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MSc in Climate Change

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Climate Change sensitivity and adaptation of cross-country skiing in Northern Europe

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Title:	Climate Chance sensitivity and adaptation of cross-country skiing in Northern Europe
Description:	A survey-based study investigating how climate change has affected and will affect cross-country skiing among ski areas in Northern Europe.
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Abstract

In Northern Europe cross-country skiing is part of the cultural heritage and an important sport and leisure activity. Climate change has already and will impact cross-country skiing in the future. There climate projection indicates an increase in temperature and a loss in the number of days with snow cover in almost the entire area. The role of ski areas and their adaptation action will be of increasingly importance in the future to provide cross-country skiing opportunities. This survey-based study investigates ski areas and their responses to climate change. By examine their exposure, sensitivity and adaptive capacity their vulnerability to the effects of climate change could be evaluated. The finding presents the large array of adaptation measures implemented and the effectiveness of them to lower the vulnerability of the ski area to climate change. However the difference among the ski areas were large and especially smaller ski areas, and to some extent public and southern ski areas are indicated to be more sensitive and having lower adaptive capacity. The expansion of track fees can increase the adaptive capacity for ski areas but the cultural aversion towards those fees may limit its future adaptive success.

Abbreviations

ASL Above sea level
GHG Greenhouse gases
IOC International Olympic Committee
NH Northern Hemisphere
NOK Norwegian kroner
RCP Representive concentration pathway
SCC Social cost of carbon
SCD Snow cover duration
SCE Snow cover Extent
SD Snow depth
SEK Swedish kronor
SWE Snow water equivalent

Introduction

Large parts of the world population are living in areas where seasonal snow exists. In Europe, about half of the 800 million inhabitants live in areas that on average have snow cover in January (Füssel, Jol, and others 2012:73). Living in areas with snow cover allows for winter sport and recreation. The winter sport industry is huge in Europe, generating 50 billion euro annually (Füssel, Jol, and others 2012:212), with about 170 million skiing visits yearly (Scott and McBoyle 2006). In northern Europe, cross-country skiing is part of culture and everyday life, in some of the countries as many as 40% of the population are skiing annually (Pouta, Neuvonen, and Sievänen 2009; Sælen and Ericson 2013). Ongoing climate change is predicted to increase the annual mean temperature with amplification during the winter months resulting in a decrease in the snowpack depth and duration at most locations (Stocker 2014). This will affect winter outdoor activities and skiing particularly (Füssel, Jol, and others 2012:73). Most studies on climate change and skiing have been focused on downhill skiing (Pouta, Neuvonen, and Sievänen 2009) and are projecting a large decrease in the number of skiers in the future (Fukushima et al. 2002; Scott and McBoyle 2006).

Cross-country skiing is stated to be one of the most sensitive activities to climate change (Loomis and Crespi 1999) and are also foreseen to have a large decrease in the number of skiers, and skiing days per skier in the future as a result of climate change (Pouta, Neuvonen, and Sievänen 2009). Further on, climate change is expected to bring negative social effects, reducing wellbeing and the depletion of cross-country skiing tradition, as well as financial impacts in tourism regions (Landauer, Sievänen, and Neuvonen 2015). Climate change will negatively affect both the supply side of cross-country skiing (the ski areas) and the demand side of cross-country skiing (the skiers) (Pouta, Neuvonen, and Sievänen 2009). The vulnerability is spatial different and skiers and ski areas in locations with mild winters are the most vulnerable (Landauer, Sievänen, and Neuvonen 2015).

Even though cross-country skiing can be performed anywhere there is sufficient of snow, it is mostly performed on groomed ski tracks at specific ski areas (Pouta, Neuvonen, and Sievänen 2009). There are a variety of technical and business adaptations techniques for the ski areas and resorts providing ski tracks, such as snow production or diversification of activities and income in order to adapt to thus climatic effects (Landauer, Haider, and Pröbstl-Haider 2014). However, climatic, financial and ecological constrains to such adaptations limits the adaptive capacity (Scott and McBoyle 2006). The few existing studies on climate change and cross-country skiing focus on the vulnerability and adaptive capacity of skiers (Pouta, Neuvonen, and Sievänen 2009; Landauer, Sievänen, and Neuvonen 2015; Landauer, Haider, and Pröbstl-Haider 2014; Landauer, Sievänen, and Neuvonen 2009) and not on the supply side, the ski areas. This study will investigate how climate change has affected and will affect cross-country skiing suppliers in the Northern European region in the past, near (1-10 year) and far future (10-30 years) and beyond. This will be done by examine their exposure, sensitivity and adaptive capacity to climate change, indicating their vulnerability to climate change. Further on, this study will look into the adaptation strategies for maintaining cross-country skiing to a changing climate on the supply side, investigate the cost and efficiency of those strategies. Additionally, the awareness of the carbon footprint from those activities, and the mitigating efforts among the suppliers of cross-country skiing will be examined.

Background

Importance of winter sport in general

The winter sport industry in Europe attracts millions of tourists every year and generating 50 B euro annually (Füssel, Jol, and others 2012:212). 54% out of the ski industry's 330 million annual global skier visits are made in Western Europe and the direct revenue is estimated to US$3 billion (Scott and McBoyle 2006). Winter sports and skiing are among the most popular sports to engage in Europe and millions follow the competitions in the various skiing disciplines. The media value of all the skiing and snowboarding sports under the international ski federation (FIS) were as of 2016 valued to 1.6 billion euro (FIS 2016a).

Few studies have investigated the numbers of cross-country visitors or the revenue associated with those visits. Partly because it is a much smaller part of the total winter tourism compared to alpine skiing. Further on, track passes are not as common in cross-country skiing as they are in alpine skiing, making it harder to count the number of visitors, and its associated revenue (Landauer, Haider, and Pröbstl-Haider 2014). However, cross-country skiing plays an more important part in the everyday life and tourism in Northern Europe compared to the rest of Europe (Pouta, Neuvonen, and Sievänen 2009).

Importance of cross-country skiing

The history of cross-country skiing dates back thousands of years and has been documented by numerous archeological findings and petroglyphs in Scandinavia and Russia (Hottenrott, Urban, and Neumann 1996). Cross-country skiing was first used as an transportation method and later also become a popular competitive sport, where the first documented competition were held in Tromsö, Norway in 1848 (Bryhn and Tvedt 1990). The sport evolved and was included in the 1924 winter Olympics in Chamonix where the formation of the International Ski Federation (FIS) also took place (Rusko 2003). In 1960 in Squaw Valley, USA groomed ski tracks were first introduced made cross-country skiing more accessible and popular among recreational skiers (Hottenrott, Urban, and Neumann 1996).

Cross-country skiing is practiced in regions with snow-covered landscape most commonly in Europe, Russia, Canada and the USA (Bryhn and Tvedt 1990). It is estimated that more than 16 million people worldwide are participating regularly in cross-country skiing, and it is particularly popular in the Nordic countries (Smith, Matheson, and Meeuwisse 1996), where it is part of the cultural heritage, included in the Norse mythology (Gudar & Gudinnor I Nordisk Mytologi 2014) and everyday lifestyle (Sælen and Ericson 2013; Pouta, Neuvonen, and Sievänen 2009; Landauer, Sievänen, and Neuvonen 2009). In northern Europe the recreational use of nature is a central or the most central aspect of cultural heritage and cross-country skiing is one of the most popular ways of engage in outdoor recreation (Sælen and Ericson 2013; Landauer, Sievänen, and Neuvonen 2009). Finnish people learn on average to ski by age five and 94% of the finish adult population have the skills to cross-country ski (Landauer, Sievänen, and Neuvonen 2009) and 38 % of the population participate annually in cross country skiing (Pouta, Neuvonen, and Sievänen 2009). As many as 10% of all outdoor activity tourist trips has skiing as its main purpose (Landauer, Sievänen, and Neuvonen 2009). In Norway as many as 40 % participate annually in cross country skiing and in Norway's capital and largest city Oslo 25% of the residents go cross-country skiing weekly (Sælen and Ericson 2013). In Sweden 46% of the population state they are interested of cross-country skiing (Scandinavian Traveler 2014). The interest for the famous race Vasaloppet is enormous and the 16 000 starting spots for the main races are sold out in under two minutes (Vasaloppet n.d.). Cross-country skiing has a high status in Sweden, three out of ten CEOs are cross-country skiing regularly (Centric 2014). Participating in Vasaloppet, Birkebinerrennet or other races is seen as prestigious and a merit stated in CVs in both Sweden and Norway (Centric 2014; Sælen and Ericson 2013). Cross-country skiing is also an excellent way of exercise, enhancing both the physical and mental health (Landauer, Sievänen, and Neuvonen 2009), and is proven to have large health benefits (Pouta, Neuvonen, and Sievänen 2009). A study of the participants of the ski race Vasaloppet showed that they, on average, live seven years longer and have a better health than the average Swede (Fredriksson 2012). A study by Uppsala university including 200 000 cross-country skiers concluded that they had 30% less risk of having cancer types that are affected by endurance activities, such as colon cancer or cancer in the kidneys or ovaries. For all other types of cancer the cross-country skiers had a 6% reduced risk, except for skin cancer that they, because of being more exposed for sun, had a 40% increased risk compared to the rest of the population (DN 2015).

The many health benefits and the large will to engage in outdoor recreation, also in the wintertime, make many northern Europeans to choose cross-country skiing as the purpose for tourist trips (Landauer, Sievänen, and Neuvonen 2009). Winter tourism, especially alpine skiing and cross-country skiing, is an important economic sector in many regions in Northern and Central Europe (Landauer, Pröbstl, and Haider 2012; Pütz et al. 2011; Elsasser and Messerli 2001; Landauer, Sievänen, and Neuvonen 2009). The large races Birkebeinerrennet, Vasaloppet, Tartu marathon and Finlandialoppet included in this study generate large gains in tourism and money that participants and their companions spend in the area of the races. Birkebinerrennet state that the number of visitors is much higher than the number of participants; they have around 60,000 participants to their events but estimates that they have 300,000 visitors during the event, including non-racing relatives, friends and spectators (Database in Appendix). Vasaloppet have investigated the gain from tourism for the region as a result of the race. During the winter week of ski races 24M € are spent by the tourists in the area, the same number is 6.6M € for the summer events making it a total of 30.5M € per year. In addition, training camps leading up to the races added another 3.1M € of tourism spending in the area. This makes Vasaloppet extremely important for the regions' tourism industry (Vasaloppet 2016).

The large interest of cross-country skiing can also be seen in the popularity of the cross-country skiing world cup. In the season 2015/2016 the world cup in cross-country skiing were broadcasted 1511 hours and watched by cumulative audience of 1.19 billion people, with a calculated media value of 637 million euro for the broadcast (FIS 2016b).

The value of cross-country skiing can't be estimated in tourism revenues and media value only. Many skiers participate regularly in cross-country skiing in their close to home area, and how much they value this can also be measured. However this recreational value of suitable conditions for cross-country skiing is generally not included in economic assessment of climate change impacts, since the value is not reveled in any market value. Although, determine this value will make one of the consequences from climate change more tangible to people (Sælen and Ericson 2013). The only studies measured the value of cross-country skiing conditions is a study from Vermont (McCollum 1990) and a study from Oslo, Norway (Sælen and Ericson 2013). The willingness to pay for a cross-country skiing trip in a close to Oslo recreational area were estimated to be 209 NOK (Norwegian crown) (28 €) for snow conditions compared to 125 NOK (17 €) for bare ground and 47 NOK (6€) for slush conditions (Sælen and Ericson 2013). This is indicating that suitable conditions for cross-country skiing have a high value.

Current and projected future climate change and its effects on seasonal snow parameters

Cross-country skiing is with exceptions to ski tunnels an outdoor-sport and affected by weather and in the long run the climate and the changes that occur in the climate. To understand how the climate has changed today and how it is expected to change in the future is therefore crucial to understand the development and faith of cross-country skiing in the future. The current climate parameters that are of most interest for cross-country skiing will be examined in the following chapter.

According the fifth assessment report, working group one (WGI), by the Intergovernmental panel on climate change (IPCC), the global mean temperature has been rising since the mid-1800s with 0.7-0.8 C° and accelerating in the last decades figure 1. Although with large inter annual variation, figure 1 and spatial variation of the temperature change, figure 2. Most of the warming has occurred in the high latitudes and over land (figure 2), places where most cross-country skiing is practiced. The major reason for this is the phenomena of polar amplification where the high latitudes temperature increase is greater than the global average. The main drivers of the polar amplification are the reduced albedo from a reduced snow and ice cover and the increased heat exchange from an ice-free Arctic and Antarctic Ocean (Stocker 2014:396). The magnitude of the polar amplification in the Arctic is an amplification of 3-4 times the global average (Serreze and Barry 2011).

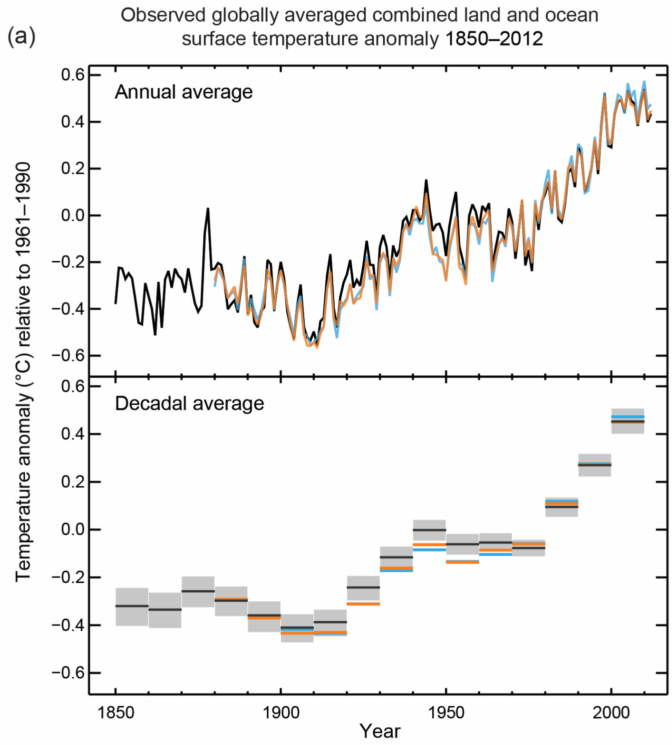

Figure 1: Observed combined land and ocean global mean surface temperatures anomalies, from 1850 to 2012. Presented as annual mean values at the top and decadal mean values with uncertainties for the black data set in the figure at the bottom. The anomalies are relative to the mean of 1961-1990 (Stocker 2014).

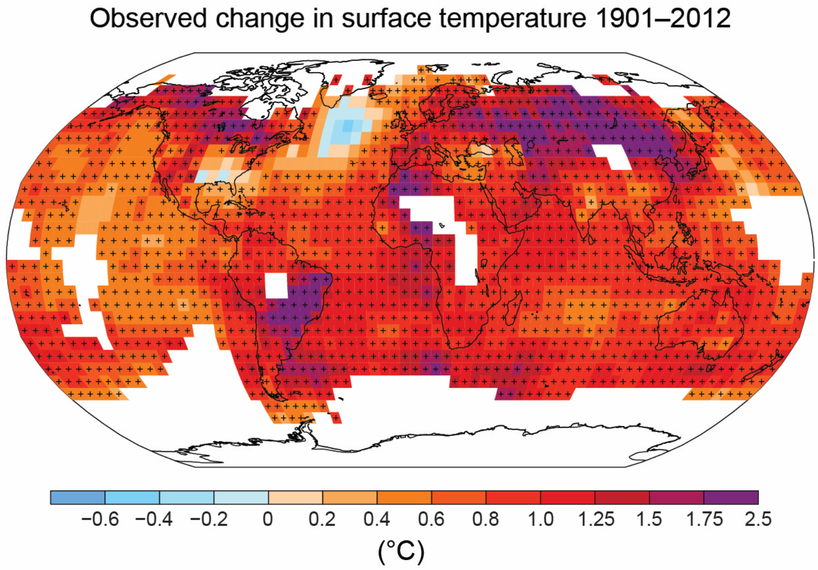

Figure 2: Map of observed surface temperature change from year 1901 to 2012, only for grids with greater than 70% complete records and more than 20% data availability in the first and last 10% of the time period. Remaining areas are white. Grid boxes that are within the 10% significant level are indicated by a + sign (Stocker 2014).

The temperature increase is not only spatially unevenly distributed but also temporally unevenly distributed with most of the warming occurring in the Northern Hemisphere (NH) winter (Stocker 2014; Hansen et al. 2010) and the least in the NH summer, displayed in figure 3. Since cross-country skiing is mostly performed in the NH winter and at high latitudes it will be extra vulnerable to climate changes.

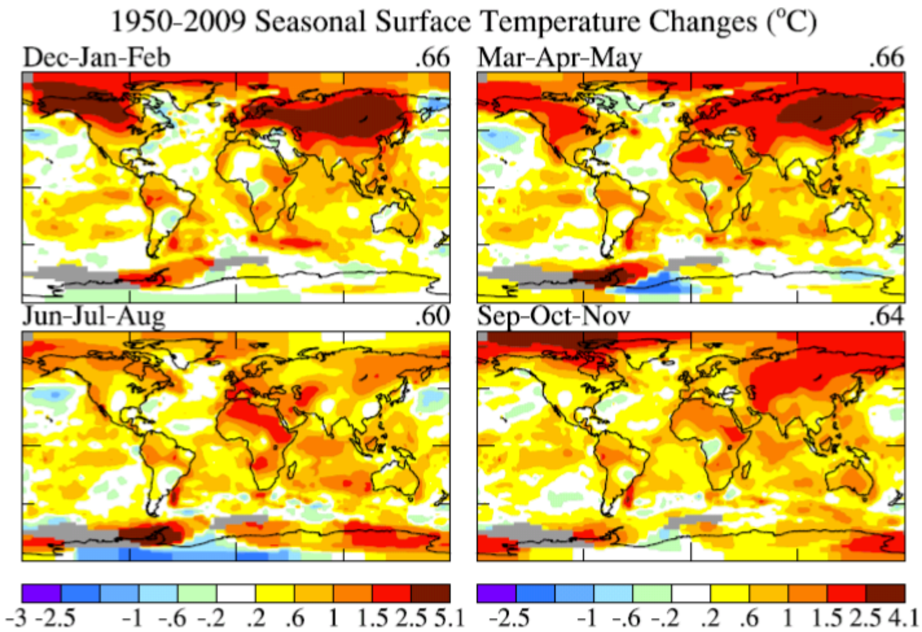

Figure 3: Global map of four season temperature anomaly trends in C° for period 1950-2009 (Hansen et al. 2010).

Precipitation has globally increased in the last century, although due to low data coverage the confidence is low to medium (Stocker 2014:202) There is low confidence for most of the precipitation changes except in the SH mid-latitudes where a decrease is detected and in the NH mid-latitudes where an increase is detected, with medium to high confidence depending on the time scale (Stocker 2014:204).

It is likely that the increased winter temperatures observed in North America, Europe, Southern and East Asia will lead to a decrease in snowfall events (Stocker 2014:204). It is however not possible to conclude any global changes in observed snowfall since the spatial difference is very large. In North America a decrease in number of snowfall events has been observed in the Western USA, the Pacific Northwest, Central USA, northeast USA and southwestern Canada. While an increase have been observed for northern Canada, western Great Plains and Great Lakes region in the USA. A decrease of snowfall has also been observed in Honshu Island, Japan, in western Himalaya, East Asia and Europe, while an increase is observed in parts of Northern Europe and Russia. In general areas with average winter temperatures close to 0 C° and where warming leads to an earlier onset on of spring have shown a decrease in snowfall events (Stocker 2014:204).

The changes in precipitation and temperature are likely to affect the seasonal snow parameters. The seasonal snow can be measured and reported in various metrics, such as snow depth (SD), snow cover duration (SCD), snow cover extent (SCE) or snow water equivalent (SWE). Both in situ measurements and satellite data (since 1966) are used to measure seasonal snow. Satellites can only detect SCD and SCE accurately (Stocker 2014:358)(Dicks et al. 2011:10). The SCE and SCD in the Northern Hemisphere (NH) has decreased over the past 90 years and the decrease has accelerated since the 1980s see figure 4 (Stocker 2014:358). The decrease is largest in the spring (Stocker 2014:358), figure 5, and are increasing with increasing latitudes as a result of stronger albedo feedback (Déry and Brown 2007), and its proximity to oceans (Dicks et al. 2011:10). In June when the albedo feedback in the Arctic is at maximum, the decrease can be contributed about equally to temperature increase and the albedo feedback. Figure 4 displays that averaged March-April NH SCE have decreased by 1.6% per decade for the 1967-2012 period and 2.2% per decade for the 1979-2012 period; while the average June NH SCE have decreased by 11.7% and 14.8 % respectively per decade. The SCE data can also be used to determine the SCD, indicating a decline of 5.3 days per decade since the winter 1972-1973 (Stocker 2014:358). In situ measurements are also documenting a downward trend in SCD and SWE in most places where areas at low elevation and warmer locations are most affected (Stocker 2014). In Europe the trend is even more obvious and the snow cover extent have decreased almost twice compare to the Northern hemisphere (European Environment Agency 2014).

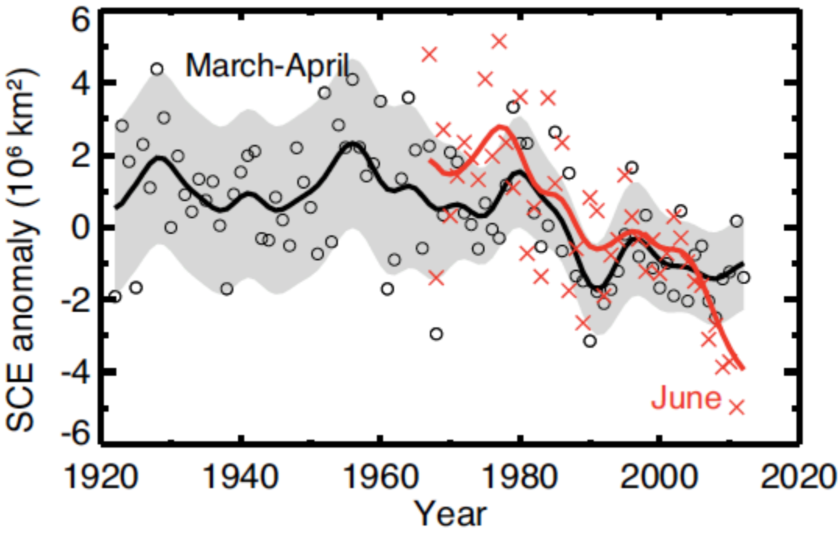

Figure 4: March-April NH snow cover extent (SCE) in circles, over the period 1922-2012 with a 13-term smoother and with shading indicate the 95% confidence interval. In red crosses, June SCE also filtered and with 95% confidence interval. All anomalies are calculated relative to the 1971-2000 mean (Stocker 2014:238).

Since SCD is determined by both the snow accumulation and the ablation, areas with increasing snowfall could experience increasing SCD. Eurasia shows increase in snow accumulation in many places but also a shorter melting season (Stocker 2014:358). This has led to an increase in SCD in a few areas in Northern Europe, and Russia but a decrease in most areas, where the decreases is more profound in the spring, see figure 5.

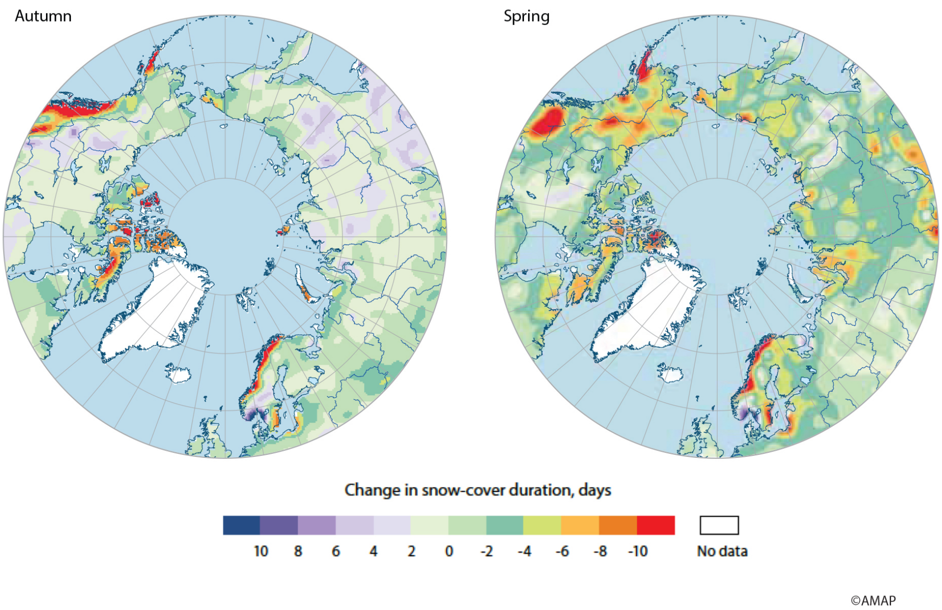

Figure 5: Changes in Arctic snow-cover duration for autumn (snow-cover onset) and spring (snow-cover melt period) between 1972/73 and 2008/09 derived from satellite data (Dicks et al. 2011).

The global annual mean surface temperature is predicted to continue to increase in most places during the 21st-century (figure 6). The amount of increase is depended on the future emissions of greenhouse gases (GHG). IPCC present four different Representative concentration pathways (RCP) in a way to display four different climate change scenarios. The scenarios are named after the increase in watt per square meter the scenario adds by year 2100. RCP 8.5 is a high scenario predicting high usage of fossil fuel and large emissions of GHG emissions. RCP 6 is a medium scenario and have emissions peak by 2060 and diminish to 25% higher than current greenhouse gas emissions. Scenario 4.5 is a medium scenario where the GHG emissions culminate by 2040 and finally the low scenario 2.6 where the GHG emissions culminate by 2020 (Stocker 2014). The following sections will examinant the RCP 4.5 and 8.5 effects on future snow parameters.

The temperature change difference is not large between RCP 4.5 and 8.5 in the mid-century but become greater in the end of the century figure 6. Similar as for temperature changes, SCE doesn't differ significant for the different RCP in the beginning or middle of the 21st century. The effects are much greater in the end of the century, where the differences between the RCP are 20% in SCE figure 7.

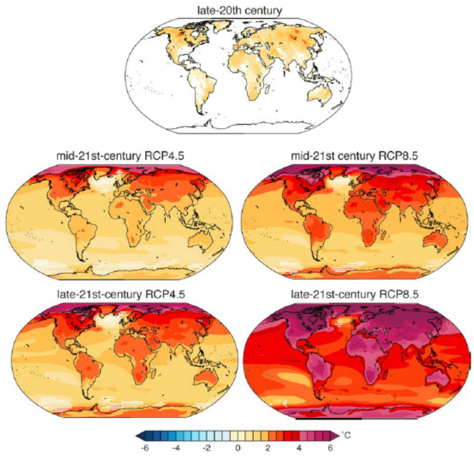

Figure 6: Predicted global annual mean surface temperature change for RCP 4.5 and 8.5 for mid and late 21st-century (Stocker et al. 2013).

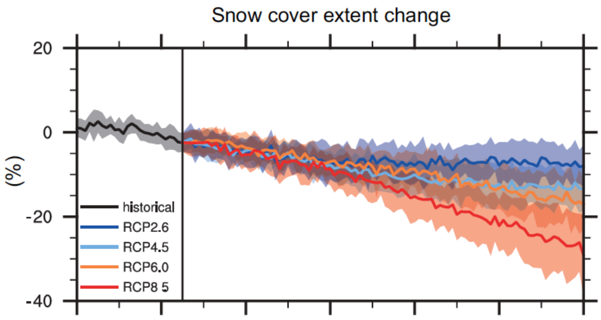

Figure 7: Future scenarios for snow cover extent change for various RCPs (Stocker 2014).

With increasing temperature, the snow cover extent, figure 7, snow cover duration and snow depth is predicted to decrease in most places as a result of less snowfall, more rain and more frequent and longer periods of above freezing in winter time (Stocker 2014; Déry and Brown 2007). In the following section the study region and its regional climate and projected changes in snow cover will be examined. Before examine the regions SCD, the population density and the topography will be examined in order to understand the consequences of the reduced SCD presented in the following maps to the availability to cross-country skiing for people in Northern Europe. In figure 8, the population density map conclude that most of the inhabitants in the Northern Europe countries live in the southern areas and close to the ocean or the Baltic Sea, areas with relative few SCD days (figure 10). In figure 10 below, both historical and future projected days of SCD are presented. The historical observations reveal that the number of days with SCD varies greatly in the study area, from as few as 30 days in southern Sweden and costal Norway to as many as over 240 days of snow cover in central mountainous and Northern Norway, Northern Sweden and above 210 days in Northern Finland. The southern third of Sweden, whole Estonia and Southwest Finland have less than 150 days of SCD, while only low laying areas close to the ocean experience similar conditions in Norway (figure 10). All these areas are the highly populated (figure 8) in these countries. Even though most of the area of Norway are covered by more than 150 days of snow cover, the areas with the highest population density are low-lying areas (figure 8 and 9) with fewer days of snow cover figure 10. The future climate change will reduce the SCD days significant in Northern Europe. Figure 10 display that in the end of the century (2071-2100) based on the older A2 emission scenario, similar to something between RCP 8.5 and 6 (van Vuuren et al. 2011; IPCC 2016) large part of Northern Europe will lose more than 50 days of snow cover. The SCD will be reduced to zero in the most southern part of the area and to only one or two months in most of the areas with high population density. The reduction for the Northern and mountainous parts is smaller and with an already longer SCD time they will be less impacted. In the following sections the individual countries' projected changes in future SCD and SWE will be investigated.

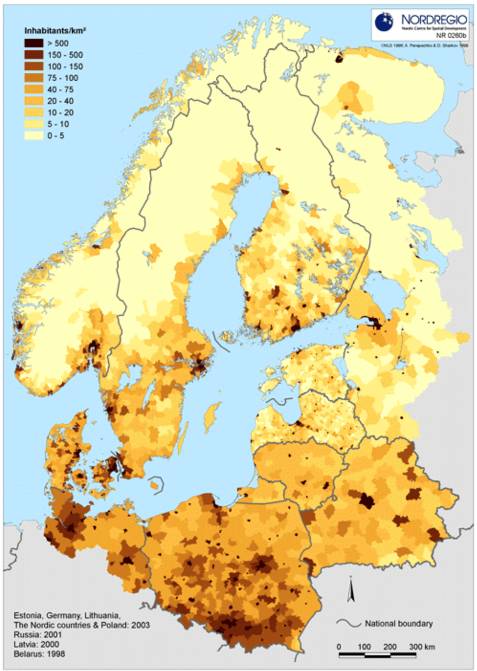

Figure 8: Map of population density for Northern Europe from 2003 (Nordregio 2003)

Figure 9: Map of topography for Northern Europe (LastminuteZeilvakanties Aanbiedingen in Scandinavie n.d.)

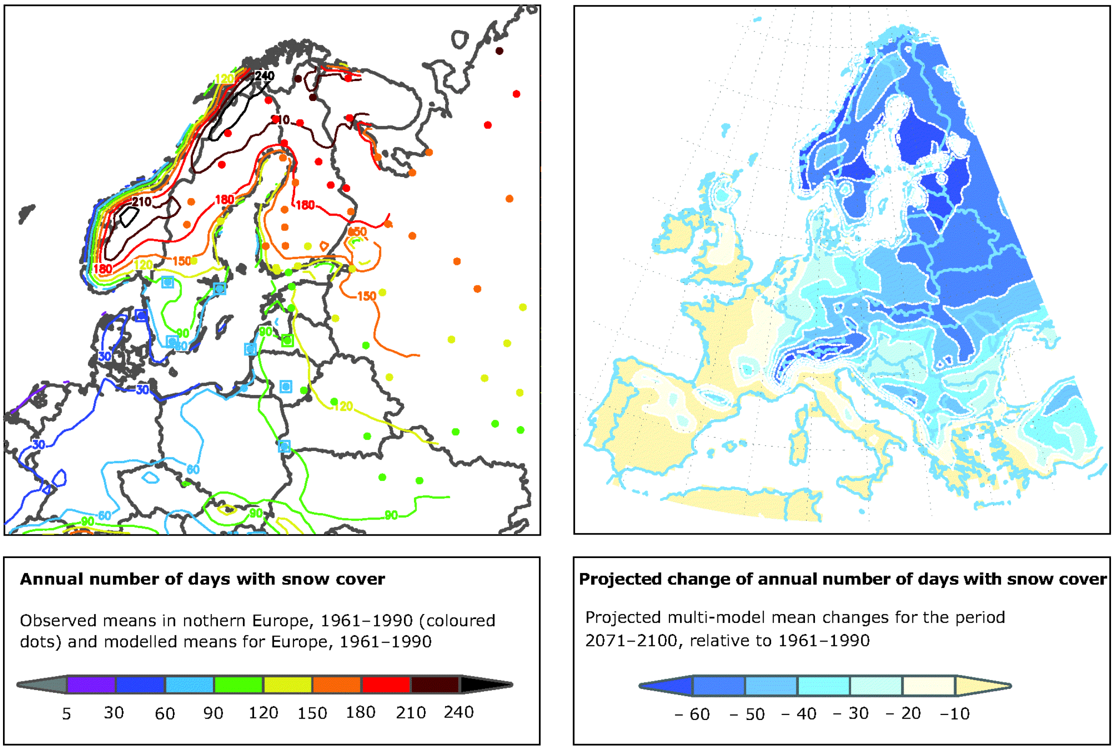

Figure 10: To the left, map of Europe with observed annual number of days with snow cover 1961-1990 (dots), and mean of seven RCM-H control simulations (contours). Boxes indicate stations having an observed inter-annual variation coefficient greater or equal to 30%. To the right: projected change of annual number of days with snow cover for period 2071-2100 relative to 1961-1990 from multi model mean changes by seven RCM-H-A2 experiments, based on the SRES scenario A2. (European Environment Agency 2009).

The snow conditions in Norway are general good. For the reference period 1971-2000 almost entire Norway were covered by snow during the whole winter months or parts of the winter, except for a few areas along the coast. During the last 100-year period, the length of the snow season has decreased at most measurement stations as well as the maximal snow depth. Although there were not possible to detect a consistent change in entire Norway in the number of days with skiing conditions (25 cm snow depth) (Hanssen-Bauer et al. 2015). Although in Southern Norway at the station Bjørnholt (360 meter asl) in Nordmarka close to Oslo they have lost about 30 days with skiing conditions compare to the reference period 1961-1990, and are down to about average 100 days (Løken 2015). While the Blindern area in down town Oslo have lost 11 days of skiing condition per decade. Southern Norway has also shown a decrease in the SWE in places below 1350 m above sea level in the period of 1991-2009 (Hanssen-Bauer et al. 2015).

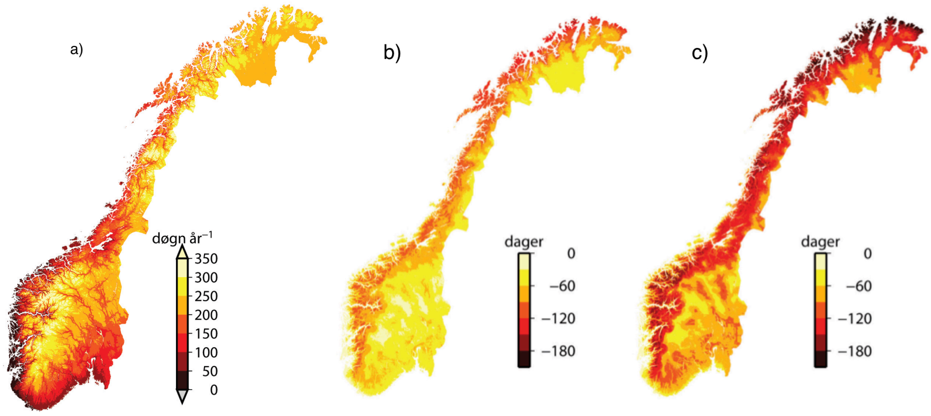

Figure 11: a) Shows days with snow cover in Norway for reference period 1971-2000. b) Displays projected change of days with snow cover form period 1971-2000 to 2071-2100 for RCP 4.5 and c) for RCP 8.5 (Hanssen-Bauer et al. 2015).

According to Schuler et al. (2006) the mean annual SWE and SCD is predicted to decrease in the later part of the century almost everywhere in Norway with greater impact in low altitudes and closer to oceans. It is projected that the start of the snow season will be approximately 3-4 weeks later and the end of the snow season is projected to be 1-7 weeks earlier. A more recent report from Norway's environment department concludes the same trend; where SWE is expected to diminish in almost entire Norway except for inland high altitude locations (Hanssen-Bauer et al. 2015). For SCD, the reduction in the later part of the century is expected to be up to 90-140 days shorter in costal low altitude areas and between 30 to 90 days shorter for the interior Norway for RCP 4.5.The SCD will be 120-210 days shorter for coastal low altitude areas and 30-120 days shorter for interior Norway for RCP 8.5, see figure 11. In the end of the century it is likely that most winters in low altitude areas in Norway will be snow free (Hanssen-Bauer et al. 2015).

The Swedish metrological and hydrological institute, SMHI, have generated maps of snow cover both for historical periods and projected future maps. These maps are based on nine global climate models and the RCA4 regional climate model, for both RCP 4.5 and 8.5. The maps are generated with 5 and 20 mm SWE (SMHI 2015) . The purpose of the 20 mm SWE is to see changes in conditions suitable for skiing, which require something like 20 or 25 mm of SWE (Hanssen-Bauer et al. 2015). Other maps and data on snow cover doesn't include the exact number of days with skiing conditions, which is significantly lower than the number of days with snow cover. SMHI also present maps with 5 mm SWE and the difference between the 5 and 20 mm SWE is between 20-40 days, a difference that would be even larger with a 1 to 20 mm SWE difference (SMHI 2015). In figure 12, it is obvious that in a) the 1961-1990 historical period, a large part of southern Sweden didn't have any or just a few days with above 20 mm SWE while in northern Sweden there were more than 200 days with above 20 mm SWE. In b) the 1990-2013 historical period in figure 12, it is possible to detect that the number of days in many places have been reduced by about 20 days, the decrease is larger in the southern parts. For the future scenarios c) 4.5 and d) 8.5 for the period 2069-2098, the southern third of Sweden will on average not have any days with above 20 mm SWE for both scenarios. For the rest of the country there is a reduction with about 40-60 days of SWE of 20 mm for the RCP 4.5 scenario and with about 60-90 days for the RCP 8.5 scenario compared to the most recent 1991-2013 historical period.

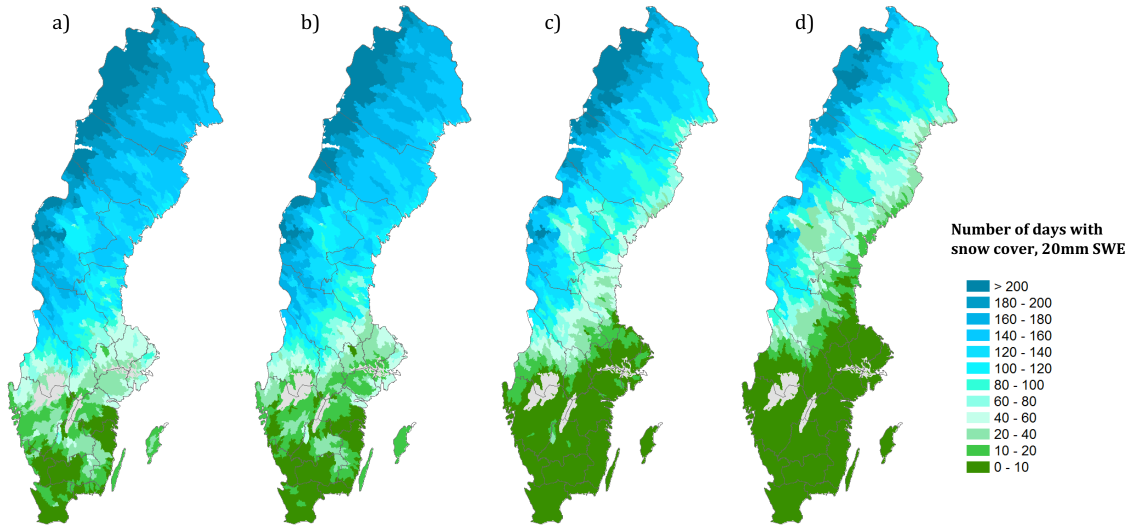

Figure 12: Historic and projected number of days with snow cover equivalent to 20 mm of water content in Sweden for a) historical period 1961-1990 b) historical period 1991-2013 c) future period 2069-2098 for RCP 4.5 d) future period 2069-2098 for RCP 8.5. (SMHI 2015)

The low elevation country Finland will be very vulnerable to a warming climate that will reduce the snow cover and snow water equivalent significantly at the end of the century. Especially in the southern and western parts of the country, the SCD days will be reduced by 50-70% (figure 13) with a decrease in the SWE with 80-90%. In the northern Finland the precipitation increase will partly reduce the loss to only 20-30% in SCD days and 40-70% in SWE. The southern parts of Finland will on average only see sporadic snow cover in the end of the century similar to the conditions in the month of November today. Northern Finland will still have permanent winter snow cover in the end of the century although with shortened in both ends (Klimatguiden.fi n.d.)

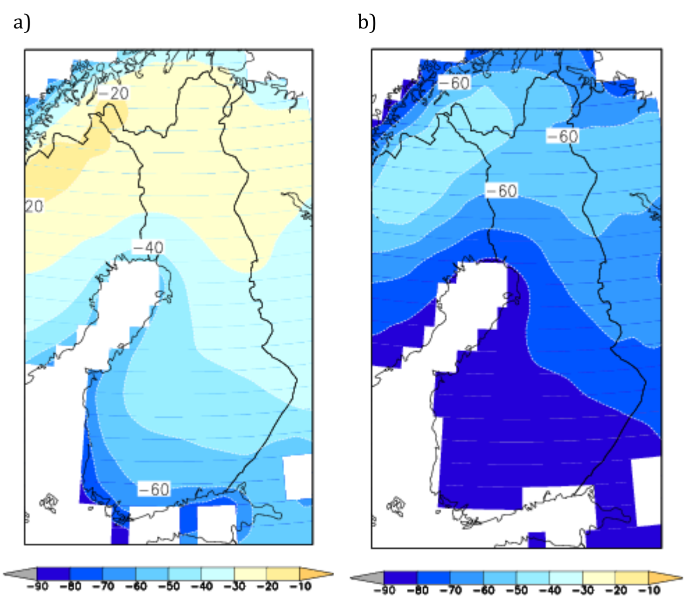

Figure 13: a) Percental change in number of days with snow cover from the period 1961-1990 to 2070-2099 b) Percental change average water equivalent of snow (SWE) from the period 1961-1990 to 2070-2099. Both figures are based on a regional climate model with the high emission scenario A2 (Klimatguiden.fi n.d.).

No maps with snow cover were found specifically for Estonia, although it is likely that Estonia will experience similar changes in snow cover as southern Finland. According to figure 10, Estonia is expected to have a reduction of more the 60% in SCD by the end of the century. The Estonian Climate Adaptation Strategy for Infrastructure and Energy estimate that the number of days with snow cover will be less than ten in Estonia by the end of the century with the RCP 8.5 scenario (weADAPT 2015).

How climate change is affecting winter sport and tourism

The projected future decreases in snow cover will greatly affect the snow reliability and the length of the ski season. It is projected that a large share of the ski areas that are relaying on natural snow in the Alps, Black forest region in Germany and in Sweden will not be able to do this in the future (Füssel, Jol, and others 2012). Since, on average, the snowline rises about 150 m per 1°C due to the adiabatic laps rate (Gobiet et al. 2014), low laying ski areas are affected the most and it is estimated that those areas will lose six weeks of skiing per one degree of temperature increase (Füssel, Jol, and others 2012:212). In the Alps, a large decrease in SWE is projected in area below 1500 m asl and even in areas above 2000 m asl (Gobiet et al. 2014). An increases of 2°C in the Alps would make one third of the ski areas that is considered snow reliable (100 days of skiable condition at least 7 out of 10 years) unreliable and an increase with 4°C would reduce that to two thirds (Færaas et al. 2016). Even with snowmaking, that number of snow-reliable areas will decrease although to less extent; by 0% for 2035, 3% for 2060 and 25 % for the 2085 for the A2 scenario (Raible and CH2014-Impacts Initiative 2014).

The effects of climate change are not fifty or hundreds of years away, it is already affecting winter sport and skiing today. In the record-warm winter of 2006/07 some low-altitude alpine ski area in Austria where unable to offer a continuous skiing season between December and April, even though equipped with snowmaking systems (Füssel, Jol, and others 2012:212). In Switzerland, banks have very high restrictions on bank loans to ski resorts that are below 1500 m asl (Scott and McBoyle 2006), indicating low faith in future economic profit at low laying ski areas in a future of climate change. Based on results from multiple surveys, it is likely that a third to half of the skiers would pursue other activities or choose more snow reliable ski resorts if presented with future climate change conditions. However empirical evidence from two different climate analogy years, represent present and future (mid 21st century) snow conditions indicated only a loss of 11% of visitors in Eastern North America (Scott and McBoyle 2006). Another worrying phenomena is something called the "backyard syndrome," meaning that people tend not to think of skiing until it snows where they live. With less snow in urban areas fewer people are likely to go ski tourism (Seelye 2012).

There is not only the tourism industry that is affected, also the competitive winter sport suffering from the effects of climate change. Races in alpine skiing, Nordic combine and biathlon were canceled during the season 2015/16 as a result of warm weather and poor snow conditions. Most of the ski races are ensured by the production of machine-made snow and many races have been arranged on a white stripe in a green landscape (Færaas et al. 2016).

How climate change is affecting cross-country skiing

As in other winter sport, cross-country skiing is also affected by climate change. Ski races in cross-country skiing attract both elite and the amateur skiers, especially the long distance races. Long distance races are especially vulnerable to bad winters and poor snow conditions since they usually are skied from one point to another and are not as lap courses. In addition, they are usually between 30-90 km long (Visma ski classic 2016) and is therefore harder to cover with machine made snow . Below is a summary of the largest long-distance cross-country skiing races in the four countries of Norway, Sweden, Finland and Estonia and there history of canceled races.

Vasaloppet is the oldest long distance race and started in 1922. I has been canceled three times (1932, 1934 and1990) due to lack of snow (Vasaloppet n.d.) Birkebinerrennet started in 1932 and have been canceled 8 times, 1941-1945, 1948, 2007 and 2014. The first years it was canceled due to the Second World War, only in 2007 and 2014 due to climatic reasons, because of too strong winds (Birkebeiner 2016). Finlandialoppet started in 1973 and has only been canceled one time in 1973. Although the original course has been changed to avoid skiing over frozen lakes, since the ice have become weaker (Finlandia-hiihto 2016). The first Tartu Marathon took place in 1960. The race has been cancelled 14 times in the following years 1961, 1972, 1973, 1974, 1975, 1988, 1989, 1990, 1992, 2000, 2004, 2008, 2014 and 2016 due to lack of snow. It may be hard to determine a trend in climate change by only looking at the cancelation years. Although for Tartu marathon, the first 28 years the race has been canceled five times and in the following 28 years nine times (see dataset appendix).

Cancelation of the race may not be a perfect indicator for a chaining climate since it may have been climate change adaptation measures done during the progress of the race history. Such adaptations are for example improving the smoothness of the trails, reducing the thickness of the snowpack needed, or use of artificial snow, increasing the likelihood the race can be hold (Vasaloppet n.d.). Although looking at the long distance series of skiing, Ski Classics during the last four years, 14 out of 29 races had to change plans and they either held the race on an alternative course, on a shorter lap course or canceled and moved the event. 16 of those events had to rely on machine-made snow on parts of or on the entire course in order to ensure the event, which is quite an effort when the races are typical 30-90 km long (see table 1).

	Normal Course	Changed course	Race held on corse with multiple laps	Canceled and moved	Usage of machine made snow
2012/2013	Jizerska (Czech republic)				
	Marcialonga (Italy)				yes
			König Ludwig Lauf (Germany)		yes
	Vasaloppet (Sweden)				yes
	Bikenbinerrennet (Norway)				
	Årefjällsloppet (Sweden)				
2013/2014				Jizerska (Czech republic)	
	Marcialonga (Italy)				yes
			König Ludwig Lauf (Germany)		yes
	Vasaloppet (Sweden)				yes
	Bikenbinerrennet (Norway)				
		Årefjällsloppet (Sweden)			
2014/2015	La Sgambeda (Italy)				yes
		Jizerska (Czech republic)			
			La diagonella (Switzerland)		yes
		Marcialonga (Italy)			yes
	König Ludwig Lauf (Germany)				
	Vasaloppet (Sweden)				yes
	Bikenbinerrennet (Norway)				
		Årefjällsloppet (Sweden)			
2015/2016			La Sgambeda (Italy)		yes (entierly)
			Jizerska (Czech republic)		yes
		La diagonella (Switzerland)			
	Marcialonga (Italy)				yes (entierly)
				König Ludwig Lauf (Germany)	
		Toblach-Cortina (Italien)			yes (entierly)
	Vasaloppet (Sweden)				yes
	Bikenbinerrennet (Norway)				
		Årefjällsloppet (Sweden)			yes

Table 1: The last four seasons of Ski Classics (2012-2016). The table is showing if the race were held on a normal course, a changed course, a course with multiple laps, if the race was cancelled or moved or if they used machine-made snow (Visma Ski Classics 2016).

Theoretical concept

Climate change adaptation

According to IPCC, climate adaptation is "the process of adjustment to actual or expected climate and its effects; in human systems adaptation seeks to moderate or avoid harm or exploit beneficial opportunities" (Field et al. 2014:40). The effects and impacts of climate change on an individual or to society are determined by a variety of factors. The degree of climate change and the location of humans or human dependent activities will affect the exposure. The degree to which this system is affected by climate change determines the sensitivity. While the adaptive capacity is defined as the ability of a system to adjust, moderate potential damage, take advantage of opportunities or to cope with the effects and consequences of climate change (Field et al. 2014). Adger (2006) states that by estimating the components of exposure, sensitivity and adaptive capacity, the vulnerability of a system can be evaluated. Socioeconomic processes such as the strength of the governance, economical status and adaptive capacity also determine the degree of vulnerability of a system to climate change, by affecting the above-mentioned components. Climate change adaptation is used to reduce the risk by building adaptive capacity to reduce the sensitivity and vulnerability to the effects from actual or expected climate changes (Field et al. 2014).

The exposure in the context of ski areas refers to the climate impacts affecting the possibility to supply ski tracks. It can therefore be defined as number of days with snow cover sufficient for skiing conditions (Landauer, Sievänen, and Neuvonen 2015). However, the number of days with minus degrees for snow production could be relevant if the ski area have machine-made snow production. The sensitivity of the ski areas ability to supply ski track is dependent on the climatic exposure the ski area will experience. It is also determined by the degree those effects will affect the ski tracks. Adaptation measures such as production of snow will reduce the sensibility. The sensibility can therefore be measured as the exposure minus the technical adaptation. Finally, the adaption capacity will determine the sensitivity by technical adaptation but it is also reducing the vulnerability of the ski area by adaptation measures such as revenue and seasonal diversification. Adaptive capacity can therefore be measured as the ski areas ability to invest in adaptation measures and the ability of revenue diversification.

Future adaptation of nature and winter-based recreation and tourism will not only take place on the supply side among ski areas. It is a combination two things; people will react and adapt autonomously to the new climate by changing their recreational and travel behavior to match the new conditions, and the tourism services will adapt to those new conditions in a changing climate (Pouta, Neuvonen, and Sievänen 2009).

Climate change adaptation of cross-country skiing

Adaptation for the individual skier

The individual cross-country skier will have the adapt to the new climatic conditions by either travel further to find snow, change behavior (e.g changing from classic skiing to skate skiing, which is more suitable for icier and lower snow volumes), or changing to other recreational activities (Pouta, Neuvonen, and Sievänen 2009). The ongoing and future climate changes will also affect individual skiers differently. Since an individual will take part in skiing if the utility (enjoyment) from skiing is larger than the utility from other activities, within the monetary budget and time limits of the individual (Gilbert and Hudson 2000). The rate of participation in skiing is constrained by the cost, both monetary and time cost. Cross-country skiing that can be performed everywhere there is snow, is therefore extra vulnerable to climate change, since it increases the time cost when skiing is only available at specific areas with machine-made snow or at locations with natural snow further away (Pouta, Neuvonen, and Sievänen 2009). In general climate adaptation, the effects from climate change is argued to be greater for smaller communities with low level of technology, poor information and skills and with limited economic recourses, due to lower adaption capacity (Grothmann and Patt 2005). On an individual level, the ability to adapt similarly depend on the access to resources (Adger 2003). A study of Finish cross-country skiers expected future response to climate change conclude that low socioeconomic status skiers had the highest sensitivity to climate change and are more likely to stop skiing or ski less frequent than any other group. Other extra sensitive groups were females and urban citizen (Pouta, Neuvonen, and Sievänen 2009).

Adaptation for the ski area

The effects from climate change will pose challenges for both public and private ski areas. For the public providers, the challenge is how to provide equal opportunities for all citizen groups, including those groups with weaker adaptation capacity. It is important that public agencies promoting health and wellbeing have the information on which groups are more likely to give up cross-country skiing in a changing climate and are able to encourage those groups to find alternative physical activities. For the private ski areas the question is how to keep the customers and the business running under the changing conditions (Pouta, Neuvonen, and Sievänen 2009). Most of the research have investigated the adaption options for private alpine ski areas (Scott and McBoyle 2006), although some of those adaptation techniques can also be applied for public owned ski areas and for cross-country skiing as well. In a study by Scott and McBoyle (2006) they concluded that there are two major categories that a ski area can adapt in, either technical (trail improvement and snowmaking) or business solutions (revenue diversification, marketing and ski conglomerates). Similar, Unbehaun, Pröbstl, and Haider (2008) stated the adaptation actions into three categories; invests in technical solutions, offer non-snow dependent in and outdoor activities, or decrease the dependency in the winter season by invest into an all-seasonal tourism product.

Technical solutions

Snow production

The production of snow by machines is the most common climate adaptation technique for ski areas (Füssel, Jol, and others 2012:212; Scott and McBoyle 2006). This production of snow has been called many different things, such as artificial snow, technical snow or machine-made snow. The word artificial snow is not popular among the ski areas or within the snow-making industry, as it implies to the customer that the produced snow would be artificially or strange, when it in fact is made of frozen water just as natural snow (SMI Snowmakers n.d.). Hereafter snow produced by machines will be named machine-made snow in this report.

The difference between machine made snow and natural snow is that the grains are rounded in machine-made snow, similar to natural snow in an advanced state of metamorphism. This leads to the fact that machine-made snow is more packed with higher density than natural snow, resulting in that less snow is needed for skiable conditions. Further on, machine-made snow is more durable and resists wind, water and temperature better than natural snow. This fact makes the machine-made snow extra popular in above zero conditions and for storing it over summer so called snow storage (Lintzén 2012). Machine-made snow is quantified using cubic meters. Although it can be hard to imagine how much that number is, and how much is needed to produce a ski track. A simple calculation experiment could make it easier to comprehend. A ski track that is 6 meters wide and 1 000 m (1 km) long with a snow thickness of about 0.33 m would require 6*0.33*1000 = 2 000 cubic meter snow. Roughly 1 cubic meter of snow would cover 0.5 m of ski track. The thicker the layer is the better it isolates from the ground before it has frozen or the longer it last during periods of melting (Lintzén 2012). Therefore, it is likely that more than 1 cubic meters of snow per 0.5 meter of ski track is preferred.

The Production of machine-made snow was first seen as a luxury and back up for warmer than average winters, when it was introduced. Later, it became a widespread technique to prolong the opening season and became less dependent on climate variability, in order to ensure snow guarantee and set opening dates (Scott and McBoyle 2006). The rapid expansion of snow production both in North America (Scott and McBoyle 2006) and in the Alps (Marty 2011) were triggered by this need, and hundreds of millions of dollars have been invested in snowmaking equipment (Scott and McBoyle 2006). The importance of snowmaking to climate variability is great and in a study by Scott and McBoyle (2006) investigating 6 ski areas in Eastern North America, machine-made snow production proved to extend the average ski season by 55 to 120 days for the reference period 1961-1990. In the future, the role of snow making will become even more important as climate change increases the difference between the length of the ski season with natural snow cover and with machine-made enhanced snow cover (Scott and McBoyle 2006). In 2011, as much as 38 % of the total alpine skiing area in the Alps were covered by machine-made snow-making systems, and it expanded by 48% between 2004-2011 (Füssel, Jol, and others 2012:212). The usage of machine-made snow is also increasing in cross-country skiing. In 2010, the Swedish ski federation made a report investigating the ski areas in Sweden that used machine-made snow and could determine that there were 98 ski areas (Åkesson 2010). A number that has grown to 116 ski areas in 2016 (Kjällbring 2016).

The most common way of producing snow is with snow guns, including the fan guns and lances. Both build on the technology of spraying out compressed air together with a mist of water. The compressed air expands and cools, freezing the water vapor in that air which acts as a nucleation site where water can build on to, forming ice crystals as it cools from the surrounding cold air. Nucleation sites can also form by ions or impurities in the water such as clay particles. Special nucleation mixes in form of bacteria can be bought and added to the water improving the snow formation, especially in marginal conditions. The water/ice mix need hang time in order to freeze. For a lance gun that is provided by having a 5-10 meter high lance, and for the fan gun, a fan behind the water and air nozzles throw the water mist high into the air. The produced snow is general very wet and humid and should be let untouched up to a day before grooming (Lintzén 2012). About -2°C is usually the warmer limit to produce snow with this technology, but in fact it isn't the actually temperature that is important, it is the wet bulb temperature which including the cooling from the evaporation of water. Lower relative humidity increases the water evaporation and reduces the wet bulb temperature. With really low relative humidity the wet bulb temperature can be negative even in above zero degrees, enabling snow production, although those conditions are rare. The fan snow gun is better to produce snow in marginal conditions (when the wet bulb temperature is close to -2°C) compared to the lance snow gun. The fan gun is also better in windier conditions because the fan can direct the snow. The fan gun is in general more expensive than the lance gun and also consumes more electricity to propel the fan (SMI Snowmakers n.d.). The overall energy efficiency have increased tremendously in the last year and a snow gun only uses on average 1 kWh per cubic meter of snow produced compare to 7 kWh per cubic meter in 1976 (SLAO n.d.) There are even snow gun lances that requiring no electricity input, only water pressure. If the water pressure is obtained by the potential energy of the water, for example a reservoir high above the snow lance, the snow lance can produce snow without any electricity input (NIVIS n.d.; SLF n.d.). The water consumption is about 2.5 cubic meter of water for one cubic meter of snow produced. Many large ski areas have a water consumption of tens of thousands liter per minute for snow production (SLAO n.d.).

The energy and water efficiency have increased even further for the snowmaking with the new computer based software programs, which can be installed in the snow production system. This is usually referred to as Smart snow system, since the snow production can be optimized after the changing weather conditions. The water and air ratio is automatic adjusted after the changing wet bulb temperature in order to produce the maximum volume and quality (not to dry or wet) of snow. The production is also adjusted depending on the wind conditions, avoiding producing unusable snow outside the piste or ski track (Lintzén 2012).

The price for snow guns differs a lot depending on the size or type. For a large fan snow gun the prize is about 25 000€ (Bångman 2012). A study by Damm, Köberl, and Prettenthaler (2014), conclude that as of 2008 a snow gun with associated infrastructure cost 131 000 dollars. The price of producing one cubic meter of snow is only in the range of 0.1-0.5 euro, only including the electricity cost (Lintzén 2012). However the electricity cost is only about a quarter of the total cost. Including the investment and other operational costs in the snow production, the cost is about 1.5 euro per cubic meter (Damm, Köberl, and Prettenthaler 2014). The cost of snow production is larger in marginal conditions and the overall cost may be uneconomic for some ski areas (Scott and McBoyle 2006) indicating that there is economical constrains with the expansion of snow production as an climate change adaptation method, as well as climatic constrains (Füssel, Jol, and others 2012:212). Newer types of snow producing machines that can produce snow in above freezing temperatures have moved the climatic constrain of snow production. But since this technique is not using the cold outdoor air for freezing the water, the energy consumption is much larger than for traditional snow guns. So far the cost is considered too high and the volume possible to produce per unit of time too low for it to be a game changer. Instead it is used as a complement to normal snow production (Kihlberg 2016; Eklund 2016; TechnoAlpin 2015).

There is also non-market cost associated with snow production such as the social cost of carbon associated with emission from the electricity production. In the European Alps, the electricity used to produce the artificial snow have a higher carbon footprint compared to the Northern Europe countries where most of the electricity is produced with renewable and nuclear energy sources (Færaas et al. 2016). Another non-market cost and potential constrain of snow production is the ecological cost (Füssel, Jol, and others 2012:212). The water used for snow production is in general more mineral rich, changing the composition of plans to ones with higher nutritional needs. Therefore snow production should be avoided in ecological rich areas (Wipf et al. 2005). There is also a concern of the ecological impact from the many reservoirs recently built in the Alps for snow production (Evette et al. 2012) The reservoir and snow production also interferes with the ground water table since more water are evaporating (Wipf et al. 2005). If no reservoirs are built, water for snow production is usually taken from lakes and rivers. The uptake of large amounts of water in the wintertime when the water levels are already low can harm the stream and lake ecology, especially the fish eggs (Scott and McBoyle 2006). Many ski areas in Sweden have restriction on how much water they are allowed to use and have gone to court to be able to increase their water usage for snow production (Bergstedt 2016).

Landscaping and trail improvements

This strategy involves changing the landscape in order to improve the snow conditions or the amount of snow required for skiing. Bulldozing and machine grading the ski track in order to smoothing the surface, as well as removing rocks and shrub vegetation will reduce the amount of snow needed for skiing (Marty 2011). Additionally, investing in contouring to improve the drainage of melt water during periods of melt and rain will reduce the loss of snow (Scott and McBoyle 2006) . Planning the route of the ski track to avoid climate sensitive locations such as south facing slopes, open windy locations or creating shaded and wind protected areas, and if possible increase the elevation of the ski track will also reduce the snow needed and or increase the length of the season (Marty 2011; Scott and McBoyle 2006).

Artificially cooling the ground with cooling loops

Another way to prolong the skiing season is to artificially cooling the ground with a coolant (e.g freezium), which is still liquid in sub zero degrees temperature, in contrast to water. The liquid is cooled and pumped around in pipes bellow the ground, artificially freezing it. Stored snow is thereafter applied on the artificially frozen ground making it more resistant to thawing. (Appendix climate change adaptation, others). Two areas in the survey stated that they used artificially cooled track Högbo (2.1 km) (Högbo Brukshotell 2016) in Sweden, and Kontiolahti (1.5 km) (Cooled Ski Track 2016) in Finland. The ski area in Kontiolahti stated that this technique will prolong the season with on average 90 days (Cooled Ski Track 2016). This technique have been questioned previously of its efficiency when the snow turn into ice during periods of melt (Jonsson 2010), although Kontiolahti ski area seem to have come around this problem with applying a thick (70 cm) layer of artificial snow on top. The investment cost is large, about 2 million euro for the artificial cooled ski track in Högbo, the cooling loops consumes a lot of electricity resulting in a high operation cost, making it economical viable only on shorter loops (Jonsson 2010).

Snow farming, storing snow over the summer

Storing snow over the summer is a climate adaptation measures, which is usually referred to as snow farming. Storing snow and ice during the summer have a long history and was commonly used to preserve food before the time of refrigerators. Snow farming today is used for drinking water storage, glacier protection or as a cooling medium (Grünewald and Wolfsperger 2016; Skogsberg 2005). Although it is also commonly used as a snow guarantee for winter sport, such as cross-country skiing, alpine skiing and ski jumping (Grünewald and Wolfsperger 2016), prolonging the seasons by one to two months for the ski area (O'Neil 2016). Snow farming is usually a complement for cross-country ski and alpine ski areas because the snow volume required to cover the entire pistes or ski tracks is usually too large for snow farming. The stored snow is enough for open one or a few pistes earlier for the alpine ski resort, or a few kilometers of ski tracks for the cross country area (O'Neil 2016). The snow farming started in 2001 in northern Finland by Mikko Martikainen that now owns a snow security company (Dunfors 2016). As of 2016, 34 cross-country ski areas in Finland are using snow farming as an adaptation technique to the changing climate (Etusivu - Hiihtoliitto n.d.), and the technique is increasing in popularity in other parts of the world (O'Neil 2016).

The principle of snow farming is to produce machine made snow (most common) or accumulate natural snow during the winter. The accumulated snow is stored in a pile and covered with some isolation materials, such as sawdust, wood chip or geotextiles (Grünewald and Wolfsperger 2016). Geotextile is a two millimeter thick Polypropylene tarp with reflective properties (O'Neil 2016). The sawdust and wood chip cover material have higher insulating capacity than the geotextile and is performing better at lower elevations where the contribution of sensible heat to the energy balance is larger than at higher elevation where the shortwave radiation plays an increasingly larger role instead (Olefs and Lehning 2010). Therefore, geotextiles is mostly used to protect melting glaciers or saving snow in high altitude pistes (Olefs and Lehning 2010).

The cost of snow farming is quite large including investment cost in clearing a site of snow farming, building infrastructure for water, electricity and machinery as well as purchase or leasing of snow making equipment and cover material. Additionally, yearly operational costs for electricity or diesel for snow making, transportation cost of the snow to the ski track by lorries as well as covering and uncovering the cover material of the snow pile adds to the cost, including the increased cost of man power. Few studies reveal the full cost of snow farming, although a study of the snow farming in Östersund, Sweden, investigating the socio-economic costs and benefits of snow farming (Gisselman and Cole 2016). The study concludes that the yearly operational cost was between 138 000-202 000 euro and including the historical investments of 1.6M euro averaged out per year the cost increased to 217 000- 307 000 euro per year (Gisselman and Cole 2016). Also, the social cost of carbon (SCC) was estimated to 8 500-11 700 euro per year using a high SCC values of over 100€/ton. The relative low SCC has its background in that Östersund's municipal only using renewable electricity, so the only SCC comes from the machinery and transportation lorries. The Northern European countries generally have a high usage of low carbon electricity due to the high share of hydropower and nuclear power (Nordregio 2010).

Indoor ski halls and tunnels

Indoor skiing may be the most technical climate change adaptation there is, making it possible to ski the whole year around independent of the climate (Määttä 2010). The first indoor ski hall opened in 1986 and there are today more than 50 downhill ski halls in the world, and it is even possible to ski in places like Dubai (Scott and McBoyle 2006). Cross-country skiing is also performed as an indoor sport and the first tunnel for indoor skiing opened 1998 in Vuokatti, Finland (Määttä 2010). Finland is also the country that host the most ski tunnels or ski halls for cross-country skiing (8) (Määttä 2010), while there is two in Sweden, with two new under construction (Frygell 2016), one in Germany (DKB SKISPORT HALLE Oberhof n.d.) and two planned ski tunnels in Norway (NRK 2014; Rogne 2015). The advantage of indoor skiing is the possibilities to year around skiing with stable conditions inside, compared to weather dependent conditions outside. Indoor-skiing can also be placed where most people live, in the southern parts, where climate change will affect the snow conditions the most. It therefore reduces the travel distance for cross-country skiing in some areas, increasing the probability that people continue to ski in a future with diminishing natural snow. Further on, they are also suitable for children learning to ski, which possible maintaining the skill and interest of future generations (Scott and McBoyle 2006; Määttä 2010). However, most or all the indoor ski areas are private owned, having large energy cost of cooling the indoor facility. Expenses are covered by user fees, making the skiing fairly expensive (Määttä 2010).

Business solutions and reduced dependency of snow and winter solutions

Ski conglomerates

This business model involving conglomerates of ski resorts by larger companies that acquire ski areas in different location. The business model wasn't intended as a climate adaptation but it may prove to be very effective one (Scott and McBoyle 2006). Conglomerate multiple ski resort in various location improves access to marketing and capital, enhancing the adaptive capacity; it also reduces the vulnerability of the conglomerate to effects of climate change and climatic variability. Since the probability of poor snow conditions is much greater in one single location than over several regions simultaneously (Scott and McBoyle 2006). The company Skistar is an example of the conglomerate business model in Northern Europe with ski resorts in multiple locations in Sweden, Norway and Austria (Skistar n.d.).

Merger and cooperation

A similar form of business adaptation to conglomerates is cooperation in form of mergers between companies within the geographical location of the ski areas, or between neighboring areas. The aim with the merger is to reduce the operational and marketing cost, or having the accommodation sector helping with the investment costs of snow production for examples (Marty 2011). Providing one ski pass for several neighboring areas is a form of cooperation that benefits the single ski area and potentially increasing the number of skiers in the area. Another form of collaboration that may be very important in the future is between small close to city ski areas and large ski resorts. The larger ski resorts can nurse the future interest of skiing by supporting or running a close to city ski area, where it also can market the resort (Marty 2011). This will become very important since the ski areas close to where most people live will be most affected by future climate change (Scott and McBoyle 2006) and the interest of skiing is predicted to decrease in the future (Pouta, Neuvonen, and Sievänen 2009; Scott and McBoyle 2006). The large company Skistar owns Hammarbybacken the only alpine ski area in Stockholm nursing the alpine interest in the capital of Sweden (Skistar n.d.). Årefjällsloppet, a ski race in northern Sweden did the same for cross-country skiing when they provided a machine-made snow ski track in central Stockholm (Årefjällsloppet n.d.).

Diversification of income

A way of reducing the vulnerability to climate change and poor snow conditions is to diversify the source of income, and be less dependent on the income from skiing or the winter season. In US, the revenue from lift tickets in alpine ski resorts represented 80% of the total revenue in 1974-1975, a share that had declined to 47% in 2001-2002 (Scott and McBoyle 2006). Other activities that requires less snow such as hiking, snow showing, tobogganing (Marty 2011) skating, indoor pools, fitness centers, spa and health centers, restaurants and retail stores have been increasing in importance for ski resorts (Scott and McBoyle 2006). Many ski areas have also become or are also striving after becoming all year around resorts, providing activities such as mountain biking, water sports and paragliding to name a few, in order to reduce the dependency on the winter season (Scott and McBoyle 2006). For Cross-county skiing areas also roller ski tracks and indoor ski tunnels are summer diversification, see appendix.

"Politically" adaptation, adjusting the competition schedule of cross-country skiing

The timing and the length of the competitive cross-country season is not entirely determined by climatic factors and snow distribution, instead TV broadcasting plays an important part. The TV broadcasting advocates for an early start of the world cup season in November, to fill out the TV schedule in the early winter. This force the world cup races to take place in the very northern parts of Scandinavia, the only places that usually have abundant snow and cold conditions during that time. This leads to events with few spectators, due to the low population density of those areas and the unattractiveness to travel to those places where the sun barely rises over the horizon at that time of the year. Resulting in events that have hard time to break financially even (Kristiansen 2015). In a future with a warmer climate, more races have to move further north, resulting in more events with fewer spectators and a decreasing interest for skiing as a result.

A snowball effect of the broadcaster companies pushing for an early start is that the smaller races serving as national qualification for the world cup have to move earlier as well. For example, the opening race in Norway, Beitosprinten in Beitostølen was arranged the 28th of November in 1988 (skihistorie n.d.), in 2015 the same race was held on the 13-15th of November (Langrenn 2015). A difference with about two week despite that the climate changes is making an early start of the season less predictable. In 2011, the race in Beitostølen was canceled and in 2015 they were close to having to cancel the race, and used geotextiles borrowed from Gielo to prevent the little snow they had from melting (Sveriges Radio 2015).

Adaptation case study; winter Olympics

The greatest symbol for winter sport is the winter Olympics. Recent host of the winter Olympic games have struggled with unfavorable climate conditions for winter sport (Scott et al. 2014), In a future of raising temperatures from climate change, what is the faith of the winter Olympics? An analyze of the maximum average high February temperatures at the Olympic venues show that the temperature have increased from 0.4 °C in the host venues in 1920s-1950s compare to 7.8 °C in the 2000s-2010s host venues (Scott et al. 2014). This temperature change of 7.4 °C is larger than the observed global temperature change during the same time (Stocker et al. 2013), indicating that the International Olympic Committee (IOC) have awarded the games to warmer host locations. Without all the adaption techniques available today, this would have been impossible (Scott et al. 2014). Analysis of the effects of future climate change on winter Olympics host venues indicating that in a high emission scenarios, only 6/19 of the previous host venues would be able to hold the Olympics in the 2080s, even with today's available adaptations techniques (Scott et al. 2014). This is limiting the potential distribution of the games to future snow safe location jeopardizing the global distribution and interest in winter sports. The IOC have encouraged environmental and climate sound games and the most recent host have claimed to host carbon neutral games, mainly by buying carbon credits (Scott et al. 2014). Maybe IOC should also choose host with more suitable winter conditions, than the last winter games in Sochi.

The winter Olympics in Sochi 2014 was the warmest location ever to host a winter Olympics up to date. The skiing venues were placed in the Caucasus Mountains where temperature were colder, but still, with unsecure snow predictability (NBCnews 2014). To be able to guarantee enough snow for the competition, the Olympic hosts invested in an enormous ambitious snow program. The program involved three steps; snowmaking with traditional snow guns, snowmaking with three snow towers (so called snow factories) producing snow in up to +15 C° and storing of 500,000 cubic meters of snow produced the previous winter (Sonne 2013). 450 snowmaking station completely computer automated for optimizing snow production with a pumping capacity of 2750 m^3 high pressurized water per hour were used (SMI at Rosa Khutor Russia n.d.). The water was also cooled to near freezing and bacteria proteins were added to the water to provide improved nucleation capacity. In this way they were maximizing the snow production in otherwise tricky warm and humid conditions. This made it possible to produce 1.3 million cubic meters of snow, enough to cover 1000 football fields under 30 cm of snow (Fountain 2014). 500,000 cubic meters of snow from previous winters were stored in piles under geotextiles with reflective properties in the Caucasus Mountains over the summer. This served as a backup if no natural snow would come, or if it would be too warm to produce enough artificial snow. Most of this snow was not used, except for a small layer providing the base for the newly produced snow (Sonne 2013).

Climate change mitigations and skiing

There is plenty of literature accessible on climate adaptation within the ski industry but there are much less focus on one of the most important adaptation efforts, climate change mitigation. Ski tourism have considerable emissions of greenhouse gases, especially if snowmaking is involved, simultaneously they are also one of the most vulnerable sectors to global warming (Simpson et al. 2008). Therefore, they should be interested in lowering their emissions of greenhouse gasses, by reducing their carbon footprint. In US, 28 ski resorts have started purchase 100% of their electricity from renewable sources to lower their carbon footprint. And Aspen Ski Company have gone even further and committing itself to GHG accounting and a 10% emission reduction by constructing renewable solar and hydro plants and swapping the fuel in the snow groomers to bio diesel (Simpson et al. 2008). It is clear that these reductions on a global scale are tiny, but they send out a message of responsibility and might give those destinations a competitive advantage, attracting future costumers. There are different labels and certification for a climate friendly ski resort to achieve, and on the booking site 'TripAdvisor', certified businesses were 20% more frequently booked (Birch 2015). Most of the emissions associated with ski tourism derive from the transportation to and from the resort. 75% of the emissions from alpine tourism in the Alps are caused by the transportation. An important part of the mitigation for the ski resorts are therefore to provide low emission transportation alternatives for the tourists (CIPRA International 2011). Another way of encouraging mitigation within ski tourism is the creation of groups such as '*Protect our winters'* and '*Save our Snow'* that communicate the effects of climate change on winter sport in order to mobilize people found of winter sport to mitigate climate change (Save Our Snow n.d.) (Protect Our Winters n.d.).

Method

In order to investigate the effects of climate change on ski areas a survey were constructed and delivered to ski areas in Northern Europe. There are many areas in northern Europe that provide groomed ski tracks. In Sweden alone there are 1651 registered ski tracks (Kjällbring 2016). Most of the ski tracks are situated in small villages with relative few users. To include all or most of them in a survey would be beyond the scope of this study. The target of the survey is therefore the medium and large sized ski area, mostly situated next to cities or in popular tourism destinations. The ski areas and resorts selected for participating in the survey were purposefully sampled to represent certain types of ski areas and resorts.

- Large sized ski resorts for tourists
- Medium to small sized ski resorts for tourists
- Large sized ski areas located next to cities
- Medium sized ski areas located next to cities
- Ski areas hosting large competitions with advanced climate adaptation measures.

By purposely sampling these types of ski areas it is possible to include the largest and most advanced cross-country ski areas in northern Europe. Those ski areas should be in the forefront of climate change adaptation and therefore it is interesting to investigate their adaptation techniques. Further on, the difference in tourist ski resorts and close to city ski areas are that tourist ski resorts mostly are privately owned and close to city ski areas are public owned. Public and private ski areas are likely to have different challenges associated with climate change and are therefore interesting to separate (Pouta, Neuvonen, and Sievänen 2009). Therefore, two subgroups of public and private ski areas were created for further analysis (see below). Grothmann and Patt (2005) stated that size and amount of recourses are important factors to determine adaptive capacity, something that (Scott and McBoyle 2006) also concluded matters in alpine ski resorts. Therefore, larger and medium to small ski resort were also separated into different subgroups for further analysis. The grouping in southern and northern ski areas is based on the existing differences in snow conditions and the future expected difference in climate changes, with larger impacts for the southern regions (European Environment Agency 2009). The pressure of hosting large races on specific dates calls for advanced climate change adaption actions in order to cope with climate variability and ongoing climate change (Færaas et al. 2016). Ski areas hosting large international races were purposely selected and analyzed against the subgroup that didn't host large international races, to analyze differences in climate change adaption between the two.

The survey was delivered by calling the targeted ski area to obtain the most suitable person for answering the survey at the ski area. The ski area decided themselves who were most suitable and no specific work positions were asked for. Since the questions were asked about the ski area and not about the person, the role of the informant was of less importance as long as he or she had knowledge about the area. Once the right person was obtained, he or she was informed about the study and the survey was delivered to the respondents email by the survey program SurveyXact. In total 67 ski areas were selected for the survey out of which 45 completed the survey, four places partially completed the survey and 16 didn't answer the survey and for two places the survey couldn't be delivered for various reasons.

Answered

Sweden (19)	Norway (12)	Finland (6)	Estonia (7)
Östersund ski stadium	Birkebinerrenet	Voukatti sport center	Alutaguse
Idrefjäll	Lillehammer ski stadium	Ruka	Tehvandi, Otepää
Högbo bruk	Myrkdalen ski center	Rovanniemi	Joulumae
Orsa Grönklit	Sauda ski center	Olos (Munio)	Tartu marathon
Vasaloppet	Trysil	Kontiolahti cold ski track biathlon stadium	Pirita, Tallinn
Bruksvallarna	Skeikampen	Imatra ski stadium	Nõmme U, Tallin
Vålådalen	Beitostølen ski stadium		Tähtvere Spordipark, Tartu
Edsåsdalen	Dombås Ski center		
Harsa	Alta ski stadium		
Gellervare ski stadium	Granåsen ski stadium, Trondheim		
Hemavan Tärnaby	Storås ski stadium		
Borås ski stadium	Holmenkollen ski stadium, Oslo		
Billinge ski stadium, Skövde			
Landvetter ski stadium			
Falun Lugnet ski stadium			
Umeå ski stadium			
Torsby ski stadium			
Ulricehamn ski stadium			
Tranemo Ski stadium			

Partly Answered

Sweden (1)	Norway (1)	Finland (3)	Estonia (0)
Kiruna ski stadium	Kjölen Sport Center	Lahti	-
		Ylläs	
		Levi	

Not Answered

Sweden (7)	Norway (5)	Finland (6)	Estonia (0)
Säfsen	Sjusøen ski stadium	Laajavouri ski stadium, Jyväskylä	-
Långberget	Konnerud ski stadium, Drammen	Vanataa ski area, Helsinki	
Söderhamn ski stadium	Tromsö ski stadium	Vierumaki ski area	
Piteå ski stadium	Gielo	Lempäälä ski area	
Sundsvall Södra Berget ski stadium	Gålå *	Finlandialoppet	
Skellefteå ski stadium		Paloheinä Recreational Centre, Helsinki *	
Stockholm Gärdet ski area			

*Table 2: List of target ski areas by country, which completed, partly completed or did not complete the survey. * Indicates unable to deliver survey.*

Figure 14: Map of study area and all 67 targeted ski areas. Yellow star indicating completed survey, purple star partly completed survey and red star indicating not completed survey or unable to deliver survey.

In the appendix the raw material result from the survey is presented, with some additional tables generated. The result have been recalculated and edited in a few ways in order to eliminate a few misunderstandings and some currency discrepancy. Some answers in one category could be placed in another category after reading and analyzing the text of the other answers. Two outliers were removed after investigating the potential of truth in the answer. One was for visitors and cross country visitors, where a ski area claimed to have too high numbers of visitors compared to the literature confirmed (Hemavan Tärnaby 2015). In the other case there was a smaller ski area in Estonia which claimed to have spent 35M € on onetime climate change adaptation investments for cross-country skiing during the last 20 years. That number is 4.5 times larger than the second highest, which is a large ski area known for its advanced climate change adaptations including a ski tunnel. Therefore, it seems to be highly unrealistic for that number to be correct and it was therefore eliminated from further analysis. The Norwegian and Swedish ski areas have been recalculated to Euros in order to fit with the results from the Finish and Estonian ski areas using the exchange rate of 0,106173017 Swedish kronor (SEK) per Euro (Currency Converter - Google Finance 2016). Since the value of the currency of Norwegian kronor (NOK) and SEK where almost identical at the time, the same exchange rate were used for both. The elevation was also added afterwards to each location by using Google Earth to track down the ski areas, and read off the elevation. The elevation of the ski area is important since it affects the climate and was used to group in ski areas in warmer and colder areas. All ski areas below the latitude of 63 degrees N (which are the middle of Northern Europe) and below the elevation of 500 meters above sea level were categorized as southern, warmer areas. Where the rest were categorized as colder more northern areas in order to carry out comparison between them.

Another categorization was made dividing the ski areas into if they host large ski races or not. Ski areas hosting large races have to be modern and should be advanced in climate change adaptation, therefore of interest to analyze as a sub group. The definition for a large ski races include hosting the World cup, Scandinavian cup, Worldloppet races or season opening races before the first world cup (which usually attracts skiers from all over the world). Also large races in Biathlon were included such as the World cup and the IBU cup. The ski areas that have hosted any of these races during the last ten years or are scheduled to host one of these races in 2016/2017 were included (FIS-Ski 2016; International Biathlon Union - IBU 2016; Worldloppet n.d.).

Based on the answers in the survey, two further sub-groups were made based on ownership and size of the ski area. The ownership was based out of one of the survey questions, were the ski areas categorized themselves into public, private or other ownership. The group with other ownership is quite diverse including non-profit association of the large marathon races other associations or foundations. There are a few places with both public and private ownership, especially common in Finland, where the ski area could be public but the machine-made snow production and the machine-made snow tracks were run by a private company. Because of the diversity of the other group, this sub-group is not used in any analysis.

The size of ski areas was based on two things, the number of cross-country visitors and the stated turnover or cost of operation. The upper one third in both of these categories were included in the group larger ski areas. The reason behind using this combination of attributes to differentiate size has its origin in that a few respondents misunderstood the question of estimating the number of visitor days at your resort. Instead, they reported the number of days per year they have visitors, leaving a few ski areas with no data on number of visitors. A combination of cross-country visitors and turnover renders a good mix of the most frequently visited cross-country places and the large places based turnover, which in most cases also are the ones with most cross-country visitors. Additionally, one ski resort also purposely left out its turnover because they didn't wanted it to be public. This is an area that was within the top third on cross-country visitors, which in a list solely based on turnover would have been left out as a larger area. The ski areas that are in the category smaller ski areas are not actually small, rather medium in size. They are only small in comparison to the largest ski area. One should bear in mind that the largest ski areas in Northern Europe were purposely selected for this study among other medium sized ski areas providing a complementary mix based of geographically location, ownership and ones hosting large races. The categorization of the different ski areas is presented in the appendix.

The answers from the survey were made into tables, using categorization and frequency of answer. Further on, the minimum, maximum, median and average values were calculated for all the numeric values. In case statistical analyses were possible and relevant it was performed. The small sample size interfered with the recommended rule that a chi-square test shouldn't have more than 20% of the cells with an expected frequency of less than five (The Pennsylvania State University 2016), limiting the number of chi-square test that could be performed. Additional a linear regression analysis was also performed. In the appendix, complementary data, figures and tables are situated. In addition to the appendix, the whole data set is added as a digital supplementary file, providing information about complete answers for each individual ski area.

Analysis

The ski areas

The person considered best suitable to answer at the ski area answered the survey. In most cases, it was the manager or leader of the area, municipal manager of leisure activates in the area, the ski track manger, collaboration with the above mentioned or another person who managed to cover the broad content included in the survey. The average respondent has worked at the area in 10 years and within the field of skiing for 15 years (median).

In table 3, among the 49 ski areas that completed or partly completed the survey, 49.0% (24) were public areas, 30.6% (15) were private owned areas and the rest 20.4% (10) had other ownership. All ski areas except one stated that they had other activities at the ski area than cross-country skiing. Most common other activities were running, biking, hiking, roller skiing and downhill skiing respectively. Out of the other options, biathlon, ski jumping, orienteering and other outdoor activities were most common. The ski areas turnover or cost of operation for public areas were on average 1 881 535€ with a median of 298 642€ with about 30% of the areas having a turnover above 1 000 000€ and about 16% above 5 000 000€. There are differences in the turnover between the various subgroups displayed in table A20 in the appendix. Among ownership differences, the public group has a much smaller turnover compared to the private group, which have a smaller turnover than the other ownership group. The subgroup 'larger ski areas' have not surprisingly larger turnover compared to the 'smaller ski areas'. The 'northern ski areas' located more north or at higher elevation also have a higher turnover compared to the more 'southern ski areas', while there is no real difference between the group hosting large races or the one that do not.

Ownership	Frequency (Number of respondents) (49)
Public	49.0% (24)
Private	30.6% (15)
Other	20.4% (10)
Activities other than cross-country skiing at the area (49)	(49)
Running	85.7% (42)
Biking	75.5% (37)
Hiking	63.3% (31)
Roller skiing	55.1% (27)
Downhill skiing	44.9% (22)
None	2.0% (1)
Other	57.1% (28)
Turnover/Cost of operation (Public) in Euro	(44)
0-100000	18,2% (8)
100001-250000	25,0% (11)
250001-500000	20,5% (9)
500001-1000000	6,8% (3)
1000001-5000000	13,6% (6)
>5000000	15,9% (7)
Median	298642
Average	1881535
Max	13802492
Min	5309

Table 3: Displays facts about the ski areas responding to the survey

The ski areas were asked to estimate how many visits or visitor days per year they have (one person staying two days is two visitor days). 38.1% (16) of the ski areas have relative few visitor days (less than 50 000), although there were also 33.3% (14) of the places that had more than 200 000 visitor days. It is a large spread with a median of 95 000 visitor days and an average value of 240 405 days. By comparing different sub-groups' number of visits (see table A8 in the appendix) one can conclude that the median for private ski areas visitors are higher compared to the public ski areas which in turn is higher than the group 'other'. Larger areas have significant more visitors than the smaller areas. The group hosting large races and the northern group have slightly more visitors than their counterparts. The respondent were also asked how certain they were about this number (see table A9 in the appendix). About half of the respondents are certain or quite certain about their number, about one third of the respondents are medium and about one sixth of the respondents are not very certain or not certain. Further on, the respondents had to state the percentage of those visitors that were from cross-country skiing. The range was from 3-97% and on average approximately 40% of the ski areas' visitors were from cross-country skiing, quite evenly spread out in the 20% ranges (see table A10 in the appendix). Again, the respondents had to state their certainty of this number. The frequency of responses is similar to the certainty of total visits except that there are more answers in the medium certain category and less in the certain and not certain category (see table A11 in the appendix). The fact that less than half of the ski areas are certain about the number of cross-country skiers they have isn't really that strange since only about half of the ski areas have a method for calculate skiers (table A14 in the appendix). The most common methods are to see how many track passes are sold, hotel nights, survey and by counters in the ski track. Private ski areas are better at counting cross-country skiers than the public ski areas are.

Although, with some uncertainty about the number of estimated cross-country skiing visits, each ski areas' visits were calculated and presented in table 4. Most ski areas, 40.5% (17), have less the 25 000 cross-country skiing visits per year and 23.8% (10) were also in the lower range of 25 001 – 50 000, while 19% had as much as 100 000 or more, with a maximum value of 600 000 cross-country skiing visits per year. When comparing the different sub groups and their number of cross-country visits in table A13 in the appendix, it is possible to see that they follow the exact same pattern as for the total visitors presented above, except that there is not possible to conclude any difference of cross-country skiing visitors in the group hosting large races and the one that do not.

The ski areas were further asked if most of their visitors came from further than 100 km and if they were staying two days or more at the time. Differentiating between ski areas closer to where people live and ski areas that are visited during weekends and holidays. The result in table 4 conclude that there are about half of each kind in this study.

Visitors any type/year range	(42)
0-50000	38,1% (16)
50001-100000	23,8% (10)
100001-150000	4,8% (2)
150001-200000	0,0% (0)
>200000	33,3% (14)
Median	95000
Average	240405
Max	1000000
Min	3000
Cross-country skiing visitors/year range	(42)
0-25000	40,5% (17)
25001-50000	23,8% (10)
50001-75000	9,5% (4)
75001-100000	7,1% (3)
>100000	19,0% (8)
Median	32500
Average	73312
Max	600000
Min	2500
> 75 % of visitors staying for two days or more at the time	(49)
Yes	49% (24)
No	44.9% (22)
Don't Know	6.1% (3)
> 75 % of visitors from further then 100km away	(49)
Yes	46.9% (23)
No	46.9% (23)
Don't Know	6.1% (3)

Table 4: Displays facts about the ski areas responding to the survey

The ski areas were asked to state how dependent their turnover is from the winter season and from cross-country skiing; to estimate how vulnerable the ski areas are to a changing climate and fewer days with snow. Seen in table 5, most of the ski areas state that they are 60-80% dependent of the winter season with similar frequency on the other 20% ranges. Although there are large variations in the subgroups, private areas are much more dependent than public areas are and about half of them state that 80-100% of their turnover comes from the winter season. The dependency difference was tested in a chi-square test by grouping the 0-60% into one group and 60-100% into another group. The calculated chi-square indicated a very strong statistical difference (P-value<0.001). The null-hypothesis, that there is no difference within dependency of winter season between the groups, can therefore be rejected. For dependency of cross-country skiing the statistical difference is weaker (p-value of 0.127) between the groups. Smaller ski areas state a higher dependency of the winter season compare to the larger ski areas. The chi-square test although indicate no strong statistical difference between the groups for dependency of winter season, (p-value of 0.295) or dependency of cross-country skiing (p-value of 0.239). The group that is most dependent is smaller private ski areas (table 6) where 71.4% of those areas are almost entirely dependent of the winter season. The same table also indicates that there is more difference between public and private than between the sizes of the ski area. There are only small differences between the other groups where northern areas are little more dependent than southern ski areas as well as areas that don't host large races are more dependent than the ski areas that are hosting large races. On average, the ski areas are not as dependent on cross-country skiing as they are on the winter season. This is not so surprising since most ski areas have other winter activities. The subgroups follow the same pattern for cross-country skiers as for dependency on the winter season. Within the most dependent sub groups, about a quarter of the ski areas state that their turnover is almost entirely dependent on cross-country skiing.

		How dependent are your ski resort/area's turnover from the winter season, all activities included?	How dependent are your ski resort's/area's turnover from cross-country skiing?
All respondents (45)	0-20%	20.0% (9)	37.8% (17)
	20-40%	13.3% (6)	20.0% (9)
	40-60%	17.8% (8)	13.3% (6)
	60-80%	28.9% (13)	11.1% (5)
	80-100%	20.0% (9)	17.8% (8)
Public owned (22)	0-20%	31.8% (7)	45.5% (10)
	20-40%	22.7% (5)	27.3% (6)
	40-60%	22.7% (5)	4.5% (1)
	60-80%	13.6% (3)	4.5% (1)
	80-100%	9.1% (2)	18.2% (4)
Private owned (13)	0-20%	7.7% (1)	38.5% (5)
	20-40%	0.0% (0)	7.7% (1)
	40-60%	7.7% (1)	15.4% (2)
	60-80%	38.5% (5)	15.4% (2)
	80-100%	46.2% (6)	23.1% (3)
Larger ski areas (22)	0-20%	22.7% (5)	45.5% (10)
	20-40%	9.1% (2)	18.2% (4)
	40-60%	27.3% (6)	18.2% (4)
	60-80%	31.8% (7)	4.5% (1)
	80-100%	9.1% (2)	13.3% (6)
Smaller ski areas (23)	0-20%	17.4% (4)	30.4% (7)
	20-40%	17.4% (4)	21.7% (5)
	40-60%	8.7% (2)	8.7% (2)
	60-80%	26.1% (6)	17.4% (4)
	80-100%	30.4% (7)	21.7% (5)
Hosting large races (21)	0-20%	28.6% (6)	33.3% (7)
	20-40%	9.5% (2)	23.8% (5)
	40-60%	19.9% (4)	9.5% (2)
	60-80%	33.3% (7)	19.0% (4)
	80-100%	9.5% (2)	14.3% (3)
Don’t hosting large races (24)	0-20%	12.5% (3)	41.7% (10)
	20-40%	16.7% (4)	16.7% (4)
	40-60%	16.7% (4)	16.7% (4)
	60-80%	25.0% (6)	4.2% (1)
	80-100%	29.2% (7)	20.8% (5)
Northern (20)	0-20%	20.0% (4)	45.0% (9)
	20-40%	5.0% (1)	15.0% (3)
	40-60%	15.0% (3)	15.0% (3)
	60-80%	35.0% (7)	10.0% (2)
	80-100%	25.0% (5)	15.0% (3)
Southern (25)	0-20%	20.0% (5)	32.0% (8)
	20-40%	20.0% (5)	24.0% (6)
	40-60%	20.0% (5)	12.0% (3)
	60-80%	24.0% (6)	12.0% (3)
	80-100%	16.0% (4)	20.0% (5)

Table 5: Dependency of winter season and cross-country skiing for various sub-groups of the respondents.

Larger private owned (6)	0-20%	0.0% (0)	50.0% (3)
	20-40%	0.0% (0)	0.0% (0)
	40-60%	16.7% (1)	16.7% (1)
	60-80%	66.7% (4)	16.7% (1)
	80-100%	16.7% (1)	16.7% (1)
Smaller private owned (7)	0-20%	14.3% (1)	28.6% (2)
	20-40%	0.0% (0)	14.3% (1)
	40-60%	0.0% (0)	14.3% (1)
	60-80%	14.3% (1)	14.3% (1)
	80-100%	71.4% (5)	28.6% (2)
Larger public owned (9)	0-20%	44.4% (4)	55.6% (5)
	20-40%	11.1% (1)	22.2% (2)
	40-60%	33.3% (3)	11.1% (1)
	60-80%	11.1% (1)	0.0% (0)
	80-100%	0.0% (0)	11.1% (1)
Smaller public owned (13)	0-20%	23.1% (3)	38.5% (5)
	20-40%	30.8% (4)	30.8% (4)
	40-60%	15.4% (2)	0.0% (0)
	60-80%	15.4% (2)	7.7% (1)
	80-100%	15.4% (2)	23.1% (3)

Table 6: Dependency of winter season and cross-country skiing for sub-groups of the ownership and size groups.

Perception of climate change

The ski areas were asked if and how they had noticed a changing climate in the past 20 years, and if they believed that climate change is going to affect them in the near future (1-10 years), in the far future (10-30 years), and if those effects are thought to be positive and negative. For all respondents, 80% (36), had noticed a changing climate in the past 20 years, see table 7. There is a large difference between public areas 86.4% (19) and private areas 61.5% (8) and a smaller difference between larger areas 77.3% (17) and smaller areas 82.6% (19) on how many that had noticed a chaining climate. There were no difference between the northern and the southern ski areas and almost no difference between the ski areas that hosted large races and the ones that didn't for the same question. One interesting note is that five out of 13 ski areas (38.5%) in Norway stated they hadn't notice a changing climate in the past 20 years, which are far more than the answer of all respondents (20%). Out of those ski areas that had experience a changing climate, the most common effects were higher temperatures in the winter, longer warm spells and less days with temperatures below zero degrees reducing the number of days with potential snowmaking. The increased number of days with above zero degrees and increased periods of freeze-thaw also make the tracks icier, making grooming more complicated and increasing the required frequency of grooming. The winter and snow covered season is experienced shorter; shrinking on both sides of the winter but stated to have decreased more in the autumn and early winter than the spring. The maximal snow depth is also experienced to be smaller. Many areas have experienced more precipitation during the winter, but also more frequent as rain. All areas state negative experience except one area in northern Finland that says that "mid-winter time is on average warmer, meaning more days with good XC-skiing conditions".

For the near future (1-10 years) only 77.8% (35) answer that they think that climate change will affect their ski area (table 7). It is one respondent less than that answered yes for the past 20 years. On fact, there were not just one respondent that changed their answer. Six of the respondents that answered no, on if climate change had affected them in the past changed their answer to yes, and seven that answered yes in the past changed to no for the near future (1-10 years). The difference between the public and private owned ski areas are exactly the same in the near future (1-10 years) as for the past 20 years, while the difference between the larger and the smaller ski areas are almost non-existing. There is still a small difference between the areas hosting large races and the ones that don't but now it is the opposite compared to in the past. Additionally, northern ski areas now state that they, to a smaller degree, will be affected by climate change compared to the southern ski areas. Northern ski areas also state more frequently that they believe that the effects from climate change will be positive for them in the near future (1-10 years) compared to southern areas. There are also more ski areas positive about the effects of climate change in the private compared to the public group. The situation is the same among the larger ski areas compared to the smaller ski areas and for the ski areas hosting large races compared to the ski areas that don't. Overall, among all the respondents, about three fourth of the ski areas see the effects from climate change as negative.

Further, in the far future (10-30 years), all respondents except three think that climate change will affect their ski area in the future (table 7). Also, the ski areas that believe that the effects of climate change will be positive have decreased from the nine in the near future (1-10 years) to eight respondents for the far future. Since there are only three people that don't think that there will be any effects from climate change, it is hard to conclude any differences among the sub groups. The result is similar in the far future (10-30 years) as for the near future (1-10 years) for all sub groups when asking if they think that the effects of climate change will be positive or negative. The only difference is that the ski areas don't hosting large races have become more positive and are now more positive than the ski areas hosting large races.

		Have your ski resort/area noticed a changing climate?	Do you think that climate change will affect your ski resort/area in the near future (1-10 years)? If Yes how will it affect your ski area?	Do you think that climate change will affect your ski resort/area in the far future (10-30 years)? If Yes how will it affect your ski area?
All respondent (45)	Yes	80.0% (36)	77.8% (35)	93.3% (42)
	No	20.0% (9)	22.2% (10)	6.7% (3)
	Positive		25.7% (9)	19.0% (8)
	Negative		74.3% (26)	81.0% (34)
Public owned (22)	Yes	86.4% (19)	86.4% (19)	100% (22)
	No	13.6% (3)	13.6% (3)	0% (0)
	Positive		15.8% (3)	9.1% (2)
	Negative		84.2% (16)	90.9% (19)
Private owned (13)	Yes	61.5% (8)	61.5% (8)	76.9% (10)
	No	38.5% (5)	38.5% (5)	23.1% (3)
	Positive		37.5% (3)	30.0% (3)
	Negative		62.5% (5)	70.0% (7)
Larger ski areas (22)	Yes	77.3% (17)	77.3% (17)	100% (22)
	No	22.7% (5)	22.7% (5)	0% (0)
	Positive		35.3% (6)	22.7% (5)
	Negative		64.7% (11)	77.3% (17)
Smaller ski areas (23)	Yes	82.6% (19)	78.3% (17)	87.0% (20)
	No	17.4% (4)	21.7% (5)	13.0% (2)
	Positive		16.7% (3)	15.0% (3)
	Negative		83.3% (15)	85.0% (17)
Hosting large races (21)	Yes	81.0% (17)	76.2% (16)	95.2% (20)
	No	19.0% (4)	23.8% (5)	4.8% (1)
	Positive		37.5% (6)	15.0% (3)
	Negative		62.5% (10)	85.0% (17)
Don’t hosting large races (24)	Yes	79.2 % (19)	79.2 % (19)	91.7% (22)
	No	20.8% (5)	20.8% (5)	8.3% (2)
	Positive		15.8% (3)	22.7% (5)
	Negative		84.2% (16)	77.3% (17)
Northern (20)	Yes	80.0% (16)	75.0% (15)	95.0% (19)
	No	20.0% (4)	25.0% (5)	5.0% (1)
	Positive		33.3% (5)	26.3% (5)
	Negative		66.7% (10)	73.7% (14)
Southern (25)	Yes	80.0% (20)	80.0% (20)	92.0% (23)
	No	20.0% (5)	20.0% (5)	8.0% (2)
	Positive		20.0% (4)	13.0% (3)
	Negative		80% (16)	87.0% (20)

Table 7: Comparison of perception of climate change for all and various sub-groups of the respondents.

Climate change adaption

The ski areas that stated they had notice a changing climate in the past were asked if they had done any climate change adaptation for cross-country skiing (see table 8). Almost all of the respondents stated that they had done some adaptation action during the past 20 years. All ski areas were then asked if they are planning any climate change adaptation for cross-county skiing in the near future (1-10 years) and in the far future (10-30 years). Two thirds of all the respondents stated that they had planned climate change adaptation in the near future (1-10 years). For the far future (10-30 years), only 13,3% (6) respondents stated that they are planning climate change adaptation for cross-country skiing, where the most answered that they don't know. There are some differences between the subgroups; the larger ski areas stated that they had done more of climate change adaptation in the past than the smaller ski areas. A majority of the private ski areas, 84.6% (11), stated that they are planning adaptation in the near future (1-10 years) compared to only 63.6% (14) of the public ski areas. Among the larger ski areas, as many as 90.9% (20) are planning adaptation actions compare to only 60.9% (14) for the smaller ski areas. A chi-square test grouping 'no' and 'don't know' answers together confirms with strong statistical significance (p-value of 0.019) that there is a difference between larger and smaller ski areas in this area. There is harder to detect any differences among the sub groups in the far future (10-30 years) since most respondents have answered 'don't know', the signal look however similar to the one in the near future (1-10 years). There was no obvious signal for any difference for the north/south groups or the group hosting large competitions or not, see table A65 in the appendix.

Out of the 33 respondents that answered that they had done some climate change adaptation for cross-country skiing, two changed answer to 'no' for the near future and additional four changed to no in the far future. Five changed answer to 'don't know' in the near future. Seven new 'yes' were recorded in the near future from respondents that didn't answer the question if they had done any adaptation in the past since they answered 'no' on if they had noticed any climate change. Out of those new yes answers in the near future, two answered also yes in the far future. The rest four yes answers in the far future are from respondents answering yes in the past and the near future. One respondent that answered no to climate change adaptation in the past answered yes in the near future. The other changes were that many who answered yes and no in the beginning changed to don't know, which become more common in the far future.

		Have your ski resort/area taken any actions to adapt to a changing climate during the last 20 years?	Is your ski resort/area planning on doing any investments in the near future (1-10 year) to adapt to a changing climate?	Is your ski resort/area planning on doing any investments in the far future (10-30 year) to adapt to a changing climate?
All respondents	Yes	91.7% (33)	75.6% (34)	13.3% (6)
	No	8.3% (3)	8.9% (4)	17.8% (8)
	Don't know	-	15.6% (7)	68.9% (31)
	Total	100% (36)	100% (45)	100% (45)
Public ski areas	Yes	89.5% (17)	63.6% (14)	13.6% (3)
	No	10.5% (2)	13.6% (3)	18.2% (4)
	Don't know	-	22.7% (5)	68.2% (15)
	Total	100% (19)	100% (22)	100% (22)
Private ski areas	Yes	87.5% (7)	84.6% (11)	15.4% (2)
	No	12.5 (1)	0.0% (0)	7.7% (1)
	Don't know	-	15.4% (2)	76.9% (10)
	Total	100% (8)	100% (13)	100% (13)
Larger ski areas	Yes	94.1% (16)	90.9% (20)	18.2% (4)
	No	5.9% (1)	4.5% (1)	22.7% (5)
	Don't know	-	4.5% (1)	59.1% (13)
	Total	100% (17)	100 % (22)	100% (22)
Smaller ski areas	Yes	89.5% (17)	60.9% (14)	8.7% (2)
	No	10.5% (2)	13.0% (3)	13.0% (3)
	Don't know	-	26.1% (6)	78.3% (18)
	Total	100% (19)	100% (23)	100% (23)

Table 8: Adaptation of cross-country skiing to a chaining climate, in the past (previous 20 years), in the near future (1-10 years ahead) and in the far future (10-30) for all respondents and subgroups.

In table 9 below, it is possible to see what types of adaptation actions ski areas have done to adapt cross-country skiing to a chaining climate. Out of the 33 that stated that they had done some adaptation actions, the most common adaptation action was trail improvement (90.9%) to make the ground smoother or relocation of track to a more snow safe location to reduce the amount snow needed for skiing. Second most common were to produce machine-made snow (87.9%), followed by gathering knowledge and education (75.8 %), storing snow over the summer (snow farming) (48.5 %), trucking snow from other locations (33.3%), merger and cooperation with other ski resorts (30.3%), installing smart snow system (27.3%) and other adaptations (24.2%). Answers in other adaptation includes ski tunnels (2), cooling system under the ground (2), cooling system for the water to produce machine-made snow in warmer temperatures, improved drainage to cope with more rainfall and investment planning for the future. In the near future (1-10 year), fewer respondents plan to invest in trail improvement (64.7%) and snowmaking (73.5%) but more of the respondents plan to invest in smart snow systems 52.9% (18), snow farming 50.0% (17) and other solutions 38.2% (13) compared to the past. Some of the other solutions for the near future are new water supply system (2), cooling system, water cooling system, upgrade of equipment, a mobile snow production system, making a ski hall with other sports included or invest in off-snow ski training facilities. There are eight new places that state that they will do adaptation actions in the future that did not do this in the past. Out of those, six will invest in trail improvement and snow making equipment, five will invest in smart snow system and three will invest in snow storage and other solutions.

A comparison of how different sub-groups differ in their adaptation actions (table A66 and A67 in the appendix) conclude that private ski areas tend to invest more in smart snow system and snow farming and take part more in cooperation and merger than public ski areas do. Public ski areas although states that they have invested more in gathering knowledge and education than the private areas. The larger ski areas have done more adaptation action and are planning to do more than the smaller in every aspect expect investing in snowmaking equipment. There are some interesting differences between the northern or high elevation areas and the southern areas. Northern areas state that they have done more climate change adaptation by producing machine-made snow than they have done trail improvement, which is opposite compared to the southern areas. Although in the near future, this is reversed and northern areas are planning to do more trail improvement than they are planning to invest in snowmaking equipment, while the southern areas have the opposite strategy. Most of the snow farming take place in the northern group where 10/15 have done snow farming in the past and 11/16 plan to do it in the near future, compare to 6/18 in the southern group for the past and the near future. The difference is even larger between the host large races group and the group that don't host large races. 11/16 in the host large races group have done snow farming in the past and is planning to do so in the near future (1-10 year) compared to only 5/17 in the past and 6/18 in the near future. The northern and hosting large races group also states that they truck snow from other locations more than their counter parts. The adaptation actions in the far future have very few respondents, but all that answers state that they tend to invest in smart snow system, which is not that commonly used today by the respondents. The respondents were also asked to state the approximate volume machine-made snow they produce, and how much they store over the summer. In the appendix, tables indicate how much snow the ski areas are producing and saving. Most ski areas (57.7%) produce smaller amounts of machine made snow, <20 000 cubic meters, although 15.4% of the ski areas produce as much as over 50 000 cubic meters. The range is between 2 000-300 000 cubic meters and with a median of 20 000 cubic meters. The stored snow for snow farming in the past range between 8 000-60 000 cubic meters and the median is 22 500 cubic meters. The planed volumes for the near future (1-10 years) has grown to a range between 10 000-100 000 with a median of 30 000 cubic meters of snow.

		What kind of action have your ski resort/area taken in order to adapt to a changing climate during the past 20 years? Answer all that applies.		What kind of investments are your ski resort/area planning in order to adapt to a changing climate during in the near future (1-10 years)? Answer all that applies.	What kind of investments are your ski resort/area planning in order to adapt to a changing climate during in the far future (10-30 years)? Answer all that applies.
All respondents	Trail improvement	90.9% (30)	Invest in snowmaking	73.5% (25)	83.3% (5)
	Making machine-made snow	87.9% (29)	Trail improvement	64.7% (22)	100% (6)
	Knowledge/Education	75.8% (25)	Smart snow system	52.9% (18)	100% (6)
	Storing snow	48.5% (16)	Storing snow	50.0% (17)	33.3% (2)
	Trucking snow	33.3% (11)	-	-	-
	Merger and cooperation	30.3% (10)	-	-	-
	Smart snow system	27.3% (9)	-	-	-
	Other	24.2% (8)	Other	38.2% (13)	0.0% (0)
	Total respondents	(33)		(34)	(6)

Table 9: Display what types of climate change adaptation actions ski areas have taken in the past 20 years and what they are planning to invest in the near future (1-10 years and far (10-30 years) future to adapt cross-county skiing to a changing climate. 1. Trail improvement (making the ground smoother to reduce the amount of snow needed, relocate the path of tracks to more snow safe locations), 2. Making machine-made snow, 2.5 Invest in snowmaking guns (fans or lances) 3. Installing a smart/automatic machine-made snow system for optimizing snow production, 4. Storing machine-made snow to use next season (snow farming), 5 Trucking snow from another location, 6 Gathering knowledge/education, 7. Merger and cooperation with other ski areas, 8 Other.

The cost of climate change adaptation

Most of the installed and planned climate change adaptation actions for cross-country skiing are expensive. In table 10 below, the cost for the adaptation actions is displayed. Out of those respondents that stated they have done climate change adaptations in the past 20 years, the cumulative onetime expenses ranged from 10 617-8 000 000€ with a median of 849 384€. Most ski areas have spent in the range of 100 001-1 000 000€ (12/31) and 1 000 001- 3 000 000€ (8/31). The cost for the stated near future (1-10 years) planned adaptation actions are lower (median of 515 433€) in total than the past actions, but the time scale is only the half, 10 versus 20 years, which makes the planned actions more expensive per year. The adaptation action are not just one time investment expenses but can also increase the operational cost for a ski area, for example the production of machine-made snow. All ski areas that had a onetime cost for adaptation also stated that they have increased their operational costs. The ski areas stated that they have an increased cost of operation between 2 123-637 038€ with a median of 50 000€. For the near future, not everyone stated the operational cost to increase with climate change adaptation. According to table X in the appendix, 23 respondents stated that their operational cost would increases because of their adaptation actions. One stated that the cost would decrease and ten stated that it would stay the same out of the total 34 respondent claiming they would do climate change adaptation in the near future (1-10 years). The median out of those 23 answers is 51 543€ for the stated increase in the future operational cost. This number is similar to the stated past increase in operational cost due to adaptation actions.

The large cost of adaptation actions may seem arbitrary if not set in relation to anything. The adaptation costs were therefore set in relation to the ski areas turnover or cost of operation for public areas. In table 10, these numbers vary from 0.59% - 4000.0% of the turnover for past onetime investment with a median of 159.09%. Divided by 20 years indicating that the median ski resort have a cost for onetime investment of about 8.0% of the turnover per year for cross-country skiing climate change adaptation actions. The same number is about 10% per year for the stated future onetime investments, 16.4% for the past increase in operational cost and 12.1% for the future expected increased operational costs.

Investigating table A68 and A69 in the appendix, it is possible to detect some differences in different sub groups. Both the larger and the smaller ski areas have the similar trend as the total group of respondents that their adaptation cost will increase in the future for the onetime investments. Although the larger areas have stated that their cost of operation isn't supposed to increase as much in the future as in the past. The larger ski areas have spent more money in the past and are planning to spend more money in the future on adaptation action compared to the smaller ski areas. A linear regression analysis (figure A1 in the appendix) were performed and could conclude the trend where the adaptation costs for onetime investment during the past 20 years increases by 0.094€ per increased euro in turnover, although not statistical significant (p-value > 0.05). The same analysis was made for the increase in operational cost due to the climate change adaptations actions. It showed a statistical significant relationship where, on average, the operational cost for climate change adaptation increases by 0.026€ per increased euro in turnover, see figure 15.

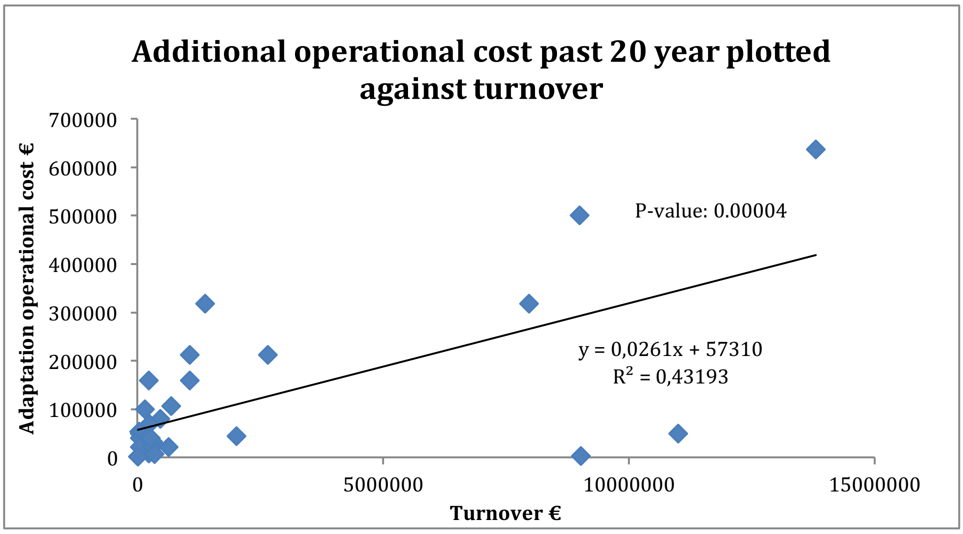

Figure 15: Cost of climate change adaptation for cross-country skiing for additional operation expenses during the last 20 years plotted against the ski areas turnover.

The fact that the larger ski areas would spend more isn't surprising at all. It is more interesting to look how much these groups spend relative to their turnover or cost of operation. It turns out that the smaller ski areas spend multiple times the percentage of the turnover compared to the larger ski areas. Comparing the median percentage of turnover for the larger and smaller ski areas indicates a difference by about six times the percentage in the past and about ten times in the future. Per year, the median smaller ski areas have spent 25.0% of the turnover in onetime investment plus 29.4% in increased operational cost in the past. Further, they are planning on spending 31.9% for onetime investments and 20.2% in increased operational cost for the future investments. Similar linear regression analyses were performed for the adaptation costs as a percentage of the turnover in relation to the ski areas turnover. Figure A5, A6, A7 and A8 in the appendix indicates that there is a trend that the higher the turnover a ski area has the lower is its cost of adaptation investment as a percentage of its turnover. The equation of the lines in the figures indicates that, on average, the onetime investments in the past for climate change adaptation actions as a percentage of the turnover decreases by 90% for every million euro the turnover increases. The increased operational costs because of those actions decreased by 4% for every million euro the ski areas turnover increases. The same percentages for the near future are a decrease by 60% and 4% for onetime investments and increased operational cost as a percentage of the turnover respectively. There is only a statistical significant trend for the increased operational adaptation cost in the past 20 years as a percentage of turnover, see figure 16.

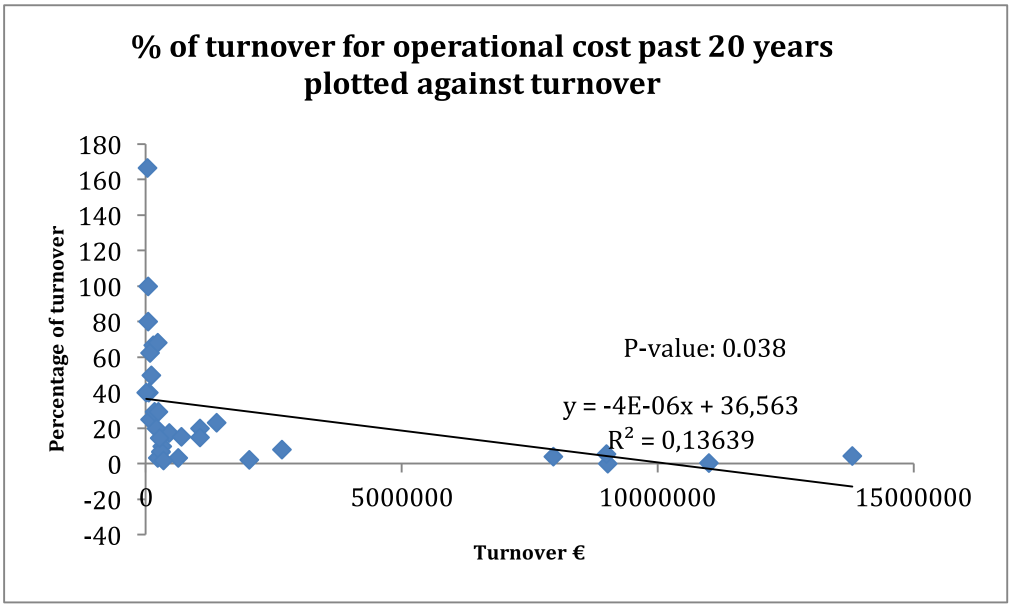

Figure 16: Cost of climate change adaptation for cross-country skiing for additional operation expenses during the last 20 years as a percentage of the ski areas turnover, plotted against the ski areas turnover.

For the following differences in adaptation costs between the subgroups, chi-square tests were carried out were possible, using 1 000 000€ and 50 000€ as a divider for onetime and increased operational cost respectively. If a difference is stronger than 95% it is stated as statistical significant. The public ski areas have stated that they have spent less on climate adaptation in the past for both cumulative cost and operational cost compared to private ski respondents. For the future planned adaptation, the expected costs are more similar between the groups. Looking at the median percentage of turnover, the public areas are spending more, although the differences are small (no chi-square possible). The ski areas that are hosting large international races have spent more on adaptation action in the past, both for onetime investments (statistical significant) and increased operational cost (not statistical significant), compared to the ski areas that don't host these races. For the planned future actions, it is more similar between the groups and the 'no races' group actually states that it will spend more on onetime investments than the 'races' group (not statistical significant). This is also obvious in the percentage of turnover spent where the 'races group' has spent more of the turnover in the past than the 'no races' group. On the other hand, the 'no races' group state it will spend more in percentage of the turnover in the future with about a ten-fold differences. The 'Southern' and 'Northern' groups state similar investments in climate change adaptation in the past, although the 'southern' group state it will spend more in the future (not statistical significant). The differences are even larger looking in percent of turnover (about five times for the turnover percentage for the median).

	Range of cumulative cost of onetime investments for climate change adaptation actions for cross-country skiing during the last 20 years in Euros	Frequency (number of respondents)	Range of expected cumulative cost for onetime investments for climate change adaptation actions for cross-country skiing in the near future (1-10 years) in Euros	Frequency (number of respondents)	Range of estimated yearly additional operational cost for climate change adaptation actions for cross-country skiing during one year of operation in Euros	Frequency (number of respondents)	Range of expected increase in yearly operational cost in the near future (1-10 years) because of planned cross-country skiing adaptation actions to a changing climate. In Euros.	Frequency (number of respondents)
All	1-100000	12.9% (4)	1-100000	21.9% (7)	1-25000	28.1% (9)	1-25000	45.5% (10)
	100001-1000000	38.7% (12)	100001-1000000	40.6% (13)	25001-50000	25.0% (8)	25001-50000	4.5% (1)
	1000001-3000000	25.8% (8)	1000001-3000000	21.9% (7)	50001-100000	18.8% (6)	50001-100000	22.7% (5)
	3000001-5000000	16.1% (5)	3000001-5000000	3.1% (1)	100001-200000	9.4% (3)	100001-200000	9.1% (2)
	>5000000	6.5% (2)	>5000000	12.5% (4)	>200000	18.8% (6)	>200000	18.2% (4)
	Total	100% (31)	Total	100% (32)	Total	100% (32)	Total	100% (22)
	Min	10617		31852		2123		2654
	Max	8000000		10617302		637038		318519
	Median	849384		515433		50000		51543
	Average	1632690		1644350		109572		82804
		% of turnover		% of turnover		% of turnover		% of turnover
	Min	0,59		3,42		0,03		0,22
	Max	4000,00		2916,67		166,67		125,00
	Median	159,09		100,00		16,39		12,08
	Average	674,06		446,34		29,39		25,27

Table 10: The frequency of responses for various ranges of expenses for climate change adaptation of cc-skiing in the past and expected expenses in the future; both cumulative expenses and operational expenses. Minimum, maximum, median and average values are also displayed below as well as for their % of the stated turnover or cost of operation.

The ski areas were also asked what they saw as the main obstacle, risk or insecurity with these future investments (see appendix for complete answers). Their answers can be divided into a few categories (number of answers in brackets).

- The insecurity about the ongoing climate change (12)
- The insecurity about decreasing interest in cross-country skiing due to for example climate change (8)
- The insecurity about funding (4)
- The insecurity about other ski areas and the competition for skiers/customers. (2)
- Not insecure because of their location or investment security (5)

The areas that worry about the climate are concerned that the climate change will be faster or stronger than believed and that it will be too warm with no snow for cross-country skiing. Many are also worried about that the temperatures will be too warm to produce machine-made snow, which many areas are relaying on today. Another concern is that it will be too expensive to produce machine-made snow in those new warmer conditions. Other respondents state concern about how they think that the interest for cross-country skiing will decrease, mostly as a result of the warmer climate or that other sports and recreational activates becomes more popular resulting in less cross-country skiers. The respondents that stated that they don't see any risk with investments are all located in the north or at higher elevation. Respondents for all countries except Norway stated that they are worried about the decreasing interested of skiing as a result of climate change.

Financing climate change adaptation

Because of the large cost of adaptation, especially as the percentage of the turnover for some groups, it is of interest to understand how they will finance those adaptations in the future. The ski areas were asked to fill in if they planned to finance their adaptation investments by private investors, public funds, track-passes or other funds. They were asked to state all the finance options that were applicable and estimate the percentage that should be received from each category. In table 11 below, it is visible that the ski areas are planning on receive most of their funding for climate change adaptation from public funds 70.7% (29), track passes 65.9% (27), private funds 53.7% (22) and other funds 24.4% (10). What is more interesting is to see how this percentage differs between various sub groups. Public areas will receive the majority of the adaptation funding from, not surprisingly, public funds. More interestingly, they also plan on some private funds. Public areas don't plan on funds from track passes as much as the total group or the private group. Private areas state they will receive most of their funding from private funds and ski passes, but also with some public and other funding. A chi-square test was performed for the public and private group and for three of the funding options, private, public and track passes. The calculated chi-square generated a p-value of 0.157, there is only 84.3% probability that null-hypothesis "there is no difference between the adaptation funding between the groups" is incorrect and can be rejected. To conclude, there is a small significance that the adaptation funding is different between the ownership groups but not a 95% or larger statistical difference ($p\text{-value}<0.05$). Smaller ski areas tend to be more diverse in the funding than larger ski areas, with high percentages in all categories. The smaller ski areas also have a large percentage of respondents that state that they will receive money from track passes, more than the average. There is however no statistical correlation for any adaptation funding difference between the larger and smaller ski areas based on a chi-square test (p-value of 0.87). It is also interesting to see the volume of funds that is estimated to come from each source. In table 12, it is possible to see that about half of the respondents don't plan to receive any funding from private funds, one forth from public funds and from track passes and three forth from other funds. Only one respondent plans to receive almost all of their funds from private investors, six ski areas almost all from public funds, three ski areas almost all from track passes and two ski areas received almost all from other funds. The average in table 12 indicates that of a ski areas funding for climate change adaptation for cross-country skiing, 42% are from public funds, 31% from track passes, 24% private funds and 11% from other funds.

	All	Public areas	Private areas	Larger areas	Smaller areas	Hosting large races	Do not host large races	Northern ski areas	Southern ski areas
Public funds	70.7% (29)	83.3% (15)	53.8% (7)	66.7% (14)	75.0% (15)	78.9% (15)	63.6% (14)	68.4% (13)	72.7% (16)
Track passes	65.9% (27)	55.6% (10)	84.6% (11)	57.1% (12)	75.0% (15)	63.2% (12)	68.2% (15)	68.4% (13)	63.6% (14)
Private investors	53.7% (22)	38.9% (7)	84.6% (11)	42.9% (9)	65.0% (13)	42.1% (8)	63.6% (14)	63.2% (12)	45.5% (10)
Other	24.4% (10)	22.2% (4)	30.8% (4)	28.6% (6)	20.0% (4)	21.1% (4)	27.3% (6)	26.3% (5)	22.7% (5)
Total respondent	41	18	13	21	20	19	22	19	22

Table 11: How the ski areas are planning to finance their adaptation actions to climate change.

	Range percentage	Private funds	Public funds	Track passes	Other funds
All	0	42.4% (14)	24.2% (8)	26.5% (9)	76.5% (26)
	0.1-20	12.1% (4)	9.1% (3)	23.5% (8)	8.8% (3)
	21-40	24.2% (8)	18.2% (6)	20.6% (7)	2.9% (1)
	41-60	9.1% (3)	18.2% (6)	14.7% (5)	5.9% (2)
	61-80	9.1% (3)	12.1% (4)	5.9% (2)	0.0% (0)
	81-100	3.0% (1)	18.2% (6)	8.8% (3)	5.9% (2)
	Total	100% (33)	100% (33)	100% (34)	100% (34)
	Median	20	40	23	0
	Average	24	42	31	11
	Max	100	100	100	100
	Min	0	0	0	0

Table 12: Future (1-10 year) funding for climate change adaptation of cross-country skiing from the four categories, private funds, public funds, track passes and other funds.

Diversification of activities

Diversification of activities is a common way of climate change adaptation within tourism (Scott and McBoyle 2006) and could have been included in the adaptation section above. However the reasons for diversification can be others than climate change and therefore the topic will be investigated below together with an investigation of the reason behind the diversification. Table 13 below show how many ski areas that have diversified their activities in the past 20 years and are planning on doing that in the near future (1-10 years). Out of the 45 respondent, about half stated that they had done some diversification in the past, with about half of the rest answered 'no' and 'don't know'. The type of diversification that were stated taken place are mainly increasing the number of sports, commonly running, mountain biking, roller skiing or different kind of events both summertime and wintertime. The respondents answered very similar for the future, both as displayed in table 13 and in the types of diversification they are planning to invest in for the future as seen in the appendix. Most of the respondents focus on increasing activates during non-winter season. Hosting events and races are another common diversification in the future. By looking in various sub-groups it is visible that the diversification is more or less common in some groups than others. Table A48 in the appendix displays that diversification has been less common in public area compared to private areas, but both state less diversification than the total group indicating that the ownership group other have a higher level of diversification then the rest. Larger ski areas, ski areas that host large races and ski areas located in the south have a higher percentage of diversification then their counterparts, with the differences of about 15 percent units. The result is similar for the planned near future (1-10 years) diversification, table A53 in the appendix. There is one exception though; the public areas have now a higher percentage of diversification than both the private sub-group and the all respondents group.

	Diversification of activities in the past 20 years	Planned diversification of activities in the near future (1-10) years
Yes	53.3% (24)	53.3% (24)
No	20.0% (9)	22.2% (10)
Don't know	26.7% (12)	24.4% (11)
Total respondent	45	45

Table 13: The number of ski areas that have diversified activities in the past 20 years and planned diversification of activities for the near future (1-10 years).

The ski areas were asked to rank, in order, the reason for the diversification out of the following four options; climate change, less dependency of winter season, less dependency of cross-country skiing or other reasons. In table 14 below, the result is displayed both for diversification in the past (20 year) and for diversifications planned in the near future (1-10 years). The most common reasons in the past for diversifications is less dependency of the winter season, followed by other reasons, climate change and less dependency of cross-country skiing, counting the first choices. If second ranked reasons are also included, 'less dependency of the winter season', is still first with 'less dependency of cross-country skiing' and 'others' tied second and 'climate change' the least common reason. In the future, 'less dependency on the winter season' is still the first choice and 'other's, followed by 'climate change' and 'less dependency of cross-country skiing' respectively for the first choices. This is identical to the answers for the past diversification, although by including the second ranks again it is possible to detect that climate change is the only reason that have become more common and this reason is now ranked second after less dependency of winter season.

	Ranking	Climate change	Less dependency of winter season	Less dependency of cross-country skiing	Other
Past 20 years	1	20.8% (5)	54.2% (13)	0.0% (0)	25.0% (6)
	2	8.3% (2)	33.3% (8)	41.7% (10)	16.7% (4)
	3	37.5% (9)	4.2% (1)	50.0% (12)	8.3% (2)
	4	33.3% (8)	8.3% (2)	8.3% (2)	50.0% (12)
	Total	24	24	24	24
Future 10 years	1	20.8% (5)	54.2% (13)	0.0% (0)	25.0% (6)
	2	25.0% (6)	29.2% (7)	37.5% (9)	8.3% (2)
	3	29.2% (7)	12.5% (3)	45.8% (11)	12.5% (3)
	4	25.0% (6)	4.2% (1)	16.7% (4)	54.2% (13)
	Total	24	24	24	24

Table 14: Ranking of reason for diversification; Climate change, Less dependency of the winter season, Less dependency of cross-country skiing and other reasons. Both for the past (20 years) diversification and for the planned diversifications in the near future (1-10 years).

Climate mitigation at ski areas

Like most human activities, ski areas do have a carbon footprint and so does many of their climate change adaptation action for cross-country skiing. In table 15, ski areas responses on question about their carbon footprint are displayed. About 70 percent of the ski areas state that their ski area and their adaptation actions have a carbon footprint. Just over 90 percent have worked to minimize their carbon footprint. The most common ways ski resorts state to reduce the carbon footprints are

- More climate kind fuel for machinery
- New more efficient motorization
- Planned and more efficient driving of the groomers
- Invest in newer more efficient low energy snow guns
- Change to LED light for the floodlighted trails or buildings
- Provide public transportation for the guests or racers
- Tight planning reducing distance of transportation, for example the stored snow that needs to be distributed out

Although there are many efforts to reduce the carbon footprint there are still many obstacles to further reduction, some of the most stated obstacles are

- Visitors have to travel
- Transportation of stored snow
- Funding for investments
- Low carbon footprint solution are general more expensive
- Alternative fuels for groomers and other heavy machinery
- Information
- Climate change

A quote from one of the respondents explain one of the obstacles to reduce the carbon footprint well, "perhaps not minimize but at least decrease by buying modern machines that consumes less fuel. Invest in better snowmaking equipment so the footprint/m^3 snow is reduced but the amount of snow produced has increased so I don't really know if it's a reduction". Despite that many ski areas are working on lower or minimizing their carbon footprint only about 10% or 3 out of 28 ski areas have worked on quantifying there carbon footprint, and no ski area have quantified the specific carbon foot print from the adaptation actions. Furthermore, only 40 percent believe that advertising them as a low or no carbon footprint would have a competitive advantage over other ski areas. The argumentation from the no side is that customers don't care or choose places because of carbon footprint or environmentally friendly reasons; it is skiing and quality that attracts visitors. The yes side state that they think that skiers will choose ski areas depending on the carbon footprint among other aspects that are not only location or cost, and that people will become more aware of this in the future.

All	Do you think that your operations at the ski area/resort have a carbon footprint?	Do you think your specific adaptation actions to a changing climate at your ski resort/area have a carbon footprint?	Have your ski resort/area worked to minimizing your carbon footprint?	Have your ski resort/area worked to quantify your carbon footprint from your regular everyday operation?	Have your ski resort/area worked to quantify your carbon footprint from you adaptation actions to a changing climate?	Do you think that advertising your ski area, as a climate friendly resort with low or no carbon footprint would have a competitive advantage over other resorts?
Yes	70.5% (31)	70.5% (31)	90.3% (28)	9.7% (3)	0.0% (0)	40.0% (18)
No	29.5% (13)	29.5% (13)	9.7% (3)	90.3% (28)	100.0% (31)	60.0% (27)
Total	100% (44)	100% (44)	100% (31)	100% (31)	100% (31)	100% (45)

Table 15: Responses of ski areas carbon footprint

Discussion

The results from the analysis state that climate change is already happening and affecting ski areas in most places in Northern Europe. It also displays that most ski areas in this study have taking actions and started to adapt to this changing climate, reducing their vulnerability.

Dependency of winter and cross-country skiing

The vulnerability of a ski area to climate change is also determined by its dependency on income from the winter season (Scott and McBoyle 2006) and cross-country skiing. The result from the analysis indicating that almost all of the ski areas has other activities than cross-country skiing, however, the result also indicating that many ski areas are almost entirely dependent on the winter season and or cross-country skiing. The private ski areas are more dependent on the winter season than the public ski areas (strong statistical difference), and about half of the private ski areas state that they are almost entirely dependent on the winter season. The difference is the same for dependency of cross-country skiers, however with a weaker statistical difference. However as Pouta, Neuvonen, and Sievänen (2009) discuss, public and private areas have different challenges. For private areas it is beneficial to become less dependent on skiing since resource diversification reduces the vulnerability to climate change. While for public areas, the ski area itself may not be less vulnerable to climate change by being less dependent on skiing and the winter season. Instead, reduced dependency and increased diversification of the ski area will reduce the vulnerability of the people in the municipality that needs an outdoor physical activity substitute for cross-country skiing. Therefore, the question might be best suitable for private ski areas. Also, because it is hard to interpret how the public ski areas are counting their equivalent to turnover, cost of operation. Including only the cost of the ski area with skiing and the other sports and activities that are offered there, or if they count skiing as part of the whole municipal sport and leisure budget. Anyhow, it is possible to detect that many private ski areas are very dependent on the winter season and cross-country skiing, especially the smaller private ski areas. Since smaller ski areas tend to have lower adaptive capacity (Scott and McBoyle 2006) than larger areas, the smaller ski areas are likely to be more vulnerable to climate change because they also seem more dependent on the winter season and cross-country skiing.

Perception of climate change

By investigating the ski areas perception of past and future climate change it is possible to estimate the sensitivity of the ski areas. 80% of the ski areas stated that they had notice a climate change. Based on the known past climate impacts in Northern Europe (European Environment Agency 2014) it is likely that more than 80% of the ski areas should have notice a climate change. It might be that the ski areas have done adaptation measures that lower their sensitivity and therefore not notice a climate change? However, how logical is it that ski areas have done climate change adaptation measures without haven't noticed any climate change? This is not possible to detect in the survey result since ski areas that answered no if they had noticed climate change were not asked if they had done any climate change adaptation, logically. Although, by going through the ski areas that stated that they hadn't notice any climate change, it is possible to detect that at least a few of them are doing climate change adaptations such as producing machine-made snow or snow farming (Åkesson 2010; Stokke Skianlegg, Storås n.d.; Langd.se 2015). This said, it is not certain to conclude that common climate change adaptation actions such as producing machine-made snow or snow farming, are done to adapt to a changing climate. Instead, those measures can be applied to prolong the season or to make a ski area less vulnerable to natural variability in winter temp and snowfall increasing the possible days of skiing and increasing the revenue, or as a result of competition against other ski areas (Steiger and Mayer 2008; Scott and McBoyle 2006). Further on, in the most northern and high elevation areas the effects from climate change have been unnoticeable or even positive in the context of skiing, since increased precipitation have increased the SWE (Hanssen-Bauer et al. 2015). Although only a few of the ski areas are located at these locations, but both small and positive effects may be less obvious than the negative effects and therefore less reported. However, if those small and positive effects are not noticed, it indicates a low sensitivity to those effects. This would indicate that all the ski areas that had answered that they had experienced a climate change and stated that as negative are sensitive to those effects. There is a large difference between the public owned and private owned ski areas, where the public owned ski areas have noticed climate change to a higher degree. By looking at the non-existing differences between the northern and the southern ski areas (in observed climate change) it is possible to conclude that the difference between the public and private ski areas can't be associated with skewed geographical relationship where the public and private ski areas are located. A possible reason for this might be that public ski areas are more sensitive to climate change. Public ski areas may also have experienced climate change in a more negative way than private ski areas (something which they stated for the future effects of climate change). This might also be true because they won't benefit of a competitive advantage, as some well-adapted or low sensitive private areas will. Because public areas' purpose is not to make profit on the ski tracks as most private areas are, the will only see effects of climate change as costs not investments as private areas might.

The ski areas' response on how they have notice climate change does agree well with the climate change presented in the introduction. Except that more respondents claimed that the season had become shorter in the autumn than it had in the spring. Figure 5 display that, in fact, the decrease of the snow cover is larger in the spring than in the autumn. One possible explanation for this discrepancy could be that racing season have been pushed earlier with a few weeks as seen in the background, therefore it feels like the season have been shortened more in the autumn. Although, Vegard Ulvang at the international ski federation confirms that they are discussing of starting the World cup season later in the winter as a result of climate change. The later end of the season might be a problem, not for the snow-security but for the potential lack of interest for the audience watching skiing in the spring, when it competes with other summer sports (Færaas 2016).

The ski areas response to if climate changes in the near future (1-10 years) will affect them is very similar to the answers for the past, however as many as 25% of the ski areas think that the effects will be positive. The percentage of positive answer is higher in the larger ski areas, ski areas that host large races group and northern ski areas. The first two groups might see the effects of climate change as more positive as the have large adaptive capacity, and the northern ski areas because they are likely to have less exposure, making them all having a competitive advantage over other ski areas.

In the far future (10-30 years), most of the ski areas believe there will be an effect from climate change and less ski areas think that the effects will be positive than earlier. This is consistent with the literature that states that there may be positive effects for some less exposed and well adapted ski areas in the short term but in the long term they will likely also be affected by the decreasing interest of skiing (Pouta, Neuvonen, and Sievänen 2009). Since climate change will affect the number of snow cover days in the low laying areas where most people live to a greater extent (European Environment Agency 2009), the backyard syndrome will become more noticeable when large areas of the population will not see snow anymore, as well as fewer children will learn to ski reducing the interest for skiing further (Pouta, Neuvonen, and Sievänen 2009). Many of the ski areas also state this as a concern.

Even though the future snow cover duration maps are showing changes as far ahead as in the end of the century, a reduction in the number of days with snow cover and the total amount of snow water equivalent are already happening in most places in Northern Europe. This reduction is projected to continue in coming decades, with accelerating speed (Hanssen-Bauer et al. 2015; SMHI 2015; Klimatguiden.fi n.d.). Most of the maps in this study present projections for the pessimistic RCP 8.5 or SERS A2 scenario and for the medium scenario RCP 4.5. There is of course large uncertainty which scenario that is going to be closest to the future, and hopefully for cross-country skiing it will not be the high emission scenarios of RCP 8.5 or SERS A2. No matter what scenario path will be followed, there will not be any large differences in temperature change, SCD or SWE between the scenarios until after the mid-century (Stocker 2014; Déry and Brown 2007; Klimatguiden.fi n.d.). Therefore until the mid-century, those climatic changes are inevitable with following consequences for cross-country skiing. Worth notice is that all projections are averages and even areas that are predicted to have no or very little snow cover in the future will in especially cold winters receive snow and areas that on average is projected to receive snow, can be without snow in warmer than average winters. This is because inter-annual variation of winter temperatures and precipitations will continue in a changed climate as well (Klimatguiden.fi n.d.). However, adaptation actions of cross-country skiing are already or will become needed, how extensive those climate change adaptation actions for cross-country skiing need to be in the end of the century depends on the future emissions.

Adaptation to climate change

Most ski areas (91.7%) in this study stated that they have done climate change adaptation in the past. Compared to the statistic from Kjällbring (2016) where only 7% (116 out of the 1651) registered ski areas have snow production, 87.9% of the ski areas in this study stated they have the capacity to produce machine-made snow. This is indicating that most of the ski areas in this study have done technical adaptation and have a larger adaptive capacity than the whole population of ski areas where the majority hasn't done any technical climate change adaption. This is making them much more vulnerable than many of the ski areas participating in this survey. However, there is possible to detect differences in adaptation efforts and capacity among the ski areas in this study as well.

In the near future (1-10 years), about 75% of the ski areas stated that they are planning for climate change adaptation. There are some larger differences between sub groups. Private ski areas are planning for adaptation investments more than the public ski areas and larger ski areas are planning for more investments than smaller ski areas, the later was possible to test statistically and showed a robust difference. This agrees with Scott and McBoyle (2006) that states that larger and more financial strong alpine ski areas have adapted more. The observed difference between the public and private ski areas may be explained by that the public area also have less financial capacity compared to the private ski areas and that they use less track fees compared to private areas, that are discussed further down in the discussion. Private ski areas may also see the adaptation actions as investments rather than expenses as the public ski areas, therefore being more willing to invest.

Out of the ski areas that have done adaptation actions the most common actions are the relative easy ones, such as trail improvement, producing machine made snow and gather knowledge and education. Fewer have done some of the more complicating or expensive actions such as invest in snow farming or smart snow system. In the future, those are becoming more common among the planned adaptation investments, while the most common actions in the past are becoming less common. This is indicating that most of the ski areas that have done any adaptation have come pretty far in the adaptation and are now investing in the more advance and more expensive investment. The fact that this sampled group involves some of the most advanced ski areas in technical adaptations is indicated by that about half of the ski areas included in this study that have done any adaptation action have invested in the pretty extreme climate adaptation technique of snow farming. There are also a few respondents that have built cooling systems in the ground and ski tunnels (the most extreme climate adaptation). Comparing various sub groups and their adaptation action concludes that the larger ski areas have done more climate change adaptation and are also planning on doing more than the smaller ski areas in every aspect than invest in snow making equipment. This is supported by the fact that the large ski areas already invested in those easier cheaper adaptation investments.

According to the analysis, most of the snow farming in the study area takes place in the north or at high elevation. There is no temperature limit for storing snow in the summer, there are snow farming in places with even warmer summers than any of the ski areas included in this study, for example Ruhpolding in Germany or the snow farming in Sochi Olympics 2014 and the planned snow farming in Olympics 2018 in South Korea (O'Neil 2016; BASF PlasticsPortal - Plastics Magazin 2006; Sonne 2013b). Although, the higher the temperature the larger the expected loss of snow would be (Skogsberg 2005; Olefs and Lehning 2010) increasing the cost per amount of stored snow. However, the main reason for the fact that most of the snow farming is taking place in more northern locations in the study area might be that snow farming is used mostly to have an early season start and to ensure that early season races can be hold (Lintzén 2012; Grünewald and Wolfsperger 2016). The result from the survey indicates also that there are mostly ski areas that are hosting large races that are saving snow, as a security to be able to hold the races. Many of the ski areas that are hosting large international races are located in the northern parts or at higher elevation of the study area, hosting races early in the season. These areas and other northern areas have natural early snow so it makes sense that snow farming is most common where it is possible to extend the early season. With snow farming, it is possible to maintain or moving the start date of skiing forward even with an on-going climate change. However, snow farming may be necessary for southern ski areas in order to provide any skiing or maintain the number of skiable days in the future, although the result of this study don't show that the southern ski areas are planning on expanding snow farming in the near future.

The total size of snow storage in the future is planned to increase from an average of 27 000 cubic meters to 37 000 cubic meters. Larger amount of snow stored will increases the total length of ski track that can be opened independent of the climate conditions. The large size will also reduce the percentage that is melted each summer (Olefs and Lehning 2010).

Climate adaptation costs

Climate change adaptations for cross-country skiing may seem obvious and necessary for private ski areas, since it can be the only solution to keep the skiing guests and ensure a continued profit for the resort. However how can a public ski area justify expensive climate change adaptation? In a study from the public ski area Östersund in Sweden, the cost of the climate change adaptation actions snow farming were set in proportion to the socio-economic gain of the extra days of skiing generated (Gisselman and Cole 2016). The study used a recalculated WTP value for skiing conditions from the Norwegian study (Sælen and Ericson 2013) together with number of skiers on the extra days added and compared to the yearly cost of snow farming, including historical and future investment. The study concluded that on a yearly basis for the next 20 years the societal gain of those extra days of skiing were larger than the cost of the snow farming, with about 42 000 euro per year or 7-12% higher societal gain compared to the cost based on two scenarios (Gisselman and Cole 2016). The study didn't include other potential societal gains such as; potential improved health of the citizens and reduced public health care cost, increased gain from equipment rental for the municipal and increased attractiveness of the city as a result of providing more days of skiing and that the city is able to arrange a world cup in biathlon every year. A few potential costs were not included as well as potential environmental cost at the snow storage site, the cost of cleaning drinking water used for snow production or the esthetical effects of fog in the city as a result of snow production (Gisselman and Cole 2016).This study proves that it is possible that climate change adaptation for cross-country skiing can be beneficial for public areas and the society, justify the cost of those adaptation actions.

These findings are important since the investments in technical adaptation solutions are expensive and the analysis concludes that lots of money has been spend on adaptation, and the investment cost is stated to increase in the future to meet the challenges from a warming climate. Although, the operational cost are not predicted to increase for the ski areas in the future, most likely because of increased energy efficiency of snow-making since the smart snow system reduces the amount of manpower needed (SLAO n.d.; Lintzén 2012). The southern ski areas indicated that they will spend more on adaptation in the future. It also agrees that they stated that they will be more negatively affected by future climate change. Southern areas have also stated more increase in operational cost in the past and future, which could be related to the fact that it is more expensive to operate in the south where more machine-made snow is needed. Smaller ski areas spend much more of their turnover on adaptation as a percentage (more than 50% for the median area) than larger ski areas. This agrees with Landauer, Pröbstl, and Haider (2012) which state that especially small ski areas have high investment costs when adapting to a changing climate. Indicating that their budgets are strained, affecting future adaption investments and that they need to increase their turnover by increasing track passes sale (Landauer, Pröbstl, and Haider 2012). Increasing track fees can be an important way for ski areas to finance climate change adaptation investments and more than 65% of all ski areas in this study stated that they plan to finance adaptation investments with track passes. It will on average cover 31% of the ski areas adaptation cost. However there are regional differences in how useful track fees can be to finance climate change adaptation.

Many countries in northern Europe have what is called "everyman's right" that guarantees access to both private and public land for recreational and exercise purposes, free of charge (Lejman 2010; Landauer, Haider, and Pröbstl-Haider 2014). This right triumph the right to take out track passes for a ski area many argues, including the Swedish Nature agency, although the case haven't been tested in court yet in Sweden (Lejman 2010). There is therefore a strong will opposing track fees in northern Europe as compared to the Alp region where most ski areas are maintained by private operators and track fees are public accepted (Landauer, Haider, and Pröbstl-Haider 2014). In Finland, climate adaptation of skiing is seen as a public responsibility and track passes and fees are opposed by the majority, only if the skiing is done entirely on machine-made snow there is, to some extent, accepted with track passes. This is likely to hold true for most of northern Europe due to similar culture (Landauer, Haider, and Pröbstl-Haider 2014). The result from this study also conclude that the public ski areas are not relaying on track passes to cover their adaptation action to the same degree as the private areas, agreeing with the conclusion that Finish skiers and most likely other northern European skiers believe the public sectors should pay for climate change adaptations (Landauer, Haider, and Pröbstl-Haider 2014). Further on, (Landauer, Haider, and Pröbstl-Haider 2014) state that especially small ski areas should be careful to count on track passes to cover the adaptation cost since most people are not willing to pay for skiing, opposite to the result from this survey that conclude that smaller ski areas tend to relay on income from track passes to a larger degree than the larger ski areas. This is indicating that the cultural acceptance for track fees may have increased since 2014, or that it is higher in the rest of northern Europe compared to Finland. Norwegian ski areas were for a longer period opposing track passes compared to Swedish ski areas, with similar argument that it intrude the "everyman's right" and that skiing is a national identity with large health benefits (Halvorsen 2009b; Halvorsen 2009a). The first ski area in Norway to use track passes were Sjusjøen that introduced it in 2011 (Svendsby 2011), a long time after many Swedish ski areas had started collecting money from its visitors (Halvorsen 2009a). Already in 2009, around 60 cross-country ski areas in Sweden had track fees (DN 2009). The result from the survey concludes the same, that fewer Norwegian ski areas are planning on finance its adaptations cost with track passes compared to Swedish ski areas. The Finish and Estonian answers in this study is skewed in the ownership of the ski areas between the countries and is therefore not analyzed. It seems that the idea of track passes in Sweden is becoming more accepted and more public ski areas are also introducing track passes (Jerden 2013). Further, the protests or opposition to the fees are not that strong (Lejman 2010).

It is interesting that until recently cross-country skiing, because it is performed in the nature, although on a groomed track by a grooming machine or snow machine and usually with trail clearing maintains during the no snow season, is expected to be free. While people accept fees for other arenas such as gyms or swimming pools (Landauer, Haider, and Pröbstl-Haider 2014). The maintenance of a groomed ski track also has a cost and could or should be associated with a fee covering the expenses, although it have been expected that this cost should be covered by the public or the private ski resort (Pouta, Neuvonen, and Sievänen 2009). The introduction of technical climate change adaptation actions such as producing machine-made snow and snow farming have been proven very efficient but expensive. It has increased the costs for ski areas significantly, calling for increased funding for those actions, which in many cases have resulted in a track fees. The skiers understand the cost from those adaptation actions and is more willing to pay track fees for areas that have machine-made snow than for the ones that haven't (Landauer, Haider, and Pröbstl-Haider 2014). Climate change and the technical climate change adaptation actions have made it more accepted with track passes at cross-country skiing areas, since it have made it more obvious that the ski track is an arena that need maintenance (therefore not covered by the "everyman's right") instead of a track in the nature. The increased thought of the ski track as an arena have increased the number of track passes on ski areas that don't produce machine-made snow also (Kristiansen 2009). The problem of seeing the ski tracks as an arena instead of covered by the "everyman's right" is that ski areas usually cover large areas and ski tracks often crosses private properties. This means that the private landowners can say no to having a ski track passing over its property (Jerden 2013), limiting the area of cross-country skiing. The question of if track passes for cross-country skiing tracks is against the "everyman's right" or not will probably continue, at least until it has been tested in court. However cross-country skiing isn't the same today as it was before the first groomed ski tracks in 1960 (Hottenrott, Urban, and Neumann 1996), but the "everyman's right" still make it possible to ski for free wherever you want in the nature outside of the groomed ski track just like it was before 1960. Although, most skiers prefer to ski on groomed ski tracks (Pouta, Neuvonen, and Sievänen 2009). As the cost of providing skiable conditions will increases from the effects of climate change and the following technical adaptation actions, track fees are a way to finance that increased cost. That the skiers understand this and are paying are crucial for the faith of many ski areas, and the alternative is less climate change adaptation and fewer days of cross-country skiing available. However, there is still a risk in charging large track fees for ski areas as long as the opposition against it is strong, since cross-country ski tourist are usually nomadic in their choice of skiing destination and can easily chose another location with a lower or no track fee (Landauer, Pröbstl, and Haider 2012). Another solution is that studies of the socio-economic value of skiing such as (Gisselman and Cole 2016) and other studies proving the health benefits of skiing are becoming more widespread and accepted. This might ensure that the public will continue to pay for maintenance and climate change adaptation of ski areas, and enable cross-country skiing also for the socio-economic week groups in society that already are most sensitive to climate changes (Pouta, Neuvonen, and Sievänen 2009). Those groups will likely be affected even more if track fees are implemented for cross-country skiing.

Diversification of activities

As a complement to invest in expensive technical adaptation actions, diversification of activities and revenue is also a way to reduce the vulnerability for the ski area from the effects of climate change. Most of the ski areas already have other activities at the ski area and over 50% of the ski areas are planning on diversification of activities in the future. The most stated reason for the diversification is to become less dependent on the winter season. This can be both a general business adaptation improving the total revenue; however, it will also work as a climate change adaptation. Climate change has increased in importance and is the second most common reason for diversification in the future. This is indicating that the ski areas are aware of and preparing for the effects of climate change. Smaller, southern and ski areas that don't host large races are all groups that have lower diversification than the rest. This is lowering their adaptive capacity, and potentially increasing their vulnerability.

Carbon footprint

The final and ultimate climate adaptation, mitigation, was also investigated among the ski areas since many of the ski area's technical adaptation have a large carbon footprint. Most of the ski areas acknowledged their emissions and stated that they worked on minimizing them, however almost none had quantified their emission such as alpine ski areas have (Simpson et al. 2008). Further on, relative few (40%) believe that there is a competitive advantage promoting themselves as climate friendly resorts even though the literature state that there is (Birch 2015). There is signs that climate awareness are becoming more important among skiers' choice of resort, and groups like 'Save our snow' are advocating for choosing climate friendly resorts as well as encourage the skier to think about climate change mitigation (Save Our Snow n.d.). The skier's transportation to the resort is actually the majority of a ski visits carbon footprint (CIPRA International 2011) and need to be addressed both by the skier and the ski resort in the future.

To conclude the adaptive capacity among ski areas is, to a large degree, dependent on how much they can afford to invest in expensive technical adaptation solution in the future. Indicating that smaller ski areas have a lower adaptive capacity, the adaptive capacity in the future will to a large degree be dependent on the success of implementation of track fees. However, large regional differences seem to exist with the region where track passes are more common and accepted in Sweden than in Finland and Norway. This is lowering the adaptive capacity of the ski areas in Finland and Norway, making them more vulnerable to climate change. The ski areas are also seeing risks with their adaptation investments and the insecurity of the climate is seen as the largest risk. There is a risk that, eventually, there will also be a limit to how much snow it is possible to produce with increasing temperatures. The minimum temperatures, an important factor for snow production, are also predicted to increase the most. (Seelye 2012). The costs for snow production will also increase to the a limit when it will be uneconomical to keep open for some areas in the future (Seelye 2012). The second most stated risk with future investments are the potential decline in the interest of skiing as a consequence of climate change.

Climate change effects on the sport and leisure activity of cross-country skiing.

Even though machine made snow and other technological solution can make future cross-country skiing possible in certain locations, the recruiting of new skiers take place in areas where children live (Færaas et al. 2016). Inexpensive close to home options are crucial for children learning to ski. Raising children to ski will therefore be less common with decreasing close to home option for skiing. (Pouta, Neuvonen, and Sievänen 2009). The study by Pouta, Neuvonen, and Sievänen (2009) concluded that the participation and frequency of cross-country skiing would decrease by about 40% in Finland in the mid to end of the century with the A2 climate scenario. This decrease is likely to be larger because it is based on today's living peoples future preferences, with a 94% cross-country skilled population. If fewer children learn to ski in the future, fewer would also be interested in cross-country skiing in the far future. With less snow in areas where people live, it is likely that in the future, cross-country skiing will not be part of the Nordic way of life and national culture; instead it will become an activity for those with recourses and possibility to travel to resorts for skiing and not a recreation activity for the majority. (Pouta, Neuvonen, and Sievänen 2009; Færaas et al. 2016). This is resulting in a loss of culture diversity and Northern Europe's leisure culture will become similar to the one in Central Europe (Pouta, Neuvonen, and Sievänen 2009). The decreased interest and predicted decline in participation in skiing is also likely to affect the tourist resorts. The result from this survey proves that this is a large concern among the ski areas. An adaptation action that should be implemented among the large ski resorts in the future is nursing the interest for cross-country skiing. This could be done by operating or supporting high technical adapted ski areas and ski tunnels in densely populated areas in the southern or low elevation areas, where the natural snow cover is expected to decrease to critical limits for cross-country skiing.

Limitations and aspects for further research

The survey was made in English, a non-native language, for all the participants of the survey. It is possible that some of the respondents answered wrong because of linguistic misunderstandings. It is also possible that some respondents did not answer as a result of not understanding the survey or the extra workload by answering a survey in language they are not that familiar with. In some places it was even impossible to find an English speaking person at the ski resort/area or that the only person that could answer the survey didn't speak English.

In the analysis of the survey, the respondents were divided into two groups, one with colder climate and one with warmer climate to analyze if they respond any differences. The specific climate conditions for every location are not know, due to limited size and time constrains of this study; instead a arbitrary value of 63 degrees north or above 500 m above sea level was used to divide the respondents into a colder climate vs a warmer climate. Both the latitudinal degree difference and the altitude difference will on average reduce the temperature with about 3 degrees compared to the most southern parts of the study area or from sea level (Ahrens 2008). It is likely that some places are placed in the wrong group due to regional climate differences based of the specific geography of the study area, such as approximation to the ocean. Even so, the elevation and geographical positions of the ski areas are good enough parameters to differentiate the two climate groups for this study.

Further on, the sensitivity of ski areas to climate change is not just a matter of snow cover since most of the ski areas are using machine-made snow. Therefore, the sensitivity of many ski areas is also dependent on number of days with a wet bulb temperature of below -2°C to produce machine-made snow. Future climate change scenario data and maps including these data would be of great interest in order to determine the sensitivity and adaptive capacity to climate change for ski areas in the future. Further on, a more comprehensive survey that also includes the very small ski areas would be of interest in order to gain a better understanding of their sensitivity, adaptive capacity and vulnerability, since they are expected to be more vulnerable than the ski areas in this study. Further surveys of the cross-country skiers response to climate change such as in (Pouta, Neuvonen, and Sievänen 2009; Landauer, Sievänen, and Neuvonen 2009; Landauer, Pröbstl, and Haider 2012; Landauer, Haider, and Pröbstl-Haider 2014; Landauer, Sievänen, and Neuvonen 2015) is needed for other Northern European countries than Finland, in order to understand the cultural differences and how it affect skiers response to climate change. Of most interest would be to investigate the opposition to track fees, if it is consistent in all countries or if different management advices need to be communicated in different countries.

Conclusion

The presented study may be the first of its kind to investigate the supply side of cross-country skiing (the ski areas) and their responses to climate change. By examine their responses, the exposure, sensitivity and adaptive capacity could be estimated and their vulnerability to the effects of climate change could be evaluated. The findings indicates that despite predicted exposure for almost all of the respondents, the sensitivity of many ski areas are low, and the substantial part of the respondents perceived the coming effects from climate change as positive, indicating high adaptive capacity among many ski areas. It also presents the large array of adaptation measures implemented and the effectiveness of them to lower the vulnerability of the ski area to climate change. However, the differences among the ski areas were large and especially smaller ski areas, and to some extent public and southern ski areas are indicating that they are more sensitive and having lower adaptive capacity. Especially smaller ski areas have invested less and are planning on less climate change adaptation actions in the future and the cost for those adaptation actions will become a very large share of their turnover. Track fees are and can be an even more important way of financing the adaption investments in the future. However the success will depend on how the cultural opposition to track fees will develop during the coming years. Even though, with the state of art technical adaptation, there will be both climatic, financial and ecological constrains limiting the success of the adaptation. The number of days with skiing condition in predicted to go down resulting in lower participation and frequency of cross-country skiing in the future. Especially in the geographical south were most of the Northern European population lives. Future generation will be less likely to be introduced to skiing, reducing the interest further. High technological adaptation solution in ski areas in highly populated areas is of most importance to nurse the interest of cross-country skiing. The tourist ski resorts are highly dependent on that people want to go skiing, therefore they should support ski areas in highly populated places to maintain that interest.

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Appendix

What is the name of the ski resort/area or event?

- Vålådalens Fjällstation
- Vasaloppet
- Tranemo
- Östersunds ski stadium
- Idre Fjäll
- Birkebeinerrennet
- Orsa Grönklitt
- Hellnerstadion Gällivare
- Beitostølen
- Högbo Bruk
- Billingens fritidsområde
- Lugnet Nationalarena
- Skidstadion Borås
- Vuokatti Sports Institute, Finland
- Lillehammer Olympiapark AS
- Skeikampen Resort
- Levi Ski Resort
- Tartu Maraton
- bruksvallarna
- Jõulumäe Tervisespordikeskua
- Hemavan Tärnaby
- Trysil
- Kontiolahti Biathlon Stadium/Cooled Ski Track (Finland)
- Alutaguse Sport and Recreation Centre
- Kiruna
- Myrkdalen
- OK Landehof/Landvetter
- Sauda Skisenter
- Nõmme Spordikeskus/Nõmme Sport Center
- Granåsen, Trondheim
- Harsa
- Olympic Training Center Rovaniemi
- Edsåsdalen
- Dombås skistadion,
  Norway
- Over Kölen
- Umeå
- Lassalyckan Ulricehamn
- Torsby Skidtunnel & Sportcenter
- Ruka
- Ski Resort OLOS
- Ylläs
- Tehvandi Sport Center, EST, Otepää
- Tähtvere Leisure Center - Estonia, Tartu
- Pirita Spordikeskus
  Tallinn, Estonia
- Lahti
- Storås Skistadion
- Kaiskuru Skistadion
- South Carelia in Finland, Town Imatra and Club Imatran Urheilijat (Imatra sports club)
- Holmenkollen

What is your position at the ski resort/area

- Facility manager and chief of ski tracks
- sportdirector/ cheif of competition
- Project manager
- Stadium chief
- Operational manager
- CEO
- Bygg- och fastighetschef
- Project manager
- Daglig leder
- Track manager
- Head of Unit
- Director of Sport an leisure by the municipality of Falun
- Södra Sverige

- Manager of Olympic training center in Vuokatti Sports Institute
- CEO
- Sport event- and sport development coordinator
- Route supervisor
- Press officer/Marketing manager
- projektledare
- Manager
- Destinationsbolag
- Daglig leder i Trysilfjell Utmarkslag SA - vi administrerer grunnen til 26 grunneiere - 120 000 dekar
- Development Manager
- Project Manager, Organizer of main events
- Kiruna
- Leader
- Chairman of the board
- Leder
- Assistant Director
- Driftsleder og planlegger (svarer sammen)
- owner
- Training Center Manager
- Ägare och vd
- Leader snowproduction.
- Ansvarig för skidspår och snötillverkning
- Head of maintenance
- Kommunal förvaltare av området
- Marknadsföringsansvarig
- ceo
- Hotel Manager
- Executive Manager of Ylläs Travel Association
- memeber of the board
- Managing Direcor
- Sales and develeopment manager
- Sports Director in Lahti2017 FIS Nordic World Ski Championships
- Eks Leder - 2016.
- Manager. Stadium own by Alta kommune
- The member of cross country skiing board, top athlete manager and competition manager (often), coach of five athletes
- Chief of track

Sub-groups

Public owned	Private owned	Other ownership
Östersunds ski stadium	Vålådalens Fjällstation	Vasaloppet
Hellnerstadion Gällivare	Orsa Grönklitt	Tranemo
Högbo Bruk	Beitostølen	Idre Fjäll
Billingens fritidsområde	Skeikampen Resort	Birkebeinerrennet
Lugnet Nationalarena	Levi Ski Resort	Vuokatti Sports Institute, Finland
Skidstadion Borås	bruksvallarna	Tartu Maraton
Lillehammer Olympiapark AS	Trysil	Kontiolahti Biathlon Stadium/Cooled Ski Track
Jõulumäe Tervisespordikeskua	Myrkdalen	Olympic Training Center Rovaniemi
Hemavan Tärnaby	Sauda Skisenter	Torsby Skidtunnel & Sportcenter
		South Carelia in Finland, Town Imatra and Club Imatran Urheilijat (Imatra sports club)
Alutaguse Sport and Recreation Centre	Harsa	
Kiruna	Edsåsdalen	
OK Landehof/Landvetter	Ruka	
Nõmme Spordikeskus/Nõmme Sport Center	Ski Resort OLOS	
Granåsen, Trondheim	Ylläs	
Dombås skistadion, Norway	Storås Skistadion	
Over Kölen		
Umeå		
Lassalyckan Ulricehamn		
Tehvandi Sport Center, Otepää		
Tähtvere Leisure Center, Tartu		
Pirita Spordikeskus Tallinn		
Lahti		
Kaiskuru Skistadion, Alta		
Holmenkollen		

Northern or southern high elevation ski areas	Southern ski areas
Vålådalens Fjällstation	Vasaloppet

Östersunds ski stadium	Tranemo
Idre Fjäll	Orsa Grönklitt
Birkebeinerrennet	Högbo Bruk
Hellnerstadion Gällivare	Billingens fritidsområde
Beitostølen	Lugnet Nationalarena
Vuokatti Sports Institute, Finland	Skidstadion Borås
Skeikampen Resort	Lillehammer Olympiapark AS
Levi Ski Resort	Tartu Maraton
bruksvallarna	Jõulumäe Tervisespordikeskua
Hemavan Tärnaby	Kontiolahti Biathlon Stadium/Cooled Ski Track (Finland)
Trysil	Alutaguse Sport and Recreation Centre
Kiruna	OK Landehof/Landvetter
Myrkdalen	Sauda Skisenter
Granåsen, Trondheim	Nõmme Spordikeskus/Nõmme Sport Center
Olympic Training Center Rovaniemi	Harsa
Edsåsdalen	Over Kölen
Dombås skistadion, Norway	Lassalyckan Ulricehamn
Långbergets Sporthotell Ab	Torsby Skidtunnel & Sportcenter
Umeå	Tehvandi Sport Center, EST, Otepää
Ruka	Tähtvere Leisure Center - Estonia, Tartu
Ski Resort OLOS	Pirita Spordikeskus Tallinn, Estonia
Ylläs	Lahti
Kaiskuru Skistadion, Alta	Storås Skistadion
	South Carelia in Finland, Town Imatra and Club Imatran Urheilijat (Imatra sports club)
	Holmenkollen

Larger ski areas	Smaller ski areas
Vålådalens Fjällstation	Tranemo
Vasaloppet	Hellnerstadion Gällivare
Östersunds ski stadium	Högbo Bruk
Idre Fjäll	Lugnet Nationalarena
Birkebeinerrennet	Skidstadion Borås
Orsa Grönklitt	bruksvallarna
Beitostølen	Jõulumäe Tervisespordikeskua
Billingens fritidsområde	Hemavan Tärnaby
Vuokatti Sports Institute	Kontiolahti Biathlon Stadium/Cooled Ski Track
Lillehammer Olympiapark AS	Myrkdalen
Skeikampen Resort	OK Landehof/Landvetter
Levi Ski Resort	Sauda Skisenter
Tartu Maraton	Nõmme Spordikeskus/Nõmme Sport Center
Trysil	Harsa
Alutaguse Sport and Recreation Centre	Edsåsdalen
Granåsen, Trondheim	Dombås skistadion
Olympic Training Center Rovaniemi	Over Kölen
Umeå	Ski Resort OLOS
Lassalyckan Ulricehamn	Tehvandi Sport Center, Otepää
Torsby Skidtunnel & Sportcenter	Tähtvere Leisure Center, Tartu
Ruka	Pirita Spordikeskus Tallinn
Ylläs	Storås Skistadion
Kaiskuru Skistadion, Alta	Town Imatra and Club Imatran Urheilijat (Imatra sports club)
Holmenkollen	

Ski areas hosting large races	Ski areas that do not host large races
Vasaloppet	Vålådalens Fjällstation
Östersunds ski stadium	Tranemo
Idre Fjäll	Orsa Grönklitt
Birkebeinerrennet	Högbo Bruk
Hellnerstadion Gällivare	Billingens fritidsområde
Beitostølen	Skidstadion Borås
Lugnet Nationalarena	Skeikampen Resort
Vuokatti Sports Institute	Levi Ski Resort
Lillehammer Olympiapark AS	Hemavan Tärnaby
Tartu Maraton	Trysil
Bruksvallarna	Alutaguse Sport and Recreation Centre
Jõulumäe Tervisespordikeskua	Kiruna
Kontiolahti Biathlon Stadium/Cooled Ski Track	Myrkdalen
Granåsen, Trondheim	OK Landehof/Landvetter
Olympic Training Center Rovaniemi	Sauda Skisenter
Lassalyckan Ulricehamn	Nõmme Spordikeskus/Nõmme Sport Center
Torsby Skidtunnel & Sportcenter	Harsa
Ruka	Edsåsdalen
Ski Resort OLOS	Dombås skistadion, Norway
Tehvandi Sport Center, EST, Otepää	Over Kölen
Lahti	Umeå
Holmenkollen	Ylläs
	Tähtvere Leisure Center - Estonia, Tartu
	Pirita Spordikeskus Tallinn, Estonia
	Storås Skistadion
	Kaiskuru Skistadion, Alta
	South Carelia in Finland, Town Imatra and Club Imatran Urheilijat (Imatra sports club)

Number of year you have worked at the ski resort/area

Range years worked at the ski area	Frequency
0-5	36,7% (18)
5.1-10	14,3% (7)
10.1-15	20,4% (10)
15.1-20	8,2% (4)
20.1-25	12,2% (6)
25.1-30	6,1% (3)
>=30	2,0% (1)
Total	100% (49)

Median	10
Average	12
Max	40
Min	1

Table A1: Number of year respondent has worked at the ski area.

Number of years working within the field of skiing

Range years worked within the field of skiing	Frequency
0-5	26,5% (13)
5.1-10	12,2% (6)
10.1-15	18,4% (9)
15.1-20	4,1% (2)
20.1-25	8,2% (4)
25.1-30	22,4% (11)
>=30	8,2% (4)
Total	100% (49)

Median	15

Average	17
Max	50
Min	1

Table A2: Number of year respondent has worked within the field of skiing.

What activities do you have more than cross-country skiing at your ski resort/Area

	Respondents	Percent
None	1	2.0%
Downhill skiing	22	44.9%
Hiking	31	63.3%
Running	42	85.7%
Biking	37	75.5%
Roller skiing	27	55.1%
Other	28	57.1%
Total	49	100.0%

Table A3: Number of responses for other activities at the ski areas.

What activities do you have more than cross-country skiing at your ski resort/area - Other (please fill in)

- Indoor sports
- orienteering
- Biathlon
- ?
- Rovdjurspark
- Orienteering
- Canoeing
- 62 other sports
- Frisbee
- tennis, ballgames etc
- Bob, Luge, Skelleton, Biathlon, Skijumping, sportscenter, multipurpose sportinghall
- Biathlon, tennis, golf, alpine touring
- Disc-golf
- Golf, ridning, båt og elveaktiviteter, dyresafarier mv
- Biathlon
- Adventure park, discgolf,
- orientering
- gym, beachsoccer, -volley, swimming
- skihopping, kombinert, skiskyting, skiorientering, hundekjøring (nordiske grener), scootercross, orientering
- Many different sports indoor and outdoor
- Redskapsträning (minigym)
- Rekreation
- skidskytte, frisbeegolf, fotboll, rullskidskytte, isbana, boule
- canoeing, white water rafting etc
- skating (winter)
- Fotball, School yard
- Biathlon, artificial ski track, roller skating sprint track, football, tennis, ice hockey, golf, riding, finnish baseball, art
- Ski jumping

Are most of the visitors > 75 % at your ski resort/area visiting for two days or more at the time?

	Respondents	Percent
Yes	24	49.0%
No	22	44.9%
Don't know	3	6.1%
Total	49	100.0%

Table A4: Number of ski areas where the majority >75% of visitors staying for two days or more at the time.

Are most of the visitors > 75 % ski resort/area typical from further then 100km away?

	Respondents	Percent
Yes	23	46.9%
No	23	46.9%
Don't know	3	6.1%
Total	49	100.0%

Table A5: Number of ski areas where the majority >75% of visitors traveling further then 100km to visit

Are your ski resort/area a public or private owned?

	Respondents	Percent
Public	24	49.0%
Private	15	30.6%
Other	10	20.4%
Total	49	100.0%

Table A6: ownership of the ski areas.

Are your ski resort/area a public or private owned? - Other

- Non-profit organization, owned by Mora SK and Sälen IF
- Association
- ?
- Non-profit organization, owned by sports clubs, Rena IL, Lillehammer biking and skiing club
- Borås Stad
- foundation
- Stadium is owned by the municipality. Cooled Ski Track is company owned by Kontiolahti Sport Club and Kontiolahti municipality.
- owned by city of Tallinn (capital of Estonia)
- Consisits of a public educational organization (sports institute) and a private service company
- En kombination av kommunal verksamhet, privata intressenter och föreningsliv
- Mostly public, but also private

Estimate the approximate number of visitor of any kind at your ski resort/area per year, answer in total number of days they visit all together?

Visitors any type range	Frequency
0-50000	38,1% (16)
50001-100000	23,8% (10)
100001-150000	4,8% (2)
150001-200000	0,0% (0)
>200000	33,3% (14)
Total	100% (42)

Table A7: number of visitors of any kind at the ski areas.

	Min	Max	Median	Average
All	3000	1000000	95000	240405
Public	3000	1000000	100000	284056
Private	13000	1000000	155000	265286
Other	40000	650000	70000	127000
Larger	22000	1000000	150000	336826
Smaller	3000	1000000	50000	123684
Host large races	3000	1000000	95000	253450
Don't host large race	4000	1000000	80000	228545
Northern	3000	1000000	100000	232800
Southern	10000	1000000	70000	247318

Table A8: Minimum, maximum, median and average value for number of visitors for all respondents and various subgroups.

How certain are you about this number?

	Respondents	Percent
I'm certain	8	16.7%
Quite certain	17	35.4%
Medium certain	15	31.2%
Not very certain	5	10.4%
Not certain	3	6.2%
Total	48	100.0%

Table A9: Certainty of number of visitors at the ski areas.

Estimate the approximate share in % of those visits that is from cross-country skiing.

Range of percentage of visitors at the ski area that are from cross-country skiing	Frequency
0-20	25,0% (12)
21-40	27,1% (13)
41-60	18,8% (9)
61-80	18,8% (9)
81-100	10,4% (5)
Total	100% (48)

Median	40
Average	44
Max	97
Min	3

Table A10: Percentage of cross-country ski visits at the ski areas.

How certain are you about this percentage

	Respondents	Percent
I'm certain	6	12.5%
Quite certain	16	33.3%
Medium certain	20	41.7%
Not very certain	5	10.4%
Not certain	1	2.1%
Total	48	100.0%

Table A11: Certainty of number of visitors

Recalculated number of cross-country visits by using total visits and the percentage that was from cross-country skiing.

Cross-country skiing visitors range	Frequency
0-25000	40,5% (17)
25001-50000	23,8% (10)
50001-75000	9,5% (4)
75001-100000	7,1% (3)
>100000	19,0% (8)
Total	100% (42)

Table A12: Number of cross-country skiing visits at the ski areas.

	Min	Max	Median	Average
All	2500	600000	32500	73312
Public	2700	600000	32500	89526
Private	2500	255000	43400	73082
Other	6000	195000	29500	44450
Larger	6000	600000	75000	120011
Smaller	2500	48000	9000	16782
Host large races	2700	600000	31500	79240
Don't host large race	2500	320000	33500	67923
Northern	2700	320000	39500	80548
Southern	2500	600000	32500	66734

Table A13: Minimum, maximum, median and average value for number of cross-country visitors for all respondents and various subgroups.

Have your ski resort/area any method of calculate number of cross-country visitors

	Respondents	Percent
Yes	25	52.1%
No	23	47.9%
Total	48	100.0%

Table A14: If the ski area has any method for calculating number of cross-country skiers.

What method/methods?

- Track passes
- we organize ski race, participants
- Selling skipass and registration of youths
- starting bibs for the enteries, but we have estimated that a total of 300000 visitors are coming all together during the events, and the total economic turnover with all the guests are 300000000 NOK
- The gate at the Pay&Ski track register all passages. The gate are not used when it's natural snow in the whole track system and then there is no method for calculate the visitors.
- Counting how many tickets who have been sold during the season.
- Trail fee
- Åkkort

- Ticket sale, accomondation overnights in our Institute
- We use IR counting stations in the cross country tracks regularly. We also use mandatory questbacks among the private cabin owners yearly asking about visit frequenzy and use during their stays.
- Race registration gives us exact number of participants in the races.
- SPÅRKORTSFÖRSÄLJNING
- During the Cooled Ski Track season: ticket sales

  During the competitions: participants and service persons
- Ski rent ticket sales statistics. Tracks are public though, but we have some statistics. Lot is depending of weather
- Track fee
- Educational organization follows "course days", other accommodations are followed as hotel stays.
- During good contakt With hotells and motells
- Via biljettsystem, dörräknare samt en uppskattning utomhus.
- customer survey
- Ski tickets & competitions
- counters on the skiing tracks
- survey
- Registered cars
- The visitors of the local hotels and spad registed, sold tickets to artificial snow track, competition partisipians.
- A counter wich count The number of passes in one part of The track

Number of Employees (full time and part time/seasonal) - Fulltime all year, number

Employees full time all year range	Frequency
0-0.99	21,3% (10)
1-4.99	19,1% (9)
5-9.99	14,9% (7)
10-49.99	27,7% (13)
50-99.99	12,8% (6)
>=100	4,3% (2)
Total	100% (47)

Median	8
Average	19
Max	100
Min	0

Table A15: Number of fulltime all year around employees at the ski area.

Number of Employees (full time and part time/seasonal) - Part time all year

Employees part time all year range	Frequency
0-0.99	40,4% (19)
1-4.99	21,3% (10)
5-9.99	6,4% (3)
10-49.99	23,4% (11)
50-99.99	6,4% (3)
>=100	2,1% (1)
Total	100% (47)

Median	1
Average	15
Max	200
Min	0

Table A16: Number of part time all year around employees at the ski area.

Number of Employees (full time and part time/seasonal) - Fulltime seasonal, number

Employees full time seasonal range	Frequency
0-0.99	27,7% (13)
1-4.99	25,5% (12)
5-9.99	14,9% (7)
10-49.99	17,0% (8)
50-99.99	4,3% (2)
>=100	10,6% (5)
Total	100% (47)

Median	3
Average	28
Max	300
Min	0

Table A17: Number full time seasonal employees at the ski area.

Number of Employees (full time and part time/seasonal) - Part time seasonal, number

Employees part time seasonal range	Frequency
0-0.99	31,9% (15)
1-4.99	19,1% (9)
5-9.99	12,8% (6)
10-49.99	19,1% (9)
50-99.99	6,4% (3)
>=100	10,6% (5)
Total	100% (47)

Median	4
Average	117
Max	4500
Min	0

Table A18: Number part time seasonal employees at the ski area.

What is the approximate current economic turnover per year (cost of operation for public areas), in your own currency? Recalculated to Euros for comparison.

Turn over/Cost of operation (Public) in Euro	Frequency (number of respondents)
0-100000	18,2% (8)
100001-250000	25,0% (11)
250001-500000	20,5% (9)
500001-1000000	6,8% (3)
1000001-5000000	13,6% (6)
>5000000	15,9% (7)
Total	100% (44)

Table A19: Frequency of various turnover/cost of operation ranges for all ski areas.

	Min	Max	Median	Average
All	5309	13802492	298642	1881535
Public	5309	5152472	287500	666311
Private	10617	5000000	1061730	1747197
Other	53087	13802492	1300000	5028797
Larger	106173	13802492	1300000	3720239
Smaller	5309	530865	150000	202719
Host large races	50000	13802492	875927	3333864
Don't host large race	5309	7962976	236790	671261
Northern	84938	11000000	424692	2455784
Southern	5309	13802492	240000	1445106

Table A20: Minimum, maximum, median and average value for turnover or cost of operation in Euros for all respondents and various subgroups.

Part II: Sensitivity of winter activities and cross-country skiing to climate change

How dependent are your ski resort/area turnover from the winter season, all activities included?

	Respondents	Percent
0-20 %	9	20.0%
20-40 %	6	13.3%
40-60 %	8	17.8%
60-80 %	13	28.9%
80-100 %	9	20.0%
Total	45	100.0%

Table A21: Dependency of winter season for ski areas turnover

How dependent are your ski resort/area turnover from cross-country skiing?

	Respondents	Percent
0-20 %	17	37.8%
20-40 %	9	20.0%
40-60 %	6	13.3%
60-80 %	5	11.1%
80-100 %	8	17.8%
Total	45	100.0%

Table A22: Dependency of cross-country skiing for ski areas turnover

Have your ski resort/area noticed a changing climate?

	Respondents	Percent
Yes	36	80.0%
No	9	20.0%
Total	45	100.0%

Table A23: Ski areas response to if they have noticed a changing climate.

How have your ski resort/area noticed a changing climate during the last 20 years?

- Warmer falls, more and longer warm spells during winter, earlier snow melt.
- less snow more rain
- Higher temperarures during winter, more soil moisture during the autumn and winter, less natural snow over the season.
- winter starts later, less snow depth, higher temperatures. More difficult to make artificial snow (less days). Groom more often due to warmer and icier conditions.
- shorter winters
- Shorter season, and stronger winds
- Mindre natursnömängd under November-Januari med hänsyn till högre temperatur trots höjdläget 540 m.h.h
- Later start of season
- Higher temp in October, more days over 0 degrees
- fewer days with low (minus) temperature.
- There are less Days with minus degrees that means that we´have a problem to make snow.
- Mildare väder
- Uncertain early winter Now-Dec, more rain and wind, less snow average during winter, shorter skiseason in April
- Later season start
- Snowgun snow
- Seasons changes, snow comes later...
- Shorter winters. Ski season on natural snow start about 1 month later than earlier.
- Last 4 years winter have been started later and sping is coming earlier. Amount on precipitation has increased in winter time,when itś snowing more snow is comming.
- temp
- It depends. We have had 3-4 very good winter seasons in a row, then again 3-4 bad ones. Last January was 2nd best January of all times, February though was one of worst.
- -Høyere
  lufttemperaur

-Mer nedbør i form av regn
- Høyere RF

- no
- Mid-winter time is on average warmer, meaning more days with good XC-skiing conditions.
- warmer and rain instead of snow
- Higher temperature.
  Not so much snow during all Winter.
- Mildare och längre perioder under säsong
- The temperature has risen and thaw-freese-thaw-freese conditions makes maintenance and grooming harder. More rain and less snow, especially nov-dec. Fewer Days with snowmaking conditions oct-dec.
- ..
- Mindre snösäkra vintrar. Det är en av anledningarna till att vi byggt Sveriges första skidtunnel.
- Natural snow comes later (earlier in October, nowadays mainly in November)
- We used only artifical snow
- yes
- Much milder and shorter winter seasons. Our ski track is located only few hundred meters from the sea. As the sea is not getting covered by ice anymore, therefore the temperature near our ski track is 3-5 degrees warmer than the ski track what is located 15-20 km further from the coast. Also nowadays we cannot rely on the natural snow anymore and every season we are making artificial snow (snow cannons).
- Yes. Warmer temperature
- Shortened snow season and uncertainity of the circimtances in the winter
- Yes probably, haven't Worked there so long

Do you think that climate change will affect your ski resort/area in the near future (1-10 years)?

	Respondents	Percent
Yes	35	77.8%
No	10	22.2%
Total	45	100.0%

Table A24: Ski areas response to if they believe that climate change will affect their area in the near future (1-10 years).

How do you think that climate change will affect your ski resort/area in the near future (1-10 years)?

	Respondents	Percent
Positive	9	25.7%
Negative	26	74.3%
Total	35	100.0%

Table A25: Ski areas response to how they believe that climate change will affect their area in the near future (1-10 years).

Please explain your answer

- Less days with snow, less money earned
- less snow will lead to fewer skiers
- We get more visitors on the artificial snow
- Less distance of skiable tracks. Shorter loops. Shorter season.
- interest of xc skiing is falling, risk of reducing the interest for the race.
- Fortsatt förändring i högre medeltemperatur under vintermånaderna
- We have a colder climate than competing locations, warmer weather could possibly increase amount of snow.
- We are the most skilled snow storager in Norway
- The plans are to build longer track with artificial snow and be stronger in the competition against other resorts.
- More periods of higher temperature
- Svårare att göra snö
- it will be more difficult to find customers if hlaf part of the country is snow free.
- Affects other resorts more than us, thus moving competitions to us
- Less snow in Oslo area and good snow conditions at our resort makes the area more attractive. The last few years the winter here has been stretched in both ends making a six month cross country season.
- SENARE SÄSONGSTART, SVÅRT ATT STARTA SKIDSÄSONGEN UNDER OCTOBER NOVEMBER
- Less people in winter season
- Wintersports are our main activities and we are in a big need for snow bu also it can bring us customers/ competitions if we manage to handle the challenge
- More work to maintain good skiing possibilities.

  We have good resources to produce artificial snow to prevent this problem.
- More expences to produce snow, if snow situation is critical we lose costumers.
- less snow/higher temperature
- Could be positive as well. The winter in Estonia is always different. Nothing to expect.
- More interest in northern resorts with reliable and good skiing conditions.

- It will be necessary making more snow
- Higher temperature and less snow.
- Oförutsägbart, snabba växlingar mer nederbörd vid + gr
- Skiing will gradually only be possible on produced snow or other manmade conditions.
  Natural ice for skating will gradually disappear.
- .
- Regn, blåst, snöfattiga vintrar eller sträng kyla gör inomhusskidåkning till ett säkert alternativ för att kunna genomföra planerad träning.
- on short term we have guaranateed snow
- less snow, less people
- If it might even warmer, then it will be hard to make even artificial snow.
- Less snow around at home gives fewer skiers.
- Warmer temperature. More manmade snow. Shorter ski season
- We have the system to make artificial snow, but the warmer winter the more expensive todo snow and tracks. In the other hand, our roller skiing track 3,3km is a big plus to training
- More heavy rain at a short periods and warmer temperatures

Do you think that climate change will affect your ski resort/area in the far future (10-30 years)?

	Respondents	Percent
Yes	42	93.3%
No	3	6.7%
Total	45	100.0%

Table A26: Ski areas response to if they believe that climate change will affect their area in the far future (10-30 years).

How do you think that climate change will affect your ski resort/area in the far future (10-30 years)?

	Respondents	Percent
Positive	8	19.0%
Negative	34	81.0%
Total	42	100.0%

Table A27: Ski areas response to how they believe that climate change will affect their area in the far future (10-30 years).

Please explain your answer?

- Less days with snow, less money earned.
- With no snow at all in the most poulated cities the skiers will not come to vasaloppet events
- It will get hard to even have tempratures below zero degrees, that will do it impossible to make artificial snow.
- Very short season of skiing. Unsecure about enough cold days to make and store enough snow.
- same as previus question
- Lika svar som tidigare fråga
- I don't see a real threat within this time period, but cost of producing snow will increase.
- Higher temperatures need new developments
- If the winters gets warmer and warmer I think the interest for cross country skiing will go down. It will also be harder to produce snow.
- We have less Days to make snow depending on the higher temperature.
- Less and shorter periods of low temperatures
- Samma som förra svaret
- the solutions to offer snowconditions will be crucial and this gives a chance to find new ideas. Skiresort has to offer a year-round facilities for winter sport.
- Direct impact + reduced interest in winter sports due to little snow in population rich ares.Loss of interest.
- Less snow in the alps makes the high areas of Norway more attractive. Latitude wins.
- No snow means no Tartu Maraton.
- MINDRE SNÖ, OCH DEN VIKTIGA FÖRSÄSONGEN FÖRSENAS
- Less visitors
- We can turn it to be positive if we learn and think new
- Trysil er et av de mest snøsikre steder og vil være en vinner selv om klimaet vil endre seg.
- More work to maintain good skiing possibilities. If natural snow falls later the number of skiers can decrease.

  We have good resources to produce artificial snow to prevent this problem.
- Same like short term.
- Less days With Cold weather
- unability to produce artificial snow
- Same answer
- Kortere ski-sesong
- Attractiveness of snow sports may be affected By lack of winter-like conditions in many traditionally active winter sports areas

- Problem with snow
- Same answer
- Ingen köper dyr utrustning när osäkerhet råder om den kommer till andvändning
- Man made conditions will be the only way too ski and skate in 30 years.
  There will be better conditions for activities on bare ground, so the total might be better for sports and leisure.
- .
- Vi har säkrat möjligheten att erbjuda skidåkning på konstsnö både i skidtunneln och vintertid utomhus. Men det finns även en stor risk med klimatförändringarna och det är att allt färre utövar vinteraktiviteter. Därför behövs fler konstsnöanläggningar för att upprätthålla längdskidåkning som en bred och folklig sport.
- skiing as hobby will decline
- no gold wether to produced snow
- new alternative activities
- It is hard to say, but I guess the reasons are the same. If it is getting warmer, it is hard to talk about ski resorts anymore. But in 30 years maybe the climate change has stopped. Or the technology is so advanced that we are skiing on plastic granules.
- We will offer rollerski in summertime in the near future.
- Warmer temperature. More manmade snow Shorter ski season
- No further answer
- Probably The same as previous question

Part III: Adaptation of winter activates and cross-country skiing to a changing climate.

Have your ski resort/area taken any actions to adapt to a changing climate during the last 20 years?

	Respondents	Percent
Yes	33	91.7%
No	3	8.3%
Total	36	100.0%

Table A28: The ski areas' response to if they have done any climate change adaptation for cross-country skiing.

What kind of action have your ski resort/area taken in order to adapt to a changing climate? Answer all that applies.

	Respondents	Percent
Trail improvement (making the ground smoother to reduce the amount of snow needed, relocate the path of tracks to more snow safe locations).	30	90.9%
Making machine-made snow, approximate how much in cubic meters?	29	87.9%
Installing a smart/automatic machine-made snow system for optimizing snow production.	9	27.3%
Storing machine-made snow to use next season (snow farming), approximate how much in cubic meters?	16	48.5%
Trucking snow from another location	11	33.3%
Gathering knowledge/education	25	75.8%
Merger and cooperation with other ski resorts/areas	10	30.3%
Other	8	24.2%
Total	33	100.0%

Table A29: Types of climate change adaptation action for cross-country skiing for the ski areas.

What kind of action have your ski resort/area taken in order to adapt to a changing climate? Answer all that applies. - Making machine-made snow, approximate how much in cubic meters?

Range of produced machine made snow in cubic meters	Frequency
1-10000	30,8% (8)
10001-20000	26,9% (7)
20001-30000	7,7% (2)
30001-40000	7,7% (2)
40001-50000	11,5% (3)
>50000	15,4% (4)
Total	100% (26)

Median	20000
Average	39058
Max	300000
Min	2000

Table A30: Amount of machine-made snow produced per year by the ski areas.

What kind of action have your ski resort/area taken in order to adapt to a changing climate? Answer all that applies. - Storing machine-made snow to use next season (snow farming), approximate how much in cubic meters?

Range of stored machine made snow over summer in cubic meters	Frequency
1-15000	35,7% (5)
15001-30000	28,6% (4)
30001-45000	21,4% (3)
45001-60000	14,3% (2)
>60000	0,0% (0)
Total	100% (14)

Median	22500
Average	26750
Max	60000
Min	8000

Table A31: Amount of machine-made snow produced to store in snow farming per year by the ski areas.

What kind of action have your ski resort/area taken in order to adapt to a changing climate? Answer all that applies. - Other

- Invest in cooling tower for cooling the water for snow production
- Alternative plans, including the ability to produce machine-made snow if necessary, and the possibility to change the location of the track.
- cooled track
- ski tunnel in use
- We have 1.5 km track with cooling pipes under the asphalt. This track will be opened this year at 13.10. Also on same day we will have 700 metres extended track that does not have cooling pipes. Total length of the track on opening day is 2.2 km. We will put about 70 cm snow on the track so the artificial snow won't melt that fast and track maintenance is easier. This track is easy (height difference is 6 m). - In the end of the October/beginning of November we will extend track to 3-4 km. Then we have height difference of 31 m. - In cooling pipes we have Freezium liquid that is not harmful to the nature if there is leakage. - During the last five years our Cooled Ski Track has lengthened ski season about 90 days. For example last winter natural snow came in the middle of the January and our pre-season lasted 95 days. - Basic information can be found here: http://cooledskitrack.fi/cooledskitrack/
- Investment planning for the future
- skidtunneln
- More draining to cope with heavy rainfall

What is the estimated cost for those adaptation actions - Cumulative onetime investments during the last 20 years (in your local currency)? Recalculated to Euros for comparison.

Range of cumulative cost of onetime investments for climate change adaptation actions for cross-country skiing during the last 20 years in Euros	Frequency
1-100000	12,5% (4)
100001-1000000	37,5% (12)
1000001-3000000	25,0% (8)
3000001-5000000	15,6% (5)
>5000000	9,4% (3)
Total	100% (32)
Median	955557
Average	2675418
Max	35000000
Min	10617

Table A32: Cost of onetime investment for climate change adaptation actions for cross-country skiing during the last 20 years in Euros.

What is the estimated cost for those adaptation actions - Yearly additional operational cost for climate adaptation actions during one year of operation (in your local currency)? Recalculated to Euros for comparison.

Range of estimated yearly additional operational cost for climate change adaptation actions for cross-country skiing during one year of operation in Euros	Frequency
1-25000	28,1% (9)
25001-50000	25,0% (8)
50001-100000	18,8% (6)
100001-200000	9,4% (3)
>200000	18,8% (6)
Total	100% (32)
Median	50000
Average	109572
Max	637038
Min	2123

Table A33: Cost of yearly additional operational expenses for climate change adaptation actions for cross-country skiing.

Is your ski resort/area planning on doing any investments in the near future (1-10 year) to adapt to a changing climate?

	Respondents	Percent
Yes	34	75.6%
No	4	8.9%
Don’t know	7	15.6%
Total	45	100.0%

Table A34: Response to if the ski areas are planning any climate change adaptation for cross-country skiing in the near future (1-10 years).

What types of investments in the near future (1-10 year)? Answer all that applies.

	Respondents	Percent
Trail improvement (making the ground smoother to reduce the amount of snow needed, relocate the path of tracks to more snow safe locations).	22	64.7%
Invest in snowmaking guns (snow fans or lances)	25	73.5%
Invest in smart/automatic snowmaking system	18	52.9%
Storing machine made snow to use next season, so called snow farming, if yes approximately how much in cubic meters?	17	50.0%
Other	13	38.2%
Total	34	100.0%

Table A35: Types of climate change adaptation for cross-country skiing investment in the near future (1-10 years).

What types of investments in the near future (1-10 year)? Answer all that applies. - Storing machine made snow to use next season, so called snow farming, if yes approximately how much in cubic meters?

Range of future (1-10 years ahead) intended stored machine made snow over summer in cubic meters	Frequency
1-15000	25,0% (4)
15001-30000	31,3% (5)
30001-45000	6,3% (1)
45001-60000	25,0% (4)
>60000	12,5% (2)
Total	100% (16)

Median	30000
Average	37375
Max	100000
Min	10000

Table A36: Estimated amount of machine-made snow produced for snow farming in the near future (1-10 years) in cubic meters

What types of investments in the near future (1-10 year)? Answer all that applies. - Other

- Upgrade of equipment, compressor, upgrading heads of lances, ground preparation
- Mobile snow production system
- new water supply system
- spara föregående säsongs snö i lager
- Cooling systems
- Alternate small course with artificial snow cover
- Vi lagrer i dag 30000 m3 snø og åpner 6 km langrennsspor 29. oktober. Vi har investert i automatisk snøproduksjonsutstyr allerede. Vi har også investert i rulleskiløyper og lysløype.
- will not do 'snow farming' again, because it was too expensive and did not work out for us.
- investments in off-snow ski training faciilities
- Better grooming capacity
- Vattensystem
- Cool down the water used for snow production
- Making a big ice hall for bandy, track skating and cross coyntry skiing (a ski tunnel)

What is your estimated cumulative onetime cost for those planned adaptation actions in the near future (1-10 years) in your local currency? Recalculated to Euros for comparison.

Range of expected cumulative cost for onetime investments for climate change adaptation actions for cross-country skiing in the near future (1-10 years) in Euros	Frequency
1-100000	21,9% (7)
100001-1000000	40,6% (13)
1000001-3000000	21,9% (7)
3000001-5000000	3,1% (1)
>5000000	12,5% (4)
Total	100% (32)

Median	515433
Average	1644350
Max	10617302
Min	31852

Table A37: Estimated cumulative onetime cost for planned climate change adaptation actions for cross-country skiing in the in the near future (1-10 years) in Euros.

How are you expecting your yearly operational cost to change in the near future (1-10 years) because of those planned adaptation actions? Answer in your own currency.

	Respondents	Percent
Increase	23	67.6%
Decrease	1	2.9%
No difference	10	29.4%
Total	34	100.0%

Table A38: Respond to how ski areas area expected their operational cost to increase in the near future (1-10 years) because of their climate change adaptation action for cross-country skiing.

How are you expecting your yearly operational cost to change in the near future (1-10 years) because of those planned adaptation actions? Answer in your own currency. - Increase (by how much) Recalculated to Euros for comparison.

Range of expected increase in yearly operational cost in the near future (1-10 years) because of planned cross-country skiing adaptation actions to a changing climate. In Euros.	Frequency
1-25000	45,5% (10)
25001-50000	4,5% (1)
50001-100000	22,7% (5)
100001-200000	9,1% (2)
>200000	18,2% (4)
Total	100% (22)

Median	51543
Average	82804
Max	318519
Min	2654

Table A39: Expected increase in yearly operational cost in the near future (1-10 years) as a result of planed climate change adaptation action for cross-country skiing, in Euros.

How are you expecting your yearly operational cost to change in the near future (1-10 years) because of those planned adaptation actions? Answer in your own currency. - Decrease (by how much) Recalculated to Euros for comparison.

- 20000

Is your ski resort/area planning on doing any investments in the far future (10-30 years) to adapt to a changing climate?

	Respondents	Percent
Yes	6	13.3%
No	8	17.8%
Don't know	31	68.9%
Total	45	100.0%

Table A40: Response to if ski areas are planning any climate change adaptation for cross-country skiing in the far future (10-30 years)

What types of investments in the far future (10-30 year)?

	Respondents	Percent
Trail improvement (making the ground smoother to reduce the amount of snow needed, relocate the path of tracks to more snow safe locations).	6	100.0%
Invest in snowmaking guns (snow fans or lances)	5	83.3%
Invest in smart/automatic snowmaking system	6	100.0%
Storing machine made snow to use next season, so called snow farming, if yes approximate how much in cubic meters?	2	33.3%
Other	0	0.0%
Total	6	100.0%

Table A41: Types of planned climate change adaptation for cross-country skiing in the far future (10-30 years)

What types of investments in the far future (10-30 years)? - Storing machine made snow to use next season, so called snow farming, if yes approximate how much in cubic meters?

- 20000
- 50000

What do you see as the main obstacles/risks/insecurities for future investments?

- Faster climate change then expected, harder or impossible to produce snow, winters are getting better, the ownership of the ski resort, The other serives on the resort are not good enough to attract visitors, The cost for the visitor could get too high, Communication of public transport, trains
- less interesed from skiers
- The risk is that temperatures below freezing point absent throughout the winter season
- If temperatures increases too much to use the equipments for snowpoduction.
- Högre medeltemperatur vintertid mot nuläget dvs +3-5 grader, då blir det vattenland land istället
- Due to place and altitude we don't worry too much
- Thar the interest in skiing will be lower because of warmer winters
- The high temperature that prevent us to make snow.
- I can´t see risks in these.
- Lack of cash flow due to much of the activity being public goods.
- funding investments is the main challenge
- 15000000
- VET EJ
- Vanskelig å spå hvordan skitrendene vil utvikle seg. (type ski, skigåing, kjøring)
- Not enough users, not enough income to cover expenses
- Economical situation in Estonia.
- Bad weather With strong wind
- Increase of other cross-country skiing facilities. Other sports getting more popular as snowboarding and downhill skiing
- kan ikke se noe usikkerhet, da det skal investeres/bygges ut masse i forindelse med Vm-søknad og i hverdagsanlegget i årene framover. Planleggingsprosessen har nettopp startet
- Warm winters
- Popularity of recreational cross-country skiing.
- Too many destinations making stored snow.

- As long as it's possible to make snow with guns the cost is manageable. But When will the conditions make even the modernest snowguns unsufficient and economically untenable.
- x
- increasing temperature, decreasing number of skiers
- no
- temperature
- no state funding
- Climate, is cross country skiing still attractive sport.
- Lack of snow during wintertime.
- None
- The strong decreasing of popularity of cross country skiing and other relative sports
- Enviromental issues, the politicans priorities

How will your ski resort/area finance adaptation actions to a changing climate? Select more than one option if applicable and state the approximate percentage of each if possible afterwards

	Respondents	Percent
Private funds	22	53.7%
Public funds	29	70.7%
Ski passes/track passes	27	65.9%
Other	10	24.4%
Total	41	100.0%

Table A42: Types of finance for future climate change adaptation for cross-country skiing.

How will your ski resort/area finance adaptation actions to a changing climate? Select more than one option if applicable and state the approximate percentage of each if possible afterwards - Private investors

Range of percentage of adaptation cost for cross-country skiing to climate change covered by private funds	Frequency
0-0.09	42,4% (14)
0.1-20	12,1% (4)
21-40	24,2% (8)
41-60	9,1% (3)
61-80	9,1% (3)
81-100	3,0% (1)
Total	100% (33)

Median	20
Average	24
Max	100
Min	0

Table A43: Percentage of adaptation cost for cross-country skiing to climate change covered by private funds

How will your ski resort/area finance adaptation actions to a changing climate? Select more than one option if applicable and state the approximate percentage of each if possible afterwards - Public funds

Range of percentage of adaptation cost for cross-country skiing to climate change covered by public funds	Frequency
0-0.09	24,2% (8)
0.1-20	9,1% (3)
21-40	18,2% (6)
41-60	18,2% (6)
61-80	12,1% (4)
81-100	18,2% (6)
Total	100% (33)

Median	40
Average	42
Max	100
Min	0

Table A44: Percentage of adaptation cost for cross-country skiing to climate change covered by public funds.

How will your ski resort/area finance adaptation actions to a changing climate? Select more than one option if applicable and state the approximate percentage of each if possible afterwards - Ski passes/tickets

Range of percentage of adaptation cost for cross-country skiing to climate change covered by track passes	Frequency
0-0.09	26,5% (9)
0.1-20	23,5% (8)
21-40	20,6% (7)
41-60	14,7% (5)
61-80	5,9% (2)
81-100	8,8% (3)
Total	100% (34)

Median	23
Average	31
Max	100
Min	0

Table A45: Percentage of adaptation cost for cross-country skiing to climate change covered by track passes.

	% Of respondent planning finance adaptation actions with track passes
Sweden	80% (12/15)
Norway	58.3% (7/12)
Finland	85.7% (6/7)
Estonia	28.6% (2/7)

Table A46: Percent of respondent planning finance adaptation actions for cross-country skiing with track passes, for various countries, number in brackets indicating number of respondents and total respondents for the question how would you finance your climate change adaptation.

How will your ski resort/area finance adaptation actions to a changing climate? Select more than one option if applicable and state the approximate percentage of each if possible afterwards – Other

Range of percentage of adaptation cost for cross-country skiing to climate change covered by other funds	Frequency
0-0.09	76,5% (26)
0.1-20	8,8% (3)
21-40	2,9% (1)
41-60	5,9% (2)
61-80	0,0% (0)
81-100	5,9% (2)
Total	100% (34)

Median	0
Average	11
Max	100
Min	0

Table A47: Percentage of adaptation cost for cross-country skiing to climate change covered by other funds.

- Increase starting fee
- Sponsorship
- subsidy fom foundations 60%
- Ski clubs

Have your ski resort/area diversify your source of income by increasing the number of activities you offer at your resort in the past 20 years?

	All	Public areas	Private areas	Larger areas	Smaller areas	Hosting large races	Do not host large races	Located north or high elevation	Located south
Yes	53.3% (24)	40.9% (9)	46.2% (6)	63.6% (14)	43.5% (10)	61.9% (13)	45.8% (11)	45.0% (9)	60.0% (15)
No	20.0% (9)	27.3% (6)	23.1% (3)	18.2% (4)	21.7% (5)	19.0% (4)	20.8% (5)	30.0% (6)	12.0% (3)
Don’t know	26.7% (12)	31.8% (7)	30.8% (4)	18.2% (4)	34.8% (8)	19.0% (4)	33.3% (8)	25.0% (5)	28.0% (7)
Total respondent	45	22	13	22	23	21	24	20	25

Table A48: Diversification of activities in the past 20 years.

What type of diversification?

- Biking, trail running, rollerskiing, inroved conditions for hiking, ski touring, biathlon.
- MTB and running
- cafe´, races
- running, increased pavement for rollerskiing.
- running in 1998, MTB 1993
- MTB, hotel, outdoor activities for groups like team building etc.
- Making Active kommunikations and advertising.
- Development of more sports
- activities and services with a year-around principal.
- Other events. Summer avtivity
- Golf, biking, tennis, assorted group activities in the winter.
- We have started new races and events during the last 20 years - MTB maratho, inline skating marathon, city marathon.
- EVENMANG TÄVLINGAR AKTIVITETER, MÄSSOR OCH OLIKA SKIDTÄVLINGA, BARNANPASSNING
- More activities
- Ved å legge til rette for langrenn og andre aktiviteter vil vi bli mer attraktive og kunne selge flere tomter og hytter
- Pre-season: training camps, ticket sales, company events

  Different events: Biathlon and cross-country skiing competitions (organized by Kontiolahti Sport Club, but Cooled Ski Track Company ensure the skiing conditions).
- active activities

- 1) ice skating
  2) beach soccer
  3) beach volleyball
  4) street basketball
  5) swimming
  6) running
  7) biking
  8) orientation
  9) picnic
  10) gym
  11) climbing park
- Broad variety of sports as well as recreational physical exercise: a training center of "all sports" + a fitness/health club for local consumers.
- Genom att ta betalt för de olika aktiviteter som området erbjuder.
- broad both winter & summer
- Adding a skating park, opening a football field, opening a small judo hall, opening a beach football and volleyball field.
- Extended traning, cooperation with other cities, cycling etc.
- Biathlon, roller ski track, roller skating sprint track, fotball/baseball hall, ice hockey hall, tennis gall, wo spa hotels, holiday chalets...

What are the main reasons for this diversification? Rank the options you choose by dragging the text in position. - Climate change

	Respondents	Percent
1	5	20.8%
2	2	8.3%
3	9	37.5%
4	8	33.3%
Total	24	100.0%

Table A49: Ranking of climate change as either first, second, third or fourth reason for diversification of activities in the past 20 years.

What are the main reasons for this diversification? Rank the options you choose by dragging the text in position. - Less dependency of winter season

	Respondents	Percent
1	13	54.2%
2	8	33.3%
3	1	4.2%
4	2	8.3%
Total	24	100.0%

Table A50: Ranking of less dependency of winter season as either first, second, third or fourth reason for diversification of activities in the past 20 years.

What are the main reasons for this diversification? Rank the options you choose by dragging the text in position. - Less dependency on cross-country skiing

	Respondents	Percent
1	0	0.0%
2	10	41.7%
3	12	50.0%
4	2	8.3%
Total	24	100.0%

Table A51: Ranking of less dependency on cross-country skiing as either first, second, third or fourth reason for diversification of activities in the past 20 years.

What are the main reasons for this diversification? Rank the options you choose by dragging the text in position. - Other

	Respondents	Percent
1	6	25.0%
2	4	16.7%
3	2	8.3%
4	12	50.0%
Total	24	100.0%

Table A52: Ranking of other reasons as either first, second, third or fourth reason for diversification of activities in the past 20 years.

Is your ski resort/area planning on diversifying your source of income, in the next 1-10 years?

	All	Public areas	Private areas	Larger areas	Smaller areas	Hosting large races	Do not host large races	Located north or high elevation	Located south
Yes	53.3% (24)	54.5% (12)	38.5% (5)	59.1% (13)	47.8% (11)	61.9% (13)	45.8% (11)	40.0% (8)	64.0% (16)
No	22.2% (10)	22.7% (5)	38.5% (5)	27.3% (6)	17.4% (4)	23.8% (5)	20.8% (5)	30.0% (6)	16.0% (4)
Don't know	24.4% (11)	22.7% (5)	23.1% (3)	13.6% (3)	34.8% (8)	14.3% (3)	33.3% (8)	30.0% (6)	20.0% (5)
Total respondent	45	22	13	22	23	21	24	20	25

Table A53: Planned diversification of activates in the near future (1-10)

What type of diversification?

- Try to use the empty indoor sporthall more, Develop the other activities more
- mtb and running
- Mountainbiking, outdoor gym.
- utökade vår-,sommar- och höstaktiviteter
- Roller-ski track, Roller-ski traidmill, facilities for rent.
- Increase the prices.
- New sports
- offer and selling more services for customers.
- Other type events
- Some new non-winter events.
- TÄVLINGAR MÄSSOR ARRANGEMANG, ÖKA MARKNADSINSATSER MOT SOMMARSÄSONGEN
- More activities
- different types of events and other activities
- More activities which are more independent of weather
- tennis courts, table tennis courts, add more picnic areas, add more volleyball fields, organize more sports- or summerdays for companies, more public events-concerts
- Emphasizing also ice sports and strengthening the development/operation of the "all sports" training center ideology.
- Uthyrning
- Public funds can't finance all investments needed. More fees and private funding will bee a necessity.
- Hockeyplan.
- by season, by nationality
- different kind of activities
- We are planning to build a a multifunctional sport arena with indoor velodrome in it.
- Rollerski / Cycling / summertime
- The newhall of bandy, cross coyntry skiing and skating

What are the main reasons for this diversification? Rank the options you choose by dragging the text in position. - Climate change

	Respondents	Percent
1	5	20.8%
2	6	25.0%
3	7	29.2%
4	6	25.0%
Total	24	100.0%

Table A54: Ranking of climate change as either first, second, third or fourth reason for diversification of activities in the near future (1-10 years).

What are the main reasons for this diversification? Rank the options you choose by dragging the text in position. - Less dependency of winter season

	Respondents	Percent
1	13	54.2%
2	7	29.2%
3	3	12.5%
4	1	4.2%
Total	24	100.0%

Table A55: Ranking of less dependency of winter season as either first, second, third or fourth reason for diversification of activities in the near future (1-10 years).

What are the main reasons for this diversification? Rank the options you choose by dragging the text in position. - Less dependency on cross-country skiing

	Respondents	Percent
1	0	0.0%
2	9	37.5%
3	11	45.8%
4	4	16.7%
Total	24	100.0%

Table A56: Ranking of less dependency on cross-country skiing as either first, second, third or fourth reason for diversification of activities in the near future (1-10 years).

What are the main reasons for this diversification? Rank the options you choose by dragging the text in position. - Others

	Respondents	Percent
1	6	25.0%
2	2	8.3%
3	3	12.5%
4	13	54.2%
Total	24	100.0%

Table A57: Ranking of other reasons as either first, second, third or fourth reason for diversification of activities in the near future (1-10 years).

Part IV: Carbon footprint of winter activities and cross-country skiing

Do you think that your operations at the ski area/resort have a carbon footprint?

	Respondents	Percent
Yes	31	70.5%
No	13	29.5%
Total	44	100.0%

Table A58: Response to if the ski areas that think their operations have a carbon footprint.

Do you think your specific adaptation actions to a changing climate at your ski resort/area have a carbon footprint?

	Respondents	Percent
Yes	31	70.5%
No	13	29.5%
Total	44	100.0%

Table A59: Response to if the ski areas think that their adaptation actions to a changing climate have a carbon footprint.

Have your ski resort/area worked to minimizing your carbon footprint?

	Respondents	Percent
Yes	28	90.3%
No	3	9.7%
Total	31	100.0%

Table A60: Response to if the ski areas have worked to minimize their carbon footprint.

In what way

- More efficient motorisation, energy efficiency, planing the driving of grooming, Changed to LED for the lighted loops on the ski trax.
- use modern machines
- efficiency
- Goal to have fossil free fuel in 2030 (municipal goal) started to change some fuels in the machines. Order energy efficient snow guns. control on the transports fuel economy when they buy transport hours. Changed to LED lights for the lighted loops. the events that are renting the area have to recycle. Warm garage for the snow groomer, reduce the emissions for cold starts.
- Redusing it by planning logistic of transportation of the participants, and always have focus on the challange
- Energieffektivisering av gamla snökanonanläggningar.
- Changing from diesel power to el power, changing from high pressure lances to snow guns
- electric cars, heating by wood chips
- More climate kind fuel
- Reduce energy consumption on snow production
- fex. the ski trails which are covere by man made snow are located close to the snow storage to eliminate carrying distances. Trying to find less energy consuming solutions to ski tunnel (lights for example)
- Energy efficiensy
- Running machines on mixed biodiesel
- Less paper and more digital data. Special waste gathering areas during the races.
- EFFEKTIVARE MASKINER MINDRE KÖRNING MED STORA MASKINER FÖR SPÅRPREPARERING NYTTJA ANDRA MINDRE FORDON
- More efficient snow-producing system, so we are using less energy (electricity) for the production.
- We build cabins and are planning ski inn / out and we don't want the customs too use car when they stay here. We can offer skibuss daily. Every large building we build must have renewable energy too heat the buildings.
- preparere hoppbakker og skiløyper smartere mere effektiv kjøring, god planlegging av prepareringen og mere miljøvennlig snøproduksjon i form av energismarte løsninger. Samarbeider tett med NTNU og forskningsmiljøet der og elektriske eller hybrid tråkkemaskiner vil nok bli kjøpt inn i framtiden.
- Compact design of services: everything is near.
- Using electrisity.
- Bättre snökanoner

- Perhaps not minimize but at least decrease by buying modern Machines that consumes less fuel. Invest in better snowmaking Equipment so the footprint/m3 snow is reduced but the amount of snow produced has increased so i don't really know if it's a reduction.
- Optimering av system och hushållning med material och resurser. Teknisk översyn, materialval och strävan efter hållbarhet i området.
- more efficient snow making solution
- Changed the old snow cannons to the newer ones, which were more economic.
- Adapting to Winters. Not more manmade snow than needed. Piste machines With low fuel consuption
- Using the citys central heating system, wich is produced by woodchips and such
- Producing artificial snow require more electricity, we try to reduce over use of electricity overall, but in the area of snowproduction it increases

Have your ski resort/area worked to quantify your carbon footprint from your regular everyday operation?

	Respondents	Percent
Yes	3	9.7%
No	28	90.3%
Total	31	100.0%

Table A61: Response to if the ski areas have worked to quantify their carbon footprint from the everyday operation.

In what way?

- ukentlig oppfølging av energiforbruket
- Översyn av energisystem
- Statistics over used electricity

Have your ski resort/area worked to quantify your carbon footprint from you adaptation actions to a changing climate?

	Respondents	Percent
Yes	0	0.0%
No	31	100.0%
Total	31	100.0%

Table A62: Response to if the ski areas have worked to quantify their carbon footprint from the adaptation actions to a changing climate.

In what way?

- No answers

Do you think that advertising your ski resort/area as a climate friendly resort with low or no carbon footprint would have a competitive advantage over other resorts?

	Respondents	Percent
Yes	18	40.0%
No difference	27	60.0%
Total	45	100.0%

Table A63: Response to if the ski areas think that, by advertising the area as climate friendly, they would have competitive advantage over other resorts.

Please explain your answer?

- Not so important today, since everyone expect that you are thinking and doing as much as possible in that area anyway.
- We need snow and it would help if we did not increase the carbon
- Customer category have low or no sensitivity to the type of argument
- Don't think people make the connection yet that the snow produced and distributed have a carbon footprint. But think that that will change.
- ?
- We adevertise a enironmental friendly thinking but not climate specific.
- Har inte för det !

- Maybe if other locations are getting bigger footprint, we can take advantage of this.
- People don't care, see to ecological groceries sale in Norway, close to nothing
- i think people in general will think more about the enviorment
- Our visitors to our are is expecting us to work for a bether climate.
- Other quality qounts for our visitors
- Folk tänker inte så när det gäller snö
- green values are more important in the future. The actions/operations at ski resort which supports this may have an influence to visit for some customers
- Environmently issues are typically a hygen factor
- We think climate friendliness is important to our customers now and in the future.
- We don't think that skiers choose marathons according to the carbon footprint but look at other areas.
- BETYDELSEN AV ÅTGÄRDER ATT MINIMERA KLIMATPÅVERKAN ÖKAR BENÄGENHETEN ATT BESÖKA TURISTORTER
- In my opinion our clients are not ready for this yet
- More and more people make active choose and the price isn't always the main reason of their decision.
- Jeg tror ikke de ferierende vil velge resort ut fra dette
- Climate friendly operations will help to get more skiers here.
- People don´t care about carbon footprint too much.
- Maybe in the future if there will be more expensive with old systems.
  The custom will also maybe chose a modern destination who care.
- If we were to be able to produce artificial snow with Little or no carbon footprint it would be a competetive advantage (our "clients" are to a large degree environmental conscious people).
- no
- In Tallinn, there are 2 ski resorts. We both belong to city of Tallinn and do not have advantage over each other
- letter å få folk til å forstå bruken av masse penger for å lage kunstsnø osv.
- People expects good tracks
- People who travel a lot, e.g. to ski resorts, are becoming more and more conscious of the effects of travelling and upkeeping of reacreational or sports facilities. The design of having all services near works for both easiness and covenience as well as reduced carbon footprint.
- Because people today have a growing interest of our nature
- Difficult to explain.
- Vet ej
- The facilities we have today doesn't attract visitors from outside the local area at any great extent.
- Det står i vårt svar
- Dagens medvetna gäster vill veta att anläggningen är klimatsmart och har en hållbar verksamhet.
- it´s more a choice of responsibilty than a ad message
- Our clients are for eg. the Olkympic Ski Teams fo many countires. They choose their resort for practising according to the snow conditions.
- can´t explaine
- just
- In our case, we have a public ski track, where people do not have to pay anything to ski on it, therefore what matters to them that it is free of charge.
  Overall it might make a difference, as people are getting more aware of the climate change and carbon footprint.
- We are only using electricity.
- Ski resort most for inhabitans in Alta city
- The sports that we are doing, happen in the middle of nature. I think the athletes and trainers will value nature and carbon footprint more and more
- Holmenkollen is the main resort for cc skiing in Oslo, people expect snow there. Regardless of how much electricity we use..

What do your ski resort/area see as the main obstacles for minimizing your carbon footprint?

- Information and economy.
- Less transports of snow
- warmer weather
- Few alternative on transportation fuel for groomers, and tansportation viechels.
- transportation options for Our participants
- Energiförbrukning på anläggningen.
  samlade resealternativ för gästerna, Tåg,buss, elbil
- I think we already have a low footprint compared to other locations
- Snow production is not very enviromentaly friendly
- I takes huge investments to get new vehicles, machines and equipment
- We are deppending on the electricite. Its hard to finance climate kind electricite.
- Lack of investment resources
- to find finance for more ecological solutions on different areas.
- Location. Customers have to travel
- Preparation of cross country tracks and running an alpine skiing facility is energy consuming. Easier access to climate friendly fuel would help the situation. We also need heavy investments in energy economizing our buildings in a cold climate.
- Green and climate friendly operations are usually more expensive than the regular ways.

- EFFEKTIVISERA TILLVERKNING AV SNÖ DEN LAGRADE SNÖN SKA KUNNA KÖRAS UT MED MINIMALA TRANSPORTSTRÄCKOR EFFEKTIVISERA LOGISTIK VID UTKÖRNING EFFEKTIVISERA MASKINPREPARERING AV SPÅR
- dont know
- Not enough planning.
  Not enough workers to do needed actions.
- Too have more custom's to stay here longer.
- smartere og mere energi effektive løsninger for å produsere kunstsnø ledlys i hoppbakkene og arena langrenn og i løypenettet. elektriske eller hybride løype-tråkkemaskiner
- Long distance logistics. Travelling far north usually means a long way to travel, even if locally everything is compact.
- Difficult to answer
- More energy will bee needed to maintain future ski resorts. Artificcial climate cost energy.
- Vi producerar värme under en stor del av året när värmen inte är efterfrågad.
- money
- Limited resources
- A green electricity helps us.
- climate change
- Energy saving solutions in sport houses is maybe the most important thing
- Don't know

		How dependent are your ski resort/area's turnover from the winter season, all activities included?	How dependent are your ski resort's/area's turnover from cross-country skiing?
All respondents	0-20%	20.0% (9)	37.8% (17)
	20-40%	13.3% (6)	20.0% (9)
	40-60%	17.8% (8)	13.3% (6)
	60-80%	28.9% (13)	11.1% (5)
	80-100%	20.0% (9)	17.8% (8)
	Total	100% (45)	100% (45)
Public owned	0-20%	31.8% (7)	45.5% (10)
	20-40%	22.7% (5)	27.3% (6)
	40-60%	22.7% (5)	4.5% (1)
	60-80%	13.6% (3)	4.5% (1)
	80-100%	9.1% (2)	18.2% (4)
	Total	100% (22)	100% (22)
Private owned	0-20%	7.7% (1)	38.5% (5)
	20-40%	0.0% (0)	7.7% (1)
	40-60%	7.7% (1)	15.4% (2)
	60-80%	38.5% (5)	15.4% (2)
	80-100%	46.2% (6)	23.1% (3)
	Total	100% (13)	100% (13)
Larger ski areas	0-20%	22.7% (5)	45.5% (10)
	20-40%	9.1% (2)	18.2% (4)
	40-60%	27.3% (6)	18.2% (4)
	60-80%	31.8% (7)	4.5% (1)
	80-100%	9.1% (2)	13.3% (6)
	Total	100% (22)	100% (22)
Smaller ski areas	0-20%	17.4% (4)	30.4% (7)
	20-40%	17.4% (4)	21.7% (5)
	40-60%	8.7% (2)	8.7% (2)
	60-80%	26.1% (6)	17.4% (4)
	80-100%	30.4% (7)	21.7% (5)
	Total	100% (23)	100% (23)
Smaller private owned	0-20%	14.3% (1)	28.6% (2)
	20-40%	0.0% (0)	14.3% (1)
	40-60%	0.0% (0)	14.3% (1)
	60-80%	14.3% (1)	14.3% (1)
	80-100%	71.4% (5)	28.6% (2)
	Total	100% (7)	100% (7)
Hosting large races	0-20%	28.6% (6)	33.3% (7)
	20-40%	9.5% (2)	23.8% (5)
	40-60%	19.9% (4)	9.5% (2)
	60-80%	33.3% (7)	19.0% (4)
	80-100%	9.5% (2)	14.3% (3)
	Total	100% (21)	100% (3)
Don’t hosting large races	0-20%	12.5% (3)	41.7% (10)
	20-40%	16.7% (4)	16.7% (4)
	40-60%	16.7% (4)	16.7% (4)
	60-80%	25.0% (6)	4.2% (1)
	80-100%	29.2% (7)	20.8% (5)
	Total	100% (24)	100% (24)
Northern	0-20%	20.0% (4)	45.0% (9)
	20-40%	5.0% (1)	15.0% (3)
	40-60%	15.0% (3)	15.0% (3)
	60-80%	35.0% (7)	10.0% (2)
	80-100%	25.0% (5)	15.0% (3)
	Total	100% (20)	100% (20)
Southern	0-20%	20.0% (5)	32.0% (8)
	20-40%	20.0% (5)	24.0% (6)
	40-60%	20.0% (5)	12.0% (3)
	60-80%	24.0% (6)	12.0% (3)
	80-100%	16.0% (4)	20.0% (5)
	Total	100% (25)	100% (25)

Table A64: Dependency of winter season and cross-country skiing for various sub-groups of the respondents.

		Have your ski resort/area taken any actions to adapt to a changing climate during the last 20 years?	Is your ski resort/area planning on doing any investments in the near future (1-10 year) to adapt to a changing climate?	Is your ski resort/area planning on doing any investments in the far future (10-30 year) to adapt to a changing climate?
All respondents	Yes	91.7% (33)	75.6% (34)	13.3% (6)
	No	8.3% (3)	8.9% (4)	17.8% (8)
	Don't know	-	15.6% (7)	68.9% (31)
	Total	100% (36)	100% (45)	100% (45)
Public ski areas	Yes	89.5% (17)	63.6% (14)	13.6% (3)
	No	10.5% (2)	13.6% (3)	18.2% (4)
	Don't know	-	22.7% (5)	68.2% (15)
	Total	100% (19)	100% (19)	100% (22)
Private ski areas	Yes	87.5% (7)	84.6% (11)	15.4% (2)
	No	12.5 (1)	0.0% (0)	7.7% (1)
	Don't know	-	15.4% (2)	76.9% (10)
	Total	100% (8)	100% (13)	100% (13)
Larger ski areas	Yes	94.1% (16)	90.9% (20)	18.2% (4)
	No	5.9% (1)	4.5% (1)	22.7% (5)
	Don't know	-	4.5% (1)	59.1% (13)
	Total	100% (17)	100 % (22)	100% (22)
Smaller ski areas	Yes	89.5% (17)	60.9% (14)	8.7% (2)
	No	10.5% (2)	13.0% (3)	13.0% (3)
	Don't know	-	26.1% (6)	78.3% (18)
	Total	100% (19)	100% (23)	100% (23)
Hosting large races	Yes	94.1% (16)	76.2% (16)	14.3% (3)
	No	5.9% (1)	14.3% (3)	19.0% (4)
	Don't know	-	9.5% (21)	66.7% (14)
	Total	100% (17)	100 % (21)	100% (21)
Don't hosting large races	Yes	89.5% (17)	75.0% (18)	12.5% (3)
	No	10.5% (2)	4.2% (1)	16.7% (4)
	Don't know	-	20.8% (5)	70.8% (17)
	Total	100% (19)	100% (24)	100% (24)
Northern	Yes	93.8% (15)	80.0% (16)	20.0% (4)
	No	6.2% (1)	5.0% (1)	15.0% (3)
	Don't know	-	15.0% (3)	65.0% (13)
	Total	100% (16)	100% (20)	100% (20)
Southern	Yes	90.0% (18)	72.0% (18)	8.0% (2)
	No	10.0% (2)	12.0% (3)	20.0% (5)
	Don't know	-	16.0% (4)	72.0% (18)
	Total	100% (20)	100% (25)	100% (25)

Table A65: Adaptation of cross-country skiing to a chaining climate, in the past (previous 20 years), in the near future (1-10 years ahead) and in the far future (10-30) for all respondents and subgroups.

		What kind of action have your ski resort/area taken in order to adapt to a changing climate during the past 20 years? Answer all that applies.		What kind of investments are your ski resort/area planning in order to adapt to a changing climate during in the near future (1-10 years)? Answer all that applies.	What kind of investments are your ski resort/area planning in order to adapt to a changing climate during in the far future (10-30 years)? Answer all that applies.
All respondents	Trail improvement	90.9% (30)	Invest in snowmaking	73.5% (25)	83.3% (5)
	Making machine-made snow	87.9% (29)	Trail improvement	64.7% (22)	100% (6)
	Knowledge/Education	75.8% (25)	Smart snow system	52.9% (18)	100% (6)
	Storing snow	48.5% (16)	Storing snow	50.0% (17)	33.3% (2)
	Trucking snow	33.3% (11)	-	-	-
	Merger and cooperation	30.3% (10)	-	-	-
	Smart snow system	27.3% (9)	-	-	-
	Other	24.2% (8)	Other	38.2% (13)	0.0% (0)
	Total respondents	(33)		(34)	(6)
Public	Making machine-made snow	94.1% (16)	Invest in snowmaking	78.6% (11)	66.7% (2)
	Trail improvement	88.2% (15)	Trail improvement	57.1% (8)	100% (3)
	Knowledge/Education	82.4% (14)	Smart snow system	57.1% (8)	100% (3)
	Storing snow	35.3% (6)	Storing snow	42.9% (6)	33.3% (1)
	Trucking snow	35.3% (6)	-		-
	Merger and cooperation	23.5% (4)	-	-	-
	Smart snow system	17.6% (3)	-	-	-
	Other	23.5% (4)	Other	35.7% (5)	0.0% (0)
	Total respondents	(17)		(14)	(3)
Private	Trail improvement	100% (7)	Invest in snowmaking	81.8% (9)	100% (2)
	Making machine-made snow	85.7% (6)	Trail improvement	81.8% (9)	100% (2)
	Knowledge/Education	57.1% (4)	Smart snow system	72.7% (8)	100% (2)
	Storing snow	57.1% (4)	Storing snow	54.5% (6)	50.0% (1)
	Merger and cooperation	57.1% (4)	-		-
	Smart snow system	42.9% (3)	-	-	-
	Trucking snow	14.3% (1)	-	-	-
	Other	0.0% (0)	Other	27.3% (3)	0.0% (0)
	Total respondents	(7)		(11)	(2)
Larger	Trail improvement	93.8% (15)	Invest in snowmaking	70.0% (14)	75.0% (3)
	Making machine-made snow	93.8% (15)	Trail improvement	75.0% (15)	100% (4)
	Knowledge/Education	87.5% (14)	Smart snow system	60.0% (12)	100% (4)
	Storing snow	56.2% (9)	Storing snow	55.0% (11)	25.0% (1)
	Trucking snow	43.8% (7)	-	-	-
	Merger and cooperation	37.5% (6)	-	-	-
	Smart snow system	31.2% (5)	-	-	-
	Other	37.5% (6)	Other	55.0% (11)	0.0% (0)
	Total respondents	(16)		(20)	(4)
Smaller	Trail improvement	88.2% (15)	Invest in snowmaking	73.5% (11)	100% (2)
	Making machine-made snow	82.4% (14)	Trail improvement	64.7% (7)	100% (2)
	Knowledge/Education	64.7% (11)	Smart snow system	52.9% (6)	100% (2)
	Storing snow	41.2% (7)	Storing snow	50.0% (6)	50.0% (1)
	Trucking snow	23.5% (4)	-	-	-
	Merger and cooperation	23.5% (4)	-	-	-
	Smart snow system	23.3% (4)	-	-	-
	Other	23.5% (2)	Other	38.2% (2)	0.0% (0)
	Total respondents	(17)		(14)	(2)

Table A66: Type of climate change adaptation for cross-country skiing actions and investments for past, near future (1-10 years) and far future (10-30 years) for various sub groups.

		What kind of action have your ski resort/area taken in order to adapt to a changing climate during the past 20 years? Answer all that applies.		What kind of investments are your ski resort/area planning in order to adapt to a changing climate during in the near future (1-10 years)? Answer all that applies.	What kind of investments are your ski resort/area planning in order to adapt to a changing climate during in the far future (10-30 years)? Answer all that applies.
Host large races	Trail improvement	87.5% (14)	Invest in snowmaking	62.5% (10)	66.7% (2)
	Making machine-made snow	87.5% (14)	Trail improvement	62.5% (10)	100% (3)
	Knowledge/Education	68.8% (11)	Smart snow system	50.0% (8)	100% (3)
	Storing snow	68.8% (11)	Storing snow	68.8% (11)	66.7% (2)
	Trucking snow	50.0% (8)	-	-	-
	Merger and cooperation	31.2% (5)	-	-	-
	Smart snow system	25.0% (4)	-	-	-
	Other	37.5% (6)	Other	37.5% (6)	0.0% (0)
	Total respondents	(16)		(16)	(3)
Don't host large races	Trail improvement	94.1% (16)	Invest in snowmaking	83.3% (15)	100% (3)
	Making machine-made snow	88.2% (15)	Trail improvement	66.7% (12)	100% (3)
	Knowledge/Education	82.4% (14)	Smart snow system	55.6% (10)	100% (3)
	Storing snow	29.4% (5)	Storing snow	33.3% (6)	0.0% (0)
	Merger and cooperation	29.4% (5)	-		-
	Smart snow system	29.4% (5)	-	-	-
	Trucking snow	17.6% (3)	-	-	-
	Other	11.8% (2)	Other	38.9% (7)	0.0% (0)
	Total respondents	(17)		(18)	(6)
Northern	Making machine-made snow	93.3% (14)	Invest in snowmaking	75.0% (12)	75.0% (3)
	Trail improvement	86.7% (13)	Trail improvement	81.2% (13)	100% (4)
	Knowledge/Education	73.3% (11)	Smart snow system	62.5% (10)	100% (4)
	Storing snow	66.7% (10)	Storing snow	68.8% (11)	50.0% (2)
	Trucking snow	46.7% (7)	-		-
	Merger and cooperation	33.3% (5)	-	-	-
	Smart snow system	20.0% (3)	-	-	-
	Other	26.7% (4)	Other	37.5% (6)	0.0% (0)
	Total respondents	(15)		(16)	(4)
Southern	Trail improvement	94.4% (17)	Invest in snowmaking	72.2% (13)	100% (2)
	Making machine-made snow	83.3% (15)	Trail improvement	50.0% (9)	100% (2)
	Knowledge/Education	77.8% (14)	Smart snow system	44.4% (8)	100% (2)
	Storing snow	33.3% (6)	Storing snow	33.3% (6)	0.0% (0)
	Smart snow system	33.3% (6)	-		-
	Merger and cooperation	27.8% (5)	-	-	-
	Trucking snow	22.2% (4)	-	-	-
	Other	22.2% (4)	Other	38.9% (7)	0.0% (0)
	Total respondents	(18)		(18)	(2)

Table A67: Type of climate change adaptation for cross-country skiing actions and investments for past, near future (1-10 years) and far future (10-30 years) for various sub groups.

	Range of cumulative cost of onetime investments for climate change adaptation actions for cross-country skiing during the last 20 years in Euros	Frequency (number of respondents)	Range of expected cumulative cost for onetime investments for climate change adaptation actions for cross-country skiing in the near future (1-10 years) in Euros	Frequency (number of respondents)	Range of estimated yearly additional operational cost for climate change adaptation actions for cross-country skiing during one year of operation in Euros	Frequency (number of respondents)	Range of expected increase in yearly operational cost in the near future (1-10 years) because of planned cross-country skiing adaptation actions to a changing climate. In Euros.	Frequency (number of respondents)
All	1-100000	12.9% (4)	1-100000	21.9% (7)	1-25000	28.1% (9)	1-25000	45.5% (10)
	100001-1000000	38.7% (12)	100001-1000000	40.6% (13)	25001-50000	25.0% (8)	25001-50000	4.5% (1)
	1000001-3000000	25.8% (8)	1000001-3000000	21.9% (7)	50001-100000	18.8% (6)	50001-100000	22.7% (5)
	3000001-5000000	16.1% (5)	3000001-5000000	3.1% (1)	100001-200000	9.4% (3)	100001-200000	9.1% (2)
	>5000000	6.5% (2)	>5000000	12.5% (4)	>200000	18.8% (6)	>200000	18.2% (4)
	Total	100% (31)	Total	100% (32)	Total	100% (32)	Total	100% (22)
Public	1-100000	12.5% (2)	1-100000	28.6% (4)	1-25000	35.3% (6)	1-25000	44.4% (4)
	100001-1000000	43.8% (7)	100001-1000000	35.7% (5)	25001-50000	23.5% (4)	25001-50000	0.0% (0)
	1000001-3000000	31.3% (5)	1000001-3000000	28.6% (4)	50001-100000	17.6% (3)	50001-100000	33.3% (3)
	3000001-5000000	12.5% (2)	3000001-5000000	0.0% (0)	100001-200000	5.9% (1)	100001-200000	0.0% (0)
	>5000000	0.0% (0)	>5000000	7.1% (1)	>200000	17.6% (3)	>200000	22.2% (2)
	Total	100% (16)	Total	100% (14)	Total	100% (17)	Total	100% (9)
Private	1-100000	14.3% (1)	1-100000	20.0% (2)	1-25000	28.6% (2)	1-25000	40.0% (2)
	100001-1000000	28.6 % (2)	100001-1000000	40.0% (4)	25001-50000	28.6% (2)	25001-50000	0.0% (0)
	1000001-3000000	28.6 % (2)	1000001-3000000	10.0% (1)	50001-100000	14.3% (1)	50001-100000	40.0% (2)
	3000001-5000000	28.6 % (2)	3000001-5000000	10.0% (1)	100001-200000	14.3% (1)	100001-200000	20.0% (1)
	>5000000	0.0% (0)	>5000000	20.0% (2)	>200000	14.3% (1)	>200000	0.0% (0)
	Total	100% (7)	Total	100% (10)	Total	100% (7)	Total	100% (5)
Large races	1-100000	6.7% (1)	1-100000	21.4% (3)	1-25000	13.3% (2)	1-25000	40.0% (4)
	100001-1000000	20.0% (3)	100001-1000000	42.9% (6)	25001-50000	26.7% (4)	25001-50000	10.0% (1)
	1000001-3000000	40.0% (6)	1000001-3000000	28.6% (4)	50001-100000	13.3% (2)	50001-100000	10.0% (1)
	3000001-5000000	20.0% (3)	3000001-5000000	0.0% (0)	100001-200000	20.0% (3)	100001-200000	10.0% (1)
	>5000000	13.3% (2)	>5000000	7.1% (1)	>200000	26.7% (4)	>200000	30.0% (3)
	Total	100% (15)	Total	100% (14)	Total	100% (15)	Total	100% (10)
No large races	1-100000	18.8% (3)	1-100000	22.2% (4)	1-25000	41.2% (7)	1-25000	50.0% (6)
	100001-1000000	56.3% (9)	100001-1000000	38.9% (7)	25001-50000	23.5% (4)	25001-50000	0.0% (0)
	1000001-3000000	12.5% (2)	1000001-3000000	16.7% (3)	50001-100000	23.5% (4)	50001-100000	33.3% (4)
	3000001-5000000	12.5% (2)	3000001-5000000	5.6% (1)	100001-200000	0.0% (0)	100001-200000	8.3% (1)
	>5000000	0.0% (0)	>5000000	16.7% (3)	>200000	11.8% (2)	>200000	8.3% (1)
	Total	100% (16)	Total	100% (18)	Total	100% (17)	Total	100% (12)
Larger	1-100000	6.7% (1)	1-100000	22.2% (4)	1-25000	26.7% (4)	1-25000	41.7% (5)
	100001-1000000	40.0% (6)	100001-1000000	33.3% (6)	25001-50000	13.3% (2)	25001-50000	8.3% (1)
	1000001-3000000	20.0% (3)	1000001-3000000	27.8% (5)	50001-100000	0.0% (0)	50001-100000	8.3% (1)
	3000001-5000000	20.0% (3)	3000001-5000000	5.6% (1)	100001-200000	20.0% (3)	100001-200000	16.7% (2)
	>5000000	13.3% (2)	>5000000	11.1% (2)	>200000	40.0% (6)	>200000	25.0% (3)
	Total	100% (15)	Total	100% (18)	Total	100% (15)	Total	100% (12)
Smaller	1-100000	18.8% (3)	1-100000	21.4% (3)	1-25000	29.4% (5)	1-25000	50.0% (5)
	100001-1000000	37.5% (6)	100001-1000000	50.0% (7)	25001-50000	35.3% (6)	25001-50000	0.0% (0)
	1000001-3000000	31.3% (5)	1000001-3000000	14.3% (2)	50001-100000	35.3% (6)	50001-100000	40.0% (4)
	3000001-5000000	12.5% (2)	3000001-5000000	0.0% (0)	100001-200000	0.0% (0)	100001-200000	0.0% (0)
	>5000000	0.0% (0)	>5000000	14.3% (2)	>200000	0.0% (0)	>200000	10.0% (1)
	Total	100% (16)	Total	100% (14)	Total	100% (17)	Total	100% (10)
Northern	1-100000	14.3% (2)	1-100000	28.6% (4)	1-25000	28.6% (4)	1-25000	44.4% (4)
	100001-1000000	35.7% (5)	100001-1000000	35.7% (5)	25001-50000	28.6% (4)	25001-50000	11.1% (1)
	1000001-3000000	28.6% (4)	1000001-3000000	21.4% (3)	50001-100000	14.3% (2)	50001-100000	11.1% (1)
	3000001-5000000	14.3% (2)	3000001-5000000	7.1% (1)	100001-200000	14.3% (2)	100001-200000	11.1% (1)
	>5000000	7.1% (1)	>5000000	7.1% (1)	>200000	14.3% (2)	>200000	22.2% (2)
	Total	100% (14)	Total	100% (14)	Total	100% (14)	Total	100% (9)
Southern	1-100000	11.8% (2)	1-100000	16.7% (3)	1-25000	27.8% (5)	1-25000	46.2% (6)
	100001-1000000	41.2% (7)	100001-1000000	44.4% (8)	25001-50000	22.2% (4)	25001-50000	0.0% (0)
	1000001-3000000	23.5% (4)	1000001-3000000	22.2% (4)	50001-100000	22.2% (4)	50001-100000	30.8% (4)
	3000001-5000000	17.6% (3)	3000001-5000000	0.0% (0)	100001-200000	5.6% (1)	100001-200000	7.7% (1)
	>5000000	5.9% (1)	>5000000	16.7% (3)	>200000	22.2% (4)	>200000	15.4% (2)
	Total	100% (17)	Total	100% (18)	Total	100% (18)	Total	100% (13)

Figure A68: Display frequency of responses for various ranges of expenses for climate change adaptation for cc-skiing for following groups; All respondents, Public owned ski areas, Private owned ski areas, Ski areas hosting large races, Ski areas that are not hosting large races, Larger ski areas, Smaller ski areas, Northern and high elevation ski areas, and Southern ski areas respectively.

Combined table with cost of climate change adaptations in the past and projected investments in the future for various subgroups and as percentage of turnover.

All	1. C past	2. C future	3. O past	4. O future	5.% of T(1)	6.% of T(2)	7.% of T(3)	8.% of T(4)
Min	10617	31852	2123	2654	0,59	3,42	0,03	0,22
Max	8000000	10617302	637038	318519	4000,00	2916,67	166,67	125,00
Median	849384	515433	50000	51543	159,09	100,00	16,39	12,08
Average	1632690	1644350	109572	82804	674,06	446,34	29,39	25,27
Public								
Min	26543	31852	2123	2654	20,00	10,00	2,00	1,14
Max	3185191	10617302	318519	212346	4000,00	769,23	100,00	90,91
Median	849384	621606	40000	53087	229,55	133,33	20,00	18,58
Average	1080418	1457198	78238	80711	712,13	269,73	31,42	21,38
Private								
Min	10617	50000	21235	10617	0,59	3,42	0,03	0,22
Max	5000000	8493841	318519	106173	3333,33	2916,67	166,67	125,00
Median	1061730	424692	44593	53087	100,00	94,12	15,00	11,76
Average	1747197	2045115	101044	49872	633,44	583,71	27,09	27,96
Large races								
Min	53087	50000	2654	10000	0,59	3,85	0,03	0,22
Max	8000000	8493841	637038	318519	4000,00	2857,14	100,00	90,91
Median	1061730	515433	100000	51543	176,47	32,67	15,00	2,94
Average	2332027	1257718	156893	101309	759,28	280,68	27,83	14,74
No large races								
Min	10617	31852	2123	2654	20,00	3,42	2,00	1,14
Max	3716056	10617302	318519	300000	2667,67	2916,67	166,67	125,00
Median	690125	515433	40000	37161	146,21	319,29	20,00	20,16
Average	977061	1945064	67819	67383	594,16	575,19	30,76	34,05
Larger								
Min	53087	31852	2654	2654	0,59	3,42	0,03	0,22
Max	8000000	10617302	637038	318519	1076,92	1200,00	68,18	90,91
Median	1061730	690125	159260	51543	88,89	31,00	4,62	2,15
Average	2145517	1724605	183794	93128	179,72	192,91	11,68	14,83
Smaller								
Min	10617	31852	2123	10617	20,00	10,00	6,67	3,57
Max	5000000	8493841	100000	300000	4000,00	2916,67	166,67	125,00
Median	690125	462346	42469	37161	450,00	319,29	29,41	20,16
Average	1151914	1541165	44083	70415	1137,50	772,19	45,01	37,80
Northern								
Min	53087	31852	2654	2654	0,59	3,42	0,03	0,22
Max	8000000	8493841	500000	212346	3333,33	2857,14	68,18	90,91
Median	955557	409260	47296	50000	146,21	31,67	8,57	3,57
Average	1675451	1351942	100425	76495	466,88	383,08	20,32	18,85
Southern								
Min	10617	50000	2123	5000	7,69	3,85	2,00	0,77
Max	7432111	10617302	637038	318519	4000,00	2916,67	166,67	125,00
Median	849384	637038	51543	53087	176,47	160,26	24,04	15,38
Average	1597475	1871779	116687	87171	844,67	495,55	36,44	29,72

Table A69: Displays minimum, maximum, median and average for the following categories 1. Estimated cost for adaptation actions for cc-skiing, cumulative onetime investments during the last 20 years, 2. Estimated cumulative onetime cost for planned adaptation actions for cc-skiing in the near future (1-10 years), 3. Expected increase of yearly operational cost due climate change adaptation for cc-skiing in the past 4. Expected increase of yearly operational cost due to climate change adaptation for cc-skiing in the near future (1-10 years), 5 Percentage of turnover/cost of operation for estimated cost for adaptation actions for cc-skiing, cumulative onetime investments during the last 20 years different subgroups, 6. Percentage of turnover/cost of operation for estimated cumulative onetime cost for planned adaptation actions for cc-skiing in the near future (1-10 years), 7. Percentage of turnover/cost of operation for expected increase of yearly operational cost due climate change adaptation for cc-skiing in the past, 8. Percentage of turnover/cost of operation for expected increase of yearly operational cost due to climate change adaptation for cc-skiing in the near future (1-10 years), for different sub-groups.

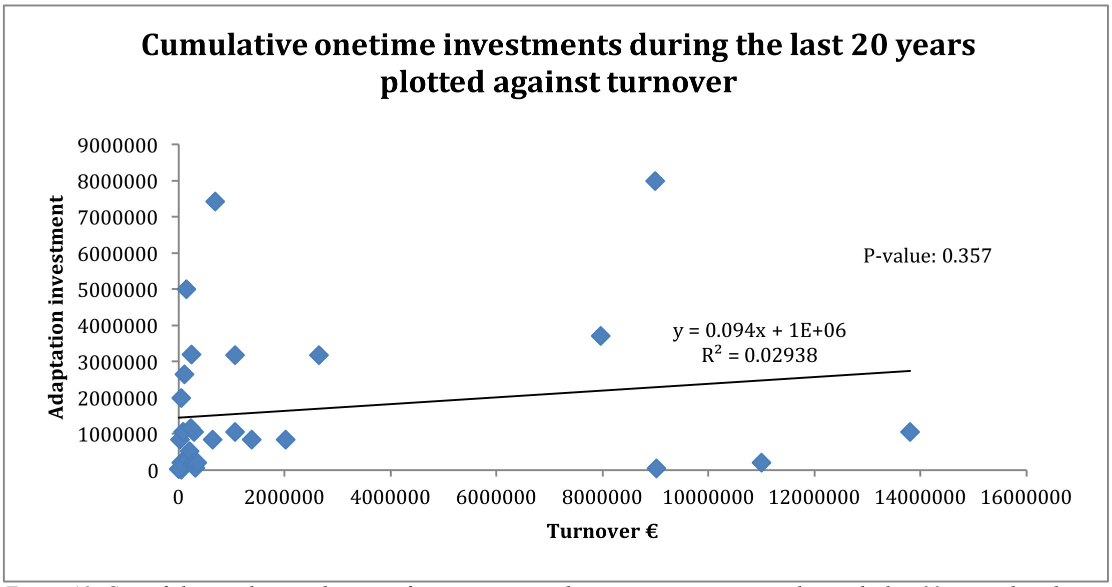

Figure A1: Cost of climate change adaptation for cross-country skiing onetime investments during the last 20 years plotted against the ski areas turnover.

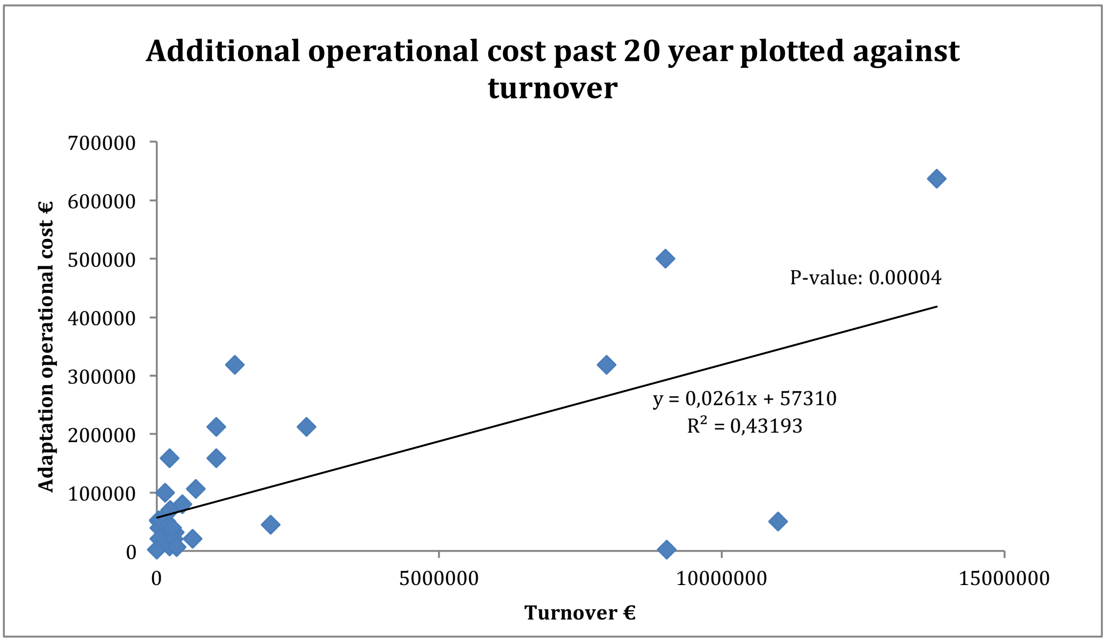

Figure A2: Cost of climate change adaptation for cross-country skiing for additional operation expenses during the last 20 years plotted against the ski areas turnover.

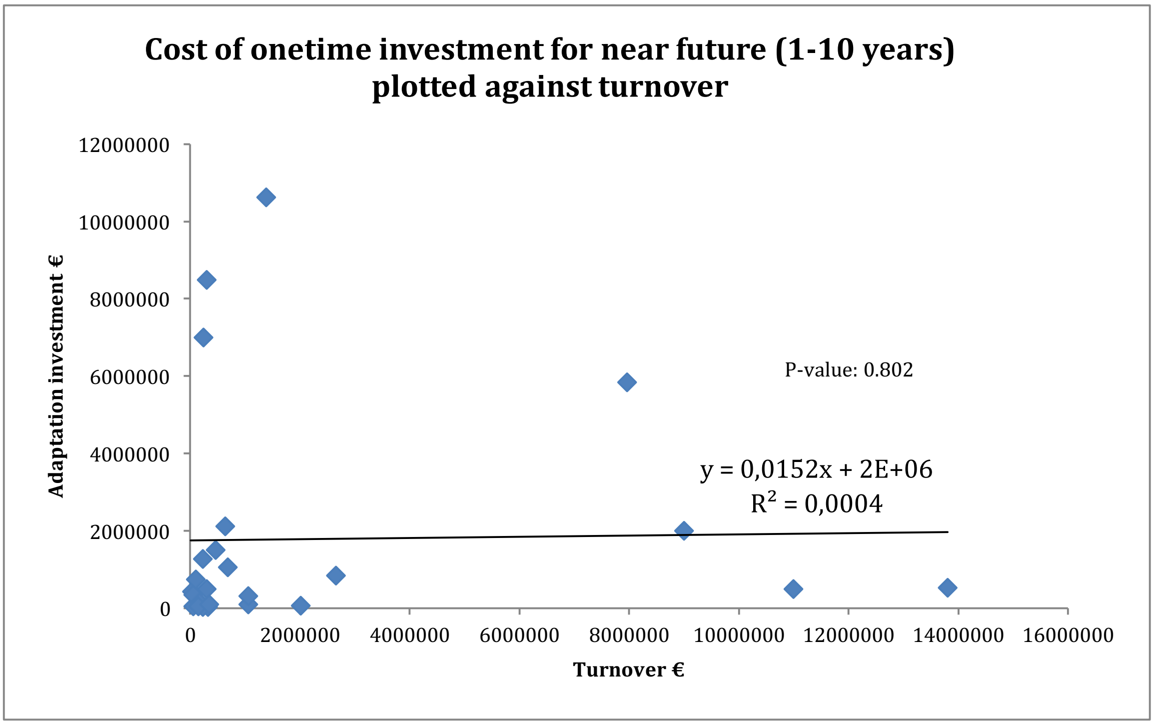

Figure A3: Cost of planned climate change adaptation for cross-country skiing onetime investments for the near future (1-10 years) plotted against the ski areas turnover.

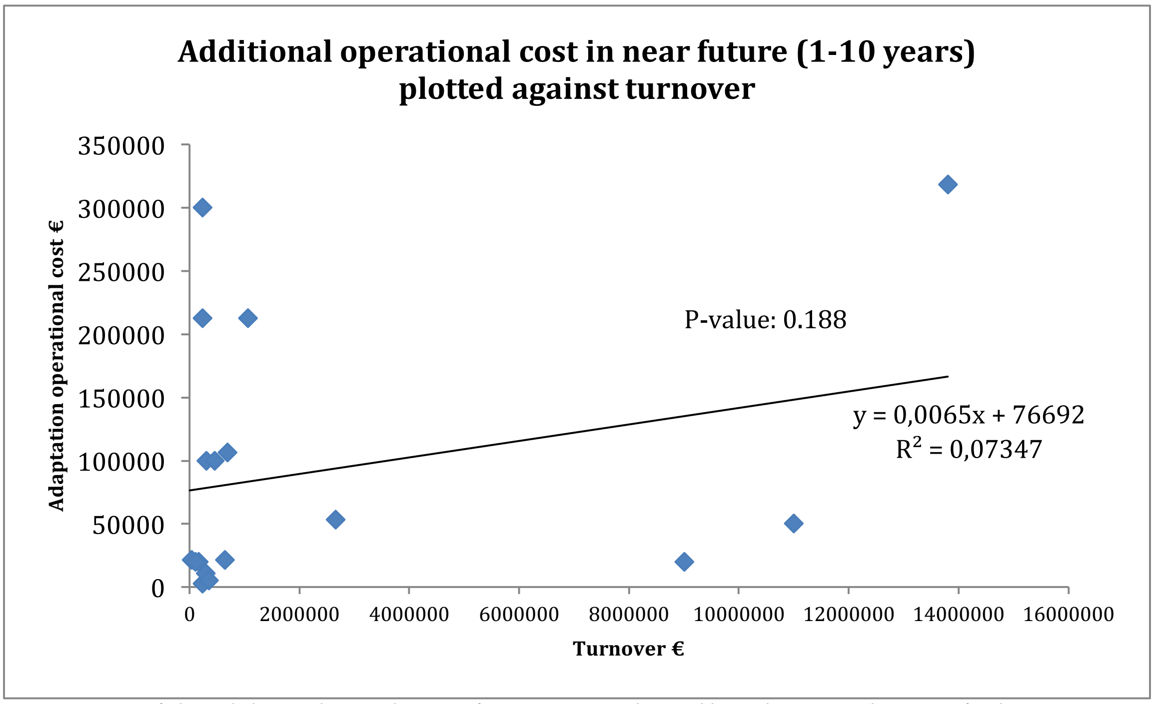

Figure A4: Cost of planned climate change adaptation for cross-country skiing additional operational expenses for the near future (1-10 years) plotted against the ski areas turnover.

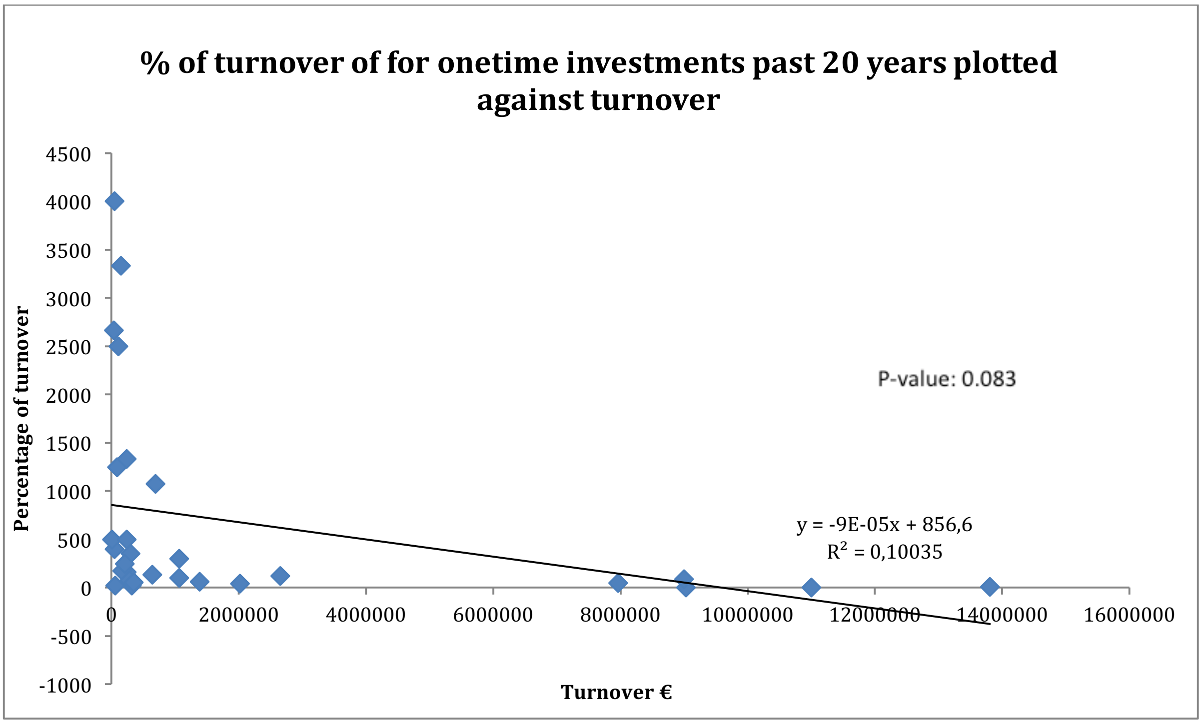

Figure A5: Cost of climate change adaptation for cross-country skiing onetime investments during the last 20 years as a percentage of the ski areas turnover, plotted against the ski areas turnover.

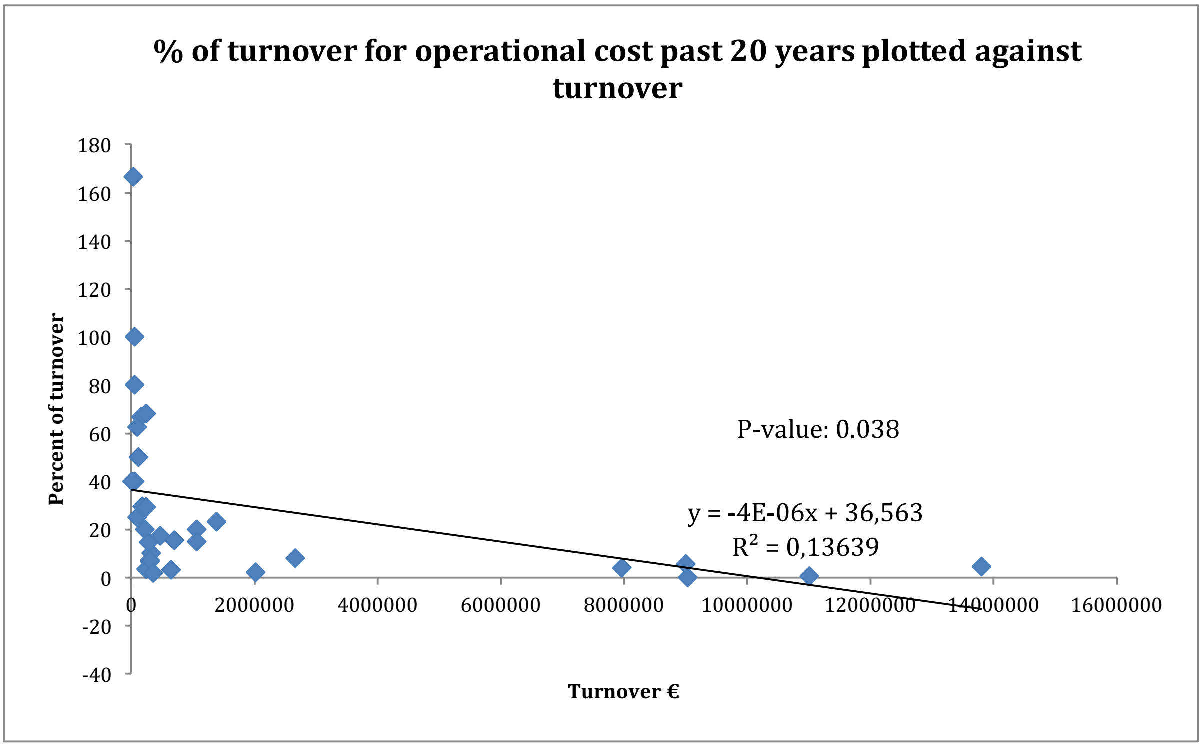

Figure A6: Cost of climate change adaptation for cross-country skiing for additional operation expenses during the last 20 years as a percentage of the ski areas turnover, plotted against the ski areas turnover.

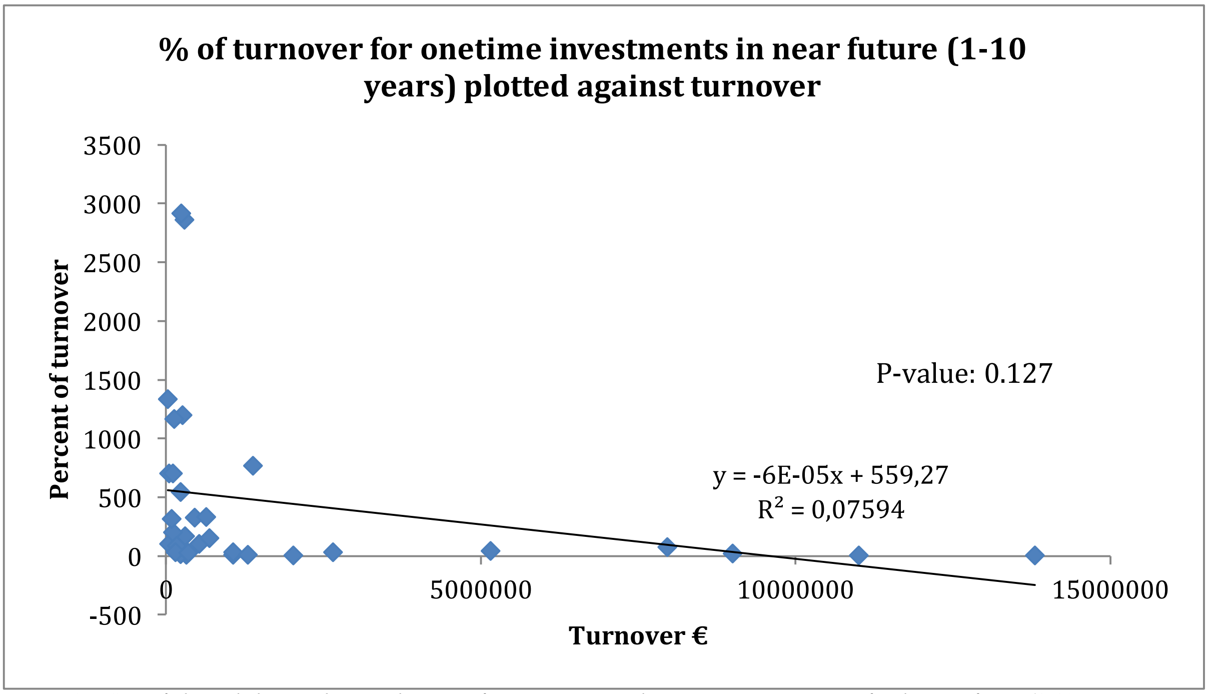

Figure A7: Cost of planned climate change adaptation for cross-country skiing onetime investments for the near future (1-10 years) as a percentage of the ski areas turnover, plotted against the ski areas turnover.

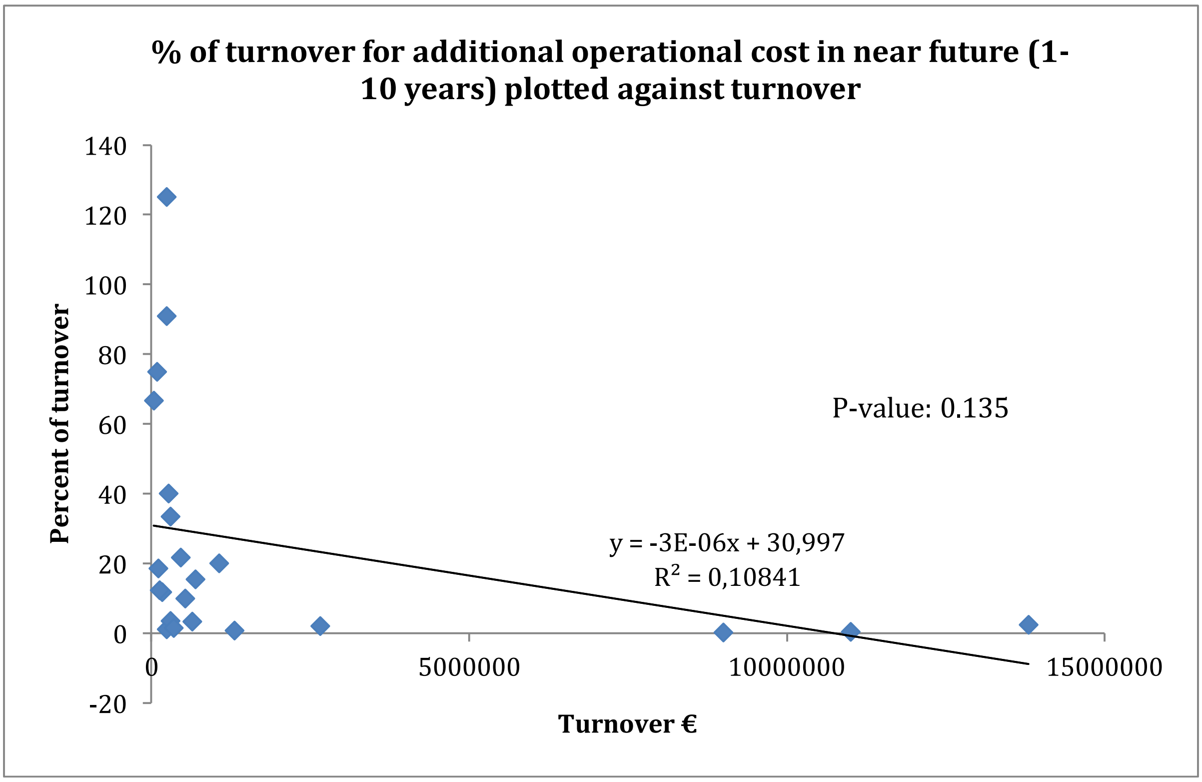

Figure A8: Cost of planned climate change adaptation for cross-country skiing additional operational expenses for the near future (1-10 years) as a percentage of the ski areas turnover, plotted against the ski areas turnover.