Norwegian School of Economics
Bergen, Spring 2022

Storms, insurance, and climate change

- An exploratory study of property damage, compensation, and climate adaptation

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Master thesis in Economics and Business Administration Energy, Natural Resources and the Environment, and Business Analytics

NORWEGIAN SCHOOL OF ECONOMICS

Abstract

This thesis is structured around four research questions that explore different aspects of storms and how they affect the insurance sector. Due to climate change, extreme weather events, such as storms, are expected to occur more frequently and more intensely than before. This is quite costly in terms of compensation payouts for the insurance companies.

The purpose of this thesis is to provide insight into the occurrence of storms, to what extent they cause damage, at what speeds they cause damage, and evaluate to what extent the insurance sector is able to incorporate this increased climate risk in their policies.

Data from the Norwegian Natural Perils Pool and SSB have been used to explore which counties in Norway that have been hardest affected by storm-related damages over the years. As they vary considerably in size, the number of damages per building has been included to neutralize the importance of the area of a county and determine which areas that have been most affected by winds per building. Furthermore, data on wind measurements from different weather stations has been downloaded from the Norwegian Meteorological Institute and compared to the damage observations to determine what wind speeds that cause damage. At last, the non-life insurance contribution criteria from the EU Taxonomy have been validated against the current operation of the Norwegian Natural Perils Pool to identify the most apparent weaknesses of the scheme from a climate perspective.

To answer the research questions, we have assessed a considerable amount of literature and discussed it in light of the observations from our data. Regarding the probability of wind damage for different wind strengths, we have used a practical approach and modeled the results in R.

In sum, the research has shown that the occurrence of storms is highly challenging to predict but that certain areas are more prone to storms than others due to various climatic conditions. Despite the complexity, simple methods have often provided high accuracy and relatively good predictions on the wind strengths that cause damage. Nevertheless, the increased climate risk seems hard to incorporate into the insurance sector due to large uncertainties.

Acknowledgements

This thesis is written as a part of our majors in Energy, Natural Resources and the Environment, and Business Analytics at the Norwegian School of Economics during the spring of 2022.

Despite many challenges and obstacles along the way in finding a research topic, we are thankful for the direction the thesis has taken and satisfied with the result. We knew from the beginning that we wanted to write a thesis related to climate change but struggled to narrow it down into a tangible and precise formulation. From the moment we agreed on the final topic, the goal has been to create an exciting and interesting thesis on a field that, to our knowledge, has not been discussed to this extent.

First and foremost, we would like to thank Ola Haug for introducing us to this field and inspiring us to take this further. Furthermore, we would like to thank our supervisor Professor Håkon Otneim for guidance and supervision along the way.

Last but not least, we would like to thank our supportive friends and family for their encouragement. Thank you for keeping up with us during this challenging time!

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List of Abbreviations

ACC	Accuracy rate
AUC	Area under the receiver operating characteristic curve
BREEAM	Building Research Establishment Environment Assessment Method
DSB	Direktoratet for samfunnssikkerhet og beredskap
ERR	Error rate
EU	European Union
FN	False negatives
FNR	False negative rate
H	Hypothesis
IPCC	Intergovernmental Panel on Climate Change
NASK	Norwegian Natural Damage Statistics
NNPP	Norwegian Natural Perils Pool
NVE	The Norwegian Water Resources and Energy Directorate
RCP	Representative Concentration Pathway
RF	Random forest
ROC	Receiver operating characteristic curve
RQ	Research question
SSB	Statistisk Sentralbyrå
TN	True negatives

TNR	True negative rate
TP	True positives
TPR	True positive rate
UN	United Nations
WMO	World Meteorological Organization

Glossary

Mean wind speed	Mean wind speeds and transport patterns and their diurnal and seasonal cycles (Ranansinghe et al., 2021, p.12)
Severe wind storm	Severe storms including thunderstorms, wind gusts, derechos, and tornados (Ranansinghe et al., 2021, p.12)
Tropical cyclone	Strong, rotating storm originating over tropical oceans accompanied by high winds, rainfall and storm surge (Ranansinghe et al., 2021, p.12)
Sand and dust storm	Storms causing the transport of soil and fine dust particles (Ranansinghe et al., 2021, p.12)
Highest measured wind gust	Defined as the highest wind gust per day and is measured as the highest mean value over three seconds (Dannevig & Harstveit, 2020).
Highest measured mid-wind	Defined as the average wind per day and is usually measured as the average wind over a period of 10 minutes (Seter, 2020).

1 Introduction

It is well established that climate change is caused by the pressure of human activities (Birkmann et al., 2022, p.82). Reports and articles on how climate change will affect life on earth are frequently published, and there is a broad global consensus that the consequences will be fatal if drastic measures are not taken (United Nations, 2022). Since the late 1800s, the average temperature on earth has increased by ~1,1°C, and the goal is to keep the temperature increase below 1,5°C above pre-industrial levels (IPCC, 2018). This is a very ambitious goal, as the current rate of progress suggests that the earth will reach this limit by around 2033 (Rohde, 2022). The most common scenarios used when forecasting future climate scenarios are UN's Representative Concentration Pathways (RCPs) 4.5 and 8.5, which are both projected to exceed the 1,5°C goal with high confidence. For RCP 8.5, warming is projected to exceed 2°C with high confidence (IPCC, 2014, p.10). Staying below this temperature increase is crucial because a higher average temperature on earth does not simply imply warmer weather, it will also cause significant ripple effects throughout the world's ecosystems (Klima- og miljødepartementet, 2021-b).

One of the most significant reasons for concern regarding climate change is the increased frequency of extreme weather events (IPCC, 2022-b, p.14). According to the IPCC, an *extreme weather event* is defined as "an event that is rare at a particular place and time of year" (Seneviratne et al., 2021, p.1522). If a weather event is to be classified as extreme, there has to be a high probability of physical damage or danger to human life over a large geographical area (Meteorologisk Institutt, 2020). Research has shown an especially strong link between climate change and the frequency of heatwaves, heavy rain, storms, flooding, and droughts (Pidcock & McSweeney, 2021).

One sector that is particularly vulnerable to increased extreme weather is the insurance sector. There has been an increasing trend in the number of insurance claims related to extreme weather events, with 2021 being the fourth-highest year on record for global insured catastrophe losses since 1970. Some of the extreme weather events that caused the most damage in 2021 were hurricane Ida in the US, the flood in Germany, Belgium, and the nearby countries, as well as some severe flooding events in China and Canada. As a result, the previous ten-year average was exceeded once again in 2021, which might not be very surprising as there has been an annual increase of 5-6% in insured losses from natural disasters in recent decades (Swiss Re, 2021).

This trend is also visible in Norway. Since 2010, seven out of the ten years with the highest compensation payouts from the Norwegian Natural Perils Pool (NNPP), which is the Norwegian compensation scheme for damages to private property caused by natural hazards, have occurred (Finans Norge, 2022, p.13). According to the latest climate research, the trend is more frequent natural damages due to more extreme weather, and the increase is especially strong in the costs related to storms and floods (Westby, 2015). In Norway, statistics on compensation payouts by the NNPP related to extreme weather events are available back to 1980. As displayed in Tables 1.2 and 1.3, storms accounted for 75,84% of the total natural disasters and 54,62% of the total natural damage compensations (Finance Norway, n.d.-a). Therefore, storm damages have historically been the costliest form of extreme weather events in Norway and will be the research topic in this thesis.

Total natural damage compensations from 1980-2021 (in million NOK)					
Storm	Storm surge	Flood	Landslide	Earthquake	Sum
14619,38	1580,54	7575,83	2973,89	15,17	26764,81
54,62 %	5,91 %	28,31 %	11,11 %	0,06 %	100,00 %

Table 1.1: Total Natural damage compensations from the NNPP 1980-2021 (Finans Norge, n.d.-a).

Total reported natural damages from 1980-2021					
Storm	Storm surge	Flood	Landslide	Earthquake	Sum
271541	18466	52931	13993	1091	358022
75,84 %	5,16 %	14,78 %	3,91 %	0,30 %	100,00 %

Table 1.2: Total reported natural damages from the NNPP 1980-2021 (Finans Norge, n.d.-a).

Even though storms have resulted in the highest total compensation payouts since 1980, the average compensation for a single storm-related damage is usually low compared to other types of natural damage such as landslides or floods. Storms often cover a larger geographical area compared to other extreme weather events, which may cause several minor damages over a larger region (Finans Norge, n.d.-a). Typical ramifications of a storm are property damages, either directly or as a result of impact damage from, for example, movables or other building components (Norwegian Natural Perils Pool, n.d.). In addition to damages to buildings, strong winds threaten infrastructure, undermining energy systems, water and sewer systems, transportation, and flood management structures. Therefore, reducing greenhouse gas emissions on a global level is essential to reduce the risk of the most severe storms in the future (Center for Climate and Energy Solution, n.d.).

Considering that strong winds are the most significant driver of economic damage from disasters globally (Ritchie & Roser, 2014) and nationally (Finance Norway, n.d.), we find it interesting to examine what wind speeds that cause damage and if the probability of damage for a given wind speed differs between different geographical areas. Furthermore, we are curious about the historical development in insurance claims from storm-related damages, whether these have increased or decreased compared to the building mass, and how to the NNPP manages to incorporate the increased climate risk in their policies.

Since data on storm damages, compensation payouts, and weather measurements are publicly available for Norway, we think it will be possible to reveal trends on an even more local level. Norway is an elongated country with many mountains and valleys, suggesting that wind patterns will not be the same all over the country. Therefore, studies that include Norway on a Northern European scale might fail to address local differences between coastal and inland counties. Hence, local differences in wind patterns and trends in Norway will be the basis for this thesis, together with the importance of climate adaptation in the insurance sector. The research questions and the thesis structure will be presented in the following part.

1.1 Research questions

This thesis will explore historical data from the NNPP on storm-related damages and compensation payouts to identify trends, seasonal differences, or deviations from previous research. In addition, SSB data on building mass in a selection of Norwegian counties will be analyzed in relation to damage and compensation data to potentially uncover any patterns and whether these vary between the counties. Furthermore, an inferential statistical analysis between the NNPP data and wind measurements from the Meteorological Institute of Norway will be conducted to estimate the probability of property damage for a given wind speed.

For the probability estimation, data on the storm-related damages will be categorized as a binary variable (damage vs. non-damage) and serve as the response variable. Regarding the wind measurements, the highest wind gusts and mid-winds from all weather stations in the counties subject to analysis are collected to see which values predict damage best. Moreover, different classification methods will be applied, and the model with the highest performance will be selected as the basis for the probability estimation. The models used to evaluate the data are logistic regression and classification trees, as well as the ensemble methods boosting, and random forest. In all models, wind measurements will serve as explanatory variables.

Furthermore, we expect the two independent data sources to reveal some logical patterns related to what wind speeds that create damage. We also consider it likely that there will be significant regional differences between different counties in Norway, both in terms of closeness to the coast and differences in northern versus southern climate. Due to time constraints, only a few counties will be subject to analysis. Since it is assumed that the most significant differences in wind strengths and damage extent will occur between the coastal and inland counties, the analysis will be limited to three coastal counties and three inland counties. To decide which counties to include in the analysis, an overview of damages and compensation payouts for the different counties is created. The three coastal counties and inland counties with the most storm-related damages are selected as the basis for our analysis.

Finally, the contribution criteria of the EU Taxonomy will be assessed to identify the most significant weaknesses of the NNPP, and risk mitigation measures will be proposed based on previous Norwegian studies and suggestions.

Based on the sections above, four research questions are formulated.

RQ1: *Which Norwegian counties experience the most repercussions related to storm damages?*

RQ2: *In proportion to the building mass, has there been an increase or decrease in storm-related damages?*

RQ3: *For a given wind speed, what is the probability of property damage, and does this probability vary between different geographical areas in Norway?*

RQ4: *What are the most prominent weaknesses of the Norwegian Natural Perils Pool, and how can these be mitigated?*

1.2 Overview of Sections

This thesis consists of six chapters. In Chapter 2, the existing literature on wind patterns, the insurance sector, climate adaptation, and classification models will be introduced. Based on our findings, we will conclude the literature review by formulating four hypotheses to be evaluated in the course of this thesis. Furthermore, Chapter 3 describes the machine learning algorithms, the ensemble methods, and the model assessment and validation techniques used in our modeling. An overview of the datasets and the preprocessing steps is given in Chapter 4, whereas Chapter 5 describes our exploratory research and modeling results. Finally, in Chapter 6, we conclude the findings of this thesis together with an overview of limitations and further research.

2 Literature review

In this chapter, we present existing literature on wind patterns and how these are affected by climate change both globally and nationally. This is followed by an explanation of the Beaufort scale and wind classification standards. Furthermore, the impact of extreme weather on the insurance sector will be addressed, along with a presentation of the NNPP explaining the scheme's structure. Next, the current status of risk mitigation and adaptation in Norway is described, along with international and European initiatives for such activities. Then, findings on prior applications of classification techniques in the context of binary variables are introduced. Finally, the literature review is summarized, and hypotheses are derived.

2.1 Expected wind pattern developments globally

Recently, the confidence level regarding intensified winds as a consequence of warmer ocean temperatures and higher sea levels has increased. Stronger winds will be more expensive in terms of physical damage and deaths. In addition, storms and hurricanes are subject to several climate change-related influences. For example, warmer sea surface temperatures are predicted to cause intensified tropical storm wind speeds by up to 10 percent. Moreover, warmer sea temperatures cause the hurricanes to wetter by 10-15 percent according to complex modeling of a temperature increase of 2°C scenario. Sea levels worldwide are also projected to rise due to climate change. This is likely to make future coastal storms more damaging (Center for Climate and Energy Solutions, n.d.).

Furthermore, it seems like the areas affected by hurricanes are shifting poleward, which might be associated with expanding tropics due to higher global average temperatures. This could increase the number of properties and human lives at risk, but further research is required to build sufficient models on the development of wind patterns. The connection between climate change and wind speeds is not straightforward. However, current predictions find that the number of storms will likely remain the same or even decrease while the intensity increases. This suggests that there will be a trade-off between the intensity and frequency of high wind speeds (Center for Climate and Energy Solutions, n.d.).

Some of the most comprehensive scientific frameworks on the global impact of climate change on extreme weather events are the IPCC assessment reports. The IPCC is the United Nations body for assessing the science related to climate change (IPCC, n.d.). The assessment reports are published every six to seven years, and as of May 2022, the IPCC is in the process of finalizing its sixth assessment report (AR6). This report comprises three working group contributions: Working Group I, II, and III. First, the report by Working Group I was published on August 9, 2021. This report summarizes the physical science basis in the world. Furthermore, the report by Working Group II, published on February 28, 2022, reviews the impacts, adaptation possibilities, and vulnerability of climate change. Finally, the last report by Working Group III consists of information related to mitigation, along with a Synthesis report that will be published in September 2022 (IPCC, 2022-a).

To map out the global wind pattern trends, the physical science basis by Working Group I is used as the primary source of information. In the report, four different wind measures have been assessed; mean wind speed, severe wind storm, tropical cyclone, and sand and dust storm (see definitions in the glossary), as seen from the overview in table 2.1.

Key	
(dark blue)	**High confidence of decrease**
(light blue)	**Medium confidence of decrease**
(white)	**Low confidence in direction of change**
(light red)	**Medium confidence of increase**
(dark red)	**High confidence of increase**
(grey)	**Not broadly relevant**

1. Very high confidence in the direction of change, but low to medium confidence in the magnitude of change due to model uncertainty.
2. Tropical cyclones decrease in number but increase in intensity.
3. Medium confidence of decrease in frequency and increase in intensities.
4. Decreasing in northern regions and increasing toward south.
5. Low confidence of increasing intensity, and high confidence of decreasing occurrence.
6. General decrease except in Aegean Sea exhibiting increase.
7. Higher confidence in southern regions and lower toward north.
8. Increase in intensity; decrease in frequency except over central North Pacific.
9. Increase in convective conditions but decrease in winter extratropical cyclones.

Continent	Region	Wind			
		Mean wind speed	Severe wind storm	Tropical cyclone	Sand and dust storm
Africa	North Africa*		3		
	Sahara (SAH)				
	Western Africa (WAF)				
	Central Africa (CAF)				
	North Eastern Africa (NEAF)				
	South Eastern Africa (SEAF)			3	
	West Southern Africa (WSAF)				
	East Southern Africa (ESAF)			3	
	Madagascar (MDG)			3	
Asia	Arabian Peninsula (ARP)				
	West Central Asia (WCA)				
	West Siberia (WSB)				
	East Siberia (ESB)				
	Russian Far East (RFE)				
	East Asia (EAS)			2	
	East Central Asia (ECA)				
	Tibetan Plateau (TIB)				
	South Asia (SAS)				
	South East Asia (SEA)			2	
Australasia	Northern Australia (NAU)			5	
	Central Australia (CAU)				
	Eastern Australia (EAU)				
	Southern Australia (SAU)				
	New Zealand (NZ)				
Central and South America	Southern Central America (SCA)			2	
	Northwestern South America (NWS)				
	Northern South America (NSA)			2	
	South American Monsoon (SAM)				
	Northeastern South America (NES)				
	Southwestern South America (SWS)				
	Southeastern South America (SES)				
	Southern South America (SSA)				
Europe	Mediterranean (MED)	6	3		
	Western and Central Europe (WCE)				
	Eastern Europe (EEU)				
	Northern Europe (NEU)				
North America	North Central America (NCA)				
	Western North America (WNA)		9		7
	Central North America (CNA)		9		4
	Eastern North America (ENA)		9		
	Northeast North America (NEN)		9		
	Northwest North America (NWN)		9		
Small Islands	Caribbean (CAR)			8	
	Pacific Islands			8	

* North Africa is not an official region of IPCC AR6, but assessment here is based upon the African portions of the Mediterranean Region

Table 2.1: Projected changes in wind-patterns mid-century for scenario RCP4.5, approximately corresponding to global warming levels between 2°C and 2,4°C from the IPCC Sixth Assessment Report (Ranasinghe et al., 2021, p.1797-1840).

Quantifying the effect of climate change on extreme winds is challenging as these events are rare, short-lived, local, and primarily influenced by stochastic variability (Seneviratne et al., 2021, p.1583). Significant geographical differences also make it problematic to predict a general pattern that can be applied globally (Hanssen-Bauer et al., 2015, p.57). Another challenge when developing models to assess wind patterns is the limited period with sufficient data. The "satellite period" is the best-track wind data, stretching approximately 40 years back, and is found challenging to analyze due to its heterogeneous character (Seneviratne, 2021, p.1585). However, there have been several attempts to model wind patterns, and even though most of the research findings are of low confidence, some trends have been identified.

Table 2.1 displays an overview of the various weather regions identified by the IPCC. A map of these regions can be found in the Appendix, Figures 1-6. As mentioned in Chapter 1, Norway is included in the region of Northern Europe. For this region, tropical cyclones and sand and dust storms are considered unlikely and therefore marked as irrelevant (gray). Another notable aspect is that most research is of low confidence regarding the development of wind speeds in frequency and intensity. This is quite different from the predictions on other types of extreme weather, where the findings have a higher degree of certainty (Ranasinghe et al., 2021, p.1797-1840). Europe is the continent with the most confident predictions regarding the development of severe wind storms. In all of Europe, it is of medium confidence that the frequency and amplitude of severe wind storms will increase. However, in Northern Europe, it is also medium confidence that the mean wind speed will decrease. Both predictions are based on the RCP 4.5 scenario, with an approximate temperature increase of 2-2,4 °C (Arias et al., 2021, p.132). This somewhat contradicts the projection from the report "Klima i Norge 2100," which will be discussed in section 2.2.

Furthermore, the IPCC report presents an overview of which sectors and assets that are most affected by changes in future wind patterns, as seen in Table 2.2. Most fields are white, indicating that the findings have no or low confidence, but there are relatively few predictions with low to moderate confidence. As this thesis regards damages to buildings, the assets under "Cities, settlements and key infrastructure" are of most importance. In this category, it is in general high confidence that severe wind storms, which is the phenomenon we will investigate in this thesis, will cause impacts and increased risks in terms of costs, damages, and deaths.

Impacts and Risk Relevance
None/low confidence
Low/moderate
High

		Wind			
Sector	**Asset**	**Mean wind speed**	**Severe wind storm**	**Tropical cyclone**	**Sand and dust storm**
Terrestrial and freshwater ecosystems (WGII Chapter 2)	**Tropical forests**		Low/moderate		Low/moderate
	Temperate and boreal forests		Low/moderate		
	Lakes, rivers and wetlands	Low/moderate			Low/moderate
	Grasslands and savanna	Low/moderate			High
	Deserts	Low/moderate			High
	Mountains	Low/moderate			Low/moderate
	Polar				
Ocean and coastal ecosystems (WGII Chapter 3)	**Coastal land and inertial zones**			Low/moderate	Low/moderate
	Coastal seas	Low/moderate		Low/moderate	Low/moderate
	Shelf seas and upwelling zones	Low/moderate			Low/moderate
	Polar seas	Low/moderate			
	Open ocean and deep sea	Low/moderate			
Water (WGII Chapter 4)	**Cryosphere reservoir**				
	Aquifiers and groundwater				
	Streamflow and surface water				Low/moderate
	Water quality				Low/moderate
Food, fibre and other ecosystems products (WGII Chapter 5)	**Crop systems**	Low/moderate	Low/moderate	Low/moderate	Low/moderate
	Livestock and pasture systems		Low/moderate		Low/moderate
	Forestry systems	Low/moderate	Low/moderate		
	Fisheries and aquaculture systems	Low/moderate	Low/moderate	Low/moderate	
Cities, settlements, and key infrastructure (WGII Chapter 6)	**Cities**		High	High	High
	Land and water transportation		Low/moderate	Low/moderate	High
	Energy infrastructure	High	High	High	Low/moderate
	Built environment		High	High	Low/moderate
Health, wellbeing and communities (WGII Chapter 7)	**Labor productivity**				Low/moderate
	Morbidity				Low/moderate
	Mortality		High	High	
	Recreations and tourism +		Low/moderate	Low/moderate	Low/moderate
Poverty, livelihoods and sustainable development (WGII Chapter 8)	**Housing stock***		High	High	
	Farmland*				High
	Livestock mortality*			Low/moderate	
	Indigenous traditions				

Table 2.2: Overview of the climatic impact of wind for major categories of sectoral assets from IPCC Sixth Assessment report (Ranasinghe et al., 2021, p.1778-1779).

+ The Recreation and tourism asset category includes outdoor exercise and the tourism industry (including ecosystem services) assessed in many WGII chapters.
** This asset category is distinguished by the threat of a full loss of key investments and living environments rather than a recoverable damage or loss of productivity or profit.*

2.2 Expected wind pattern development in Norway

The report "Klima i Norge 2100" by Hanssen-Bauer et al. (2015) is the most recent scientific foundation for climate adaptation in Norway and contains information on atmospheric climate, hydrology, permafrost, crater, and marine climate. Reasons for climate change and variations in Norway, as well as Norway's location in relation to large-scale weather and flow patterns, are also included in this report. Most of the calculations presented are based on climate projections from the fifth assessment report from the IPCC. Therefore, some of these findings will deviate slightly from the findings in the sixth assessment report as introduced above. Furthermore, the climate projections in this report are compared with equivalent values from the first "Klima i Norge 2100" report published in 2009 (Hanssen Bauer et al., 2015, p.3).

As mentioned in Chapter 1, different RCP scenarios serve as common indicators of how the climate will develop under different emission levels. In Norway, the temperature increases for the most commonly referred scenarios have been calculated on a median, low, and high projection scale on both a seasonal and annual basis, as displayed in Table 2.1.

Region	Season	RCP 2.6			RCP 4.5			RCP 8.5		
		Median	Low	High	Median	Low	High	Median	Low	High
Norway	Annual	1,6	0,9	3,1	2,7	1,8	4,2	4,6	3,3	6,4
	Winter	1,9	0,8	3,6	3,3	1,8	5,2	5,6	3,8	8,5
	Spring	1,8	0,9	3,2	2,9	1,9	4,5	4,3	3,2	6,2
	Summer	0,7	0,0	1,9	1,5	0,5	2,8	2,9	1,7	4,9
	Autumn	2,0	0,8	3,3	3,3	2,2	4,8	4,7	3,5	7,1

Table 2.3: Estimated temperature changes (ºC) per annum and season in Norway from 1971-2000 to 2071-2100 for the three emission scenarios RCP 2.6, RCP 4.5, and RCP 8.5 according to the median, low and high projections from empirical- statistical downscaling (Hanssen-Bauer et al., 2015, p.98)

Nationally, scenario RCP 2.6 only remains below the 1,5°C goal under the low projections, suggesting that in Norway, even this scenario will cause a temperature increase above the goal of the Paris Agreement (Klima- og miljødepartementet, 2021-a). Such temperature increases will affect the climate in Norway, and noticeable changes have already occurred. The growth season lasts longer, and the winter is shorter in several places in the country. Most glaciers are smaller than they have been for hundreds of years, and the melting happens remarkably faster than at the turn of the millennium. (Klima- og miljødirektoratet, n.d.-c). In addition to this, extreme weather events are occurring more frequently and intensely than before (Miljøstatus, 2022).

In line with the IPCC assessment report, "Klima i Norge 2100" by Hanssen-Bauer et al., acknowledges that the wind conditions in Norway are hard to analyze due to local differences, differences in measuring points, observation practice, and instrumentation through the ages. Furthermore, an analysis of longtime changes in modeled wind over Northwestern Europe (the British Isles, the North Sea, and the Norwegian Sea) concludes that there has not been any clear trend in the frequency of storms in the Norwegian sea- and coastal areas since 1880. However, an analysis of the frequency of strong winds, measured at a selection of Norwegian weather stations from 1957 to 2014, concluded that the number of winds with a mid-wind above the 90-percentile is increasing. Even so, there is a negative or no trend for the 90-percentile for wind gusts (Hanssen-Bauer et al., 2015, p.57-58). The terms mid-wind and wind gusts are defined in the glossary.

Season	RCP 4.5			RCP 8.5		
	Medium	Low	High	Medium	Low	High
Annual	-0,8	-2,6	0,9	-0,9	-3,6	0,9
Winter	1,2	-0,1	2,6	1,2	-0,5	2,5
Spring	-1,5	-2,6	-0,6	-2	-3,9	-0,8
Summer	-1,9	-4	-0,3	-2,7	-5,5	-1,2
Autumn	-0,3	-2,1	0,8	0,1	-2,4	1,1

Table 2.4: 1971-2000 to 2071-2100 projected change (%) in wind strength under different scenarios (Hanssen Bauer et al., 2015, p.113)

A nationwide target for changes in strong winds was developed by analyzing changes in the annual 99-percentile in the modeled wind between 1961 and 2010 for all of Norway. This analysis shows that there has been an increase in strong winds of up to 6-8 percent on Norway's East- and West coasts over the period 1961 to 2010. However, there are some areas with little or no increase, such as parts of Finnmark and the South, as well as a few mountain areas in Southern Norway. This implies that even though the wind development appears quite flat overall, there can be huge regional differences. Analyses of maximum values for wind strengths over 1,3,6,12 and 24-hour periods have also been conducted. The results showed that the most powerful wind gusts mainly occurred in winter. Some of them also appeared in the fall, while only a few occurred in the spring (Hanssen-Bauer et al., 2015, p.58-59).

Furthermore, the Norwegian Center for Climate Service has published an overview of the climate profiles for the Norwegian counties. All counties have high uncertainty related to whether there will be any changes in the occurrence of strong winds in 2071-2100 compared to the wind levels recorded in 1971-2000 (Norsk Klimaservicesenter, 2022a-q). This uncertainty applies regardless of the future scenario used (see table 2.3.)

2.3 Classification standards of wind

Over the last 50 years, there has been a transition from the visual Beaufort scale to instrumental wind speed measurements at several weather stations with long wind series (Hanssen Bauer et al., 2015, p.57). However, the classification standards of wind speeds have remained the same, as displayed in Table 2.4.

Name	m/s	Characteristics
Quiet	0,0-0,2	Smoke rises vertically.
Light air	0,3-1,5	Direction shown by smoke drift but not by wind vanes.
Light breeze	1,6-3,3	Wind felt on face; leaves rustle; wind vane moved by wind.
Gentle breeze	3,4-5,4	Leaves and small twigs in constant motion; light flags extended.
Moderate breeze	5,5-7,9	Raises dust and loose paper; small branches moved.
Fresh breeze	8,9-10,7	Small trees in leaf begin to sway; crested wavelets form on inland waters.
Strong breeze	10,8-13,8	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
Near Gale	13,9-17,1	Whole trees in motion; inconvenience felt when walking against the wind.
Gale	17,2-20,7	Twigs break off trees; generally impedes progress.
Strong Gale	20,8-24,4	Slight structural damage (chimney pots and slates removed).
Storm	24,5-28,4	Seldom experienced inland; trees uprooted; considerable structural damage.
Violent storm	28,5-32,6	Very rarely experienced; accompanied by widestread damage. Medium-sized ships lost to view behind waves.
Hurricane	32,6-	Devastation. Air filled with foam and spray, very poor visibility.

Table 2.5: The Beaufort scale (Met Matters, n.d.)

Beaufort's wind scale is widespread internationally and was originally used in the 19th century. The scale was initially built on the wind's impact on sailing vessels but was later adapted to instrumental measurements of wind speed. The wind speed is usually measured in meters per second (m/s) (Dannevig & Harstveit, 2020), and to be classified as a storm, the wind must reach a speed between 24,5-28,4 m/s. For hurricanes, the wind speed must exceed 32,6 m/s.

All wind is caused by horizontal differences in temperature. As a result, it is usually windier in the winter due to the temperature difference between the equatorial and polar regions, cold continents, and the temperate sea. A complicated interaction between several factors causes the wind direction on the ground level. Weak winds tend to blow parallel by coastal-, fjord-, valley, and mountain chain direction. With stronger winds, the air can be pressured over mountain range ridges and down into the lowlands (Dannevig & Harstveit, 2020).

For meteorological observations and notifications, the mid-wind is usually given as the mean wind speed over 10 minutes, which is the standard method for measuring wind in the Beaufort scale. The highest measured wind gusts, however, are given as the highest mean value over three seconds. It is internationally decided that wind measures for weather forecast and climate purposes are to be done ten meters above the ground. That is because the wind speed increases with height. At a few hundred meters height, the wind direction changes to the right (in the northern hemisphere), but close to hills, mountains, and mountain ranges, the wind is primarily controlled by the terrain, and the height change may behave differently (Dannevig & Harstveit, 2020).

2.4 The insurance sector

Climate change is recognized as a high importance issue by the insurance sector. Weather-related changes pose challenges to insurers as they introduce new risks, alter existing risks, as well as change the dependencies between risks (Botzen, 2013, p.26). Increasing hurricane intensity, for example, may result in an increased correlation between insured losses in areas that are located far from each other (Kousky and Cooke, 2009; as referred in Botzen, 2013, p.27). As the insurance sector covers most weather-related risks, future insurance claims may increase noticeably if natural disasters occur more frequently and intensively (Botzen, 2013, p.26). In

Norway, there are several insurance schemes for natural hazards, and we will now present the most commonly referred scheme.

2.4.1 The Norwegian Natural Perils Pool

The Natural Damage Insurance Act (Naturskadeforsikringsloven) §1 defines *natural damages* as "damages directly caused by natural hazards, such as landslides, storms, flooding, storm surges, earthquakes, or volcanic eruptions" (1989). In Norway, damages caused by natural hazards are covered by a twofold compensation scheme, as illustrated in Figure 2.1. Depending on whether an object is suitable for fire insurance or not, the relevant compensation scheme will be applied (Norsk Naturskadepool, 2017).

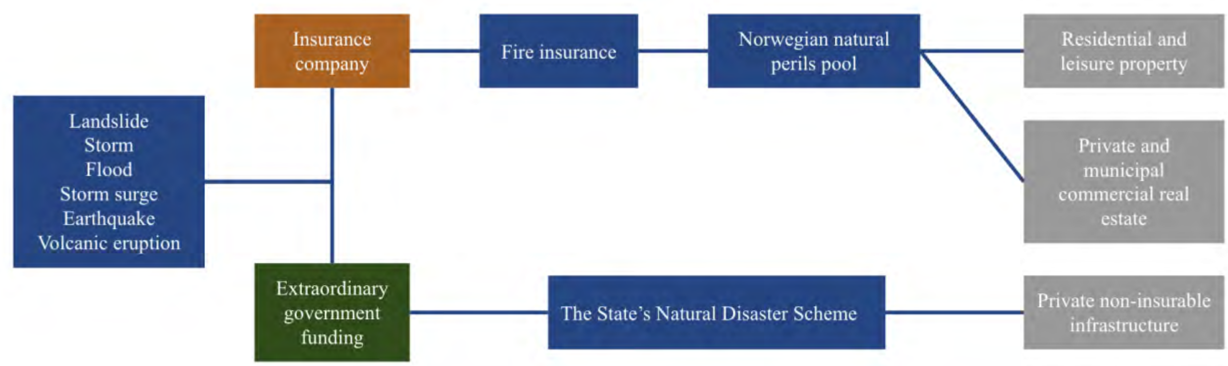

Figure 2.1: The compensation schemes for different natural damage scenarios in Norway (Sandberg et al., 2020, p.23)

The first scheme is the Norwegian Natural Perils Insurance Act. The act covers buildings and movable properties with fire insurance (Norsk Naturskadepool, 2017), and historically there has been an average payout of ~637 million NOK per year since 1980 (Finans Norge, n.d.-a). The Norwegian Natural Perils Insurance Act is administered by the NNPP, which acts as a distribution mechanism between its members. Insurance losses are distributed according to the insurer's share of the pool, which corresponds to their market share for fire insurance and not to the damages within their customer base. In Norway, policyholders with fire insurance are automatically covered in the event of natural damage (Sandberg & Bjelle, 2021, p.13), and all companies providing fire insurance are obliged to join the pool (Norsk Naturskadepool, n.d.-d). The insurance premium is currently 0,065 per mille of the fire insurance sum, which is set aside for future natural damages (Sandberg & Bjelle, 2021, p.14). If the annual insurance premium is higher than the compensation rates the surplus will be set aside as earmarked funds on the balance sheet to be spent in a year where the compensation rates are higher than the insurance premiums (Sandberg et al., 2020, p.24). Furthermore, in case of natural damage, the deductible of the policyholders is fixed at 8000 NOK (Norsk Naturskadepool, n.d.-b).

The second scheme is the States Natural Disaster Scheme, also known as the Norwegian National Fund for Natural Damage Assistance. This scheme compensates for damages caused by natural perils not covered by ordinary insurance schemes (Norsk Naturskadepool, 2017). The total payouts from the State Natural Disaster Scheme over the past ten years have been approximately 14% of the total payouts from the NNPP (Aamaas et al., 2018, p.52). However, this scheme will not be subject to further discussions as the focus of this thesis is the NNPP.

In the case of wind damage, the insurance companies will evaluate whether the claim is eligible for a compensation payment (If, n.d.). As mentioned in Chapter 1, property damage, as a result of high wind speeds, can either be caused directly by the wind or due to impact damage from, for example, gravel, twigs, and trees. In addition, property damages caused by waves are also considered wind damage (Norsk Naturskadepool, n.d.c). To acquire compensation, the main rule is that the wind gusts must have reached a speed of at least 20,8 meters per second (a strong gale), which equals 75km per hour. It is sufficient that a single wind gust reaches this level to get compensated. However, wind gusts may reach far greater strengths than the wind reported by meteorologists. Therefore, the impact of topography and possible wind load amplifying effects must be taken into account as well (Norsk Naturskadepool, 2021). Topographical conditions are central as they can lead to a sharp increase in wind speed. Examples include narrow fjords, high mountains, and headwinds (Norsk Naturskadepool, n.d.-c).

As there are relatively few weather stations located close to densely populated areas in Norway, the tariff consultants assessing the wind's damaging properties might have to rely on measurements registered far away from the site of damage. In the case of insufficient documentation in the form of wind measurements, the tariff consultant must consider if it is likely that the leading cause of damage was a wind-gust equal to or above 20,8 m/s. If so, the damaged party might still be eligible for compensation. The tariff consultant also has to evaluate if the building had too weak construction according to the building regulations that applied at the time of construction. If new requirements for wind loads have been applied after the time of constriction, this has to appear in the report, as well as a map sketch illustrating the wind conditions. However, there are a few exceptions to these rules. Damage to roofing due to hail, loss of electricity, and water/snow blown into buildings are not considered storm damage (Norsk Naturskadepool, n.d.-c). When the damage has been assessed and compensation has been granted, it is registered at the site where the policyholder is registered and not necessarily where the storm damage has occurred. Therefore, the reported number of storm-related damages in a county sometimes deviates from the real number of claims belonging to that area (Hauge et al., 2017, p.57).

2.5 Climate adaptation and mitigation

The Norwegian Environment Agency defines *climate adaptation* as “An understanding of the consequences of climate change and the implementation of actions to stop or reduce damage, while at the same time exploiting the opportunities that the changes might entail” (Miljødirektoratet, n.d.-b). Climate adaptation has been a central part of the literature for quite some time. Even so, the IPCC found that the financial flows for adaptation are insufficient and constrain the implementation of adaptation options, particularly in developing countries (IPCC, 2022-b, p.28). A European study also points to limited financial and personal resources while at the same time pointing at low political priority and uncertainty as the main barriers (Aguiar et al., 2018, p.38). This is also the case in Norway, as several Norwegian studies suggest that local authorities lack knowledge of climate adaptation and are often unwilling to spend the necessary resources. In addition, the coordination between the different government agencies and their responsibilities seems to be deficient (Hauge et al., 2017, p.37; Rusdal & All, 2019, p.31). This might not be surprising, as the system is quite complex, as displayed in Figure 2.2.

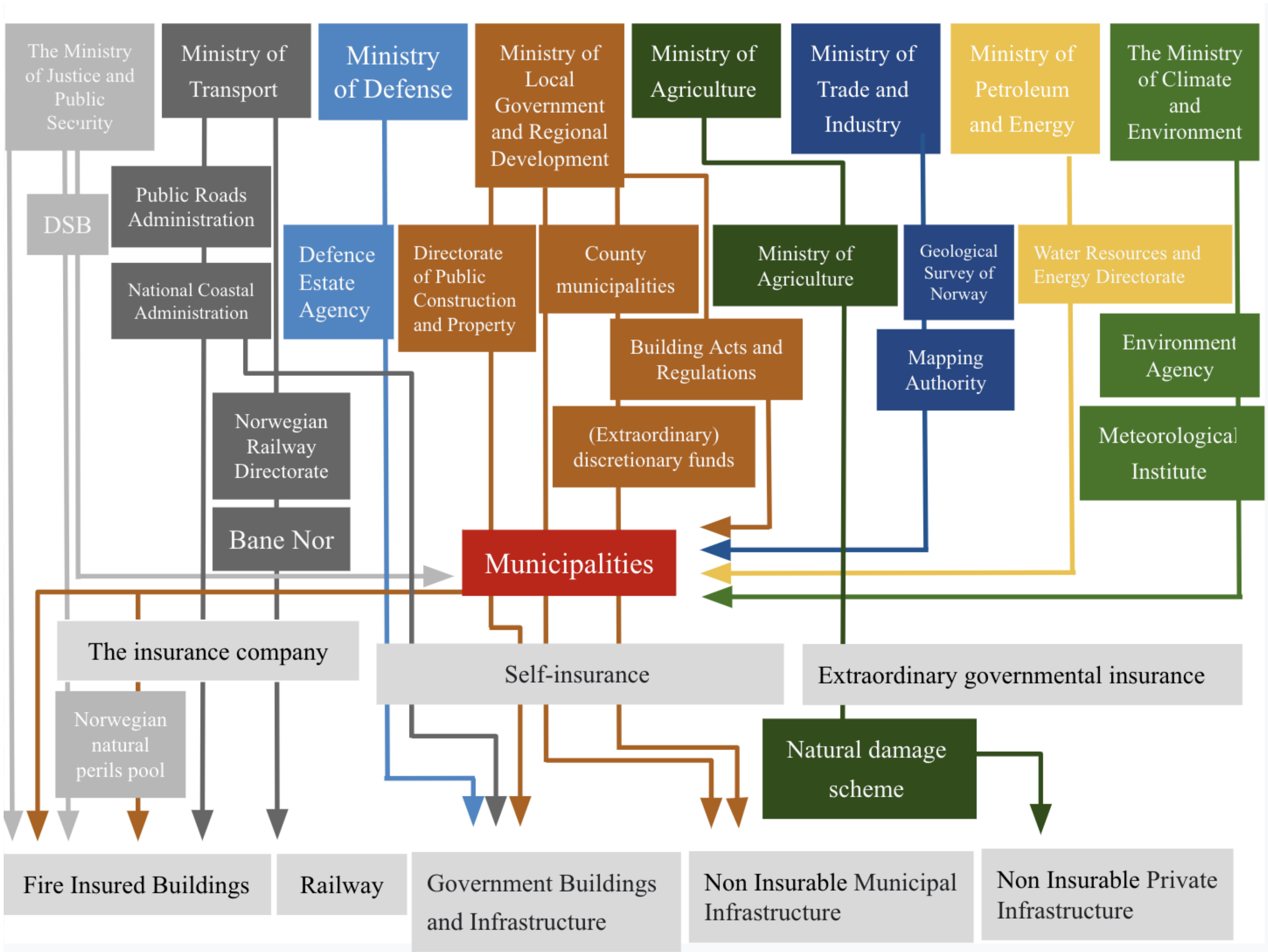

Figure 2.2: Division of responsibilities for climate adaptation in Norway (Sandberg et al., 2020, p.20)

According to the Natural Damages Compensation Act §5, the compensation sum shall correspond to the cost of rebuilding the damaged object to the same standard as before the accident occurred. The law does not mention that it should be built better. However, §6 states that lack of maintenance and supervision can lead to a reduction in compensation. Furthermore, §1 sixth paragraph also states that weak construction and lack of maintenance and supervision, or that the damage could have been prevented or reduced, may lower the compensation payout (Sandberg et al., 2020).

Currently, there is no connection between the risk of natural damage and insurance premium in Norway. However, some adaptations have been made in the NNPP. For example, until the end of 2017, it was required that buildings damaged by floods should be rebuilt in the same place. The downside of this is that the new building only would stay undamaged until the next flood, which caused major unnecessary payments for the insurance companies. Therefore, in collaboration with the Norwegian insurance sector, Finance Norway opened up for homeowners to get their plot value and rebuild their houses in a safer place (Solberg, n.d.).

Even though climate adaptation has been on the agenda in several countries over the last decade, especially in the EU, there are still adaptation gaps between the current levels of adaptation and the levels needed to respond to impacts and reduce climate risks (IPCC, 2022-b, p.22). Therefore, the EU taxonomy for sustainable finance was developed. The goal of the taxonomy is to provide companies, investors, and policymakers with appropriate definitions for which economic activities can be considered environmentally sustainable (European Commission, n.d.-b), thus preventing greenwashing. The taxonomy was presented as the foundation of the EU's action plan for sustainable finance in 2020, which is a part of The European Green Deal's growth strategy to make Europe the first climate-neutral region by 2050. From January 1, 2022, all businesses affected by the EU Taxonomy will have to report on their work to mitigate and adapt to climate change. Climate change mitigation and adaptation are the two first environmental objectives of the taxonomy. The remaining four goals will be implemented from January 1, 2023. In this way, the taxonomy will be dynamic and change in line with new research and technology. It is expected that this will be applied in Norway despite not being a member of the EU. This is because the Norwegian government has already suggested implementing a law that requires Norwegian companies to report on how "green" their activities are, based on the criteria set by the EU (NHO, n.d.).

The taxonomy addresses five main criteria for actions that will lead the insurance sector in a more sustainable direction. The first area addressed is the need for leadership in modeling and pricing climate risks. Furthermore, the industry needs to improve product design to make sustainable solutions more attractive to the consumers, as well as communicate the benefits of the green alternatives over the standard solutions more effectively. The third criteria concern innovative insurance coverage solutions, indicating that the insurance industry should strive to find new business models that cover climate-related perils and include different risk-transfer solutions, such as non-physical damage-related loss factors. To make this happen, the fourth criterion is crucial. Insurance companies have to share data with relevant authorities and stakeholders. Currently, the insurance sector is in possession of essential data on damages that could be of great help to the public authorities to enhance climate adaptation in a region, country, or internationally. At last, the taxonomy requires that the industry offers a high level of service in post-disaster situations (European Commission, n.d.).

2.5.1 Climate adaptation of buildings in Norway

In Norway, natural hazards are relatively common, and therefore, climate adaptation of buildings has been important for many years. A good example of this is the "climate helper" (Klimahjelperen) developed by a group of municipalities and government agencies in the period from 2012 to 2014. The guide addresses the need for climate adaptation to limit the impact of climate change in Norway and prevent damage to critical societal functions (DSB, 2015, p.5).

The "climate helper" refers to examples from different municipalities in Norway on how to implement climate adaptation in building processes, as well as relevant laws and regulations. One example is taken from Oslo municipality's plan strategy stating that "increased risk of floods due to increased precipitation, sea-level rise, landslides, wind and settlement damage must be taken care of in future development" (DSB, 2015, p.17). However, it is not voluntary for the municipalities to perform climate adaptation of buildings. In the guidance to TEK17 (The building code), it is stated that the effect of climate change will have consequences on the built environment, both in terms of placement of buildings and what loads the buildings must withstand. The Planning and Building Act with regulations shall ensure that new buildings and constructions are adapted to a changing climate (Direktoratet for Byggkvalitet, n.d.). Another law regulating the building permits is the Civil Protection Act which states that the municipality is obliged to identify which adverse events that may occur due to human activities and natural conditions. The analysis conducted to identify such events must include existing and future risk- and vulnerability factors, for example, events due to climate change (DSB, 2015, p.12).

In addition to the climate helper, several other guidelines have been developed to improve climate adaptation in building processes. For example, a wind load standard from Standard Norge was developed to serve as a guide for dimensioning buildings in Norway, which was most recently updated in 2009 (Standard Norge, 2009). Furthermore, a building research series providing an overview of how to decide the wind loads on buildings depending on location and design has been developed (Byggforskserien, 2003). As these indicative standards are relatively old and behind a payment wall, they will not be a part of the reflections in the analysis.

2.6 Classification theory

Even though there are four questions to be answered in this thesis, as listed in section 1.1, one of the primary purposes is to determine the probability of property damage at different wind speeds. This question is identified as a classification problem as the wind speeds will be used to predict damage or no damage. Therefore, each wind observation will be assigned to a category based on the probability of that observation belonging to a specific category of the qualitative variable (James et al., 2021, p.133).

In this sense, one might also say that classification methods behave like regression methods. The most widely used classifiers are logistic regression, linear discriminant analysis, quadratic discriminant analysis, naive Bayes, and K-nearest neighbors (James et al., 2021, p.129).

To build a classifier, it is necessary to have a set of training and test observations (James et al., 2021. p.130). When a classifier is built, it is possible to find the error rate of the analysis. Usually, the training error rates will be lower than the test error rates, which are the actual quantity of interest. That is because the parameters in the test data are specifically adjusted to do well on the training data (James et al., 2021, p.148). However, overfitting may occur if the test and training data are too similar. *Overfitting* is a statistical modeling error that occurs when a function is too closely aligned to a limited set of data points. In our case, overfitting may occur if the predictions on the training set fit exactly against the training data. Then the algorithm will not be able to perform accurately against new and unseen data (IBM Cloud Education, 2021). As a result, this can cause the model to be useful only in reference to its initial data set and not to any other datasets (Twin, 2021).

A classification model makes two types of errors. It can either assign an observation as a false positive or a false negative. Often, it is of interest to determine which of these two errors is being made (James et al., 2021, p.148). That can easily be displayed in a confusion matrix that visually displays and summarizes the performance of a classification algorithm (Singh et al., 2021). This will be further described in section 3.3.1.

2.7 Concluding the Literature and Hypothesis Formulation

Following the review of the relevant literature, we realize that there is a lot of research available on the topic of wind patterns, insurance claims related to natural hazards, and climate adaptation seen in the context of climate change. However, several of the research findings are ambiguous, and few certainties can be drawn.

Based on the literature review, and the research questions defined in Chapter 1, the following hypotheses are derived:

H1: *The number of storm-related damages will vary depending on the location of each county.*

This hypothesis is based on research by Hanssen-Bauer et al. (2015, p.57), who found that in the most exposed areas along the coast and the high mountains, the wind is over 15 m/s for more than 1% of the time. For the eastern part of Norway, most places only reach a wind of about 6 m/s 1% of the time. These estimates are based on model calculations that downscale global observation-based datasets to a 12x12 km grid (the “NORA10 dataset”). In this model, the measuring points predict a mean wind speed of just 1-2 m/s lower than the observed values. This marginal difference suggests that the observed spatial variations are modeled quite well, and the geographical differences are therefore expected to be representative. In addition, numbers from Finance Norway suggest that winds occur most frequently in the Northern- and Western parts of Norway (Finans Norge, n.d.-a). Therefore, we believe that the number of storm-related damages is strongly dependent on the location of the county.

Furthermore, based on the findings from RQ1, it seems natural to investigate whether the number of storm-related damages has increased or decreased in line with the development in the building mass in the last years. Hence, H2 reads as follows:

H2: *The number of storm-related damages and compensation payouts have increased proportionally more than the building stock.*

The reasoning behind this hypothesis is that if the number of property damages and compensation payouts have increased in line with the building mass, it might suggest that there has been no difference in the strong wind occurrences in Norway. If the building mass has increased proportionally more than what is shown in the statistics of the NNPP, the case could be just the opposite. However, based on recent data on both property damages and compensation payouts, it seems reasonable to assume that these have increased proportionally more than the building stock.

Another perspective that could be interesting to look at is if this development differs between the inland and coastal counties. Hanssen Bauer et al. (2015) found more frequent and intensive winds along the coast than inland. If that is the case, it would be interesting to investigate whether there are any differences in the wind loads the buildings can handle. As the coastal counties are more exposed to wind and therefore expected to be more adapted to them, the following hypothesis is formulated:

H3: *The probability of wind damage will be lower in coastal counties than in inland counties.*

In several counties in Norway, strong winds are quite common, and the building structures have been adapted thereafter (Miljødirektoratet, 2019). For example, in Refvik, all of the buildings have a thick concrete wall without windows on the southern/southwestern wall because the wind from the Refvik water is known to be very strong and causes a lot of damage (Eldevik & Solheim, 2011). With that in mind, it would be interesting to see if the counties that are more familiar with strong winds are also better prepared for them and can handle more intense wind gusts.

Finally, following RQ4, the last hypothesis was formed to summarize the current performance of the NNPP compared to the non-life insurance criteria by the EU Taxonomy:

H4: *The current structure of the Norwegian Natural Perils Pool is not in line with the contribution criteria of the EU Taxonomy.*

Currently, the majority of climate finance has been targeted at mitigation and not adaptation. Furthermore, the adaptation sources mainly come from public resources (IPCC, 2022-b, p.27), even though the world is dependent on the private sector investments to also play a crucial role (Ara Begum et al., p.52). Therefore, to act in line with both the recommendations from the IPCC and the EU Taxonomy, both the finance and insurance industry needs to take a more active part in combating climate change.

In addition, it is known that adaptation measures tend to have a positive economic and environmental impact in both developing and developed countries (Caretta et al., 2022, p.6). Hence, the degree of which the EU Taxonomy is incorporated in the NNPP may reveal their current level of social responsibility.

3 Methodology

As the main research question subject to modeling is RQ3, the method to analyze this question will be presented in the following chapter. The research question is, as mentioned in section 2.6, identified as a classification problem, where the output variable (Y) can be classified as "damage" or "no damage". Furthermore, different wind measurements (X) will be used as predictors. For a given wind speed, the goal is to determine the probability of damage and whether it varies between the different counties in Norway. The remaining research questions are answered based on exploratory research, and discussions are linked to the literature review.

The following chapter consists of three main parts. First, the applied classification models are presented. This is followed by methods for refinement before we proceed to describe the procedure of evaluating and validating the methods.

3.1 Machine Learning Algorithms

This section describes the selected machine learning algorithms used in the analysis. The classification methods applied to model the data are logistic regression and classification trees.

3.1.1 Logistic Regression

Logistic regression is a statistical model used to describe and explain the relationship between a dependent binary variable and one or more independent variables. Responses such as Yes/No are frequently used, and the model estimates the probability of Y belonging to a specific category. Mathematically, this can be written as follows: $p(X) = Pr(Y=1|X)$ (James et al, 2021, p.133).

Fitting a linear regression model to a binary response may produce $p(X) > 1$ for some values of X and $p(X) < 0$ for others. In most cases, these predictions will not be sensible. To obtain outputs between 0 and 1 for all values of X, the logistic function can be used (James et al., 2021, p. 134):

$$p(X) = \frac{e^{\beta_0+\beta_1 X}}{1 + e^{\beta_0+\beta_1 X}}$$

The regression coefficients 0 and 1 can be estimated using the general method of maximum likelihood. This method is preferred due to its statistical properties, and estimates of 0 and 1 are chosen based on values that maximize the likelihood function (James et al., 2021, p.135):

$$\ell(\beta_0, \beta_1) = \prod_{i:y_i=1} p(x_i) \prod_{i':y_{i'}=0} (1 - p(x_{i'}))$$

Once the coefficients have been estimated, predictions can be made. These are made by plugging the coefficient estimates into the function p(X). The predicted probabilities are then categorized according to a set threshold (James et al., 2021, p. 135).

A simple logistic regression model can easily be extended to cover multiple predictors, thus creating a multiple logistic regression (James et al., 2021, p.137):

$$p(X) = \frac{e^{\beta_0+\beta_1 X_1+\cdots+\beta_p X_p}}{1 + e^{\beta_0+\beta_1 X_1+\cdots+\beta_p X_p}}$$

As in the case of a simple logistic regression, the maximum likelihood method can be applied to estimate β_0, β_1, ..., β_p (James et al., 2021, p.137). In sum, this method seems like a suitable approach for the problem at hand.

3.1.2 Classification Trees

Classification trees are used to predict qualitative responses through recursive binary splitting. Each observation is predicted to belong to the most commonly occurring class of training observations in the region it belongs to. To make these binary splits, the classification error rate is used as a criterion. The classification error rate is the fraction of the training observations in the region that do not belong to the most common class (James et al., 2021, p.335):

$$E = 1 - \max_{k}(\hat{p}_{mk}).$$

In this equation, $\hat{p}_{mk}$ constitutes the number of training observations in the mth region from the kth class (James et al., 2021, p. 336).

The main advantages of classification trees are that they are easy to explain and interpret, can be displayed graphically, and are good at handling qualitative predictors without the need for dummy variables. On the other hand, the main disadvantages of classification trees are that they usually do not have the same level of predictive accuracy as other classification models and that they can be very non-robust, meaning that a slight change in the data can cause significant change to the final estimated tree (James et al., 2021, p. 339). In addition, classification trees tend to suffer from high variance, leading to significant differences in results when applied to distinct data sets. However, ensemble methods, such as bagging, random forest, and boosting, can improve prediction accuracy and will be presented in the following section (James et al., 2021, p.340).

3.2 Ensemble Methods

Ensemble methods are processes where different and independent models are combined to improve the output of a model (James et al., 2021, p.340). The methods applied in this thesis are bootstrap aggregation, random forest, and boosting.

3.2.1 Bootstrap Aggregation

Bootstrap aggregation, also known as bagging, is a general-purpose technique used to reduce the variance of a statistical learning method. The procedure is beneficial for classification trees to raise the stability of the model and eliminate the challenge of overfitting (Corporate Finance Institute, n.d.). In bootstrap aggregation, samples from a single training set are repeated to generate B distinct bootstrapped training sets. These different training sets are taken from the population to build a separate prediction model based on the average observations from all training sets. As a result, we get a low-variance statistical learning model given by (James et al., 2021, p.340-341):

$$\hat{f}_{\text{avg}}(x) = \frac{1}{B}\sum_{b=1}^{B}\hat{f}^{b}(x)$$

A bagged tree is grown deep and not pruned, which causes the individual trees to have a high variance but a low bias. Taking the average of these B trees reduces the variance, and bagging has proven to enhance model accuracy by combining several trees into a single procedure (James et al., 2021, p.341).

The described bagging procedure applies to the regression context. However, bagging can easily be extended to a classification problem when dealing with a qualitative outcome Y. In that case, for a given test observation, the predicted class by each of the B trees is recorded, and the most frequently occurring class is chosen as the overall prediction (James et al., 2021, p.341).

3.2.2 Random Forest

Similar to bagging, random forest produces a number of decision trees based on bootstrapped training samples. Nevertheless, when a decision tree is built, each time a split is contemplated, a *random sample of m predictors* is selected as candidates for the split. The split candidates are chosen from the full set of *p* predictions, and a new sample of *m* predictors is selected at each split, typically $m \approx \sqrt{p}$. As a result, the algorithm is not allowed to consider most of the available predictors when building a random forest. This is beneficial as it reduces the impact of strong predictors in the data set. On average, *(p-m)/p* of the splits will not even consider the strong predictor, making room for other predictors. In bagging, strong predictors will be used in the top split in most of or all of the trees, thus making the trees quite similar and the predictions highly correlated. This is avoided when building a random forest (James et al., 2021, p.344).

3.2.3 Boosting

In boosting, the decision trees are grown sequentially. Each tree is grown based on knowledge from existing trees and fitted on a modified version of the original data set (James et al., 2021, p.345). Boosting is a slow learning algorithm where a decision tree is fitted using the current residuals, instead of the outcome Y, as the response variable. The number of terminal nodes is determined by the parameter d in the algorithm, and the decision trees are fitted to the residuals to improve f. The process is slowed down by the shrinking parameter λ, allowing a variety of different shaped trees to process the residuals. Overall, slow statistical learning approaches tend to perform well (James et al., 2021, p.346).

To perform boosting on a classification model, a vector of values for each class with the values 1 or 0 is created. Furthermore, different boosting trees are fitted to each class of the dependent binary variable to indicate whether or not an observation does belong to the respective class. In consecutive boosting steps, the logistic transformation will be applied to the algorithm to compute the residuals. Final classification probabilities are then computed by applying the logistic transformation for each 0/1 coded vector (TIBCO Software Inc., 2020).

3.3 Assessing Model Performance and Validation

In this section, an explanation of the methods used to assess the model accuracies of the different classification methods, as well as the validation methods, will be presented.

3.3.1 Confusion matrix

A common measure to evaluate the performance of a predictive classification model is to calculate the accuracy. This can be done by creating a confusion matrix that compares the model predictions to the actual classifications. This is a convenient way to display information and has two types of errors; it can incorrectly assign a wind measurement to the category *damage* (1) or incorrectly assign a wind measurement to the category *no damage* (0). In a confusion matrix, the elements on the diagonal of the matrix present the observations that have been correctly predicted, and the off-diagonal elements represent observations that have been misclassified (James et al., 2021, p.148).

Prediction \ Actual	No	Yes
No	True negatives (TN)	False positives (FP)
Yes	False negatives (FN)	True positives (TP)

Table 3.1: Confusion matrix

3.3.2 Metrics

Several metrics can be derived from the confusion matrix and used to assess the performance of a statistical model. The most common metric, accuracy (ACC), provides the percentage of correctly classified observations. The error rate (ERR), on the other hand, represents the fraction of incorrectly classified observations. There are two types of error rates, namely training error rate and test error rate. The training error rate is calculated based on the training data used to fit the model, whereas the test error rate is a result of providing a new set of observations. The test error is most important, and a small test error rate indicates a good classifier. ERR and ACC are calculated as follows (James et al., 2021, p.37):

$$ACC = \frac{TN + TP}{TN + FN + FP + TP}$$

$$ERR = \frac{FP + FN}{TN + FN + FP + TP} = 1 - ACC$$

Additional metrics can also be derived from the confusion matrix. For example, the true positive rate (TPR) specifies the correctly classified positive cases, and the true negative rate (TNR) defines the number of correctly classified negative cases. TPR and TNR can be calculated by dividing the predicted values by the observed classes (Markoulidakis et al., 2021, p.5):

$$TPR = \frac{TP}{TP + FN} \qquad TNR = \frac{TN}{TN + FP}$$

Moreover, the false-positive rate (FPR) defines the number of negative cases incorrectly classified as positive. In contrast, the false-negative rate (FNR) specifies the number of positive cases incorrectly classified as negative. These can be given as (Markoulidakis et al., 2021, p.5):

$$FPR = \frac{FP}{FP + TN} \qquad FNR = \frac{FN}{FN + TP}$$

A trade-off between TPR and TNR, also known as sensitivity and specificity, occurs when model accuracy is assumed fixed. The Receiver Operating Characteristic (ROC) curve can be used to evaluate this trade-off and will be the focus of the next section.

3.3.3 The ROC curve and AUC

The ROC curve is a graphical illustration used to display the balance between the two types of errors. The performance of a model (AUC) is given by the area under the curve when summarized over all possible thresholds, and the higher the value, the better the classifier performs. In an optimal model, where TPR = 1 and FRP = 0, the ROC curve will favor the top left corner, and the AUC will be maximized (James et al., 2021, p.151).

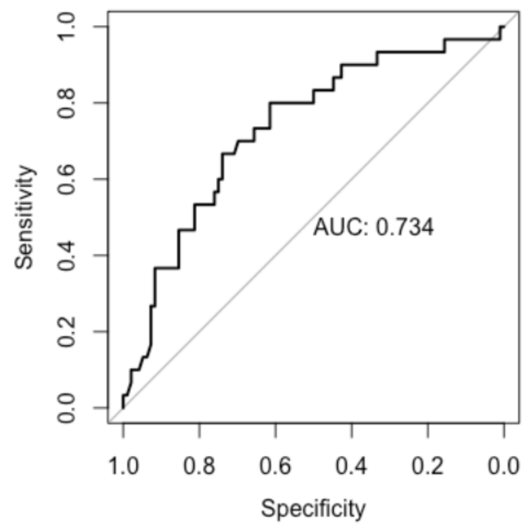

Figure 3.1: ROC Curve

3.3.4 The Validation Set approach

The validation set approach is a strategy used to estimate the test error associated with fitting a model on a set of observations. As overfitting may occur when a model is trained and validated using the same data, the performance of a model should be assessed based on observations from a separate sample. This can be achieved by using the validation set approach, where the available set of observations is randomly divided into a training and a test set. Then, the model is fitted to the training set, and predictions are made based on observations from the test data (James et al., 2021, p. 198).

4 Data and Preprocessing

This chapter is divided into three parts. In the first section, relevant datasets are introduced. The second section provides a description of the preprocessing and preparation steps, where the raw data is prepared for the main analysis. Finally, an overview of the complete datasets is presented.

4.1 Introduction to the Dataset

In this thesis, we use three primary data sources. First, data on property damage and compensation payouts are retrieved from the NNPP. The compensation term used in the Norwegian Natural Damage Statistics (NASK) is the determined compensation, which is the paid insurance compensations plus the compensation provided for the damages that have occurred and been claimed. (Finans Norge, n.d.-c). At NASK, it is possible to filter the extreme weather events into storms, storm surges, floods, landslides, earthquakes, volcanic eruptions, and other unclassified events that have led to property damage. Based on the county division before the reform on January 1, 2020, the total compensations and damages can also be displayed per county for all 19 counties. Furthermore, the data can also be downloaded per day, month, or year (Finans Norge, n.d.-b).

As this master thesis primarily focuses on storm events, only the number of damages and compensations for storm events are downloaded. To create a total overview, these are retrieved on a monthly and annual basis from 1980 to 2021. This data is intended for exploration purposes only and is not a part of the analysis to estimate the wind speeds required to cause property damage.

Furthermore, as mentioned in Chapter 1, seven out of the ten years with the highest insurance compensations from the NNPP have occurred in the period from 2010 to 2021 (Finance Norway, 2022). Several scientists also agree that the insurance companies will have to expect higher compensation rates in the years to come due to an increased number of extreme weather events. Therefore, data on claims are retrieved on a daily basis back to 2010, as it is suggested that we are going into a new and higher normal for the number of damages in the years to come (Westby, 2015).

The second data source is the Norwegian Meteorological Institute. In sum, there are approximately 320 weather stations in Norway with measurements on climatic observations (Statens Vegvesen, n.d.), dating back to 1900 (Meteorologisk institutt, 2021-c). Despite this, not all weather stations are equipped to measure wind, thus reducing the number of stations that can be used in our analysis. A range of filters can be applied, making it possible to choose between ~100 different meteorological variables, such as temperature, participation, wind, and air pressure. As most property damages occur at high wind speeds (Rommetveit, 2014), we found it sensible to retrieve the highest wind gust per day and the highest mid-wind per day dating back to 2010. This data will be combined with the NNPP data to estimate the probability of property damage at different wind speeds.

Since the NNPP still operates with the previous county division, both the highest wind gust and highest mid-wind are downloaded based on the old county division. We found this county division to be more suited than the new one due to the assumption that more accurate information can be obtained from smaller counties. In sum, there are 123 weather stations included in the analysis. However, several weather stations have experienced considerable downtime during the last years, resulting in multiple missing values. The proportion of missing values is displayed in Table 4.1.

	Missing Values in the Meteorological data					
	Møre og Romsdal	Hordaland	Nordland	Oppland	Akershus	Østfold
Highest measured wind gust	18,30 %	24,90 %	25,10 %	17,40 %	35,10 %	6,80 %
Highest measured mid-wind	18,90 %	24,30 %	23,10 %	17,00 %	35 %	24,60 %

Table 4.1: The proportion of missing meteorological data in each county.

For the majority of the counties, there are only minor differences between the two measurements. In Østfold, on the other hand, the deviation is more substantial. This is because the weather station Prestebakke only provided measurements for mid-winds and not wind gusts, thus not included when downloading the wind gusts measurements. However, this station had a considerable amount of downtime in the selected period, resulting in a high number of missing values for mid-wind, as seen in Table 4.1.

The third data source is SSB. To answer RQ2, annual building data from 1997 to 2021 and an overview of the population in the different counties are retrieved. This was done as a basis for comparing the number of damages and compensation payouts per building in each county. However, this data has not undergone any further processing.

4.2 Dataset Preprocessing

The first preprocessing step involves converting all rows containing dates in a character format into a date format recognized by R. Second, all compensation data are adjusted for inflation according to the annual development in the consumer price index (SSB, n.d.-c). Furthermore, the annual compensation payout is divided by the number of damages to calculate the average compensation payout per damage.

For the daily NNPP data, further preprocessing steps are conducted. Based on the daily number of damages, the binary variable ***category*** is created. This variable categorizes "damage" as 1 regardless of the number of registered damages and "no damage" as 0.

Moreover, the data from the Norwegian Meteorological Institute are assigned NAs to fill in the missing rows in the initial datasets. This is done to create a more continuous timeline. In light of this, the max and mean values of the wind variables described in section 4.1 are calculated. The number of wind stations in a county does not matter, as only one wind value per county per day will be applied. This results in four different wind measurements per county per day: ***max_wind_gust***, ***mean_wind_gust***, ***max_mid_wind,*** and ***mean_mid_wind***.

Finally, the daily data retrieved from the Norwegian Meteorological Institute and NNPP are joined into a single dataset, according to the variable "date".

4.3 The Finished Datasets

In light of the preprocessing activities described above, we are left with a total of four datasets.

This is data on monthly and annually compensation payouts and storm-related damages per county, annual building, and population per county, and finally, daily wind measurements and storm-related damages per county. The reasons for not having a single dataset are due to difficulties downloading data from the NNPP. The website is not particularly user-friendly, making it too time-consuming to download data from 1980 to 2021 on a daily basis. A snippet of the daily dataset is displayed in Figure 4.1.

Date	variable	value
All	All	All
2021-01-01	Damages_møre	0
2021-01-01	Max_wind_møre	11
2021-01-01	Mean_wind_møre	7
2021-01-01	Max_mid_møre	7
2021-01-01	Mean_mid_møre	5
2021-01-01	category_møre	0
2021-01-01	Damages_nordland	2
2021-01-01	Max_wind_nordland	16
2021-01-01	Mean_wind_nordland	10
2021-01-01	Max_mid_nordland	12
2021-01-01	Mean_mid_nordland	8
2021-01-01	category_nordland	1
2021-01-01	Damages_hordaland	0
2021-01-01	Max_wind_hordaland	14
2021-01-01	Mean_wind_hordaland	6
2021-01-01	Max_mid_hordaland	12
2021-01-01	Mean_mid_hordaland	5
2021-01-01	category_hordaland	0
2021-01-01	Damages_akershus	3
2021-01-01	Max_wind_akershus	7
2021-01-01	Mean_wind_akershus	5
2021-01-01	Max_mid_akershus	4
2021-01-01	Mean_mid_akershus	2
2021-01-01	category_akershus	1

Figure 4.1: Snippet of the finished dataset.

All counties have four predictors based on the mean and maximum registered mid-wind and wind gusts from all weather stations in each county. The first row, ***damages_*county*,*** displays the number of storm-related damages on a given day. The following four rows display the wind variables serving as predictors, while the last row serves as the binary response variable as described in section 4.2.

5 Exploration, Modeling and Results

In this chapter, the research questions will be discussed and analyzed in light of the theory presented in Chapter 2. Based on our findings, the hypotheses will be accepted, or rejected.

The first two questions aim to explore the datasets at hand. Then, the models for answering RQ3 will be compared, the selected predictors will be discussed, and the modeling results will be presented. Finally, the current state of the Norwegian Natural Perils pool in regard to the contribution criteria of the EU Taxonomy will be assessed, and we will suggest measures for future improvements.

5.1 Research Question 1

This question aims to investigate whether the data retrieved from the NNPP are in line with or deviate from the research findings presented in Chapter 2, and reads as follows:

RQ1: *Which Norwegian counties experience the most repercussions related to storm damages?*

To answer this question, data on the number of storm-related damages and compensation payouts are compared on a total, annual and seasonal basis. For a thorough discussion, the findings on the total number of damages, the annual number of damages, the development in the average compensation per damage, and the seasonal variations in terms of compensations and damages are examined. Table 5.1 displays the total number of damages, the compensation payouts, and the average payout per property damage for all Norwegian counties from 1980 to 2021. Each county is categorized according to its geographical placement, and the division from Coastal forestry is used to determine whether a county is classified as coastal or inland. Coastal forestry is a collaboration between all coastal counties in Norway to exploit forestry potential along the coast (Kystskogbruket, n.d.). An overview is presented in Table 5.1.

Category	County	Number of storm-related damages	Total storm-related damage compensations (in million NOK)	Average compensation per storm-related damage (in million NOK)
Coastal counties	Møre og Romsdal	**44024**	2895,83	0,0658
	Nordland	**39411**	2484,75	0,0630
	Hordaland	**39016**	1579,42	0,0405
	Rogaland	25446	1085,45	0,0427
	Sør-Trøndelag	17721	1103,27	0,0623
	Sogn og Fjordane	16063	921,05	0,0573
	Troms	14274	792,02	0,0555
	Nord-Trøndelag	11349	714,95	0,0630
	Finnmark	9073	493,99	0,0544
	Vest-Agder	6933	278,74	0,0402
	Aust-Agder	3781	120,03	0,0317
Inland counties	Akershus	**9304**	487,53	0,0524
	Oppland	**5798**	264,48	0,0456
	Østfold	**5700**	205,54	0,0361
	Buskerud	5348	241,44	0,0451
	Telemark	5325	228,36	0,0429
	Hedmark	4633	177,18	0,0382
	Vestfold	4536	166,47	0,0367
	Oslo	4069	258,69	0,0636

Table 5.1: Number of storm-related damages, compensation payouts, and average compensation per damage (inflation-adjusted) for each county in Norway (before the county merge on January 1, 2020) from 1980-2021 (Finans Norge, n.d.-b)

From Table 5.1, it is evident that coastal counties have been subject to significantly more storm-related damages than inland counties, with the exception of Finnmark, Aust-Agder, and Vest-Agder. This is in line with findings from Hanssen-Bauer et al. (2015, p.58), who found that there has been a marginal decreasing linear trend (in %) in the wind patterns over these areas in the period 1961-2010. On the other hand, the inland counties have a similar rate of damage, with the exception of Akershus. The reason for this is unknown, but it could be a result of their large population and the possibility that several homeowners own vacation houses or cabins in other parts of the country while being in the national register of Akershus. This can cause many damages to be registered in the wrong place as they are registered in the hometown of the policyholder (Hauge et al., 2017, p.57).

The top three inland and coastal counties with the highest number of storm-related damages are marked green. As expected, Møre og Romsdal, Nordland, and Hordaland are the three counties with the highest number of damages in total. This is in line with previous research findings from Finance Norway, stating that Møre og Romsdal is the county most exposed to storm damages, with a corresponding 20% share of the total compensation payouts. Hordaland and Nordland's shares are ~11 and ~17%, respectively, precisely in line with the numbers presented by Finance Norway (Ebeltoft, 2020).

Another interesting observation from Table 5.1 is that the counties with the highest number of damages often have the highest compensation payouts as well. However, there are a few exceptions, such as Buskerud, Oslo, and Telemark. These counties have a higher compensation payout than Østfold, even though they have experienced fewer damages. Previous research has not identified any particular reasons for this, but we presume it to result from numerous factors. First of all, wind is mainly caused by horizontal differences in temperature (Dannevig & Harstveit, 2020), and as the temperature changes, it is hard to predict how wind patterns will develop. Since the wind considerations taken into account when constructing a building are normally based on historical observations, a change in wind patterns might cause the wind to hit from a direction the building is not adapted for. This could cause severe damages and may explain the increased compensation payouts in some counties. Another factor could be that buildings are affected by wear and tear, making them less endurable to high wind speeds over time (Gjensidige, 2020). Therefore, it is likely that wind causes more extensive damage to areas with a high number of old buildings. Furthermore, it could also result from inadequate climate adaptation or unfortunate placement of movables, causing hit damage where such incidents otherwise would not occur. In sum, this is a very complex subject, making it hard to state anything with certainty based on our knowledge.

The average compensation payout per storm-related damage also deviates slightly from the ranking based on the number of damages. For Møre og Romsdal and Nordland, the ordering is correlated for all columns. However, further down the list, the average compensation payout per storm-related damage seems more randomized and does not seem to correlate with the number of damages. For example, Oslo, the inland county with the least registered number of storm-related damages, makes the top 5 counties when ordered by average compensation rate per damage (> 60 000 NOK per damage). While both Hordaland and Østfold are ranked third in their respective category, they are in the bottom tier when ranked by average compensation payout per damage (=< 40 000 NOK per damage). As discussed above, this could be a result of many factors, but altogether, both coastal and inland counties are found both in the top tier and bottom tier, suggesting that the average compensation rate per damage is a result of other factors than the number of damages.

Be that as it may, Table 5.1 might not reflect the annual distribution of storm-related damages and compensation payouts. As mentioned in Chapter 1, seven out of the ten years with the highest total compensation payouts for the insurance companies have occurred since 2010 (Finans Norge, 2022, p.12). Therefore, we found it interesting to examine if this distribution is representative of the most recent development in wind patterns. To unveil potential new trends, Figures 5.1 and 5.2 are created, showing the annual number of damages and compensation payouts in the period 1980 to 2021..

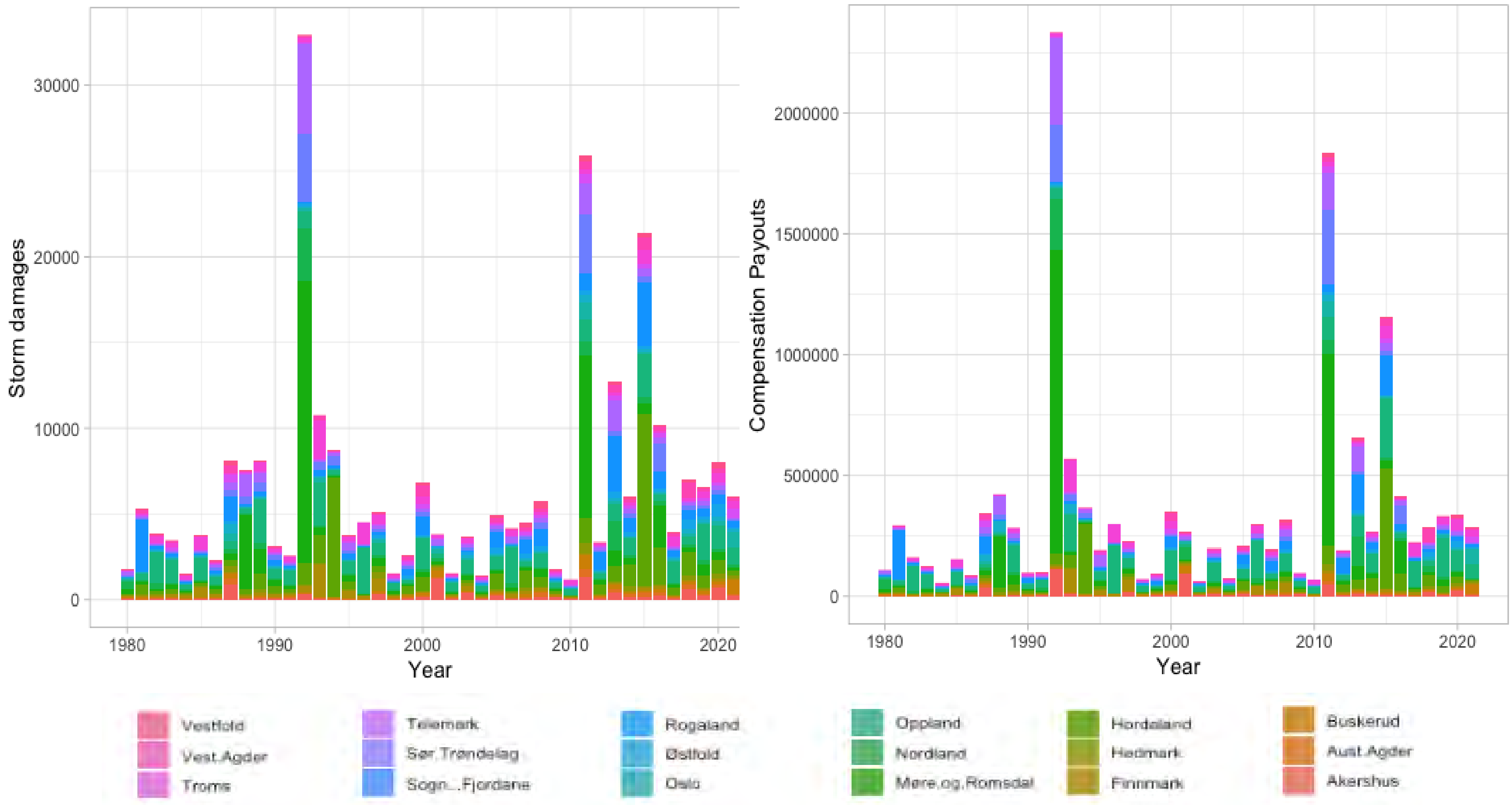

Figure 5.1: Number of storm-related damages per county per year in the period 1980-2021 (Finance Norway, n.d.) & Figure 5.2: Total compensation payouts per county, per year in the period 1980-2021 (Finance Norway, n.d.)

The overall picture seen in Figure 5.1 does not display a clear upward-facing trend in the number of storm-related damages. However, the years from 2011-to 2021 seem to have a slightly higher average than the previous ten-year periods, and most damages seem to occur in the coastal counties in Norway. This corresponds to the information presented in Table 5.1. Furthermore, we found it interesting to investigate whether the number of damages correlates with the compensation payouts, as displayed in Figure 5.2. This stacked bar chart is based on the inflation-adjusted annual compensation payouts per county and is, for the most part, proportional to Figure 5.1, suggesting that the compensation payouts and the number of damages are correlated. However, in both plots, the years 1992, 2011, and 2015 stand out. This is because some of the most severe wind storms ever to take place in Norway occurred these years (Pettersen, 2015).

On January 1, 1992, the “New Year’s Day Hurricane” took place. This hurricane struck Trøndelag and parts of Northwest Norway. To this day, the “New Year’s Day Hurricane” is the most catastrophic Norwegian natural disaster in modern times, with wind measurements up to 62m/s (223km/h). The economic consequences were estimated to be ~2 billion NOK, and a total of 50 000-60 000 buildings were damaged. Statistically, a hurricane of this intensity only occurs once every 200 years (Meteorologisk institutt, 2021-b). In 2011 there were two severe storms in Norway. First, the storm “Berit” hit central Norway and Nordland on November 26-27, followed by the hurricane “Dagmar”, which hit Møre og Romsdal on December 26. “Berit” caused damages of approximately 300 million NOK (Leth-Olsen, 2012), but the strength of the wind gusts is unknown. The hurricane “Dagmar”, on the other hand, had wind gusts up to 55 m/s (Skogbrand, n.d.), and according to Finance Norway, the event led to compensation payouts of ~1,3 billion NOK, of which 700 million took place in Møre og Romsdal, and 20 000 registered property damages (Gytri, 2016). At last, the storm “Ole” hit the northern parts of Norway on February 7, 2015, with a maximum measured wind speed of 31,2 m/s. This storm caused thousands of households to lose electricity (NRK, 2015). However, the economic consequences of “Ole” have not been published.

Due to time constraints, we will only include the three coastal and inland counties with the highest number of damages, as displayed in Table 5.1, in the following sections. A further evaluation of the development in average compensation payout per storm-related damage is illustrated in Figure 5.3.

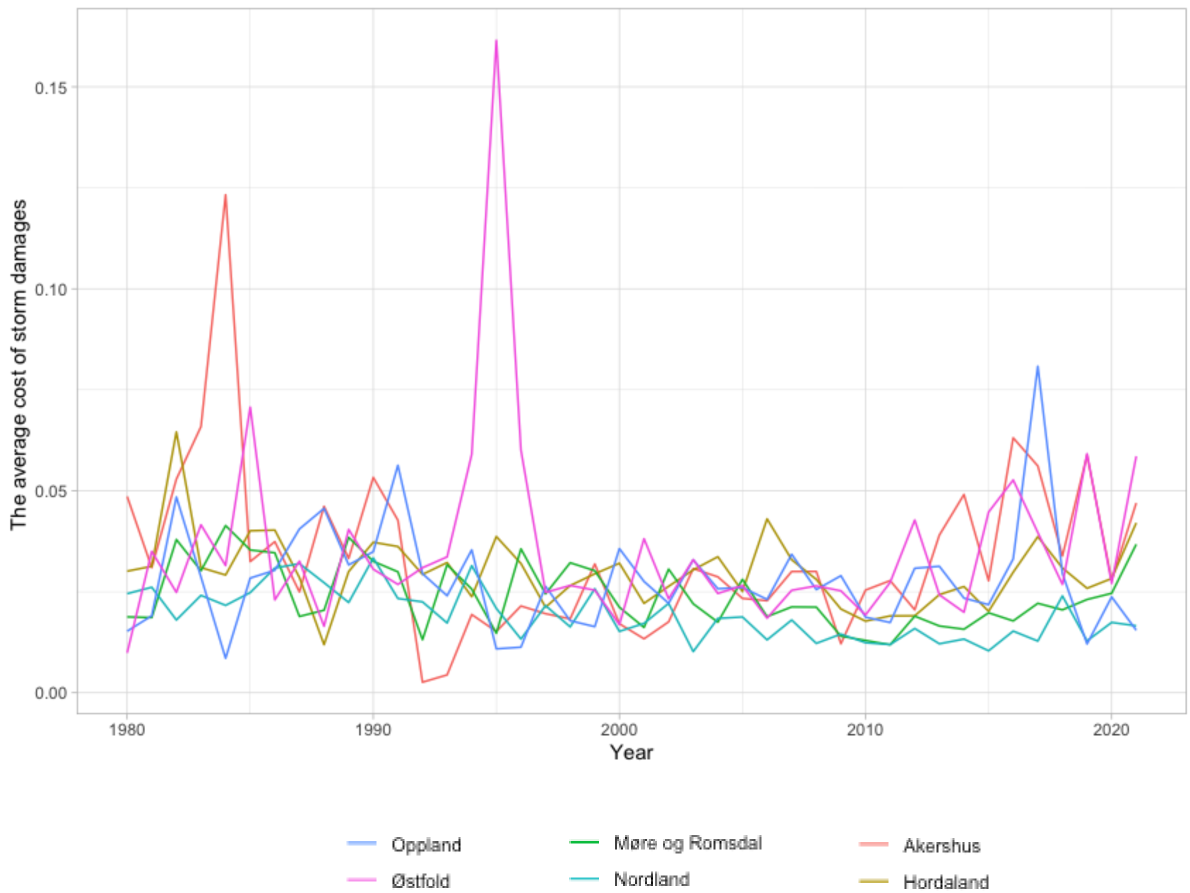

Figure 5.3: The average storm-related inflation-adjusted compensation rates in the selected counties (Finance Norway, n.d.).

As seen in Figure 5.3, there is no apparent trend in the average compensation rate per damage. Surprisingly, all of the highest peaks belong to the inland counties, suggesting a higher average compensation payout than coastal counties. The first peak occurred in Akershus in 1984, the second peak in Østfold in 1995, and the third peak in Oppland in 2017. However, no particular severe wind storms have been recorded in these years. As these counties experience relatively few wind damages in general, it could result from a single, or just a few, storm-related damages with extraordinary high compensation costs, causing the average compensation payouts to appear unusually high.

Except for the three most apparent peaks, the development seems relatively stable despite the high volatility of the graphs. The high volatility is most likely a result of the significant differences in the number of damages from year to year, as displayed in Figure 5.1. Other than that, the counties seem to be reasonably correlated in terms of average compensation rate per damage, even though they differ in terms of climate and population. Furthermore, neither of the severe storm events seem to have caused increased compensation payouts in the affected counties, as there are no peaks in 1992, 2011, or 2015. This might suggest that the damages that occur from uncommonly strong winds are not more severe than the damages that occur in a typical year. Hence the average compensation payout per damage is not particularly affected by the number of damages.

Furthermore, we want to investigate whether the most severe wind storms do, in fact, occur in the winter, as claimed by Hanssen-Bauer et al. (2015). The storms mentioned in this analysis all took place in the winter, but to what extent does the number of storm-related damages and compensation payouts differ between the different seasons? This is investigated in Figures 5.4 and 5.5. The graphs provide a visualization of the seasonal differences for different time intervals and might give a more nuanced picture, helping us identify the extent of the seasonal variations.

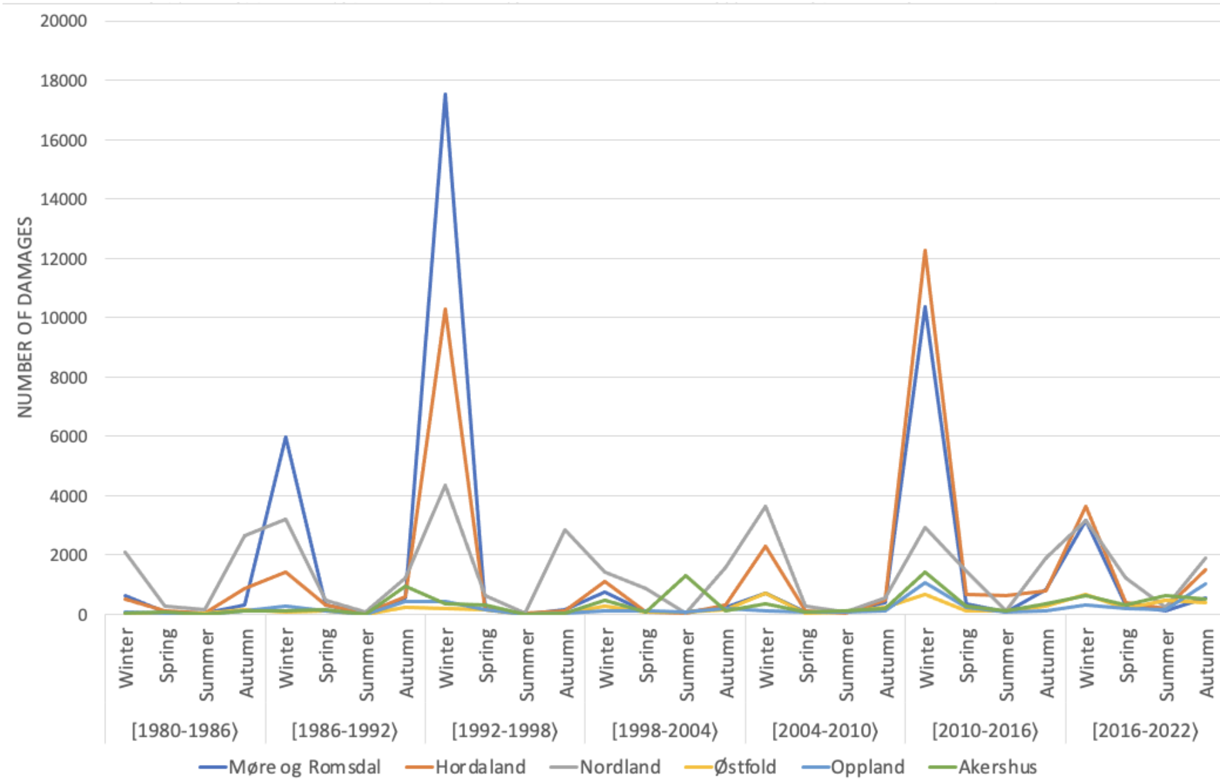

Figure 5.4: The number of storm damages in a 6-year seasonal interval.

From Figure 5.4, it is apparent that there are relatively large differences in the number of storm-related damages depending on the season of the year. In this Figure, December-February are classified as winter months, March-May as spring months, June-August as summer months, and September-November as autumn months. There seems to be a systematic peak during wintertime in all counties for all time intervals, and the highest peaks always belong to the coastal counties. As the selected coastal counties are placed in the Western- and Northern parts of Norway, this might confirm previous research stating that these parts of the country are most prone to strong winds (Finans Norge, n.d.-a).

To determine whether the number of storm-related damages and compensation payouts are correlated on a seasonal basis, Figure 5.5 is created, displaying the development in the payouts between the different seasons and time intervals.

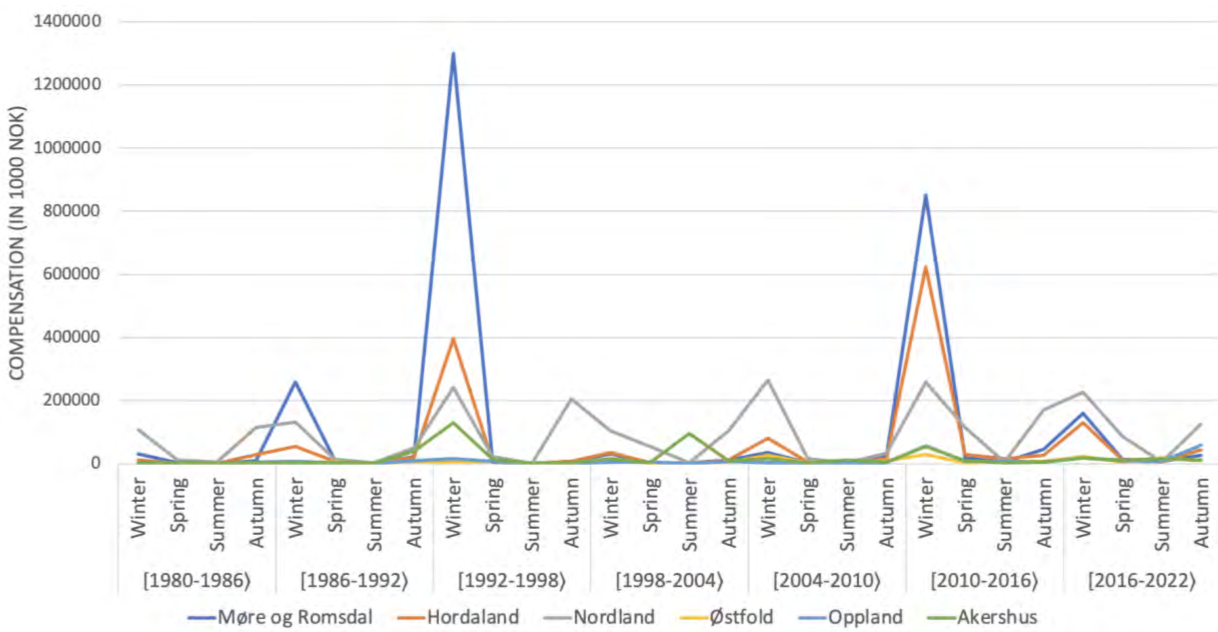

Figure 5.5: Storm-related compensation payouts in a 6-year seasonal interval.

When comparing Figure 5.4. and 5.5, we can see some interesting differences between the compensation payouts related to storm damages in the selected counties. All coastal counties seem to have a significantly higher number of damages and compensation payouts during the wintertime compared to the rest of the year. This applies to all time intervals. The inland counties, on the other hand, appear to have a more stable curve all year round, indicating fewer seasonal differences. The compensation payouts in the inland counties seem to be relatively correlated to the number of storm-related damages in all seasons. In addition, both the number of damages and compensation payouts appear to be significantly smaller in the inland counties than in the coastal counties, especially in the wintertime, while being quite similar in the other seasons.

The highest peaks appear during wintertime in the periods 1992-1998 and 2010-2016, corresponding to the time intervals where some of the most severe storms in Norwegian history took place. In line with the occurrence of these storms, we can see a significant increase in compensation payouts and the number of storm-related damages in the coastal counties. However, these storms do not appear to have caused any extraordinary repercussions in Nordland, as Nordland has fairly equal peaks both in damages and compensation payouts during the wintertime for all time intervals. In Hordaland, on the other hand, the compensation payouts seem to be systematically lower compared to the number of damages, which is in line with the observed lower average compensation payout in Table 5.1. Møre og Romsdal appears to have relatively higher compensation payouts than the number of damages, especially when compared to Hordaland.

As discussed earlier, there could be numerous reasons for these differences. For example, it might suggest that Hordaland is better at climate adaptation or that the damages occurring are, in general, less severe than the damages that occur in other counties. At last, in light of this analysis, we will now conclude on H1:

5.1.1 Hypothesis 1

H1: *The number of storm-related damages will vary depending on the location of each county.*

From Table 5.1, there seems to be a higher number of storm-related damages in the coastal counties in general, as most of these counties are in the top-tier of registered damages. Furthermore, Figure 5.1 and 5.2 reveals that the compensation payouts appear to be somewhat correlated with the number of storm-related damages, indicating that compensation payouts per damage are relatively similar in all counties. This is also confirmed in Figure 5.3, where all counties have a fairly similar average compensation payout per damage. However, this figure also reveals that there is significant volatility in the average compensation payouts per year and that the payouts stemming from a single damage can have a huge range. Therefore, the total average compensation payouts might not be the best to indicate which county that has the highest average compensation rate.

However, the seasonal differences seem to confirm the indication of Hordaland having a lower average compensation payout than most counties included in the analysis. The figures also confirm the hypothesis that the number of storm-related damages varies depending on the geographical location of a county, as all significant peaks occur in the coastal counties. However, our findings indicate that the wind patterns are similar in all counties during the spring, summer, and autumn, while they vary considerably during the winter. Based on this, we are fairly certain that the number of storm-related damages does indeed vary depending on the geographical location of each county.

In all other seasons, the observed number of storm-related damages is relatively similar in all counties. Therefore, H1 can be partially accepted. The number of storm-related damages in a county depends on the location. However, these differences seem to apply primarily during wintertime.

5.2 Research Question 2

As the selected counties vary significantly in both area and population, we found it interesting to compare the number of storm-related damages to the building mass in each county. A comparison between the number of damages and compensation payouts to the building mass is expected to reveal a more realistic picture as to which county does, in fact, experience the most repercussions due to storm-related damages. Therefore, research question 2 aims to answer the following question:

RQ2: *In proportion to the building mass, has there been an increase or decrease in storm-related damages?*

To answer this question, statistics on building mass are downloaded from SSB for all counties included in the analysis. Unfortunately, the data is only available back to 1997, resulting in a shorter time interval than the NNPP data. Another important aspect is the missing data for Østfold, Akershus, Oppland, and Hordaland in 2020 and 2021 due to the county reform that came into force on January 1, 2020. Therefore the compound annual growth rate (CAGR) from 1997 to 2019 is used to estimate numbers for these years. The CAGR used can be found in Table 1 in the Appendix. Furthermore, the number of damages per 1000 buildings is calculated. The total building mass and the number of storm-related damages per 1000 buildings per county are displayed in Table 5.2.

Existing building mass. All buildings, by region, building type*, year and statistical variabel. The number of buildings per km² is also displayed in this table.												
County & area	**Østfold (4 181 km²)**		**Akershus (4 918 km²)**		**Oppland (25 192 km²)**		**Hordaland (15 460 km²)**		**Møre og Romsdal (14 356 km²)**		**Nordland (38 155 km²)**	
Year	**Number of buildings**	**Damages per 1000 buildings**	**Number of buildings**	**Damages per 1000 buildings**	**Number of buildings**	**Damages per 1000 buildings**	**Number of buildings**	**Damages per 1000 buildings**	**Number of buildings**	**Damages per 1000 buildings**	**Number of buildings**	**Damages per 1000 buildings**
1997	175558	0,923	252350	1,316	242086	0,620	265236	1,116	195018	2,436	208848	3,548
1998	177821	0,045	254885	0,035	243792	0,115	275215	0,338	197034	0,873	210350	1,892
1999	179201	1,071	257644	0,446	246458	0,089	291294	1,246	199331	0,722	212072	0,976
2000	181767	0,501	263879	0,477	250797	0,211	293923	2,793	205776	1,307	214475	8,425
2001	183974	0,348	269490	4,783	253514	0,840	303720	0,148	208647	0,839	219411	1,249
2002	188070	0,282	275444	0,185	257141	0,381	307827	0,312	209989	0,357	223125	1,936
2003	192424	0,961	278084	1,438	260908	0,318	308019	0,422	211662	1,559	224752	3,586
2004	194184	0,304	283103	0,230	264458	0,087	315483	0,311	213419	0,637	227651	1,305
2005	195924	1,725	286312	0,772	269444	0,301	320764	2,871	215438	0,854	230859	3,119
2006	197447	0,223	289360	0,156	272255	0,231	327682	0,415	217116	0,783	233112	8,785
2007	198898	1,378	291591	0,381	275100	0,356	334291	3,084	218704	0,814	235335	1,288
2008	202600	1,303	294927	0,604	278312	0,234	339620	1,758	221263	2,147	238591	3,424
2009	204303	0,299	298294	0,473	280900	0,078	344386	0,465	223478	0,595	240338	1,331
2010	206196	0,194	301896	0,123	283850	0,106	350344	0,220	226239	0,164	244333	1,330
2011	207881	1,458	309103	4,367	288726	3,637	355975	3,936	229328	41,277	246904	4,828
2012	209662	0,215	315718	0,285	292069	0,322	360574	1,498	232351	1,184	249232	1,192
2013	210981	1,758	322454	1,250	294446	0,554	363359	2,430	235007	4,128	250951	3,961
2014	212421	1,144	328602	0,511	296361	0,256	366680	3,597	237293	1,323	253309	3,936
2015	213678	0,917	331874	0,398	298313	0,268	369527	27,324	239734	2,369	254878	10,056
2016	214784	0,782	333561	0,696	299890	0,494	372443	5,738	241485	10,088	256866	1,141
2017	216094	0,421	336637	0,199	301762	0,225	374985	1,179	242898	0,716	258738	5,078
2018	216300	2,529	339401	1,803	305188	0,590	377034	3,589	244199	1,065	259987	1,781
2019	217596	0,809	341719	0,740	306609	0,453	379368	1,972	240977	2,473	261077	7,948
2020	219730	2,990	346461	1,931	309920	0,810	385590	2,150	240035	2,016	259412	5,447
2021	221884	0,401	351268	0,732	313266	3,135	391914	0,684	241453	0,762	261064	3,777

* Building types included: Residential buildings, other buildings and unspecified

Table 5.2: Number of buildings in the counties included in the analysis. Based on statistic 03158 from SSB (n.d.-b). The number of storm-related damages per 1000 buildings is also included in the table.

From Table 5.2, it is apparent that Akershus has the highest number of buildings per square kilometer. An interesting observation is that the county is less than ⅓ of the size of Hordaland while having a similar number of buildings. Østfold comes second in the number of buildings per square kilometer, which is not surprising. Both Akershus and Østfold are among the top 10 counties with the most inhabitants in Norway, while at the same time being among the smallest counties in area. Nordland, on the other hand, is the largest county in the analysis but is only ranked as the tenth most populated county in Norway (SSB, n.d.-a), describing the low number of buildings compared to its vast area.

Hordaland is the third most populated county in Norway, while Møre og Romsdal and Oppland are ranked 8th and 12th, correspondingly. Note that the population numbers are taken from the entrance of Q4 2019, and these rankings might have changed since then. On average, the number of buildings has increased by ~1% per annum in all counties. The total percentage growth in building mass per county over the given period is displayed in Table 5.3.

County	Østfold	Akershus	Oppland	Hordaland	Møre og Romsdal	Nordland
Total increase in building mass 1997-2021	26,39 %	39,20 %	29,40 %	47,76 %	23,81 %	25,00 %

Table 5.3: Total percentage increase in building mass for each county in the period 1997-2021.

In sum, Hordaland has experienced the highest increase in building mass over the last 25 years, with Akershus as a solid second. The remaining counties have a more similar growth rate, varying between ~24-30% increase. To answer RQ2, we need to compare the increase in building mass to the development in property damages over the years. As the number of storm-related damages varies significantly from year to year, the average annual growth rate will not be sensible. Therefore, the annual average number of damages per 1000 buildings in the period 1997-2009 is compared to the annual average in the period 2010-2021. These intervals are selected based on the report from Finance Norway, suggesting that storm events have been affecting an increasing share of policyholders more frequently since 2010 (Finans Norge, 2022, p.20). Additionally, the difference between the average numbers in percent is displayed in Table 5.4.

Annual average number of damages per 1000 buildings	Østfold	Akershus	Oppland	Hordaland	Møre og Romsdal	Nordland
1997-2009	0,720	0,869	0,297	1,175	1,071	3,143
2010-2021	1,135	1,086	0,904	4,526	5,630	4,206
Average increase	**57,58 %**	**25,01 %**	**204,36 %**	**285,11 %**	**425,70 %**	**33,81 %**

Table 5.4: Percentage difference between the average annual number of storm-related damages per 1000 buildings in 1997-2009 and 2010-2021 per county.

The table reveals major differences in the average number of storm-related damages per 1000 buildings per year. All counties have seen a disproportionately high increase in damage incidents compared to the increase in building mass, except for Akershus, which has seen a higher increase in buildings than in damages. However, it is important to bear in mind that a normal interval for suggesting weather patterns is 30 years, as decided by the World Meteorological Organization (WMO). This interval assures an adequately long data period to avoid impacts from short-term variations (Meteorologisk Institutt, 2021-a). Despite this, there are only ~40 years of best-track satellite data available (Seneviratne, 2021, p.1585). In our case, as the data from SSB only dates back to 1997, we are left with intervals of 13 and 12 years, respectively. Since the time frames taken into account are considerably shorter than the intervals suggested by WMO, it is still too early to state with certainty that there has, in fact, been a change of pace in the intensity and frequency of strong wind occurrences, even though the last decade might suggest that.

From 2011 to 2015, storm events occurred on an annual basis. This was also the case in 2018 and 2019, but individually, these storms were not that destructive (Finans Norge, 2022, p.13). However, these storms mainly occurred in the North and Western parts of Norway and cannot explain the striking increase in Oppland. The uncommonly high number of storm occurrences in Møre og Romsdal and Hordaland might be a case of short-term variation. However, there is no apparent reason to our knowledge as to why this table should not be representative of the other counties. Both Nordland and Østfold have seen a slightly higher increase in the number of damages per 1000 buildings than in the number of buildings, which seems reasonable as Finance Norway reports that in the latest years, the storms seem to have affected more people more frequently (2022, p.20).

Whether this table is able to capture the actual increase in storm-related damages is uncertain due to the limited time perspective and the unusually frequent occurrences of storm events in the last 12 years. However, it might provide some interesting new insights. Hanssen-Bauer et al. predict that overall, the wind patterns in Norway will be fairly similar in the years 2071-2100 as they were in 1971-2000, regardless of climate scenario and season (2015, p.113). However, they also found that the occurrences of strong winds had increased by 6-8% in the East- and Western parts of Norway in the period 1961-2010 (Hanssen-Bauer et al., 2015, p.58). The significant increase in the average number of damages per 1000 buildings in, particularly Oppland, Hordaland, and Møre og Romsdal might confirm that the trend of increasingly strong winds in these areas has continued. The reason for Akershus' limited increase in damages compared to the building mass is uncertain, but some factors could be more efficient climate adaptation and the fact that new buildings can handle more wind than old buildings as they are less affected by wear and tear.

Moreover, we also consider it interesting to examine the development of compensation payouts compared to the building mass. Therefore, the average annual compensation payouts per 1000 buildings have been calculated, as displayed in Table 5.5, based on the same intervals as described above.

Annual average sum of compensation payouts per 1000 buildings (in 1000 NOK)	Østfold	Akershus	Oppland	Hordaland	Møre og Romsdal	Nordland
1997-2009	78,817	49,740	11,228	115,907	136,371	589,832
2010-2021	141,009	33,170	47,404	699,534	1356,743	1160,080
Average increase	**78,91 %**	**-33,31 %**	**322,20 %**	**503,53 %**	**894,89 %**	**96,68 %**

Table 5.5: Percentage difference between the average annual sum of compensation payouts per 1000 buildings in 1997-2009 and 2010-2021 per county.

The most surprising finding when comparing the two time intervals in terms of average annual compensation sum per 1000 buildings is the ~900% increase in Møre og Romsdal. This is twice as much as the average increase in the number of annual storm-related damages in the same period. At the same time, there is a corresponding expansion in building mass at only ~24%. As mentioned, the main reason for this is most likely the increased frequency of storms in the last decade, such as “Dagmar”, “Berit” and “Ole” which caused significant damage to the infrastructure in Møre og Romsdal. Even though these events are extraordinary, it might also suggest that the trend is more frequent storms in this area. Similarly, Hordaland is also close to doubling the compensation payouts compared to the number of damages. This suggests that the damages over the last decade have been more costly than in the previous years, even though Hordaland overall has seen lower average compensation costs per damage than most counties, as found in RQ1.

For all counties, except Akershus, the inflation-adjusted compensation payouts per 1000 buildings seem to increase more than the number of damages, suggesting that the average cost per damage has increased over the last decade. Akershus, on the other hand, has seen a decrease in the average compensation costs per 1000 buildings, even though the number of damages has increased by 25%. Compared to the development in the building mass, Akershus seems to have had a decrease in the number of property damages and the corresponding compensation payouts. As mentioned, this could be a result of more efficient climate adaptation in Akershus. This appears as a fair assumption as the economy of municipalities in Norway primarily is dependent on the income tax of the inhabitants and block grants from the state of Norway. Both of these sums are dependent on a range of things, but mainly the population in a municipality (Kommunal- og distriktsdepartementet, n.d.). As Akershus has a large number of inhabitants and a small area to maintain, they are likely to have more resources for climate adaptation. As Akershus and Oslo are similar in terms of population, climate, and resources, in addition to having the same climate profile, the climate vulnerability analysis conducted by Oslo is also applicable in Akershus (Norsk Klimaservicesenter, 2022-j). Oslo is currently the county in Norway that has progressed the most in the area of climate adaptation, and they intend to share their experiences in this area through the climate adaptation network “I front”. Akershus is also included in this network (Handberg & Pedersen, 2018, p.4). As Akershus is already included in the analysis conducted by Oslo municipality, they are likely to have progressed at a similar pace, which could explain their overall decrease in storm-related consequences.

Nevertheless, we find it important to mention that inland counties often are more prone to extreme precipitation (Finans Norge, n.d.-a). This, in combination with high wind speeds, may result in more severe property damages. However, these damages are often classified as flood damage, thus not captured in our analysis. Therefore, this could also be an explanation for the lacking increase in storm-related compensation payouts in Akershus.

Based on the analysis above, we will now discuss H2.

5.2.1 Hypothesis 2

H2: *The number of damages and compensation payouts has increased proportionally more than the building stock in the counties.*

As the time interval taken into account is a lot shorter than recommended, the hypothesis has to be assessed with discretion. Nevertheless, it appears that the number of storm-related damages and compensation payouts have increased considerably more than the building mass over the last 25 years, and the increase is especially notable in the coastal counties located in Western Norway. In Akershus, however, the trend seems to be the opposite.

Due to the ambiguous findings, it is uncertain whether the hypothesis can be rejected or substantiated. Therefore, we suggest the development of storm-related damages compared to the increase in building mass as a topic for further research. Having explored the differences in building mass, damages, and compensation payouts, we got curious as to whether the wind speed required to cause damage varies between different counties. As displayed in the wind maps by Kjeller Vindteknikk and NVE, the winds in North and Western Norway are, in general, a lot stronger than the winds in the Eastern and southern parts of Norway (2009). However, Oppland has experienced an unusual increase in damages and compensation over the last decade. Could it result from poor climate adaptation, as inland counties might not be used to strong winds like coastal counties? This brings us to RQ3.

5.3 Research Question 3

As a result of the findings in the exploratory phase of this thesis, we got curious as to whether the probability of wind damage varies between the counties under the same wind strengths. Therefore, RQ3 was formed:

RQ3: *For a given wind speed, what is the probability of property damage in Norway, and does this probability vary between different geographical areas?*

To answer RQ3, four separate models are used, conducting the same analysis on the six selected counties. As mentioned in the methodology chapter, logistic regression, and classification tree, in addition to the ensemble methods boosting, and random forest, are considered the best models to evaluate the problem at hand. In addition, out-of-sample measurements are used to calculate the performance of each model. All models are provided with the four wind measurements presented in Chapter 4, and the models are left to decide which explanatory variable that predicts property damage the best.

Surprisingly, neither of the models favors the highest measured wind gust as a predictor. This might be due to the placement of some weather stations, as some are located on top of mountains or out at sea, far away from densely populated areas. These areas often experience strong wind gusts but have few corresponding property damages. In highly populated areas, property damage is often inevitable in the event of an equally strong wind. In cases where high wind speeds have occurred, and no damage has been registered, the models might struggle to correctly classify an observation, which may cause several misclassifications and lower accuracy. Similarly, none of the mid-wind predictors are proven suitable due to their measurements being relatively low. The average highest measured wind gust, however, is preferred by the majority of the models. Compared to the highest measured wind gust, its values are considerably lower, thus reducing the risk of misclassification. As a result, the maximum wind gusts' mean value for all weather stations in a given county will be used when estimating the probability of wind damage. The results from the analyses are displayed in Table 5.6.

	Møre og Romsdal		Nordland		Hordaland	
	AUC	ACC	AUC	ACC	AUC	ACC
Logistic Regression	0,646	0,782	0,662	0,696	0,645	0,735
Classification Tree	0,619	0,783	0,641	0,686	0,629	0,736
Random Forest	0,644	0,768	0,642	0,672	0,619	0,707
Bagging	0,643	0,747	0,636	0,666	0,610	0,696
Boosting	0,638	0,764	0,662	0,693	0,628	0,715

	Oppland		Akershus		Østfold	
	AUC	ACC	AUC	ACC	AUC	ACC
Logistic Regression	0,576	0,876	0,543	0,809	0,564	0,853
Classification Tree	0,609	0,884	0,500	0,798	0,607	0,843
Random Forest	0,591	0,871	0,592	0,799	0,584	0,847
Bagging	0,593	0,871	0,592	0,750	0,589	0,845
Boosting	0,599	0,872	0,577	0,798	0,580	0,851

Table 5.6: Model comparison - AUC and ACC values

For a given county, model performance is quite similar. However, when comparing performance across all counties, it varies greatly. For example, the inland counties perform significantly better than the coastal counties in terms of accuracy. Regarding the AUC scores, on the other hand, none of the models performs very well. However, an interesting finding is that the coastal counties outperform the inland counties in terms of AUC.

There might be numerous reasons why these differences occur, such as the placement of some weather stations, the number of weather stations in each county, or the area of a county. Due to geographical differences, the placement of each weather station varies considerably. Møre og Romsdal, for example, is characterized by fjords, valleys, and tall mountains. Therefore, many of the weather stations are placed far away from civilization, for example, on a mountain top or out at sea. This causes them to be more exposed to strong winds, as seen in the wind map from Kjeller Vindteknikk and NVE (2009) in Appendix, Figure 13-18. In addition, local winds might not get captured by any of the weather stations. Moreover, some counties have considerably more weather stations than others, and not all stations are equipped to measure wind speed. A map displaying the distribution of the selected weather stations used in the analysis can be found in Appendix Figure 7-12. Furthermore, the area of a county may affect the performance of a model. As the data from the NNPP is aggregated per county, it is logical to assume that the smaller inland counties generate a higher accuracy due to more precise data.

Overall, the best-performing model is highly dependent on the county. Logistic regression is slightly superior to the other models in terms of accuracy, with an average accuracy of 79,2% and a corresponding error rate of 20,8%. Regarding AUC, logistic regression also outperforms the other models in three out of six counties, with an average score of 0,61. Therefore, logistic regression is used to calculate the probability of wind damage for different wind speeds in all six counties, as displayed in Figure 5.5. It is also important to clarify that the model predicts the probability of the occurrence of damage in general, and the number of damages will not be taken into account.

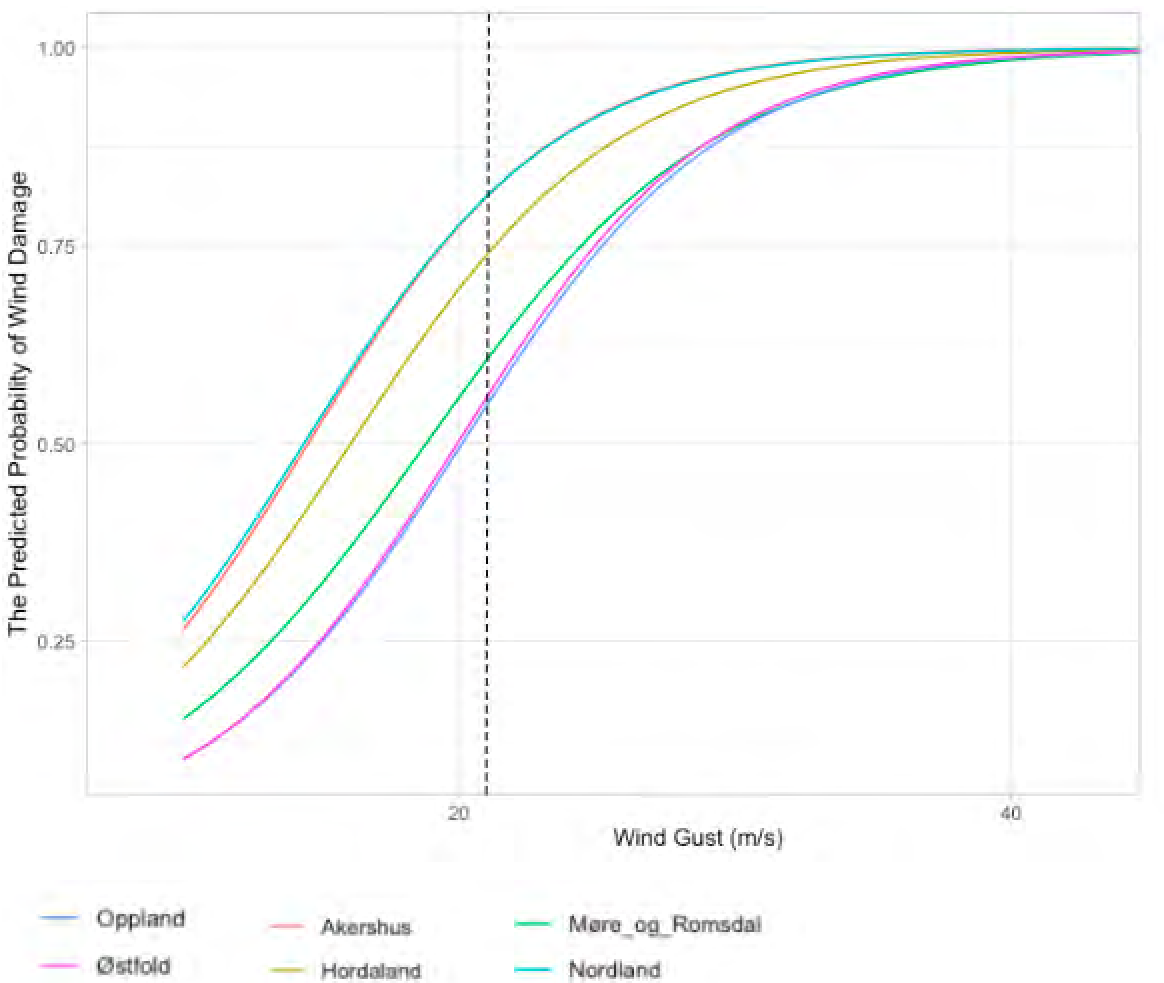

Figure 5.6: Probability distribution for wind damage per county.

Based on Figure 5.5, it is clear that the estimated probability distribution varies notably depending on the county. The dotted line illustrates a wind speed of 20,8 m/s. This equals a strong gale, which is the required minimum strength of a wind gust in order to be eligible for compensation. At this wind speed, Akershus has the highest probability of wind damage at 78,2%. Oppland, on the other hand, has the lowest probability, at 48,5%. Overall, it appears as two out of the three inland counties are in the bottom-tier of damage probabilities, which deviates from H3, stating that the probability of wind damage will be lower in the coastal counties. Furthermore, the coastal counties have a surprisingly high probability of property damage at a wind speed of 20,8m/s. Nordland is ranked second, at 78%, whereas Møre og Romsdal and Hordaland have a 56,4% and 69,1% likelihood, respectively. We found these results a bit surprising, as it was expected that the building structure in the coastal counties would be better adapted to strong winds.

Since our findings in logistic regression are somewhat twofold, the models constructed from classification trees might be a good alternative as well due to their clear visualization and easy interpretation. Figure 5.6 displays a graphical illustration of the classification tree for all six counties.

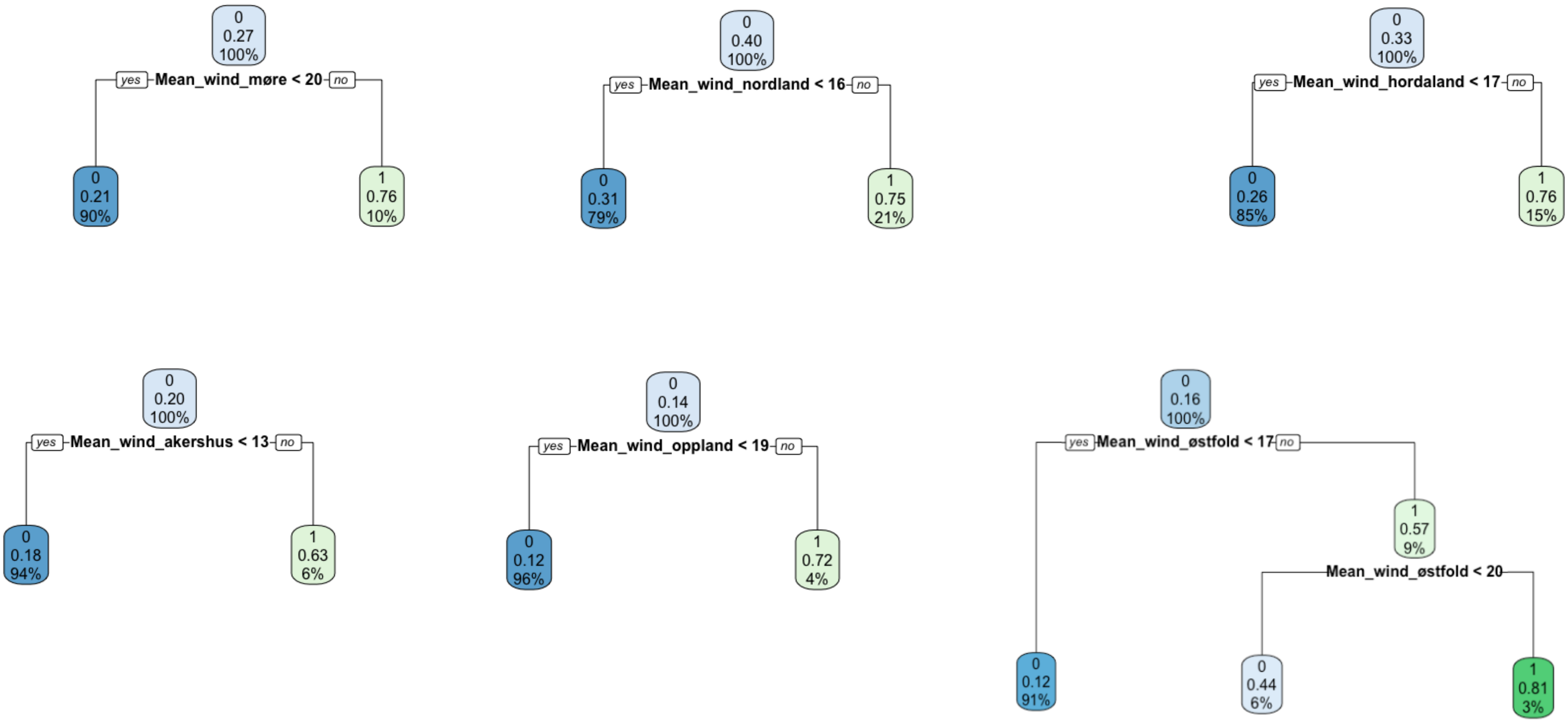

Figure 5.7: Classification trees for all six counties.

Each tree consists of three to five boxes illustrating the node classification, the fraction of observations that are not classified as damage, and the fraction of observations included in the node. As seen in Figure 5.6, the overall probability of wind damage varies substantially. The coastal counties, Møre og Romsdal, Nordland, and Hordaland, have the overall highest shares of wind damage at 27%, 40%, and 33%, respectively. The classification tree of Nordland has the highest share of damage at 40%, as displayed in the root node. In contrast, Oppland has the lowest proportion of damage at only 14%. The remaining inland counties, Akershus and Østfold, have a relatively low share of damages at 20% and 16%. These findings align with our previous research in RQ1, stating that coastal counties usually have more storm-related damages than inland counties. Furthermore, another interesting aspect is the wind speed at which property damage occurs.

Surprisingly, the classification trees predict that most of the damages take place at relatively low wind speeds. As mentioned earlier, a wind speed of 20,8 m/s is required for wind damage to be eligible for compensation. According to the classification trees, however, most damages occur at lower wind speeds. This might be a fault in our model due to the highly aggregated data from the NNPP. As seen in Figure 5.6, 10% of property damages transpire at wind speeds higher than 20 m/s in Møre og Romsdal. In Østfold, however, only 3% of damages occur at wind speeds higher than 20 m/s. For the remaining counties, the wind speed at which property damage takes place varies extensively. However, it appears as the coastal counties have a higher share of damages that occur at higher wind speeds, as seen in the nodes to the right.

The findings in both logistic regression and classification trees could be a result of many factors. As discussed in Chapter 2, the policyholders are not eligible to receive any compensation if the tariff consultant does not find it likely that a wind gust equal to or above 20,8m/s has taken place. However, this is not accounted for in our model, resulting in predicted damages at low wind speeds. The reason for damage classifications at low wind speeds could also be that several observations have been registered in the county where the policyholder is registered, while the damage might actually have taken place in another county. In that case, there would have been other weather stations that captured the harmful wind. Other factors could, for example, be the number of old buildings in an area, the degree of climate adaptation, or the resources available to implement preventive measures. However, this is a complex subject, making it difficult to state anything with certainty. Based on the analyses, we will now discuss H3.

5.3.1 Hypothesis 3

H3: *The probability of wind damage will be lower in coastal counties than in inland counties.*

The modeled results seem somewhat ambiguous. According to the logistic regression, two out of three coastal counties have the highest probability of property damage at a wind speed of 20,8 m/s. The classification trees, on the other hand, seem to suggest that a higher wind speed is required to cause damage in the coastal counties than in the inland counties, as a higher proportion of damage takes place in the right node for these counties. The findings from the logistic regression somewhat contradict H3, with the apparent exception of Akershus. Moreover, from Figure 5.6, it is clear that the wind speed at which property damage is projected to occur varies substantially between the counties. This suggests that the geographical characteristics of a particular county, regardless of being identified as a coastal or an inland county, are of greater importance. However, these factors are difficult to include in our analysis as the data we have used is on a county level and not grid-based as the data used in the report “Klima i Norge 2100”. This will be further addressed in limitations and suggestions for further research.

In sum, there are large uncertainties as to whether the hypothesis can be accepted or rejected. Therefore, we cannot conclude anything with certainty regarding whether the probability of wind damage will be lower in the coastal counties than in the inland counties.

As a final part of our analysis, we will now proceed to address the current organization of the NNPP and how it might be improved to reduce the repercussions of storm-related damages in the future.

5.4 Research Question 4

In this question, we will discuss the weaknesses of the Norwegian Natural Perils Pool in light of the contribution criteria of the EU Taxonomy. Therefore, RQ4 is given as:

RQ4: *What are the most prominent weaknesses of the Norwegian Natural Perils Pool, and how can these be mitigated?*

To identify any weaknesses of the NNPP's insurance scheme, the contribution criteria from the EU Taxonomy will be used as the baseline for discussion. The taxonomy consists of five contribution criteria for non-life insurance, which is the category that both fire insurance and other insurances related to property damage fall under. Each of these five criteria is supplemented by certain sub-criteria.

The first contribution criterion of the EU Taxonomy is that the insurance sector should take leadership in the process of modeling and pricing climate risks. Currently, there are several initiatives to model climate risks in relation to extreme weather events in Norway, such as the nationwide model for risk of rainfall-induced water damage, which is a part of the "Climate futures" research project (Heinrich-Mertsching et al., 2021), and the process of renewing the "Climate in Norway 2100" report. This report will most likely be the first scientific framework to be based on the IPCC sixth assessment report and is projected to be finished in 2024 to 2025 (Miljødirektoratet, n.d.-a). However, as the current pricing scheme of the NNPP is standardized with a risk premium of 0,065 per mille of the insured sum and a set deductible of 8000 NOK, there is, for the time being, no price discrimination to reflect climate risk (Sandberg & Bjelle, 2021, p.14; Norsk Naturskadepool, n.d-b)

Furthermore, sub-criterion 1.1 states that insurers are obliged to not rely on historical trends, integrate forward-looking scenarios and properly reflect climate change risks. To what extent this criterion is being contemplated will likely vary between different insurance companies, but overall, this criterion does not seem fulfilled. Both Cicero and Vestlandsforsikring find that preventive measures are mainly triggered by events that cause damage (Solberg, n.d.). For the time being, few insurance companies offer incentives for climate change mitigation or adaptation before the occurrence of damage. An example of this is Storebrand's implementation of support for climate-friendly adaptation of properties. The company offers 150 000 NOK for climate-friendly upgrades of properties when rebuilding after total damage in their home insurance. This can contribute to making people rebuild their houses more robustly and not by the original standard (Solberg, n.d.). However, it does not serve as a preventive measure as the support is only offered after the damage has occurred.

Sub-criterion 1.2 declares that the insurance sector should publicly disclose how they consider climate risk in their insurance activities. Finland's scheme is an example of how this can be organized. In Finland, several insurance companies provide guidance for climate adaptation in their insurance agreements and reduce compensation payouts if these objectives are not fulfilled (Sandberg et al., 2020, p.58). However, this might be hard to implement in Norway due to a lack of competence in preventive measurements for climate-related perils, especially in small and medium-sized counties (Rusdal & All, 2019, p.33). Due to this, there are no publicly disclosed policies as to how the climate change risks are considered in the insurance activity. An important explanation of lacking maturity in regard to climate adaptation is that the term is relatively new compared to the reduction in greenhouse gas emissions. While reducing emissions has been on the political agenda in Norway since the Brundtland Commission in 1987, climate adaptation of buildings first became a topic in 2008. This could explain the limited coordination and knowledge among the government agencies. The lack of knowledge might also explain why ineffective measures have been prioritized and why not enough resources have been allocated to reduce the risk of natural damage to buildings and infrastructure (Sandberg et al., 2020, p.59).

Sub-criterion 1.3 states that insurers shall provide incentives for risk reduction by setting the conditions for (re-)insurance coverage based on risk and have this function as a price signal of risk. Reduced premiums or deductibles for climate adaptation measures, based on supportive information on existing or possible actions, are examples of how this can be conducted (European Commission, n.d.-a). As mentioned in Chapter 2, there is currently no connection between the risk of natural damage and insurance premium in Norway as the pricing model is highly standardized. This is because the solidarity principle stands strong in Norway. Therefore, it might be challenging to implement this contribution criterion, and it seems hard to increase the incentives for climate adaptation while at the same time maintaining this principle. A risk-based insurance premium or deductibles could provide incentives for preventive measures, but at the same time, the state safety net or EU funds might counteract these incentives (Sandberg et al., 2020, p.56).

Moreover, sub-criteria 1.4 of the EU Taxonomy encourages insurers to inform customers about the benefits of building better after a climate risk event and provide revised conditions for renewal of the insurance coverage (European Commission, n.d.). Germany's compensation scheme is an example of this. Following natural damage, the scheme has arranged for buildings to be rebuilt according to the current recommendations on climate adaptation, often resulting in an increased risk premium (Sandberg et al., 2020, p.58). In 2017, Finance Norway introduced the possibility of rebuilding houses at a different location after flood damage. This facilitates for homeowners to increase the number of climate considerations when constructing their new house. However, to what extent the benefits of building better are expressed to the policyholders will likely vary between the different insurance companies. Again, as the NNPP is standardized, the insurance companies still have to provide the same conditions for the renewal of the insurance coverage.

The second contribution criterion in the EU Taxonomy relates to the design of the insurance package. It suggests that the insurance activity should offer risk-based rewards for preventive actions taken by policyholders. This is the case for some insurance companies in Canada, which offer a lower insurance premium if the property owner can document climate adaptation measures in their private home (Sandberg et al., 2020, p.58). In Norway, several companies intend to use incentives rather than retribution in their work to encourage climate adaptation, as cuts in the insurance payments are described as an intricate process that the insurance companies do not benefit from (Sandberg & Bjelle, 2021, p.39). Moreover, it is highly challenging to carry out socio-economic analyses on the profitability of measures for prevention versus reconstruction after damage. The NIF project, which was a collaboration between NVE, Norwegian Public Roads Administration, and Jernbaneverket, attempted to calculate this but experienced that these analyses were complicated and that both experience figures and damage data were lacking. The lack of methods and experienced figures is the reason why socio-economic analyses are rarely performed for climate adaptation measures (Aunaas m. fl., 2016; as referred in Hauge et al., 2017, p.43).

Nevertheless, the Global Center on Adaptation has found that for every dollar spent on climate adaptation, the net economic benefit will range between two and ten dollars (Global Center on Adaptation, n.d.). This indicates a huge potential to minimize costs by encouraging preventive measures before the damage has occurred.

Contribution criterion three in the EU Taxonomy states that the insurance coverage solutions should be innovative and offer coverage for the climate-related perils where the demand and needs of policyholders require so (European Commission, n.d.-a). This does not seem to be a weakness of the NNPP, as the whole purpose of this scheme is to cover damages due to climate-related perils in the form of natural damages (Norsk Naturskadepool, 1980). However, the scheme does not include risk transfer solutions such as protection against business interruption or other non-physical damage-related loss factors, as mentioned in the taxonomy's third criteria. This is something that would probably have to be included in another insurance package, as there is most likely a limited demand for such coverage.

The fourth contribution criterion of the taxonomy regard data sharing. The insurance companies possess valuable data on natural damage, and by providing the municipalities with access to this data, they can improve their decision-making in the work of climate adaptation. Especially in the small municipalities, this could be very advantageous as they often lack the resources to perform comprehensive analyses on climate risk (Solberg, n.d.). In 2013-2014, a pilot project was conducted in ten separate Norwegian municipalities. The project explored different methods of making data from the insurance sector available down to the specific street address to strengthen the knowledge foundation and help the municipalities prevent climate-induced natural-damage events. In light of the project, it was concluded that the insurance data would be beneficial for the municipalities, but a certain level of detail is necessary to ensure its usefulness. It remains to be figured out how to share insurance data while, at the same time, maintaining sufficient anonymity for privacy reasons. This is currently being worked on in a collaboration between DSB, Finance Norway, and the Norwegian Mapping Authority (Rusdal et al., 2019, p.13-14). When this is in place, the NNPP will fulfill the data-sharing requirements for analytical research to enhance the adaptation to climate change, as stated in contribution criteria 4.1 in the EU Taxonomy. However, the intention is there, suggesting that they already fulfill sub-criteria 4.2 (European Commission, n.d.-a).

The last contribution criterion for the insurance sector is to provide a high level of service in post-disaster situations. This involves handling the claims in a timely manner, with respect to customers, and in accordance with applicable laws (European Commission, n.d.-a). According to our literature review, there does not seem to be any apparent problems with the current system of handling claims in the different insurance companies. Claims settlement between the NNPP and the respective insurer in the pool takes place (mainly) on a quarterly basis, based on information received on the companies' payments (Norsk Naturskadepool, n.d.-a), suggesting that the procedures for compensation payouts are quite standardized and in line with the requirements of the Taxonomy.

In sum, the most prominent weakness of the NNPP seems to be the lack of climate adaptation incentives due to a very standardized scheme. Hudson et al. (2019) recommend a private-public scheme with risk-based insurance premiums (Sandberg et al., 2020, p.14). Norway has a private-public scheme, but the insurance premiums are currently not risk-based. Furthermore, there should be developed indicators for climate adaptation. Indicators on the degree and quality of climate adaptation will be of massive value in mapping the work's status and further development of incentive schemes. These indicators can be used to rank policyholders and adapt their insurance premiums (Sandberg et al., 2020, p.60). Previous studies on climate change adaptation in the insurance sector have concluded that efficient insurance premiums are important to make people choose to build in low-risk areas (Botzen, 2013, p.30). Therefore, the implementation of such measures could be highly beneficial to mitigate the risks of the NNPP. However, as the insurance and natural damage compensation schemes are currently under revision, several of these aspects might be included in the future (Sandberg et al., 2020, p.59).

The most important adaptation the Norwegian government can make is to reduce greenhouse gas emissions (Regjeringen, n.d., p.2). Considering the record-high compensation payouts over the last ten years, it is understandable that the insurance sector is initiating change. As the NNPP sets aside the insurance premiums to cover future natural damages (Sandberg & Bjelle, 2021, p.14), a long-term period of compensation rates that exceed the insurance premium will cause economic distress. Continuous deficits resulting from an increased number of damages will decrease their resources to implement innovative changes to the scheme. Therefore, it might be beneficial to earmark a certain amount of money for preventive measures. The French compensation scheme is an example of this, where parts of the insurance premiums are earmarked for prevention (Sandberg et al., 2020, p.58). In France, the solution is quite popular (Sandberg et al., p.56), indicating that it could work well in Norway as well since the schemes are quite similar

In light of this discussion, we are now able to conclude on H4:

5.4.1 Hypothesis 4

H4: *The current structure of the Norwegian Natural Perils Pool is not in line with the contribution criteria of the EU Taxonomy.*

In short, the assessment conducted of the current organization of the NNPP compared to the contribution criteria of the EU Taxonomy shows that they do not align. A summary of our assessment is presented in Table 5.7.

EU Taxonomy substantial contribution criteria for non-life insurance	Sub-criteria	Norwegian Natural Perils Pool
1. Leadership in modeling and pricing of climate risks	1.1 State-of-the-art modeling techniques	In progress
	1.2 Public disclosure of climate risk consideration in the insurance activity	Not in place
	1.3 Provide incentives for risk reduction by (pre-)conditions for insurance coverage and by using the price as a signal of risk	Not in place
	1.4 Sufficient information after a climate risk event on reqirements to renew or maintain the insurance coverage and particularly the benefits of building better	Unclear
2. Product design	2.1 Risk-based rewards for preventive actions	Not in place
	2.2 Sufficient information on relevance of preventive measures	Unclear
3. Innovative insurance coverage solutions	3.1 Offer coverage for climate-related perils	Fulfilled
	3.2 Products that include risk transfer solutions	Not in place
4. Data sharing	4.1 Make data available to public authorities for research	In progress
	4.2 Intention to share data	Fulfilled
5. High level of service in post-disaster situations	5.1 Claims are processed in a timely manner with respect to customers, and in line with applicable laws	Unclear

Table 5.7: The contribution criteria and sub-criteria for non-life insurance in the EU Taxonomy and the current state of the Norwegian Natural Perils Pool.

The most prominent structural shortfalls relate to missing climate risk considerations and pricing. This is not surprising as the analysis reveals major knowledge gaps, making it hard to conduct sufficient climate risk analyses. Furthermore, there are some sub-criteria that are subject to uncertainty. For example, whether the insurance companies provide sufficient information on the benefits of building better after a disaster and the relevance of different preventive measures will likely vary between the different insurance companies in the pool. The same goes for whether the claims are being processed promptly and according to applicable laws. The process of administering claims is expected to vary between different insurance companies and for each particular case depending on the degree of difficulty in deciding whether the policyholder is eligible for compensation, and, in that case, what compensation sum they are eligible for.

However, several initiatives aim to cover the knowledge gaps on climate adaptation in Norway, suggesting that these shortfalls might be easier to consider in the nearest future. The insurance companies have also expressed their intention to share data with relevant authorities. A safe solution for data sharing while maintaining the policyholders' privacy is currently in progress, hence fulfilling sub-criteria 4.2. The other criteria that the NNPP fulfills are 3.2, as not all countries have a separate scheme for dealing with natural disasters.

6 Conclusion

The goal of this thesis has been to provide valuable insights into the development of storm-related damages in Norway, what wind speeds that cause property damage and map out the current practice of the NNPP compared to the contribution criteria of the EU Taxonomy. The thesis is an exploratory study meant to create a foundation for further research in areas where the research is found quite lacking and otherwise uncertain. Our findings have revealed some interesting insights into wind patterns and how they affect the insurance companies in Norway in terms of property damages. Furthermore, we have identified some weaknesses with the current practice of the NNPP in relation to the criteria of the EU Taxonomy. The following chapter summarizes the newly gained insights on the research questions posed in Section 1.1 and the hypotheses presented in Section 2.7.

RQ1: Which counties experience the most repercussions related to storm damages?

By exploring data from the NNPP, in the period 1980 to 2021, we found significantly more storm-related damages in the Western and Northern coastal counties compared to the inland counties in Norway. In line with previous studies, we confirm that Nordland, Møre og Romsdal, and Hordaland are substantially more prone to property damages than the rest of the country. Moreover, the inflation-adjusted compensation payouts and the number of storm-related damages appear to be quite correlated.

For the remaining part of the analysis, it was decided to proceed with the top three inland and coastal counties with the highest number of storm-related damages. The six counties chosen for further examination were Møre og Romsdal, Nordland, Hordaland, Akershus, Oppland and Østfold.

The next step involved evaluating the development of the average compensation payout per storm-related damage. The analysis showed no apparent trend, but the average compensation payouts were highly volatile. However, an interesting finding was that all of the highest peaks in average compensation payouts belonged to the inland counties, despite no registered storm events.

Finally, the selected counties were analyzed on a seasonal basis to examine whether the observed annual pattern of compensation payouts and storm-related damages would deviate in particular seasons. We examined all years from 1980 to 2021 in 6-year intervals, confirming that the selected coastal counties have the highest number of storm-related damages and compensation payouts during the winter for all time intervals. In the summertime, however, the number of damages and compensation payouts were fairly similar in all counties, suggesting that the findings are highly dependent on the season. In sum, our findings seem to confirm the results presented in previous research.

RQ2: In proportion to the building mass, has there been an increase or decrease in storm-related damages?

To answer this question, statistics on building mass were retrieved from SSB in the period 1997 to 2021. Then, the total percentage increase in building mass, number of damages per 1000 buildings, and compensation payouts per 1000 buildings were calculated for all available years. The 25-year period from 1997 to 2021 was split in two, leaving us with intervals of 13 and 12 years, respectively. The average number of storm-related damages per 1000 buildings in the first interval was compared to the second interval, and the percentage change was compared to the percentage change in the increase in building mass. Furthermore, the same calculation was conducted on the average annual compensation costs per 1000 buildings for the same period.

The percentage increase in building mass varied from ~24% in Møre og Romsdal to ~48% in Hordaland. The percentage increase in damages per 1000 buildings, on the other hand, varied from 25% to 425% between the time intervals, suggesting that for most of the counties, the number of storm-related damages has increased more than the building mass. This became apparent in the difference between the average annual compensation payouts in the two time periods as well. These varied from -33% to ~990%, confirming that the building stock seems to have developed quite differently than wind patterns.

Based on our findings, it does not seem like the development in the building mass has been proportional to the development in storm-related damages. This is especially not the case in Hordaland, Møre og Romsdal, and Oppland, as these counties have seen a >200% increase in damages and compensation payouts per 1000 buildings. Moreover, Akershus is the only county with decreased damages and compensation payouts compared to the increase in building stock. For the remaining two counties, the increased number of damages and compensation payouts are slightly higher than the increase in building stock.

RQ3: For a given wind speed, what is the probability of property damage in Norway, and does this probability vary between different geographical areas?

To address RQ3, four separate models are tested. These are logistic regression and classification trees, as well as the ensemble methods boosting, and random forest. In light of the model comparison, we decided to use logistic regression and classification trees to estimate the probability of wind damage.

Based on the findings from logistic regression, it is clear that the probability of wind damage varies significantly depending on the county. As mentioned, when the wind speed reaches 20,8 m/s, Akershus has the highest probability of property damage of all counties, at 78,2%. The coastal counties, Nordland, Hordaland, and Møre og Romsdal, are close behind with a damage probability of 78%, 69,1%, and 56,4%, respectively. Moreover, two out of three inland counties are in the bottom tier of damage probabilities at 20,8 m/s. Oppland has the lowest probability of wind damage at only 48,5%, whereas Østfold has the second-lowest probability at 52,7%. Nevertheless, it seems like that the probability of wind damage is higher in the coastal counties than in the inland counties, with the exception of Akershus.

The trees, on the other hand, might suggest that the probability of damage is higher in the inland counties than in the coastal counties at high wind speeds. Most of the damages take place at relatively low speeds, which is quite surprising. Merely 10% of Møre og Romsdals' property damage materializes at wind speeds higher than 20 m/s. In Østfold, on the other hand, 3% of its property damage occurs at a similar wind speed. For the remaining counties, there is no clear pattern as to when property damage takes place. However, the model confirms the findings from RQ1, that the coastal counties have the overall highest proportion of wind damage, and a larger share of these damages occur at higher wind speeds compared to the inland counties. This somewhat contradicts our findings in logistic regression.

To conclude, the probability of wind damage for a given wind speed seems to depend on a county's geographical characteristics. However, as our model results are ambiguous, we cannot draw any conclusions as to which county have the highest probability of property damage.

RQ4: What are the most prominent weaknesses of the Norwegian Natural Perils Pool, and how can these weaknesses be mitigated?

From the assessment of the NNPP, in relation to the EU Taxonomy, the most prominent weakness of the NNPP appears to be the missing incorporation of climate risk in the insurance policy. This problem mainly stems from the challenges associated with developing state-of-the-art climate models. Further development of climate risk models is likely to be a helpful tool for the insurance companies in the process of incorporating climate risk to a larger extent in their insurance activities.

Several contribution criteria in the EU Taxonomy address the need for risk-based pricing, risk-based advice to policyholders, and risk-based insurance policies. A long time horizon combined with costly and relatively rare events makes it hard to calculate the risk by not performing climate adaptation measures. Such large uncertainties regarding risks and consequences can be inhibitory to a proactive attitude. This, in combination with a highly standardized compensation scheme, limits the NNPP's ability to incorporate climate risk in its activities. Seen in context, climate adaptation appears as an immature area, supported by ongoing revisions of the insurance and natural damage compensation schemes.

Furthermore, a lack of knowledge and data on probability and costs is a barrier to identifying relevant preventive measures and what events these measures should be pointed at. Data can contribute to better decisions and, to a larger extent, make it possible to quantify the effect of climate adaptation measures, for example, compared to recovery or no action. In the future, when the insurance data is in place, this might be easier to model. It is, however, hard to calculate the effect because climate adaptation is currently being done and has been performed for hundreds of years, even though it was not addressed politically in Norway until 2008. When it comes to insured infrastructure, it is hard to tell what is insured losses and what is wear and tear.

Research has suggested that it could be a good idea to increase the costs of insurance in line with the identified climate risk to increase the incentives for climate adaptation. As the NNPP does not have any practice of insurance premium differentiation based on risk, this does appear to be the biggest weakness of the pool as it does not incentivize climate adaptation or climate risk mitigation. It only serves as a compensation mechanism for when damage has first occurred. By increasing the costs for insurance in areas of high risk regarding extreme weather events and decreasing the costs for projects with a solid climate perspective, the pool's seemingly biggest weakness will likely be mitigated. Nevertheless, the EU Taxonomy might help push the insurance industry in a direction that has already been recommended in the literature for years, such as higher pricing of climate risks, benefits for the policyholders that perform climate adaptation measures, and more data sharing.

6.1 Limitations and Further Research

This section highlights the limitations of the master thesis and will hopefully provide interesting topics for further research.

One limiting factor is the data used for modeling. The data from NNPP is aggregated per county, whereas the meteorological data provide wind measurements from several locations in each municipality. Due to the large geographical differences, the modeling, discussion, and results of RQ3 are based on a single wind variable per day per county, which might not be very realistic. If the data from the NNPP were aggregated per municipality, not only would we be able to pinpoint a more precise location for each wind damage, but the measurements used as predictors would be more accurate. Nevertheless, the findings in this paper may still be used as an indicator for when property damage, as a result of high wind speeds, might occur.

The model calculations could also have been conducted by using down-scaled global observation-based data, such as the NORA-10 dataset as used by Hanssen-Bauer et al. Their model deviated by 1-2m/s from the observed wind, suggesting that these measurements could result in more precise predictions.

Other limiting factors are the weather stations themselves and their placement. Many weather stations have experienced considerable downtime, resulting in lost wind measurements. Some of the selected counties have a limited number of weather stations, making each station important in studies such as this one. Moreover, many weather stations are often located far from densely populated areas, such as mountain tops or out at sea. These areas often experience a different wind strength than a standard neighborhood, which might result in some measurements being misleading when modeling.

6.2 Final Remarks

In concluding this thesis, we summarize that property damages, compensation payouts, and the likelihood of wind damage on buildings vary significantly depending on the geographical placement of a county, as well as the season. Historically, there is no apparent trend in wind development, making it even more challenging to make predictions. Furthermore, the area of climate adaptation appears to be immature, hence making it difficult for insurance companies to incorporate climate risk into their insurance policies.

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8 Appendix

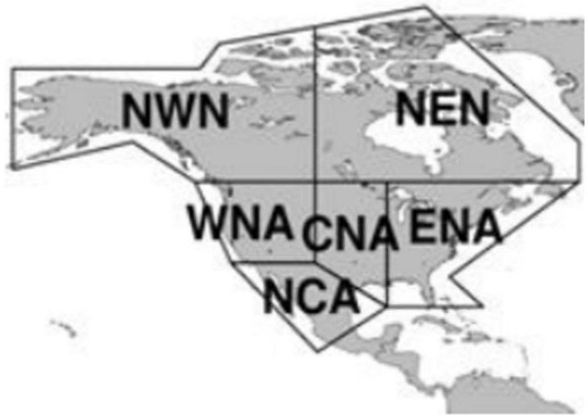

Figure 1: Map over the regions of North America

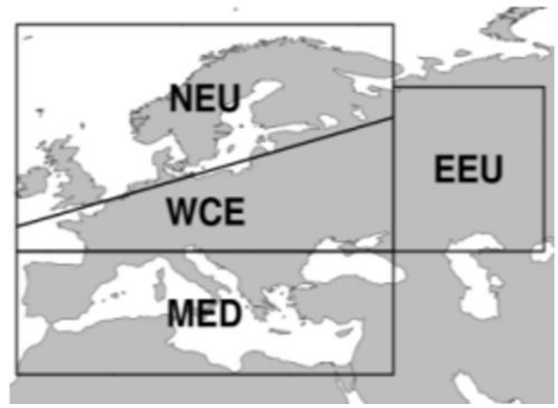

Figure 2: Map over the regions of Europe

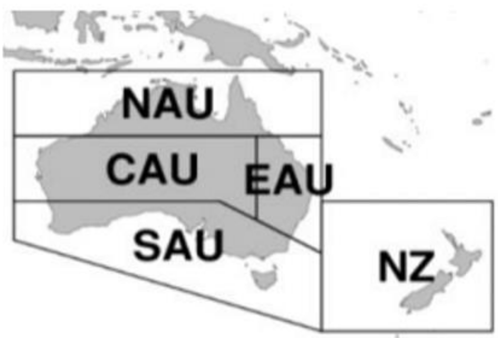

Figure 3: Map over the regions of Australasia

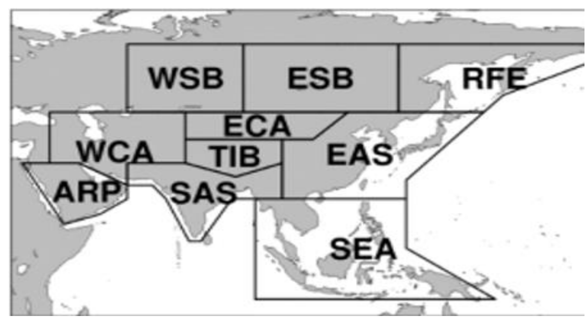

Figure 4: Map over the regions of Asia

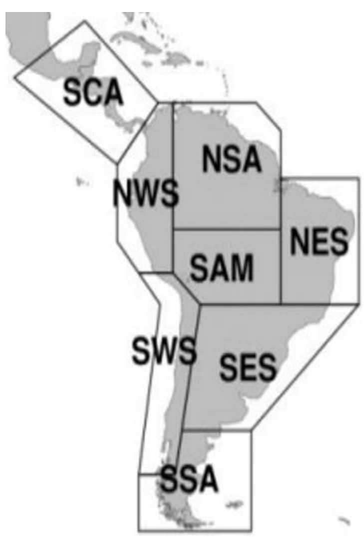

Figure 5: Map over the regions of Central and South America

Figure 6: Map over the regions of Africa

	Østfold	Akershus	Oppland	Hordaland
CAGR	0,98 %	1,39 %	1,08 %	1,64 %

Table 1: CAGR used in 2020 and 2021 in Table 5.2.

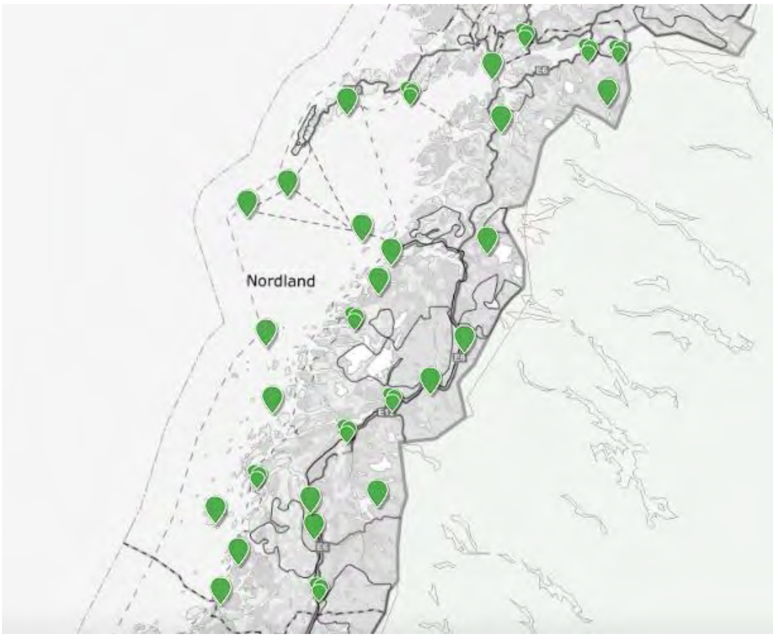

Figure. 7: Map of weather stations in Nordland (Norsk Klimaservicesenter, n.d.)

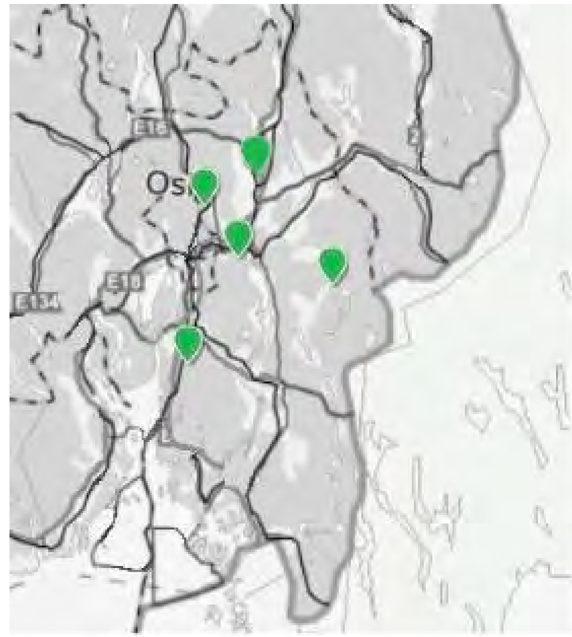

Figure. 8: Map of weather stations in Akershus (Norsk Klimaservicesenter, n.d.)

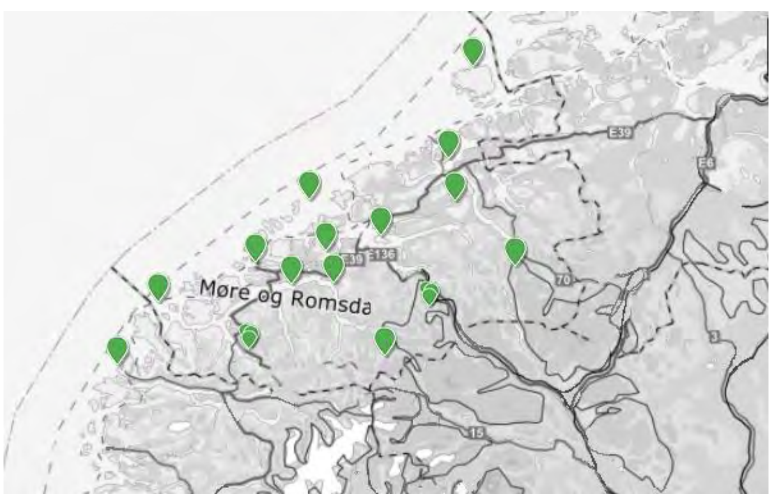

Figure 9: Map of weather stations in Møre og Romsdal (Norsk Klimaservicesenter, n.d.)

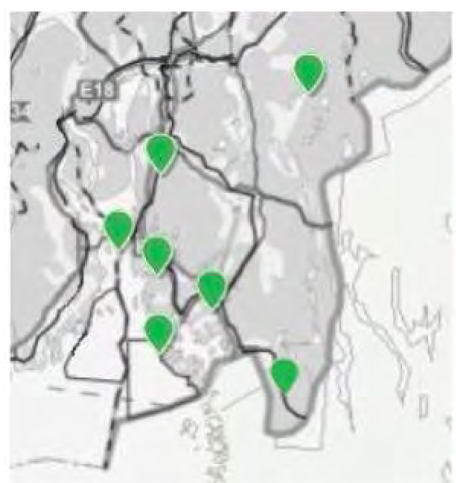

Figure.10: Map of weather stations in Østfold (Norsk Klimaservicesenter, n.d.)

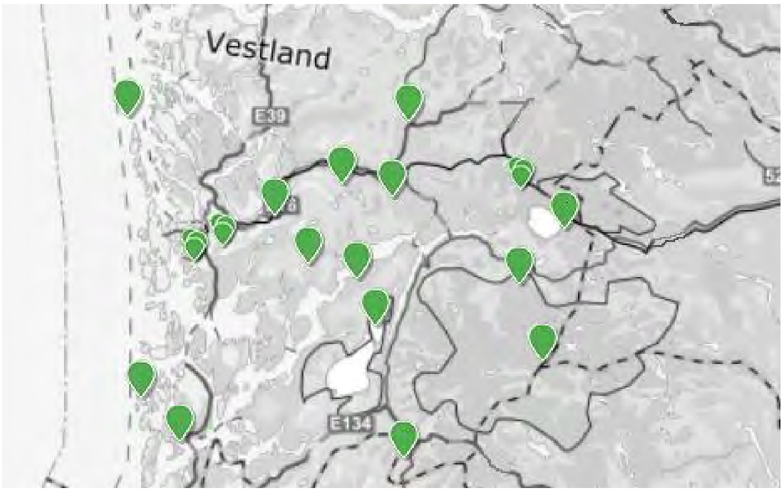

Figure.11: Map of weather stations in Hordaland (Norsk Klimaservicesenter, n.d.)

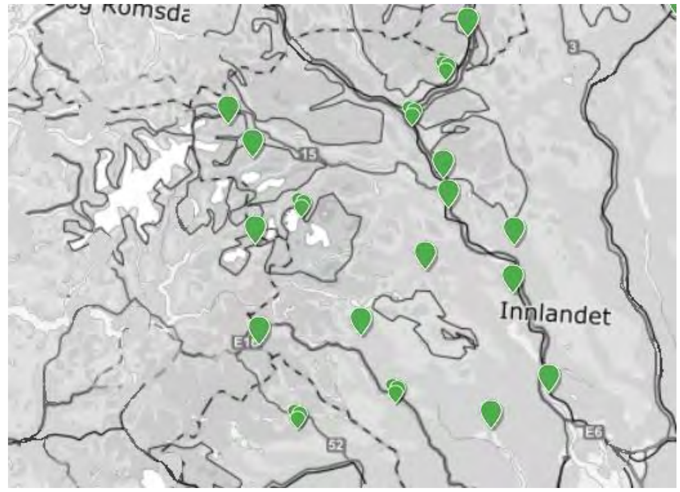

Figure.12: Map of weather stations in Oppland (Norsk Klimaservicesenter, n.d.)

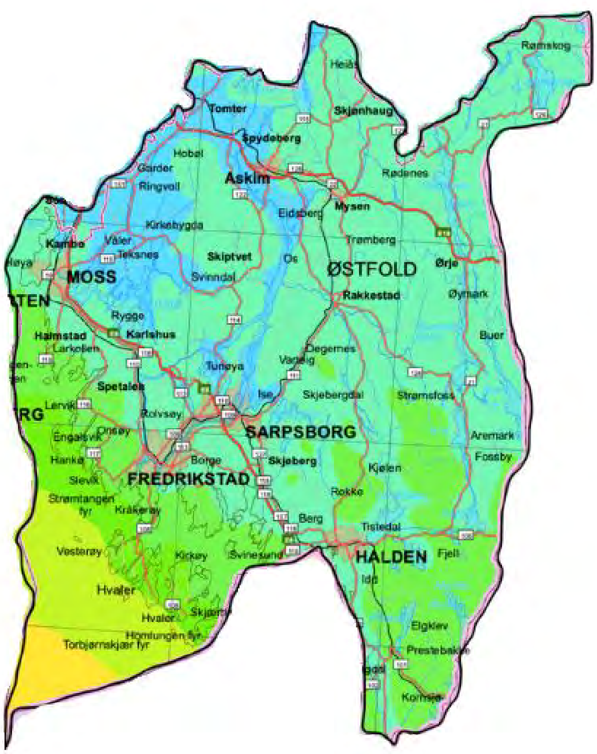

Figure 13: Weather map Østfold (Kjeller Vindteknikk & NVE, 2009)

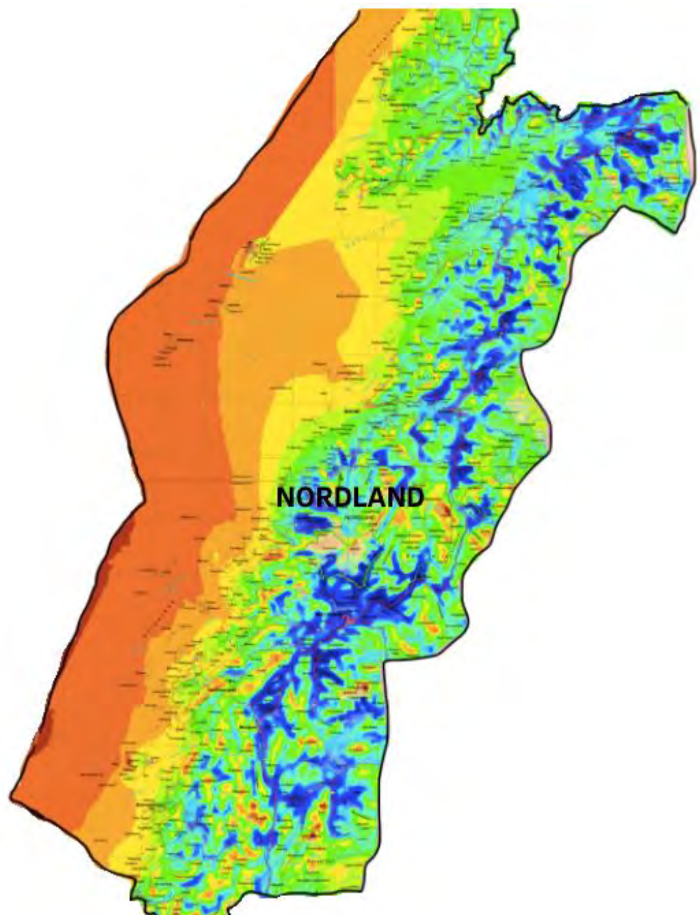

Figure 14: Weather map Nordland (Kjeller Vindteknikk & NVE, 2009)

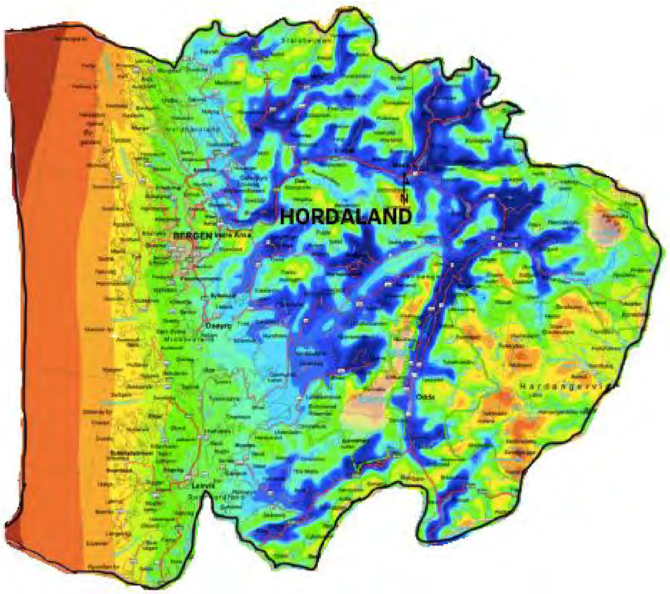

Figure 15: Weather map Hordaland.
(Kjeller Vindteknikk & NVE, 2009)

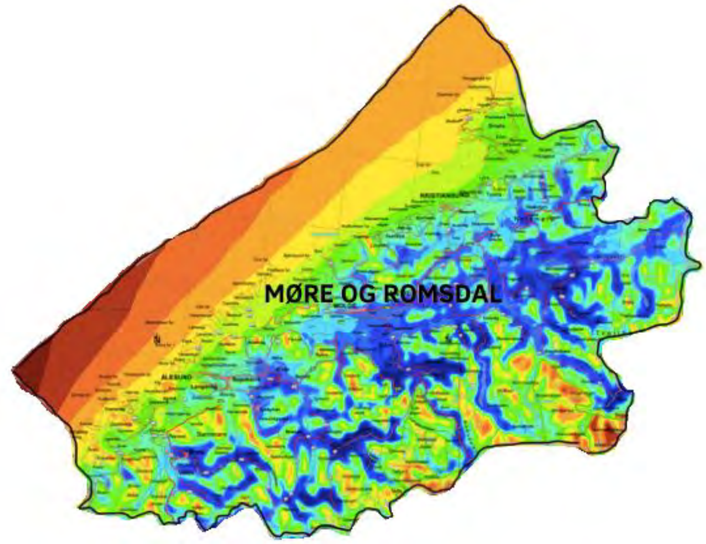

Figure 16: Weather map Møre og Romsdal.
(Kjeller Vindteknikk & NVE, 2009)

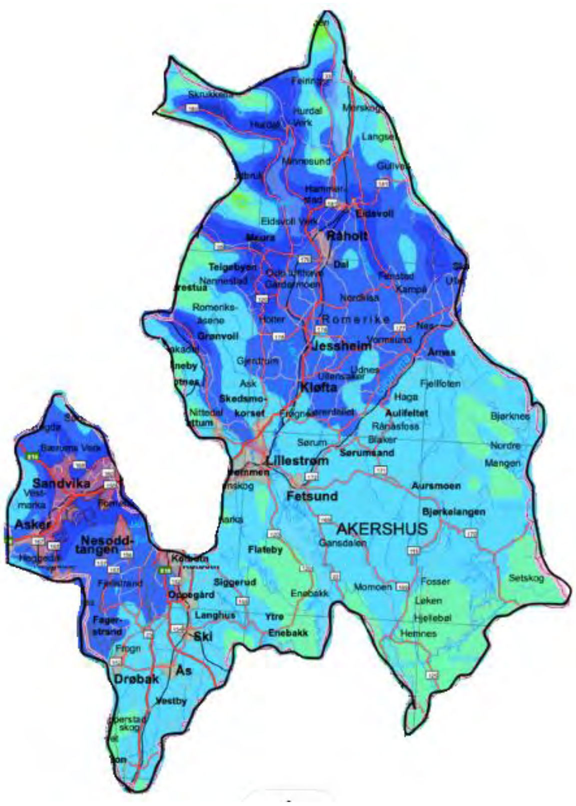

Figure 17: Weather map Akershus
(Kjeller Vindteknikk & NVE, 2009)

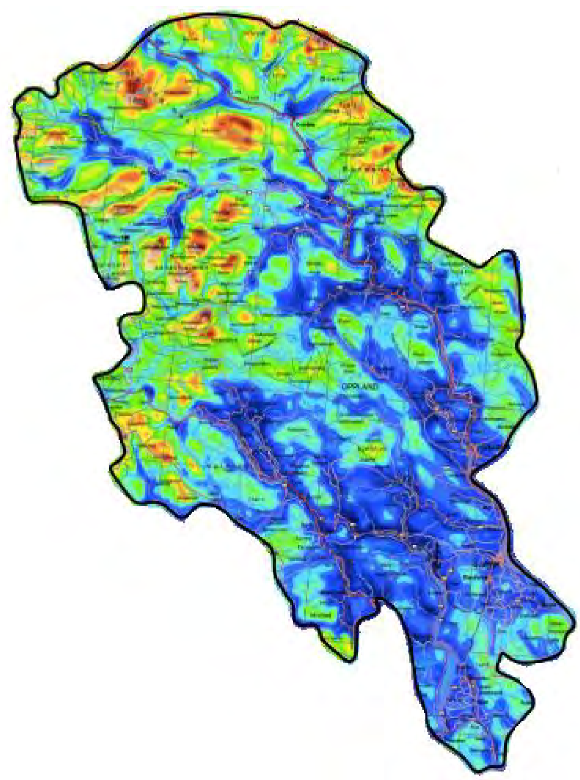

Figure 18: Weather map Oppland
(Kjeller Vindteknikk & NVE, 2009)

Årsmiddelvind i 80m [m/s]

3.5 - 4.0	7.5 - 8.0
4.0 - 4.5	8.0 - 8.5
4.5 - 5.0	8.5- 9.0
5.0 - 5.5	9.0 - 9.5
5.5 - 6.0	9.5 - 10.0
6.0 - 6.5	10.0 - 10.5
6.5 - 7.0	10.5 - 11.0
7.0 - 7.5	11.0 - 11.5

KJELLER VINDTEKNIKK

NVE