3 Locating Positionality in Language and Cultural Dynamics

An important, yet obvious positionality in this research was conducting the interviews in English instead of Norwegian. While all interviewed participants spoke English, it was sometimes difficult to translate emotions, connect ideas and ascribe meaning to certain places. Additionally, since most participants predominately spoke Norwegian in their work and personal lives, some respondents stated that they felt a bit insecure with their English and were uncertain if their ideas were being communicated clearly. On the contrary, the researcher also felt a bit insecure when Norwegian phrases or place names were mentioned, since it was not always clear what was being described. While linguistic positionality affected translation and the interpretation of the data, conducting the interviews in English was also a power dynamic that was continuously reflected upon. As mentioned by Dowling (2016), some of the English expressions, phrases or words used to communicate could have led to different speaking positions, where the participant felt confused, embarrassed, or unwilling to communicate experiences (pp.36-37). When language was a challenge for participants, ideas and questions were spoken slowly. Additionally, reviewing themes and topics with the participants that were discussed during the interviews helped to minimize miscommunication or misinterpretations. Moreover, through the collaborative nature of the GOTHECA team, it was possible to ask a colleague for clarification on a Norwegian word, phrase, or place that was mentioned by a participant during the interview. The ability to ask a

Norwegian speaker for clarification prevented important information from being overlooked and ultimately, helped to balance the differences in speaking positions.

The language and cultural distinctions between the participants' and researcher were further complicated by other components of outsider positionality, such as occupation, educational background, age, and residence. As many of the "expert" participants interviewed for this research worked in fields related to engineering, glaciology or hydrology, there was a knowledge gap between the interviewees and interviewer. While it was important to understand how glacier run-off and hydropower catchments could be affected by an increase or decrease in melt, it was sometimes difficult to ask relevant questions. This was apparent after the first interview with an expert in hydrology, as the questions prepared did not align as well as they did with participants from backgrounds or occupations familiar to the researcher. After this experience, the interview guide for experts in fields related to engineering, hydrology or glaciology was reworked to be more fluid, where participants were asked questions that allowed them to expand on topics in different ways.

While insider research can provide notions of trustworthiness and legitimacy between the researcher and participants, outsider positionality can provide a degree of objectivity during the interviewing process, as the knowledge or experience of living in the study area is not preconceived and able to shape participant responses (Dwyer & Buckle, 2009). Although it was often difficult to understand everything that was shared by the participants, being an outsider was also advantageous. For example, as the participants were aware of the cultural gap, many respondents went into great detail describing the physical and social dynamics of the study sites, as it was assumed that the local or insider knowledge was unknown to the researcher. Several participants also spent time explaining cultural norms like *allemannsretten*[9] and *friluftsliv*[10] and connecting them to the interview questions. Because of this, it was sometimes easier to identify patterns and themes during data analysis.

[9] Freedom to roam public or privately owned land in Norway.
[10] Embracing the outdoor life.

### 4.4.4 Sharing of Information

As this research was in collaboration with other GOTHECA projects, eight of the interviews were conducted physically in Stryn by two Norwegian-speaking students. All six participants provided consent for the recorded interviews and translated transcripts to be shared between the GOTHECA students. The opportunity for other GOTHECA students to travel to conduct interviews in the study sites and share the information was beneficial, as some of the participants interviewed would have been inaccessible otherwise. In addition, through this collaboration, insider research was able to be collected for this study by a Norwegian colleague, which provided important qualitative data on the economic impacts of glacier retreat on the ski industry.

To ensure that the data collected would be relevant to the research objectives, an interview guide was created and agreed upon before the fieldwork began. While the sharing of data presented new ethical concerns, such as ensuring that participants understood how their information would be used and stored between the four researchers, it also helped to avoid duplication and research fatigue. For example, since many identified stakeholders held specialized roles within smaller communities, it would have been an interest to all GOTHECA researchers to inquire and ask for a meeting. However, inviting and interviewing the same participants was avoided through the sharing of qualitative data from fieldwork.

### 4.4.5 Limitations During Covid-19

The Covid-19 pandemic presented many challenges that impacted the results of this study. In connection to the interviewing process, most of the interviews were held online via Zoom or Teams due to travel restrictions and the inability to travel from Trondheim to villages within the six municipalities. Although video-calling was utilized to conduct interviews, there were several limitations that had to be addressed, including inadequate Wi-Fi connection, uneven technological knowledge, and underrepresented municipalities. For instance, due to weather or poor internet connection, some interviewees were interrupted while responding to a question. On the contrary, there were events where the internet froze while the interviewer was asking a question or summarizing a participants' response. To prepare for internet connection issues, key ideas stated by participants were continuously written down, so in the event a response was interrupted, the conversation could restart on the topic that was being discussed before the disruption. Moreover, to ensure participants could access the online interviews, all meetings via Zoom and Teams were

scheduled based on participant preference and included clear instructions on how to access the videocall. Finally, as it was not always possible to read body language during the online interviews, it was sometimes difficult to interpret how participants were understanding the questions. To overcome this barrier and check for understanding during the interview process, ideas were summarized back to the respondent, where they had the opportunity to agree, disagree or further elaborate on a point.

As this research had to rely partially on an online questionnaire to collect data, it was difficult to gather information that equally represented the actors living in the six municipalities. As a result, the data collected for this research may not be representative of all actors living in Luster, Stryn, Kvinnherad, Kvam, Sogndal, and Ullensvang. For instance, it was easier to find questionnaire respondents living in Luster than in Sogndal or Stryn. While this was a major limitation, both, Sogndal, and Kvinnherad were better represented during the interviewing process. Moreover, since the study emphasized informant anonymity, respondents were not asked to specify the village or city they were from on the questionnaire. Because of this, it was impossible to assess differences in opinions between specific locations. Importantly, as qualitative research is embedded in social constructionism, including how research is designed, collected, and analyzed, it is emphasized that the findings in this research represent one truth or interpretation of a complicated narrative.

## 4.5 Chapter Summary

This chapter described the research methods used to prepare, collect, and analyze data from actors living in the six municipalities. As the Covid-19 pandemic restricted travel to the study areas, this research relied heavily on online interviewing and a questionnaire to collect data. Using a combination of criterion and snowball sampling during the selection process, twenty participants participated in the interviews. The interview participants included experts, farmers, businesses owners, municipality or county employees and actors who lived or worked in one of the six municipalities. While interview guides were initially created at the start of the project, they were continuously adapted to better fit participant knowledge. Additionally, while this research initially focused on natural hazards, especially GLOFs, this quickly changed to encompass all forms of glacier change. To find respondents for the online questionnaire, businesses, farmer organizations, and the six municipalities were contacted via email. Additionally, the questionnaire was posted on Facebook groups and in two local newspapers. A total of eighty-six respondents completed the

questionnaire. While convenience sampling was used to find both, interview participants and questionnaire respondents, it was extremely difficult to find informants through nonprobability techniques due to the travel restrictions and cultural and language barriers. After transcribing the interviews and reviewing the questionnaire responses, the data was analyzed through deconstruction, interpretation, and reconstruction. Through these three processes, codes were organized into categories, which were then connected to larger themes. While ethical considerations existed throughout the entirety of the project, participant privacy, confidentiality and anonymity were prioritized by the researcher. For example, as online research raises ethical issues surrounding the collection and storage of data, *Nettskjema*, a secure data collection website authorized by NTNU, was used to create the questionnaire. Although outsider research can be limiting due to language or cultural barriers, it was at times advantageous. The following chapter will review the findings from the online interviews and questionnaire.

# 5 FINDINGS

## 5.1 Introduction to Findings

In this chapter, the findings from the online questionnaire and interviews are combined and organized by the *Localized Social Vulnerability Framework* (LSVF) presented in Chapter 3. The beginning of the chapter presents *who* and/or *what* is vulnerable to the environmental impacts of glacier change. Additionally, this chapter examines how research informants perceive the impact of glacier change. Subsequently, the impact of glacier change on tourism, hydropower and agricultural activities are identified. Moreover, this chapter examines the adaptive capacities of local actors in strengthening resiliency to glacier change. For the purpose of this chapter, the term "participants" refers to interviewees, while "respondents" refers to those who completed the questionnaire. "Informants" is the term used to refer to both, participants, and respondents at the same time. Finally, although eighty-six respondents answered the questionnaire, ten were omitted from the findings due to living or working outside of the research municipalities. The findings presented in this chapter reflect this adjustment. A table differentiating the respondents by number and reported municipality is located at the end of the chapter (Table 7).

## 5.2 Experiencing the Environmental Impacts of Glacier Change

This section investigates how glacier melt and associated hazards are experienced by local actors. According to the questionnaire, 89% of questionnaire respondents believed that glaciers have drastically decreased. While 30% of respondents believed their community was at risk from glacier hazards, flooding was cited most frequently (Table 6). However, although glacier melt can result in changes to the magnitude and frequency of hazard, the perceived risk was not evenly distributed between stakeholder groups or within the studied municipalities. For example, several interview participants suggested that although icefall was a risk to tourists who cross barriers and ignore warning signs to get closer to the glacier, it was generally not a risk to local actors. Despite many informants being aware of glacial hazards, especially the risks associated with GLOFs, some participants reported feeling uninformed. Although several experts recognized GLOFs as a major hazard to immediate and downstream communities, the risks were generally well-mitigated through both, NVE's monitoring programs, and the utilization of hydropower reservoirs for flood control.

### 5.2.1 Melt and Retreat

To investigate the extent to which actors were aware of glacier melt and retreat, online respondents and interview participants were asked about their concerns regarding glacier change. While completing the online survey, 89% of respondents selected "yes" to the closed question asking if they believed glaciers were melting fast[11]. As the result of selecting "yes", an open question followed asking respondents to state why they believed glaciers were melting fast. Within the questionnaire, a total of seventy-three respondents answered the open question, where many responses entailed explicit descriptions of glaciers that have noticeably shrunk:

**Respondent #14**: "Several visits to Nigardsbreen and Briksdalsbreen show that they are retreating sharply."

**Respondent #24**: "When I was a child in the 2000s, we drove between walls of snow up to Folgefonna ski center in late spring. The glacier surrounded the center, and it was only white. Skiers did stunts both above, below, and off-piste. From home we could see the glacier lying wide over the rock. Now it is sunk between two rocks. The center must pack and pull a lot more snow to be able to stay open in the summer, but the blue ice comes earlier and earlier every year. We notice the melting on where it is safe to go, new rocks coming into view and calving on the outside."

**Respondent #36**: "Comparing photos from when I grew up to now. Folgefonna has decreased significantly. I can see Fonna from my living room window. By fast melting, I mean over 50 years. You do not need a scientific study to confirm this. Highly visible."

**Respondent #41**: "Where I live, I see the northern part of Folgefonna from Kvam. It has changed a lot in the last 20 years. Uses this part of the glacier for outdoor activities and has also registered this up close. Also, I have a view of the Northern Fonna from my small farm in Sørfjorden, and I see great disturbing change."

**Respondent #46**: "I grew up in Sundal by the Bondhus glacier. There is also a resort there where I often go. I have noticed a big change in the fact that the glacier has decreased in the last 20 years."

**Respondent #47**: "I see it. The glacier edge of Folgefonna is easily reached by arches. A popular trip. The glacier is much further away than before. A warning sign about calving can probably be moved one kilometer closer."

**Respondent #60**: "Sees that the glaciers in the area have melted at a high pace in recent years, such as the Briksdalsbreen glacier. Also see that the glaciers seen in the mountains are decreasing."

**Respondent #68**: "I visit several of the glaciers in Jostedalen every quarter of a year. Think well of the late 1960s when the Nigardsbreen glacier lay all the way down to the lake. There is almost nothing left of the Bergset glacier."

**Respondent #73**: "I see a difference every year. Among other things, arriving on the ice has become much more difficult and longer than before. From the time I started working on the Nigardsbreen glacier in 2018 until today, the glacier has retreat about 100-200m. And that the front has become steeper due to rapid retraction and steep slope."

**Respondent #75**: "We see it clearly that the front of the Nigardsbreen glacier has retreated."

[11] See Appendix D.

To these respondents[12], changes to the environment were very evident. Some of the respondents noted that melting had occurred rapidly in recent years, which was very visible to local inhabitants. Indeed, respondent #41 described the change as "disturbing", whereas respondent #36 remarked that retreat was so visible that a "scientific study was not needed to confirm this." As respondents #14, 24, 36, 41, 46, 47, 60, 68, 73, and 75 had lived in their municipalities for at least ten years, with many of them living there for their entire life, changes to popular glaciers like Nigardsbreen, Briksdalsbreen and Folgefonna were obvious. Specifically, respondent #24 recounted their childhood experiences at the Folgefonna Ski-Centre when there were "walls of snow", and skiers could be found on the designated runs and in the back country. Respondent #73 associated glacier retreat with new challenges when on the glacier. For instance, it was stated that retreat had resulted in trips to the glacier as "much more difficult and longer than before." Interview participants also reflected on melt and retreat when asked if they had personally noticed any form of glacier change:

> "The ice patch was there into the early 2000's. There was another ski lift there that brought people all the way up to the glacier, with masts that were mounted onto the ice. But those melted away. The biggest change we noticed is not on Tystigbreen but in Erdalen and Erdalsbreen. There, the glacier has retreated about 2km since the end of the millennium and a big lake that is now over 1km long has appeared."—Marius
>
> "Most definitely. We could see retreat from the day I started. And the last day I was on the glacier for the summer season, it retreated about 10 to 15 meters in length. So you can absolutely see the changes. We also are drilling poles into the glacier for security when we have guests with us, and they have to be re-drilled every day, every morning because they melt out during the day."—Gerhard
>
> "There is a lot less ice here now than there twenty years ago. Twenty years ago it was not possible to see the bedrock sticking up from the top of the glacier, as it was completely covered by the glacier. So, the glacier has been thinning, and the slope where people are skiing is much steeper now because the glacier has been retreating. There was also a ski slope to the right of the current slope, but it's not possible to ski there anymore"—Nils

Like many of the survey respondents, Marius used specific examples of glaciers to describe retreat in his community. While Gerhard spoke about the retreat he experienced this summer as a seasonal glacier guide, where the poles "had to be re-drilled every day because they melt out during the day", both Marius and Nils spoke about the changes that had occurred within the past twenty years. Specifically, Marius and Nils mentioned past ski slopes and chair lifts that no longer existed, as it was "not possible to ski there anymore." While all three participants spoke about their own

[12] Note. Table 7 presents respondent list. See page 84.

experiences with glacier melt, respondents #22, 26, 51, 66 and 70 mentioned photographic evidence as a basis for why they believed the glaciers in their communities were melting rapidly:

**Respondent #22**: "Sees major changes in the immediate area compared to older photos."

**Respondent #26**: "Because I see old pictures and see the withdrawal happening faster now than one 50 years ago."

**Respondent #51**: "Can compare pictures from year to year and see how much the glacier arms (eg farmhouse glacier) have melted."

**Respondent #66**: "Picture of the Nigardsbreen glacier from the 90s and picture from today's victory."

**Respondent #70**: "Read and hear news, know best about Jostedalsbreen (Nigardsbreen, Tuftebreen, Fåbergstølsbreen, Austerdalsbreen, Bøyabreen). Seeing the picture before and now, the glaciers have diminished a lot."

For most of these respondents, they were under the age of 39 years old or had only lived in the community for 2-5 years. Because of this, old photographs played a key role in their understanding of the glacier retreat that had occurred within recent decades.

### 5.2.2 Natural Hazards

As glacier retreat and melt can result in changes to the frequency and magnitude of natural hazards, the following section reviews which hazards are perceived as a risk to respondents and participants. The natural hazards identified by respondents and participants include floods, GLOFs, icefall, landslides, and avalanches.

#### 5.2.2.1 GLOFs and Other Flood Events

When informants were asked which hazard was the biggest threat to them or their community, flooding was frequently mentioned[13]. Specifically, while 30% of questionnaire respondents believed their community was at risk of glacier hazards, 50% of the same respondents selected "flood" as a glacier hazard that they were currently exposed to (Table 6). When questionnaire respondents were asked whether glacial flooding or a GLOF had occurred in their community, nearly 36% answered "yes." However, only 31% of respondents acknowledged being concerned about glacier flooding in the future. Despite some participants believing flood risk posed a threat to their communities, only five respondents had been personally affected. However, when

[13] See Appendix A, B, C, and D.

respondents were asked about their future concerns of glacier change, six respondents cited GLOFs or other flood events:

> **Respondent #1**: "Water that has been dammed up by ice comes in full force with lots of loose mass when these dams melt. It affects the water quality, and we have seen an approximate layer of mud on the fish where it has happened."
>
> **Respondent #3**: "In general, a sign of rapid climate change. A change in the slope can change the waterways. Jökullaup?"
>
> **Respondent #28**: "Around glaciers, there is often water that is dammed up by ice or moraines. A rapid withdrawal could lead to an increase in the water level in these, which could lead to glacial run-off in exposed areas."
>
> **Respondent #34**: "….Can we have a tidal wave down the valley towards Jondal?...."
>
> **Respondent #41**: "That the microclimate that the glaciers create will lead to different conditions for food production in the area. The melting entails changing waterways and the danger of calving, landslides and floods."
>
> **Respondent #74**: "The economic basis will change (glaciers and tourism) and greater water flow in the rivers increases the chance of erosion and flooding."

Although GLOFS and flood events were often mentioned in connection to other concerns, such as the effects glacier change could have on industry, biodiversity, water quality or other natural hazards, some respondents believed the events were risky. Moreover, when interview participants were asked about glacier hazards, some regarded flooding, especially GLOFs as a potential risk to communities. For instance, while Finn acknowledged that "flooding was a big problem in the community for the past ten years", Jan suggested that the "biggest risk to downstream communities would probably be an outburst flood." Ola also believed that GLOFs posed the biggest risk to actors living in glacier villages:

> "Flooding both for people close to the glacier and for societies a little bit further away, down downstream from the glaciers. We are concerned that we will have GLOFs, which can be a serious event. And if the glaciers are retreating, then you know that the conditions around the glaciers are changing, and you can have these lakes appear rapidly."—Ola

Although Ola was concerned that retreat could result in GLOFs that affected both, actors living in areas close to the glacier, and in downstream communities, Johan suggested that such flood risk also existed when the "glacier was growing." However, when asked about the possibility of future GLOF risk, Jørund suggested that glacier change could make it more difficult to monitor and manage floods:

> "There could be more glacial lakes with potential flood risks that we aren't able to manage. There have constantly been new lakes showing up—have been for some years. But only maybe one or two of those lakes might be problematic here. And there have been two events in the last 16 years. One of them did a lot of damage but didn't cause any fatalities…. There have been some catastrophic GLOF loss in history, but the really bad ones have been regulated by hydropower development…. So if they really pose a risk it might not be discovered if they are partly hidden by ice."—Jørund

While Jørund predicted glacier change could result in an increase in glacier lakes that were difficult to monitor, he also suggested that most outburst floods had not been "problematic" due to hydropower management. Cathrine also believed that Norway was not at risk from GLOFs, as hydropower companies often released water from their reservoirs before the event occurred. Using the GLOF at Harbarsbreen as an example, where thirty-six million cubic liters of water was released from the hydropower reservoir before the flood, Cathrine suggested that hydropower companies were going to adapt.

#### 5.2.2.2 A Well-Managed Risk

Though some participants felt that flooding and GLOFs could continue to be a risk to their communities, Tom and Nils reflected on how glacier change sometimes resulted in less risk:

> "We also have the opposite situation, close to where I live now. There used to an annual, big GLOF that caused a lot of damage in the 1920s and 30s, I think. And when the reservoir was built in the 70s, the situation for the people living downstream was better because the water flowed into the reservoir. But as the glacier melted, that dammed lake became smaller, and the lake disappeared permanently. Now, it's not there anymore. And that was the biggest and riskiest GLOF situation that we have had in this area, and it's now gone? So, glacier change can also lead to that."—Tom

> "The glacier that caused the GLOF here in 2009 has retreated much since then, so it will not happen in that place again. So, it is not a glacial hazard anymore."—Nils

Although flooding and GLOFs had affected actors in some of the municipalities, Cathrine believed that those risks were well-managed through NVE and local hydropower companies. While Jørund suggested that it could become more difficult to monitor outburst flood risk in the future, Tom and Nils provided examples of situations where GLOF risk completely disappeared. While most of the interview participants knew what a GLOF was, Anders and Pia were completely unaware of the phenomenon:

> "No, I have never even heard of a GLOF before. I have never heard that there could be glacier lakes that drain into the river. No one has told me this, and I do not think anyone else [at my job] knows of this phenomenon either."—Anders

> "Glacial outburst floods were not something I knew about before speaking to you today."—Pia

While Anders had recently moved into the community, Pia had lived and worked in the community for many years. Although Anders and Pia did not have background knowledge or prior experience with GLOFs, both participants knew about the seasonal floods in the community.

As flooding and GLOFs were a primary focus during the initial stages of data collection, there was less emphasis on other hazards within the questionnaire and interview guide. However, when participants were asked which hazards posed a risk to their community, icefall and avalanches were frequently mentioned. Additionally, when questionnaire respondents were asked to select which glacial hazards' they believed posed a risk to their community, avalanche was selected seventeen times and icefall ten times (Table 6).

#### 5.2.2.3 Icefall

Several interview participants identified icefall to be a significant risk to tourists visiting the area. The following section will present the interviewee responses from Jan, Cathrine, Wida, Gerhard, and Birgit after being asked which hazards pose a risk to the community:

> "Icefall coming from the ice. It's been quite a big risk connected to tourists not respecting barriers. I think it was a couple of years ago someone died because they went too close, so maybe a risk for them."—Jan

> "I think the main one is icefall. It's one of these things where you go and stand in front of the glaciers and it's probably not that dangerous. But if you have a popular glacier and lots of people stand in front of it, someone's going to get hurt. You know, you see someone else doing it, you see people getting very close to the glacier. If you have ropes, you'll see people standing across from them and people right in front with someone taking a photo, and nothing happens—it looks totally safe. And you know, we try and put-up signs and state that this is dangerous and not to get too close… So you do want to terrify people but you do want to explain to them that this is you know, a very hazardous situation and you shouldn't be too close to the glacier."—Cathrine

> "We had a lot of deaths in 1986. There were a lot of deaths in Nigardsbreen which is another glacier up here in Jostedal. And then also some deaths on the west side. And three on Berdahl. I think there were six casualties in a week or something. Some of them were as close as possible to where the glacial river exits the glacier—And it's very nice blue ice. That's where everyone wants to take their picture, and everyone wants to go inside and have a look. But that's also where you have the most icefall. And that's also where we had these casualties in 2014 and 2018."—Wida

> "There's a lot of tourists at Nigardsbreen and they're not aware of the dangers or they don't know how dangerous it is to be that close to the glacier. There is risk of icefall and people are walking directly under places where ice could fall onto them."—Gerhard

> "A direct risk is around the glaciers…The park puts up signs and security fences to prevent people from walking into dangerous areas, but then a lot of tourists ignore them. This is what happened in 2018. And I think that that's, of course, one risk, but that will influence the whole tourism industry in that area, because suddenly it becomes rumored as being extremely dangerous."—Birgit

To all five participants, icefall posed the biggest risk to tourists who ventured off designated routes to get closer to the glacier. As icefall had been responsible for the deaths of tourists in 2014 and 2018, it was frequently cited by interview participants. Although additional warning signs and barriers had been installed around Nigardsbreen, Gerhard had seen several tourists walking in areas where ice had been collapsing after the event in 2018. When asked why Gerhard believed tourists were overstepping the boundaries, he suggested that some tourists felt "disappointed" by the vantage point and went into dangerous spaces to get a closer look. While he would attempt to warn them of the dangers, he felt that "they usually didn't care." Additionally, as Norwegian culture encourages *friluftsliv* and the *allemannsretten,* Gerhard suggested that beyond signs and barriers, there was not much more the National Park could do to prevent actors from going into exposed icefall areas.

Although all five participants referred explicitly to the direct risks of icefall, Birgit also highlighted the indirect risk of icefall on the community. In particular, Birgit mentioned the reputation of Nigardsbreen following the death of the tourist in 2018. She suggested that after the incident, the area was deemed as "dangerous", despite it being quite safe to go on the glacier with an experienced glacier guide. This opinion was shared by the other participants as well, since glacier guides were well-trained, whereas many of the tourists visiting Nigardsbreen did not have this experience. For these five participants, the risk was not the icefall itself, but the willingness of tourists to venture beyond barriers to get closer to the glacier.

#### 5.2.2.4 Avalanches and Landslides

Avalanches, including both, dry, and wet were referred to by a few participants during the interview process. When asked about which natural hazards posed a risk to the community, Øyvind reflected on his experiences with slushflow:

> "We can get slushflow which is an enormous force that can be very devastating. I have experienced slushflow three times in the time I have been here. The avalanche can be triggered in different places, dependent on where the water seeks its way under the snow. Above Folven, there was a slush/ice avalanche in June last year that reached the road on the other side of the valley and damaged cars."—Øyvind

In Øyvind's perspective, slushflow was unpredictable and had caused destruction within his community, including during a recent event in June 2021. In tandem with Øyvind's opinion, 28% of questionnaire respondents who believed their community was at risk from a natural hazard selected "dry or wet avalanche (Table 6)." While Øyvind was concerned about slushflow potentially occurring in greater frequency in the future, Wida reflected on her childhood when the glacier in her village was still advancing, and dry avalanches were quite common:

> "When I was a kid growing up, I was scared of potential avalanches along the school road. I know in Veitastrond, which is another village in Luster municipality, they still have a lot of avalanches during winter….. I think they had to make tunnels through avalanches during certain periods to be able to commute."—Wida

For Wida growing up in her community, avalanches were a common natural phenomenon. While they were currently less frequent in the community she grew up in due to significant melt within the past two decades, *Veitastrond*, a village within Luster municipality, still experienced many avalanches. Wida recalled from her childhood how actors from Veitastrond had to "make tunnels through avalanches during certain periods to be able to commute." Although Wida acknowledged avalanches to be a risk to glacier communities, the risk was nothing new to locals. However, as precipitation increased and more terrain was exposed as the glacier retreats, Wida suggested that communities surrounding Jostedalsbreen could see an increase in landslides and rockfall:

> "We have a lot more precipitation now in the form of rain. I think it's 18 or 19% more precipitation in Western Norway than 100 years ago. We know that it's steadily increasing. And we can see we have more terrain that is being exposed as the glacier is retreating, so we might get more rock fall or landslides."—Wida

Although landslide risk was rarely mentioned by interview participants or questionnaire respondents, Johan also suggested that landslide and rockfall risk could increase in the future, which was reflected in contemporary zoning laws and insurance schemes. According to Johan, zoning laws had become stricter to mitigate the risks associated with natural hazards:

> "The national plan and laws for building have changed in the past 10 years to take into consideration climate change. There are now stricter laws about where you can build now

> and how you can build your home. Not only because of emissions, also related to different hazards like flooding, avalanches or rockfall or landslides."—(Johan)

As mentioned by Johan, to reduce the risks, and ultimately the vulnerability of local actors, property and infrastructure to natural hazards, zoning permits had shifted to better adapt to the realities of climate change. Although older dwellings could still be at risk from flooding, avalanches, or landslides, newer homes would be built in areas that were deemed less risky by the government.

#### 5.2.2.5 Awareness of Hazards

Although many of the questionnaire respondents and interview participants were aware of natural hazard risk in their communities, some reported feeling uninformed. For instance, during the interview process, both Anders and Pia were completely unaware of what a GLOF was and how it was a potential threat to their downstream community. In tandem with Anders and Pia, only 22% of respondents stated that their municipality informed them about glacial hazards, which was predominately shared through social media and the municipality website. However, when respondents were asked if they had learned about glacier hazards through alternative sources, nearly 77% selected "yes." Alternative sources included social media, conversations with friends and family, and local and international news outlets. Though over 75% of respondents did not learn about glacier hazards from their home municipality, information was accessed through different means. While 43% of respondents felt that they had some knowledge on glacier hazards, only 31% felt well-informed.

## Overview of Closed Questionnaire Responses

| QUESTION | FREQUENCY % |
|---|---|
| **Belief that glaciers are melting fast** | 76 (100%)<br>** Other municipalities removed from total |
| Yes | 68 (89.4%) |
| No | 8 (10.6%) |
| **Belief that community is vulnerable to glacial hazards** | 76 (100%)<br>** Other municipalities removed from total |
| Yes | 23 (30.2%) |
| No | 53 (69.8%) |
| **Reported exposure to glacial hazard type** | 60 (100%)<br>** Other municipalities removed from total. Only participants who selected ***yes*** in the previous question (30=100%) could select hazard type. Respondents could select one or more options. |
| Icefall | 10 (16.6%) |
| Avalanches (snow and slush) | 17 (28.3%) |
| Flood | 30 (50.0%) |
| Other | 3 (5.0%) |
| **Reported glacial flooding or GLOF incidence in community residence** | 76 (100%) |
| Yes | 27 (35.5%) |
| No | 49 (64.5%) |
| **Personally affected by glacial flooding or GLOFs** | 28 (100%) |
| Yes | 5 (17.9%) |
| No | 23 (82.1%) |

**Table 6**. Showcases the representative sampling from five closed questions on the online questionnaire. Ten respondents were omitted due to living outside of the research municipalities.

## 5.3 Perceptions of Glacier Impact

In the following section, local perceptions of glacial change will be presented through two key themes: place attachment, and glacier melt as a signifier of global climate change. Specifically, *place attachment* investigates the local feelings associated with the physical setting and symbolic connection to the glaciated landscape (place identity) and the degree to which the physical setting supports conditions for an intended use (place dependence) (Raymond et al., 2010). As several local actors living in glacier villages both, feel connected to the landscape, and depend on it to support industry, future retreat is perceived by some informants to challenge cultural identity and livelihoods. Moreover, as glacier melt is highly visible to local actors within their communities, it serves to signify a wider phenomenon—global climate change. While retreating glaciers are regarded as highly visible to local actors, it is also suggested to be largely invisible to those living outside of glacial environments.

### 5.3.1 Place Attachment

#### 5.3.1.1 Place Identity

Many survey respondents and interview participants associated the glaciated landscape to be a part of their identity (place identity) and feel a sense of sadness concerning glacier change in their communities. Importantly, online respondents were only able to access this open question if they selected "yes" to being concerned about future glacier change[14]. The following responses were derived from the online questionnaire and interviews, where participants were asked to highlight future concerns of glacier change.

[14] See Appendix D.

**Respondent #5**: "I think it's a shame that an aesthetically beautiful landscape feature melts away. There is also food for tourism in the home areas. Also, as a water reservoir for power production. In addition, it's a shame when I grew up in a glacier village than it disappears."

**Respondent #54**: "The change of microclimate in Sogndalsdalen, including poorer snow conditions and fewer ski days. Otherwise, the glaciers are important pieces of the landscape and identity."

**Respondent #58**: "Glaciers are beautiful to look at and tell a story. This will disappear if the glaciers melt. Melting will also go beyond tourism in the area, which many people subsist on."

**Respondent #69**: "I worry that they will melt so much that it will affect agriculture, tourism and animal and plant life. Sad to lose a nice view to the glacier."

**Respondent #76**: "I lose my beautiful view, and glacier walks. Tourism decreases and the economic base for many of those who live, and work here disappears."

**Respondent #80**: "It is boring to lose the glaciers, they are cool and nice natural phenomena, which also contribute to tourism, hydropower and more."

Survey respondents #5, 54, 58, 69, 76, and 80 mentioned the aesthetic beauty of the glaciers by using the concepts "beautiful", "nice", and "cool" to describe the landscape. Although response #5 regarded the glaciers as an "aesthetically beautiful landscape", it was admitted that it would be a "shame" if it were to melt away as the respondent's "home" was identified as a "glacier village." In addition to response #5, 54, and 58 also attached the glaciated landscape to feelings of identity and as a signifier of "home", where the glaciers were considered "important pieces of landscape and identity." While these survey respondents wrote specifically about how glacier melt could impact their lives, several other respondents spoke about future generations and how they might not be able to "see and experience" the glaciers. In addition to the survey participants, interview informants also reflected on their deep-rooted connection to the natural landscape and their feelings of sadness when thinking about the "dying" glaciers. The following passages from Wida, Elin, and Birgit were in response to an interview question asking participants about glacier change in their communities:

> "The glacier seems stagnant and is kind of dying. It's really sad to see. We can see the thinning and retreating at the same time and it's just stagnant. It's not flowing and cracking up and making these sounds that it did when I was younger when it was really advancing….. I have kids and it will be really, really sad if they are never able to walk on the glacier like I have been able to."—Wida
>
> "When you live in this valley and are used to seeing this huge glacier it seems to provide a safe and big white wall. But you can see it is melting and people feel sadness. We don't

> want the landscape to be different because it's where we grew up, and people my age are used to seeing the glacier. So, while it may impact tourism in the future, it also changes my life."—Elin
>
> "It is losing a whole segment within tourism, that has been quite important for this specific region. And I think it creates a lot of place identity—you have a glacier, you can see the glacier, and you have this type of industry or sector in that area. I think that does a lot for the culture and the identity of the people who live there. And I think that is under researched…. In Hardanger, Ullensvang and Kvinnherad, the more you talk to the people around there, you notice that they identify with the glacier. And I think when that sort of moves out of sight, you have some of the people who are struggling to sort of figure out who they are."—Birgit

The glaciated landscape in the six municipalities represented a connection to their cultural heritage, identity, and livelihoods. For Wida, the topic of glacier change brought a sense of grief, as even though the glaciers were a living entity that supported life, she associated retreat with death. There was also a deep sense of sadness when Wida talked about the effects of climate change and the melting of the glaciers in her community. As Wida lived near glaciers all her life, she had a deep connection and felt personally that if:

> "If all children and adults in Norway had the opportunity to experience the glacier maybe they would also establish a connection with the glacier in order to actually have some empathy and kind of see what the fuss is about—to understand why people actually want to keep the glaciers and preserve the nature instead of just thinking about their $CO_2$ budget, etc."—Wida

Thus, for Wida, empathy and connection to the glacier could be learned through direct experiences. By experiencing the glaciers, Wida believed that governmental authorities would understand why it was important to strengthen climate change policies and reduce $CO_2$ emissions.

Elin enjoyed the easy access to nature in her small town in Sogndal. Like Wida, she also lived in the same municipality for all her life. For Elin, the glaciers represented familiarity, safety, and an important piece of cultural identity. However, such perceptions were challenged by the excessive melting that was changing the landscape and "her life." She reflected on the recreational activities she participated in, and it was evident that much of the physical activity she partook in was centered around the glacier. While Elin stated the phrase "Norwegians are born with skis on their feet", she suggested that it was the locals in the area who go on long hikes up the glacier (without a guide) as "many Norwegians who visit were from cities or towns and were not used to being in such nature." For Elin and some of the locals she referred to, the ability to go glacier hiking was important, and to an extent, exclusive to those who could make the challenging and sometimes,

multi-day trek. However, Elin acknowledged that glacier retreat had changed the ways in which locals navigated the landscape as well and stated that they: “used to go hiking and it would be very safe—we didn’t have to use a rope. But now you must use a rope and you think you're not so safe.”

Birgit explicitly referred to place identity while describing the importance of the glaciers to actors in the region. She suggested that locals in the area perceived the glaciers to be a part of their identity and culture but admitted that this had been under researched. In addition to place identity, Birgit connected the importance of the glaciated landscape to the local economy, as stated that as the glacier melted and a “whole segment” of tourism was lost, many local actors who identified and depended on the glacier for income may “struggle to figure out who they are.” For Birgit and many of the other interview participants and survey respondents, perceived identity was intrinsically linked to dependence on the physical landscape to support local economies and livelihoods.

#### 5.3.1.2 Place Dependence

While some of the survey respondents and interview informants reflected on the “beautiful view” and how future retreat could change the “view” and recreational activities, including glacier walks and skiing, others had explicitly connected the physical setting to industry (place dependence). The impact of glacier changes on industry, specifically tourism, hydropower and agriculture were shared by other survey respondents when asked about why such change was concerning to them:

**Respondent #1**: “A danger is for tourism, as places that are financially dependent on the glacier may lose their tourism industry.”

**Respondent #7**: “Changed runoff, affects power production, wildlife in and along glaciers and tourism.”

**Respondent #12**: “First and foremost, the consequences for tourism.”

**Respondent #13**: “The business base and thus the workplace can be reduced in the long-term and possibly, disappear.”

**Respondent #24**: “The biggest concern is the financial consequences in the local community of a closed summer ski center.”

**Respondent #34**: “I see daily and annual ice melting. Large parts of the Jondal community are affected in one way or another by the ripple effects of the summer ski center—shops, ferry, accommodation etc.”

**Respondent #85**: “Less great nature experiences, less tourism and activity. More erosion and less storage capacity for hydropower plants.”

From the survey responses, the impacts of glacier retreat on the tourism industry were frequently highlighted. To a lesser extent, the impacts of glacier change on hydropower and agriculture were also mentioned generally by some respondents. While many respondents broadly mentioned tourism, respondents #24 and 34 explicitly referred to the skiing industry and the impact a closed summer-ski center could have on other operations, including the "shops, ferry, and accommodation" businesses. To both of these respondents, the effects of a closed ski center would greatly impact other businesses and locals who depended on the resort for work. Both, questionnaire respondents #1 and 13 feared that glacier change would result in less tourists, and ultimately diminished income for local actors. Specifically, respondent #34 stated that decreased ski tourism would have a "trick-down effect" in Jondal, as many separate businesses were tied to the ski resort. Respondent #13 shared a similar sentiment and feared the tourism industry in the future would be "reduced or possibly disappear." Through the survey responses, it was suggested that some local actors depended on the glaciated landscape to attract tourists to the area but felt as though continued melt made those livelihoods vulnerable.

### 5.3.2 Glacial Melt as a Signifier of Climate Change

The following section explores glacier retreat as a perceived signifier of climate change. During the interviews, participants were asked questions relating to climate change adaptation and future concerns. Questionnaire respondents were also asked to write down any future concerns they had regarding glacier change. Through both, the online questionnaire and interviews, many participants identified glacier melt to be a visible marker of glacier change. The following quotes were taken directly from the questionnaire responses:

**Respondent #3**: "In general, a sign of rapid climate change."

**Respondent #6**: "Symptoms of human-made climate change in general, which in turn can create uninhabitable conditions in many countries and present significant challenges nationally."

**Respondent #14**: "Melting of the glaciers is a good climate indicator, and they point to a higher average temperature throughout the year, and this does not seem to "stop"."

**Respondent #31**: "The fact that the glacier will disappear completely for this may indicate that the climate is changing."

**Respondent #39**: "Signs of global warming, larger perspective."

**Respondent #51**: "It feels like the glacier is supposed to be there, and then it is worrying that it disappears. There is something abnormal about it, or something that is not meant to happen. At the same time, it's a very visual example of global warming, and it's scary."

**Respondent #64**: "Glacier melting is only a symptom of climate change. There will be major consequences for society, in all countries, and at all levels."

While many survey respondents referred to their sense of identity and dependence on the glaciers for livelihoods when asked to write what future concerns they had regarding glacier change, respondents #3, 6, 14, 31, 39, 51 and 64 focused on glacial melt as a signifier of global climate change. Although response #51 mentioned how concerning it was to personally see the glacier retreat and how there was "something abnormal about it", the other responses focused on melting as a global issue that had "consequences for society as a whole" that could "create uninhabitable conditions." Indeed, many of the responses indicated that the overarching effects of climate change were particularly concerning, instead of focusing explicitly on how retreat had the ability to change local identity and businesses. This sentiment was also shared by Gerhard when he was asked about whether he was concerned about glacier change:

> "It'd be wrong to say that I'm not concerned. But I think it's, it's kind of a marker of how the climate is changing. So, you can tell by the retreating glaciers that the climate is

> changing. And it's kind of it's quite visible, in my opinion. You can see it almost from day to day that the glacier is retreating during the summer. So, for me, it's kind of a marker of climate change."—Gerhard

Gerhard perceived glacier retreat to be a marker of climate change that was visible "from day to day" when he worked as a glacier guide on Nigardsbreen during the summer season. However, Johan, Birgit, and Jørund suggested that although glacier change was an important topic for many local actors, it was almost invisible to those who lived outside of glaciated landscapes:

> "I think when people haven't experienced glacier change, they believe that this topic is far away from them. But when you see things happen closer to you, you care about them"—Johan

> "There's been some articles in the media where glacier guides report that glaciers are shrinking because of climate change. But when I talk to people in the real world who are not affected by the issue, they just don't care. I think it's starting to become a bigger topic now."—Birgit

> "If you're not aware or concerned you don't adapt to climate change. Well, in Norway we have more glaciers per capita than any other countries except Iceland, and glacial retreat is one of the most visible impacts of climate change. I guess it's not so much on the agenda to raise awareness, but there's potential to kind of use the melting glaciers as a way to raise awareness about the need for climate action."—Jørund

As both Johan and Birgit had lived in glacier villages for most of their lives, glacier change had been highly visible within the past two decades and a topic of discussion within their communities. However, Johan suggested that the issues associated with retreat had been highly localized, where those living outside of mountainous landscapes had not been affected by the changes. Because of this, many Norwegians regarded glacier change as a distant problem. Birgit also suggested that actors living in the "real-word" outside of the local communities or academia "just don't care" that the glaciers were shrinking as the result of climate change. While Birgit and Johan revealed that some actors were apathetic to the effects of climate change due to being unaffected, Birgit believed the narrative was starting to change. Although Jørund acknowledged that it had not been on the political agenda to raise awareness about the effects of glacier change, he perceived it to be "one of the most visible impacts" of climate change. Since warming had resulted in considerable melt, he believed it could be used to showcase the very real consequences of climate change and raise awareness about the need for enhanced climate action in Norway.

For many survey respondents and interview participants, glacier melt was a visible sign of climate change. As all the informants lived and worked in communities near glacial environments, the

effects of glacier melt were real, present, and had the potential to affect local economies and livelihoods. Because the effects of glacier melt were so localized, it had been suggested by several interview participants that most actors living in Norway were unaware of the consequences. Thus, for local actors, melt was perceived to be a highly visible signifier of climate change, whereas it remained invisible to the population living outside of mountainous landscapes.

## 5.4 Economies and Livelihoods

The purpose of the following section is to examine how retreating glaciers are affecting key industries, including tourism, hydropower, and agriculture in the six municipalities. As many local actors are dependent on these three industries for subsistence, it is essential to understand *what* or *who* is vulnerable to glacier change. While ski resort businesses that have had to invest in expensive infrastructure are reported to be more vulnerable to glacier retreat, other tourism operations, such as glacier guiding, are identified as flexible and able to rebrand themselves to reflect changing environmental conditions. Likewise, despite excess melt creating future uncertainty in the agricultural and hydropower sectors, changes to precipitation patterns and the landscape may also offer new opportunities.

### 5.4.1 Tourism

As many local actors depend on the revenue generated by tourist activities to support the economy, the impact glacier retreat could have on the industry was frequently mentioned by both, interview participants, and questionnaire respondents. Through the online questionnaire and interviews, two predominant themes emerged when locals spoke about the impact glacier change could have on tourism: *out of business* and the *lifestyle entrepreneur*.

#### 5.3.1.1 Out of Business

For some of the interview participants, there was a concern that glacier change in the county could lead to certain companies going out of business:

> "You must invest, and you can say this year, it looks good. Maybe the next year too. But if the glacier retreats another 100 meters or so maybe we can't use this entrance to the glacier. What then? Maybe we're out of business in three years. What to do then? We have this example from Briksdal in Stryn, where they had quite a large glacial guiding industry on Briksdalbreen from around 1995 until about 2005. I guess several companies had glacier guiding on the lower glacier tongue, but now the glacier is gone. And they were out of business—more or less."—Ola

> "Briksdalsbreen used to be very popular like 15-20 years ago. They had horse and carriages. And, and now it would be hard for anyone to get on. And same with Nigardsbreen. It was very popular, and they had family tours onto the glacier, but it just retreated so much. It is too far for the younger kids to go now. And for adults, it's a lot of time now. So, if you're trying to build a tourist industry in remote parts of Norway, that's really going to make things difficult for you."—Cathrine

Both Ola and Cathrine provided examples on how glacier change had already affected certain businesses, primarily glacier guiding companies, within the past two decades. Ola specifically mentioned how glacier change could result in investment uncertainty for guiding companies, as retreat restricted tourist access to the glacier. While Ola suggested that retreat could result in guiding companies going out of business, Cathrine mentioned how change could affect *who* was able to hike up the glacier. Using Nigardsbreen as an example, Cathrine recalled when the glacier hike was advertised as a family activity but was now a long and challenging journey for some adults. Although both participants contended that glacier guiding companies were vulnerable to glacier change, Cathrine further suggested that attempting to build a tourist industry in remote parts of Norway could be challenging. This sentiment was also shared by several survey respondents:

> **Respondent #24**: "The biggest concern is the financial consequences in the local community of a closed summer ski center."
>
> **Respondent #55**: "Change in nature, melting of ice and snow, tele disappearance, landslide danger, flume. Tourists do not come on holiday as before and many centers, hotels and restaurants lose business."
>
> **Respondent #34**: "I see daily and annual ice melting. Large parts of the Jondal community are affected in one way or another by the ripple effects of the summer ski center—shops, ferry, accommodation etc. At the same time, I think that changes usually create new possibilities, what emerges under the ice?"

While respondent #55 believed that the area had already seen a decline in the number of tourists, respondents #24 and 34 wrote specifically about how a closed ski center could impact other businesses in the area, including shops, hotels, and the ferry. However, while there was a concern that some operations could go out business, other participants suggested that some business owners often founded new activities to generate income, as they were *lifestyle entrepreneurs*. This notion was also shared by respondent #3, who suggested that glacier could also result in new opportunities for the community.

#### 5.4.1.2 The Lifestyle Entrepreneur

Although some questionnaire respondents and interview participants felt concerned that glacier retreat could affect tourism in the area, Live felt as though the municipality and some businesses were starting to anticipate such changes:

> "We sell the glacier as something you should come look at. So, when the glacier is melting, and our main attraction is getting further away, and is maybe not there in 100-200 years, we need to think—what is the next step? What can we do without the glacier? So that's

> been kind of hard way to think. But for several businesses around here, we know the glacier is melting, so we need to think about it."—Live

For the municipality and several local businesses, it had been important to think about how the region could adapt to the changing landscape. Although the main attraction was "getting further away", there was the possibility of new business venture opportunities. Jørund, who had experience working as a glacier guide in the past, used his own experience to highlight the flexibility of the tourism industry:

> "If glaciers disappear out of sight, we could expect tourism to decline… But when it comes to the tourism industry, they're very adaptable. I started my career as a glacial guide, but the glacier I worked on disappeared completely, so it was no longer possible to work there. But the business owner developed other products, and they're still in business. So, a lot of the people involved in this type of industry are more like lifestyle entrepreneurs. They're motivated by the way of life rather than to maximize profits. I don't think the glacier is kind of crucial to the region tourism industry. They'll manage one way or another, but this means a lot less tourists going on glaciers because they are getting harder to access."—Jørund

In Jørund's experience, the actors or "lifestyle entrepreneurs" who were involved in outdoor tourist activities like glacier guiding were "motivated by the way of life" instead of financial compensation. Because of this, Jørund did not believe that glaciers were crucial to attracting tourists to the region. Gerhard also believed that tourist operations like glacier guiding could be flexible and "rebrand" itself as an activity for an exclusive crowd. Additionally, Gerhard suggested that glacier companies could also expand their businesses to include other adventure activities or sports. However, it was also noted that glacier guiding companies had the ability to be more flexible than other businesses, as it did not require permanent infrastructure. This was in stark contrast to ski-center businesses who had to spend a lot of time and resources on preserving the glacier. Nils, an employee at one of the local ski-centers, described the amount of work it had taken to keep the business operating:

> "Money and time is something we constantly spend here to preserve the glacier and the snow. We spend time all year around trying to conserve the snow. This is because we try to extend the season, so that we can have the ski centre open with snow in the slopes."—Nils

Specifically, to maintain the slopes, Nils stated that they had installed UV cloths to prevent melt during the summer, used snowmobiles to push snow into the crevasses to preserve the glacier, and had plans to invest in snow cannons to produce their own snow. Additionally, in anticipation of increased melt, they also had plans to build an infinity pool, which would collect water from the

melting glacier. While the ski-centre utilized different mitigation technologies to preserve the ski slopes, the implementation of an infinity pool also served to attract non-skiing tourists to the resort.

Although many respondents and participants were concerned that changes to the glaciated landscape could affect tourism and the revenue generated for the local economy, other participants suggested that many tourist companies were adaptable to changing environmental conditions. Indeed, Live suggested that her municipality and many businesses in the area were already exploring new investment opportunities. While it was acknowledged by Cathrine that new tourist ventures could be challenging for business owners in remote Norwegian villages, Jørund suggested that some operations, specifically glacier guiding companies, had been quite flexible, since they were motivated by the "lifestyle" instead of maximizing profit. Although certain businesses that needed to invest in expensive infrastructure, such as ski-centers, accommodation services or tourist shops were less flexible, there was still the possibility of enhancing existing facilities to continue to attract guests. This was exemplified by the ski center and their plans to construct an infinity pool to attract tourists in the future.

### 5.4.2 Hydropower

Hydropower production plays an important role in the lives of many actors in Vestland County. Building from Samu's (2020) research on the effects of climate change on hydropower production in Norway, the following section will investigate the potential impacts of glacier melt on water and electricity resources.

#### 5.4.2.1 An Extra Bank Account

When asked about the effects glacier retreat had on hydropower production, Ola, an expert in the field, suggested that hydropower companies "will benefit from glaciers as they melt away, since it gives them extra inflow." Rune, another hydropower expert, also stated that "increased meltwater from glaciers was providing the opportunity to produce more hydropower than we were used to." Moreover, Cathrine regarded the excess melt as "an extra bank account" for hydropower companies since they were able to store the additional water in their reservoirs. Indeed, while interviewing hydropower experts it was often mentioned that glacier melt was profitable for large hydro companies, as they had the reservoirs to store the excess water. However, due to decreased snowfall in the wintertime and a dry summer in Western Norway, Ola recalled some privately owned hydropower were unable to produce as much electricity as they had planned last year. In

Ola's opinion, this showcased the "vulnerabilities of the system." Further, while glacier melt was currently resulting in the ability to generate extra electricity and ultimately profit for hydro companies, some interview participants suggested that the long-term outlook was uncertain:

> "I think glacier change is more of a risk to hydropower, because hydropower has at least a twenty-year perspective. So, they really need to know what is profitable when they build the plant. So I think that's probably the biggest risk, which is not risk in the usual ways, it's a financial risk, you know, will they get the return on the investment."—Cathrine

> "We are now seeing increased meltwater from glaciers giving the opportunity to produce more hydropower than we are used to. At some point in the future the glaciers will decrease and eventually disappear and then the inflow to the hydropower reservoirs will decrease again, because then the meltwater glacial meltwater has been used and will probably not come back."—Rune

> "In the near future they will benefit from the glacier melt, as it gives them an extra inflow. And that will be for quite a long time maybe 10-40 years, where they will have quite a lot of extra inflow. You get this extra inflow when the glaciers shrink, and then when the glaciers get quite tiny, then this extra inflow will decrease rapidly. In the end, if the glaciers are gone, you are left with the same conditions as hydropower companies in glacier free areas. In the end, it's very hard to say what the hydropower production will look like because it also depends very much on the precipitation conditions."—Ola

Both Rune and Ola suggested that in the event the glaciers drastically retreated or disappeared entirely, the amount of water in the hydropower reservoirs would decrease as well. Because of this, Cathrine believed that glacier change could be a financial risk to hydropower companies in the long-term, since it was unknown how profitable some of the plants would be in twenty or more years. Importantly, Ola also mentioned the impact precipitation patterns could have on the amount of water stored in the reservoirs. Similarly, Tom, another hydropower expert, highlighted the importance of precipitation while thinking about hydropower resources in the future:

> "Some of the water will probably be compensated by increased precipitation. So, the amount of water might not decrease, but it won't be stored in the mountains. So, we will have to have the bigger reservoirs perhaps to be able to handle increased amounts of water."—Tom

Although hydropower companies were currently benefiting from increased melt, the excess water was not guaranteed in the long-term. However, according to Tom, increased precipitation, and the construction of larger reservoirs in new areas had the potential to compensate for this.

#### 5.4.2.2 Competition

When asked during the interview whether glacier change was resulting in new opportunities for hydropower companies, altered watershed boundaries was mentioned by Tom and Rune:

> "Opportunities are not necessarily only to do with GLOFs, but to changes to watershed boundaries. If you end up having a bigger watershed due to glacier change, then you'll get more water. We have a situation here where the boundaries between two small watersheds changed because the glacier became smaller. But in that particular case, it didn't matter because both watersheds went to two different intakes on the same tunnel, so the same company received water anyway. But that's sort of a coincidence. It could have been that one of the watersheds was giving water to hydro power on the other one wasn't and then the change in boundaries becomes more interesting. And I guess that will probably happen on a small scale. But still, there will be changes, but it's not easy to say if it's good or bad because you don't know which direction it will go."—Tom

> "There is a situation on the Folgefonna glacier…. and it has been concluded that the drainage area at some point in in the future will change drainage directions. And then they will lose part of the water or drainage catchment. It will start draining south to the neighboring hydropower company. So, they will lose water and the neighbors are going to get extra water."—Rune

Although Tom suggested that changes to watershed boundaries due to glacier change could result in more water for hydro companies, it was not guaranteed that it would be equally shared between businesses. Using Folgefonna as an example, Rune stated it was already anticipated that glacier change would affect drainage catchment in the future, and ultimately, competition between the two hydro companies operating in the area. Since future changes to watersheds and drainage catchments remained largely uncertain for Norwegian hydropower companies, it was impossible for Tom or Rune to state whether such changes were "good or bad." Despite this, future glacier change had the potential to change the economic landscape for hydropower companies.

#### 5.4.2.3 Future of Benefit-Sharing

While hydropower companies had profited off glacial melt to produce electricity for decades, host municipalities also relied on the direct investments from the companies to boost economic development. When Live was asked about benefit sharing for having hydropower projects in her municipality, she stated that they had two large hydropower plants that generated a lot of income for the community. The revenue gained from these two hydropower plants was used to enhance social goods or help build new businesses. Additionally, there was an agreement, where the municipality was able to sell a specific amount of electricity to other communities. To Live, this

was an important incentive for the municipality. When asked about whether the municipality was concerned or anticipating any changes to hydropower production in the long-term, Live responded:

> "I don't think so, but we should be thinking about it. But some of the glaciers here in [municipality] are so large, so we don't think that it would go away. But I know, different power plants, smaller ones in the Municipality, that when the small glaciers melt you won't be able to fill the reservoirs. So, I guess the price will rise. And the municipality could sell maybe less, but again, at a higher price. So, I don't know if it will change the municipality as much."—Live

Although Live acknowledged that she did not believe the municipality was preparing for possible changes to hydropower generation in the long-term, she did suggest it was something that should be considered. While glacier change in the future could affect smaller hydro plants and their ability to fill the reservoirs, Live suggested that such economic vulnerability could be compensated by higher electricity prices.

#### 5.4.2.4 Section Summary

According to several participants, increased glacier melt had been profitable for hydropower companies and the municipalities in which they operated. While smaller companies had some difficulties filling their reservoirs the previous year due to decreased precipitation and a dry summer, higher electricity prices compensated for the shortfall. Although increased prices compensated for a decrease in electricity production for these smaller companies, Ola believed it demonstrated the "vulnerabilities of the system." Further, while excess glacial melt was profitable in the short-term for hydro companies, the long-term viability of such profits remained largely uncertain. For Cathrine, this presented a "financial risk" for hydro companies, since constructing hydropower plants and reservoirs was a large economic investment. Although it was noted by hydro experts that most glaciers would decrease and ultimately produce less water and electricity in the future, increased precipitation could compensate for this. However, as glaciers melt, watersheds and drainage catchments could also change. Because of this, some hydro companies could gain or lose water to their competitors. As the six municipalities relied on hydropower investment and benefit-sharing to boost economic development in their respective communities, it was important that this continued for future-generations. Although in the long-term accelerated glacier melt could result in the amount of inflow into the hydropower reservoirs decreasing, this was not currently being planned for by Live's municipality.

### 5.4.3 Agriculture

Even though the agricultural sector is vital to the local economy, there is a knowledge gap on the impact glacier change could have on agricultural resources in Western Norway. Despite the knowledge gap on glacier melt and agricultural production, several participants identified two dimensions of vulnerability on the livelihoods of farmers: future water availability and the geographic spread of invasive species. The following section will review the responses of interview participants when asked about the risks or vulnerabilities glacier melt poses to agricultural communities.

Agricultural lands fed by glacier and snow melt were identified by interview participants as "green" and "lush." In particular, after the drought in the summer of 2018, Jørund recalled:

> "In the summer of 2018, there was a bad drought. But the valleys with glacier fed rivers, they were very green and they had a lot of grass. So that's that that was a very striking difference between the fields that can utilize this high groundwater level that what I found in this valley is with a glacier, glacier fed streams versus those didn't."—Jørund

In Jørund's perspective, the agricultural lands fed by glacier rivers fared much better than their non-glacier fed counterparts during the drought in 2018. Elin also suggested that some farmers living in close proximity to the glacier were using excess melt as an irrigation system:

> "And one farmer I know, lives very close to the glacier. And they don't have an irrigation system because it used to rain enough during the summer. But now, there are some summers where it doesn't rain for many weeks. But then they have this huge glacier river producing more water because it's because melting and it costs a lot of money to build an irrigation system, so they made a little inlet to store the water."—Elin

According to Elin, using excess glacier melt to supply agricultural lands during times of irregular rainfall or drought helped such farmers maintain their crops. Additionally, through digging an inlet to store the melt water, farmers did not have to purchase expensive irrigation systems. Conversely, in the event that farmers were unable to store excess water in the future, the costs of production could increase, as they would need to invest in new irrigation systems. Moreover, Birgit suggested that excess meltwater was only sustainable for a "limited-time" and in the future, there would be a "breaking-point." Specifically, she stated:

> "Right now, the more the glaciers melt, the better it is for hydro companies and farmers because it's extra water for a limited time. Then once they hit a Breaking Point, things could get bad. So, I think for farmers, it will be quite hard for them once changes to the water supply occurs."—Birgit

Both, Elin, and Birgit highlighted the importance of glacier melt to farmers. Although, according to Birgit, while the excess melt was currently benefiting farmers and hydropower companies, it was not sustainable in the long-term. Moreover, while several experts regarded glacier melt as beneficial for farmers, Katie suggested it could also become a hazard:

> "But I know a lot of farmers who depend on water from the glacier. But at the same time, they're afraid of the snow and glacial melt combination. So, it's something that you need to tame when it's big, but you need it badly when it's small."—Katie

Thus, while farmers were able to capitalize on glacier meltwater supply to irrigate their crops, they were also vulnerable to flooding, GLOFs, and other hazards. As a result of rising temperatures and glacial retreat, the spread of invasive species was mentioned by Live as an emerging risk to farmers:

> "We have a lot of agriculture, which needs water from the glacier. And the temperature is critical. For the agriculture in the area, we can see with temperature change, new species are coming into areas that we haven't seen before."—Live

Specifically, according to Live, the tick species had spread into higher latitudes, which had a negative influence on the exposed sheep in the municipality she lived in. According to Live, this was making sheep sick and particularly vulnerable to the effects of climate change. However, she also suggested that glacial melt could result in new areas closer to the glacier for livestock to graze in, where ticks would be unable to survive.

### 5.4.4 Section Summary

Although the tourism and hydropower sectors were regarded to be specifically vulnerable to changing glacial conditions, the long-term effects of increased melt on agricultural production, was also recognized by several interview participants. As farmers relied on glacier melt to irrigate their crops during dry periods, Birgit suggested a decrease in melt water in the future could have a large impact on crop production. In addition, a decrease in water could also raise the costs of production, as farmers would need to invest in expensive irrigation systems to supply their crops with water during periods of irregular rainfall or drought. Moreover, an increase in the distribution of invasive species, especially ticks, due to an increase in temperature had also been noted by Live. Ticks were regarded as being particularly problematic for farmers, since they transmitted diseases in sheep. Both, the future availability of glacier melt, and the increased distribution of invasive species, were regarded as key issues that could increase farmers' vulnerability to climate change.

## 5.5 Enhancing Adaptative Capacities—Bridges and Barriers

In tandem with the overall research objective, the following section will investigate the bridges and barriers for stakeholder groups in building adaptive capacities in Vestland County. Specifically, *bridges* include rebranding initiatives by the tourism and agricultural industry, and the legitimization of municipality climate networks. Conversely, *barriers* to enhancing adaptive capacities include the inequitable distribution of scientific information and knowledge between the core and periphery, limited financial resources, and the lack of enforced climate leadership at the municipal level.

### 5.5.1 Bridges to Adaptive Capacity

This section will examine the identified bridges to enhancing adaptive capacity in the region. Although tourism was regarded as highly vulnerable to the effects of climate change by some participants and respondents, new tourist strategies aimed to mitigate those effects through reducing the carbon footprint of tourists travelling to the area. In addition, due to climatic changes, viticulture was now possible in the area and was described as an emerging benefit to local actors. Alternatively, while somewhat depressing, *doom tourism* and seeing the glaciers before they completely disappeared, was also identified as a motivation for tourists to visit the region. Although tourism areas surrounding Jostedalsbreen, Breheimen, and Folgefonna National Parks were challenged by the changing environment, both, viniculture, and doom tourism, were examples of how local actors could socioeconomically adapt to glacier retreat. Finally, this section will briefly review the *Climate Network* and its role in co-creating knowledge on local adaptation solutions to climate change in Vestland County.

#### 5.5.1.1 Refocusing the Tourism Paradox

Several participants and respondents emphasized both, the importance of tourism for the local economy, and the perceived vulnerability of the tourist sector to climate change. To Katie, this was a *paradox*, as tourist activities were directly contributing to GHG emissions, and subsequently, increased glacier melt. Specifically, she stated:

> "I would still say that most of the tourists are international and come on a cruise ship or a plane, and when they arrive, they will experience nature and be at peace. I don't think there's a focus on how the tourists get to the location. But when they're at the location, they need to be environmentally friendly. It's kind of a paradox. But now there's a focus on the

> direct emissions, and people are realizing that their footprint is bigger than they thought."—Katie

While international tourism was contributing to increased emissions, Katie also suggested that actors were starting to become more aware of their carbon footprint. Such climate awareness was also mentioned by Live, Elin, and Wida, who spoke about changes to the Jostedalsbreen National Park Plan and tourist strategy. In particular, the aim of the new plan was to focus on attracting Norwegian and European tourists, as they did not need to travel as far and tended to spend more time in the local communities. As it was the local actors who "maintained the cultural landscape and acted as the ambassadors of the park" it was important to Wida that the new visitors' strategy encompassed the needs of the surrounding villages. As glaciers were "protected by the state and the whole world" instead of the municipalities, Live also believed that the new strategy would help lower local $CO_2$ emissions.

Within the new Jostedalsbreen National Park Plan, lowering $CO_2$ emissions by shifting the tourist strategy was a conscious decision by local actors. Specifically, Live mentioned that global $CO_2$ emissions were partially responsible for climate change, including glacier melt. However, the decision to refocus the tourist strategy and potentially reduce the number of international travelers was an example of climate adaptation at the local level. While Jostedalsbreen National Park revised their tourist strategy to lower their carbon footprint, some local entrepreneurs were also adapting to the changing environment by establishing new business ideas.

#### 5.5.1.2 The Flexible Entrepreneur

Despite several questionnaire respondents and interview participants feeling concerned about how glacier change, especially retreat, could result in less tourists visiting the region, there was also evidence of entrepreneurs promoting local capacities by establishing new business ventures. For example, Johan spoke about how some local actors were experimenting with viticulture and started one of the most northern vineyards in the world. In particular, Johan recalled:

> "Some farmers close to Sogndal started to experiment on grapes within the past five to ten years. So, some are making white wine in this area. In the past, in the Hardanger fjord area, it wasn't possible to grow grapes. This is a positive consequence of a warmer climate, as some farmers have been able to make great white wine. So that is that is quite special."—Johan

Although climate change could negatively impact the region in certain aspects, Johan believed that warmer temperatures could result in new opportunities, which was demonstrated through the viticulture example. While Johan spoke about the establishment of a vineyard as an example of local actors capitalizing on the changing landscape, Elin and Wida mentioned the phenomenon of *doom tourism*. According to Elin and Wida, Jostedalsbreen as a "doomed" destination mainly entailed international tourists coming to see the glaciers before they disappeared entirely. According to Elin, doom tourism and "seeing the glacier before it was too late" represented a shift in why some tourists wanted to visit the region. This sentiment was shared by Wida who reflected on a report from 2017, where tourists were asked why they visited Jostedalsbreen National Park. Specifically, Wida shared:

> "In 2017, there was a report that investigated why visitors came and what they wanted to get out of the day, etc. From the report, the most important was of course, to experience the glacier. But that doesn't mean that they wish to walk on the glacier ice or touch it. Many wanted to have a picture and see it before it melts. And in Norway, the fjord landscape is, of course, why most of them come here, the glacier is a bonus, basically."—Wida

The findings from the 2017 tourist report showcased that several travelers came to visit the National Park to see and take a picture of the glacier "before it melts." Although tourists were fascinated by the glaciers, many were disinterested in glacier activities. According to Wida, while many tourists wanted to see the glaciers when they visited, it was the fjord landscape that attracted them to the region initially.

#### 5.5.1.3 Networks and Co-creation of Knowledge

The *Climate Network* was established to build adaptive capacity on climate action within Vestland County. According to Katie, there were meetings roughly every month, where representatives from the municipalities attended online seminars and discussed topics such as ecosystem-based adaptation. The goal of the Climate Network was to both, disseminate scientific knowledge to the municipalities, and then, find practical solutions as to how the knowledge can be used within municipal planning. In Katie's experience, municipalities had a wider focus on climate issues and had begun to investigate how climate change could affect schools, tourism, or caring for the elderly in the future.

### 5.5.2 Barriers to Adaptive Capacity

#### 5.5.2.1 Core Versus Periphery

This section will review the relationship between the core and the periphery as a barrier to adaptive capacity. Specifically, the *core* refers to the major Norwegian cities, including Oslo, Bergen, Stavanger, and Trondheim, whereas the *periphery* is used to describe the communities outside of Oslo and the other large cities. Although interview participants do not explicitly refer to Oslo as the core and their community as the periphery, there are several instances where Oslo and the national government are mentioned in comparison to the study municipalities. As identified by interview participants, the uneven access to information, an inherent knowledge gap, the allocation of funding and resources, and the disconnect between national strategies and localized realities are described as key issues between the core and periphery in relation to adapting to the effects of climate change.

#### 5.5.2.2 The Knowledge Gap

The dissemination of information and knowledge between the core and periphery was mentioned as a barrier to adapting to climate or glacier change. In Katie's opinion, it had been difficult for municipalities and Vestland County to access information. In particular, she recalled:

> "We see that we want to do more than the national authorities want or prioritize. So, for municipalities and regional authorities, it's often that we have to find our own way. We have to combine 10 articles to get good information. And for the small municipalities, it's kind of hard because all the national research is done in big cities. So, I guess my point would that we need more national action that is more adaptable to local levels. We can't all do the same, we must adapt to how the conditions are in municipalities and regions. And maybe a bigger toolbox, where you can pick some tools, but not all of them."—Katie

For Katie, it was challenging to find and gather useful information for the local municipalities in the county, since the majority of climate research was produced by actors living in larger cities. While she acknowledged it was challenging to obtain information, it was also sometimes difficult to decode the information that was readily available. For instance, although the municipality of Oslo had provided some guidance material on climate budgeting, it was difficult to enact without a professional analyst. According to Katie, a pathway to strengthening climate action at the national level would include policies that were adaptable at local levels. While Birgit also suggested the knowledge gap between the core and peripheries was preventing proactive climate

policy, strengthening networks within these communities could be a solution. Specifically, Birgit highlighted:

> "There's not that much competence in the rural districts because the professional environments like NVE, NGI, and all the institutes of climate research happen in the cities. So, it's kind of difficult to disseminate that out to the local areas because they don't get to go to conferences, they don't get to go to seminars, they don't get to go to courses, because it's just too far for them to travel. And it's too expensive, so they also don't get to build their own sort of competence and capacity. So, I think putting conferences out in more remote areas or doing courses out in the districts would help a lot and really utilize those networks that exist."—Birgit

From Birgit's perspective, it was difficult to disseminate information to the local municipalities, since much of this knowledge was coproduced at seminars, workshops, and courses in the larger cities. In addition, the amount of time and resources it would require local actors to attend such functions was ultimately a barrier to enhancing "competence and capacity." However, by planning to have conferences in remote locations, the unequal dissemination of climate information between actors living in the core and those in the periphery could be lessened.

#### 5.5.2.3 Funding, Resources and Participation

While the unequal dissemination of scientific knowledge was acknowledged as a significant barrier to enhancing adaptive capacity to glacier change in the six municipalities, the allocation of funding and resources was also mentioned by Birgit:

> "It's incredibly difficult for smaller local authorities or governments to have expertise on climate adaptation. Those bigger city municipalities have a lot of resources, a lot of capacity, a lot of competence, while smaller municipalities where the effects of climate change often happen, are places where they are struggling to keep schools open. So having climate adaptation on top of other social issues is extremely challenging…. And I think that's why just handling something that's happening today, like having the risks associated with floods and, and rock falls and stuff that happens. It's difficult for them to handle it, if it happens, it will be even more difficult for them to handle or to try to envision what could happen. So, I think it's, it's a matter of capacity and resources."—Birgit

In Birgit's experience, the capacity of remote communities to adopt climate policy was limited by local realities or other pressing issues, including the limited funding that was needed to support essential social services. Because of the *finite pool of worry*, where future environmental concerns were perceived as trivial in comparison to current social issues (Linville & Fischer, 1991), it was challenging for local governments to envision the future and invest in proactive climate

management. Likewise, Katie believed limited funding combined with political reluctance to enact climate strategies was acting as a major barrier to climate action:

> "Making politicians and people living here aware that climate change is a serious topic, and we need to spend a lot of money, making sure it doesn't happen. And then it's kind of like you don't see a result. You only see a result when it happens, and you haven't prepared. But if you're well prepared, you probably won't see it resolved—it's just the river won't flood. So that means it's like normal. Because people are generally not happy with spending taxpaying money that's supposed to go to schools and taking care of elderly. It's also the question of when do we need to do it? Can we still spend money on this urgent topic this year, and next year, and maybe wait a bit with climate change action?"—Katie

As the future impacts of climate change remained largely uncertain, it was difficult for some local politicians to prioritize a potential future issue instead of current problems. By using flood mitigation as an example to highlight the invisibility of climate action, Katie suggested that this further served to politicize the issue. However, with more funding from the national government to be used specifically for climate adaptation, Birgit believed that rural communities would have the ability to create or strengthen plans:

> "It's very easy to say we need more resources from the state. That is, of course, the answer, but it is not always easy to do…. they receive money from state level, but then they see other things that are more important."—Birgit

Although Birgit acknowledged the need for additional funding from the core to support climate plans in the periphery, there was also a need for strengthened rules surrounding the participation and implementation of policy at the local level. Specifically, Birgit suggested:

> "Many municipalities are lacking having climate adaptation in municipal plans. I think better planning and incorporating climate adaptation into those plans would help. And, coupling that with a budget is extremely important. I think that's where the missing link is—a budget including concrete numbers, and then actually doing it. Because I don't think there's many requirements. It's more like a guideline, like a wish that every municipality has a climate adaptation plan, but there's no requirements by law that you have that in his plans, and I think putting more stricter rules and laws for what is demanded of the Minister of planning would really do a lot. And I think providing the sort of knowledge to help municipalities do that, I think is quite important."—Birgit

In Birgit's opinion, the government needed to implement stricter rules on what forms of climate adaptation needed to be included within municipal plans. While both, increased funding from the national government, and providing opportunities for the dissemination of scientific information to be shared between the core and periphery was important, without the requirement for municipalities to implement climate adaptation solutions, communities could remain vulnerable to

the effects of climate change. The belief that rules should be strengthened to encourage all municipalities to participate in climate adaptation solutions was also shared by Katie. Specifically, while the Climate Network was established to enhance local resiliency to climate change, municipal participation was not required. As the result of this, some municipalities did not participate in the monthly meetings and workshops.

## 5.6 Chapter Summary

In this chapter, the findings from the online questionnaire and interviews were combined and organized by the four internal factors of social vulnerability. The four internal factors of vulnerability included the environmental impact of glacier change, perceptions, local economies and livelihoods, and the bridges and barriers to strengthening adaptive capacity in Vestland County. While glacier melt was identified as being highly visible and a signifier of global climate change to local actors, it was also regarded to be highly invisible to outsiders. Despite some informants being particularly vulnerable to glacier hazards, including floods and GLOFs, icefall, landslides, and avalanches, the perceived risks were not equally shared between actor groups or communities. The notion of place attachment and the extent to which actors identified and depended on the physical environment to sustain local economies and livelihoods was identified as an important perception that could either enhance or reduce climate vulnerability. Although the tourism, hydropower, and agricultural sectors were found to be vulnerable to glacier melt, new investment opportunities, reducing the carbon footprint of tourists, and aided municipal climate planning were classified as bridges to strengthening adaptive capacities in the region. Alternatively, the inequitable distribution of knowledge, resources, funding, and capacity between the core and periphery was recognized a barrier to enacting proactive climate adaptation plans in the six municipalities. In the following chapter, the findings from the LSVF are discussed in relation to the three research questions presented in Chapter 1.

## Questionnaire Respondents

| RESPONDENT # | GENDER (F/M) | MUNICIPALITY | RESPONDENT # | GENDER (F/M) | MUNICIPALITY |
|---|---|---|---|---|---|
| **1** | M | Stryn | **44** | F | Kvam |
| **2** | M | Ullensvang | **45** | M | Kvam |
| **3** | F | Kvinnherad | **46** | F | Etne |
| **4** | M | Bærum | **47** | M | Luster |
| **5** | F | Luster | **48** | F | Luster |
| **6** | F | Stryn | **49** | F | Luster |
| **7** | M | Bergen | **50** | F | Luster |
| **8** | F | Stryn | **51** | F | Kvinnherad |
| **9** | M | Stryn | **52** | F | Kvam |
| **10** | F | Sogndal | **53** | F | Kvinnherad |
| **11** | M | Stryn | **54** | M | Sogndal |
| **12** | F | Stryn | **55** | F | Lom |
| **13** | M | Luster | **56** | F | Stryn |
| **14** | F | Trondheim | **57** | F | Stryn |
| **15** | M | Midt-Telemark | **58** | F | Stryn |
| **16** | F | Midt Telemark | **59** | M | Bergen |
| **17** | F | Midt-Telemark | **60** | M | Stryn |
| **18** | M | Luster | **61** | M | luster |
| **19** | M | Kvinnherad | **62** | M | Luster |
| **20** | F | Ullensvang | **63** | F | Luster |
| **21** | F | Kvinnherad | **64** | M | Luster |
| **22** | F | Ullensvang | **65** | F | Luster |
| **23** | F | Ullensvang | **66** | M | Luster |
| **24** | F | Ullensvang | **67** | M | Hemsedal |
| **25** | F | Kvinnherad | **68** | M | Luster |
| **26** | M | Ullensvsng | **69** | F | Luster |
| **27** | M | Ullensvang | **70** | F | Luster |
| **28** | F | Ullensvang | **71** | F | Luster |
| **29** | F | Luster | **72** | M | Luster |
| **30** | F | Ullensvang | **73** | F | Luster |
| **31** | F | Luster | **74** | M | Luster |
| **32** | M | Luster | **75** | F | Luster |
| **33** | F | Luster | **76** | F | Luster |
| **34** | M | Ullensvang | **77** | M | Luster |
| **35** | F | Sogndal | **78** | M | Luster |
| **36** | M | Ullensvang | **79** | M | Luster |
| **37** | F | Ullensvang | **80** | M | Sogndal |
| **38** | F | Kvam | **81** | M | Luster |
| **39** | F | Kvam | **82** | M | Luster |
| **40** | M | Kvam | **83** | M | Luster |
| **41** | M | Kvam | **84** | M | Luster |
| **42** | F | Kvam | **85** | M | Sogndal |
| **43** | F | Vik | **86** | F | Luster |

**Table 7**. Respondents are organized by #. Please note that respondents #4, 7, 14, 15, 16, 17, 43, 46, 59, and 67 were omitted from the results due to living/working outside of study municipalities.

# 6 DISCUSSION AND CONCLUSION

## 6.1 Introduction to Discussion

In this research, *vulnerability* is defined as the range of social and ecological conditions that prevent actors and society from adapting to the uneven impacts of climate change (Hopkins, 2015; O'Brien, 2007). Subsequently, *resiliency* refers to the process that links adaptive capacities following disruption or change (Ford et al., 2018; Norris et al., 2008). Using a vulnerability framework, the aim of this research is to investigate how adaptive capacities and resiliency are strengthened by actors living in areas undergoing environmental change. Building from previous scholarship on vulnerability, this research applies the *Localized Social Vulnerability Framework* (LSVF) to assess vulnerability and resilience to glacier change in Vestland County. Specifically, the LSVF is used to examine how environmental impacts, perceptions, economies and livelihoods, and adaptive capacities of actors are influenced by glacier change. The findings from the LSVF intend to answer the three research questions:

1. How does glacier change influence vulnerability in Vestland County?
2. How are retreating glaciers affecting key industries, such as tourism, hydropower, and agriculture in Vestland County?
3. What are the adaptive capacities of actors in relation to glacial change in Vestland County?

The following section is organized by the three research questions. To begin, this chapter presents *place* and its role in influencing climate vulnerability. In addition to place, the knowledge and resource gap between the cities and remote villages is suggested as another key element contributing to vulnerability. Moreover, this chapter discusses the positive and negative impacts of glacier change on the tourism, hydropower, and agricultural sectors. In tandem with the final research question, the adaptive capacities of local actors in strengthening climate resilience are described. Finally, it ends with concluding thoughts, as well as recommendations for future research.

## 6.2 Glacier Change and Drivers of Vulnerability

In tandem with the first research question, this research identified several social vulnerabilities to glacial change in Vestland County. The following section presents the notion of *place* and its role

in increasing vulnerability to glacier change. Additionally, this section suggests that the relationship between the national authorities (core) and remote glacial villages (peripheries) is central in influencing vulnerability. Finally, this section assesses risk awareness in relation to managing vulnerability to hazards within the six municipalities.

### 6.2.1 The Role of Place in Shaping Vulnerability

According to the findings of this research, glacier change is visible and concerning to the research informants. Questionnaire respondents observed glacial change, and used words such as "sadness", "disturbing", "loss" and "shame" to describe how they felt about retreat. While several informants suggested that industry, especially tourism, are the most vulnerable to continued retreat, others attached the retreating glaciated landscape to losing a sense of identity and culture.

While participants like Birgit acknowledged that economic and cultural values were interlinked, she also emphasized the importance of glaciers in maintaining local identity[15]. Specifically referring to communities surrounding Folgefonna, Birgit suggested that local identities were strongly influenced by place. As glaciers continued to retreat, it was emphasized that the place identity of local actors could be threatened. For communities near glacial environments, this is perhaps unsurprising since local recreational activities, livelihoods, and family heritage are directly connected to the glaciers. Although this finding may be obvious, the impact of climate change on place attachment is an area that has been under researched within vulnerability studies (McNamara et al., 2019; Kelman, 2013). Despite this, the notion of *place* and its role in shaping or lessening vulnerability has been central to the findings of this research. For instance, while glacier recession threatens the place identity ascribed by local inhabitants, such cultural values also have the capacity to mobilize actors to protect their home environments from change. The following section presents the relationship between the national authorities (core) and the remote glacial villages (peripheries) in maintaining vulnerability to glacier change.

### 6.2.2 Knowledge & Resources

The findings indicated the role of *peripherality*[16] in influencing vulnerability in Vestland County. Particularly, an information and knowledge gap was evident between governmental actors living in the major cities, and those residing in smaller communities. For instance, most climate research,

[15] See Chapter 5—section 5.3.1.
[16] To be peripheral.

workshops, and seminars occurred in institutions located in Oslo, Bergen, Stavanger, and Trondheim. While actors living in remote areas were invited to the cities to participate in the workshops, resources and travel time often acted as barriers to enhancing climate competence and capacity. Likewise, the unequal dissemination of climate knowledge served to increase vulnerability to glacier change, as information was not always adaptable to local conditions.

Although several villages within the six municipalities were exposed to the effects of climate change, local actors sometimes lacked the knowledge or resources to respond. Moreover, as conceptualized by Linville & Fischer's (1991) *finite pool of worry*, it was often unrealistic for local governments to prioritize funding climate initiatives over maintaining other important services, like schools and senior living accommodations. Additionally, as the future effects of climate change in these areas were largely uncertain, it was difficult to proactively plan and spend limited municipal resources on mitigation or adaptation solutions. Indeed, while there is growing scientific evidence that there is a need to implement drastic climate policies, national and local authorities often cite *uncertainty* as an excuse for climate inaction (Whitmarsh, 2011). Such discourse on climate uncertainty was also found in Vestland.

Through interview responses from participants, Birgit, and Katie[17], it was evident that while the unequal distribution of information and knowledge between the core and peripheries served to maintain disparities, the political unwillingness of some local politicians to participate in climate action further induced vulnerability to climate change. For instance, although an invitation to partake in the *Climate Network*, a collaborative platform to promote climate knowledge capacity, was offered to all municipalities in Vestland, it was found that approximately thirteen municipalities did not participate in the monthly workshops. This is problematic, as climate adaptation requires planners to consider how the local conditions, including the landscape, land-use, economics, and public perception, can be impacted by climatic changes (Campos et al., 2016). While there were other ways in which municipalities could participate in climate action, the Climate Network was perhaps unique, as it was collaborative and tailored towards the specific problems arising in the County. As suggested by Campos et al. (2016) & Wise et al. (2014), collaborating and involving diverse knowledge domains, including ecological and local knowledge in planning helps to reduce climate vulnerability. Although a county representative

[17] See results from Chapter 5—section 5.5.2

contended while "…the challenges of climate change may vary between the municipalities…", it was the level of preparedness and planning that determined the degree to which communities are affected. Arguably, a solution to noninvolvement in county-level climate programs, would be mandatory participation.

As referred to by Katie[18], the success of climate solutions also prevented local politicians from investing in future adaptation initiatives. The often, *invisibility* of climate change impacts and when successfully implemented, adaptation solutions, has been discussed by a plethora of scholars within the past several decades (Lehtonen et al., 2019; Norgaard, 2006; Brechin, 2003; Bulkeley, 2000). Although some authors have argued that the effects of climate change remain largely invisible to the general-public due to climate apathy (Lehtonen et al., 2019; Brechin, 2003) and/or lack of accessible scientific information (Bulkeley, 2000), Norgaard (2006) suggested the phenomenon of *denial* (pp.365-6). According to Norgaard, denial is neither "greed nor inhumanity", but instead, non-response to information that may seem too difficult to integrate into everyday life (p.366). When the effects of climate change were invisible, it was perhaps easier for local politicians to stay in denial and maintain the status quo. The inequitable effects of climate change on social and environmental systems also helped to perpetuate the invisibility of climate change on the national scale. While many of the research informants stated that glacier change in their communities was highly visible, it was also mentioned that it remained highly invisible to actors living outside of mountainous landscapes.

For actors living in the major Norwegian cities, it was possibly easier to disassociate or distance themselves from the social or environmental consequences of climate change, such as retreating glaciers. Although climate action was stated as a priority for the national Norwegian government, carbon emissions emitted from the petroleum sector have remained relatively constant between 1998-2020 (Norsk Petroleum, 2020). As GHGs were responsible for the greenhouse effect, there was undeniably a disconnect between national climate policies and addressing the root causes of climate change. This becomes more complicated when considering the emissions released by the Norwegian oil and gas trade outside of its border. Unfortunately, unambitious climate policies have real-localized effects, which is captured by this research. Specifically, this research has suggested that glacier melt as the result of climate change, is influencing the relationship local

[18] See Chapter 5—section 5.5.2

actors had with "place" in shaping identity, culture, and connectedness to nature. While place attachment and notions related to identity are vulnerable to glacier melt, these same values were also found to enhance community resilience. The role of place attachment in strengthening adaptive capacity and resilience will be discussed further in this chapter.

### 6.2.3 Vulnerability and Risk Awareness to Natural Hazards

While this research initially anticipated that GLOFs and flooding would be perceived as the main hazard risks to informants, this was not the case. Despite some questionnaire respondents reporting that a GLOF had previously occurred in their community, very few were concerned about future outburst floods. In addition, while some interview participants regarded GLOFs to be a risk to some downstream communities within the study sites, it was considered a well-managed risk, as NVE constantly monitored the glacier lakes. Noteworthy was the role of state institutions, like NVE, in shaping social trust to minimize vulnerability to climate risk.

Even though adaptation challenges existed, perspectives on Norway's readiness and ability to adapt to the effects of climate change was also reflected in the *University of Notre Dame's ND-GAIN Country Vulnerability Index*. From 1995 to 2019, Norway had been ranked by the Country Index as the least vulnerable country to climate change, due to its wealth and geographic exposure to impacts (ND-Gain, 2019). Of course, being the least vulnerable to climate change did not imply that vulnerabilities did not exist, in fact, this research suggested otherwise, but geography and state safety nets and/or insurance schemes were perhaps why some informants did not feel threatened or compelled to educate themselves on local hazards. Specifically, while many interview participants were aware of local hazards, two participants were found to be completely unaware of what GLOFs were and the risks associated with them. This was also revealed in the questionnaire, where only three out of ten of respondents reported feeling "very informed" about possible glacial hazards in their communities. Although there are various explanations as to why locals may be unaware of glacial risks, including high social trust, education, previous experience, or proximity to potential hazard site, it is interesting to consider the extent to which risk awareness influences vulnerability to hazards. This is especially relevant when considering icefall and the risk it poses to tourists.

Although in 2014 and 2018, tourists visiting Nigardsbreen were killed by icefall after overstepping the chained barriers, several participants mentioned that some tourists were still ignoring the dangers to get a closer look at the blue ice. Perhaps tourists were unaware of how unpredictable and precarious the situation really was or believed the risk was worth the experience or photograph. Regardless of the cause, failure to obey warnings or signs increased tourist vulnerability to hazards, especially icefall. For the surrounding municipalities, tourist injury or death could also have a negative impact on the reputation of the area. According to one participant, after the event in 2018, there was a decrease in tourists visiting Nigardsbreen the following season, as the area was deemed as "dangerous." This also suggests that while tourists who ignore the risks are increasingly vulnerable, surrounding communities reliant on tourism expenditure can also be economically impacted. While *tourist risk awareness* and its role in influencing vulnerability is beyond the scope of this research, this is an area that can be investigated in future studies.

## 6.3 Impact of Glacial Retreat on Industry

Motschamn (2020) found that successful climate planning includes understanding how local businesses are affected by glacier loss (p.838). As glaciers in Western Norway are undergoing significant retreat, this research aimed to explore the potential impacts glacier change can have on local tourism, hydropower, and agriculture operations[19]. As few studies have explored the possible effects of glacier change on these three industries in Norway (Demiroglu et al., 2018; Kvalvik et al., 2011; Tveteras et al., 2011; Uleberg et al., 2013), it is intended that this research contributes to the emerging field.

### 6.3.1 Impacts of Glacier Change on Tourist Activities

Worldwide glacier related tourism is experiencing challenges and new opportunities from ongoing glacial change. Unsurprisingly, the impact of glacial retreat on tourism in Vestland was a primary concern for many research informants. Indeed, glacier related tourism significantly impacts the region's local economy, as many actors are directly or indirectly dependent on tourist activities to supplement income. However, as glaciers have thinned and retreated, the topography and ice slopes are increasingly unstable and dangerous for certain glacier activities, such as hiking and climbing (Purdie, 2013). Because of this, glacier hiking, an activity that was once advertized as family friendly, may need to be rebranded and restricted to those who can handle the difficult

[19] In connection to RQ #2.

terrain. Additionally, as temperatures rise and snow cover diminishes, the viability of the ski industry becomes precarious, since business owners need to invest and rely on technology to produce and retain snow (Demiroglu et al., 2018). In addition, as other services, such as hotels, food and beverage operations, and transportation services are dependent on mountain related activities to attract guests, such businesses are also vulnerable to retreat. However, while certain tourist operations were found to be economically and socially vulnerable to glacier change, new opportunities in the face of changing environmental conditions were also revealed.

#### 6.3.1.1 The Resilience of the Lifestyle Entrepreneur

Although glaciers in Jostedalsbreen, Breheimen, and Folgefonna are melting at an alarming rate, many local entrepreneurs and municipality planners were adapting to such changes. For instance, although continued recession suggested that some glacier guiding companies would no longer be able to operate in the future, these businesses had been found to be particularly adaptable to changing circumstances.

According to Steiner & Atterton (2015), *lifestyle entrepreneurs* often have attributes, such as motivation, flexibility, proactivity, and resources, to turn environmental challenges into new business opportunities (p.33). As the result of their values and motivations, their influence on climate adaptation and ultimately, community resilience, is positive (Tervo-Kankare, 2018; Steiner & Atterton, 2015). Likewise, as suggested by Jørund, the flexible lifestyle entrepreneur would continue to play an important role in attracting tourists to Vestland County. While certain businesses dependent on glacier tourism, such as ski resorts, accommodation operations, and food and beverage stores, may be economically vulnerable to a decrease in tourists visiting the glaciers, these businesses could also enhance existing services to attract guests. For instance, one interviewee revealed that a local ski resort had plans to construct an infinity pool filled from collected glacial melt water. Although an infinity pool did not necessarily compensate for the impact climate change has had on snow and precipitation patterns, it demonstrated the adaptability and resilience of local business owners in finding solutions to environmental issues.

Meanwhile as certain businesses adapted existing operations, some were capitalizing on new entrepreneurial opportunities. During this research, it was discovered that a new form of glacier-related tourism was marketed to potential visitors—*doom tourism*. As Jostedalsbreen National Park was experiencing rapid environmental change, tourists were visiting the park to see the

glaciers before they disappeared entirely. As noted by several participants, the interest in Jostedalsbreen as a *doomed* destination was increasingly cited as the reason why tourists were visiting the national park. As glaciers are well-recognized as an indicator of climate change, this finding is perhaps expected. However, while the phenomenon of doom tourism is rather dark, it offers local actors the opportunity to continue to benefit from the physical environment. Alternatively, changes to temperature had also resulted in the possibility of new crop ventures, including viniculture. The establishment of the *Slinde Vineyard* was possibly another example of local actors embracing new environmental opportunities and ultimately, building resilience to climate impacts. Nonetheless, despite some entrepreneurs having the capacity to create a new business venture or reinvent current operations to reflect environmental change, this was arguably, not feasible for all business owners. Reasons for this can include financial constraints, uncertainty, and personal motivation.

### 6.3.2 The Future Uncertainties of Hydropower

Currently, 95% of consumed electricity in Norway is generated through 1681 hydropower plants across the country (Regjeringen, 2021). Even though hydropower companies have profited off glacial melt to produce electricity for decades, host municipalities also rely on the direct investments from the companies to boost economic development. Because of Norway's reliance on hydropower plants to supply electricity to the country, this research investigated how glacial retreat could impact the hydropower industry and ultimately, the host municipalities. This research found that while, benefit sharing boosted economic development in some of the municipalities, such as a Luster, changes to future glacial run-off was not necessarily planned for by some municipalities. As municipalities that host hydropower companies in their jurisdictions relied on the benefit sharing scheme, this could influence future climate resilience. Moreover, while this research found that retreating glaciers were not currently impacting hydropower production, a few experts contended that smaller plants had difficulties filling up their reservoirs the past summer. While increased electricity prices mitigated this shortfall, for one participant, this showcased the "vulnerabilities of the system."

Although there are uncertainties regarding future precipitation patterns, changes to watershed boundaries, and run-off, glacier melt was currently regarded by hydropower employees and academic experts as beneficial. Even though some experts suggested that at some point, the

glaciers will drastically retreat or disappear entirely, resulting in a decrease of water for some hydropower reservoirs, this was far into the future. However, as certain municipalities are dependent on hydropower investment to supplement new business ventures or enhance social goods, it would perhaps be beneficial for municipal planners to consider future changes to hydropower production to increase resilience. While this study acknowledges there are a lot of uncertainties surrounding the future influence of glacier discharge on hydropower production in Norway, this is an area that would greatly benefit from continued research.

### 6.3.3 Agriculture and Economic Vulnerability

Climate research has suggested future changes to temperature and precipitation will have a large impact on agriculture in Norway (Uleberg et al., 2013). Generally, such climatic changes are predicted to have many positive effects on agriculture, as new crops can be introduced, areas for production can be expanded, leading to an increase in crop yield (Uleberg et al., 2013). However, although some studies have assessed the impacts climate change will have on agriculture production in Norway (Hanssen-Bauer et al., 2010; Kvalvik et al., 2011; Uleberg et al., 2013), there is a knowledge gap on how retreating glaciers could affect surrounding farms. While a knowledge gap is arguably, influencing the capacity of local farmers to adapt to future climate impacts, this is also an opportunity for research to explore this topic in greater detail. Nonetheless, according to the findings of this research, two dimensions of vulnerability on the livelihoods of farmers were revealed: future water availability and the increased distribution of disease-bearing insects.

While a decrease in future melt water due to retreating glaciers would have an obvious impact on downstream communities and businesses, it would also affect farmers who relied on the water to irrigate crops. Even though excess melt water from the glacier fed rivers or streams had been beneficial to farmers during periods of sporadic precipitation or droughts, the reliance on future melt water was less dependable. For instance, for some farmers who have dug infiltration ditches to supplement irrigation, a future decrease in glacier melt could increase production costs, as irrigation technology would need to be purchased. The reliance on excess glacier melt to irrigate crops by some farmers revealed potential economic vulnerabilities. Specifically, in the event that new irrigation systems were acquired, the cost of production would increase. This may be economically unviable for small-scale farmers, who frequently face liquidity and funding

constraints that prevent them from purchasing new equipment (Tveteras et al., 2011). To enhance farmer resilience, it would be beneficial for policy makers to better understand the social and economic risks associated with a decrease in glacial melt water on agriculture productivity.

Another identified vulnerability was the link between glacier retreat and the spread of disease-carrying insects. Specifically, due to changes in snow cover, precipitation, slope stability, and increased thaw in mountainous areas, it is expected that there will be an increase in shrub distribution (Uleberg et al., 2013). Such changes to vegetation have been reported to be favourable for herding animals, especially sheep, as they enjoy extended grazing periods on fresh grass (Uleberg et al., 2013). While several interview participants mentioned the fresh grassland to be beneficial to sheep, the changing glacial landscape also supported the distribution of disease-bearing ticks. Because of this, sheep were regarded as particularly vulnerable to climatic changes. Since sheep farming is vital to livelihoods and economies in Vestland, it was perhaps expected that some participants were concerned about the increased abundance and range of ticks. Indeed, the economic loss as the result of tick-borne fever is a major challenge to Norwegian sheep farmers, as lambs are incredibly susceptible to exposure and death (Gilbert et al., 2017). Surprisingly, while participants mentioned the economic costs of tick-borne illness for livestock farmers, the increased spread of ticks and its impact on human health and other animals was not mentioned. To control the increasing manifestation of tick-borne illness to livestock, and ultimately build farmers' adaptive capacity to climate change, more research is needed into *where* exposure is most likely.

## 6.4 The Adaptive Capacities of Local Actors

Although several elements contributing to vulnerability were identified, including the erosion of identity and cultural values, economic dependence, denial, risk awareness, and knowledge gaps, the findings also revealed the adaptive capacities and resilience of local actors. Although examples of adaptive capacity in relation to glacial change have been illustrated and integrated into this chapter, the purpose of this section is to emphasize how decisions by local policy makers is influencing the climate resiliency of Vestland. In tandem with the final research question, this section outlines the adaptive capacities of the National Park board and local businesses in influencing climate action.

### 6.4.1 Strengthening Local Resilience to Climate Change

While the past few years have been unusual due to the COVID-19 pandemic, the economic importance of tourism in Norway cannot be understated. In 2018, the tourism industry significantly contributed to the annual GDP and employed thousands of workers (Innovasjon Norge, 2019). Even though domestic tourist consumption has significantly increased since 2008, the expenditure by foreign visitors is increasing at a faster rate (Innovasjon Norge, 2019). The increase in foreign visitors is quite beneficial for food and beverage businesses, airlines, and accommodation operations, since they tend to have a higher daily expenditure than Norwegian tourists (Innovasjon Norge, 2019). Unfortunately, although tourism plays a critical role for economic development and value creation, it contributes significantly to climate change. As previously mentioned, the release of $CO_2$ and other GHGs are responsible for increases to global temperature, and ultimately, melting glaciers. For many actors in Vestland, this perhaps represents a paradox, since tourists are essential to the local economy, but also represent a part of the climate problem. While the continued reliance on tourists to support the local economy was presented in this research as a vulnerability, changes to the Jostedalsbreen National Park visitor strategy was also found to be an example of stakeholders strengthening climate resilience.

As tourism was regarded as both, vulnerable to the effects of climate change, and directly contributing to the melting glaciers, the new tourist strategy at Jostedalsbreen National Park aimed to mitigate these impacts through reducing the carbon footprint of tourists travelling to the area. Since Norwegian and European tourists tended to emit less to reach their destination and spent more time in the local communities than their international counterparts, the National Park Board decided to refocus their visitor strategy to embrace these elements. While it was acknowledged by one participant that preserving the glaciers was beyond the capacity of the local municipalities, the shift in the tourist strategy perhaps showcased the agency of local actors in protecting their *place* from the impacts of climate change. Of course, with any decision or policy, certain actors benefit while others lose (Aguiar et al., 2018). For instance, while marketing to domestic and European tourists could help to lower national carbon emissions, actors such as bus drivers, souvenir shop owners, excursion managers, and cruise port personnel who relied on international tourists to supplement income may be negatively affected by such changes. Likewise, as international expenditure is increasingly important to the economic development of certain areas and the national GDP, the tourist strategy in Jostedalsbreen National Park could also conflict with other

organizations who have an interest in continuing to attract visitors from outside of Europe. Although it is important to consider how climate decisions conflict or contradicts the aims of different stakeholders, it is also recognized that current tourism trends are not sustainable. Perhaps the shift in the visitor strategy could set a precedent for how climate initiatives could be adapted and realized at the local level. As this research has also highlighted the adaptability of lifestyle entrepreneurs in realizing new business ventures, it is possible that the shift in visitor strategy could create new opportunities for local actors.

# 6.5 CONCLUSION AND FUTURE RESEARCH

To investigate how adaptive capacities and resiliency are strengthened by actors experiencing environmental change, this research developed and applied the LSVF to the six municipalities. The purpose of the LSVF was to understand the different factors driving vulnerability: the environmental impact of glacier change, perceptions, economies and livelihoods, and bridges and barriers to adaptive capacities. Although the ND-GAIN index identified Norway as the least vulnerable country to climate change, it was evident from this research that several vulnerabilities exist. Factors shaping climate vulnerability in Norway include the unwillingness of certain policy makers to enact stricter climate measures, the information and knowledge gaps between the cities (core) and remote villages (periphery), and limited resources. In addition, perceptions such as climate apathy, uncertainty, and denial continue to prevent the implementation of adaptation solutions at the local level. At the national-scale, climate plans are unambitious or fail to address the real issues. For instance, while Norway has committed to lowering GHGs, carbon emissions from the oil and gas industry have remained constant since 1998 (Norsk Petroleum, 2020). In addition to the oil and gas industry, the tourism industry plays a significant role in both, global carbon emissions, and Norway's GDP. Unsurprisingly, while tourist expenditure supports local economies and livelihoods, is it also contributing to environmental change (Schäfer & Waitz, 2014). However, as many local actors in the six municipalities depend on mountain and glacier related activities to support livelihoods, preserving the landscape remains a priority. Specifically, to mitigate the tourist paradox, the revised Jostedalsbreen National Park strategy aims to reduce the carbon footprint of individuals travelling to Norway. The new visitor strategy is a clear example of local actors using adaptive capacities to enhance community resilience to climate change. In the future, it would be relevant to investigate whether tourist patterns have changed following the revised Jostedalsbreen National Park visitor strategy. In the event the revised national park strategy results in lowering the carbon footprint of tourists, policy makers should consider similar initiatives in other parts of Norway.

The notion of *place* in addressing vulnerability to build resilience is an important theme throughout this research. For instance, while glacier melt challenges identity and livelihood, it also has the capacity to mobilize actors to protect their communities from climate impacts. This has been emphasized by the revised Jostedalsbreen National Park Strategy, the Climate Network, and the

lifestyle entrepreneur. As resiliency involves embracing change and capitalizing on new opportunities (Steiner & Atterton, 2015), the lifestyle entrepreneur will perhaps play a crucial role in strengthening climate resilience in Vestland. Nonetheless, while this research showcased new opportunities for tourism, hydropower, and agricultural businesses, it is unknown the extent to which all stakeholders will adapt to future glacier retreat. As the impact of climate change on place attachment (identity and dependence) is an area that has been under researched (McNamara et al., 2019; Kelman, 2013), this perhaps represents an opportunity for future research. Specifically, it is evident that there is a need to investigate the role of place attachment and glacier retreat in Norway. As this research focused broadly on the six municipalities of Kvam, Kvinnherad, Luster, Sogndal, Stryn, and Ullensvang, it may be of interest to apply the LSVF to specific villages undergoing significant environmental change.

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# 8 APPENDICES

# Appendix A: Interview Guide for Locals/Business Owners/Workers

(Interviews were held in English. The questions below were prepared for the interviews, but only certain questions were selected based on participant knowledge/interest).

**Background:**

1) Where do you live?
2) What is your age?
3) What is your gender?
4) Where do you work?
5) What is your job position?
6) How long have you worked/lived in **X** (*dependent on location*)?
7) Why do you live in **X**/ what brought you to this area?

**Personal Connection to Glacial Change:**

8) Glacial changes include melting, retreating, erosion, and flooding, as well as increased/decreased precipitation. Have you personally noticed any forms of glacial change?
- If so, please describe.

9) In your opinion, has glacial change increased, decreased or stayed constant since moving/working into the area?
10) What do you believe to be the causes of glacial change?
11) Has glacial change affected your household or job?
- If so, how?

12) Has glacier change changed or interrupted your job?
- If yes, how?
- If yes, will adapting to glacier change at work continue to occur?

13) Does glacial change pose any danger/threat to you?
- If so, what are the largest risks to you?

14) Glacial change can impact individuals and communities in a variety of different ways, including socially, environmentally, and economically. Are you personally concerned about the effects of glacial change? Why or why not?
15) Does glacial change present any socioeconomic opportunities for you?
- If yes, what?

16) Does glacial change present any environmental opportunities for you?
- If yes, what?

17) Do you believe that the glaciers present a hazard to you and your household?
- If so, what is at risk?

18) Would you consider moving because of a glacial hazard or threat?
- Why or why not?

19) Would you consider changing jobs because of glacial change or hazards?
- Why or why not?

**Glacial Change and Community:**

20) Beyond your own property, has glacial change impacted your community/community you work in?
- If so, how?
- Direct/in direct risks

21) Does glacial change currently pose any danger to your community?
22) If so, what are the risks?
- What is at risk?

23) Has there been a situation where different individuals from the community worked together to mitigate any form of glacial change or its impacts?
- If so, how?

24) Has glacial change and/or flooding impacted any visitors or tourists who have visited the area?
- If so, please explain how.
- If yes, are you worried about glacial change continuing to impact the tourist experience in the future?
- Do you believe that retreating/melting glaciers will result in less people coming to the area for vacation or recreational sport?

25) Does glacial change present any new opportunities for your community?
- If so, what?

**Flooding:**

26) Glacial flooding can be the result of excess melting or the sudden release of a contained glacial lake on the glacier—also known as a Glacial Lake Outburst Flood (GLOF). Since living/working in this area, have you noticed any changes in flood frequency or magnitude?
- If so, please explain.

27) What has caused flooding to occur?
28) Adaptation measures or technologies include devices that help to minimize the impact of flooding. Such technologies may include early warning systems, floodwalls, planting vegetation to retain excess water etc. Have you personally implemented any adaptation or mitigation technologies to protect your property from flooding?
- If so, what type of adaptation or mitigation technologies?
- Have you had to personally fund such measures? (*If appropriate, a good follow-up question could include asking participant to state amount of money spent on such technologies*)

29) Has the government or NVE implemented any adaptation technologies protect your household and community?
- If so, do you have any examples?

30) Do you believe that such adaptation and mitigation technologies have been sufficient?
- If so, why?
- If not, what would you like to see implemented/changed?

**Communication:**

31) Does the municipality communicate information regarding **natural hazard risks**?
32) Does the municipality communicate information regarding **glacial hazard risks**?
- If so, how does the municipality communicate that information?

33) Do you believe that the information reaches all community members?
34) How knowledgeable are you on glacial hazard risks?
35) Where have you learned about glacial hazard risks?

**Future:**

36) Are you concerned about the future risks of glacial change and/or glacial flooding?
- If so, what are you concerned about?
- If not, why are you not concerned?

37) Is there anything you would like to discuss that was not addressed within the interview?

# Appendix B: Interview Guide for Government Actors

(Interviews were held in English. The questions below were prepared for the interviews, but only certain questions were selected based on participant knowledge/interest).

**Background:**

1) What is your name?
2) What is your age?
3) Where do you work?
4) What is your job title and work responsibilities?
5) How long have worked at X (*dependent on location*)? (*Question may have been answered in previous question, but in case it is not, this is good information to have*)
6) Do you also live within the municipality?

**Glacial Hazard Risks and Opportunities:**

7) Do any natural hazards pose a risk to the municipality?
- Which ones?
- Why?

8) Glacial changes include melting, retreating, erosion, and flooding, as well as increased/decreased precipitation of a glacier. Is glacier change considered a risk to the municipality/county?
- If so, why?
- If not, why?

9) Do glacial changes present new opportunities for the municipality/county?
- If so, what?

**Glacial Policy Decisions:**

10) Are there local policies in place to protect people, property, and infrastructure from the impacts of glacier change?
- If so, what are examples of policies in place to protect people, property, and infrastructure from glacier change?

11) How are climate/glacial policies decided and acted upon in the area?
- Who decides on what?
- Which research/information does the municipality rely on to make decisions?

12) Is glacial change and/or GLOF regarded within development or planning decisions? (*Hydropower, building of new homes/cabins etc.)*
- If so, how?

13) Does the municipality/county communicate information on glacial hazard risk?
- If so, how is information communicated to residents?
- Are there any limitations to how the information is disseminated to residents?

14) Do you work with other municipalities on developing new climate or hazard plans?
15) How does the municipality coordinate with the county and national governments on climate policy?

**Current and Future Challenges of Adaptation Technologies**

16) Currently, what do you believe to be the biggest challenges in the implementation of climate/glacial mitigation/adaptation technologies and policies?
17) Is the municipality/county concerned about the future risks that glacial change and/or glacial flooding presents for **X** (*location*)?
- If so, what are the biggest concerns?
- If not, why

# Appendix C: Interview Guide for Experts

(Interviews were held in English. The questions below were prepared for the interviews, but only certain questions were selected based on participant knowledge/interest).

**Background:**

1) What is your name?
2) Where do you work?
3) What is your job title and work duties?
4) How long have worked at X (*dependent on location*)? (*Question may have been answered in previous question, but in case it is not, this is good information to have*)
5) What is your educational background?
6) What type of research are you interested in?

**Research and Monitoring:**

7) What is X role in assessing glacier change and/or hazards?
8) How are glaciers monitored within Norway?
- Who is all involved?
9) What do you do with the information collected on glacial activity within Norway?
10) How is the information disseminated to municipalities?
11) In your expert opinion, which glacial changes or hazards pose the biggest risk to communities within Western Norway? Why?

**Challenges and Opportunities of Glacial Change:**

12) Since 2000, it has been recorded that most glaciers in Norway have shrunk considerably. What challenges does this present for Norway?
- What challenges does this present for residents?
- What challenges does this present for business owners?
13) Alternatively, melting glaciers can also present new opportunities. What are the benefits of melting and retreating glaciers for Norway?
- Are such benefits sustainable in the long-term?
14) Which areas within Western Norway are most at risk from glacial change?
- Why?
15) In your opinion, is there enough knowledge on the socioeconomic and/or environmental impacts of glacier change in Norway?
16) How will changes to glacial run-off affect biodiversity?
17) How will changes to glacial run-off affect hydropower companies?

**GLOF:**

18) Does NVE consider GLOFs to be a serious risk to communities?
19) Are GLOFs considered during the hydropower development/expansion process?
- If so, how?
20) Although GLOFs present challenges for municipalities, there are also opportunities for hydropower. What are some of those opportunities for hydropower in Norway?
- Are such opportunities sustainable in the long-term?

**Implementation of Adaptation/Mitigation Technologies:**

21) Is X involved in the implementation of adaptation technologies at the local level?
- If so, how?

- If not, who is?

22) Have current adaptation/mitigation technologies been successful at protecting private property, businesses, and other forms of development?

- If yes, which technologies have been successful and why?
- If not, how did they fail?

23) How is it decided on what forms of technologies are implemented?
24) Who decides on what is implemented?
25) Are technologies implemented equitably/equally between municipalities?
26) Currently, what do you believe to be the biggest challenges in the implementation of glacial mitigation technologies and policies?

# Appendix D: Online Questionnaire

(Questionnaire was available on *Nettskjema* in Norwegian only)

Dear Respondents,

I am a second-year master's student in the *Natural Resources Management* (NARM) programme at NTNU. As part of my research, I am investigating how individuals perceive and respond to glacial change within their communities. The research objectives include investigating the socioeconomic and environmental implications of glacial change. The research is being conducted through *Glacier Impacts on the Hydrological Systems* (GOTHECA), which is a collaboration between various universities and industry partners within Norway. The aim of the project is to better understand the impacts of climate change on glacier systems and communities. The research is focused on municipalities in Western Norway, and in particular, communities near Jostedalsbreen, Breheimen, and Folgefonna.

The questionnaire asks about the way in which you perceive and respond to glacial change in your community. I am interested in your opinions and thoughts regardless of direct experiences with glacial hazards or change. The questionnaire will take approximately fifteen minutes to complete, and completion is voluntary. The questions ask primarily about your experiences and opinions. There are no wrong or right answers. All answers will be treated with confidentiality and anonymity, and individuals will not be identifiable in the reporting of research.

Your participation is greatly appreciated. Your opinions are important in helping to understand the relation between glacier change and adaptation technologies within Norwegian communities.

Questions or other inquiries can be sent directly to kriskb@stud.ntnu.no. Thank you in advance for your participation.

**Questionnaire Questions**

**Background:**

1) How old are you?
- 19-29
- 30-39
- 40-55
- 55-67
- 67+

2) What is your job profession?

_____

3) Which municipality do you live in?

_____

4) Do you live alone?
- Yes
- No

5) How long have you lived in the area?

- 0-5 years
- 6-10 years
- 10-20 years
- 20-30 years
- +30 years

6) Why do you live in this area? Select all that apply.
- Family connections
- Proximity to nature
- Work
- Other:_____

7) What type of dwelling do you live in?
- Apartment
- Townhouse
- House
- Other:_____

8) Do you own your home?
- Yes
- No

**Glacial Change:**

9) Glacial changes include melting, retreating, erosion, and flooding, but is not limited to these forms. Have you noticed any forms of glacial change?
- Yes
- No

10) Have you been directly impacted by any form of glacial change?
- Yes
- No

11) In your opinion, do you believe that glaciers are melting rapidly?
- Yes
- No

12) If you believe that glaciers are meting rapidly, please state why you believe this below.

_____

13) Are you concerned about glacier change in the future?
- Yes
- No

14) If you are concerned about glacier change in the future, please state your concerns:

**Glacial Hazards**

15) Glacial hazards include ice falls, snow and ice avalanches and flooding. Do you believe that your community is at risk from glacial hazards?
- Yes
- No

16) If you believe that your community is at risk from hazards, please select all that you consider to be a risk in your community:
- Avalanches
- Snow and ice avalanches
- Floods
- Other:_____

17) How informed are you on glacial hazards in the area?
- Very informed
- Somewhat informed
- Not informed at all

18) Does the municipality communicate information regarding glacial hazards in the area?
- Yes
- No

19) If the municipality has communicated information regarding glacial hazards in your area, how was the information presented? Please select all that apply.
- Through email
- Information sent through the Post
- Social Media
- Information was presented on the Kommune website
- Other:_____

20) Have you ever personally contacted the municipality to ask for information on glacial hazards?
- Yes
- No

21) Have you learned about glacial hazards from other sources?
- Yes
- No

22) If you have learned about glacial hazards from other sources, please select all that apply.
- Local news
- International news

- Social media
- Through conversations with friends/family
- Other:_____

23) Would you consider moving to another area because of glacial hazards?
- Yes
- No

**Flooding:**

24) Glacial flooding can be the result of excess melting or the sudden release of a contained glacial lake on the glacier—also known as a Glacial Lake Outburst Flood (GLOF). Has glacial flooding happened in your community?
- Yes
- No

25) Has glacial flooding personally impacted you or your household?
- Yes
- No

26) If glacial flooding impacted you or your household, please state how you were affected below.

27) Is there an early warning system in place by the municipality to warn residents of flooding?
- Yes
- No

28) Approximately, how often were you warned about glacier flooding in 2020?
- 10+ times a year
- 5-10 times a year
- 3-5 times a year
- 1-3 times a year
- Never

29) How often do you evacuate following a warning from the Kommune?
- Always
- Most of the time
- Sometimes
- Never

30) How often does glacial flooding occur after being warned?
- Always
- Most of the time
- Sometimes
- Never

31) In your opinion, has glacial flooding occurred in greater frequency?
- Yes
- No

32) In your opinion, has glacial flooding occurred in greater magnitude?
- Yes
- No

33) Adaptation measures or technologies include devices that help to minimize the impact of flooding. Such technologies may include early warning systems, floodwalls, planting vegetation to retain excess water etc. Have you personally implemented any adaptation technologies to prevent damage from flooding?
- Yes
- No

34) If you have personally applied adaptation technologies to prevent damage from flooding, please state what you have you implemented below.

35) Has the Norwegian Water Resources and Energy Directorate (NVE) implemented any adaptation technologies to protect your property or community?
- Yes
- No

36) Do you believe that implemented adaptation technologies by the government has been sufficient in protecting people, property, or infrastructure? Please state your opinion and reason below.

37) Are you concerned about glacial flooding in the future?
- Yes
- No

38) If you are concerned about flooding in the future, please state your concerns below.

# Appendix E: NSD Form

The overarching purpose of this thesis research is to assess the connection between vulnerability and the implementation of climate mitigation and adaptation strategies within Norwegian communities. This project is in collaboration with the *Glacier Impacts on the Hydrological Systems in Europe and Central Asia* (GOTHECA) project, which is a research imitative between various universities and industry partners across Scandinavia, the European Alps and High Asia. The purpose of GOTHECA is to analyze the implications of climate change on both, glacial processes and society. In this letter we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project:
For this master's thesis, my focus is on the social structures that constitute vulnerability and *how* or *if* glacial change results in action or in-action by various stakeholders. As many communities within Norway are vulnerable to the effects of glacier change and hazards, I believe this research is important to improving climate policy.

To understand vulnerability in connection to glacier change and hazards, this research has the following objectives:

- To understand how glacier change impacts communities in Western Norway
- To assess how glacier change impacts key industries, such as tourism, hydropower and agriculture
- To identify how communities can cope to the effects of glacier change

The data collected during this study will be used for the study described above.

Who is responsible for the research project?

Norges teknisk-naturvitenskapelige universitet Institutt for *geografi* is the institution responsible for the project.

Why are you being asked to participate?

In order to assess climate vulnerability, I have identified different stakeholder groups who I would like to interview. Specifically, I am interested in interviewing elected government officials, business leaders/professionals, local workers, and tourists/semi-permanent cabin dwellers. I have categorized the stakeholder groups based off occupation, age, and connection to the study areas. If you have received this letter, it is because you have been identified as belonging to one of these stakeholder groups. Additionally, before receiving this letter, you have been contacted by me via phone or email and asked to participate in the study.

What does participation involve for you?
During this study, a variety of research methods will be employed physically and digitally including individual interviews and an online questionnaire. Information will be documented electronically using sound recording.

If you chose to take part in the project, this will involve a physical or digital interview, as well- as an online questionnaire. It will take approx. 30-45 minutes. The survey includes questions about climate change, natural hazards, perception, and climate policy. Your answers will be recorded electronically.

As previously mentioned, there are five stakeholder groups that are of interest to this study. These stakeholder groups include:

- Elected government officials
- Business leaders/professionals
- Local workers
- Tourists/semi-permanent cabin dwellers
- Experts

These broadly classified stakeholder groups have been identified and categorized based off occupation, age, and connection to study area. It is entirely plausible that an individual will identity with more than of the listed

stakeholder groups. All stakeholder groups will be asked to participate in the same manner. Primary questions asked by the research to each group will be identical, but it is possible that follow-up questions differ.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data

We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

- The two supervisors responsible for overseeing this research will have access to the data I collect.
- I will replace your name and contact details with a code. The list of names, contact details and respective codes will be stored separately from the rest of the collected data stored on an encrypted research server.

As stated above, participants will not be referred to by their names, but instead, codes. It is my full intention to keep your identity anonymous. Personal information recorded in the research will include a generalized occupation title connected to the affiliated stakeholder group. For instance, an individual connected to stakeholder group "Tourists/Semi-permanent cabin dwellers" would be labelled as a "tourist" or "semi-permanent resident." As the areas in which this research is occurring in tends to be small and remote communities, it is still possible that your identity may be recognizable by people who recognize familiar figure of speech or description of unique spaces that may not be known to all residents.

What will happen to your personal data at the end of the research project?

The project is scheduled to end May 2022. By June 2022, all information recorded and stored will be permanently deleted.

Your rights
So long as you can be identified in the collected data, you have the right to:
- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with *[insert name of institution responsible for the project]*, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?
If you have questions about the project, or want to exercise your rights, contact:
- Haakon Lein (haakon.lein@ntnu.no) or Irina Rogozhina (irina.rogozhina@ntnu.no) at Norges teknisk-naturvitenskapelige universitet Institutt for *geografi.*
- Our Data Protection Officer: *[Haakon Lein]*
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Kristine Katherine Bly

Project Leader

Student (if applicable)

(Researcher/supervisor)

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Consent form

*Consent can be given in writing (including electronically) or orally. NB! You must be able to document/demonstrate that you have given information and gained consent from project participants i.e. from the people whose personal data you will be processing (data subjects). As a rule, we recommend written information and written consent.*

- *For written consent on paper you can use this template*
- *For written consent which is collected electronically, you must chose a procedure that will allow you to demonstrate that you have gained explicit consent (read more on our website)*
- *If the context dictates that you should give oral information and gain oral consent (e.g. for research in oral cultures or with people who are illiterate) we recommend that you make a sound recording of the information and consent.*

*If a parent/guardian will give consent on behalf of their child or someone without the capacity to consent, you must adjust this information accordingly. Remember that the name of the participant must be included.*

*Adjust the checkboxes in accordance with participation in your project. It is possible to use bullet points instead of checkboxes. However, if you intend to process special categories of personal data (sensitive personal data) and/or one of the last four points in the list below is applicable to your project, we recommend that you use checkboxes. This because of the requirement of explicit consent.*

I have received and understood information about the project *[insert project title]* and have been given the opportunity to ask questions. I give consent:

- ☐ to participate in *(insert method, e.g. an interview)*
- ☐ to participate in *(insert other methods, e.g. an online survey) – if applicable*
- ☐ *for my/my child's teacher to give information about me/my child to this project (include the type of information)– if applicable*
- ☐ *for my personal data to be processed outside the EU – if applicable*
- ☐ *for information about me/myself to be published in a way that I can be recognised (describe in more detail)– if applicable*
- ☐ *for my personal data to be stored after the end of the project for (insert purpose of storage e.g. follow-up studies) – if applicable*

I give consent for my personal data to be processed until the end date of the project, approx. *[insert date]*

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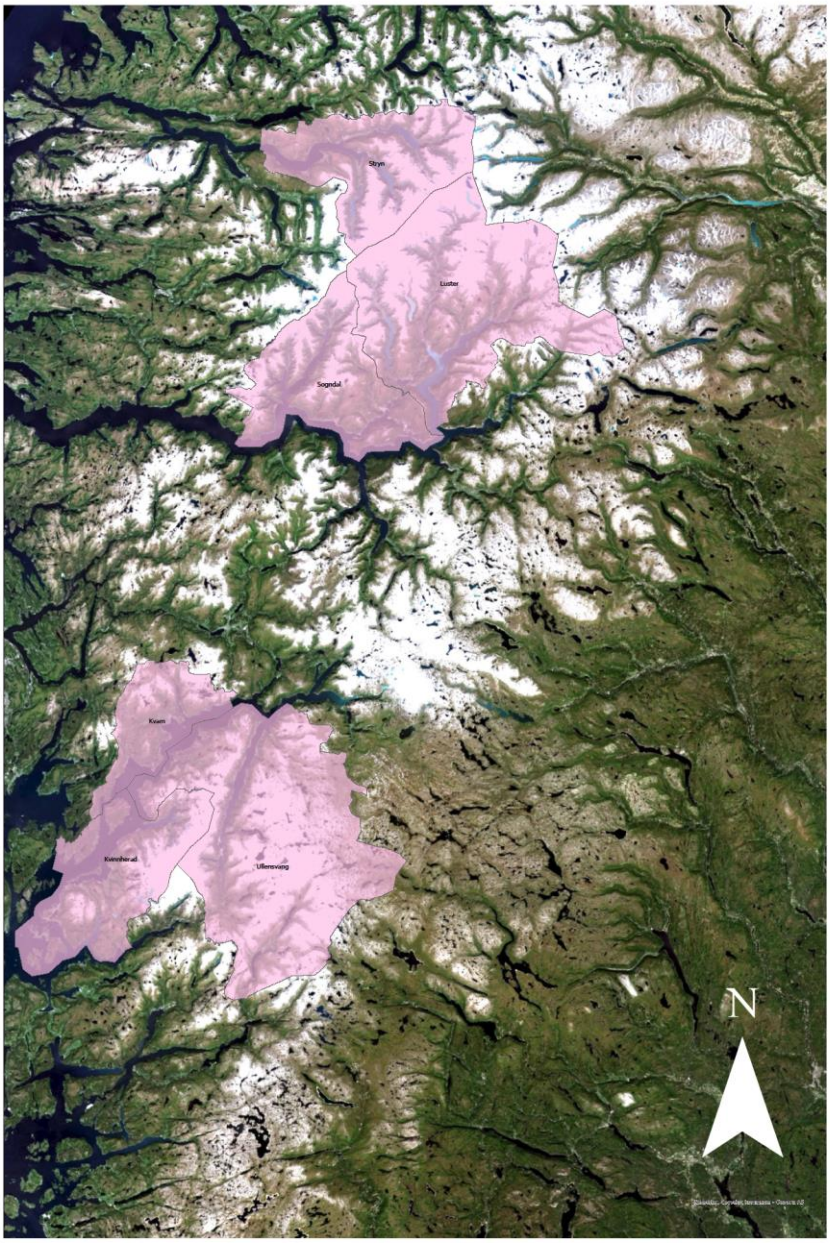
(Signed by participant, date)

# Appendix F:

Study Municipalities in Vestland County

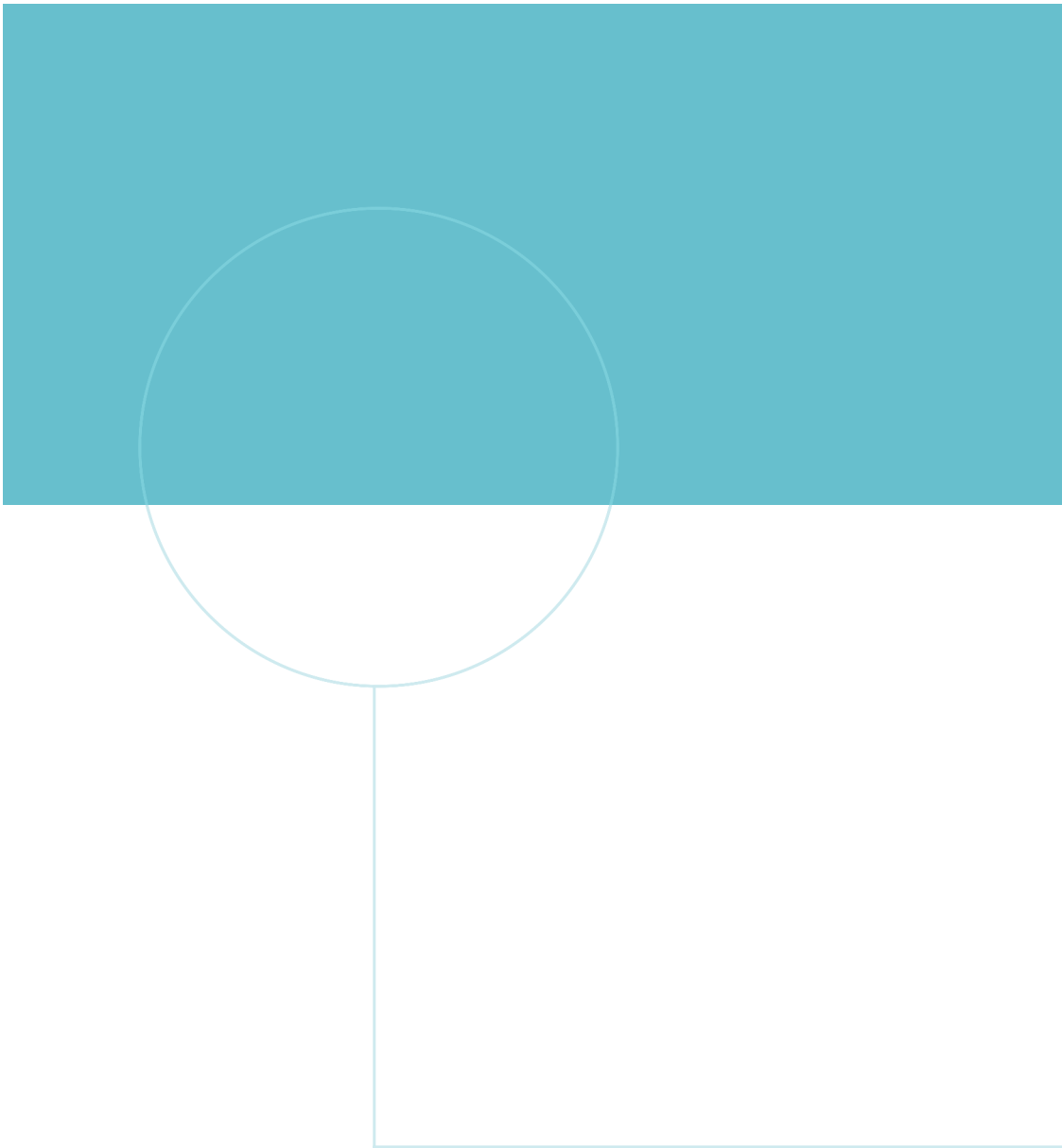



0 12,5 25 50 Kilometers

Study Municipalities

Bly (2022) "Study Municipalities in Vestland County"

Spatial Reference
Name: ETRS 1989 UTM Zone 33N
PCS: ETRS 1989 UTM Zone 33N
GCS: GCS ETRS 1989
Datum: ETRS 1989
Projection: Transverse Mercator



NTNU

Kunnskap for en bedre verden