



AISTS Client Team Project 2018

Climate Change and The Olympic Winter Games

Client: International Olympic Committee

Lin Yuebin, Melody | Melissa Drake | Nikolaus Schönfeldt | Sung Jung



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Abbreviations

AISTS	International Academy of Sports Studies and Technology
CO ₂	Carbon Dioxide
FIS	International Skiing Federation
GHG	Green House Gas
IBU	International Biathlon Union
IF	International Federation
IIHF	International Ice Hockey Federation
IOC	International Olympic Committee
IPCC	Intergovernmental Panel on Climate Change
ISU	International Skating Union
LED	Light Emitting Diode
MAS	Master of Advanced Studies
NASA	National Aeronautics and Space Administration
NF	National Federation
NHL	National Hockey League
OCOG	Organising Committee Olympic Games
RCP	Representative Concentration Pathway
SRES	Special Report on Emissions Scenarios
UN	United Nations
VANOC	Vancouver Organizing Committee for the 2010 Olympic and Paralympic Winter Games



Executive Summary

The Olympic Winter Games have been held every four years since 1924, with the most recent edition taking place in PyeongChang, South Korea in February 2018. In recent years, we have witnessed a drastic effect on winter sports resulting in delays, cancellations and venue changes due to weather inconsistency.

This project focuses on the impacts and risks of climate change and explores its potential effects on winter sports in the future, specifically on the Olympic programme. Outlined below were the objectives for the research involved.

- Highlight the impacts from climate change on sports generally, and winter sports in particular.
- Identify risks to sports from climate change.
- Document innovations occurring in sports to mitigate effects of climate change.

The methodology took a combined approach to investigate the impacts of climate change on the Olympic Winter Games. The first section of research was a review on current literature depicting the observed climate change over the last century. The second section of research included semi-structured interviews with a number of experts to examine sports at risk, technologies and the effect on major events.

Climate Change

With temperatures rising each year, climate change is occurring at a rapid rate. The global average for combined land and ocean surface temperature has increased consistently over time with 2016 being the warmest year on record. With changes occurring in the atmosphere, sea level and cryosphere there will be a significant impact on the number of days it is cold enough to make snow, the amount of natural snow available and how people have access to winter sports (ex. pond hockey).

Technology

Technologies are becoming more crucial to sport each season, as they are key to creating the environmental conditions for events. Some of these include refrigeration systems in ice rinks and sliding tracks, snowmaking and snow storage. Without these systems, temperatures would not be cold enough to keep conditions consistent (ex. ice rinks) and there wouldn't be enough snow for ski and snowboard disciplines.

Not only are the physical conditions important to consider but also the possible training and competition adaptations if the weather is not cold enough for winter sports. Without events being hosted by IFs like FIS and IBU that include roll skiing, grass skiing or summer ski jumping, these sports may not be sustainable in the long term.

Olympic Winter Games

Adaptations to the Olympic Winter Games will need to occur if the Olympic Movement hopes to continue with this event. It is necessary to rethink the Games and how people look at winter sport. Although technologies are being used to help mitigate the effects of climate change, they will not be able to stop them completely. With outdoor snow sports being most at risk, adaptations will need to be made if they are going to continue to be included in the Olympic programme. One of the biggest risk factors for snow sports comes from a lack of snow. If temperatures continue to rise, not only will natural snow be limited, but machine-made snow will be as well.

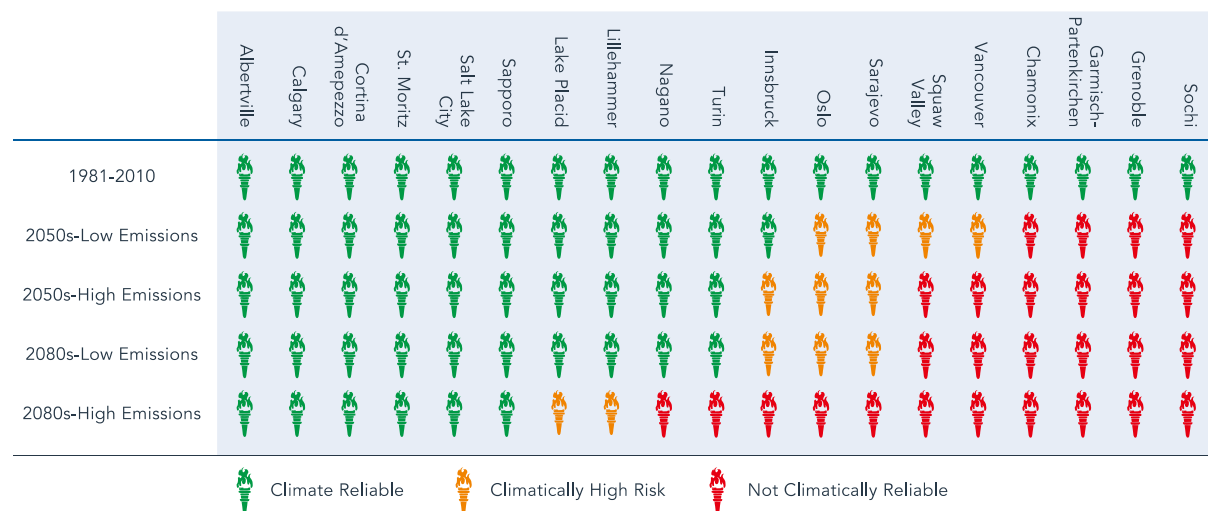


Figure 1.1 Former Winter Olympic locations climatically suitable for future Games (Scott et al., 2014)

Not only will sports be affected by climate change, but the ability to host the Games as well. The number of previous hosts who would be able to host an Olympic Winter Games is constantly decreasing to a point where only a handful of cities may be viable in the future.

This is a direct threat to the Olympic Winter Games because if there is nowhere to host the games, they won't happen.

Conclusion

It is important to be conscience of these changes and look to solutions for the future. If sports do not start taking responsibility for these impacts and look for proactive strategies to mitigate their environmental footprint, there may not be a future for the Olympic Winter Games.

1. Introduction

The Olympic Winter Games have been held every four years since 1924, with the most recent edition taking place in PyeongChang, South Korea in February 2018. In recent years, the effects of climate change have become more and more visible. We have witnessed a drastic effect on winter sports resulting in delays, cancellations and venue changes due to weather inconsistency.

A growing awareness is taking place within the Olympic Movement. As the Winter Games have developed over the years into a mega event, the sports industry is becoming more conscious about the impacts of the changing climate, and in particular the effect on the winter sports industry. While the world of climate science is vast, there is a consensus that the world will continue to warm, as evidenced by the serious efforts being made through organisations like the UN and the Framework Convention on climate change.

In December 2014, a series of reforms were ratified to help guide the world of sport through a range of topics (International Olympic Committee, 2018). This was identified as the IOC's Olympic Agenda 2020 and was based on 20 + 20 recommendations. There are a number of key areas stemming from Olympic Agenda 2020, including environmental sustainability, innovation in the programme of sports, and an overall reduction in cost and complexity. This project relates specifically to recommendations regarding the evaluation of bid cities and the sustainability of the Olympic Winter Games in the future.

Within the Olympic Movement, there are a number of key stakeholder groups directly impacted through this warming climate trend: International Winter Sports Federations (IFs), Candidate and Host Cities for the Olympic Winter Games, the International Olympic Committee and the wider winter tourism industry. This project's aim is to tackle the existing literature on the topic and conduct research to better quantify some of the real impacts of climate change on the winter sports industry and the Olympic Winter Games as a whole.

As part of the AISTS MAS programme, this project is meant to give participants experience working with a client in a controlled environment over the course of 6 months with a final

report and presentation due in June. The team of AISTS participants included Lin Yuebin (Chinese), Melissa Drake (Canadian), Sung Jung (South Korean) and Nikolaus Schönfeldt (Austrian) supervised by a member of the AISTS staff, Geert Hendriks.

This project focused on the impacts and risks of climate change and explored its potential effects on winter sports in the future, specifically on the Olympic programme. Outlined below were the objectives for the research involved.

- Highlight the impacts from climate change on sports generally, and winter sports in particular.
- Identify risks to sports from climate change.
- Document innovations occurring in sports to mitigate effects of climate change.

In the first meeting with the client, represented by Ansley O'Neal (Olympic Programme Commission Manager), the area of scope was determined and the goals of the project were specified. A project plan was then created to help guide the team over the course of the 6 months. The team was then divided into two groups, one focusing on the impacts of climate change and specifying the winter sports region to focus on while the other was tasked with researching the impact on sports and risks associated with rising temperatures and extreme weather. From the beginning it was clear that technologies play a major role in sport and it was of great interest to the client to find out what kind of technologies were used to mitigate the impacts of the global weather changes on the affected sports.

2. Methodology

This project took a combined approach to investigate the impacts of climate change on the Olympic Winter Games.

The first section of research was a review on current literature (journal articles, websites, weather data, etc.) depicting the observed climate change over the last century. Four major regions (Alps, Canada, China and South Korea) were chosen for a more detailed examination based on their current involvement in winter sport, the locations and the effect they may have on future Olympic Winter Games.

Projections of winter sports in these regions were examined based on two indicators:

- a) Conditions for machine-made snowmaking (commonly referred to as artificial snow) in terms of temperature and humidity;
- b) Natural snowfall in terms of snow cover and snow depth.

These were chosen because snow can be a good indicator of the climate needed for winter sports. Information regarding the Olympic Programme criteria and host city criteria was also provided by the IOC for review.

The method of semi-structured interviews was adopted in the examination of technology and the Winter Olympic Programme. Interviews were conducted based on a list of questions with various IFs, OCOGs, and major leagues of winter sports (see Appendix A). Most interviews were conducted towards the end of the project (April) due to the involvement of many of the organisations in the 2018 Olympic and Paralympic Games in PyeongChang. These interviews were then transcribed and translated, based on which conclusions were drawn and integrated into the discussion via thematic analysis.

A survey was designed in January to be distributed during the Games in PyeongChang but due to a limited number of responses, the data was considered inconsequential to the findings of this report.

The organisations targeted in this report include:

- International Biathlon Union (IBU)
- International Bobsleigh & Skeleton Federation (IBSF)
- International Ice Hockey Federation (IIHF)
- International Luge Federation (FIL)
- International Skating Union (ISU)
- International Ski Federation (FIS)
- National Hockey League (NHL)
- World Curling Federation (WCF)



3. Impact of Climate Change on Winter Sports

3.1. Review of General Impacts on Climate Change

This chapter reviews climate change globally through an analysis of historical data on climate systems. It focuses on observational evidence from the three main representative indicators (Atmosphere, Sea level and Cryosphere), general projections and its causes.¹

Did you know?

- Cryosphere :
The places where water is in its solid form, frozen into ice or snow.

3.1.1. Observed Changes in the Climate System

The climate system is warming unequivocally, and since the 1950s, many of the observed changes are unprecedented. As the atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen (IPCC, 2014).

Atmosphere

The global average for combined land and ocean surface temperature has increased consistently over time. The year 2016 ranked as the warmest on record since modern record keeping began in 1880 (NASA, 2017). The period from 1983 to 2012 was likely the warmest 30-year period of the last 1,400 years in the Northern Hemisphere, where such assessment is possible. Almost the entire globe has experienced surface warming during

IPCC (Intergovernmental Panel on Climate Change)

IPCC is a United Nations body founded in 1988, comprised of representatives from 194 governments, which evaluates climate change science. The IPCC assesses research on climate change and synthesises it into major 'assessment' reports every 5-7 years.

¹ Due to the natural variability, trends based on short records are very sensitive to the beginning and end dates. In order to reflect in general long-term climate trends, long-term data was used

the period where calculation of regional trends is sufficiently complete (Figure 3.1) (IPCC, 2014).

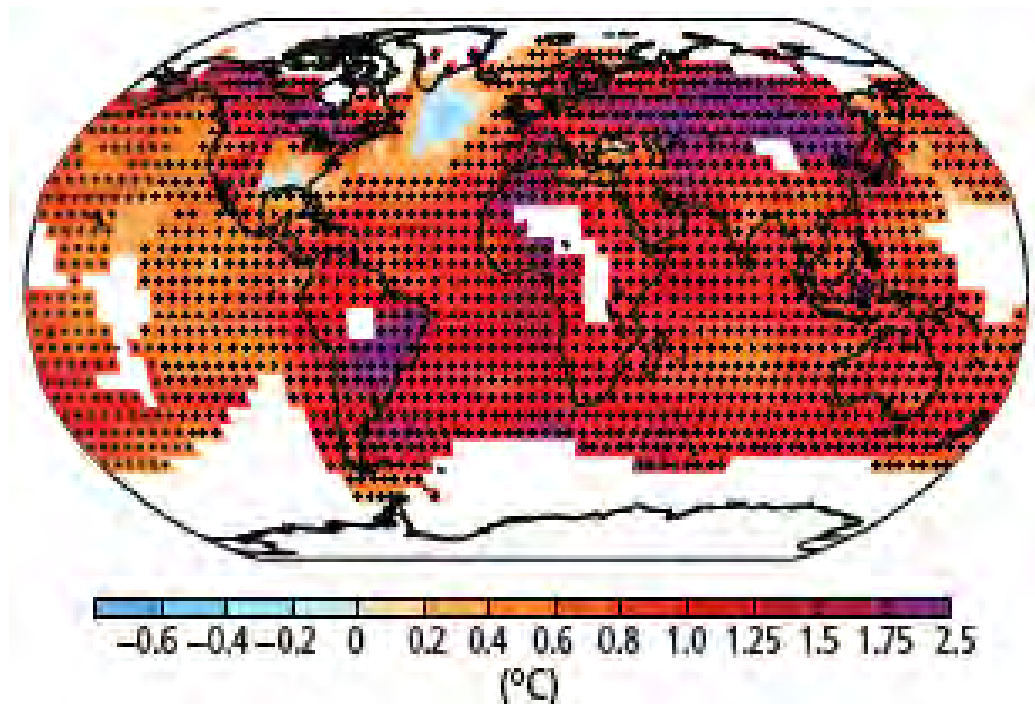


Figure 3.1 Observed change in surface temperature 1901-2012 (IPCC, 2014)

Sea level

Over the period 1901-2010, global mean sea level has risen by 0.19m and recently it has increased to a total amount of 88mm, on average 3.2mm per year from 1993 to 2017 (Figure 3.2). It is consistent with the changes in glaciers, the Greenland ice sheet, the Antarctic ice sheet and land water storage due to global warming. The rate of sea level rise since the mid-19th century has been greater than the mean rate during the previous two millennia (IPCC, 2014).

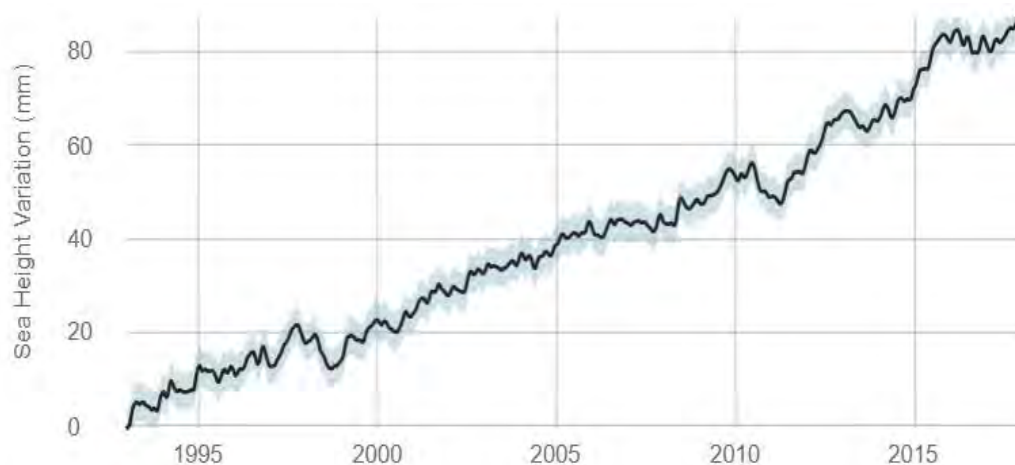


Figure 3.2 Sea level change 1993-2017 (NASA, 2017)

Cryosphere

Glaciers including Greenland and Antarctic ice sheets have continued to shrink worldwide. The land ice sheets in Antarctica have been losing mass since 2002, on average 127 gigatonnes² per year (Figure 3.3) (IPCC, 2014). Since the early 1980s, permafrost temperatures have increased in most regions of the Northern Hemisphere with reductions in thickness and areal extent in some regions (IPCC, 2014). The increase in permafrost temperatures has occurred in response to increased surface temperature and changing snow cover (IPCC, 2014).

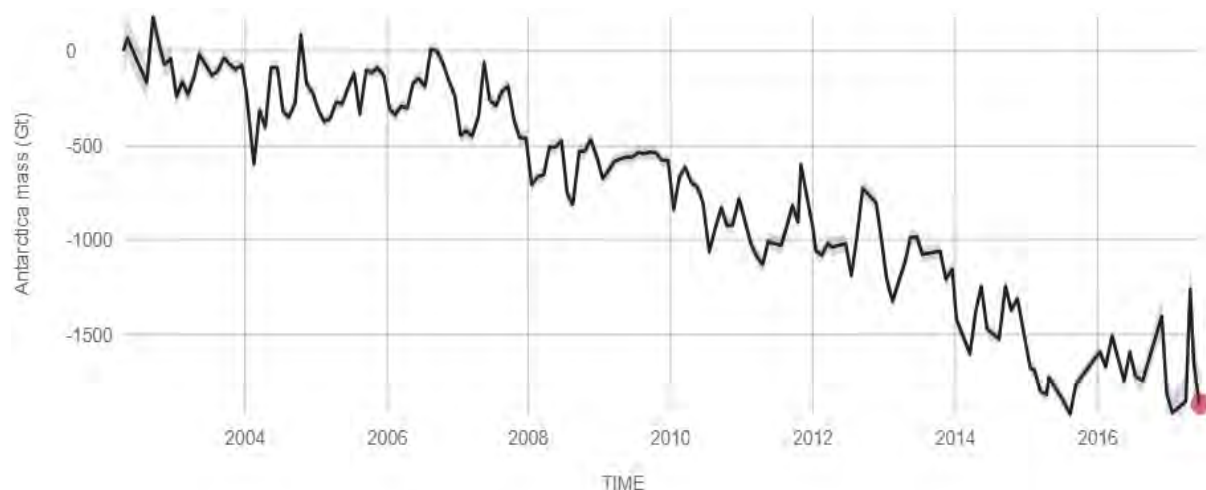


Figure 3.3 Antarctica mass variation 2002-2017 (NASA, 2017)

Past and Recent Drivers of Climate Change

When looking into the link between climate change trends and changes in anthropogenic greenhouse gas emissions, human influence on the climate system is clear. In particular, atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased to unprecedented levels over the last 800,000 years (Appendix D), and about half of the cumulative anthropogenic CO₂ emissions between 1750 and 2011 have occurred in the last 40 years (Appendix E) (IPCC, 2014).

Did you know?

■ Greenhouse gas (GHG) : Compound gases that trap heat or long wave radiation in the atmosphere. Their presence makes the Earth's surface warmer. The principal GHGs are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and the fluorinated gases, and carbon dioxide composes the most (IPCC, 2014)

² Gigaton (Gt) – One trillion tons

3.1.2. General Projection of Climate Change

Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing land and ocean surface temperature, reducing snow cover, and raising sea level (IPCC, 2014). Limiting climate change risks would require substantial and sustained reductions in greenhouse gas emission (IPCC, 2014).

Projections of future climate change vary over a wide range, depending on both socio-economic development and climate policy. Future climate changes are projected by 4 different Representative Concentration Pathway (RCPs) scenarios (IPCC, 2014).

Surface temperature is projected to rise over the 21st Century under all assessed emission scenarios. Figure 3.4 from IPCC (2014) shows surface temperature increase all over the world in two different versions of global surface temperature scenarios: a stringent mitigation scenario assuming GHG emission peak between 2010-2020 with emission declining substantially thereafter (RCP 2.6) and a scenario with very high GHG emissions assuming GHG emissions continue to rise throughout the 21st Century (RCP 8.5). It is very likely that heat waves will occur more often and last longer with the global mean sea level continuing to rise. Arctic sea ice and permafrost extent at high northern latitudes are projected to decrease for all RCP scenarios as global mean surface temperature increases. Also, the area of Northern Hemisphere spring snow cover is likely to decrease by 7% for RCP 2.6 and by 25% in RCP 8.5 by the end of the 21st Century (IPCC, 2014).

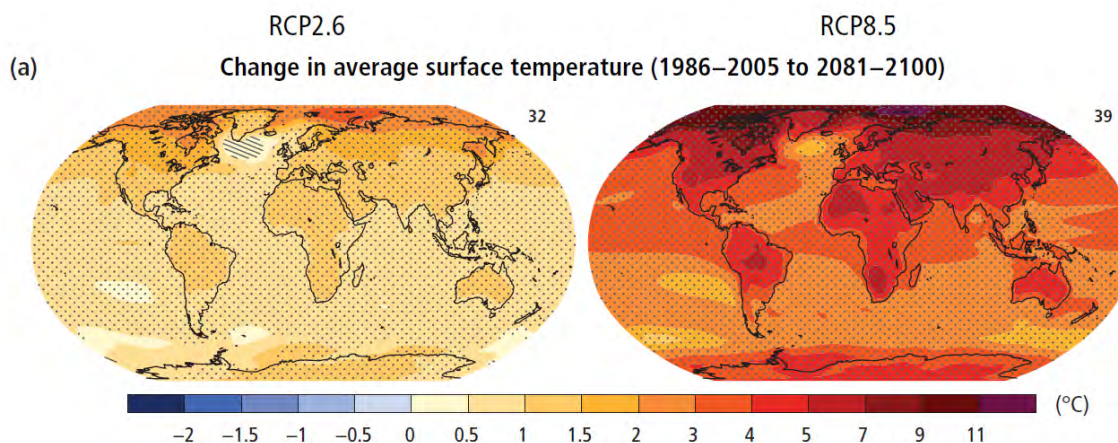


Figure 3.4 Two projection scenarios on change in average surface temperature (IPCC, 2014)

Representative Concentration Pathway (RCP)

Mentioned and defined in the IPCC report (2014), the Representative Concentration Pathways (RCPs) describe four different pathways of greenhouse gas emissions and atmospheric concentrations, air pollution and land use for the 21st Century.

RCP 2.6 is the scenario in which it is managed to keep the global temperature rise under 2°C compared to pre-industrial times.

RCP 4.5 and **RCP 6.0** are scenarios where greenhouse gases don't pass an intermediate level between RCP 2.6 and RCP 8.0.

RCP 8.5 is the scenario where the greenhouse gases are reaching way higher levels because there is no effort made to constrain them and they continue to rise.

3.1.3. Risk to the Olympic Winter Games

Climate change has a direct impact on the Olympic Winter Games. If current climate trends continue, about 47% of the previous host cities of Winter Games will be considered high risk in the 2050s as unreliable future hosts, and 68% will be impossible or difficult to host in 2080s (Scott et al., 2014).

Weather has been an integral part of all past Olympic Winter Games. Poor weather is highlighted as one of the greatest challenges faced by the organising committees. In addition to the major influence on all outdoor sport competitions (safe and fair competition surfaces, athlete performance, etc.), weather can also affect the ability to prepare for the games (venue construction, ice and snowmaking), outdoor opening and closing ceremonies, transportation, comfort of spectators, and visibility for television broadcasts (Scott et al., 2014).

University of Waterloo, together with the Management Centre Innsbruck and the Interdisciplinary Centre on Climate Change, conducted research on the risk of climate change to the future Olympic Winter Games through an assessment of 19 previous host locations on two indicators. These indicators play a significant role to determine whether host cities would be suitable to host the Olympic Winter Games, as they are directly linked to snow, which is an essential factor for outdoor disciplines in the Olympic Winter Games (Scott et al., 2014):

Indicator 1

Probability that daily minimum temperatures at the main competition elevation would remain below freezing (0°C). When daily minimum temperatures remain above freezing, snow and ice surface do not have the chance to recover from daytime melt.

Indicator 2

Probability that a snowpack of at least 30 cm can be maintained at the higher elevations of alpine events, through both natural snowfall and snowmaking.

If both indicators were achieved in 9 out of 10 winters (90% or greater probability), it was deemed climatically reliable for the future Winter Games, and if one or both indicators achieved less than 75% of winters, the location was considered unreliable for elite Olympic competitions. When indicators were achieved in 75 to 89% of winters, the location was classified as a marginal/high risk location for a future Olympic Winter Games (Scott et al., 2014).

Based on this benchmark, it was found that as few as 6 of the previous 19 former Winter Olympic locations are likely to be cold enough to host the games by the end of the century, as is shown in Figure 3.5 (Scott et al., 2014).

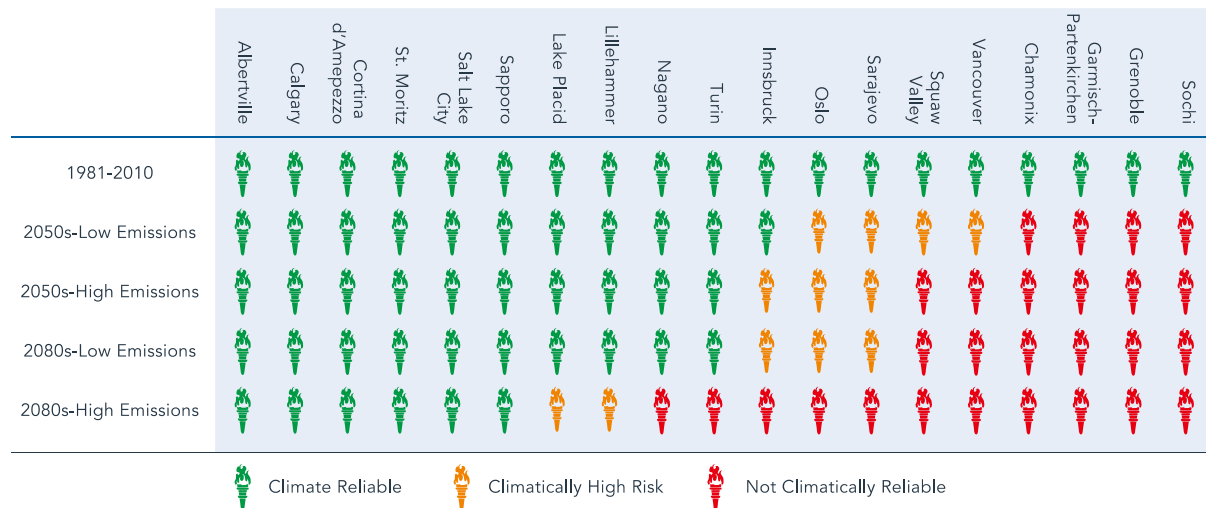


Figure 3.5 Former Winter Olympic locations climatically suitable for future Games (Scott et al., 2014)

3.2. Climate Change in Winter Sports Regions

General climate change such as the rise in average surface temperature and reduction in snow extend relate to winter sports played on snow and ice. Four specific regions, Alps, North America, China and South Korea were chosen to research further based on the consumption of winter sports and the effect was determined through the analysis of indicators affecting machine-made and natural snow related to winter sports.

3.2.1. World Winter Sports Market

Participating Countries in Ski Markets

There are currently 67 countries in the world that are equipped with snow-covered outdoor ski areas (Figure 3.6). Many of them are concentrated in the Alps (specifically major resorts) and the others are scattered across the rest of Europe, North America, parts of South America and the Asia-Pacific region (Figure 3.7) (Vanat, 2017).

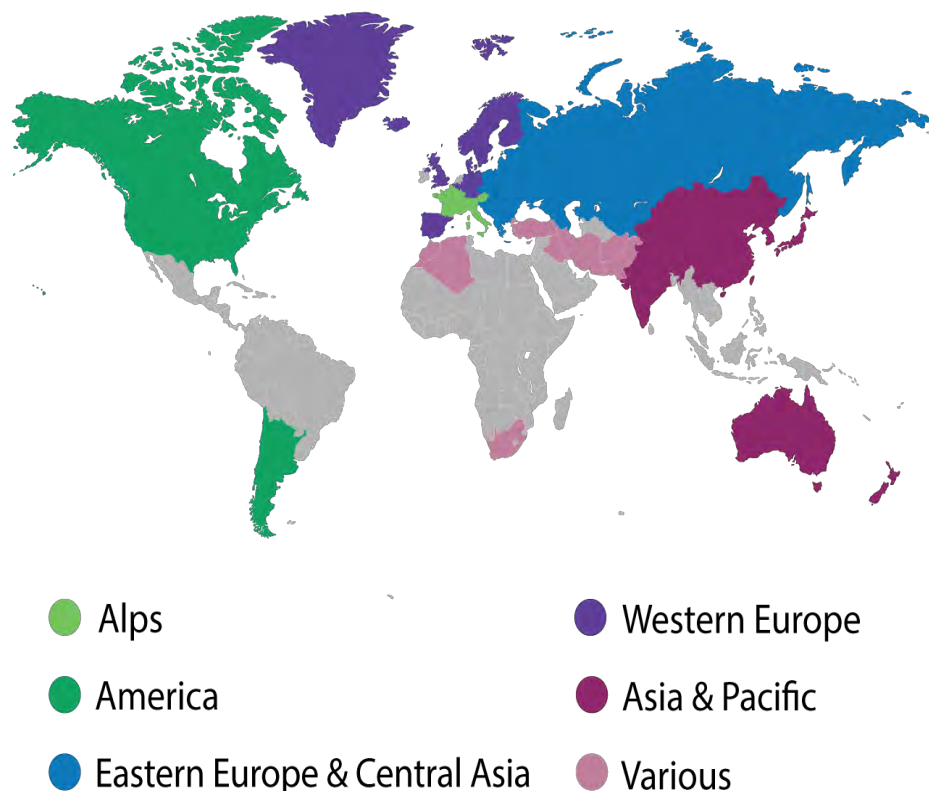
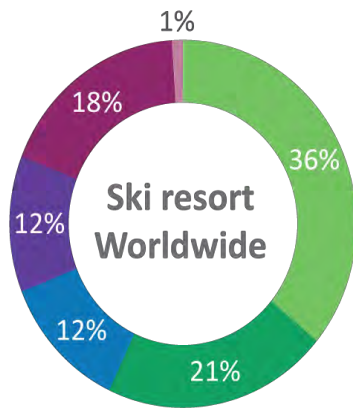
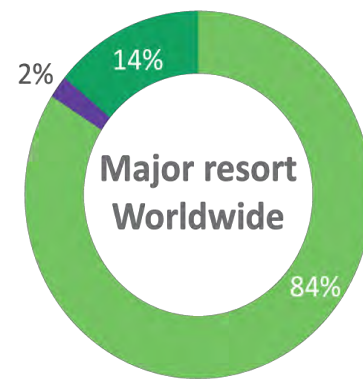


Figure 3.6 Snow-covered outdoor ski areas (Vanat, 2017)



Distribution of the number of ski resorts worldwide (Total 2,132 resorts):
More than one third of all ski resort are located in the Alps



Distribution of the number of major ski resorts worldwide (Total 49 resorts):
More than 80% of them are located in the Alps

Figure 3.7 Distribution of the number of ski resorts and major ski resorts worldwide (Vanat, 2017)

Previous Olympic Winter Games Locations

The Olympic Winter Games were first hosted in Chamonix, France in 1924. Since then, they have been held 23 times including the last one in PyeongChang, Korea in 2018. Approximately half of them have been hosted in the Alps region (Alps: 10/23, North America: 5/23, Asia 3/23, North Europe: 3/23, East Europe: 2/23, Figure 3.8) and most were located in areas ranging from 40° to 50° latitude in Northern Hemisphere.



Figure 3.8 Previous the Olympic Winter Games host regions

3.2.2. Winter Sports Season

Most snow events are held in the Northern Hemisphere starting in November and lasting until March when the temperatures are lower (Alpine Ski and Snowboard World Cup's happen between November and March), while ice events are held throughout the year due to indoor venues.

Ski resorts for public use are mainly located in the Northern Hemisphere and operated from November to April (Lee, 2018). Research in this report was compiled on the indicators related to snow, assuming the winter sports season in the Northern Hemisphere is from November to April.

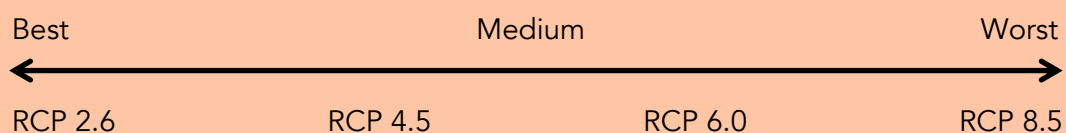
3.2.3. Projection of Climate Change in Main Regions of Winter Sports

The analytical data throughout this report focused on how the indicators affecting winter sports would change and the influence on both machine-made and natural snow in the future based on RCP climate change scenarios or SRES scenarios. SRES scenarios have been used since the 1990s and RCP scenarios were developed in 2010, which includes widely used trend of changes on GHG emissions now (Bush et al., 2014). Since snowmaking conditions are influenced by temperature and humidity, data was gathered on future projections in temperature and humidity to determine whether they are suitable for making and maintaining machine-made snow in the future. In addition, snow cover and snow depth will be used to examine future changes in natural snow.

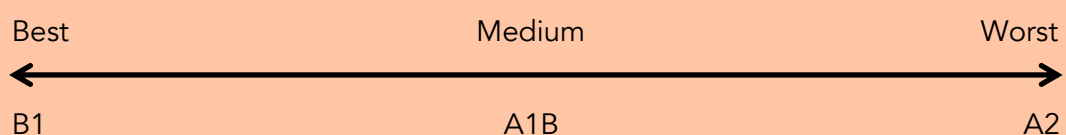
Comparison between RCP (since 2010) and SRES (since late 1990s) scenarios

Both SRES (Special Report on Emissions Scenarios) and RCP (Representative Concentration Pathways) scenarios are future climate scenarios developed by IPCC. SRES is widely used before RCP scenarios are recently developed. There are 3 scenario groups routinely models in SRES scenarios defined by the level of anthropogenic radiative forcing: B1 (low), A1B (medium), A2 (high) (Bush et al., 2014)

RCP



SRES



Criteria and Conditions About Snow

■ Natural Snow

The suitable snow depth for the operation of ski slopes is 50-100cm and the benchmark for opening ski slopes is over 30cm (Scott et al., 2003). If the snow depth goes below 30cm, the ground surface may be partially exposed and needs to be restored with machine-made snow.

The criteria for opening ski resorts is having 100 days of 30cm or higher in snowfall depth throughout the year. When this number goes below 40 days, the ski resort should be closed (Bürki et al., 2005).

■ Machine-made snow (often referred to as "Artificial snow")

The two deciding indicators of machine-made snowmaking conditions are temperature and humidity. Good quality snow should be produced in cooler temperatures and humid conditions, so called 'wet-bulb' temperature. Snow can be produced starting at an average daily minimum temperature of -1°C and the best condition is -5°C (Scott, D. and McBoyle, G, 2007; Steiger and Mayer, 2008). In case of humidity, the suitable relative humidity to make machine-made snow is 60-80% (Seo, C. B., 2008).

Projection in four main regions

Based on our research about the winter sports market above, four regions where major winter sport events happen were selected for further study (the Alps – Switzerland and other Alps, North America – Canada, Asia – China and South Korea) to determine the impact of climate change on winter sports through major projection indicators.

Alps: Switzerland & other Alps

193

Ski areas

2,959,000

National skiers

23,659,000

Skier visits



(Vanat, 2017)

The Alps are by far the largest ski market globally, attracting 43% of worldwide attendance. (Vanat, 2017) Under present climate conditions, 91% of alpine ski areas can be considered as natural snow-reliable. However, the number of those areas will drop to 61% under 2°C and to 30% under 4°C warming (Abegg et al. 2007). Ski resorts in low and mid level elevation will face challenges with machine-made snow and natural snow as snow reliability reduces and the ski season shortens (Marty, 2013).

■ Natural snow

Snow days in all Alps regions was decreasing significantly in the recent past, despite high year-to-year variability due to variations in the large-scale weather patterns (Figure 3.9) (Schmucki et al., 2017).

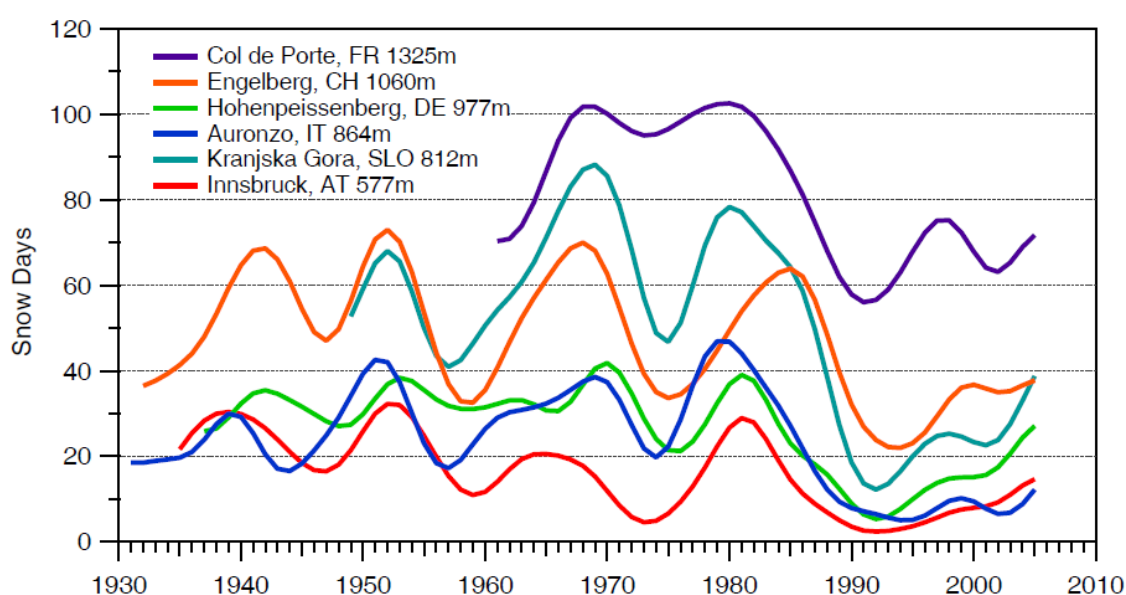


Figure 3.9 Number of snow days with at least 30cm snow on the ground (Marty, 2013)

According to the research of Schmucki et al. (2017), these trends will continue and be amplified by climate change. In all ranges of elevation, the mean annual number of snow days (>50cm) will significantly decrease in both A1B and A2 emission scenarios (SRES) (Figure 3.10) (Schmucki et al., 2017).

Snow cover and depth are also influenced by projected climate change, especially as altitude decreases. While high elevation areas are less affected, snow depth in winter season (December to February) at mid elevations will decrease 34% in 2035, 60% in 2060 and 74% in 2085. The low-elevation stations show the strongest reduction in mean winter snow depth to 59% in 2035, 78% in 2060 and 85% in 2085 based on the A1B emission scenario (SRES) (Schmucki et al., 2017).

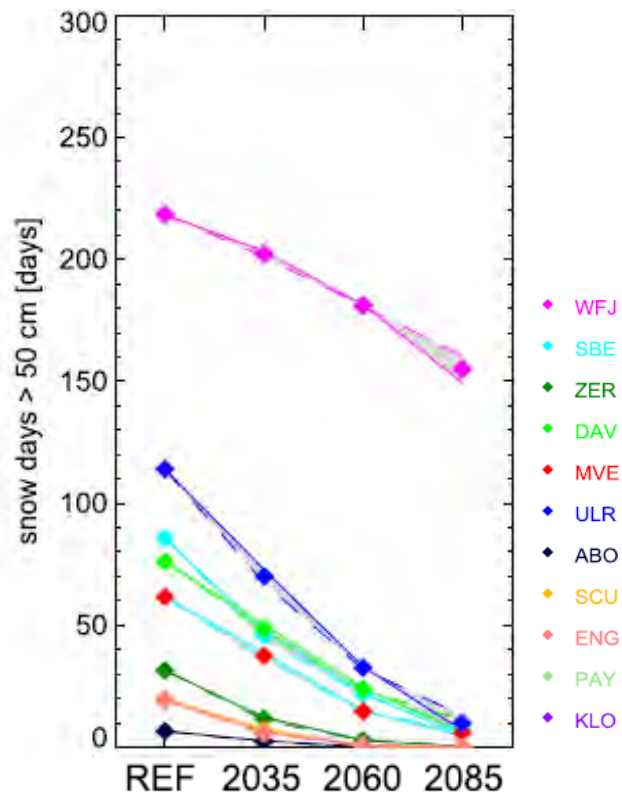


Figure 3.10 Mean annual number of snow days (> 50cm) in Switzerland (Schmucki et al, 2017)

In addition, according to another study by Marty (2013), the altitudinal limit of natural snow-reliability will rise by 150m per 1°C warming. Assuming 2°C warming, snow depth will drastically decrease by about 40-60% below 1800m; the snow cover will last 4 to 6 weeks less and the snow line will rise by about 300-500m. Figure 3.11 shows that the regions with low-altitude ski areas, for example in southern Germany, are most affected by future warming (Marty, 2013).

Toward the end of the 21st Century, a continuous snow cover is most likely to only be guaranteed at high elevations above 2000m a.s.l. (above sea level), whereas at mid elevations (1000–1700 m a.s.l.), roughly 50 % of all winters might be characterized by an ephemeral snow cover. Low elevations (below 500 m a.s.l.) are projected to experience only 2 days with snowfall per year and show the strongest relative reductions in mean winter snow depth of around 90 % (Schmucki, Marty, Fierz, Weingartner, & Lehning, 2017).

conditions (Marty, 2013)



Although ski slopes in high altitude is relatively reliable, those in low altitude run with natural snow will face difficulties to maintain the snow level in the near future and the importance of machine-made snow will be likely to increase more in order to open ski slopes in those region.

■ Machine-made snow

For machine-made snow, data for 3 regions in Austria located in different altitudes (low, medium, high) were analysed: Kufstein, at 495m, St. Anton, at 1275m, and Patscherkofel, at 2247m. Today snowmaking can guarantee snow reliability at elevations above 1000m (December to February) for 90% of all winters. However, in case the temperature increases 2°C, the number of potential snowmaking days will be reduced in all altitudes, and will not be sufficient below 1500-1600m (Appendix F) (Steiger & Mayer, 2008).

Suppose the number of snowmaking days in Switzerland is similar with those in Austria, Ski slopes in low and mid elevation, under 1500-1600m, are likely to be unsuitable to open with both natural and machine-made snow in the 2050s projected 2°C temperature increase based on the data of potential number of snowmaking days in Austria (1960-2007) and projected temperature change in Switzerland (Fischer et al., 2015).

There is a decrease in the number of snowmaking days for machine-made snow from the 1980s (Olefs & Fischer, 2010), and it is likely that the ski season will shorten and ski resorts in the Alps will face serious problems because of unreliability of snow, especially in low and mid elevation (Steiger & Mayer, 2008).

North America: Canada 

288

Ski areas

4,307,000

National skiers

17,759,000

Skier visits



(Vanat, 2017)

North America is another major player in the winter sports market. Nonetheless, global warming is changing the country as a whole toward a warmer, wetter Canada with less snow and ice (Bush, Loder, James, Mortsch, & Cohen, 2014).

■ Natural snow

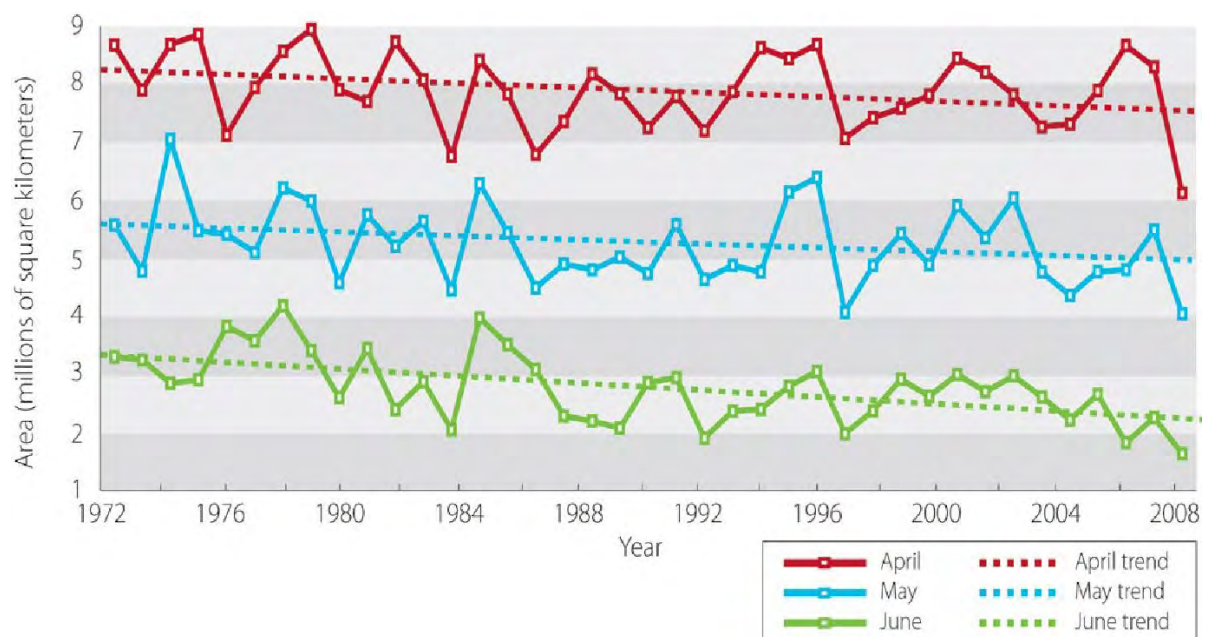


Figure 3.12 Changes in spring season snow cover extent over the Canadian land mass, 1972-2010, for the months of April (red lines), May (blue lines) and June (green lines) (Statistics Canada, 2012).

According to a report released by Environment and Climate Change Canada (2018), there is a projected increase in mean temperature and precipitation over most of North America. Figure 3.12 shows the decline of snow cover during 1972-2010 in April, May and June by

7%, 13% and 34% respectively (Statistics Canada, 2012). This observed decline in snow cover is highly correlated to the increasing temperature and rainfall. The increasing precipitation appears as rain rather than snow or more rain falling on existing snowpack due to the rising temperatures. Though regional and seasonal variability may apply, this pattern is projected to continue and accelerate throughout the 21st Century, with a large decrease in spring snow cover over much of the northern United States and Canada (Bush et al., 2014).

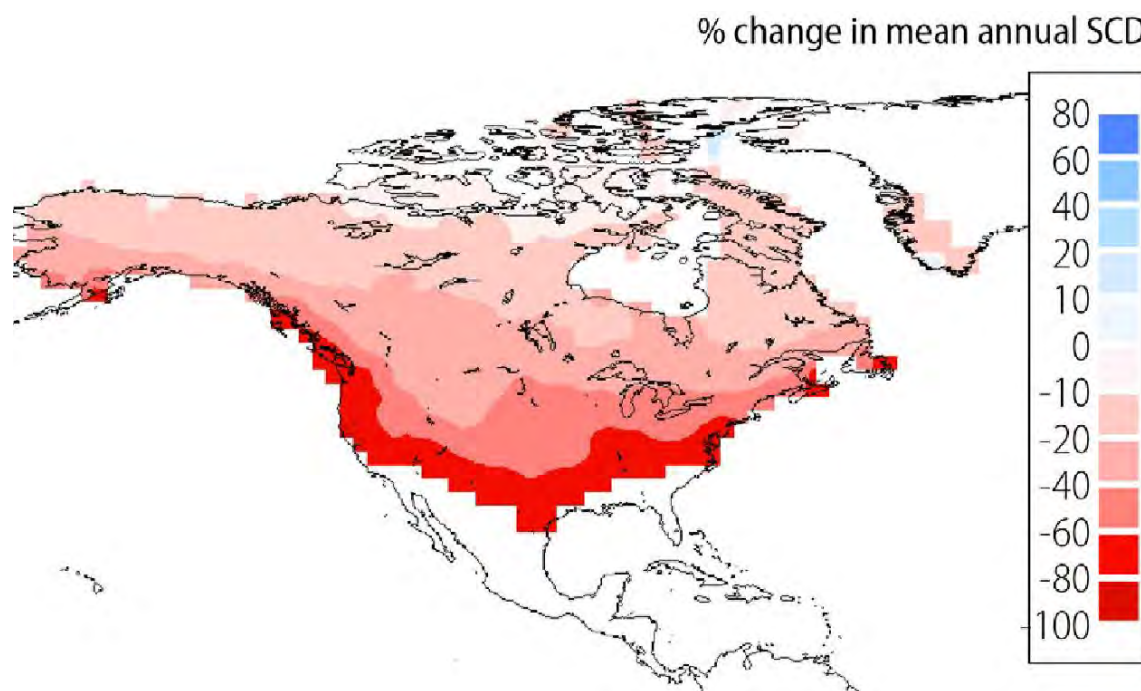


Figure 3.13 Projected percent changes in mean annual snow cover duration (SCD) between 1970-1999 and 2070-2099 for North America (Bush et al., 2014)

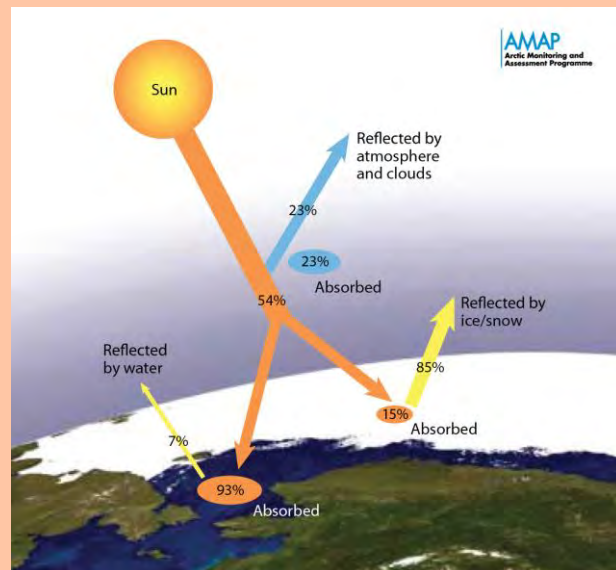
As shown in Figure 3.13, there is also a widespread decrease of snow cover in the projection of snow cover duration (SCD) by the end of the century compared to that of 1970-1999, especially in regions like the west coast. The projected changes shows a reduction in snow cover duration by the end of the 21st Century in almost all parts of North America that are snow covered today. These changes are attributed to the high sensitivity of winter precipitation to small changes in temperature due to earlier melt as a result of strong albedo feedback in spring (Brown & Mote, 2009).

Ice-Albedo Feedback :

Both ice and sea will reflect part of the sunlight back to the space, which does not contribute to atmospheric warming. This reflection rate is called albedo. If the albedo is 1, it will reflect all the light, whereas an albedo of 0 means all the sunlight will be absorbed. In ice and snow-covered regions, the highest albedo is 0.85. In comparison,

in non-snow/ice covered regions, the albedo is the lowest at 0.07.

Therefore, cooling tends to increase ice and snow cover and hence the albedo, reducing the amount of solar energy absorbed, leading to more cooling. A warming trend decreases the albedo, hence increasing the amount of sunlight and heat absorbed, which leads to accelerated warming (Enduring Ice, 2018).



■ Machine-made snow

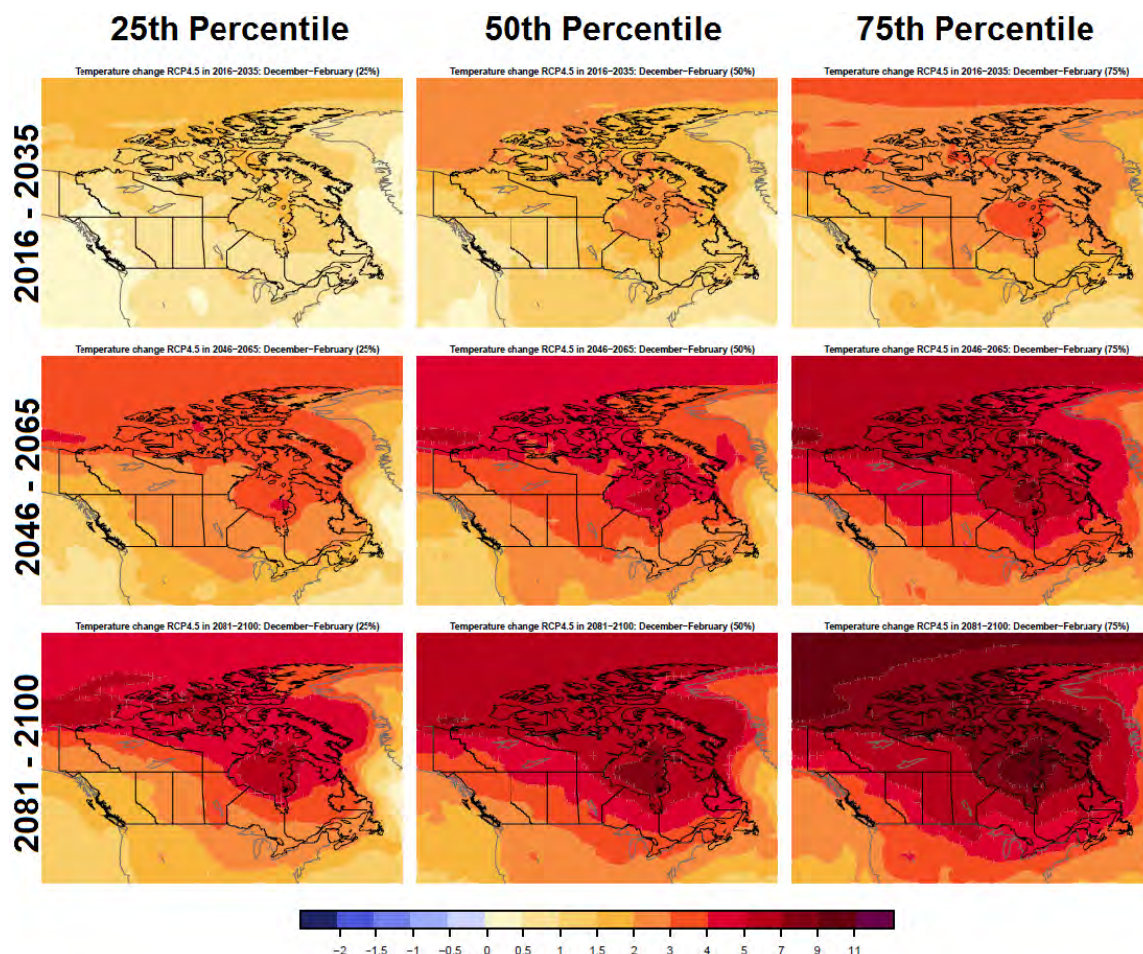


Figure 3.14 Maps of winter temperature change projection over December-February (Environment and Climate Change Canada, 2018)

Figure 3.14 reveals the projection of temperature in Canada on winter-based modeling results. The change is computed relative to the 1986–2005 baseline period. For each row, the left panel shows the 25th, 50th and 75th percentile of simulated temperature change respectively in RCP 4.5 scenario. Bush et al. (2014) claimed that the warming in Canada is spread across all seasons, especially in winter and spring.

Recognizing that snowmaking is an integral component of the ski industry, Bürki, Elsasser, and Abegg (2003) claimed that the ski areas could remain operational in a warmer climate and are less affected than their counterparts in Europe. For example, under climate change scenarios, the average ski season in the Lakelands region of Canada is projected to reduce by 0-16% in the 2020s, 7-32% in the 2050s and 11-50% in the 2080s.

Without snowmaking, the season would decline substantially by 37-57% in the 2050s. Concurrent with the projected ski season losses, the estimated amount of snowmaking required increased by 36-144% in the 2020s. The number rises to 48-187% in the 2050s (Bürki et al., 2003).



646

Ski areas

11,330,000

National skiers

10,980,000

Skier visits

(Vanat, 2017)

China is a pivotal emerging market in winter sports but is facing limited opportunities in terms of snow capacity. With the spotlight of the Olympic Winter Games shifting from PyeongChang to Beijing, the country embraces the booming winter sports industry with huge investment both in venues and promotion of winter sports among the general public.

In this context, we probe into the snow resources in China. The country is endowed with permanent snow regions in the Northeast, Inner Mongolia, Tibet Plateau and the Tianshan Mountain. Nonetheless, these regions are under threat in the context of global warming.

■ Natural snow

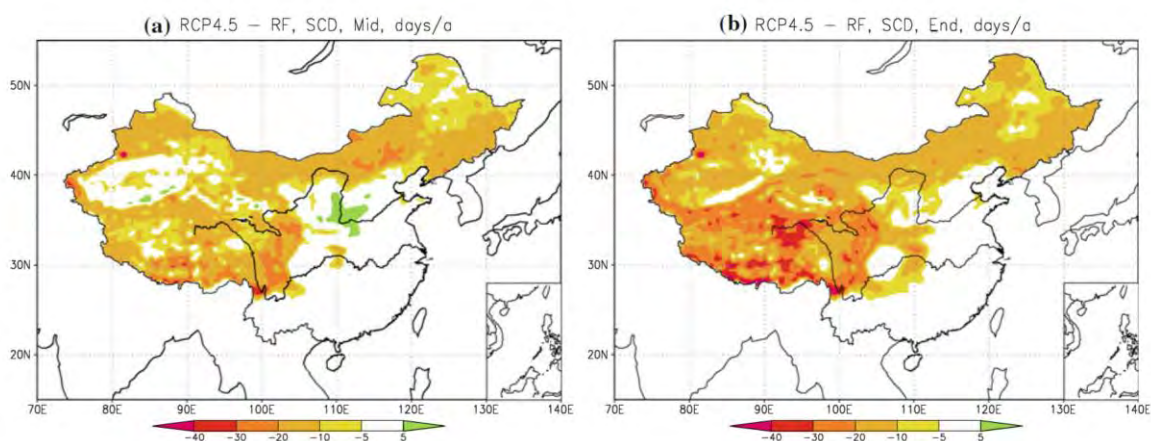


Figure 3.15 Differences in annual mean SCDs changes comparing RCP 4.5 scenario to reference (RF, 1986-2005) in the mid-term and the end-term (Ji & Kang, 2013)

Figure 3.15 reveals the projection of snow cover change in China by the middle (2040–2059) and end (2080–2099) of the 21st Century under RCP 4.5 scenario, comparing with the

reference period (RF) from 1986 to 2005. According to Ji and Kang (2013), SCDs (Snow Cover Days) are shortened by 10–20 and 20–40 days by the middle and end of the century respectively.

When we take a closer look at the Beijing-Zhangjiakou region where the Olympic Winter Games will be held during February 4-20, 2022, a recent study by Xiao W., Xiao C., Guo and Ma (2016) claimed that the projected temperature of the Olympic venues will be around -14 - 2°C. Taking into account the rising temperature, decreasing precipitation, snow cover days and maximum snow depth, 60-95% of the snow will need to be machine-made to reach the snow depth of 50-60cm for the Olympic venues (Xiao et al., 2016).

■ Machine-made snow

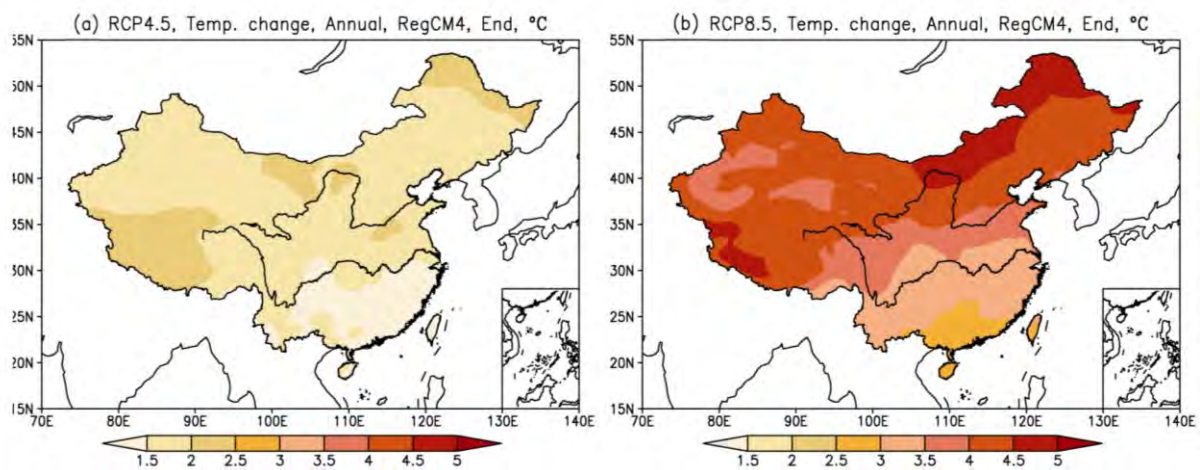


Figure 3.16 Changes in annual mean temperature over China under different scenarios (Xue, Li, & Giorgi, 2013)

With the support of China-UK-Swiss adapting to climate change in the China project, Xue, Li, & Giorgi (2013) simulated climate change in China by the end of the 21st Century (2080-2099) focusing on annual mean temperature and precipitation via a regional climate model. As is shown in Figure 3.16, significant warming is found, especially in high altitude and high latitude regions. The values increase in high emission scenario RCP 8.5.

Considering the effect of wind in maintaining machine-made snow and event postponements due to strong winds in PyeongChang (2018), we also try to probe into the factor of wind. It is found that for the past 50 years, there has been a significant decrease of wind in China, especially wind speed in winter and spring, but more research needs to be done in order to draw a conclusion on the relation between wind and winter sport (Wang, Ding, He, & Yu, 2004).

Asia: South Korea



18
Ski areas

2,937,000
National skiers

5,771,000
Skier visits

(Vanat, 2017)

South Korea's ski industry rapidly became popular and now has 18 resorts that are dependent on machine-made snow for operating ski slopes because of lack of natural snow. However, if climate change continues at the current trend (RCP 8.5), ski slopes will likely face difficulties to maintain the correct levels even with machine-made snow all over Korea.

For the analysis of climate change in Korea, we used the data of Daegwallyeong where the main venue of the PyeongChang Olympic Winter Games, Alpensia, is located.

■ Natural snow

Figure 3.17 below shows the changing trend in the number of days of snowfall depth over 30cm in the Daegwallyeong region. Snow days have decreased since the 1980s, especially in the 2000s where it was 37.8% less than the 1990s.

	over 30cm	over 20cm	over 10cm
1970s	31.5	41.5	62.1
1980s	35.3	47.8	66.3
1990s	33.6	43.2	62.2
2000s	20.9	31.5	48.5

(unit: day)

Figure 3.17 Change in the frequency of days of snowfall depth for suitable ski activity in Daegwallyeong (Heo & Lee, 2010)

According to the research of Kim et al. (2014) based on the SRES scenario, the average rate for depth of snowfall will decrease by 6% during the 2011-2040 period and by 18% during the 2071-2100 period based on 50 years frequency. In Korea, since the amount of natural snow is not suitable and expected to decrease continuously, machine-made snow is needed to run ski slopes and the importance of that will increase in the future (Figure 3.18).

Division	50y Frequency based snowfall depth (cm/day)			
	1971-2010 yrs (Reference period)	2011-2040 yrs	2041-2070 yrs	2071-2100 yrs
Average (cm/day)	17.9	16.7	15.5	14.7
Average (%)	Rate of Increase (%)	-6.5%	-13.5%	-18%
Division	80y Frequency based snowfall depth (cm/day)			
	1971-2010 yrs (Reference period)	2011-2040 yrs	2041-2070 yrs	2071-2100 yrs
Average (cm/day)	19.1	17.9	16.6	15.8
Average (%)	Rate of Increase (%)	-6.2%	-12.9%	-17.1%
Division	100y Frequency based snowfall depth (cm/day)			
	1971-2010 yrs (Reference period)	2011-2040 yrs	2041-2070 yrs	2071-2100 yrs
Average (cm/day)	19.7	18.5	17.2	16.4
Average (%)	Rate of Increase (%)	-6.1%	-12.6%	-16.7%
Division	200y Frequency based snowfall depth (cm/day)			
	1971-2010 yrs (Reference period)	2011-2040 yrs	2041-2070 yrs	2071-2100 yrs
Average (cm/day)	21.5	20.2	18.9	18.1
Average (%)	Rate of Increase (%)	-5.8%	-11.9%	-15.7%

Figure 3.18 Estimated frequency based snowfall depth and rate of increase (Kim et al., 2014)

■ Machine-made snow

Figure 3.19 shows the days of suitable weather conditions for snowmaking in Daegwallyeong from December to March (below -3°C minimum temperature and relative humidity 60-80% days). The change of suitable condition days for snowmaking shows a decreasing trend since 1973 with it decreasing 7.6% per decade over the last 35 years.

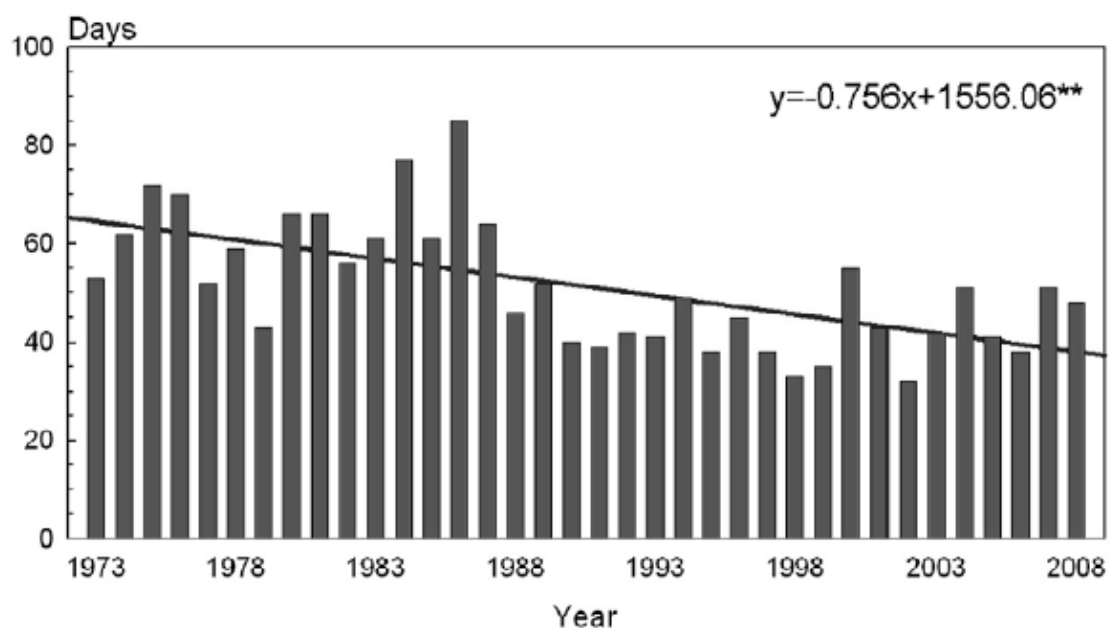


Figure 3.19 Change in the frequency of days below -3°C minimum temperature and relative humidity 60-80% days (December-March), (Heo & Lee, 2008)

According to the research of Kim et al. (2015) based on the RCP scenario, the average minimum temperature for the ski season in Daegwallyeong (November to March) rises from -8.14°C to -5.71°C (+2.43°C) for RCP 4.5. If the current trend continues (RCP 8.5), the average minimum temperature will increase from -8.14°C to -1.77°C (+6.37°C) (Figure 3.20).

	Phoenix Park	Yong Pyong	Alpensia	Wellhilli Park	Average
RCP 4.5					
Base line	-8.14	-8.14	-8.14	-8.14	-8.14
2030s	-7.66	-5.92	-7.60	-7.01	-7.05
2060s	-6.83	-5.05	-6.54	-6.24	-6.17
2090s	-6.28	-4.72	-6.09	-5.74	-5.17
RCP 8.5					
Base line	-8.14	-8.14	-8.14	-8.14	-8.14
2030s	-5.93	-5.43	-6.99	-7.44	-6.45
2060s	-3.09	-2.69	-4.09	-4.57	-3.61
2090s	-1.22	-0.95	-2.16	-2.77	-1.77

Figure 3.20 Prediction of average daily minimum temperature (°C) of ski resorts in Daegwallyeong region (Kim et al., 2015)

Based on RCP 4.5, the Daegwallyeong area will be able to operate ski slopes for more than 130 days, which is sufficient for running ski slopes with machine-made snow while the ski industry could be maintained at the same level of today. However, if climate change continues at the current trend (RCP 8.5), ski slopes will face difficulties to maintain the correct levels even with machine-made snow. The opening 130 days will be shortened by 9-30% during 2060s (about 100 days) and by 28-36% during 2090s (about 90 days). This means that the number of suitable days ski slopes are open will be less than 100. In the RCP 8.5 scenario, all the ski resorts in Korea will have less than 100 suitable opening days and be forced to close businesses (Figure 3.21) (Kim et al., 2015).

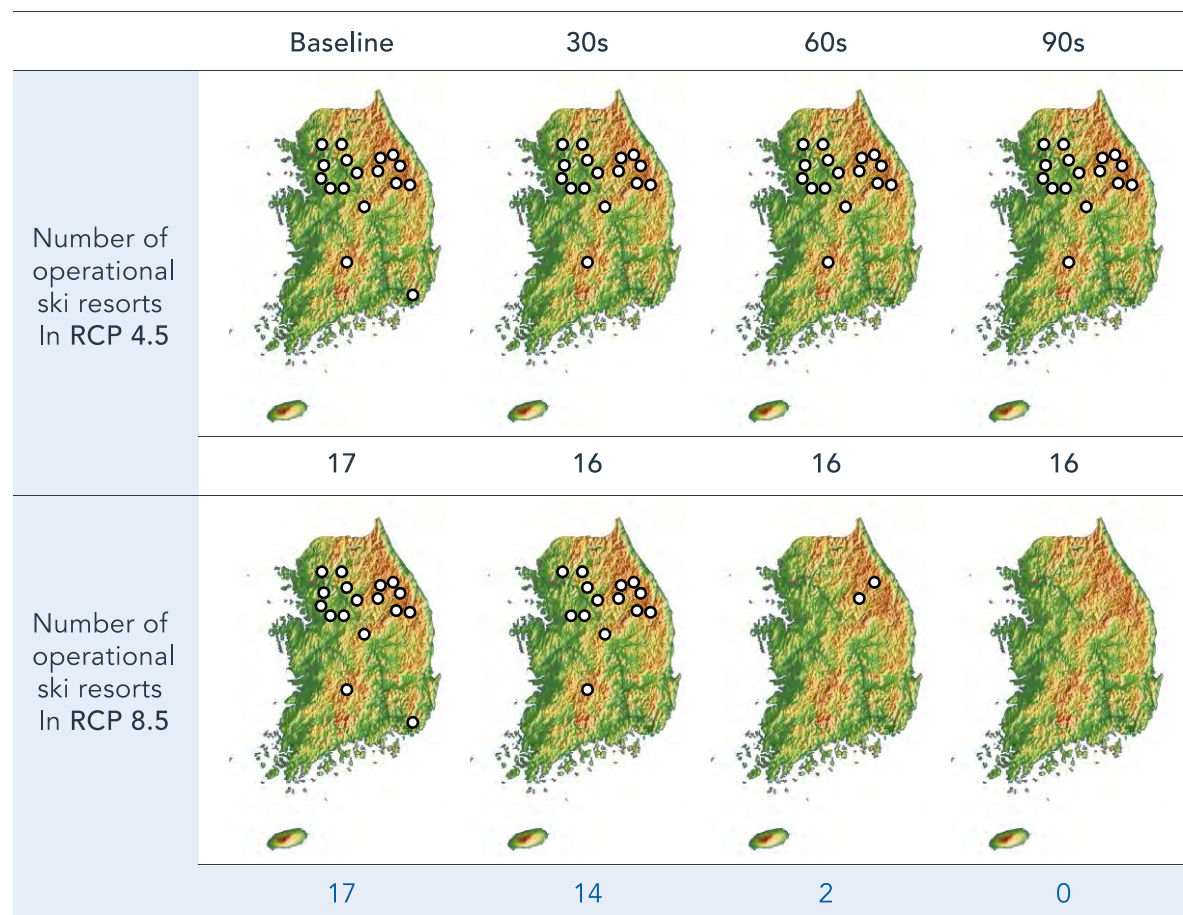


Figure 3.21 Forecast on future operation possible under the 100 days operation system (Kim et al., 2015)



4. Technology

Traditionally, the Olympic Winter Games has been made up of 7 federations.

- International Biathlon Union
- International Luge Federation
- International Skating Union
- World Curling Federation
- International Bobsleigh & Skeleton Federation
- International Ice Hockey Federation
- International Ski Federation

As the climate has been progressively getting warmer since the start of the Olympic Winter Games in 1924, technologies and strategies have been developed to mitigate the risk weather poses. Some of these have been easily introduced but others have been major changes to sports and venues. In an article by Ruty (2015) that looked specifically at weather risk management, 3 phases were identified as emergent adaptation, technological transition and advanced adaption over the course of 90 years (Chamonix 1924 to Sochi 2014). Most of these adaptations were initially introduced by the organising committees with them being mandated soon after by IFs in the Winter Games and the IOC (M. Ruty, 2015).

The emergent adaption focused on the period from 1924 in Chamonix, France to 1956 in Cortina d'Ampezzo, Italy (M. Ruty, 2015, p. 933). The major advances made during this time included:

- Weather insurance
- Using the army for moving snow
- The use of climate data
- Moving hockey indoors (from 1932 to permanently mandated in 1952)
- Moving speed skating and figure skating indoors
- Stockpiling snow

All of the sports moved indoors were because of the unpredictability of the weather and severe delays that had happened previously (M. Rutty, 2015, p. 934). Because the sports had been moved inside, they were able to mitigate risk and eliminate some delays.

The technical transition built off of the previous era while introducing more mechanised weather risk management technologies (M. Rutty, 2015, p. 935). Not only were more machines used to transport and make snow, the introduction of refrigerated tracks for bobsleigh, luge and skeleton were implemented along with the indoor ice surfaces (M. Rutty, 2015, p. 935). Innsbruck (1976) was the first Olympics to construct two indoor venues for ice hockey and figure skating while also having the largest snow transportation process at the time (M. Rutty, 2015, p. 935). The Grenoble Olympics (1968) adopted a lot of technologies to mitigate climate change such as alternative venues for alpine and concrete tracks instead of natural for the sliding sports (M. Rutty, 2015, p. 935). Even with these changes, there were a number of delays and cancellations due to warmer temperatures (M. Rutty, 2015, p. 935). This was also the era where snowmaking machines were introduced for nordic and alpine events during the 1980 Salt Lake City Games (M. Rutty, 2015, p. 936). A US\$5 million investment was made towards the permanent snowmaking system, which allowed the events to be held on schedule despite a snow drought in the USA (M. Rutty, 2015, p. 936). They were also the first to implement onsite weather offices to ensure timely and accurate data for events (M. Rutty, 2015, p. 936).

The advanced era is where the standardisation of technologies developed from previous Games were adapted but not a lot of new technologies were implemented (M. Rutty, 2015, p. 936). It was a time where the adaptations were refined and used more and more to mitigate the risk of weather delays and cancellations. Because of the large carbon footprint of all Olympic Games, a main focus was to reduce the environmental impact (M. Rutty, 2015, p. 936).

Examples include:

- The increase in weather stations,
- Snowmaking machines,
- Use of indoor venues

In Calgary (1988), new chemicals were used to ensure snow lasted longer in warmer temperatures and state of the art refrigeration was used on the sliding track which was capable of holding ice at temperatures as warm as 20°C (M. Rutty, 2015, p. 937). One of the major advancements for this period in weather data collection was the introduction of the first homepage for an Olympic Winter Games in Nagano (1998) (M. Rutty, 2015, p. 937). Not only did it allow for emails to media and other Games personnel but also featured data input directly from the Japan Meteorological Association (M. Rutty, 2015, p. 937). This was

also the first Olympics to have environmental criteria for organisers as well as the mention of global warming in a final report (M. Rutty, 2015, p. 937). In the following years, weather services became point-specific for venues, water use was monitored for machine-made snowmaking and reservoirs were built with the intention of making snow (M. Rutty, 2015, p. 938). Finally, Vancouver 2010 was the first Olympic Games (winter or summer) to host the Opening Ceremonies indoors and to implement refrigeration systems in the ski jump (M. Rutty, 2015, p. 938).

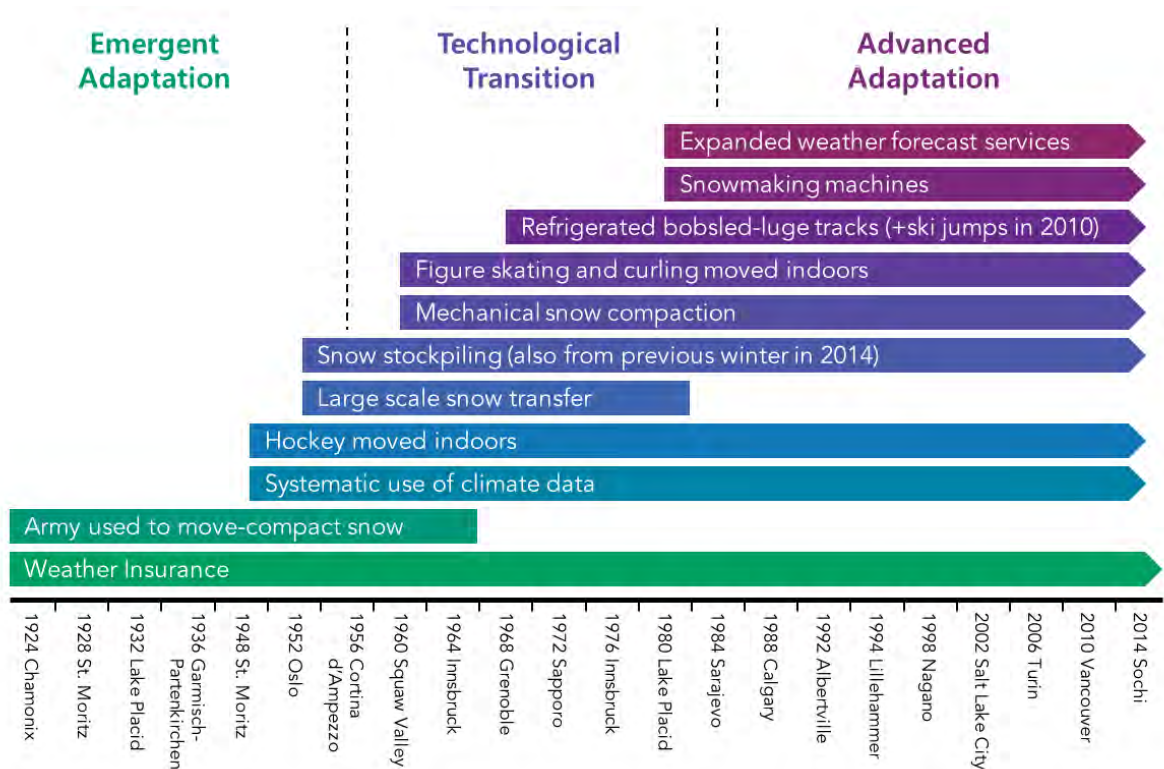


Figure 4.1 Progression of technology implementation in Olympic Winter Games

These adaptations are key in the continuation of the Olympic Winter Games as temperatures have steadily increased since 1924. It is important to note that not all adaptations were weather related. Some were also due to the ease of managing the events. When reviewing the daytime temperatures from past host cities, not only did the temperature increase, but the altitude of events also increased due to weather (M. Rutty, 2015, p. 940). It is clear that this trend will continue and a limited number of cities will be able to host these Games in the future without major changes to the sports and the Olympic Programme.

4.1. Indoor Sports

4.1.1. Refrigeration Systems

Traditionally, indoor ice rinks have been a great consumer of energy and with 4800 ice rinks in North America alone; the environmental impact they produce cannot be ignored. The NHL Green programme focuses on getting most ice rinks in North America to improve and modernise the arenas to lower the environmental impact of ice hockey (NHL, 2018).

Eco-friendly Refrigeration System:

“Many arenas are facing the reality that their refrigeration systems are reaching the end of useful life and will require major renovations or replacement. Costs associated with energy, refrigerants and the repair and upgrades of systems – along with environmental concerns have led to a new era in ice rink refrigeration system technology –

NHL.com

On January 1, 2020, production and import of HCFC-22 (Chlorodifluoromethane) worldwide will end, resulting in ice rinks across the world needing to adapt their facilities and moving to the use of natural refrigerants (Advansor, n.d.).

One major improvement regarding the global warming footprint of refrigeration systems is not running on coolants such as hydrofluorocarbons (HFCs) and other fluorinated gases with a high global warming impact but shifting to using systems optimized for primary coolants like ammonia (R-717) and carbon dioxide (R-744) (Scully, 2017). Some secondary refrigerants commonly used are calcium chloride or glycol, or ammonium hydroxide in Europe (Scully, 2017).

When examining the operation of refrigeration systems, if the CO₂ is used in the refrigeration loop and circulated rink flow, the system is referred to as “direct”. If carbon dioxide is used only in the machine room and a secondary refrigerant is also used, it is an “indirect” system (Scully, 2017).

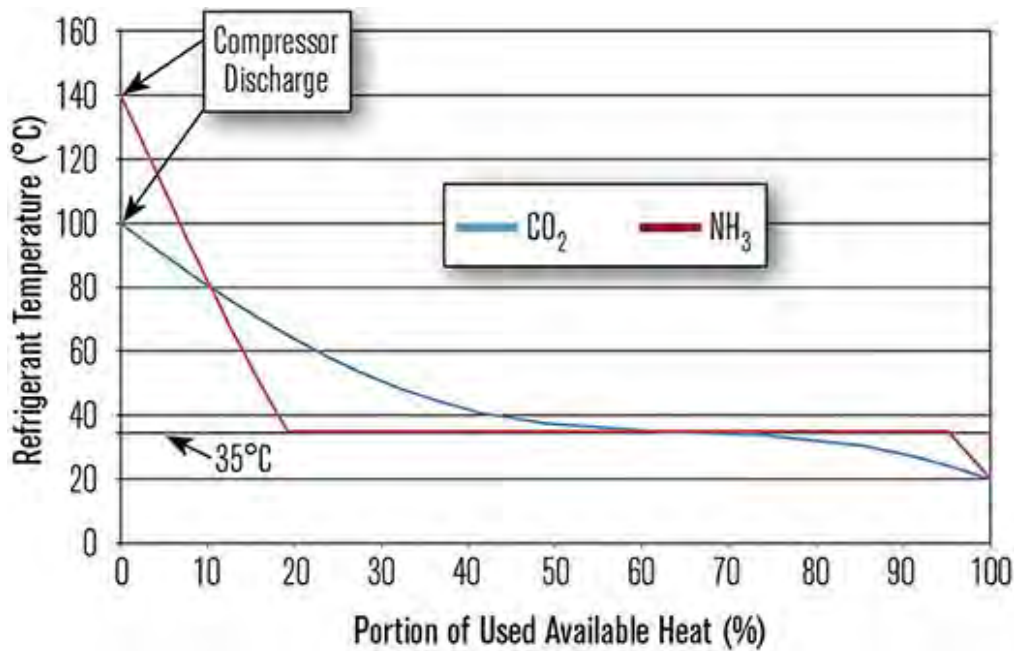


Figure 4.2 Comparison of the heat available between CO₂ and NH₃ (Scully, 2017)

In the graph above, it shows that carbon dioxide is the better alternative for the heat recovery system because more heat is available at higher temperatures. An example would be that only 20% of the heat has been removed from ammonia when it reaches 35°C compared to CO₂ which removes 60% of the heat at 35°C.

complCE is a model made by Advansor that focuses on the energy efficiency of ice rinks (Advansor, n.d.). The system uses one refrigerant, CO₂, which is neither flammable nor toxic, making it an attractive refrigerant both in terms of production, installation and operation of the unit (Advansor, n.d.). CO₂ also meets all international requirements on being an ecologically friendly cooling agent (Scully, 2017).



Figure 4.3 Heat recovery system by Advansor (Advansor, n.d.)

If the product is bought with the heat recovery system, instead of rejecting all the heat from the refrigeration system to the ambient via the gas cooler, it can fully recover the heat for utility purposes. Some of these include heating water, space heating and melting snow from ice resurfacing (Advansor, n.d.). It is able to reduce the pump energy usage 80-90% and even improves the overall ice quality (Advansor, n.d.). The whole system is compact and has a small carbon footprint (Advansor, n.d.).

Unfortunately these systems cost over US\$1 million and are therefore not affordable for many ice rinks outside of the professional leagues (Advansor, n.d.). With changes in law regarding chlorodifluoromethane, most ice rinks will need to adapt resulting in a smaller impact on global warming.

4.1.2. LED Lighting

Part of the NHL Green initiative is equipping arenas with LED lighting systems instead of traditional halogen lighting (NHL, 2018). Compared to traditional halogen lamps, LED consumes less energy and is brighter (LEDmasters, 2018). The lifespan of an LED is also significantly longer than those of a halogen with 80,000 hours for the LED vs. 10,000 for the halogen (LEDmasters, 2018). Even at the Olympic Winter Games, the lighting for all ice rinks is LED (LEDmasters, 2018). The observation from LEDmasters, a provider of LED lighting, has been that a 15,000W LED replaces 40,000W metal halide and therefore there is savings of 62.5% in energy consumption (LEDmasters, 2018).

“ ***Things like LED lights for game lights which is a significant energy reducer because of heat and not needing to use as much A/C to cool space.***

– Omar Mitchel, NHL

”



Figure 4.4 LED lightning comparison (Premier Lighting, 2017)

As LEDs can be made waterproof and are out of solid material, unlike halogen or metal halide, they were also used in PyeongChang for the bobsleigh track where they had to cope with temperatures of -40°C (Admin, 2018).

4.2. Outdoor Sports

4.2.1. Dry slope

A dry ski slope or artificial ski slope is a ski slope that mimics the attributes of snow using materials that are stable at room temperature to enable people to ski, snowboard or snow tube in places where natural, snow-covered slopes are inconvenient or unavailable.



Figure 4.5
Example of a Dry Slope
(Snowflex, 2018)

Although commonly known as "dry ski slopes", many slopes are lubricated using a mist or jet system to increase speed and prevent damage to equipment from friction heat build-up (Dry Ski Slope, 2017). As a general rule, they were predominantly found in the United Kingdom and the Netherlands as other European countries tend to have access to real snowfields, similar to North America in the winter. However, through global warming, these dry slopes can now be found in Austria, a country that has traditionally been known for natural snow (Dry Ski Slope, 2017).

A few examples of brands currently building and selling these kinds of mats include:

- Neverplast: claim to have the same frictional qualities as real snow. (<http://www.neveplast.com/de/>)
- Mr snow from Germany: claim to provide an environmentally friendly solution (with no Silicone and even tested its gliding speed vs. real snow on the Tignes glacier in France. (<https://www.mr-snow.de/en/mr-snow-en/>)
- Snowflex: from the UK and one of the first brands on the market. (<http://snowflex.com>)

Currently, these snow mats can be shaped and adapted to different forms (ex. building freestyle parks) (Hodgetts, 2014). The Olympian freestyle skier James Woods, for example, learned to ski and train on dry slopes outside of Sheffield, UK (Hodgetts, 2014). However, dry slopes are still not recognized by FIS as an official competition surface (Hodgetts, 2014).

An example of the latest project Snowflex is involved in is the Afan Valley Adventure Resort in South Wales. They have over 300 meters of descent planned, making it one of the biggest machine-made snow ski areas in the world. Some questions arising now are can dry slopes be used to hold elite level competitions? Will they stay training facilities or only be able to hold University Championship's like the BUSC in the UK as they are now?

4.2.2. Machine-made Snowmaking

Although machine-made snowmaking in itself is not a new technology, it has been a crucial factor in ensuring competitions happen while saving ski resorts when the natural snow cover is not sufficient. The technology and especially the efficiency of the snowmaking machines has been constantly improving over the years but the amount of infrastructure in ski resorts is still vast as can be seen with the example of the 2014 Winter Olympics in Sochi.

Artificial Snow for the 2014 Winter Olympics

A layer of artificially produced snow will be fired onto the slopes of the mountains around the Black Sea resort of Sochi

150 THOUSAND M³

of artificial snow is scheduled for production in Sochi prior to the Olympics

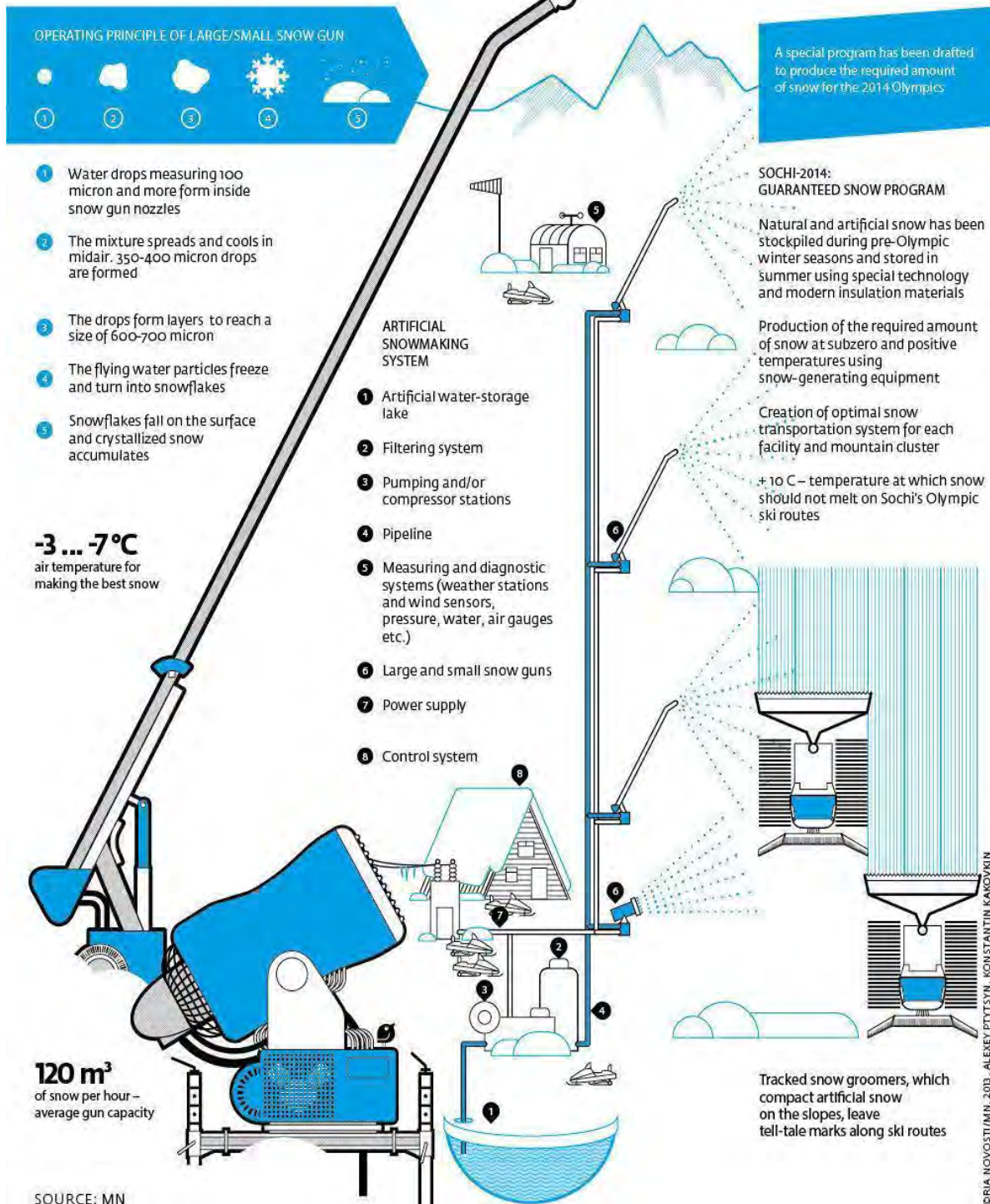


Figure 4.6 Machine-made snow at the 2014 Winter Olympic Games

Most machines are still limited to making snow when the temperature is below 0°C (Vagle, n.d.). Fortunately in 2005, the IDE, an Israeli water treatment company, built the first stationary machine that could make ice at any temperature. Since then a few models have been developed to produce machine-made snow with temperatures up to 20°C (Vagle, n.d.).

We are storing the snow over the summer, improving the artificial snow system and using snow farming and producing snow on the warm temperature

– Borut, Nunar, IBU

Temperature Independent Snowmaking (TIS)

One model is the Snowfactory by TechnoAlpin:

This model uses the method of making flake ice with their machine and then propelling it onto the slope through an air pipe. The Snowfactory is often used in biathlon arenas (ex. Lenzerheide, Switzerland) (Vagle, n.d.).

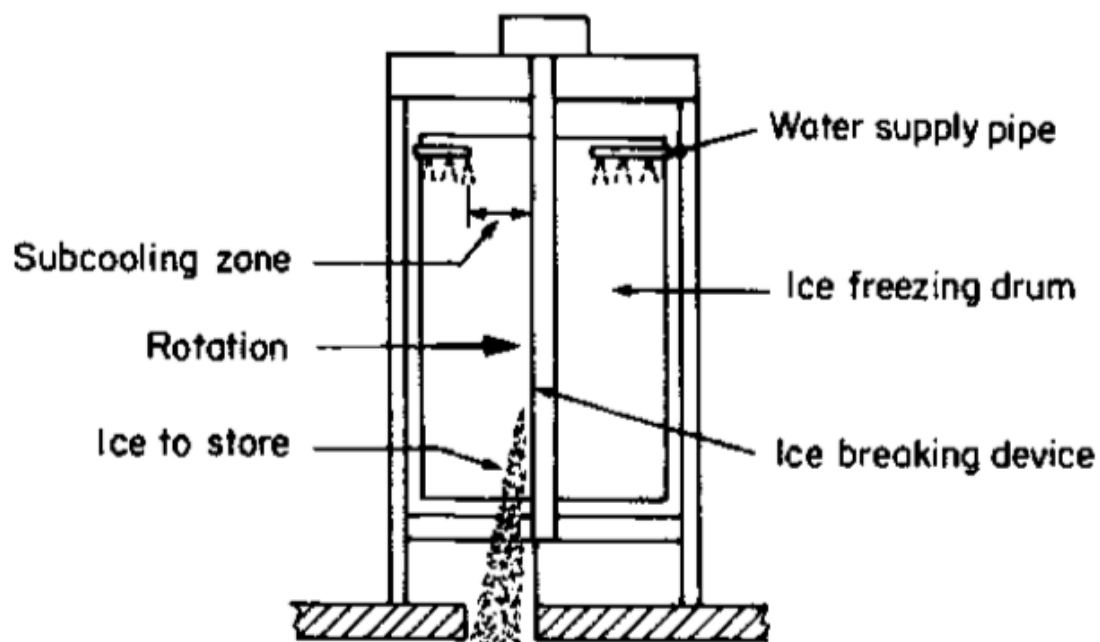


Figure 4.7 Ice flaker machine (used in SnowFactory) (Vagle, n.d.)

The other is the the SnowTek by SnowGem:

This uses the ice slurry method developed by IDE. In this method ice slurry is produced in a vacuum ice machine. The slurry is then separated into ice and water in a snow concentrator (Vagle, n.d.).

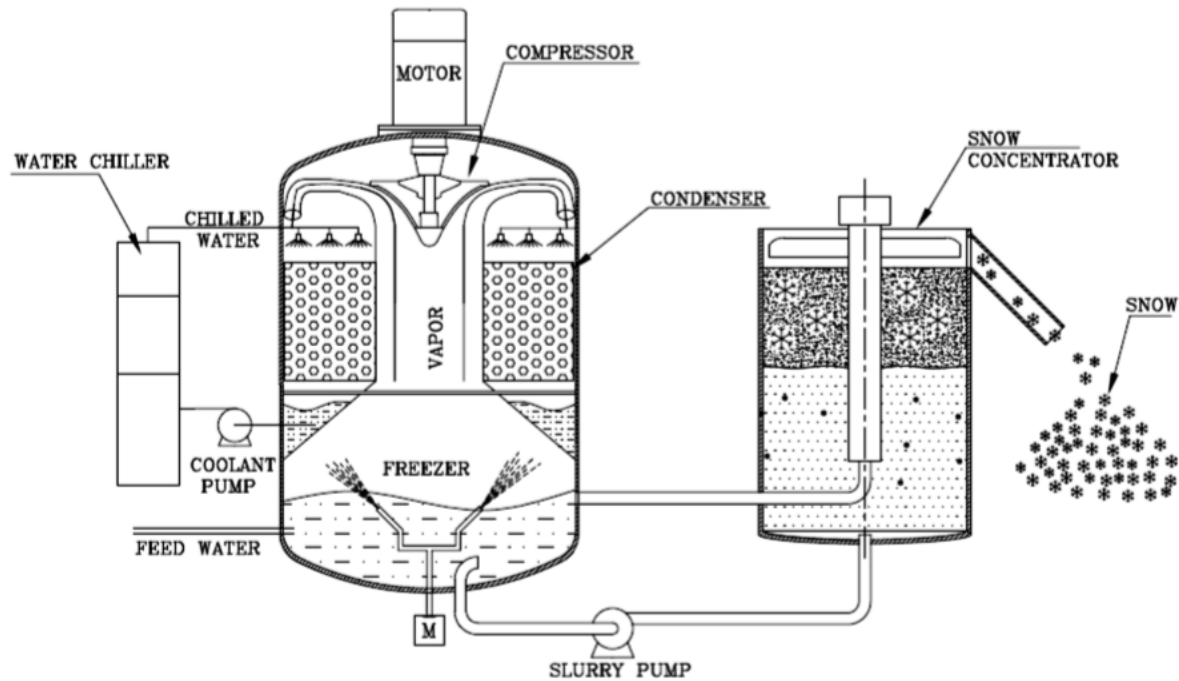


Figure 4.8 Ice slurry method (used in SnowTek) (Vagle, n.d.)



(Snowtek, n.d.)

The SnowTek is one example of a fully mobile system that can produce snow above 30°C. It was used in Sochi for the 2014 Olympic Games for ski jumping and the nordic combined discipline (SnowTek, n.d.).

4.2.3. Snow Storage

Snow storage is not a technique that can be solely used to make an event happen but it can provide an alternative for events taking place when the temperature is too high to produce snow. One of the snow storing pioneers is Mikko Martikainen who had the idea 30 years ago but at the time, natural snow was still abundant. He was also the man responsible for snow storage at the Sochi 2014 Olympic Games; the biggest snow storing operation thus far (Lintzen, 2016). Snow storage is often a requirement for events in case there is a lack of snow but different materials can be used during the summer months (Lintzen, 2016). Some of them include:

Natural Materials :

- Wood chips
- Cutter shavings
- Saw dust
- Bark
- Rice shells
- Debris

Synthetic materials :

- Loose sheets
- Geo textile
- Aluminum folio
- Plastic sheets
- Thermal foam

Place	Volume [m ³]	Cover material	Approx. melt [%]
Vuokatti	20,000-25,000	Sawdust (≈30-40cm) + Tarpaulin	20
Östersund (2006)	20,000	Sawdust (≈70-80cm)	30 (10% ice)
Östersund (2016)	2*(30,000)	Sawdust (≈40cm)	
Orsa	5,000	Bark (≈40-50cm)	
Piteå (2012)	2,400	Bark (50-70cm) + Geotextile + Plastic	30
Piteå (2013)	3,400	Bark (50-60cm) + Geotextile + Partly covered with plastic	30
Arjeplog (2013)	1,600	Bark (≈40-50cm) + Textile	60
Sochi, Russia (2013)	800,000 (several piles)	Geotextile (several layers), Thermal foam in between, Reflective aluminum on top	20-50

Figure 4.9 Examples of snow storage (pros/cons) (Lintzen, 2016)

From the table, we can see that the most efficient snow storage material is sawdust or geotextile, however it is also very dependent on the outside temperatures and weather conditions (Lintzen, 2016).

According to the interview conducted with the sports director of the International Biathlon Union, most resorts cannot afford machine snowmaking that works at temperatures above 0°C because the cost. Snowfactory, for example, is US\$500,000 for one unit. To ensure good snow conditions for the next season, they store the snow from previous years.

In an interview with Patrick Jarvis, he mentioned an issue that can arise with snow storage; where to store the snow. In the case of the 2010 Vancouver Olympic Winter Games, the snow was stored in a provincial park an hour away from the venue. This led to the question on how to transport the snow to the venue and what would be the most sustainable option in terms of cost and the environment. Another issue mentioned in the interview was the movement of local species with the snow from one location to another and how that would impact the local environment.

4.3. Summer Adaptations

Some winter sports have adapted their disciplines to summer conditions, which were initially developed to be training methods. An advantage of these sports is that they don't require snow however they may not be classified as winter sports anymore.

The summer adaptation of cross country skiing is roll skiing and combines the latter with traditional inline skates and ski rollers to imitate the feeling and movement of cross country skis.



Figure 4.10 Roll skiing (DPA, 2010)

SUMMER TRAINING IS A PART OF IT, AND WE ARE USING ROLLER SKIS FOR THE WHOLE HISTORY OF THE BIATHLON FOR TRAINING. WE ARE ALSO ORGANIZING THE SUMMER WORLD CHAMPIONSHIP IN BIATHLON ON THE ROLLER SKIS ON THE ASPHALT COURSES, THIS IS NOTHING NEW FOR THE LAST ALMOST 20 YEARS. BUT OUR KEY EVENT IS STILL IN WINTER. WE ARE NOT PLANNING TO HAVE MANY MORE THINGS IN SUMMER, BECAUSE AT THE MOMENT, DUE TO ALL MEASURES TAKEN FROM THE ORGANIZERS, IT'S NOT NEEDED AT THE MOMENT. BUT, EVEN IN CASE THE SITUATION WILL BE WORSE, WE HAVE ALREADY TODAY THE RULES AND VENUES THAT WE COULD DO SUMMER BIATHLON AS WELL. IT'S MAINLY ON THE SAME LOCATIONS WITH OUR WINTER EVENTS.

– Borut, Nunar, IBU

Grass skiing is the summer adaptation of alpine skiing initially developed as an off-snow training method introduced by the German, Richard Marting and it quickly developed into a sport of its own. It is now under the FIS umbrella holding World Cups and World Championships. But according to Jürgen Capol, the marketing director of FIS, it could be used as a backup for winter skiing or ski-jumping events.



Figure 4.11 Grass skiing
(Jansky, 2010)



5. Olympic Winter Games

5.1. Programme Criteria

After a review of the Olympic Programme criteria provided by the IOC Sports Department, there were two points that outlined environmental concerns. The first, item 67, focuses on policies for International Federations. It asks if there are any policies or guidelines in place regarding the environment but does not specify whether they are mandatory for inclusion in the Olympic Programme or the quality expected (International Olympic Committee, 2012). The second, item 68, refers to the use of event evaluation criteria and it uses the AISTS Sustainable Sport & Events Toolkit as an example, but it does not provide a mandatory criteria to use or any expectations on the quality of the criteria (International Olympic Committee, 2012).

In the questionnaire for the review of the Olympic Programme of Tokyo 2020 and Beijing 2022 sent to IFs, there was no mention of the environment or climate change in the questions (International Olympic Committee, 2016) (International Olympic Committee, 2017).

“ A good question is what would a scenario be if things really got worse with climate change? Would it be a scenario where you have to think about a plan B with another location? ”

– Claude Stricker, Sion 2026

The implementation of sustainability strategies has started to increase within IFs to the point where almost all have some form of guidelines in place. While not all have guidelines,

some such as the International Skating Union, have people who implement practices into their events and planning on a daily basis. Since 2016, the IOC has been interviewing IFs to document their sustainability practices and create case studies for other organisations to use as models. Through interviews conducted with various experts, it became evident that being aware of the environment is an important theme.

Examples of Sustainability Practices:

- NHL Green (food recovery, LED lighting, building automation)
- IIHF bike programme during the 2017 IIHF World Championships in Cologne, Germany.
- FIS working to host carbon neutral events.

5.2. Candidature Process

After a review of the 2024 Olympic Games framework, a lack of detail was found regarding the environment. It identified half a page on sustainability and that there were carbon reduction strategies in place by the IOC but did not specify what they were (International Olympic Committee, 2015, p. 77). This meant that there was little information specific to the impacts of climate change and what host cities are expected to do to mitigate these effects. In documentation coming from the IOC, this information could be included to provide clarity to bid and host cities. It can also be the responsibility of cities and governments to document and share their practices for future Games.

In Annex 3, requirements for the 2026 Olympic Winter Games and beyond were listed and stated that any current hosts will work with the IOC to meet most, if not all, of the sustainability requirements. In the Candidature Questionnaire for the 2026 Olympic Winter Games, there are questions specific to the IOC's sustainability strategy as well as the weather for the Games (International Olympic Committee, 2017). With the current development of sustainability guidelines at the IOC for host cities, it will help provide clarity and structure in the planning of policies and procedures for the Olympic Games.

“ IOC and IPC need to consider the scale of their events. Constant pressures to add more events. I think they have hit critical mass. Can't just move an event from one mountain to another.

– Patrick Jarvis, Canada Snowboard

”

Due to the impact climate change can have on an event schedule, it is important that organisers are implementing strategies to mitigate the risk associated. It became evident during interviews with OCOG's and bid committees that they had all planned or would plan sustainability strategies to incorporate into the event organising process.

Mitigation Strategies

- Reducing energy consumption – PyeongChang worked to reduce energy in various areas including venues and transportation and also produced a sustainability report (available to the public) to document their processes.
- Adhering to federal policies – Due to the structure of the Calgary 2026 Bid Committee and its affiliation with the City of Calgary, they plan to work in tandem with the Government of Canada's sustainability strategies.
- Predicting future weather patterns – Sion 2026 is working to look at past and potential future weather patterns to help them in their planning and mitigation strategies for their bid.
- Examining the best way to transport snow without a large environmental impact – VANOC considered aspects like rail, road or plane transportation for snow as well as the environmental impact of moving snow from one provincial park to another and they impact that would have on native species of plants

5.3. Sports at Risk

5.3.1.Sports

From the previously conducted research, interviews and the number of events cancellations in the last 5 years (see Appendix G), we can see that the alpine skiing disciplines are most at risk of climate change due to the lack of environmental control outdoor events have.

“ Alpine skiing is most at risk to climate change. Outdoor sports have fewer options to mitigate the impacts and need to start working with nature rather than against it ”

– Gian Gilli, Gian Gilli SA

Based on the data compiled, we have determined high risk, medium risk and low risk categories for the sports currently on the Olympic Programme. The criteria used for this ranking included cancellations over the last 5 years, the need for technologies to ensure

events would take place, the adaptability of the sport and the potential impacts of increasing temperatures.



Figure 5.1 Sports most at risk

The most common reason for cancellations that came from the interviews was safety of athletes. It was evident that event organisers took safety very seriously and if competitors could not make it down the hill, could not get to the venue safely or spectators could not get there safely, they would look at delaying, postponing or even cancelling events. When interviewing FIS, they said it was easier to cancel an event rather than reschedule because of the World Cup and World Championship schedules but when looking at past Olympic Winter Games, no event has ever been cancelled. This indicates that whether or not an event gets cancelled is very dependent on the group organising it and the calibre of the competition.

“ Actually there have been cancellations of indoor NHL games. One was in Calgary with the floods (2013). It totally destroyed the ice plant and the infrastructure on the main floor so that was certainly an issue. There have also been, as you can imagine, games that have been cancelled due to snowstorms, for example in Boston with the Nor’easter storms.

– Omar Mitchell, NHL

”

During the Vancouver 2010 Olympic Winter Games, there were a total of 5 postponements and 9 delays with all but one being due to some sort of weather incident. During the PyeongChang 2018 Olympic Winter Games, there were a total of 6 postponements and 1 delay.

When cancellations were reviewed, most, but not all, were related to weather. A list of cancellations over the last 5 years can be found in Appendix G.

5.3.2. Matrix

One of the deliverables requested was a matrix to use as a tool for sport evaluation to determine whether disciplines should be included on the Olympic Programme. It was built based on the questions and themes that arose from interviews and desk research. The three main themes used are cancellations, policies & procedures and technology & adaptations within each sport. Each area is broken down into the current situation, actions and future impacts on the sport. They are then rated on a scale of 1-10 with a total out of 30. This will help to numerically represent the viability of the discipline.

Cancellations focuses on the number of cancellations, delays or postponements a sport has over the last 5 years. It indicates the direct impact the environment, weather and climate change as a bigger picture has on a sport. Some cancellations in this section could be due to other factors and it is important to note this when using the matrix. By evaluating the last 5 years, it illustrates potential trends for the future and what actions may need to be taken to mitigate impacts.

The policies and procedures included in the matrix refer to both the current policies (situation) as well as possible policies for the future mentioned in the interviews. Procedures implemented at the present moment and in the future are also important in defining the

way each IF/organiser is handling the threat of climate change in regards to the impact on sport.

Technologies referred to in the matrix include the technologies used in different sports to fight the effects of climate change as well as taking into account technologies used to mitigate the impact of the various events held. Adaptations taken into account for the matrix are directly linked to the disciplines and how they could be adapted due to climate change.

Downhill Skiing	Current Situation	Actions	Future Impacts	Overall Evaluation (Rate 1-10)
Cancellations	<ul style="list-style-type: none"> - Less than 5% for World Cup level - Very stable number over the years 	<ul style="list-style-type: none"> - Races are often delayed or held on different venues 	<ul style="list-style-type: none"> - Lower level is a snow issue – could lead to an increase of cancellations 	8
Policies / Procedures	<ul style="list-style-type: none"> - CO2 is the main concern - FIS is too small to have an impact - Sport is closely linked to the Tourism in the region - Most CO2 by the spectators and skiers arriving with their own car - Fresh air in the mountains 	<ul style="list-style-type: none"> - Possible involvement with public transport to Events - CO2 carbon neutral Events - Target to improve the climate and the pollution 	<ul style="list-style-type: none"> - FIS is too small to have a real impact on global warming - Maybe their major events can have an impact 	6
Technology / Adaptations	<ul style="list-style-type: none"> - Machine-made snow production - Snow storage 	<ul style="list-style-type: none"> - Most locations have to have machine-made snow guns systems to ensure the competitions 	<ul style="list-style-type: none"> - Could lead to a shortening of the speed disciplines - Increase in cancellations - Less number of Kids on snow (grassroots) 	4
Total				18

Two examples were developed to demonstrate the viability of this matrix: downhill skiing and ice hockey (see Appendix H). As you can see in the downhill skiing example, compared to ice hockey (25), skiing has a relatively low score. With this being a high-risk sport, there needs to be change made if it wants to be viable long term. The lack of advancements in technology should be addressed as well the policies and procedures in organisations running the sport. Due to a lack of information available, the difference between climate change and weather patterns in relation to cancellations was not applied. In the future, this would be a good area to research and apply to the matrix.

6. Conclusion

Based on the research done on climate change, there is a definitive impact on the Olympic Winter Games. It is already evident when you look at the inability of certain regions to host events.

With temperatures rising each year, climate change is occurring at a rapid rate. The global average for combined land and ocean surface temperature has increased consistently over time with 2016 being the warmest year on record. Effects in the atmosphere, sea level and cryosphere have led to reduced snow cover, which directly affects winter sports. With most Olympic Winter Games being located in the Northern Hemisphere, it was important to narrow the search. When looking more specifically at major ski markets such as the Alps, parts of North America and Asia, a more concrete evaluation was completed, and the effects were wide spread with the biggest being the shortening of the winter season. It is important to note that the findings from this research are based on regions rather than a global scale. Because of this, the data should be analysed cautiously as it does not represent a full picture of global models used.

With the current climate data and the projections for the future, only a limited number of locations will be able to host the Olympic Winter Games due to rising temperatures. The locations will need to be colder climates and higher altitudes to find the right conditions for competitions.

Adaptations to the Olympic Winter Games and the sports involved will need to occur if the Olympic Movement hopes to continue with this event. It is necessary to rethink how these Games are approached and how people look at winter sport. Although technologies are being used to help mitigate the effects of climate change, they will not be able to stop them completely. With the outdoor snow sports being most at risk to climate change, potential adaptations could include shortening the descent of downhill skiing or reducing the size of the course for biathlon.

With the increasing impact of climate change, a time will come when sports that do not involve snow or ice will need to be considered winter sports. This may be where potential adaptations of the Olympic Winter Programme happen. Whether it is including activities like mountain running or mountain biking into the Olympic Winter Programme, or moving ski jumping to the Summer Programme, creativity will be key. It is also important to note that the organisers of major winter sport events will need to adapt in their way of thinking towards the environment because it is a changing landscape. The regions examined in this report aren't the same as 10 years ago and will not be the same 10 years from now.

Throughout the research and especially in interviews, the social impact of climate change started to appear more and more. A next step for this research could include the effects on social issues such as spectator experience, broadcasting and grassroots involvement in winter sports. These are all areas that are key to successful events and winter sport as a whole. The consequences of climate change will be widespread and so widening the view and scope of sport is important to do.

Other areas of further research could include:

- In-depth analysis on regions with winter sport not covered in this report – Oceania, South America.
- In-depth comparisons between the changes in recent weather versus projected results for the future. These findings differed throughout our research so a more concrete analysis would be beneficial.
- The correlation between climate change and extreme weather events. How does this effect winter sport?
- Analysis on what cancellations are specifically related to weather patterns created by climate change.
- How climate change will affect the accessibility for people to participate in winter sports.
- The possibility of ski resorts having a zero carbon footprint.
- Correlation of public funding for winter sports and sponsorship revenue versus global warming

Ultimately, these changes of thinking need to come from the larger organisations that organise winter sport if they are going to happen. Sport organisations need to take responsibility for these events and look to adapt. It is only a matter of time before winter sports become obsolete and if we want to try and make them last, changes need to be made to ensure the Olympic Winter Games continues.



PyeongChang 2018

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8. Appendix

Appendix A | Interview Candidates

Organization	Name	Position
Beijing 2022 Organising Committee	Tong Lixin	Sports Director
Calgary 2026 Bid Committee	Jen Brown / Ken Baker	Sustainability Department
FIS	Jürg Capol	Swiss Cross-Country Skier
Gian Gilli SA	Gian Gilli	Involved with various organizations such as IIHF World Championships, FIS World Championships and Swiss Olympics in event and management roles.
IBSF	Heike Groesswang	Secretary General
IBU	Borut Nunar	World Cup Race Director
ISU	Peter Kreik	Board Member
NHL	Omar Mitchell	Vice President Corporate Social Responsibility
PyeongChang 2018 Organising Committee	Kelly Yunkeong Ko	Sustainability Manager
Sion 2026 Bid Committee/AISTS	Claude Stricker	Executive Director
VANOC/Canada Snowboard	Patrick Jarvis	Executive Director
Whistler Ski Resort	Arthur De Jong	Mountain Planning and Environmental Resource Manager
World Academy of Sports	Riikka Karakic	Director, IF Relations

Appendix B | Interview Questions

Interviewee Information

Name:

Organisation:

Sport:

Country:

Position:

IF/NOC

1. Have you experienced delays or cancellation of events because of weather? What was the reason?
2. Has the number of cancellations/delays increased in the last 5 years? How many per year? Have all of these been related to weather or other reasons?
3. What discipline had the most cancellations/delays? Why?
4. Do you see your sport under threat of climate change? And if so, how?
5. Could you see your sport being negatively impacted because of event cancellations? e.g. diminished economic value
6. Do you have a plan to mitigate these impacts? If no, why not? If yes, what kind of mitigating measures?
7. Does your organisation have specific policies to proactively combat climate change?
8. Do you think your sport will be adapted in any way due to the risks of climate change?
9. Do you have an alternative event schedule (ex. world cup) in the case of current locations being unable to host competitions due to climate change?
10. Do you know any technologies that can reduce the impact of climate change in your sport? Are you using any of them?
11. Are there any summer training adaptations used in your sport? Would these be considered in the future for events?

Event Organiser (Already)

1. Has the number of cancellations/delays increased in the last 5 years? How many per year? Have all of these been related to weather or other reasons?
2. What discipline had the most cancellations/delays? Why?
3. What factors were considered when making the decision to delay the event?
4. Is a framework established prior to your event to help determine if an event should be cancelled? If so, what does this framework look like?

5. How can you prepare for unexpected delays or cancellations because of weather conditions?
6. Does your organisation have specific policies to proactively combat climate change?
7. Do you think sporting events will be adapted in any way due to the risks of climate change?
8. Do you have an alternative event plan (ex. world cup) in the case of current locations being unable to host competitions due to climate change?
9. Do you know any technologies that can reduce the impact of climate change in your sport?

Event Organiser (Bid)

1. Which event discipline is considered to be the highest risk for cancellations/delays?
2. What factors would you consider when making the decision to delay the event?
3. Is a framework established prior to your event to help determine if an event should be cancelled?
4. Do these preparations work or do they need to be modified when dealing with weather conditions?
5. Does your organisation have specific policies to proactively combat climate change?
6. Do you sporting events will be adapted in any way due to the risks of climate change?
7. Do you have an alternative event plan (ex. world cup) in the case of current locations being unable to host competitions due to climate change?
8. What would you do to mitigate the risk of an event being cancelled due to weather or climate change?
9. Do you know any technologies that can reduce the impact of climate change in your sport?

Appendix C | Interview Transcripts

International Federation

FIS

Name: Jürgen Capol

Organization: FIS

Sport: Skiing

Country: Switzerland

Position: Head of Marketing

1. **Have you experienced delays or cancellation of events because of weather? What was the reason?**

Yes we have in FIS. Sport the weather is decisive factor. If foggy in certain events, wind can be an issue or having no snow

2. **Has the number of cancellations/delays increased in the last 5 years? How many per year? Have all of these been related to weather or other reasons?**

World Cup level a bit different. Can cancel on race but replace somewhere else.

Cancellation # less the 5% per season World Cup level – very stable

Lower level is a snow issue

In 1 season 7000 competitions of different levels

3. **What discipline had the most cancellations/delays? Why?**

Speed events quite long – weather conditions more extreme. Wind can have a strong influence – most risky for cancellations. Need more snow and weather conditions can be more extreme

Ski Jumping a sensitive discipline –

WC level competitions not a lot of cancellations but different factors in recent years.

More wind,

lower start gate was also used in case of Wind or Fog

4. **Do you see your sport under threat of climate change? And if so, how?**

With winter sport you need snow.

Most of competitions are on resorts with snow gun/production system

maybe in the future you have to go further north for snow

Limited to a few destinations for snow, interest decreases. Events need to be closer to cities for best promotion when the first snow falls is also very important.

Climate has certain influence.

Higher destinations, less kids, less participation

Snow not direct influence on high level but on how many kids and long term

5. **Could you see your sport being negatively impacted because of event cancellations?
e.g. diminished economic value**

Not currently

WC comp

Commercial value was not influenced by how much snow there was

IF amount of skiers is less, it would have an influence. Until now it is not a factor on why a sponsor is there or not

6. **Do you have a plan to mitigate these impacts? If no, why not? If yes, what kind of mitigating measures?**

All ski clubs and NF's under FIS so not just FIS decision.

They have more influence but not all of it

Need bigger stakeholders involved in the process

How can we take care of the environment?

92% of fans have interest in high commitment to nature

Don't have the solution though

7. **Does your organization have specific policies to proactively combat climate change?**

Big picture probably not but in smaller sports, they have a committee and environment is also a topic.

CO2 carbon neutral games could be nice to have in the future

Fresh air in the mountains

Target to improve the climate and the pollution. Not saying they are there now but example of mountain destinations having a much higher approach to that.

8. **Do you think your sport will be adapted in any way due to the risks of climate change?**

Could be but if snow is only at a certain level, need to do new measurement to adapt the ski race

Look at snow guns systems, as to be safe, you have to have it

Many more cancellations

First direction of destinations was to replace it or add snow gun system, which has a direct influence to the climate

Link to sport competitions and request for tourism is tight

9. **Do you have an alternative event schedule (ex. world cup) in the case of current locations being unable to host competitions due to climate change?**

Long term perspective, snow gun issue cause doesn't work at all temperatures

Snow storage for November events for Many events they do this over the summer

10. Do you know any technologies that can reduce the impact of climate change in your sport? Are you using any of them?

CO2 a key issue

FIS is too small to have an impact

Check transportation system, how is public transport involved

Smaller issue in big picture but hopefully as a major event can have impact

Can't say they are using technologies

11. Are there any summer training adaptations used in your sport? Would these be considered in the future for events?

Roller skiing or grass ski is one adaptation

Tool for cross-country athletes another one

Winter sport federation so they focus on winter sports

Ski jump is very much the same from winter and summer. Could be done in summer but key is to keep it in winter because they are a winter federation

IBU

Name: Borut Nunar

Organization: International Biathlon Union

Sport: Biathlon

Position: Race Director World Cup

1. Have you experienced delays or cancellation of events because of weather? What was the reason?

Last 5 years, (an event is one week event) we had to cancel one, actually replaced one land with another, because of lack of snow (3 years ago, in Germany). We have more since 2010, basically happenings almost in every period.

2. Has the number of cancellations/delays increased in the last 5 years? How many per year? Have all of these been related to weather or other reasons?

I would say no. If the organizer together with us would not better prepare on the condition, there will be more cancellations, because we had less snow than we experienced like 20-30 years ago. But the moment, we have less changes of the venue, cancellations than 20 years ago.

3. What discipline had the most cancellations/delays? Why?

We are in one venue for 3-5 competition day and we have a lot of disciplines in the same venue. It's not like alpine skiing(downhill has one venue and is most cancelled event). For us it doesn't really matter. All disciplines are pretty much same, using the same courses and stadium. It's hard to say disciplines. We hold the event for a week or simply don't have.

4. Do you see your sport under threat of climate change? And if so, how?

We notice that the amount of snow is decreasing last many years. Of course, over the seasons, these will be again different like the last season(this last winter), it was actually one of the best in the last 10 years(a lot of snow at most of our venues and around the world). But, it's under threat, if it continues that the snow will be on the high altitude only or on the the coldest place in the world, then we will be affected, but the moment we are quite okay.

5. Could you see your sport being negatively impacted because of event cancellations? e.g. diminished economic value

That's all based on case. If you need to move from one venue to another, there is the one who was original event that's definitely lost of income, but in general for international organizations, it's not that we are suffering a lot. Because we are still at

the moment able to organize 99% of our competition. Basically yes. The most relevant impact is financial one.

- 6. Do you have a plan to mitigate these impacts? If no, why not? If yes, what kind of mitigating measures?**

We are doing already. While we are not having more problems with a lack of snow in the last year, this is thanked to our organizer, because they are really following the latest technology available on the market. We are storing the snow over the summer, improving the artificial snow system and using snow farming and producing snow on the warm temperature. We are fighting against this with technologies.

- 7. Does your organization have specific policies to proactively combat climate change?**

I would not call specific policies, but I would say we are consistently in conversation with our partners, stakeholders and one of the most important for us, our organizers who are organizing event for us. And we are trying to give them all information that we get from other sports, scientist, our department and all over the world. They are also testing a lot of new things how to prevent snow to be melted, what kind of storage facilities can be made, they are in progress planning with a producer of the snow making system. We are just one stone of the whole chain.

- 8. Do you think your sport will be adapted in any way due to the risks of climate change?**

Sometimes maybe we will have that some our discipline might become shorter in the future. At the moment our longest loop necessarily to be prepared for the competition Biathlon World cup is 4 km. We want to this maybe to reduce so that 2.5 km loop will be the longest loop. This means almost half of the snow needed for the World cup. It is mainly the issue. But we are not doing this at the moment, we are just preparing for it.

- 9. Do you have an alternative event schedule (ex. world cup) in the case of current locations being unable to host competitions due to climate change?**

Since most of our venues are somewhere close to the mountains or in the mountains or even high note. I cannot say that momentarily here are specific venues who are struggling the most. We still have actually the same locations that it was used 20-30 years ago. We have many new ones as well, but at the moment we are not moving our events to high altitude. We did not close down any venues because of the climate changes in the last 10 years

- 10. Do you know any technologies that can reduce the impact of climate change in your sport? Are you using any of them?**

We are familiar with all these new technologies, how and what the store industry's working on, there is the latest motion is coming from Scandinavia. And we are

gathering quite a lot of snow with snow manufactures, how to combine producing the snow with heating villages or cities, because there are a lot of energy left, when you are producing snow, on the other hand, we are familiar with the technologies that we can produce snow on the positive temperatures as well, we don't need so cold weather anymore. The only problem is that all these technologies are quite expensive at the moment. There is a very few locations that they can afford to make to buy or rent a snow factors. But of course, we are familiar with that. Mainly we are focused on the snow storage which means that the venues are preparing the snow amount for season, for the next season before. This has good results in the last 10 years.

11. Are there any summer training adaptations used in your sport? Would these be considered in the future for events?

Training is definitely used because this is not changing at all. Summer training is a part of it, and we are using roller skis for the whole history of the biathlon for training. We are also organizing the summer World championship in biathlon on the roller skis on the asphalt courses, this is nothing new for the last almost 20 years. But our key event is still in winter. We are not planning to have many more things in summer, because at the moment, due to all measures taken from the organizers, it's not needed at the moment. But, even in case the situation will be really worse, we have already today the rules and venues that we could do summer biathlon as well. it's mainly on the same locations with our winter events.

ISU

Name: Peter Kriek

Organization: ISU

Country: Germany

1. Has the number of cancellations/delays increased in the last 5 years? How many per year? Have all of these been related to weather or other reasons?

No, we are an indoor sport and not subject to weather conditions.

2. What factors were considered when making the decision to delay the event?

None, as previously said, we are indoor sport.

3. Is a framework established prior to your event to help determine if an event should be cancelled? If so, what does this framework look like?

Any kind of delays or postponements are not subject to weather conditions, but purely technical reasons. Therefore there is no framework or plans for any change needed.

4. How can you prepare for unexpected delays or cancellations because of weather conditions?

Not necessary.

5. Does your organization have specific policies to proactively combat climate change?

Yes, we are working on guidelines to introduce / educate our Teams. We include into the Guidelines for holding competitions and Championships important items for sustainability issues and climate controls. We work on water and energy saving issues.

6. Do you think sporting events will be adapted in any way due to the risks of climate change?

Yes, not indoor events, but outdoor ski events.

7. Do you have an alternative event plan (ex. world cup) in the case of current locations being unable to host competitions due to climate change?

No need.

8. Do you know any technologies that can reduce the impact of climate change in your sport?

Yes. As I said, we are working on a project to reduce water and save energy. We try to educate our Teams and make them aware, how to save energy and resources.

9. Are you using any of them?

Yes, we distribute brochures, information, have made a video clip for public, and put energy saving issues as a top criteria for awarding ISU Championships.

Other comments or questions. Opinions you'd like to provide ?

Step by step we need to implement guidelines and proposals for behaviour to our Teams and the public to save as best as possible energy, water and be careful with resources. We include tickets with the use of public transportation, select only green cars for transportation, save paper by using new ways of information distribution, held information days.

BID Committee

Calgary 2026

Name: Jennifer Brown

Organization: Calgary 2026

Country: Canada

Position: business strategist, City of Calgary

1. My background.

a) Legacy impact. What are brought from 1988.

b) Olympian. In Rio. Overlaps in summer sport.

Ice rink you can control - indoors

Alpine, downhill, cross-country skill, even bobsleigh where you cannot control mother nature. - most likely to be impacted - out in the world

All of a sudden 12 degrees in Calgary - tough to control the track

Not like indoor. Skiing sports.

2. What factors would you consider when making the decision to delay the event?

The ability to control and get quality result from the activity and safety

So windy people are flying everywhere on the course for snowboard cross or the bobsleigh track is so sketchy you can't control the safety of the athletes going down in. And Snowboard. The safety of athletes going downhill.

3. Is a framework established prior to your event to help determine if an event should be cancelled?

Decision making structure in every possible contingency plan. It is likely something to be included. Run through scenarios to see what would we do if this happens. Contingency plans for change of events.

Don't know 100% at the time but assume so

Not something you have gotten to yet but will be included

similar to disaster preparedness plans (major athlete injury, sewage back-up in village) - what would we do?

4. Do these preparations work or do they need to be modified when dealing with weather conditions?

Weather is a big part of it

safety and security issue are smaller. Weather is the biggest factor to concern.

Weather most realistic to concern - have to for sure have considerations for weather in every plan you have

5. Does your organization have specific policies to proactively combat climate change?

We have federal climate change, which is fairly new. On a city level we have a group putting together a climate change policy now. the government structure existed around the team. The conversation of the bid, it is something gonna come up. What are the pillar and what actions do we go to support the pillars.

What are the tangible recording and reporting to know we are working towards a suitable games in that area and meeting the targets we are setting.

Because still a ways out still in the conversation piece - still in dialogue - discussing this with IOC later in the month

We are going to have conversation with IOC on sustainability. we are still in dialogue. Part of it is talking about legacy and sustainability.

6. Do you think sporting events will be adapted in any way due to the risks of climate change?

Part of evolution of sport. We know more than what we know ten years ago. We have the ability to ensure that we have snow and other things. We go into the bid assuming that and preparing for the fact that there is gonna be economic crash. Most likely to have a climate event that changes thinking. The way we functioned 8 years from now. We continue to learn more and more and will definitely change.

8 years when pyeong chang selected, know a lot more now then we did

Not a moment in time thing, you think you are going in a straight line but you aren't but you will get to the games. Not a linear path

7. Do you have an alternative event plan (ex. world cup) in the case of current locations being unable to host competitions due to climate change?

May or may not have the option to do a venue change or use snow making.

Alternative event plans need to have all the options available and layers built in. the ability to potential location/ snow/ice venue you are looking at. Alternative plans. Do we have a secondary course that is certified and ok for usage .do we have the ability to go there, create ice etc. We have to go through the moving, manufacturing. To ensure that whatever happens, you gonna mitigate somehow.

Need to go through every possible scenario so that whatever scenario occurs, you can mitigate somehow. Don't know what that looks like yet. Need to build that logic in now so you are prepared for anything. Things will happen in Calgary that will require them to review plan and make changes - question is what is it and when it happens and the lead/response time - how much work is it to change it

8. What would you do to mitigate the risk of an event being cancelled due to weather or climate change?

Build every contingency you can think of. To normalize the scenario. If none of those work, what could be the impact and cost. Social wellness conversation. Look into the big picture impact.

Can we move it, can we make it, can we recreate it, can we import it - what is every possible option

Build contingencies on more contingencies - athletes train their whole lives for two hours, major impact if you cancel that two hours

9. Do you know any technologies that can reduce the impact of climate change in your sport?

Refer to Ken Baker sustainable consult.

Top 100 Resilient city. Fairly strong focus on resiliency of city

10. Other thoughts:

Disaster mitigation.

Athletes preparedness - as more events occur over time, athletes have to adjust and be ready for potential interruptions as well as it becomes more regular

Any of the legacy locations you have at the sites. - built in a moment in time and climate change events happen later - Because of specialized locations and hard to fix when damage does occur, there can be potential for things to be more expensive or things not to run for as long. for prepared to more expensive than the planned.

Building codes may change because of climate change

Impact - activity in the moment

Legacy - everything after - considerations after

Paralympics makes it more complex because of other accessibility considerations

Calgary 2026

Name: Ken Baker

Organization: Calgary 2026

Country: Canada

Event Organizer (Bid)

1. What factors would you consider when making the decision to delay the event?

- Long-term decision – looking at the right location
- Closer to event – freestyle events at Cypress in VANOC – pineapple express system – washed out all snow that was prepared a week before the opening ceremonies – couldn't move event – brought a base of large bails of hay/straw and moved in snow
- Weather conditions, not climate conditions

2. Is a framework established prior to your event to help determine if an event should be cancelled?

- Fair competition
- Safety
- Event itself – who's involved, what's the status, is it regional, international, experience of races (level – world cup or high school students)
- Financial component
- Reputation of the host – if they have a cancelled event and the risk associated with this – how would this look to IF?

3. Do your sporting events will be adapted in any way due to the risks of climate change?

- Yes – climate impacts variably depending on which portion of the world you're talking about
- Long-term climate effects are being seen already
- Early season – not enough snow
- Weather impacts affected by positioning of the Jetstream – temperature of water in Pacific Ocean (Western Canada specifically)
- Changing pattern of gulf-stream affecting how much snow early in the season.
- Glaciers receding
- Whistler used to be on the world cup list at the beginning of the season – now abandoned Whistler as a location at the beginning part of the season

4. Do you know any technologies that can reduce the impact of climate change in your sport?

- Snow-making – added this capacity at VAN to cover off the risk of a low snow year
- Need temperatures for this
- Chemicals you can add to enhance snow making capabilities
- Farm snow in snow – bury it in spring and open earlier – more of a technique

Sion 2026

Name: Claude Stricker

Organization: Sion 2026

Country: Switzerland

1. **As an event organizer doing a bid, which event discipline is considered to be the highest risk for cancellations/delays in terms of sports?**

So I guess you have to think about snow sports because snow sports there is not really a point. So snow sports... I would say downhill... downhill huh. We are talking about events, discipline level huh.

2. **What factors would you consider when making the decision to delay the event?**

The decision-making for the cancellation... Uhhh I come from the athlete side so security, safety of the athlete. And for anything else... Cause you are under uh such big pressure. The fact that you need the events to happen with the media or world looking at you. I guess something that people can the best thing to understand and makes the best sense for the athletes.

3. **Is a framework established prior to your event to help determine if an event should be cancelled or if there should be delays to make the decision process easier?**

I think it is quite structured umm it's in the hands of the international federation. Ummm and then there is the whole way it happens and the best, the technical director and the chef de mission, etc. It's really very well defined who is deciding and when and what decision. And it's not a new business and skiing. It's a year's and year's experience. So basically you apply, you should apply the same for the Olympic Games. And uh the IOC side I guess you trust the people who are in place who are the professional from international federation and the event organization.

4. **Do these preparations work or do they need to be modified when dealing with weather conditions?**

I mean normally it works. Of course it's a grey zone because there are always different adaptations and the decision is taken there is always happy and unhappy people. So there is always a debate even in the athletes. You can have different opinions on it. The athletes are now presented somehow but you need also a quick decision sometimes. I would say the governance of it, the decision I think is pretty clear then in the execution. I mean these are human you can do force decision. On

one side or on the other side. But I would say, I think now with all the the risk you have, the decision are taken more on the conservative side. I'm thinking to the high risk disciplines, uhh downhill, super G ski cross as well. The other day I think they had too much fog and got cancelled. Was it ski-cross? I can't remember. It was another discipline, another even then pure alpine ski.

5. Does your organization have specific policies to proactively combat climate change?

So usually part of the thing you have to provide to the IOC when you bid with a questionnaire. It's ongoing work... where you will explain based on the historical data. What's the situation? Not only the snow but the weather in general, the temperature. The general impression, we're talking about precise study we would have done now. We are currently collecting and discussing with the expert. Currently it's difficult to project 10 years from not but currently with the importance of such an event you produce a lot of artificial snow before. You you store the snow. Ummm you look at how they do it in Valais for instance, it's pretty organized now. You have the snow that start to be produced by the end of October and as soon as the temperature is okay.... So what is going to happen to decrease the risk is that a lot of snow production way earlier and then stored to make sure you have enough snow to bring to the slope in case of melting snow, temperature, etc. Normally February statistically is a good month cause when you have a late start of the season here basically you get uh Christmas a bit...everyone is totally depressed in the industry and then usually until February you get a chance to have this snow fall and then uh it's better. So I would say in terms of timing, you know February is the month and if my , also my what I read is correct, what the most likely the best condition for snow in Switzerland, at least in the alp region so I would say in terms of timing it's alright. Ummm.... Yeah and then yeah of course there's always... the good question is what would a scenario be if really things get worse with the climate change? Would it be a scenario where you have to think about a plan B with a venue that is in another place. That is an interesting question. That's a big issue because you know plan B in terms of having another venue that you would have to make ready in game time so it means preparing a bit the same level is a big thing.

6. Do you sporting events will be adapted in any way due to the risks of climate change?

In the scenario that the climate change would be really accelerated which means in 8 years from now I mean for instance 3 winters in a row with very bad February months, which is really big catastrophe because are not there you know. It's not like this (straight incline or decline, it's up and down). You always have a change like this winter more up and then down. So let's say then that really you have some kind of disaster starting, ummm... no you can have an adaptaion like you have in the world cup for instance a shorter length of the downhill FIS tracks. Same for super G. Do

you really cancel one event because you have no solution, that's extreme. That's quite extreme. I don't think it never happened from my knowledge. Never happened in the history of winter games in the 17 days in the end you could never do it. So you really in the extreme scenario but good planning means to take into account so what would be the solution to modify the format. You can modify to a certain point but then you cannot transfer the downhill events into a slalom event so I don't think you have much solutions. Ummm. Making a ski cross a bit easier ecetera. I think the problem is either you have you know the temperature and artificial snow that allows you to do the original concept or maybe a bit adapted, in a sense adapted, or nothing which means the other solution is changing the venue. I don't think you have this flexibility when you get close to the event to start inventing something new. It's a bit delicate. Obviously difficult to think how would you take the decision. That's the big difference between organized sport and non-organized sport. In the beginning of kite surfing you had a bunch of friends that were deciding to compete together and 5 minutes before the run or the competition they said what are the rules so they do the rules and then they agree and then they do their thing so the next day they can change the rules. And it's a common agreement between all these guys and the beginning of freeriding it was a little bit the same. Athlete had a lot to say the right as well. In the board decision meetings and had a lot of influence so they were really adapted to the conditions that can be very different from one day to another day. You know here it's another story. You have so many stakeholders, media, sponsor, everything. The decision-making would not allow to modify really a lot. But it's my own opinion. I never organized an Olympic Games.

7. Do you have an alternative event plan (ex. world cup) in the case of current locations being unable to host competitions due to climate change?

I am glad there is no journalists no politicians in the room but i think there are ski resorts at higher altitude the problem with crans montana its facing south and as you know you are all skiers it makes a huge difference the orientation of the slope. In july you have places green now and 100 meters away there is still snow due to orientation of the sun and crans is really a balkon facing towards the sun with a wonderfull ensoleillement but its bad for the snow. so its better in this regard greysonnaz which is facing north. The fallback would be greysonnaz piste del'ours the problem is that you need to do some work in greysonnaz piste de l'ours there are passage i am getting a bit technical here where you probably need to cut a few trees to make it wider especially the intermediary section. So you would indeed need to prepare indeed before. But that would be the first option as it is close and still on the comunne of sion they also have the whole freestyle part there maybe even the moguls could be held at piste de l'ours. but this is of course highly sensible

right now because of course greysonnaz is totally frustrated because the alpine ski crans say we will host all the events of alpine ski so you know how it is from one valley from one valley to another valley its a bit we cannot really discuss an option in greysonnaz otherwise they say you see you have a problem with crans and you really should have chosen us so you are trapped in these kind of discussions so its not like its in the plan now but i would say the fallback would be there even if it is not high in altitude its in the shadow and not in the sun. and then you have to look at other options which are at higher altitudes for example zinal. then there are some other places but for a downhill track no there are no other options in valais you are a bit short and switzerland in comparison to austria is indeed not very good in having several reserve and easy to equip downhill track. Slalom is not a problem you can put it anywhere, giant slalom is alright but downhill and super g its more complicated so downhill you have one sort of permanent place in stoss and you have lenzerheide then its starts being in other cantons etc.. and then you have the big classics Lenzerheide lauberhorn, Wengen, and st moritz. st moritz is actually good because they know how but they had the no and everything. would there be more snow in st moritz than in crsn, possible because its high altitude and they would be very happy to host i mean people in the canton have voted no two times so its not natural to think about graubünden but they have bobsleigh and luge/skeleton so i would say that would probably be the best candidate in terms of logistic feasibility, knowhow etc so the answer is yes in case sierra its gonna be really difficult but interesting to see two years before if these options start to be really considered how the governance will see the federations start you know are looking seriously you know what are plan b its gonna be interesting but right now in this bidding phase which is the dialogue phase its not really number one topic

8. What would you do to mitigate the risk of an event being cancelled due to weather or climate change?

I mean the risk of cancellations what do you mean by mitigate because one way is to have these options b another way is to weather is still weather forecast is still very unpredictable. you know you can even bring an event to another country the extrem the option b there could also be an option c which could be another continent event because weather pattern as you could see i mean it might be so cold with lots of snow here but its getting warmer in the northern hemisphere maybe you have north america with big snow or even asia and so the option c is to move everything there and that is a good question for the OC or we accept that there is a risk but then it becomes more difficult to sell your events to sponsors etc.. if you start already with worldcup its not simple if you start and you already tell the guy hey the event might not happen if you are the guy giving the money you get a bit nervous and you start giving less. even if you have insurance and everything. but that is a whole project in

itself but that could be a solution. i dont see any other way because whats the value proposition of olympic games i mean a worldcup or major events can still accept that there are some cancellations and then you do it elsewhere that is done every year but olympic games is every four years value proposition is that it happen right so i would say option c which is more distant like in another country solutions could be also included in the concept evn now we are in the bidding but you know politically its difficult because can you afford the sale of your concept there might be no snow so we go to austria or calgary so its like you want to organise the games but its not possible to ensure but behind after the games certainly these options that could be put in place

9. Do you know any technologies that can reduce the impact of climate change in your sport?

Which risk the risk of cancellation or bad weather? its all about snow the progress you have in storing snow in summer it has started on the glacier covering with carpets that are progressively done there is certainly a potential of development in this area the guy that invents snow that doesnt melt over one or two degrees with biological components so its biologically compatible. but no it is more on the storage of snow that things happen i think you can also have progress also in the snowmaking in the energy consumption of course there is also the problem of water cause its also limiting where you can go at some points the impact is a bit to be seen, then its again water but i guess it change a bit the water cycle. i am not an expert on it but i guess its a component so but i have no news to give you about something that is magically cooking that is giving a solution in that part

10. Do you have any other comments or opinions on this topic?

I think an interesting way to look at it is to ask what is winter games and you could think of winter games and one of the basic dnas of winter games is basically slopes altitude difference if i put aside ICE which you can better control and better handle maybe winter game could be about mountains or altitude difference then you start to have other disciplines that is in these wild environment incredible backdrop value that you need in mountains you know wheel mountains are step by step people because you have to survive in an hostile environment ifits this dna then you could start creating a dna not just this fun sport but ski mountaineering but maybe running up/down so even if you have no snow at some place you can still have these new events so iwould say everything that is really in of being in the mountains its just gliding to be a bit innovative if i would be the IOC i would also consider of winter is not that clear in comparison with summer where you have olympia the source of everything the history its a mother its not winter so iw ould rethink a little bit the package if we dont have snow anymore which is a bit the case i mean the first two

weeks in pyeongchang you dont see much snow i was staying gangnum so travelling to pyeongchang but you are not in the mountain i mean its a bit hilly but for us its not equivalent in anything we have even here in the mountains so if you have these globalizations and you have now the chance to have these events now in asia like pyeongchang, beijing it might be less and less snow even in these place so its not just the whit but it could be the dna of the mountains it has in it because its hostile and you have particular sports where its clear what the values are and not just gliding but running or doing whatever games of sport if here is no snow

Organizing Committee

VANOC

Name: Patrick Jarvis

Organization: VANOC/Canada Snowboard

Sport: Paralympic Athlete

Country: Canada

Position: Board Member

1. Is a framework established prior to your event to help determine if an event should be cancelled? If so, what does this framework look like?

- Inside sports (controlled environment) and outside sports (constantly need to be prepared for a change to the schedule)
- Becomes problematic as you add events – pyeong chang women's slopestyle event where only 9 out of 56 runs were completed – not delayed because of the pressures of the schedule and displayed the sport in a poor light and put women at risk in hazardous wind conditions
- As FIS program grows in Nordic but especially in alpine, look at where the pressures come from. Building in the what if scenario in terms of scheduling (What if we don't have enough snow, wind, too much snow)
- Can't run an event if athletes in danger
- How do we adjust and accommodate for things beyond our control
- Going forward, with addition of more snowboard and alpine events, those things have put additional pressure on the schedule (sport department needs to account for this)

2. What factors were considered when making the decision to delay/cancelling the event?

- Window of opportunity. Reschedule, no cancellation. – predominantly about facility
- Worst case is cancellation – can't recall a time at Olympics where something has been cancelled
- Need to take in other elements – access to hill if it's a speed event
- Snowboard. Do you have enough judges. Didn't want to reschedule in Pyeongchang because if the rescheduled the women's slopestyle, they had an overlap of judging for the halfpipe event then next day
- Facility of personnel in Pyeongchang in terms of judge and officials to maintain the course.
- People movement. How do you reissue ticket? Accommodation. Double the number. Compounding effect on all events. If A happens, then what happens in B, C and D.
- During Vancouver Olympics, not enough snow so you had to fly it.

- In Vancouver, there is shortage of snow. In Paralympics, there is too much snow resulting in rescheduling. – Problematic in speed sports
- A lot of moving parts

3. How can you prepare for unexpected delays or cancellations because of weather conditions?

- If then scenario. Risk management exercise. What can you mitigate? Risk is potential loss, how to mitigate sponsors and athletes. Flexibility in scheduling system. Competition day.
- Potential loss could be revenue, hazard to athletes. How do you mitigate that
- Lots of table top exercises
- Maybe you stretch the competition day
- If you know beforehand the cancel or shorten the training day. You cannot control the weather but control the surrounding scenarios of the event.
- All you can do because you can't control the weather but can control circumstances around the event

4. Does your organization have specific policies to proactively mitigate climate change?

- Mitigate the consequences of climate change in advance.
- Wouldn't say they had specific policies. Three P's in sport – Policy, practice and procedure. VANOC had procedures and practices
- In Vancouver there is procedure and practice. Freestyle venue. Shortage of snow Rain washed away amount of snow stores. When they are under a certain number of snow, can we truck it in? If we can't because of the traffic, we fly in snow with helicopters. Trying to mitigate escalating cost. Flying snow in helicopter > snow in by truck > snow on the hill
- Being in low snow areas (Pyeongchang), already have escalating costs due to bringing in snow
- The risk of public perception and damage.
- Where do you fly the snow in from? – VANOC brought it in from provincial park east of Vancouver – agreement prior to have glacier snow
- Contacted and prepared before the events in case of not enough snow.

5. What discipline had the most cancellations/delays? Why?

- Ask FIS about cancellations/rescheduling over last 10 years
- 3 years at Canada Snowboard several early season events cancelled/rescheduled (especially snowboard cross - modified)
- Mean by modified, shorten course because of lack of snow
- Probably increasing
- Don't have substantive data

6. Do you think sporting events will be adapted in any way due to the risks of climate change?

You have asked a billion dollar question. When looking at climate modeling, climate change is the accepted term. For anyone not to consider long-term effect, they are delusional. There are all sorts of opinion out there. Not to consider. People need to be cautious there would be very few places in 40 years to have outdoor alpine events in the world. Both in terms of technology and data, can have more accurate predictive models. In East Asia and Europe are facing challenges to host events.

- Variances in amount of snow. What's the predictability?
- Sapporo still has tons of snow
- Pyeongchang was questionable. Get less than 25cm of snow a year – how do you plan and manage that – expensive investment
- Not just regional, but global issue

7. Do you have an alternative event plan (ex. world cup) in the case of current locations being unable to host competitions due to climate change?

FIS and snowboard more related to this question. More specific to sport –World Cups & Championships

- Cyprus was the challenge in Vancouver.
- Olympic. IOC and IPC need to consider the scale of their events. Constant pressures to add more events. I think they have hit critical mass. Can't just move an event from one mountain to another (Ex. Women's downhill from Nakiska to Louise). That kind of nimbleness is not possible during Olympic Games. The footprint. In terms of weeks, let alone days, IOC cannot simply move an event to another hill. Because of pressure from IFs, they need to say it is not possible to IFs.
- IOC needs to be extremely diligent if not directive in managing Winter Games program – hit critical mass to combine, freestyle ski jump to biathlon to telemark skis, stating the ridiculous but an example of constantly wanting to add to their program because of pressure from their partners, the IF's.
- Even if you want to reschedule at a smaller event, still needs significant lead time
- If you have significant number of athletes shown up in an event. In European context, the curse of blessing in Canada, we have too much land. Gonna move something from AUS to FRA, need to move the official, athletes, tv rights which makes it more problematic to reschedule. Put an event on a programme, that programme is locked in not only in sport but also in TV etc. If you cannot run the event, the cost is significant. Insurance costs also come into effect. Eurosport have a three hours' window now have nothing to broadcasting and LOC has to pay. It is a multilayer onion. You cannot do it at the level of FIS in terms of the complexity of the event.
- Cancelling, not rescheduling. If rescheduling was possible, gonna have a lot of moving parts
- May see season being pushed back due to cancellation of early season events

8. Do you know any technologies that can reduce the impact of climate change in your sport?

- Investment that resorts are looking into – they are critical partners. They have to provide snow and do they want to host these events?
- See technology into snow making
- Need an environmental strategy due to the impact
- Water saturation.
- Salting. You can introduce salt to maintain the snow.
- Like Bobsleigh 1km long, challenges because of the scale and footprint.
- Scale has limitations especially outdoors as it is more difficult to manage
- Other than that, I don't know the leading trends in the area.

Last comment:

- Appreciate a copy/summary
- Threat is not typically looked at – relevance of Olympic programme: who is interested in watching your sport. Shift in snowboard over downhill sociographical there is a demographic shift in terms of watching your event. Young people are attracted to the thrillness of snowboard.
- Relevance. Lausanne, Geneva. If I don't see snow very often, I don't think of going skiing.
- Increased economic access – instead of going skiing, flying south in Calgary

PyeongChang 2018

Name: YunKeong Ko

Organization: PyeongChang Organizing Committee for the 2018 Olympic and Paralympic Winter Games

Country: South Korea

Position: Project Manager, Sustainability & Legacy

1. **Has the number of cancellations/delays increased in the last 5 years? How many per year? Have all of these been related to weather or other reasons?**

[Paralympic]

1. Men's Slalom (14.03 > 17.03): Protection and safety of the athletes against heavy rainfall probability forecast
2. Ladies' Slalom (15.03 > 18.03): Protection and safety of the athletes against heavy rainfall probability forecast

[Olympic]

1. Men's Downhill (11.02 > 15.02): Strong wind and cold weather(-17)
2. Ladies' Giant Slalom (12.02 > 15.02): Strong wind and cold weather(-17)
3. Men's Super-G (15.02 > 16.02): Due to game schedule change (Men's downhill)
4. Ladies' Giant Slalom (15.02 > 16.02): Due to game schedule change (Ladies' Giant Slalom)
5. Men's, Ladies' Giant Slalom (17/18.02 > 14.02): Protection and safety of the athletes against strong wind
6. Ladies' Super-G (11:00 > 12:00, 17.02): Protection and safety of the athletes against strong wind
7. Ladies' Snowboard Big Air (23.02 > 22.02): Protection and safety of the athletes against strong wind

2. **What discipline had the most cancellations/delays? Why?**

- Same with 1.

3. **What factors were considered when making the decision to delay the event?**

- Event schedules is changed based on players' safety, the most important priority, and whether a smooth operation is possible through a consultation with International Federation, OBS, IOC/IPC, and Organizing committee.

4. **Is a framework established prior to your event to help determine if an event should be cancelled? If so, what does this framework look like?**

- N/A

5. **How can you prepare for unexpected delays or cancellations because of weather conditions?**

- No information. (Event operating part)

6. Does your organization have specific policies to proactively combat climate change?

- We don't have specific policies mentioned above, as Organizing Committee is dissolved after the event. However, we developed a strategy to organize sustainable Olympic during the period that bid, prepared and run the event. For example, we tried to reduce energy consumption during the events by preparing the capacity of wind power system more than the energy capacity needed in the event. Beside of this, you can confirm other efforts for making the event sustainable, and interim performance in the Sustainability report.

7. Do you think sporting events will be adapted in any way due to the risks of climate change?

- I think winter sports are obviously affected by the climate change. In particular, it seems to affect snow events the most as it cannot be held unless it snows too much or not at all. However, I think a problem with making artificial snow due to temperature and a problem because of lack of snow are slightly different issues. In case of Pyeongchang, even if there were a lack of snow, we could organize the event with artificial snow.
Also, because each the Winter Olympic organizing cities has different regional and meteorological features, it seems that they have different predictable issues. Considering this, I think it is natural to change the operation of the competition. And in terms of the changes of disciplines, I think athletes' opinions are the most important.

8. Do you have an alternative event plan (ex. world cup) in the case of current locations being unable to host competitions due to climate change?

- We've prepared for any problems that may not be able to operate events properly due to drastic climate change, but the venue is located in a region which is not affected by climate change as much as it has to be cancelled. I've heard that in case of Switzerland it was difficult to host competitions because of a lack of snow, but PyeongChang has geographically different aspects with other European mountainous region such as Switzerland. So PyeongChang and Europe are likely to have different concern.

9. Do you know any technologies that can reduce the impact of climate change in your sport?

- N/A

Beijing 2022

1. Have you experienced delays or cancellation of events because of weather?

Yes. In January 2016, the National winter games was held in Ya Bu Li Skiing resort in Heihongjiang province. The ski jumping event was originally scheduled for 2 days. But we came across strong wind in the first day. The technical delegate held a meeting with sports department and meteorological bureau. According to the weather forecast, the wind is weak before 10 am the next day, and increase gradually later. We decided to cancel the first round, merge it into the second round and finish before 10 a.m. on the next day. Therefore, provided with the accurate weather forecast, if we miss the window, the athletes, referees and other staff had to wait for a long time for next window at the venue. Accurate weather report helps us to finish the event within the rule on schedule.

2. How much delays or cancellations did you experience? What event discipline had the most cancellations/delays?

In 10 years I came across 3 times of event cancellation or rescheduling. In disciplines of both ski jumping and cross-country skiing. No tendency of obvious increase.

3. What factors were considered when making the decision to delay the event?

Weather factor is most important. If possible, we try our best to hold the event on the scheduled day. If that is not possible, the second option is to reschedule to the day before or after. Cancellation is the last choice. Competition always comes first. Other changes like accommodation and transportation change is not that difficult in China. Some disciplines' competition happened only once in China. If the event is cancelled, it will affect the results, ranking and prize money of athletes.

4. Is a framework established prior to your event to help determine if an event should be cancelled?

Usually we do not set up benchmark of event cancellation. But we will inform the athletes of the risk of rescheduling events due to weather conditions. It is written in event programme and is known to all athletes.

5. Does your organization have specific policies to proactively combat climate change?

We plan to have such plan, but we haven't started it yet.

6. Do you think sporting events will be adapted in any way due to the risks of climate change?

Yes but no as much as imagined. If we exaggerate the influence too much, we will spend too much money in it. There is a Chinese saying "let the nature take its course." If the weather is extremely bad, we may have to reschedule the competition. Winter sport still has its charisma. We will make every possible effort to ensure the training and competition. But if we care too much about the influence, and spend too much money and human resources into it, it is not sustainable and unnecessary.

7. Do you think winter sports is being negatively impacted by event cancellation due to climate change? E.g. decreasing of economic values.

This problem always exists and it does not solely due to climate change. We used to come across event cancellation due to fog. It is critical for IOC to choose suitable places. If the place chosen is not suitable, then the risk is very high.

8. Do you know any technology that can reduce the impact of climate change in your sport?

I heard about some technologies like refrigeration by CO₂, snowmaking above zero temperature etc, but the cost is high. These technologies have not been fully commercialized and haven't reached a stable performance. I opted to practice winter sports in wherever applicable in nature, like in the northern part of China, instead of in places like Sanya where indoor artificial refrigeration needs to be made and is not sustainable in terms of carbon emission. Other practices like producing refrigeration in summer, building artificial indoor skiing venue should not be the trend of development. We should go back to nature, to where the mountains were. And in winter when there is low temperature. Basing on that we use some technology to reach standard conditions for skating and skiing. When natural conditions is not applicable, like in summer and in high temperature conditions, artificial snowmaking should not be encouraged.

9. General comments

I support promoting snow sports where applicable. In China, there are a lot of suitable places but they haven't been developed, like in the northwest part of China, Kunlun mountain, Aertai mountain in Xinjiang. These places have very good natural conditions but are far from big cities. Worldwidely speaking, it is very luxurious to have a place like Yanqing which is only more than 60 km away from the capital Beijing, comparing to the distance between Paris to Alps. Therefore, we shall develop the areas where the conditions apply, otherwise it is difficult to be sustainable.

AARE 2019

Name: Rikka Rakic

Organization: Aare 2019

Sport: Alpine Skiing

Country: Sweden

Position: IF relations

- 1. Have you experienced delays or cancellation of events because of weather? What was the reason?**

Yes, could be because of wind, weather, too much snow but cannot give exact numbers

- 2. Has the number of cancellations/delays increased in the last 5 years? How many per year? Have all of these been related to weather or other reasons?**

Cannot coment on this because I cant speak for FIS

- 3. What discipline had the most cancellations/delays? Why?**

I guess it was some of the alpine skiing events , cannot say for sure because I don't have FIS data

- 4. Do you see your sport under threat of climate change? And if so, how?**

Of course, Skiing could be under threat by climate change if there is no snow there is no event

- 5. Could you see your sport being negatively impacted because of event cancellations? e.g. diminished economic value**

We cannot see that yet, maybe in the future

- 6. Do you have a plan to mitigate these impacts? If no, why not? If yes, what kind of mitigating measures?**

We can work with snow machines

- 7. Does your organization have specific policies to proactively combat climate change?**

Not really, we try to work on somethings for example making Aare car free for the world championships or using electrical cars. But spectators will still come with their own cars.

8. Do you think your sport will be adapted in any way due to the risks of climate change?
9. Do you have an alternative event schedule (ex. world cup) in the case of current locations being unable to host competitions due to climate change?

Cannot answer because I am not part of FIS anymore and don't know what is happening now

10. Do you know any technologies that can reduce the impact of climate change in your sport? Are you using any of them?
11. Are there any summer training adaptations used in your sport? Would these be considered in the future for events?

Miscellaneous

NHL

Name: Omar Mitchell

Organization: NHL

Sport: Ice Hockey

Country: USA

Position: VP, CSR

1. Have you experienced delays or cancellation of events because of weather? What was the reason? – Specifically outdoor games/event

So let's talk about indoors, actually there have been cancellations of indoor NHL games like our regular season games. One was in Calgary with the floods (2013) and that was where the flooding went all the way up to row K. It totally destroyed the ice plant and all of the infrastructure because typically the infrastructure for ice is obviously below the surface or on the same level of the surface so that was certainly an issue. There have been, as you can imagine, games that have been cancelled due to snowstorms, for example in Boston with the Nor'easter storms. I remember that Boston got cancelled, Buffalo was cancelled a couple of years ago so there's that. I would say that for our outdoor games, thankfully we've never had a cancellation but we've experienced situations where it's not ideal. Impact across the continent, specifically in June directly in the summer month's situations where we may be affected. Reason why it's a challenge – control air temp. in the building but also humidity. So for NHL 40% humidity and 60 degree temp. With older buildings (majority) big issues to control climate in the building. Ice conditions an issue because you want best playing conditions but player issue. Conditions where player safety is important – bad ice can effect how games played. Biggest asset the players.

2. Has the number of cancellations/delays increased in the last 5 years? How many per year? Have all of these been related to weather or other reasons?

Can't say definitively

3. What factors were considered when making the decision to delay the event?

- Don't know exact specifics
- For snow (blizzard/storm) fans and or players getting to arena – transit or roads closed
- Building not operable

- League makes call

4. Do you see your sport under threat of climate change? And if so, how?

- Yes
- When we think of the sport, multiple different ways and where its played and impact of sport relative to the community and environment
- Most immediate threat access to natural ice conditions – northern states and Canada many people learn outdoors – roots of sport –
- With changing climates – winter cycle getting shorter, not as cold as once was, impacts how sport played outdoors. Important because of various barriers into sport (equipment and access to ice). If this threat is there, people who can't afford playing indoors or people who play outdoors may not have access and may not grow into fans, underprivileged communities who can't afford ice. Issues affect social sustainability of game. Ensure there is access to all and people who will play outdoors have the chance to play
- CARE program more immediate
- NHL partnering with Wilfred Laurier University – 2 profs started rinkwatch – NY Times new article. Rink Watch using hockey to visibly demonstrate impact of climate change on the sport and doing it through hockey so getting collected info from a huge group of people without them knowing they are contributing to an environmental concern. All they have to put is day, time and location. Exciting because we are trying to teach folks about sustainability by embedding it in something they are passionate it. Develop data set where it tracks that

5. Could you see your sport being negatively impacted because of event cancellations? e.g. diminished economic value

- Right now with being so infrequent, not negative impact, just inconvenience at this point
- No major impact right now
- Can always reschedule

6. Does the NHL have specific policies to proactively mitigate/engage climate change? - NHL Green and its impact

- NHL Green 2010 environmental sustainability platform – mandate to promote sustainable business practices around the league
- Sports properties where introducing it as a focus
- Took it on because of link to natural ice, roots of sport, fresh water issues – water is in DNA of hockey – frozen water
- Not just sharing best practices but also engaging fans about issues
- Platform public in 2010
- Series of programs from that
- 1st was food recovery project – donating unused food to local foodbanks – 2010

- 2011 water restoration initiative
- 2012 legacy tree project – tree planting
- League level
- Franchisee level – some have had awareness way before 2010 (facility operations, cultural mindset)
- Able to leverage what teams were doing and promote at league level – aggregate at the league level
- Started off with those – awareness for fans (clubs and leagues), share best practices to reduce energy and energy consumption in buildings
- Why? Ice hockey is very energy intensive sport. 65-70% of carbon footprint is directly related to energy consumption within the buildings – play in a giant refrigerator
- Not air travel flying teams but building energy consumption
- Ice plant, HVAC system, lighting system, building automation
- Ways they have been addressing climate stuff
- Body of work has built has where best practices are being brought to community level – community rinks are old and outdated – 75% of local rinks across NA are 20+ years old – operating with inefficient structures
- Use league to share best practices and influence entire industry
- NHL is governing body for pro hockey but want to ensure longevity and address access to game through natural ice and how the play
- Operating thesis – lower operating costs in building, lower ice times costs and get more people into game. Even if owner pockets the profits, at least you are showing a viable business model for other people to build more rinks. Also another barrier, not enough people are building more rinks
- Add to community rink infrastructure in 2020, there is going to be a major phase out – Montreal protocol – HCFC's being banned from production (Ex. R22 refrigerant) – most widely used refrigerant – with phase out there is going to be a systemic impact – find ways to address this – alternative/natural refrigerants, promoting education in market place and specific products people can use to upgrade their system before 202. In 2025, an amendment to Montreal protocol, phase down of HFC's (R134A) – with all of those challenges, need to educate market place. Across the world – from 20 years ago

7. Do you think your sport will be adapted in any way due to the risks of climate change?

- Don't think pro hockey will change or adapt in any particular way – with less natural ice, less people playing. Perhaps a signal that people will start to play other sport. Think that hockey may be adapted is more people playing street or ball hockey
- A lot less people playing then typically where they were when using natural ice conditions
- More diverse forms of the sport
- Newest building is in Vegas, the desert, and it is one of the most advanced buildings. If we can play hockey in the desert, it's possible to play in adverse/not ideal conditions.

- Older infrastructure needs to be changed to survive floods or play in shoulder months – update the systems or potential replace with newer structures.
- Over 75% of arenas built in 90s – 20 year life span – end of life for systems.
- Teams, cities need to decide if they will upgrade or build new. 5 of 6 new arenas built to LEEDs certification – if built with public money, seeing more buildings being built to energy efficiency and environmental design standards

8. Do you know any technologies that can reduce the impact of climate change in your sport? Are you using any of them?

- Think about reducing carbon footprint – by doing this, think about energy consumption – things like LED lights for game lights which is a significant energy reducer because of heat and not needing to use as much A/C to cool space, building automation systems (real time commissioning of data), fuel cell tech (onsite energy creation using natural gas), better design to use less resources (water, recycling, waste mitigation)
- One tech – taking water out of indoor environment and then water being used to create ice – potential to be revolutionary in industry if it works – way more effective than a regular dehumidifier. Units used disaster relief areas (tsunamis, earthquakes) where it can literally take the water out of the air and make potable water
- Implementation – not sure – first movers and laggards – only makes sense in water stressed areas or where energy costs are high – tech needs to be vetted, confirmed that it can happen, can use indifferent markets.
- LED lights – took from 2012 to now to implement in rinks and only half of the arenas have installed it and it has such a great financial return

9. Other comments or questions. Opinions you'd like to provide

- When climate change effects the sport, how is it adapted
- Some sports have to adapt because they don't have access to snow or natural ice, I think more importantly, it's going to be a cultural impact which is equally as significant
- Foreseeably that Canada's national pastime being hockey could change in next 15-20 years
- Much more diversified – already happening
- May be a function of multiple things but a factor could be not having access to natural ice conditions, more folks will want to play other sports.
- Something that will be an issue for NHL because when you look back to Bartel's sides, where do you want the sport to be in next 15-20 years and NHL doesn't have fan sustainability or viewership or how to grow the business, that's going to be a real concern as a business, not just from a sustainability standpoint but a financial sustainability standpoint
- All different things when you expand the perspective of sustainability – all things that effect the business

Freeride World Tour

Name: Nicolas Hale-woods

Organization: Freeride world tour

Sport: Freeride

Country: Switzerland

Position: Owner

1. Has the number of cancellations/delays increased in the last 5 years? How many per year? Have all of these been related to weather or other reasons?

1 cancellation out of an average of 5.5 events per year 27.5 events over 5 years

Due to too warm temperatures.

Freeriding similar to surfing the conditions have to be perfect so you cannot compare it to alpine skiing.

Conditions have to be sunny, special snow conditions, snow stability

Waiting periods of an average of 8 days while we aim for one special day mostly a Saturday

No statistics but the feeling is that 75 percent of the time the competition is not able to be held on that day.

Has to be postponed to the Sunday, Monday etc...

One time couldn't find the day in that waiting period and could not relocate because we did have to use the next event weather period to host it there.

Double up the competitions in the next resort, take all the

2. What factors were considered when making the decision to delay the event?

Snow stability so safety against avalanches risk of sliding snow

Weather, visibility, wind storms basically visibillitiy

3. Is a framework established prior to your event to help determine if an event should be cancelled? If so, what does this framework look like?

Framework head mountain guide, head judge, competition director making that decision answering a plenty of big questions

Is it safe will it be safe enough,

Head mountain guide says the final word on snow layers avalanche dangers given the weather forecast forecast for the next days

Head judge gives the riding point of view meaning are there enough Lines with enough features and are the snow conditions rideable for the athletes and then the contest director gives the go in terms of the whole infrastructure the whole rescue

aspect will it be organized for the starting time also setup of the whole transportation setup and the different stakeholders

4. How can you prepare for unexpected delays or cancellations because of weather conditions?

20 + years of experience with contingency plans

Whole organization is structured around delays and postponements

Procedure in terms of decision making and timing and who should be informed who are the decision makers also include those in the communications department so the people around the world know as well as the people on site

Very similar to surfing again where the people wake up at 5 in the morning to check if the waves are right

Those types of action sports are very environmentally dependant

But whats interesting obviously we cannot guarantee that the competition happens on Saturday (obviously not on TV) but our audience consumes it nevertheless and will make sure they watch it even during the week (at school, work, etc...) even if delayed of couple of hours

More and more over OTT platforms

5. Does your organization have specific policies to proactively combat climate change?

Yes but limited, the reason is resources, finances, either have a really good bottom line number

FWT bottom line number is 0 reinvesting everything and trying to make the product as good as possible to survive

Juggle of competitive sport event world to do it well you need to partner with someone who has a specific need to communicate combat of climate change with us

Example Paris Dakar and Swatch

We haven't found that partner yet goal is to survive looking for such a kind of partner because FWT is in the forefront and sees climate change first hand

Done so far:

Incentivise share cars, Public transport are favored, on the mountain a partner for littering. They have partners to clean the trash on the mountains

Great improvement has been seen from the part of the spectators – people are behaving different than 10 years ago.

Study 5 years ago by an AISTS student where the impact comes from and more than 90 percent comes from the spectators travelling to the mountain (transport)

On that aspect can only engage to encourage to come by train or do car pool for the spectators.

Or do tree plantations for carbon 0 but not enough financial resources

6. Do you think sporting events will be adapted in any way due to the risks of climate change?

Yes because human being has a survival instinct

Typically no more events on low altitude resorts because of temperature being too warm going higher

Believe that more and more sponsors will have an interest in going to carbon 0 and atleast the western world will change its behavior and acknowledge that there is a serious problem and take some action.

Whereas 5 years ago it was a trendy topic lots of people talking about it but no one was realizing the seriousness of it. Now there is hardly any day without a newspaper article on the topic and how fast it is happening and how serious it is.

The topic is being seriously addressed but cannot see that our behavior is changing yet- just look at the airports and how frightening and normal it is to take two flights a day.

I don't know if mankind will be agile enough to change that trend but atleast the issue is more and more in the headlines so I believe at some stage it could become better.

7. Do you have an alternative event plan (ex. world cup) in the case of current locations being unable to host competitions due to climate change?

Yes, we typically had a little tennismatch between Chamonix and Courmayeur to host the event if one had bad conditions it was possible to just move it to the other sister resort behind the montblanc and the opposite.

More and more have to do these contingency plans as it becomes more important and whats interesting is that the resorts when it happens they don't loose that much credit basically we use the whole branding of Chamonix but we are in Courmayeur. The event is still called Chamonix 80 percent of the spectators don't realize that the Chamonix event doesn't take place in Chamonix.

We are heavily dependent on destinations/ski resort funding cannot just choose a resort according to the mountain, an economical entity needs to be there that sees the benefits of hosting the freeride world tour so this is a limit to the ideal planning of weather forecast but it is a super strong tool to show the conditions of the resort. Sometimes when in winters conditions are not good elsewhere it is a way to

communicate for these resorts. The ROI is really good when compared with other sports and other partners that's why it works.

8. Do you know any technologies that can reduce the impact of climate change in your sport?

Drones vs helicopters in the filming aspect the reality today is however that drones are very good but helicopters are still good too so we have both.

Not the best for the climate.

Drones are not fast enough and enough room to replace helicopters. Riders do hike up most of the time when its operationally pheasible. Giving a good example to youth for freeride and finding powder promoting a good experience compared to heliskiing or whatever motorized skiing.

The whole idea of ski rsorts being close to hydraulic powerplant and using only that energy and promoting that idea.

Vail Ski Resorts

Name: Arthur D Jong

Organization: Vail Ski Resorts

Country: Canada

1. What discipline had the most cancellations/delays? Why?

- Struggle to ever remember a cancellation other than storms
- Don't run world cup or downhill anymore
- More La Nina off the pacific ocean – benefits them
- As general macro temperatures get warmer, more storms, warmer temperatures being pushed out away from coast
- As arctic warms, jet stream weakens

2. What factors were considered when making the decision to delay the event?

- Provide access onto courses and snow
- Up to course officials to make the call

3. How can you prepare for unexpected delays or cancellations because of weather conditions?

- Vail model front end loaded – painful to buy a day ticket
- Early season passes discounted – give you access to any Vail resorts – preseason sales
- Whistler resort in 3 different climatic zones – lots of tree zones
- Most of mountain can operate during snow

4. Does your organization have specific policies to proactively combat climate change?

- Strong focus on energy conservation
- Hope to see hybrid grooming caps – not diesel
- Become a restorative footprint – continue to apply green energy opportunities
- Lot of things changing – being bought by Vail resort
- Focused on own operating footprint – what they can control, not come up with many things for larger footprint (guests, driving to mountain, etc.) – issue is transportation

5. Do you think sporting events will be adapted in any way due to the risks of climate change?

- Big part of career to help move into more sustainable direction
- Hosting Olympics is pinnacle

- From a sustainability standpoint hard to accept to continually accept same infrastructure to host Olympics
- Moving from consumer to sustainable
- Olympics not immune to this
- Try to be an inspiration to global tourism
- Set a benchmark that is a showcase to tourism that an operation can do so much – knock footprint in half, not to 0
- Many consider them canary to coal mine –
- Snowsports could become irrelevant

6. Do you know any technologies that can reduce the impact of climate change in your sport?

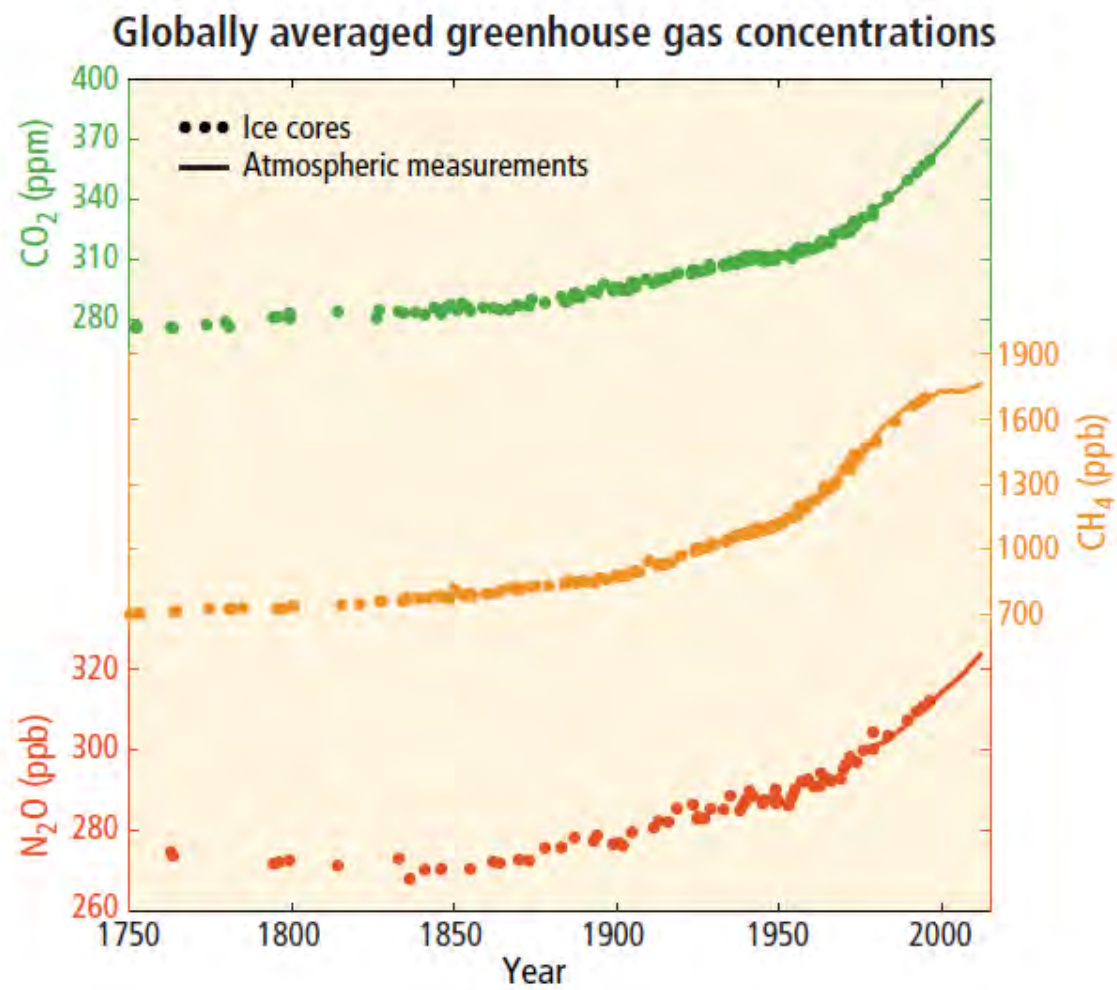
- microhydro system in middle of resort to operate the mountain
- Save \$\$\$
- Reduced waste by 71% could get to 90% if optimize all systems
- Bought byvail resorts – took strategy and mandated it to all resorts
- Artificial snow making – rely more to ensure they have enough snow early in the season
- Less snow at lower elevations so snow making becoming more important here
- More snow in mid and higher elevations and less in the valley
- Hitting break even in

7. Comments

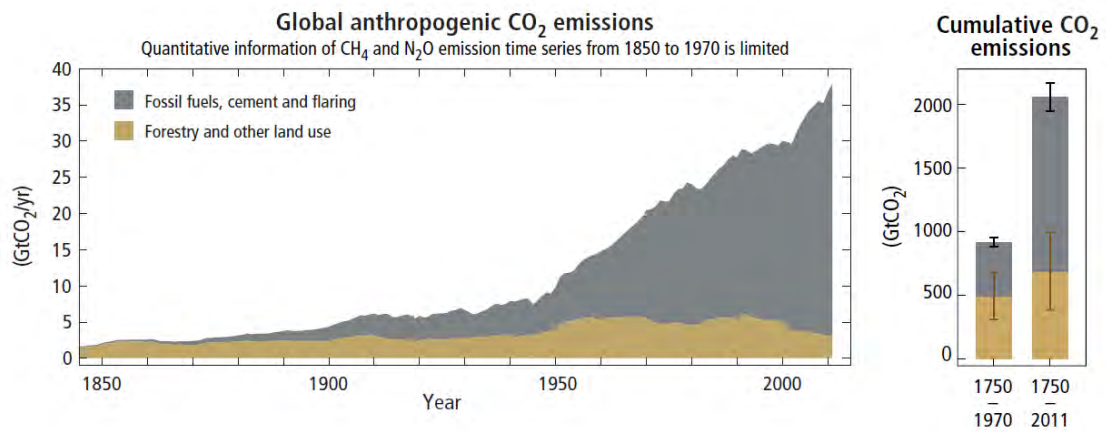
- Not climate scientist
- Planning/environmental manager at Whistler
- Built framework – got to summary – has worked very well for them
- **Emphasize to understand what climate is doing in local area**
- Glaciers are receding – look at snowpack – confused – each decade getting more snow, not less
- Look at summers, although winter temperatures have gone up, summer is significantly higher
- Glaciers receding because of heat of summer rather than amount of snow
- Some parts of the world, less snow, not more
- Threat is not snow but burning whistler down
- Might find things you didn't realize when looking at records
- Go over 2 degree Paris Accord goal, in Whistler they will be fine
- For this region, more resilience as general economy goes
- May become irrelevant not because of providing snow but because of economic
- Assessment phase very important
- 3 elements of action phase on mitigation
- Goal to become 0 carbon footprint resort – benchmark across the world
- Adaptation and Diversification are different elements in strategy
- 4 season model – more people come in summer then winter

- Understand global impacts
- Legitimate efficacy role where they are demonstrating making significant steps to decarbonize
- Winter sports industry start to collapse – then maybe other things have been have happened in global community
- Often questioned on ethics of environmental footprint of Winter Olympics here – if you weigh the Olympics purely on environmental footprint, shouldn't do it
- Social value, inspiration to youth, effect of bring world together, ease geopolitical issues, is deep so when you question sustainability of Olympics, it is unfair to look purely at environmental lenses but need to look at social value

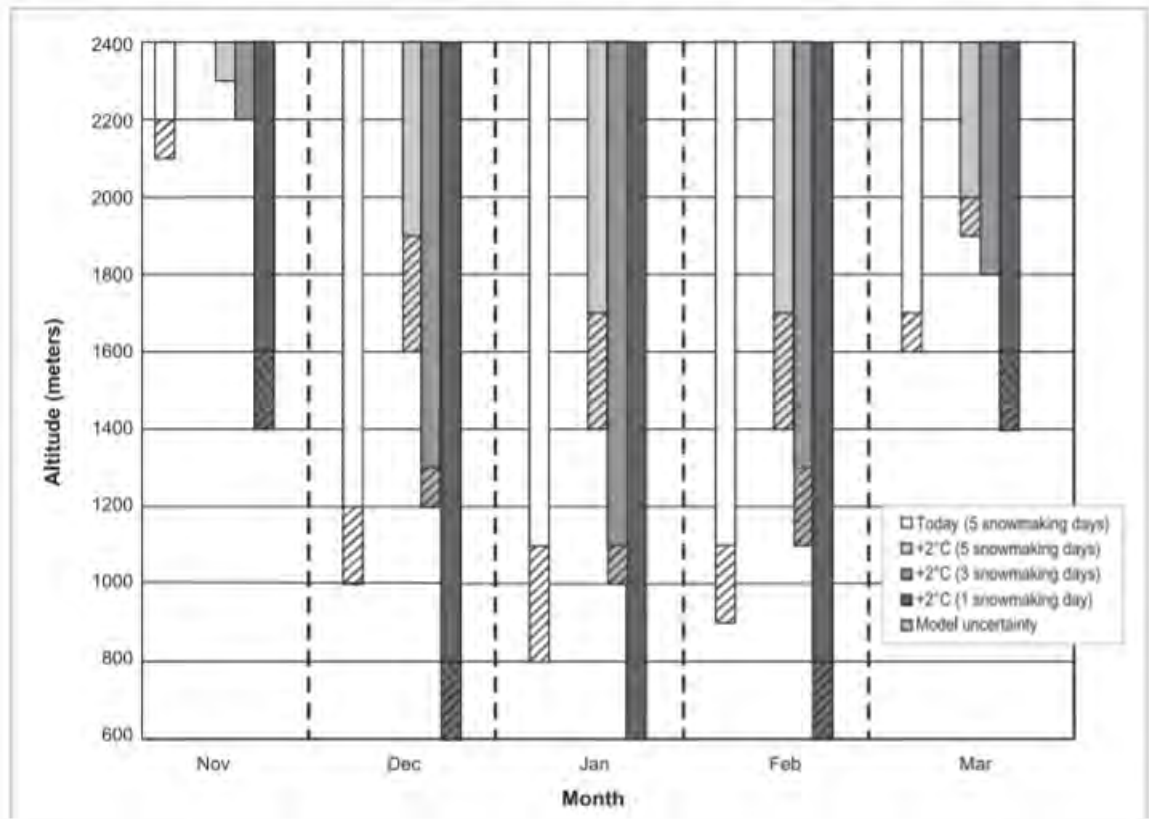
Appendix D | Globally Averaged Greenhouse Gas Concentrations (IPCC, 2014)



Appendix E | Global Anthropogenic CO₂ Emissions (IPCC, 2014)



Appendix F | Elevations suitable for snow making in 2008 (today) and with a projected 2°C warming, with different snow making intensities (5, 3, 1 snow making days) (Steiger & Mayer, 2008)



Appendix G | Cancellations

Vancouver 2010 Postponements & Delays

Alpine Skiing (5 total)

Event	Original Date & Time	Rescheduled Date & Time	Reason / Result
Alpine Skiing Men's Downhill	February 13 11:45 - 13:30	February 15 10:30 - 12:15	Poor weather on February 13 resulted in postponement to February 15.
Alpine Skiing Ladies' Super Combined	February 14 10:00-11:30 13:00-14:00	February 18 09:30-11:00 12:30-13:30	Reason for postponement was the cancellation of the ladies downhill training run on the February 12 and weather on February 13 being unsuitable for training. Downhill training run is required in order to run the super combined in a downhill/slalom run format. The time change on the 18th was due to broadcast conflicts.
Alpine Skiing Men's Super Combined	February 16 10:00-11:30 13:30-14:30	February 21 09:30-11:00 12:15-13:15	Reason for postponement was snowfall overnight and subsequent course conditions on February 16. Note: This postponement caused the men's giant slalom to originally be postponed.
Alpine Skiing Men's Giant Slalom	February 21 10:00-11:45 13:45-15:00	February 23 09:30-11:15 13:00-14:15	Reason for postponement was due to postponement of men's super combined.
Alpine Skiing Ladies' Giant Slalom (2nd run only)	February 24 13:15-14:30	February 25 09:30-10:45	Due to weather conditions (visibility), the second run of the ladies' giant slalom was delayed, and then eventually postponed.

Nordic Combined (2 delays)

Event	Date	Reason / Result
Team Event (jumping and cross-country sessions)	February 23	The original schedule for NC team event was February 23, 10:00-10:45 for the ski jumping portion, and 13:00-4:00 for the cross-country skiing portion. The revised schedule: ski jumping portion (10:30- 11:15) and cross-country portion (14:00-15:00).
Men's Individual Large Hill / Individual 10 km	February 25	Due to wind conditions, the Nordic combined men's Individual large hill scheduled on February 25 from 10:00-10:50 was re-started at 11:00. Note: all jumpers started over at 11:00. Due to the delay in the Large Hill portion of the Men's Nordic Combined event, the 10-kilometre event (cross-country portion) was delayed until 14:00 (originally scheduled for 13:00).

Snowboard (1 delay)

Event	Date	Reason / Result
Snowboard Ladies' Snowboard Cross	February 16	Ladies' snowboard cross scheduled to start at 10:00 was delayed by one hour due to visibility. Competition delayed until 11:00. Update: due to weather, the delay was two hours and the event was re-scheduled to begin at 12:00.

Skeleton (1 delay)

Event	Date	Reason / Result
Men's & Women's Skeleton (Runs 1 & 2)	February 18	There was a 30-minute delay to the start of the skeleton session due to sun exposure on the start area. Scheduled start time was 16:00. Revised start time of 16:30, and then start delayed another 20 minutes. Revised start time: 16:50.

Biathlon (3 total)

Event	Original Date & Time	Rescheduled Date & Time	Reason / Result
Biathlon Women's 15 km.	February 18 10:00-11:40	February 18 10:20-12:00	Due to alpine postponement, this event's start time was delayed by 20 minutes in order to avoid broadcast conflict.
Biathlon Men's 20 km.	February 18 13:00-14:35	February 18 13:20-14:55	Due to alpine postponement, this event's start time was delayed by 20 minutes in order to avoid broadcast conflict.
Biathlon Men's 15 km.	February 21 10:45-11:25	February 21 11:00-11:40	Due to alpine postponement, this event's start time was delayed by 15 minutes in order to avoid broadcast conflict.

Bobsleigh (1 delay)

Event	Date	Reason / Result
Bobsleigh Men's Two-man	February 21	Due to weather conditions, the two-man bobsleigh competition was delayed on February 21st. Instead of running from 13:30-15:50, the competition was rescheduled to 16:00-18:20.

PyeongChang 2018 Postponements & Delays

Olympic (8 total)

Event	Original Date & Time	Rescheduled Date & Time	Reason / Result
Men's Downhill	February 11	February 15	Strong wind and cold weather(-17°C)
Ladies' Giant Slalom	February 12	February 15	Strong wind and cold weather(-17°C)
Men's Super-G	February 15	February 16	Due to game schedule change (Men's downhill)
Ladies' Giant Slalom	February 15	February 16	Due to game schedule change (Ladies' Giant Slalom)
Men's Giant Slalom	February 17	February 14	Protection and safety of the athletes against strong wind
Ladies' Giant Slalom	February 18	February 14	Protection and safety of the athletes against strong wind
Ladies' Super-G	February 17 11:00	February 17 12:00	Protection and safety of the athletes against strong wind
Ladies' Snowboard Big Air	February 23	February 22	Protection and safety of the athletes against strong wind

Paralympic (2 total)

Event	Original Date & Time	Rescheduled Date & Time	Reason / Result
Men's Slalom	March 14	March 17	Protection and safety of the athletes against heavy rainfall probability forecast
Men's Slalom	March 14	March 17	Protection and safety of the athletes against heavy rainfall probability forecast

FIS (International Skiing Federation)

Ski World Cup

2013/14	2014/15	2015/16	2016/17	2017/18
11	8	29	13	11
Mens: 1 cancelled 3 rescheduled Womens: 2 cancelled 5 rescheduled	Mens: 1 cancelled 1 rescheduled Womens: 1 cancelled 4 rescheduled 1 postponed	Mens: 5 cancelled 5 rescheduled Womens: 10 cancelled 9 rescheduled	Mens: 6 cancelled 5 rescheduled Womens: 1 cancelled 1 rescheduled	Mens: 1 cancelled Womens: 5 cancelled 5 rescheduled

Snowboard World Cup

2013/14	2014/15	2015/16	2016/17	2017/18
1	0	3	0	1
1 Cancellation (snowboardcross Veysonnaz)	No cancellations	3 cancellations (All city Big airs in London, Seoul, Istanbul)	No cancellations	1 cancellation (Due to organiz- ational issues in Copenhagen and slopestyle cancelled in Laax due to strong winds)

Free Ski World Cup

2013/14	2014/15	2015/16	2016/17	2017/18
1	4	12	5	10
1 Cancellation (Due to low tem- peratures in Nakiska, CAN)	4 cancellations (Due to lack of snow in Innichen, ITA)	12 cancellations	3 cancelled 2 rescheduled	10 cancellations (1 in South Amer- ica, El Colorade, Chile)

Cross Country World Cup

2013/14	2014/15	2015/16	2016/17	2017/18
0	0	0	0	2
No cancellations				Mens: 1 cancelled (Due to severe weather) Womens: 1 cancelled (Due to severe weather)

IBU (International Biathlon Union)

All events

2012/13	2013/14	2014/15	2015/16	2016/17
0	0	0	1	0
No cancellations			1 Cancellation (Due to the collapse of a lighting pole onto the shooting range due to strong winds)	No cancellations

IIHF (International Ice Hockey Federation)

Men's World Championships

2013	2014	2015	2016	2017
0	0	0	0	0
No cancellations				

Women's World Championships

2013	2014	2015	2016	2017
0	0	0	0	0
No cancellations				

ISU (International Skating Union)

Speed Skating World Cup

2013/14	2014/15	2015/16	2016/17	2017/18
0	0	0	0	0
No cancellations				

IBSF (International Bobsleigh & Skeleton Federation)

Bobsleigh World Cup

2013/14	2014/15	2015/16	2016/17	2017/18
0	0	0	0	0
No cancellations				

FIL (International Luge Federation)

Luge World Cup

2013/14	2014/15	2015/16	2016/17	2017/18
0	0	0	0	0
No cancellations				

Appendix H | Matrix

Downhill Skiing Matrix

Downhill Skiing	Current Situation	Actions	Future Impacts	Overall Evaluation (Rate 1-10)
Cancellations	<ul style="list-style-type: none"> - Less than 5% for World Cup level - Very stable number over the years 	<ul style="list-style-type: none"> - Races are often delayed or held on different venues 	<ul style="list-style-type: none"> - Lower level is a snow issue – could lead to an increase of cancellations 	8
Policies / Procedures	<ul style="list-style-type: none"> - CO2 is the main concern - FIS is too small to have an impact - Sport is closely linked to the Tourism in the region - Most CO2 by the spectators and skiers arriving with their own car - Fresh air in the mountains 	<ul style="list-style-type: none"> - Possible involvement with public transport to Events - CO2 carbon neutral Events - Target to improve the climate and the pollution 	<ul style="list-style-type: none"> - FIS is too small to have a real impact on global warming - Maybe their major events can have an impact 	6
Technology / Adaptations	<ul style="list-style-type: none"> - Machine-made snow production - Snow storage 	<ul style="list-style-type: none"> - Most locations have to have machine-made snow guns systems to ensure the competitions 	<ul style="list-style-type: none"> - Could lead to a shortening of the speed disciplines - Increase in cancellations - Less number of Kids on snow (grassroots) 	4
Total				18

Ice Hockey Matrix

Ice Hockey (NHL)	Current Situation	Actions	Future Impacts	Overall Evaluation (Rate 1-10)
Cancellations	<ul style="list-style-type: none"> - Game cancellations due to inclement weather in the NHL - Safety of fans and players getting to the game 	<ul style="list-style-type: none"> - No actions are being taken - Number of cancellations/delays isn't big enough to make an impact on the sport 	<ul style="list-style-type: none"> - Chance of increase in cancellations - Increase in incidents could result in issues with building management 	8
Policies / Procedures	<ul style="list-style-type: none"> - NHL Green - Facility operations largest portion of carbon footprint 	<ul style="list-style-type: none"> - Increase team participation across the league - Montreal Protocol – banning refrigerants - Reduce CO2 footprint 	<ul style="list-style-type: none"> - Integrate initiatives into community rinks - Carbon reduction in facility operations 	9
Technology / Adaptations	<ul style="list-style-type: none"> - Use of LED lights - Fuel cell technology - Building Automation Systems 	<ul style="list-style-type: none"> - Upgrade/build new buildings - New ways to refrigerate buildings 	<ul style="list-style-type: none"> - More efficient building operations - Integrate technologies in local rinks 	8
Total				25



ABOUT THE AISTS

An academic centre of excellence for education and applied research in sport

The AISTS is an academic centre of excellence for education and applied research in sport. It forms a unique network of multi-field expertise in technology, management, economics, medicine, law, and sociology.

The mission of the AISTS is to Master Sport by positively contributing to sports management through a multi-disciplinary approach to education and sciences and by remaining at the forefront of the sports industry's development and the Olympic Movement.

The AISTS was founded in 2000 by the International Olympic Committee (IOC), the EPFL, the University of Lausanne, the University of Geneva, IMD Business School, EHL (Ecole Hôtelière de Lausanne), the City of Lausanne and the Canton of Vaud.

www.aists.org info@aists.org

**EPFL Innovation Park, Bâtiment C | 1015 Lausanne
Switzerland | +41 (0)21 693 85 93**

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