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The Future of a Sustainable Ski Resort Industry in regard to Climate Change



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Table of Contents

1	Introduction	1
2	Research problem	3
3	Academic material	4
3.1	State of the industry	4
3.1.1	100-day Rule	4
3.1.2	Projected climate change impacts on skiing and snowmobiling: A case study of the United States	5
3.1.3	Works on climate change impacts in the Alpine ski resort industry.....	5
3.1.4	IPCC Reports	6
3.1.5	The Alpine Convention.....	7
3.1.6	Business adaptation to climate change: American ski resorts and warmer temperatures	8
3.2	Adaptation	8
3.2.1	Climate change adaptation in the ski industry	9
3.2.2	The economic sustainability of snow tourism: The case of ski resorts in Austria, France, and Italy	10
3.2.3	ESPON Case Study Alpine Space	11
3.2.4	Does artificial snow production pay under future climate conditions? - A case study for a vulnerable ski area in Austria.....	11
3.2.5	Managing for climate change in the alpine ski sector	12
3.2.6	Ski resort closures and opportunities for sustainability in North America	12
4	Expert Interviews	14
4.1	Arthur DeJong	14
4.2	Marian Krogh	16
5	Benchmarking	18
5.1	Picture of the resort	19
5.2	Vail Resorts	19
5.2.1	Epic Promise	20
5.2.2	Epic Pass	21
5.3	Climate change and resource efficiency strategy	21
5.3.1	Assessment.....	22

	5.3.2	Action	23
	5.3.3	Advocacy	26
5.4		Waste reduction.....	27
5.5		Pedestrian village	27
5.6		Horstman Glacier	28
5.7		Never Ever Days	29
5.8		Conclusion of the Benchmarking	29
6		Handbook	31
6.1		Mitigation of snow scarcity.....	31
	6.1.1	Artificial snow	31
	6.1.2	Snow farming.....	33
	6.1.3	Slope grooming.....	34
	6.1.4	Selection of location	35
	6.1.5	Glacier protection	36
	6.1.6	Cloud seeding	37
6.2		Business culture	38
	6.2.1	Asset diversification.....	38
	6.2.2	Conglomerates.....	41
	6.2.3	Lobbying.....	42
7		Conclusion	43
8		Bibliography	45

1 Introduction

The ski resort industry has, in its earliest form, existed since at least the mid-19th century, and continues to enjoy popularity among most social classes (Barton, 2008). As the 21st century progresses onwards however, this industry is facing an obstacle that might threaten its whole existence in climate change. The global mean temperature is expected to rise by at least 1.5°C in the best-case scenario, with worst case scenarios seeing an increase of 2.6°C – 4.8°C, by the end of the 21st century. Glaciers, which are vital to some resorts, see similar developments in their decline (IPCC, 2014). Furthermore, unsustainable practices (such as excessive use of artificial snow) are not uncommon in the industry. Many resorts, especially those at high altitudes where they are less affected by climate change, might not consider it a priority to become more sustainable, or to change their business practices in preparation for this inevitable challenge. This trend has seen changes to the positive in more recent years however (DeChano-Cook & Shelley, 2018).

Ski resorts are also facing dwindling visitor numbers especially among younger demographics (Allen, 2017), and the number of ski resorts in the United States is falling (Unofficial Networks, 2019). Worse even, years with poor snow conditions cause an additional decrease in visitor numbers by ten percent, creating monetary losses for ski towns of about 1 billion USD (Hagenstad, Burakowski, & Hill, 2018). Clearly, the industry is at a point at which it needs to transform and innovate to remain healthy.

This thesis is meant as an examination of this topic, both in regards to how the industry will be affected in the coming decades and what it can do to renew itself in order to survive and remain not just profitable but sustainable. It is thus titled *The Future of a Sustainable Ski Resort Industry in regard to Climate Change*.

The topic was chosen because the author is an avid snowboarder, with aspirations of turning this hobby into a career, either by becoming an instructor or guide, or by working for a resort. Furthermore, she is concerned about natural conservation, and would like to see her passions of snow sports and environmental protection be brought together, as she feels that they are often at odds with each other but have potential to be harmonious. Furthermore, she has visited Whistler-Blackcomb, a ski resort of particular relevance to this thesis (see chapter “Benchmarking”), twice in her life, once in winter and once in summer, and has seen firsthand how climate change

is affecting it, and how it is still thriving nonetheless, through implementation of modern sustainability methods. To assess the future of this career path, and to broaden and prove her academic knowledge of the industry, she chose to base her thesis around this subject matter.

The client of the thesis is Protect Our Winters New Zealand, a community of outdoor professionals, that advocate for and educate about sustainable practices within the outdoor industry, particularly in regard to winter sports. It sees itself as a political lobby, that aims to give the outdoor and ski industry the same kind of political leverage that many other industries have (Sorensen, 2020). Since the outdoor community, according to them, has traditionally been too passive and not willing to engage in advocacy, they are working on breaking down those traditional barriers, by connecting people from the outdoor community and providing a platform for them to take action together and have a louder voice than any single person could have.

The focus of the thesis will mostly lie on the North American Rocky Mountains and the European Alps, as they are the most competitive markets within the ski resort industry and breed the most innovation. Because of the client, attention will also be given to New Zealand and Oceania as a whole, where appropriate.

2 Research problem

The problem that the thesis explains and strives to find solutions for, is “Ski resorts worldwide are suffering from less snowfall, shorter seasons and dwindling visitor numbers”. The thesis will first prove and illustrate this problem through data and other academic material, and then find what can be done, and how the industry as a whole, measured by a selection of examples, is looking to cope in the future.

To capture this topic in a manageable frame, the thesis will focus on sustainable practices that are already in place or are being actively developed (i.e., are currently being tested) by industry vanguards, such as Vail Resorts (specifically its biggest resort, Whistler-Blackcomb). Furthermore, when fitting, attention will also be given to ski resorts in New Zealand that are owned by NZSki, a company that is relevant for the commissioning party, as the three resorts that it owns in New Zealand are members of the Protect Our Winters organization.

Based on this research, a guide (see chapter “Handbook”) will be written, which examines different methods of adapting and modernizing a ski resort. The guide will highlight positives and downsides of each method, concluded by an overall evaluation of their merits.

3 Academic material

This section is a review of academic articles and publishings from other relevant organizations. It is meant to establish basic ideas and principles that are commonly found in relevant literature. It is divided into a “state of the industry” section, i.e. a problem-based focus on the present, and an “adaptation” section, i.e. a solution-based focus on the future.

3.1 State of the industry

This section focuses on the state of the industry at the moment, both in regards to its profitability and impact on local communities, and on how climate change is currently affecting it.

3.1.1 100-day Rule

The 100-day rule, first suggested by Witmer in 1986, states that in order for a ski resort to be considered successfully operatable, it has to have a snow-cover of at least 30 centimeters, for at least 100 days during the time period of December 1st and April 15th (only applicable to the Northern hemisphere), for at least 7 out of 10 given seasons (Witmer, 1986). Even though it was never meant as a true “rule”, but rather a guideline, to this day it still finds large popularity among researchers in studies to determine snow-reliability and profitability of ski resorts and ski regions. In reality, these two variables are dependent on many more factors, such as the viability of artificial snowmaking and scale of the resort. Furthermore, achieving a 100-day goal is only the bare minimum, a longer season is ideal (OECD, 2007). Measured by the 100-day rule, all ski resorts in the Alps are currently snow-reliable, but this is expected to fall by the end of the century to between 50% of resorts in Switzerland and 5% of resorts in Bavaria (Rojas, Doctor, & Fragnière, 2018).

3.1.2 Projected climate change impacts on skiing and snowmobiling: A case study of the United States

The case study examines a simulation of snowfall in the United States concerning the rest of the century, specifically the years 2050 and 2090. It then puts this simulation into context with average season length and thus recreational visits to these areas.

A significant finding of this study is that, while most areas will see a significant decrease in season length as expected, areas in more arid climates, which are especially present in the western United States, will actually see an increase in precipitation, and thus season length, for the foreseeable future. (Wobus et al., 2017)

3.1.3 Works on climate change impacts in the Alpine ski resort industry

Prof. Dr. Bruno Abegg, a scholar at the University of Innsbruck, has extensively researched the topic of how climate change impacts the ski resort industry, as well as some other snow-dependent industries, and co-authored tens of papers about it since the mid-1990s. He should therefore be considered a particularly valuable expert on this subject and his works pose an important literature stream.

In his research paper *Aktuelle und zukünftige Schneesicherheit der Skigebiete in Graubünden* (Current and future snow reliability of ski resorts in Graubünden) he examines snow reliability in Switzerland in general, and the region of Graubünden in particular. He finds that snow reliability is guaranteed at around 1200m of altitude, and that for each increase of average temperature by one degree Celsius, that level climbs by 150m. With the projected increase of two degrees Celsius, only 144 out of 230 surveyed ski resorts are at a high enough altitude to remain snow reliable. (Abegg, Steiger, & Walser, 2015)

In his research paper *Herausforderung Klimawandel: Alpiner Skitourismus unter Anpassungsdruck* (The challenge of climate change: Alpine Ski tourism under pressure to change), he examines the future feasibility of artificial snowmaking. The research area is the entire European Alps mountain range. Of the surveyed ski resorts, only 58% are currently snow reliable without artificial snow, but 97% are snow reliable with artificial snow. That number is downsized however, through an increase in temperature, with an increase of one degree Celsius seeing only 86% of resorts being snow reliable, and an increase of two degrees Celsius reducing this number further to 66%. This

is then put into perspective with other challenges that the industry is facing, particularly demographic changes that see the sport of skiing having decreased numbers of participants among younger generations, while older generations are slowly becoming a less reliable income source, because of their decreased ability to participate in intense outdoor sports, due to their age. (Abegg & Steiger, 2016)

3.1.4 IPCC Reports

The International Panel on Climate Change (IPCC) is a body comprised of all UN-member states and endorsed by the UN itself. It is situated in Geneva, Switzerland, and staffed by some of the world's leading scientists on climate change. Its purpose is to collect and review data and scientific research on climate change (but not to conduct any research itself), and periodically comprise it into reports, which are released on a 5–7-year cycle. The sixth assessment report is being published in segments, with the first two parts having been released in 2021, and the third part having been released in 2022 (IPCC, 2022). The sixth report is thus very recent, and therefore particularly relevant to any research on climate change, as the IPCC's status as the biggest compilation effort of scientific research on climate change makes its reports the most important literature stream in terms of evaluating climate change.

According to the newest projections, the following statements can be made about the three regions focused on in this thesis

- In New Zealand, the average temperature is now at 1.1°C higher than 100 years ago. New Zealand will see a continuation of the already present decrease of its snow cover and depth, while glaciers will continue to decrease in size. Winter rainfall will also become significantly more common.
- North America sees an even faster increase in temperature than the global mean, especially the further north one goes and particularly in winter. North America also sees a strong decline in glaciers and snow cover. Winter precipitation is projected to increase, which leads to more snow only in regions that are very far north or have very high altitude, as the extreme increase in temperature during the months of December to February will make rain in winter more common. Furthermore, the Rocky Mountains will see a loss in snow range

- Similar to North America, Europe also sees a temperature increase above the global average, with the frequency of cold extremes and frost days decreasing. Snow covers, glacier length and snow seasons will all continue to decrease, as they have already. The European Alps will see a snow cover decrease below elevations of 1500-2000 m.
- Aside from specific regions the report also looks at the changes expected for mountains worldwide. The snow line and freezing level will rise in altitude, with all glaciers on the planet declining, which would continue to happen, even if the rise in temperatures was immediately stopped altogether.

(IPCC, 2021)

3.1.5 The Alpine Convention

The Alpine Convention is a treaty of all countries that make up the area of the European Alps (Germany, Austria, Switzerland, Liechtenstein, Slovenia, France, Italy, and Monaco) as well as the EU, and has been operating since 1995. Its aim is to offer all alpine countries a platform to better coordinate their efforts in sustainability and future prosperity for the region. It focuses in particular on the climate crisis, as it sees it as a major threat to all its member states. Although the Alpine Convention does not see its main focus in ski tourism, its publications are still highly relevant, as their focus on the wellbeing of the whole region inevitably also encompasses the ski resort industry, as it is one of the most important industries in the region. (The Alpine Convention, 2022)

In its publication “Climate Action Plan 2.0” it is stated that ca. 40% of alpine communities are heavily dependent on tourism, particularly winter tourism in almost all cases. It stresses that a significant shift in tourism demand has been occurring, wherein tourists increasingly demand sustainable holiday packages and are more likely to seek out communities where they know that environmental protection is a high priority. It concludes that a common alpine strategy plan is needed (the implementation of which is supposed to begin with the publication of that report) to modernize the alps. (The Alpine Convention, 2021)

In its publication “Climate Change – How it affects the Alps and what we can do”, the board looks at the facts and figures of climate change in their region. Climate change affects the alps more than most regions, as evidenced by the mean temperature rising twice as fast in the alps as it

does in the northern hemisphere average. The glacier surface in the alps has halved since 1850 and is expected to go down to 30% of what it once was with a rise in temperatures by one degree Celsius, with each additional degree seeing a drop in surface level by another ten percentage points. It acknowledges that all forms of tourism are in danger because of the continued increase in natural disasters, and that diversification of tourism will be an important keyword in the future. (The Alpine Convention, 2017)

3.1.6 Business adaptation to climate change: American ski resorts and warmer temperatures

An article discussing the current willingness to adapt in ski resorts has found that the intensity of adaptation measures is in an inverted U-shape, relative to the intensity of the adversity faced. That is, ski resorts facing medium levels of adversity from climate change show the most willingness to adapt, while ski resorts with low levels of adversity, and, perhaps surprisingly, ski resorts with high levels of adversity show less willingness to adapt. In the case of those facing high adversity, this was explained by the phenomenon that large changes in a business culture would be required, while businesses often tend towards a more stagnant culture. In order to adapt to very radical changes, one has to change radically oneself, and especially smaller operations (which are disproportionately more likely to be heavily affected by climate change) might not be willing to do so. Larger changes also normally require larger financial investments, which is often unfeasible, and might even lead to political opposition, as expanding to higher altitudes and introducing night-time skiing, two of the more easily implementable measures, often prove controversial with politicians who govern the land and with environmental activists. Resorts where climate change shows little impact will often not consider changes necessary, while those affected by medium level- impacts are within a perfect balance of adversity and opportunity to adapt well. (Rivera & Clement, 2019)

3.2 Adaptation

This section discusses how the industry should adapt to the challenges discussed in the previous section.

3.2.1 Climate change adaptation in the ski industry

In their report, Scott and McBoyle (2006) give a comprehensive overview of adaptation measures that are already in place or actively being developed in the industry, some of which are (or were at the time of publication) relatively new ideas.

- *Artificial snowmaking* is by far the most common and most important adaptation method. The average ski season is extended by between 55 and 120 days through artificial snow, with the trend projected to increase even more with climate change. It has however a meaningful negative environmental impact, mostly because winter is often a critical time for natural bodies of water, to retain a healthy water level. Some governing bodies impose restrictions on water withdrawal for snowmaking because of this. Water also has to be treated with certain additives that are often unhealthy to the soil they are placed on, which is linked to resistance from environmental protection groups.
- *Slope development* is the next-most important adaptation method. Slopes can be groomed in a way that makes them more resilient to warmer temperatures, for example by removing rocks and shrubs in summer, thereby decreasing the minimum amount of snow depth required to operate a slope. Snow farming can also be helped by assigning sections of forest for it, as forests naturally capture snow (as well as produce shade and cool slopes). Glaciers can be protected by installing large plastic sheets over them in summer, or by installing snow fences. Lastly, expanding operations to north-facing slopes and to higher altitudes is gaining importance, though it may also see resistance from environmental protection groups
- *Cloud seeding* is perhaps the most outlandish of these methods, seeing as there is still no scientific evidence that it even works at all. Nevertheless, some Australian and North American ski resorts (most notably Vail) have been employing and budgeting for it for several decades now. It is a technology that shoots molecules that are known to attract water molecules to each other into the air, in an attempt to artificially produce clouds, thereby increasing precipitation.
- *Ski conglomerates* are joint ventures of ski resorts across a large area, often comprising multiple different regions and conditions. The idea behind this being a climate change adaptation measure is that these businesses face less adversity from variable weather

conditions. Should a single region experience a poor season, or even multiple poor seasons in a row, these regions can be “bailed out” by the revenue generated from ski resorts in regions that had better seasons. The trends currently point towards more conglomeration in North America.

- *Revenue diversification* means focusing more on becoming a year-round resort, rather than a ski resort. Resort towns can expand their programs beyond snow-dependent offers (although non-ski snow activities, such as dogsledding, or snowmobiling are also possible) to make themselves less dependent on something as fragile as cold temperatures.
- *Marketing incentives* can be used to guarantee a customer a desired experience, i.e. that at least a certain number of slopes will be open for at least a certain amount of time during their stay. Wary travelers can be attracted that way, but the business must have some sort of contingency plan if their guarantee cannot be met, and refunds have to be offered.
- *Indoor ski halls* are completely weather-independent and can be placed far from mountains and in climates that experience no freezing temperatures at all. They could be useful for ski resorts by attracting newcomers to the sport.

(Scott & McBoyle, 2006)

3.2.2 The economic sustainability of snow tourism: The case of ski resorts in Austria, France, and Italy

In this study, the long-term economic viability (particularly in regard to climate change) of a sample of ski resorts in three countries is studied. The authors assume that innovation is the driving factor in economic sustainability, and can only be achieved through financial means, and that therefore, the most profitable ski resorts are the most likely to adapt themselves well to future ecological challenges.

The study comes to the conclusion that by far the most important factor to the profitability of a ski resort is its size (although ski resorts of any size are currently on average profitable), and that there is a direct, provable link between size and profitability. It is then highlighted that ski resorts are a so-called *satellite business*, i.e. a business that drives the economy of a whole community, as a ski resort is often the main reason tourists visit a certain area, and thereby bring profits to

other business in the area as well. Ski resorts of any size, but especially smaller (and therefore more threatened) ones, should therefore diversify their assets, and cooperate with their local economy, to create a business environment that is no longer so heavily dependent on a single business in the form of the ski resort, but rather a coherent network of leisure businesses. (Moreno-Gené, Sánchez-Pulido, Christobal-Fransi, & Daries, 2018)

3.2.3 ESPON Case Study Alpine Space

The findings of the study *ESPON Climate: Climate Change and Territorial Effects on Regions and Local Economies; Annex 1 – Case Study Alpine Space* conclude, that mountain resorts that rely purely on winter tourism will see their ability to stay operational dwindle due to rising temperatures, while mountain resorts that focus on summer tourism, or have year-round attractions, will see an increase in visitor numbers in summer, as mountainous regions will have more temperate, cool temperatures than lower-altitude regions. This will attract people wanting to escape the heat during summer. Lower-lying mountain regions will see their capabilities for winter tourism almost entirely destroyed, while summer tourism should benefit those regions if they have lakes (which are particularly common in lower mountain regions), as lakes will become more relevant as summer destinations, replacing oceanic beaches. Natural disasters, such as floods, wildfires, and avalanches, will become more common overall, but will have a significantly larger negative impact on winter tourism than on summer tourism. (ESPON, 2011)

3.2.4 Does artificial snow production pay under future climate conditions? - A case study for a vulnerable ski area in Austria

In this case study, the authors looked at the snow reliability of a ski area in Austria, put into relation with the reliability of artificial snowmaking, and project these results onto a larger area in the Alps. One of their first conclusions is that many previous studies that had been conducted on the effects of climate change on ski resorts, showed results that were too pessimistic, because they only looked at natural snow, while completely ignoring the widespread use of artificial snow. They also acknowledge however, that costs of artificial snowmaking will continually rise, and that the number of days that are suitable for snowmaking will decrease, meaning that snow cannons will not completely shield ski areas from climate change. The study concluded that low-lying ski resorts in particular are in danger of no longer being profitable and that they must expect shorter

seasons. This is especially a problem if they can no longer operate in April, as easter holidays are one of the most significant peaks in ski tourism demand. Increasing ticket prices are projected to be inevitable. In order to stay in business, the authors recommend focusing on non-ski related activities, such as wellness, winter hiking and mountain biking. (Damm, Köberl, & Prettenhaler, 2014)

3.2.5 Managing for climate change in the alpine ski sector

This journal article claims that climate change is ultimately a problem that threatens individual ski resorts more than the whole industry, i.e. the industry will shrink by a lot but survive overall. In that sense, climate change will even be a boon to those resorts that manage to survive, as it kills off their competition. Resorts that have fewer lifts, are located at lower altitudes, further south, or farther away from major population centers, have historically been slowly losing their market share and going out of business for decades, even before climate change started making major impacts on the industry. Larger and otherwise more advantaged ski resorts have always been able to take advantage of this, making the market very top-heavy, i.e. in favor of those who are already benefiting from the current situation. This trend is projected to accelerate. Nevertheless, the authors stress that even these advantaged resorts need to invest a lot into adaptation measures to retain their position and not fall victim to the same processes that are destroying their smaller competition. Turning into “four-season-resorts”, i.e. investing into summer tourism is named as one of the most important of such measures. (Dawson & Scott, 2013)

3.2.6 Ski resort closures and opportunities for sustainability in North America

The authors of this study argue that, in order to combat the ongoing extinction of ski resorts in North America, a holistic approach is needed. Ski resorts need to innovate beyond the model of small and independent resorts that purely operate in winter. Consolidation is a key element for this. The study names several consolidated passes, i.e. passes that are valid for more than one resort, as examples that have had recent success. The consolidated pass model, although relatively new within the industry, is growing fast and will likely continue to dominate. Furthermore, with climate change making the future of snow sports uncertain, the authors urge resorts to invest in products that are available in other seasons, turning ski resorts into year-round resorts.

Lastly, with consumers growing ever more environmentally conscious, eco certificates are discussed as an option to attract new customers. It is concluded that only reputable certificates, preferable uniform within the industry, will achieve such an effect. (Muscovici, 2022)

4 Expert Interviews

As part of the research process, interviews with two experts within the industry were conducted. The aim for these interviews was to gather experiences that were relevant to the “Benchmarking” and/or “Handbook” section of this paper.

4.1 Arthur DeJong

The first interview was conducted with Arthur DeJong, Environmental Resource Manager at Whistler-Blackcomb from 1993 to 2022. He was asked about issues such as how Whistler-Blackcomb conducts its business and sustainability strategy or how the town of Whistler in particular is threatened by climate change. The interview lasted circa one hour. The following is a summary of the responses to the questions that were discussed.

You have been with Whistler-Blackcomb for several decades. How has the environment changed in your time?

For the town of Whistler, snow is less of an issue because mid- to high-elevation snowpack has actually slightly increased and Whistler is at a relatively high elevation. Arthur DeJong stressed that, while winters have become significantly warmer and glaciers in the region are melting, another less talked-about issue is wildfires. Whistler is in a semi-arid region and while the town itself has not had any major fires yet, he considers it virtually guaranteed to eventually be hit by major wildfires. Furthermore, smoke that is being blown over by wildfires that are more inland is already severely impacting summer tourism in Whistler. To mitigate this, forests around the town are being “fire-proofed”, by e.g. planting more deciduous trees rather than coniferous trees and by careful design planning for the town to make it more resistant to wildfires, and more able to contain a fire to an isolated area.

What do you think other ski resorts could learn from Whistler-Blackcomb? What are the best practices?

Whistler-Blackcomb is diversifying its assets. Whistler sees itself as an “event place” where summers are defined by sporting and cultural events and is now having more visitors in non-winter seasons than in winter. He stressed that no ski resort should ever see itself purely as a ski resort

but rather as a four-seasons resort. Hiking is also making a big comeback in popularity among Millennials and Generation Z, and Whistler-Blackcomb uses social media platforms, especially Instagram, to attract people to this activity. Arthur DeJong considers social media a modern replacement for classic marketing and thinks that marketing outside of social media is mostly obsolete for Whistler-Blackcomb by now.

How long do you expect summer skiing on the Horstman Glacier to continue, with one of the lifts already closed?

For now, the glacier has receded too much for any summer skiing to be viable. A smaller-scale comeback is possible in the future, but unlikely. The effort it would take would not be cost-effective at the moment. The COVID-19 pandemic was also severely impacting operations on the glacier and no lifts have been operational there in summer since 2020.

Investing more into summer tourism is an often-touted solution for ski resorts. How is this going for Whistler-Blackcomb?

Aside from the diversification efforts already mentioned in previous paragraphs, Arthur DeJong stressed that, while the resort and the town are intrinsically linked and in many regards can be treated as the same entity, they are ultimately separate. Summer tourism that benefits the town does not necessarily benefit the resort just as much. The main business model of Whistler-Blackcomb is still to sell tickets for its lifts. To capitalize on a resurgent demand for nature tourism, the resort is now investing in lifts that do not only cater to mountain bikers, but also to sightseers. A tram is being developed that will go at slow speeds from the valley to the peak of Blackcomb Mountain. While this tram will remain operational in winter, it is not a project that is mainly supposed to increase the capacity of skiers.

How has Vail's acquisition of Whistler-Blackcomb changed operations? Vail Resorts has its own sustainability plan (Epic promise).

The acquisition of Whistler-Blackcomb by Vail Resorts actually changed more things for Vail than for Whistler, in regard to environmental policy. Vail was interested in Whistler because of its renowned sustainability plan and wanted to be able to implement it for its own company. While the management structure has changed, from a sustainability standpoint, Whistler exported more policies than it imported.

How does Whistler-Blackcomb cooperate with the local government for sustainability efforts?

The resort and the town are uniquely linked and there is regular exchange between the local government and Whistler-Blackcomb's management. Whistler even has a special legal status as a "resort municipality" – one of only two communities in all of Canada to be designated as such. For its deep cooperation with the local government, the resort has won awards and recognitions and is considered a benchmark for cooperation in resort towns by the United Nations.

How well are the sustainability efforts received by customers?

Customer feedback has been entirely positive. In the current supply and demand environment, tourists are demanding "green" experiences more and more, and Whistler's reputation as an exceptionally eco-friendly resort town has been extremely beneficial. Policies that technically restrict the guest experience, like limiting the use of single-use plastics, create a positive effect of customers feeling like they are in a place that shares their values. Whistler's visitor numbers are on an upwards trend, and have been for decades, and tourists often note the feeling of being in a sustainable and environmentally friendly place as one of the main reasons they enjoyed their stay and would recommend the resort to others.

4.2 Marian Krogh

The second interview was conducted with Marian Krogh, spokesperson of Protect Our Winters New Zealand, the commissioning party of this thesis. She was asked about the political advocacy that her group engages in and what she personally believes must be done to save the industry globally and in her country. The interview lasted ca 40 minutes.

The work within her organization is currently mostly focused on advocating for better access to ski resorts through public transportation. New Zealand is a very car-centric society and things like restricting access to private vehicles or even so much as charging a parking fee would cause large public backlash according to her. She therefore believes that only cheap or free busses, ideally subsidized, would make a difference. POW's efforts in this regard have however been fruitless in New Zealand so far.

An effort that was more successful is the advocacy for a zero-waste policy. POW's partner resort Cardrona has already completely implemented a system for this because of its cooperation with the organization. Furthermore, public reception of this has been extremely positive, with many

customers praising the effort and saying they feel more confident and morally justified in engaging in their hobby as long as such measures are in place. Protect Our Winters New Zealand is therefore currently looking to expand its cooperation to other resorts, using the success of Cardrona as an example for how lucrative environmental friendliness can be.

Investing in summer activities, such as mountain biking, was described as a largely untapped market in the country, even with winters being relatively short, at only around three months. There seems to be potential for expanding into these markets, although little could be said about that during the interview, as POW is first and foremost an environmental protection group that is focused on winters.

Finally, it was the opinion of the interviewee that more companies that have a stake in the ski resort industry have to engage in political advocacy, as only large-scale political changes can truly save the industry. Protect Our Winters welcomes cooperation with any such company, as long as it is willing to also implement good measures by itself. A larger lobby for the industry was described as essential for putting pressure on politicians.

5 Benchmarking

This chapter is meant as a benchmarking project, to examine how a ski resort can be both sustainable and economically successful.

Benchmarking is defined as a tool to compare practices within an area, such as a certain industry, to determine what the best practices are, e.g. which ones achieve the best results, the highest quality, etc. Put simply, it compares companies with each other. Its goal is to improve oneself through the study of other practices. An important consideration to make while benchmarking, is that, while a successful business is always pertinent, comparing oneself to it can, in the wrong circumstances, lead to too narrow thinking, where one only tries to copy the success of another, without considering what new and unused ideas might be relevant as well. (Andersen & Pettersen, 1996)

There are three types of benchmarking; Performance based (What is a company achieving?), Process based (What is it doing to achieve this?), and Strategy based (What plans did it implement to achieve this?) (Andersen & Pettersen, 1996). This chapter will see all of these types implemented.

For the purposes of this thesis, a ski resort was chosen that represents a good example to follow for other resorts, i.e. a success story of how a ski resort can thrive in the face of adversity in the form of climate change, and how a well-made future plan can benefit a business in this sector.

To ensure reliability, a multitude of sources were used, both from streams that are outside of the ski resort (e.g. weather data, independent reports, etc.) and from insiders of it (e.g. expert interviews, internal documents, etc.). The chosen ski resort will then be analyzed through both its own publications and any other relevant material that can be found (articles, reports, interviews, etc.) on how it conducts its business, particularly its sustainability plans. Lastly, a conclusion will be drawn on how all the analyzed factors play into each other and what the main strategy of a ski resort that models itself after this benchmarking could be.

5.1 Picture of the resort

The ski resort that was chosen for this benchmarking is the Canadian ski resort Whistler-Blackcomb, which is situated in the town of Whistler, in the Canadian province of British Columbia. It is located approximately two hours away by car from the Vancouver Metropolitan Area, Canada's third largest population center (Macrotrends, 2022). The town of Whistler has around three million visitors each year (whistler.com, 2022), with roughly 2.5 million visiting the ski resort, making Whistler-Blackcomb the fifth-most visited ski resort in the world, and the most visited outside of Europe (Vanat, 2021). Its visitor numbers in summer are increasing at a faster rate than the visitor numbers in winter and have surpassed them since 2013 (DeJong, 2022).

Whistler-Blackcomb was chosen because of its international awards for sustainability, notably including a recognition by the United Nations as having the best sustainability plan for a municipality of under 10,000 people. This accolade significantly helped boost Vancouver's bid for the 2010 Winter Olympics and Winter Paralympics (Whistler-Blackcomb hosted the downhill skiing events). Domestically, it was recognized by the National Canadian Roundtable on the Economy and the Environment for its active role as a national leader in climate change awareness and sustainability. (DeJong, 2013)

The climate in the town of Whistler is dry, with low humidity, little rainfall in summer, but far above average precipitation in winter. Average temperatures range from -3.8°C in December to 19.1°C in August. (climate-data.org, 2022)

5.2 Vail Resorts

Vail Resorts is a conglomerate of ski resorts and owns over forty resorts across North America and Australia, among them Whistler-Blackcomb (Vail Resorts, 2022). The following sections explore those of Vail Resorts' company policies that directly affect Whistler-Blackcomb's operations. It should be noted that Vail Resorts' sustainability plan is largely a direct copy of Whistler-Blackcomb's plan, which had already been developed and in place long before the acquisition by Vail Resorts and was then adapted by the whole company upon Vail Resorts' acquisition of Whistler-Blackcomb in 2016 (DeJong, 2022).

5.2.1 Epic Promise

Though Whistler-Blackcomb has its own sustainability plan, since its acquisition by Vail Resorts in 2016 it also follows the parent company's plan, called the "Epic Promise", which was strongly inspired by Whistler-Blackcomb's sustainability plan (see above).

The goals and commitments of the Epic Promise plan are as follows:

- The most important part of the Epic Promise plan is a commitment to net zero emissions and 100% renewable energy by 2030 within the entire business structure of Vail Resorts. The company is currently on track for this goal, according to its own reports. This was achieved through rigorous tuning of machinery to maximum efficiency and by creating large-scale renewable energy projects, such as a wind farm, to power most of its resorts' energy needs.
- Vail Resorts is engaging in climate change advocacy, joining with other companies that see their future uncertain because of global warming in urging the United States government to adopt sustainability measurements. Furthermore, the company is cooperating with its three largest competitors (Alterra Mountain Company, POWDR, and Boyne Resorts), forming the Climate Collaborative Charter, an advocacy group against climate change, specifically for mountain towns and the resorts they depend on.
- Vail Resorts wants to send zero waste to landfills by 2030 and is also currently on track with this, according to its reports, having achieved 50.6% diversion as of March 2020. This number stagnated (but did not fall by more than three percentage points) throughout the COVID-19 pandemic, even though the changed conditions it imposed required more use of single-use products. This was achieved e.g. through innovative water and soda fountains, which do not use any single-use plastics (supplied by Vail Resort's partner PepsiCo), easier access to recycling, especially of large items, for employee housing, and a strong engagement of employees to participate in the company's programs and charities.
- Lastly, Vail Resorts commits to net zero impact on its forest habitats by 2030, and also considers itself on track for it. It is achieving this by planting seedlings in accordance to forest acreage destroyed for slope development.

(Vail Resorts, 2021)

5.2.2 Epic Pass

The Epic Pass is a season pass that gives unlimited access to all of Vail's resorts, as well as limited access to Vail's partner resorts in Europe and Japan. For the 2022 season, it cost USD 879 for adults, making it significantly cheaper than its main competitor, the Ikon Pass, at USD 1079, even though it offers access to more resorts (the Ikon pass offers limited access to a larger number of partner resorts that are not directly owned by the Alterra Mountain Company) (epicorikon.com, 2022). The benefit for any resort that participates in such a consolidated pass (Whistler-Blackcomb being no exception) is that people are more likely to buy season passes at Whistler-Blackcomb, because it gives them access to over forty other resorts as well, while season pass holders who may have purchased their season pass at different resorts, should be more inclined to visit Whistler-Blackcomb, because they have been given access as well. Furthermore, with all of Vail's resorts being consolidated, a single bad season in Whistler (e.g. because of bad weather) is more easily survivable, because the parent company Vail Resorts is also making its profits from resorts in different regions, with different climates, and is thus more likely to be able to support a resort that has had a challenging year.

Whistler-Blackcomb, along with all Canadian resorts that have found inclusion in the Epic Pass in the last decade, has seen its visitor numbers and profits increase from this joining of forces with Vail Resorts (Vanat, 2021). Having an affordable and powerful season pass also attracted more people to skiing, who would normally not ski (Walker, 2017).

5.3 Climate change and resource efficiency strategy

The Climate Change and Resource Efficiency Strategy is the master document that dictates Whistler-Blackcomb's sustainability efforts, and was written in 2013 by Arthur DeJong, environmental resource manager at Whistler Blackcomb between 1993 and 2022. It is separated into three phases (assessment, action, and advocacy) with a total of seven steps.

5.3.1 Assessment

The first phase is about taking stock of what situation the resort finds itself in, to build a base to move forward from. It assesses projects that are already in place in Whistler and the climatic and economic circumstances in the region.

Whistler's winter climate has so far been relatively stable with snowfall actually slightly increasing since weather data started to be recorded. This is due to the fact that climate change can, in certain conditions like the one Whistler is situated in, contribute to snowfall by increasing precipitation. This development is not sustainable in the long term though, as this increased precipitation will turn to erosive rainfall as soon as temperatures are above freezing, which they will be ever more often in the future.

A larger and more immediate danger are summer temperatures, which are increasing at a much faster rate, and are already two degrees higher than before. Whistler's low-humidity climate makes it extremely vulnerable to forest fires, and glacial retreat is almost entirely due to increased summer temperatures (rather than less snowfall in winter). Whistler-Blackcomb is trying to make itself an all-year destination, heavily investing in summer tourism. Higher summer temperatures make it more attractive to summer tourists, both because the otherwise chilly mountain climate of Whistler becomes more hospitable and because other regions of the world, especially those that were typical summer destinations in the past, will become less hospitable and thus less attractive. The extreme increase in heat during summers is therefore a positive and a negative – should a way for forest fires to be mitigated be found though, Whistler would become a top destination for summer.

Some of the projects highlighted in the assessment phase are a large-scale study of white bark pines, which make up a large portion of the forests in the region. The changing climate makes them particularly vulnerable to insect infestation, and once a tree is dead it becomes a fire hazard. The species is currently projected to go extinct before the end of the 21st century if no mitigating strategy is put into place.

Other projects in the report include an investigation of cushion plants and pollinators in alpine and polar regions, to better understand how one might respond to warming temperatures, and a state-of-the-art weather station on top of Whistler Mountain, which at the height it is situated at is able to measure particles from the jet stream, which largely dictates Whistler's climate.

Next, the report looks at how Whistler impacts the local economy. The province of British Columbia sees 11% of its tourism revenues generated in the town of Whistler. The report further highlights that, while Whistler is often the main destination of tourists' trips, many people who visit Whistler also make Vancouver a part of their visit as well as other surrounding towns, making Whistler's actual contribution to the tourism revenue even higher. Whistler is especially popular among British and Australian tourists, with a significant portion of them even owning holiday homes in the town.

In this popularity lies a problem for Whistler's environmental impact though. While a tourist will have a relatively low impact stay once they are in Whistler, the resort's carbon emissions rise more than fortyfold if one counts the emissions of traveling, rather than just those that are emitted in the town itself. The report acknowledges that, while a lot has been done to reduce the resort's emissions, better solutions need to be found to address the transportation issue, and that there is currently no plan for that.

Some efforts that are already in place are the large pedestrian village, with 20.000 beds within walking distance of the slopes, and the hydroelectric dam that powers the resort. The largest emitter of carbon in the village are the slope grooming machines, which run on diesel fuel and make up two thirds of emissions.

5.3.2 Action

The Action section discusses concrete actions taken by the ski resort and is further divided into the three sub-chapters Mitigation, Adaptation, and Diversification.

Mitigation

Whistler-Blackcomb strives to reduce its carbon footprint and waste usage to net zero by 2030 and is well on track for this goal. One of the most important projects to achieve this goal is a hydroelectric powerplant on Fitzsimmons creek, the river that divides Whistler Mountain and Blackcomb Mountain. The resort is now 100% running on renewable energy. Other renewable energy sources, like geothermal energy or wind turbines, were deemed unviable in the Whistler region, but an engineering study in 2004 confirmed that a micro hydro power plant on top of Fitzsimmons creek could easily meet the power demand of the entire resort. Furthermore, the site was extremely suitable for this kind of energy production, and only 30% of the land that was

used had to be cleared, making the ecological footprint of the operation very small. Combined with the relatively low fish activity in the river, the ecological problems that often come with hydroelectric power generation were negligible for the project.

To save energy consumption, Whistler-Blackcomb has instituted a large-scale renewal of the resort's energy policy, which started with an assessment of the at-the-time current energy use. By replacing lightbulbs in employee housing, offices, bars, and restaurants, and using more efficient equipment, 1.400.000 kWh were saved annually. Another 450.000 kWh were saved by contracting an external provider to develop a software that optimizes the resort's snowmaking operations, monitoring water and electricity flow.

The largest contributor of carbon emissions for the resort is its fleet of snow grooming machines. Most of the 1.6 million liters of hydrocarbon that Whistler-Blackcomb emits is from Diesel fuel that powers these vehicles. While grooming machines are essential to any ski resort, Whistler-Blackcomb sees them as being in clear incongruence with its goal of being carbon neutral. No suitable long-term solution is within sight at the moment, but smaller yet still impactful attempts are being made. The entire fleet has been converted to a hybrid model of fuel consumption (a feat that was possible because snow grooming machines tend to have a short lifespan of three to five years and can be easily replaced by newer, more efficient models because of this), and idling times were reduced by ten percent in one year, by optimizing daily procedures. This also served to reduce maintenance requirements and extend the machines' warranty, elongating the turnover.

Other carbon emissions were saved by implementing a large-scale carpooling program for the 22% of employees who do not live in Whistler, as well as a free bike rental for employees to commute to and from work, or move around within the town during work, e.g. to get to meetings in different buildings.

Adaptation

The two most important methods to adapt slopes to less snowfall are slope grooming and artificial snowmaking. Whistler Blackcomb's strategy accounts for the environmental impact of both of these measures.

Slope grooming is the artificial flattening of slopes in summer, which makes a shallower snowpack acceptable for opening the slopes in winter. Its problems lie in the fact that, by uprooting trees and removing rocks, it can be a factor in causing erosion. Furthermore, grinding up the ground

leaves nutrient-rich topsoil mixed in with rocky lower levels of earth, which is severely detrimental to any vegetation growth. Whistler addresses this by using an excavator, rather than a more traditional bulldozer, saving the topsoil in a tarp to protect it from rain, and put it back into place as the last step of its annual grooming measures.

The problems with artificial snowmaking are that it uses a lot of electricity, redirects water flow, and that artificial snow tends to melt slower because of its density, causing unnatural snowmelt patterns in spring. Whistler-Blackcomb addresses these issues by exclusively powering its snow-making machines with renewable hydroelectricity, only using water from within the valley it is located in and arguing that having snow melt later than usual is beneficial to regions that battle with dry summers, as water flow is increased later in the year. The report does concede however, that the latter point needs more research to be confirmed and that one way or another, the water flow is still unnatural.

Another project worth mentioning was the Symphony chairlift. Whistler-Blackcomb exchanged low-elevation old-growth forest land that it owned but deemed of low value for slope development, with high elevation terrain that was owned by BC Parks, a government organization that owns public land in British Columbia. The chairlift that was built on this land has won numerous awards for its eco-friendliness, including recognitions from the UN and the US National ski areas association. The planning for this project included meticulous surveying of tree and berry growth, bear habitats, and creek water flow, and made every effort to not disturb any of them. The bear population in the area has remained stable, water quality in the streams did not fall and no wild-life trees were cut down.

Lastly, forest fires pose a major threat to Whistler and the entire North American Pacific coast. While the report acknowledges that there is no long-term solution for fireproofing the village, as many houses were built before modern fireproofing measures were implemented, Whistler-Blackcomb does every other possible thing to be prepared. Sixty million gallons (roughly 227 million liters) of water are stored throughout the resort and on the mountain to provide a first defense against fires of any size. Furthermore, all staff are trained in fire prevention and containment. Whistler has never been hit by major forest fires that threatened lives, but an average of two smaller fires occurs every year, which have so far been contained successfully, with minimal damage.

Diversification

Whistler-Blackcomb recognized decades ago that a successful mountain resort must be attractive during all four seasons. Building from the success it has had as a skiing destination, it thus started to diversify towards other pull factors, such as events. Participatory events have proven particularly successful, such as the annually held World Ironman competition, which draws over 14,000 people to the valley. Other sporting events and smaller music festivals have similar visitor numbers.

The largest diversification effort however was the construction of the Whistler Mountain Bike Park in 1998. At the time of the report, the resort had built over 200 kilometers of cross-country trails, and over 250 kilometers of downhill slopes with lift service, some of which, like a trail named “Comfortably Numb”, have won prestigious awards, recognizing them as some of the best in the world. In fact, Whistler is becoming such a major destination for mountain bikers that their numbers are starting to overtake those of skiers and snowboarders.

The largest draw for tourists who want to visit Whistler is nature. Nature-based tourism experiences account for most of the visits Whistler experiences outside of Winter. To ensure that Whistler remains a top nature destination, most of the area on the two mountains is designated as an exclusively natural zone, i.e. without any development, and at least half of the mountain is accessible within a 22-minute walk from one of the lifts that are servicing the town in Summer. Whistler-Blackcomb sees nature tourism as the perfect sweet spot between for-profit development and natural preservation, as it teaches visitors to be respectful of the nature in the valley, thus providing (and preserving) the natural beauty they came for.

5.3.3 Advocacy

Whistler-Blackcomb sees itself as an international advocate for its efforts in sustainability. Its approach for this is to show that a resort that makes major changes to its operations for the sake of environmental friendliness can thrive. While it acknowledges that the political lobbying that other ski resorts do (the report names Aspen Snowmass as an example) is important, Whistler-Blackcomb wants its visitor numbers and profits to speak for themselves to motivate others to follow suit. The management of Whistler-Blackcomb believes that both of these approaches are equally valid and important.

To achieve this exposure, the resort employs a policy of extreme media friendliness and honesty, often inviting journalists and activists, especially those who are critical of the resort, to tour its

facilities or visit the sites of new projects (like the aforementioned Symphony chairlift). This strategy is often paying off and the report names several examples of critics who have turned into supporters.

Naturally, all of this is not just purely for the sake of being morally on the right side. The company believes that exporting its environmental strategies to others (both other mountain resorts and providing counseling for governments across the world) will build a global brand of being the most pioneering resort in the world and will thus increase profits.

Nevertheless, the report also states that through its advocacy the resort hopes that other resorts, as well as tourism operators in general, will follow this pioneering and make a difference in the global tourism market. Its reliance on seasonal workers, which often hail from different continents, is a benefit for this, as the high turnover of employees means that more people will return to their home countries across the world with a mindset of supporting or establishing environmentally friendly practices and businesses, having seen how successful that can be in their former employer.

5.4 Waste reduction

As mentioned in previous sections, Whistler-Blackcomb strives to reduce its environmental impact to net zero by 2030. This includes a reduction of waste. Food waste has been reduced by 25% through informative stickers on all trays in mountain restaurants and by training staff to sort packaging and food waste, and to do it in an area of the restaurant that is visible for guests (DeJong, 2013). For recyclable waste and landfill management, the resort, along with the municipality, is cooperating with the local company Carney's Waste Systems (O'Reilly & Symko, 2008). The efforts have so far been a great success, and the resort is on track to fulfill its goals potentially even slightly ahead of schedule (DeJong, 2022).

5.5 Pedestrian village

The town center of Whistler village is an area that is car free and houses a high density of shops and restaurants. This pedestrian area is directly connected to all major gondolas that serve both of the town's mountains, as well as several stops in Whistler's public transport system. The way

the village was designed, was to have various small- to mid-size plazas be connected by narrower pathways, reminiscent of streams that flow in and out of pools in nature, to optimize the flow of people and avoid congestion (O'Reilly & Symko, 2008). While this style of town planning is not uncommon in Europe, it is somewhat unique in North America, making Whistler well known and highly regarded for this feature that is considered an attraction in itself (DeJong, 2022). Naturally, having the majority of the town's businesses be connected in a walkable manner and easily reachable by public transport is a boost to the destination's eco-friendliness, supporting both Whistler-Blackcomb's goal of net zero emissions, and the town's attractiveness to the ever growing eco-logically conscious traveler segment.

5.6 Horstman Glacier

Whistler-Blackcomb's operating area includes the Horstman Glacier, located on the peak of Blackcomb Mountain. As with any glacier worldwide, it is retreating.

In 2015 it was announced that, in order to combat this retreat, four snow guns would be installed on the glacier, where they would be most effective, and would operate in summer. Furthermore, snow fences were installed, which trap runoff snow, turning it into pack-ice, and feeding the glacier. (Save Our Snow, 2022)

The snow harvested from this operation is used to ensure early-season (October) skiing at several parts of the resort. The water is collected from Fitzsimmons creek, the creek that runs in the valley between Whistler Mountain and Blackcomb Mountain, which has also had a 7.5-megawatt hydroelectric power plant installed on it, that powers the entire Whistler-Blackcomb resort. (Sheridan, 2015)

In 2020, the resort had to close one of its lifts on the glacier, the Horstman T-bar, permanently because of the glacial retreat. The other lift, the Glacier Express Chair, remained operational, making summer skiing still a possibility for at least the foreseeable future (Stern, 2020). As of 2022, summer skiing is no longer implemented though, as interest in it has declined, largely also because of the COVID-19 pandemic, though it would technically still be possible with the current snowpack (DeJong, 2022). Nevertheless, Whistler-Blackcomb should be recognized for having managed to continue summer skiing for so long, in spite of all odds.

5.7 Never Ever Days

With the number of skiers declining, in no small part because of climate change, ski areas are looking for ways to encourage younger generations to ski, in hopes of turning them into lifelong customers. Whistler-Blackcomb's solution to this are the Never Ever Days – a program for people who have either never skied or snowboarded in their lives, or who have in the past, but need a refresher course. The program is designed to be easily accessible, making a beginner lift ticket, a complete rental of gear and a group lesson available for a heavily discounted price of CAD 25.

The program has seen particular success among demographics who are least likely to be amateur skiers. Women, ethnic minorities, and first-generation immigrants are all disproportionately more likely to sign up for the Never Ever Days than they would be to ski otherwise. Whistler-Blackcomb invested CAD 90,000 into the program which has generated a revenue of one million CAD. The resort acknowledges that attracting new people to the sport is an industry-wide effort and that it is advantageous to help its competitors with this too and has thus made the program available to 81 other resorts across Canada. (Stuart, 2018)

5.8 Conclusion of the Benchmarking

Whistler-Blackcomb's business strategy seems to be to go as big as possible. Being known as a world leader of, if not outright the best at, everything, seems to be paying off. A worldwide brand of showing how sustainability can lead to profit and success has been well-established by now. What a mountain resort can learn from Whistler-Blackcomb is, that with hard times ahead for the ski resort industry, only those with a strong drive to invest and diversify will thrive. Naturally, this large-scale adaptation comes with a cost, which is an unfortunate conclusion to draw as well: In the future, the wealthiest ski resorts are in the best position to survive. Investment and diversification are the driving factors for success. Many of Whistler-Blackcomb's investments into the future were already done in the early 2000's or even late 1990's, making them a pioneer in the industry, and that foresight is clearly provided the resort with a significant advantage now.

Nevertheless, if a ski resort finds itself willing to adapt but with little previous work being done, there are still some lessons to be learned. Actions such as the adaptation of energy systems (changing lightbulbs, adjusting procedures, switching to internally generated renewable energy etc.) require relatively little investment, and are likely to even *save* money in the long run. Ski

conglomerates, like Vail Resorts, are beneficial for everyone involved, and might be even more beneficial for a struggling smaller-scale operation.

Overall, Whistler-Blackcomb is showing itself to be a model resort. The visitor numbers, deep ingrainment into the culture of British Columbia, and ultimately most importantly the profits are a clear indicator of success. It is very reasonable to expect it to continue to thrive for a long time to come and one can therefore take it as a gold standard for mountain resort development.

6 Handbook

This section is meant as a handbook on the best practices that a ski resort can employ to prepare itself for the ever-increasing effects of climate change. In the following sub-chapters, practices that are already in place will be examined by reviewing relevant literature, and their usefulness determined in a conclusive statement. The handbook is separated into a section on the mitigation of snow scarcity, and a section on other, business-related methods.

6.1 Mitigation of snow scarcity

Ski resorts need snow to stay in business. The reason why climate change is threatening to the ski resort industry is that higher temperatures will continue to make snow scarcer. Therefore, most methods to combat climate change are focused on mitigation efforts to cope with less natural snowfall.

6.1.1 Artificial snow

Artificial snowmaking is by far the most common method to implement climate resilience in ski resorts (Scott & McBoyle, 2006). Snow cannons work by spraying mist into the air at a high pressure, making water droplets form into ice crystals and subsequently fall as snow. In order for snow to form out of this mist at temperatures at or slightly above freezing, the water can be treated with certain chemicals and bacteria, that alter the molecular composition of the water mixture used (Rixen, et al., 2008). Artificial snowmaking is costly for ski resorts. Costs vary considerably with conditions, e.g. how rocky the terrain is (more rocky terrain is more expensive) or how humid the air is (drier climates are more favorable), but a general rule is that for each square kilometer treated, a resort has to invest one million euro (The Economist, 2017).

Even with its costliness, artificial snow is becoming more and more crucial for ski resorts, as even when natural precipitation would provide a snow cover that is sufficient for a small number of slopes to be open, modern-day customers expect fully opened resorts even during the edges of the season, i.e. the Christmas and Easter holidays (Smith, 2017). Investments in snowmaking to provide a snow guarantee from November until April/May are in the hundreds of millions

(Abegg;Bürki;& Elsasser, 2008). What was once a luxury, has now become an arms race among ski resorts to provide the deepest snow, the earliest season start dates and the latest end dates.

As ubiquitous as the use of artificial snow is, it is still surrounded with controversy. Mostly, artificial snow can have negative impacts on an environment's flora and fauna and its water cycle, along with being energy intensive. Flora and fauna suffer from the fact that artificial snow is denser and thus takes significantly more time to melt in spring than natural snow, delaying the growth and thus the abundance of many fragile plant species, while fauna is disturbed by the noise of the snow guns (Caravello, Crescini, Tarocco, & Palmeri, 2006). Furthermore, with the artificial treatment of bacteria and minerals that the water of snow cannons receives, the nutrient composition of the ground it eventually melts on is changed, unnaturally favoring certain species that thrive from these specific substances and making them so dominant that they suppress other species (Dambeck, 2008). Artificial snow is normally produced by draining water from a natural source, such as nearby lakes and rivers, and in many cases storing it in a manmade reservoir before use. This method also poses significant environmental challenges. Water levels are naturally at their lowest during the times of the year in which artificial snow making is at its highest, critically endangering local water levels, while water that is taken during more favorable times of the year and stored in reservoirs is still isolated from the water cycle, as reservoirs are normally tarped off from the ground (OECD, 2007). Lastly, snow cannons are a considerable expense in their energy consumption. Snow gun manufacturers estimate ski resorts normally extend two thirds of their energy costs on artificial snowmaking (Flynn, 2013). Limiting, or completely eliminating, artificial snow could therefore be a considerable cost benefit. It should be noted however, that technologies that are still relatively recent at the time of writing this are slowly being implemented, that allow for snow guns that do not use compressed air, which is one of the largest energy drains of conventional snow guns (Scanlan, 2017).

Because of the environmental impacts, some regions might also impose restrictive legislature. A notable example is the US state of Vermont, which forbids water to be drained from natural sources if they are at or below their average mean flow (Hunter, 2021). While about 60% of ski resorts and cross-country ski operators rely on artificial snow and consider it essential to their operations, a not inconsiderable number of locations is currently surviving without it, though these are mostly smaller-scale venues (Vanat, 2021). They resort to other mitigation strategies, like the ones that will be discussed later in this chapter. Being "all-natural" and "free of artificial snow" is used as a marketing boost.

Indeed, there is a certain irony in using something so energy-intensive (and potentially destructive to local environments) to offset the effects of climate change, while contributing to these very effects in the process. Ski resorts are vulnerable to climate change and need clean energy solutions to be found even more than most other industries, yet they are contributing to their own demise with their methods. Despite all of this, it cannot be denied that artificial snowmaking is a necessity and will only become more important in the future. Small scale operations that do not use it are already at risk of going out of business, and large-scale resorts would be ill-advised to completely eliminate their snow guns. A good middle ground seems to be to only use as much artificial snow as absolutely necessary, and to otherwise rely on other mitigation methods.

6.1.2 Snow farming

Snow farming is both the retention of snow from the previous season, and the redirection of freshly fallen snow onto the slopes without the use of grooming machines. The latter is done by strategically placing fences to create an artificial snowdrift from unused areas towards the pistes, where it can then be easily picked up and redistributed. The former is an effort of using excess snow to create snow mounds that are tarped off or covered in sawdust and placed in a spot with as much shade as possible. Most of the retained snow can survive through summer and can then be used to build the first slopes in late fall or early winter. Retention rates are normally at 60%-80%, and sawdust covers of at least 40cm are sufficient to shield the snow pile from all elements (Grünwald;Wolfsperger;& Lehning, 2018). While these snow piles are a method of elongating the season, the aforementioned snow fences are used to ease snow grooming and boost snow volume during the season.

Through the use of snow farming, the Austrian ski resort of Kitzbühel has recently managed to extend its season into as early as mid-October and as late as May, with a relatively small annual investment of ca 156,000€ (Jung, 2018). Other resorts, such as Timberline Lodge on Mount Hood in the US state of Oregon, use snow farming to supply their summer skiing programs, allowing for a season that extends into September (Timberline Lodge, 2018). Snow farming is no mere isolated phenomenon of a few outlying resorts. The number of Swiss ski resorts that employ it for example, has risen exponentially since the 1990s, from just below 2% in 1991 to over 20% in 2015, with an even larger number of resorts intending to implement it in the near future (Swiss Institute for Snow and Avalanche Research, 2015). Evidently, snow farming has found a large audience that

continues to grow. The technology around snow farming has also not matured yet, and new innovations are made almost every year, allowing for higher retention rates and storage at lower latitudes and altitudes (Weiss, Bierman, Dubief, & Hamshaw, 2019).

Since the snow that is used in snow farming is naturally fallen and not treated with additives, it could be considered a more eco-friendly alternative to traditional snow guns, although they do have a much higher capacity. Resorts often use it more as a way to start the season earlier. Snow farming alone cannot completely solve a resort's demand for snow, but it can significantly supplement it and contribute to stable opening dates.

6.1.3 Slope grooming

Slope grooming is the practice of modifying a ski slope to achieve more desirable results. For the purposes of this chapter, only practices that are meant to mitigate the scarcity of snow will be discussed. Slope grooming can happen both to the already fallen snow during or shortly before the season, and to the ground it will fall on during the off season.

Most commonly, slopes are flattened by evening out ground surfaces and by removing shrubs and rocks. This is because smaller total amounts of snow are required to make a slope skiable the more level the ground is (Scott & McBoyle, 2006). Furthermore, trees can be strategically planted or retained to give a maximum amount of shade on a slope, thereby decreasing snowmelt. Another method is the daily use of grooming machines on slopes during the season, which is normally done anyway to give the ski runs a higher quality. It has the beneficial side effect that groomed snow has a much higher albedo (the amount of light that is reflected from a surface, rather than absorbed) of up to 90%, as opposed to ungroomed snow which can have an albedo of as little as 47% (OECD, 2007). Snow with a higher albedo is more resilient to melting from direct sunlight.

Slope grooming can be controversial. While there is little environmental damage from the use of snow grooming machines (apart from their carbon emissions) and obviously no environmental harm from the retention of trees, landscaping of the ground in summer can have serious impacts on an environment. Healthy soil needs diversity. Shrubs, roots, and buried rocks all contribute to the eco-system and to the prevention of erosion. One local study in Bavaria found that cases of erosion are twice as likely to occur on groomed land than on ungroomed land (Bayerisches

Landesamt für Umweltschutz, 2005). Plant diversity and the health of soil is also severely negatively impacted, when compared to adjacent, ungroomed land (Wipf;Rixen;Fischer;Schmid;& Stoeckli, 2005). Furthermore, as summer tourism becomes more important for alpine environments, resorts also need to consider that summer hikers seek unspoiled nature and might find mountains with terrain that has visibly been bulldozed unattractive. With a conscious effort to repopulate and rediversify groomed land through seeding though, it has been found that ski slopes can be as healthy and erosion resistant as their untouched counterparts, though a full recovery of the ground might take several decades (Hudek, et al., 2020).

Similar to the use of artificial snow, slope grooming by means of landscaping seems to be surrounded with both very substantial positives and negatives. Without oversight, it is destructive to an environment, and a modern ski resort that wants to be ecologically friendly should not engage in it without a clear plan of how to support its local eco-system. Nevertheless, it is an effective means to mitigate the effects of decreasing natural snowfall. This also means that artificial snow can be used more sparingly, and that farmed snow can be spread out more, which are positives for environmental friendliness. Therefore, a similar conclusion to the use of artificial snow can be drawn – landscaping can often not be avoided, but one should use it as sparingly as possible, and attempt to rely more on other methods.

6.1.4 Selection of location

Another method of increasing snow reliability is expanding into higher altitudes, and onto north-facing (or south-facing in the Southern Hemisphere) slopes. Due to lower temperatures and less direct sunlight respectively, snow takes longer to melt in these areas. Naturally, this method will only be an option for those ski resorts, that have untapped parts of their mountains that they can still expand onto. As the snow line moves upwards ski runs of sufficient length will have to start at higher points. Currently, snow security on average is guaranteed in the European Alps at roughly 1200m, with that threshold projected to rise to 1500m within this century (Steiger, 2010). Glaciers, which tend to be located higher up, are particularly snow reliable (even in summer) and are often successfully used as part of ski resorts. They are, however, also particularly vulnerable to climate change, and their continued use for this might not be guaranteed. Methods of glacier protection will be discussed in section 6.1.5.

High-elevation mountain environments are disproportionately more fragile. Species richness and diversity in high elevations suffer heavily from the presence of skiing slopes, even in adjacent areas (Rolando;Caprio;Rinaldi;& Ellena, 2007). Because of this, expanding into new areas further up is linked to resistance from environmental groups and environmental protection agencies. Denials of expansion permits purely on the grounds of environmental protection are not unprecedented (Sealover, 2015). A planned expansion of an Austrian ski resort for example, was met with 168.000 signatures opposing the project, and is still not approved by authorities after three years (Metcalf, 2022).

Simply going higher is not necessarily the answer. Any such project would be associated with enormous costs, that could be invested into diversification instead (see section 6.2.1). Furthermore, with the aim of escaping the rising snowline, higher altitudes can only provide a temporary solution, as there is no projected end to this rise. Investments that are meant to be paid off over a long term are therefore especially vulnerable and risky. Continuously expanding is also simply not sustainable, as any expansion will eventually reach its limit. Should an expansion still be viable and sustainable despite all of this, it also needs to be environmentally conscious. Such expansions are possible however, as shown in Whistler-Blackcomb's Symphony chairlift (see section 5.3.2), if a conscious effort towards the environment is made.

6.1.5 Glacier protection

Glaciers were long seen as an advantage to have on a mountain. Their attractiveness in summer, both for skiing and hiking, and their ability to open seasons early is quickly waning though. Glaciers are melting at unprecedented rates. In the alps alone, 75% of glacial area will be lost by 2050, with the end of the century potentially seeing practically all glaciers in the area completely lost (OECD, 2007). Seeing as there are considerable benefits to the preservation of glaciers, both economically and ecologically, ski resorts worldwide are extending considerable effort into their protection.

In 2005, the Swiss ski resort of Andermatt became one of the first in the world to employ the use of a white tarp over their Gurschen Glacier. Although the project was surrounded by controversy, with environmental groups calling it merely a plaster on the much bigger issue of climate change, it was nevertheless a success of the resort, and resorts in Europe and North America soon followed suit (Wang & Shitai, 2012). The use of artificial snowmaking for glacier protection is also

being employed. Artificial snow can help a glacier in summer, because the cover of fresh snow protects and cools the historic ice underneath, slowing its melting process, and potentially even growing the glacier (albeit by a small margin) with enough snow being used. This method has recently been refined and made more cost-efficient through the use of a hose (rather than snow cannons, which are extremely expensive at such high altitudes) which is laid out in a zigzag pattern over the glacial cover (Parkin, 2019). Naturally, neither this method nor any other form of artificial snow is forever sustainable, but they are useful as temporary solutions nonetheless. A more sustainable and affordable, but less impactful, method is the installation of snow fences on glaciers, which trap snowfall, allowing it to freeze onto the glacier, rather than drift further into the valley.

Glacier protection is a losing battle. The issue of global warming will continue regardless of any practices on the glaciers themselves and can only be solved through government regulation. Therefore, glaciers will continue to melt, and this process can only be slowed down, but not stopped. The Canadian ski resort of Whistler-Blackcomb for example, has used tarps, snow cannons, and snow fences in the past, but as of 2022, has permanently closed most of its glacier, with the rest of it expected to follow suit within the decade (DeJong, 2022). Nevertheless, protecting glaciers can be economically viable, and is certainly a noble thing to do for the environment. As with most methods, ski resorts will have to calculate whether the costs justify the benefits. One especially has to keep in mind that glaciers are important for the image of mountains in summer too, and that summer tourism will become ever more important.

6.1.6 Cloud seeding

Cloud seeding is the practice of releasing silver iodide or other similar compounds into the air that are known to attract water molecules to each other, with the aim of making them form into clouds and thus leading to precipitation. While cloud seeding has been practiced since at least the 1970s, there is still no scientific consensus on whether it works in practice. This is because natural variation in weather is ten to a hundred times larger than the maximum variation that is thought to be achievable through cloud seeding (Pelley, 2016), making a measurement of success difficult. Even if cloud seeding does indeed work exactly as expected, it still has a limitation in the form of cloudless skies. At least a small amount of natural cloud cover is required to start the process (Moseman, 2009). Nevertheless, ski resorts and local governments are investing in it. The Vail ski resort, along with the US state of Colorado and the county of Los Angeles (which sits at the mouth of the river that drains from the mountains that Vail is located in and hopes to combat its drought

with this), invest a combined one million dollars annually into a cloud seeding program (Quinton, 2018). The practice itself though is not widespread, and there are few other examples of its use.

Investing in something that is not proven to work is always a risk. Ski resorts that are interested in implementing the practice should therefore be very cautious of it. Furthermore, something as grand as weather manipulation would require permits in most parts of the world, which might be difficult to obtain. Should such obstacles be overcome though and should a large enough sum of a resort's money be expendable for something with no guaranteed benefit, there seems to at least be no major downside to it. Behind other mitigation methods that were discussed in this chapter though, cloud seeding should remain a lower priority.

6.2 Business culture

Snow will inevitably become scarcer as time progresses, so all methods to mitigate this will ultimately have to be supplemented by a change in business culture. Ski resorts will have to deal with a new global situation in which their business model will be challenged. Those unwilling to adapt might find themselves behind their competition.

Smaller, lower-altitude resorts will benefit the most from innovations in their business culture, as they are the first to go out of business from lack of snow. Industry leaders with snow security for decades to come will still benefit from such measures, both for their own sakes and to remain on-par with their competition.

6.2.1 Asset diversification

Asset diversification is the practice of businesses reaching into previously untapped industries. With the progressively increasing uncertainty that comes with any business that relies on snow, a large part of the ski resort industry seeks the security that comes from assets that are less vulnerable to changes in the climate. The idea is to turn the traditional "ski resort" into a "four seasons resort", which would have the potential to strengthen operations even without climate change, as they could then generate revenue during the entire year, rather than the relatively short span of the four to seven months per year during which skiing is possible.

The most common form of adaptation is summer tourism (Dawson & Scott, 2013). Mountain regions are expected to gain popularity as summer destinations as temperatures increase, because places with previously pleasant climates will become too hot (DeJong, 2013). In the United States for example, an estimated three out of four ski resorts have some sort of non-winter activity on offer (Calkins, 2019). In the European Alps, a trend to build summer parks at the foot of ski resorts has already been well underway since the beginning of the 21st century, with a large share of resorts copying the tactics of industry vanguards (Zach; Schnitzer; & Falk, 2021). A race to be the most competitive summer destination among resorts can be expected to continue and gain intensity, especially for more threatened resorts. Since ski resorts typically do not own the land they operate on and only make their money from lift ticket sales (Peters, 2014), a key question is how to get summer visitors to generate revenue for the resorts.

A popular method for this is to convert the ski lifts into mountain bike lifts in summer. This adaptation method benefits from the very similar natures of both sports – both require riders to embark on lifts in a valley, with the intention of riding down groomed or natural runs from a mountain- or hilltop. Ski resorts in particular have advantages over non-ski operations when establishing themselves in the mountain biking industry, as their experience and equipment in terrain modification gives them a competitive advantage. There is a long-standing tradition of this two-way model within the industry (Freeman & Tomlinson, 2014). Unlike the stagnant or slowly declining ski industry, the mountain biking industry is booming, and it is becoming more common for ski resorts to consider their mountain biking operations equal to or even more important than their skiing operations (DeJong, 2022). Mountain biking as a sport is still relatively young and its demographics are still developing, with many potential markets still untapped, especially among younger people and women (Buning, Cole, & Lamont, 2019), so the right kind of marketing and establishment of customer loyalty can still make a large impact on the industry and generate considerable revenue.

Hikers are another significant group of people that are interesting to ski resorts in summer. Ski resorts have an advantage over other alpine hiking destinations because their lift systems can transport hikers to areas of mountains that would otherwise be difficult and strenuous to access, catering to a more casual crowd of hikers that would like to see mountaintops but is not interested in hiking all the way to the top. Indeed, it is only the convenience of the lifts themselves that generates profits out of hikers, as they could otherwise freely access the mountain without buying a lift pass anyway. The key question for lift operators therefore, is how to get hikers to buy lift passes. Other potentially revenue-generating products, such as guided tours, have been found

to be of much lower interest to the market at large than simply offering attractive scenery, though they do still find their demand if they are supplied (Needham, et al., 2010). Overly strong presence of, or marketing towards, other such products, have even been found to be detrimental to the customer experience, while smaller scale passive support, such as interpretive signs and information along well-maintained hiking paths, has been found to improve it (Needham, Wood, & Rollins, 2004). One can therefore conclude that, in order to attract hikers, scenery and unspoiled nature need to be marketed for.

Independently of a resort's lifts, special installations, such as water parks, mountain roller coasters, or ziplines, are popular. These summer parks are increasingly seen as more than side operations, and are instead treated as equal, being given their own marketing, websites, and mascots (Zach, Schnitzer, & Falk, 2021). While as much mountainous terrain as possible is normally considered good for a ski resort, flat land (usually in the adjacent valley, or on a mountain plateau) is typically seen as more advantageous for the construction of summer offerings (Hudson & Hudson, 2016). Lakes and reservoirs (e.g. from artificial snow production) also provide the opportunity to build water parks around them. A good example of a successful summer park would be Area 47 in the Austrian Ötztal region. According to its own website, it offers over forty different activities, such as a water park, canyoning, white water rafting, a climbing park, and mountain biking, stretched across an area of 9.5 hectares, which encompasses a river, a reservoir, and the adjacent mountains (area47.at, 2022). The trend towards extensive summer parks is clear. As long as the market for them is not mature yet though, investments in summer parks seem to be favorable, especially in regions that have not been quite as saturated with them yet as the Austrian Alps.

Wellness is another factor that is not directly dependent on lifts or natural sites that cannot be charged admission for. Furthermore, with wellness products generally being indoors, they are also independent of the weather and the season, making them able to also supplement a resort's winter offerings, rather than just making up for their absence in summer. The most important customer segments for ski resorts (returning, high-spending customers) are more likely to build loyalty to a single resort, if additional products, especially well-being products, are on offer and of high quality (Matzler, Füller, & Faullant, 2007). To attract non-skiers in winter, a German study found that a relaxed atmosphere in ski towns with an idyllic and picturesque snow cover, and a slow pace of life is essential (Bausch & Unseld, 2017). Wellness in this case can mean more than spas, although ski towns and spas are inevitably linked. Marketing the wellbeing aspect of a mountain vacation opens up entire new customer bases.

Finally, another way to boost off- and low-season revenue, as well as to generate publicity for a resort, is to become an event location. The Canadian resort Whistler-Blackcomb for example, hosts regular sporting competitions and concerts, and considers shoulder season periods to be the ideal time for them (DeJong, 2013). This kind of diversification is especially common in Canadian ski resorts, where in summer and shoulder seasons, an event often takes place on any given weekend (Gilani, Innes, & de Grave, 2018). Vail, the flagship resort of Whistler-Blackcomb's parent company Vail Resorts on the other hand, is advertising itself to be a year-round location for corporate events, such as conferences and trade fairs (Vail Resorts, 2022). Ski towns can benefit from this in particular, as they normally have several hotels, which can accommodate such event spaces. Evidently, if a ski resort wants to diversify and become a household name as more than a ski destination, attracting large crowds through events is a viable and common tactic.

6.2.2 Conglomerates

In the ski resort industry, a conglomerate is an alliance of different ski resorts, either owned by the same parent company or cooperating with each other, that offers benefits to people who visit multiple resorts within the conglomerate, in order to boost sales throughout the entire structure of it. The more closely connected a conglomerate is, the more a single resort can also be helped through unfortunate times. Larger conglomerates are all situated across several geographical regions, meaning that a bad snow season in one region can be made up for by the revenue generated in other regions. Typically, a single season pass that grants access to all resorts within a conglomerate is issued.

The two largest competing conglomerates are Vail Resorts, with their Epic Pass, and the Alterra Mountain Company, with their Ikon Pass. Both of them offer access to around sixty North American and Australian resorts, including limited access to partner resorts that are not owned by their parent company, and are comparable in price, with the Ikon Pass being slightly more expensive (epicorikon.com, 2022). Having dominated the North American market, Vail Resorts is now looking to expand into the Alps, which have had little conglomeration so far, with the acquisition of its first European resort in March 2022 (Wiegand, 2022). Further interest in the European continent can be expected. The coming years should therefore be of particular interest for any European ski resort that is interested in the benefits of joining a conglomerate.

Aside from the market dominance of Vail and Alterra, conglomerates of smaller and otherwise independent ski resorts are also finding their niche. The most notable example in this case is the Indy Ski Pass, which grants two-day access to 88 North American resorts and four Japanese resorts, all of which are independently owned, for 299 USD (indyskipass.com, 2022). Passes that are even smaller in scale, e.g. limited to only one mountain range and only offering discounts rather than full access to participating operations when buying a season pass at one resort, exist too (Hagenstad, Burakowski, & Hill, 2018).

The trends within the ski resort industry clearly point towards more conglomeration. Especially for a smaller resort, this offers an excellent way to remain competitive. The already established decline of smaller ski areas can be combated with this, and ski resorts that stay completely independent will continue to increasingly struggle more in the future.

6.2.3 Lobbying

Ultimately, only radical actions taken by governments can truly slow down or stop global warming (IPCC, 2021). Therefore, in order to allow skiing to have any longevity in the future, political pressure must be exerted. Most North American ski resorts are already joining forces, having formed the Climate Collaborative Charter, a political lobby that defends the interests of ski resorts, in 2021 (Vail Resorts, 2021). Notably, the CCC is a collaboration of firms that are otherwise competitors but have pledged to work together for their sustainability goals. If ski resorts remain apolitical, or only strive to internally achieve sustainability, they ultimately will not achieve enough to stay in business indefinitely. With the entire industry being as threatened as it is, lobbying should be part of any ski resort's sustainability plan.

7 Conclusion

The purpose of this thesis was to examine how healthy the global ski resort industry is, and to give struggling ski resorts a guide on how they can improve their business. This was done by researching literature on the current state of the industry and by examining notable examples of successful adversity-resistant ski resorts.

The results that were found during the research process show that the ski resort industry is at a very critical point of its existence. The market is changing from a diverse and decentralized industry of many independent ski resorts to an oligopoly where only large and strong year-round resorts dominate. Those that are not willing or not able to invest and diversify are unlikely to survive much longer. While the industry as a whole will not vanish within this century, it will nevertheless shrink, with resorts that are already healthy being most likely to be among the few remaining competitors in the mid- to long term. Those that are not as fortunate will need to take risks with large investments to have a chance of survival.

The target audience for this thesis therefore, are struggling ski resorts first and foremost. This thesis provides a modern state-of-the-art overview of possible adaptation methods, with real-life examples and theoretical research to back up this advice. Secondly, environmental protection groups, such as the commissioning party Protect Our Winters New Zealand, also benefit from this paper, as their advocacy needs tangible examples of success for what they are campaigning for. Rather than just pointing out what is wrong, theses like this can provide them with something to show how exactly adaptation to the right state can be achievable. For this purpose, the thesis will be freely made available to the client, and to the entire Protect Our Winters organization, which can then relay the information to their partners, especially ski resorts. Whistler-Blackcomb, which was prominently featured in this thesis's benchmarking chapter and was often cited as an example in other chapters as well, requested a copy of the thesis while it was still being written, through their environmental resource manager Arthur DeJong, who provided an interview for the thesis.

Since global warming is a very extensively researched topic, few gaps in the literature exist. Even research on the impacts that global warming has specifically on ski resorts, which is not usually the highest priority for climate researchers, was sufficiently available. Future research should be conducted on technologies and ideas that were still relatively new at the time of writing, such as

modern, more energy efficient snow guns, and on how conglomeration will continue to affect the global industry. Overall, enough literature was available to fulfill the goal of the thesis.

In conclusion, in order for a ski resort to be sustainable in the future, investments in modern technology and ideas need to be made. Climate change is not a guaranteed death sentence for any resort, but smaller resorts are under disproportionately higher pressure to adapt.

8 Bibliography

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