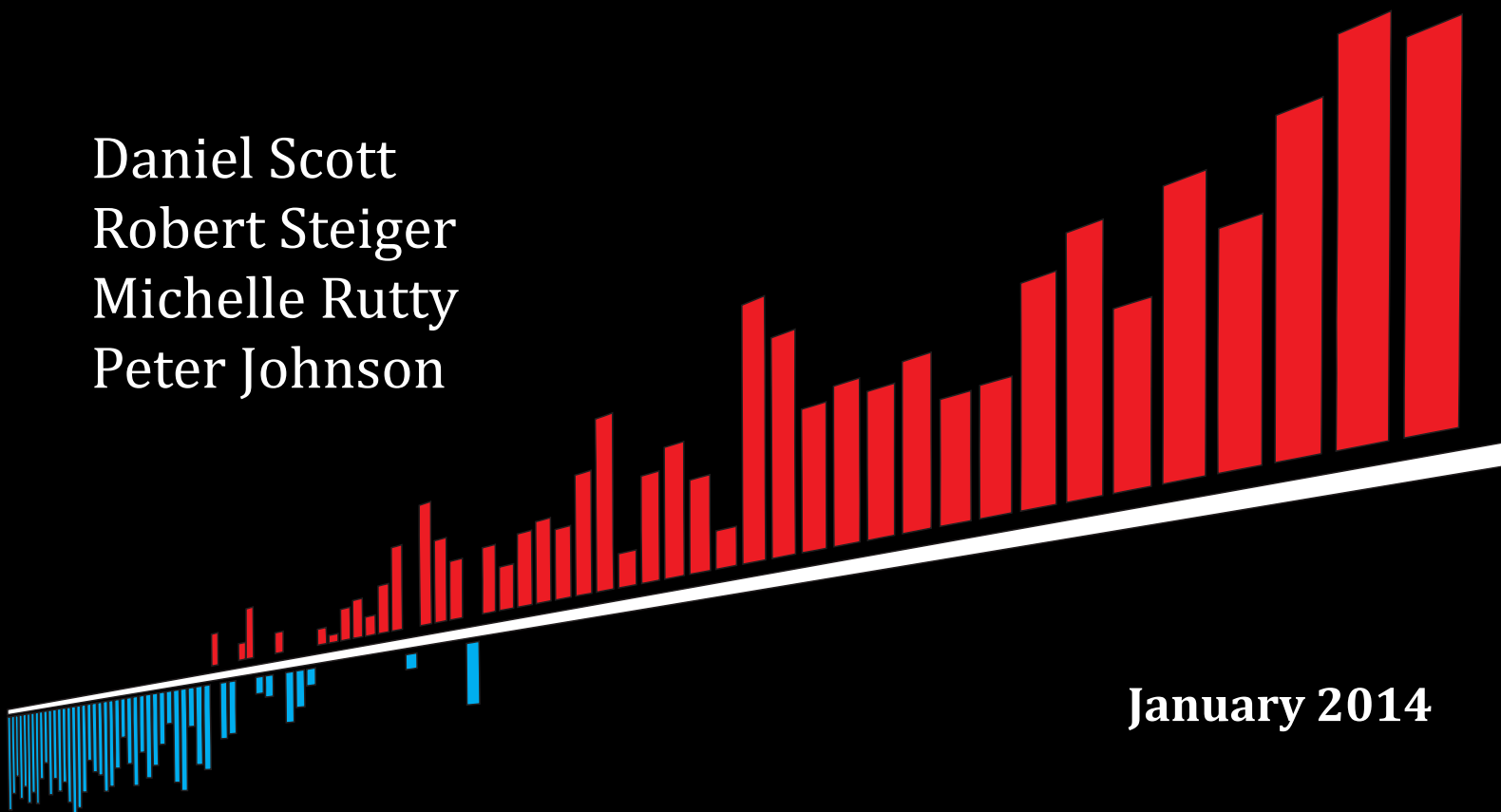


THE FUTURE OF THE WINTER OLYMPICS IN A WARMER WORLD

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The Olympic Winter Games will commemorate its first centennial in 2024. This celebration of winter sport has grown tremendously from just over 250 athletes representing 16 countries, competing in 16 medal events at the 1924 games in Chamonix, France, to over 2500 athletes representing 82 countries, competing in 86 medal events at the 2010 games in Vancouver, Canada.

Today the Olympic Winter Games is truly a global cultural event, with television broadcasts to over 200 countries reaching a potential audience of 3.8 billion people worldwide. ⁽¹⁾

As the world comes together in 2014 for the 22nd Olympic Winter Games in Sochi, Russia, the United Nations has begun to release the findings of its latest report on global climate change. The United Nations Intergovernmental Panel on Climate Change (IPCC) 5th Assessment on global climate change ⁽²⁾ documents the observed changes in the global climate system, including a 0.85°C warming in global average surface temperatures between 1880 and 2012 and continued decline in Northern Hemisphere snow cover and glacier ice since the mid-20th century. The world's elite winter athletes have told world leaders they too are witnessing changes in winter.

With even stronger scientific confidence the IPCC ⁽²⁾ concluded that the “human influence on the climate system is clear. ... (and) ... has been the dominant cause of the observed warming since the mid-20th century.” The IPCC also emphasized that human-caused global climate change has just begun and that depending on future greenhouse gas (GHG) emissions, additional warming of global average surface temperatures of 0.3°C to 4.8°C (relative to 1986–2005) is likely to occur by end of the 21st century. In all but the lowest GHG emission scenario, the goal of the international community to limit warming of global surface temperatures to no more than +2°C (relative to 1850 to 1900) is likely to be exceeded.

“Human influence on the climate system is clear... Warming in the climate system is unequivocal and since 1950 many changes have been observed throughout the climate system that are unprecedented over decades to millennia.”
- Intergovernmental Panel on Climate Change (September 2013 ⁽²⁾)

The IPCC anticipates that additional warming in the winter months will cause a further decrease in Northern Hemisphere snow cover and ice extent. The implications for winter sports are unmistakable. Many studies have demonstrated the potential negative impact of future climate change on winter sports ⁽³⁾, but questions on the implications of a warmer world for the Olympic Winter Games remain unanswered.

“As **professional athletes**, representing a community of 23 million winter sports enthusiasts, we are **witnessing climate change first-hand.**

Last year was the warmest year on record, and once again, we're currently experiencing another winter season of inconsistent snow and questionable extremes. Without a doubt,

winter is in trouble.”

– open letter from 75 US winter sports champions to US President Obama (April 2013)



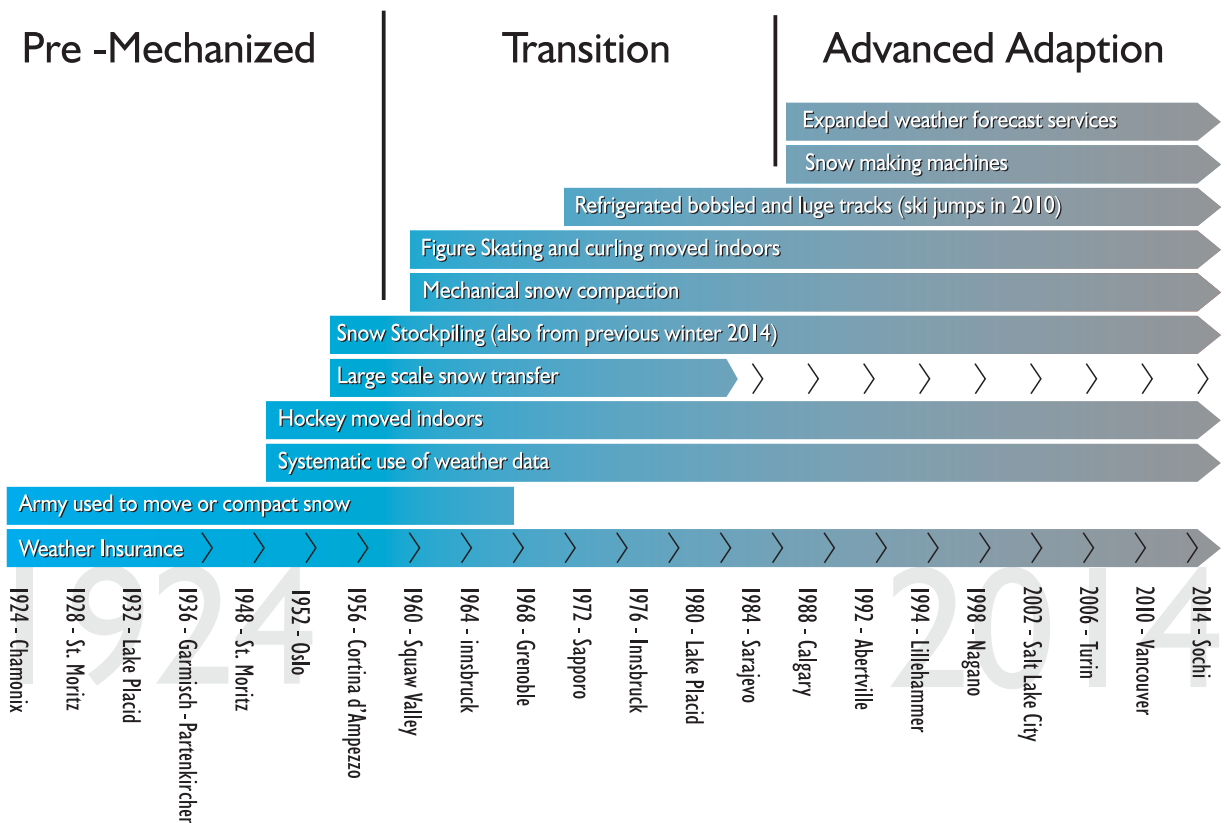
Weather Risk Management at the Olympic Winter Games

A review of the official post-games reports from the host Organizing Committees to the International Olympic Committee (IOC) from 1924 to 2010⁽⁴⁾ revealed that weather has been an integral part of all past Olympic Winter Games. Success of the games is often partially attributed to favorable weather, while as the statements to the right illustrate, poor weather is highlighted as one of the greatest challenges faced by the organizing committees. In addition to the major influence on all outdoor sports competitions (safe and fair competition surfaces, athlete performance), weather can also affect the ability to prepare for the games (venue construction, ice and snowmaking), outdoor opening and closing ceremonies, transportation of athletes and spectators, comfort of spectators, and visibility for television broadcasts.

“ ...The **weather was perfect** up until the first day of the program, when a **large violent snowstorm** swept in on the night of the Opening Ceremony. Damage (to the open air stadium) was **hastily repaired** and the ceremony proceeded. ... The program of the Olympics was executed, despite a **thaw** ... **living memory has never seen** in St. Moritz in February.”
St. Moritz, Switzerland 1928

Consequently, organizing committees, sporting federations and the IOC have continually developed and refined strategies to reduce the risk of adverse weather. The figure below illustrates when some of the major weather risk management technologies and strategies have become standard practice. The technologies associated with indoor ice surfaces, refrigerated tracks and jumps, and snowmaking that athletes and spectators take for granted today, evolved over decades, only becoming commonplace in the last 30 years. As recently as the mid-1960s, the Austrian military had to move thousands of tons of snow by truck and compact it on competition sites by walking on it. The expansion of weather services and

Weather Risk Management Strategies Used by the Winter Olympic Games



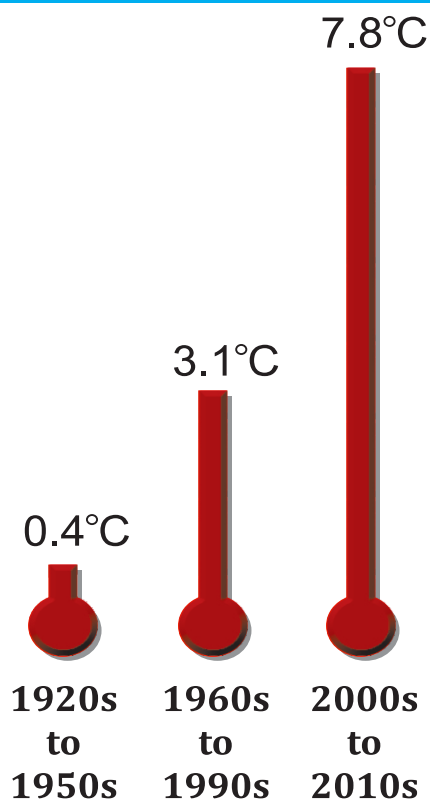
improved accuracy of forecasts is often identified as being vital to the successful operational decision-making during the games.^(4,5) As the number and diversity of medal events increased together with the much increased media coverage of the Olympic Winter Games, the need for climatic adaptations to overcome weather risks intensified.

Weather risk management strategies have allowed some games to avert the misfortune of not being able to deliver the full Olympic program. These strategies have become more important over time, because as the Figure to the lower right demonstrates, the average February daytime high temperature of winter games locations has been steadily increasing – from an average of 0.4°C in the 1920-50s, to 3.1°C in the 1960-90s, to 7.8°C in games held in the 21st century. The warmer February conditions of winter games locations in more recent decades partially reflect the observed winter temperature increases reported by the IPCC⁽²⁾, but also the willingness of the IOC to award the games to warmer host locations. Warmer host locations could be chosen due to the increased capacity to cope with adverse weather conditions. Today it would be difficult to imagine successfully completing the winter games program exclusively on natural ice and snow as it was in the early decades of the Olympic Winter Games. As essential as these climatic adaptations are to the success of recent Olympic Winter Games, an important question remains - will they be able to cope with the warmer conditions of the 21st century?

“**Extreme weather** ranging from **heavy snow** and **blizzards** to warm temperatures and **thunderstorms** plagued the competition venues from the day of the Opening Ceremony until four days before the Closing Ceremony” – Nagano, Japan 1998⁽⁴⁾

“ The **warmest** February weather in Vancouver's recorded history **forced** the Olympic committee to continuously **adapt** and **improvise** ... ” –Vancouver, Canada 2010 (4)

Average February Daily Maximum Temperature at Winter Games Locations (by decades)



What is the Climate Change Risk to the Olympic Winter Games?

In order to assess which of the 19 locations that have hosted the Olympic Winter Games in the past would have a climate suitable to once again host the games in the mid- to late-21st century, several climatic indicators important to winter sports operations were examined. These included natural snow depth on the first of February, mean daily maximum and minimum temperature in February, probability of exceeding key operational temperature thresholds, snowmaking days in January and February, probability of maintaining a snow base of greater than 30 or 60cm, and the number of days with rain. With strong correlations between several indicators, two were determined to provide the greatest insight into answering the question of whether previous host cities would have suitable future climate conditions to again host the Olympic Winter Games:

Indicator 1

the probability that daily minimum temperatures at the main competition elevation would remain the 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 surfaces do not have the chance to recover from greater daytime melt, creating soft and slow surfaces. Additionally, at these temperatures, snowmaking is not feasible to repair snow surfaces, and any precipitation is likely to fall as rain, further degrading ice and snow surfaces with even refrigerated ice degrading. Such conditions are not conducive to fair elite-level competitions and could even become unsafe for athletes.



Indicator 2

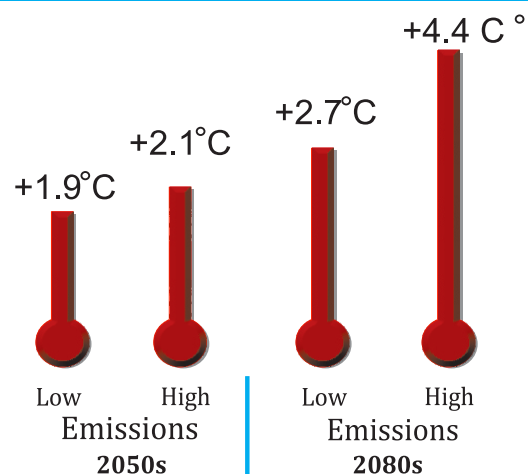
the probability that a snowpack of at least 30cm can be maintained at the higher elevations of alpine events, through both natural snowfall and snowmaking. This indicator reflects both natural climate conditions and the adaptive capacity offered by advanced snowmaking. A snow base of 30cm is utilized in many previous studies as the minimum operational threshold for skiing on very smooth terrain⁽³⁾. Because alpine terrain for elite downhill competitions is not always very smooth, this is a optimistic threshold, as a snow base of 60cm or more would be needed in many locations.



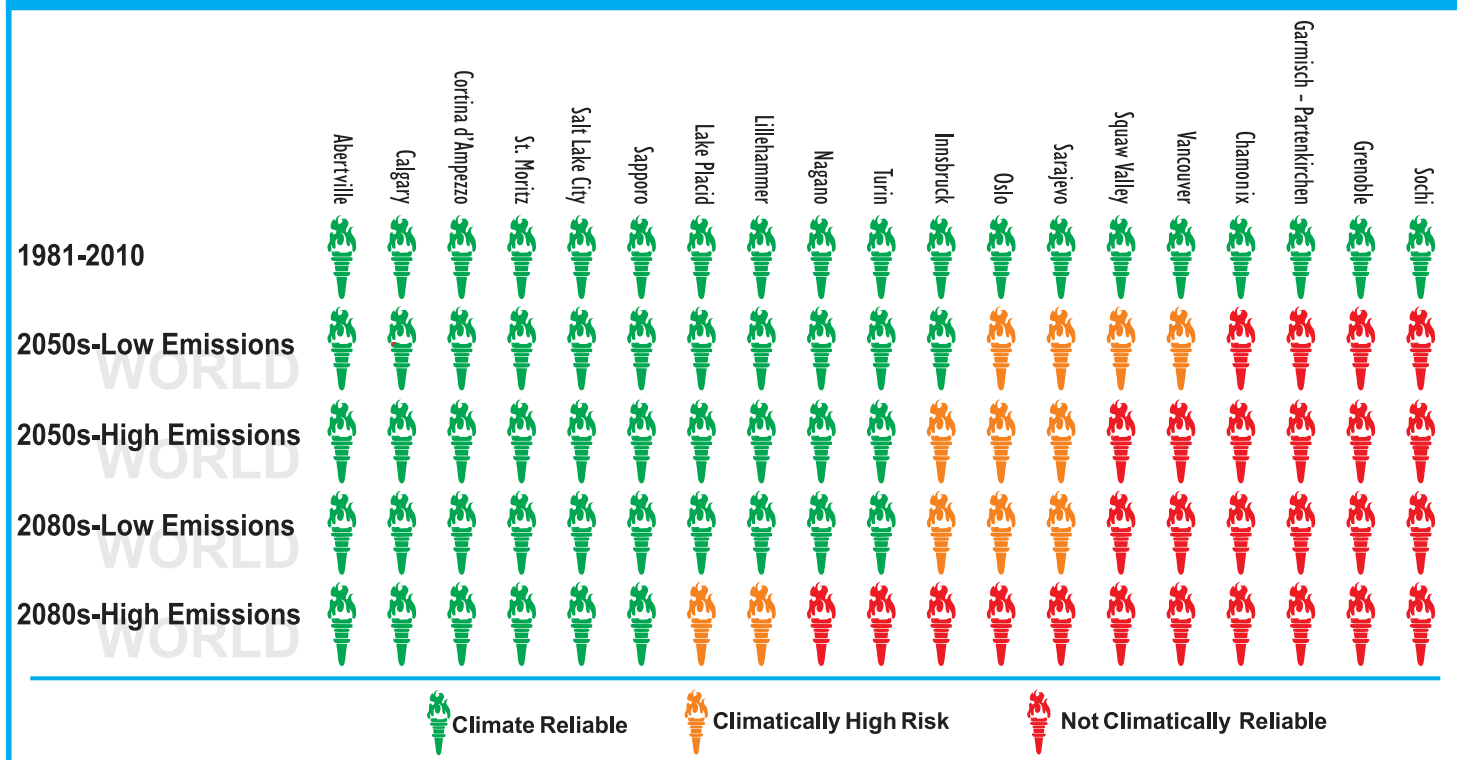
A previous Olympic Winter Games host location was deemed climatically reliable for future winter games if both indicators were achieved in 9 out of 10 winters (90% or greater probability). If one or both indicators were achieved less than 75% of winters, the location was considered unreliable for elite Olympic competitions. Where indicators were achieved in 75 to 89% of winters, the location was classified as marginal/high risk location for a future Olympic Winter Games.

Climate station data from the World Meteorological Organization and national Meteorological Services⁽⁶⁾ were combined with climate change scenarios from the IPCC⁽⁷⁾ to calculate the probability that these important climate indicators would be attained at each of the 19 past host locations under current (1981-2010) and future (2050s and 2080s) climate conditions. The IPCC climate change scenarios represent both low and high greenhouse gas emission futures. Under a low emission pathway, February temperatures are projected to increase at the 19 former Olympic Winter Games host locations an average of 1.9°C by mid-21st century and 2.7°C by late-century. As the Figure to the right indicates, the high emission pathway results in much more pronounced warming at the 19 former Olympic Winter Games host locations, with mid-century warming projected to be 2.1°C and 4.4°C by late-century.

Projected Average February Warming at 19 Former Host Cities (above 1981-2010)



Former Winter Olympic Locations Climatically Suitable for Future Games



The results of the climate change risk analysis summarized in the Figure above are unsettling. The negative impact of projected climate change on the climatic ability of former Olympic Winter Games locations to once again host the games was very evident by mid-century. Although all of the 19 former Olympic Winter Games hosts were classified as climatically reliable in the 1981-2010 period, by the middle of the 21st century this number had decreased to 11 in the low emission scenario and only 10 in the high emission scenario. In the late-21st century, only a half of former Olympic Winter Games hosts would have reliable conditions in a low emissions scenario. Internationally renowned Olympic sites, such as Squaw Valley (U.S.A.) Garmisch-Partenkirchen (Germany), as well as recent host cities of Vancouver (Canada) and Sochi (Russia), simply would not be cold enough to reliably host the Games. The outcome of the high GHG emissions in the late-21st century is far more alarming. The greater warming associated with a high emissions pathway left less than one-third (6 in total) of former Olympic Winter Games locations climatically suitable for the games. With additional warming continuing in the early-22nd century under a high emissions pathway⁽²⁾, the number of former Olympic Winter Games locations capable of hosting the games would continue to decline over time. In other words, in a substantially warmer world, celebrating the second centennial of the Olympic Winter Games in 2124 would be challenging.

Keeping the Olympic Winter Games Cool

The confluence of the 22nd Olympic Winter Games and the 5th IPCC Assessment provides an important opportunity for reflection on the long-term implications of global climate change for the world of sport and the world's collective cultural heritage symbolized by the Olympic Movement. Although the format and technologies supporting winter sports in the later decades of this century will be different from today, they will remain founded on snow and ice, as they have for the past 100 years. It is clear that the cultural legacy of the world's celebration of winter sport is at risk if the warmer climate scenarios of the late-21st century are allowed to occur. Importantly, this future is not certain. We that enjoy winter sports of all kinds and support the Olympic Movement can influence this outcome in favor of the sustainability of the Olympic Winter Games.

The IOC has officially recognized the environment as the third dimension of Olympism, alongside sport and culture. In 1996 the IOC amended the Olympic Charter to include a binding commitment to sustainable development.⁽⁸⁾ Two years later climate change first appeared in the Official Olympic report of the 1998

Nagano, Japan games (pg 277)⁽⁹⁾: “Recently, environmental concerns have become a theme of serious discussion around the world. The depletion of the ozone layer and global warming are two examples of issues affecting our natural ecosystem on a worldwide scale. Therefore, striving to host the Olympic Winter Games in harmony with nature is especially important, and we ask the IOC and future Olympic Winter Games host cities to pay close attention to the environment.”

Subsequent hosts of the Olympic Winter Games have respected the counsel of the Nagano Organizing Committee and taken actions to reduce GHG emissions and host 'climate-neutral' games. The carbon emissions associated with staging the games were calculated for the first time at the Salt Lake City (USA) games in 2002. The Salt Lake Organizing Committee subsequently purchased emission-reduction credits sufficient to certify the 2002 Games as climate neutral for the first time.⁽⁴⁾ At Turin (Italy) in 2006, climate protection was a fundamental part of the Organizing Committee's environmental strategy, including the Heritage Climate Torino project to offset the estimated 100,000 tonnes of CO₂ generated during the games.⁽⁴⁾ The 2010 games in Vancouver (Canada) used the International GHG Protocol Initiative to inventory carbon emissions over the full seven-year organizing period of the Olympic-Paralympic Games, including the first Games to track and report on indirect from air travel to and from the Games region, and the first to have carbon neutral athletes and Organizing Committee.⁽⁴⁾ The Sochi (Russia) organizers have also invested significantly in energy conservation, renewable energy sources and carbon offsetting to achieve their goal of a carbon-neutral games in 2014.⁽⁹⁾ The Olympic Winter Games has shown leadership in championing new technologies of the low-carbon economy, with no other major sporting event being able to demonstrate carbon-neutrality for over a decade.

If the Olympic Movement is to be able to call upon the world's youth to assemble at the Olympic Winter Games of the early 22nd century, the youth of today must call upon their leaders of government, business and civil society to assemble at the 21st session of the Conference of the Parties to the United Nations Framework Convention on Climate Change in Paris, France with the absolute resolve to reach a new ambitious global agreement that will ensure the rapid transition to a low carbon economy and limit warming of global average temperatures to less than +2°C over pre-industrial times.

The **cultural legacy** of the world's celebration of winter sport would be **at risk** if the warmer climate scenarios of the late-21st century are **allowed to occur.**



Sadly, if we experience climate change to the degree predicted by scientists, by the **mid-21st century, close to half** of the cities that have hosted the Olympic Winter Games in the past would **no longer be able to.** It simply would **not be cold enough.**

Notes

- (1) VANOC Report – Chapter 3: Broadcasting. <http://view.digipage.net/?id=iocvancouver2010&page=26>
- (2) IPCC, 2013: Summary for Policymakers. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. www.ipcc.ch/report/ar5/wg1/#.Upyi_aUrTHg
- (3) For a summary see: Scott, D., Gössling, S., Hall, C.M. (2012) International Tourism and Climate Change. *Wiley Interdisciplinary Reviews – Climate Change*, 3 (3), 213-232. Key studies include:
- Scott, D., et al. (2006). Climate change and sustainability of ski-based tourism in eastern North America: a reassessment. *Journal of Sustainable Tourism*, 14(4), 376-398.
- Scott, D., et al. (2006). The implications of climate change for the Québec ski industry. *Global Environmental Change*, 1, 181-190.
- Dawson, J., et al. (2009). Analogue analysis of climate change vulnerability in the US Northeast ski tourism. *Climate Research*, 39(1), 1-9.
- Steiger, R. (2010). The impact of climate change on ski season length and snow- making requirements in Tyrol, Austria. *Climate Research*, 43(3), 251-262.
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- Pons-Pons, M., et al. (2012) Modeling climate change effects on winter ski tourism in Andorra. *Climate Research* 54 (3), S. 197–207.
- Dawson, J. & Scott, D. (2013) Managing for Climate Change in the Alpine Ski Sector. *Tourism Management*, 35, 244-254.
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- Steiger, R. & Abegg, B. (2013) The Sensitivity of Austrian Ski Areas to Climate Change. *Tourism Planning & Development* 10 (4): 480–93.
- (4) The Organizing Committee of each winter games prepared an official final report to the IOC on local arrangements and facilities, events and participation, competition results, visitor attendance, finances, and other topics. In the 1970s reports to the IOC become two volumes and expand to three volumes in the 1990s as sustainability and other themes were included. Pre-games climate considerations and the impact of weather preceding and during the games are discussed in each of the reports. A content analysis of all weather/climate related terms was conducted on each official final report.
- (5) Mailhot et al. (2010) Environment Canada's Experimental Numerical Weather Prediction Systems for the Vancouver 2010 Winter Olympic and Paralympic Games. *Bulletin of the American Meteorological Society*, 91 (8), 1073–1085. Horel, J., et al. (2002) Weather Support for the 2002 Winter Olympic and Paralympic Games. *Bulletin of the American Meteorological Society*, 83, 227–240.
- (6) Historic weather data was retrieved from the World Meteorological Organization and a number of national weather services (DWD, ZAMG, Meteo France, Environment Canada, Meteo Swiss, Hydrografisches Amt Bozen and Arpa Piemonte). The data contribution of these organizations is gratefully acknowledged. Data for 30 year periods prior to the Olympic Games, where possible, and for 1981-2010 were obtained to represent average climate conditions (i.e. "climate normal") at each location. Temperature and precipitation data were extrapolated from the altitude of the climate station to both the altitude of the host city and the altitude of where outdoor snow events were held.
- (7) The assistance of Dr. A. Fenech of the Climate Lab at the University of Prince Edward Island (Canada) in obtaining and processing the concentration-driven CMIP5 model scenarios from the IPCC⁽¹⁾ for each of the 19 past Winter Games locations is gratefully acknowledged.
- (8) IOC. Focus on Sport and Sustainability – April 2011. www.olympic.org/Documents/Olympism_in_action/Sport_and_Environment/FOCUS_Sustainability-April_2011.pdf
- (9) UNEP – Carbon Neutral Network. Climate Neutral Games. unep.org/Sport_env/sochi2014/climate_neutrality%20.aspx
- (10) Big Idea 2014: The Year for Climate Action. www.un.org/climatechange/blog/2013/12/11/big-idea-2014-the-year-for-climate-action/

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“In 2014, we must turn the
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common progress toward a
sustainable future. ... Future
generations will judge our action
on this issue. In 2014, we have
the chance to step over to the
**right side of
history.**”
- Ban Ki-moon, Secretary-
General of the United Nations
(11 December 2013)⁽¹⁰⁾