

Review Article

Sustainable Play: Climate Adaptation Strategies in Modern Sports

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Abstract: The intersection of climate change and modern sports has emerged as a critical concern. As global temperatures rise and weather patterns become increasingly unpredictable, sports face unprecedented operational and existential threats. Thus, this paper is an attempt to explore the climate adaptation strategies developed within the sports sector to combat climatic pressures. Climate change impacts are most acutely encountered in winter sports, where rising temperatures and diminished snow cover threaten the viability of competitions. Beyond winter sports, rising temperatures affect summer competitions as well; the 2014 FIFA World Cup in Brazil and extreme heat at the 2014 Australian Open underscored the vulnerability of outdoor events to heat stress. In response to these mounting threats, sports organizations have developed a range of adaptation strategies. Technological adaptation has emerged as a primary response mechanism. Artificial snowmaking has become indispensable for winter sports venues; Sochi 2014 organizers stockpiled manufactured snow for a year in advance of the Games, while Vancouver 2010 was forced to truck in snow to create a functioning course. Infrastructure modifications extend beyond winter sports. The Thyagaraj Sports Complex, built for the 2010 Commonwealth Games in Delhi, incorporated fly ash bricks, rainwater harvesting and double-glazed glass to block heat while admitting light. The venue was recognized as part of the first-ever "Green Commonwealth Games," with organizers committing to low-carbon practices and community planting programs. Institutional and policy adaptations have complemented technological solutions. These adaptations demonstrate that while sports remain highly vulnerable to climatic change, proactive measures can significantly reduce risks and sustain play in a warming world.

Keywords: Climate Adaptation, Ski Tourism Vulnerability, Winter Olympics, Snowmaking

INTRODUCTION

The relationship between sport and the natural environment is fundamentally bidirectional. Sport depends upon predictable climatic conditions like moderate temperatures, reliable snowfall, adequate water resources etc. while simultaneously contributing to the environmental challenges that threaten its own viability (Mower, 2012; Sengupta, 2014). By the early 2010s, it had become increasingly apparent that climate change was no longer a distant concern for the sports industry but an immediate operational reality. From melting snowpack in alpine regions to extreme heat threatening athlete health, the sports world began confronting the necessity of adaptation. Thus, there is an imminent need to examine the climate adaptation strategies that emerged in modern sports, a period when the industry transitioned from environmental awareness to active resilience-building. The paper is in this background to explore the climate adaptation strategies developed within the sports sector to combat climatic pressures.

The emerging climate imperative in sport

The scientific evidence for climate change's impact on sports accumulated steadily through the early 2010s. It should be noted that global warming had the

potential to negatively affect winter recreation across northern countries. In Canada, where outdoor hockey and ice skating are deeply ingrained in culture and economy, winter temperatures had increased by more than 2.5°C since 1950 - more than three times the globally averaged warming attributed to anthropogenic climate change (Damyanov *et al.*, 2012). The study found that the outdoor skating season had significantly shortened across many regions of Canada as a result of changing climate conditions, with particularly pronounced decreases in Southwest and Central Canada. These biophysical changes carried substantial economic consequences. The difference between the best and worst snow years in the United States represented roughly \$1 billion in lost sales and more than 13,000 lost jobs in the winter tourism industry, which averaged \$12.2 billion annually (Chaney, 2012).

The implications extended beyond winter sports. Hanna (2015) urged sports administrators to take the issue of heat stress seriously and to take steps to safeguard players, both professional and grassroots, from health dangers. The report highlighted that summer and winter sports alike were being impacted, with some showing resilience by changing their practices and

amending playing grounds, while others would find adaptation much harder.

Winter sports: Adapting to disappearing snow and ice

Winter sports faced perhaps the most immediate and visible climate threats. Reliant directly on snow, ice and cold temperatures, outdoor winter sports were already experiencing and responding to climate change (Brocherie *et al.*, 2015). Steiger (2010) recorded the impact of climate change on ski season length and snowmaking requirements in Tyrol, Austria. The 2014 Winter Olympics in Sochi provided a stark illustration. Temperatures were a full ten degrees warmer than average, with spectators in T-shirts sloshing through mud puddles. Slopestyle and half-pipe venues became slushy and dangerous; only 31 of the 49 female alpine skiers were able to finish their course (Rees, 2014). Swiss skier Laura Gut declared, “There is no snow at the bottom. It's not funny anymore. This is a disaster, it was a shame for everybody”. Cross-country skier Andy Newell noted that several pre-Olympic events had been cancelled because of warm weather, “something that has been a consistent problem both in Central Europe and Scandinavia”.

In response, the winter sports industry developed multiple adaptation strategies. Snowmaking emerged as the dominant technological response. Ski resorts invested heavily in snowmaking infrastructure, though this approach presented significant challenges: it required secure water supplies, substantial energy inputs and considerable capital investment that smaller operations could not afford. In addition, modelling climate change effects on ski tourism in Andorra projected reductions in ski season length and drops in skier numbers, particularly at lower-elevation resorts, even with aggressive snowmaking as an adaptation strategy (LOCOG, 2007).

Some destinations pursued diversification strategies, expanding summer tourism offerings to compensate for shortened winter seasons (Kinver, 2011). Others explored more radical adaptations, including the purchase of snow-making machines in regions that had historically relied on natural snowfall (UK Parliament, 2007). Yet even where climatic conditions remained favourable for efficient snow production, snowmaking could become an uneconomic adaptation strategy and an unacceptable burden on ecosystem services.

Mega-events: Institutional responses and infrastructure innovation

The world's largest sporting events became laboratories for climate adaptation. The International Olympic Committee (IOC) positioned environmental responsibility as an integral part of Olympism alongside sport and culture (IOC, 2014). The 10th IOC World Conference on Sport and the Environment, held in Sochi in 2013 under the theme “Changing Today for a Better Tomorrow,” brought together leading environmentalists,

academics, government figures and sports experts to discuss sustainable development legacies and the role of the UN system (IOC, 2013). IOC President Thomas Bach declared that “the Olympic Movement has already shown the international community how sport can make a tangible contribution to reducing environmental impacts”.

The London 2012 Olympics established new benchmarks for sustainable event management (DCLG, 2015). It was the first Summer Games to formally adopt “triple-bottom line” sustainability management frameworks from the start, reflecting the IOC's three spheres of sustainability - environmental, social and economic. The Sustainability Plan focused on five key themes: climate change (minimising greenhouse gas emissions and ensuring legacy facilities could cope with climate impacts), waste, biodiversity, inclusion, and healthy living (Shanghai Manual, 2010). The Olympic Park was designed to minimise carbon emissions and mitigate climate impacts through features including a combined cooling, heating and power system. Parkland was designed to help the site adapt to climate change through its ability to cope with heavy rainfall events while providing greenery to combat heat island effects. The organisers reported being on target to cut the carbon footprint by 100,000 tonnes in the procurement of materials and venue construction. Thus,

- The most-sustainable and lightest Olympic and Paralympic stadium in history has been completed on time, with old gas pipes used in much of its construction;
- London 2012 is the first Olympic and Paralympic Games to measure its carbon footprint over the entire project term;
- London 2012 is the first Olympic and Paralympic Games to commit to a Zero Waste to landfill target, reusing or recycling over 98 per cent of waste in the demolition phase, and 99 percent in construction of the Olympic Park;
- London 2012 has pledged to deliver a public transport games, targeting one million extra walking and cycling journeys in London every day of the games.
- London 2012 is also utilizing a new sustainability assessment guide developed by the Global Reporting Initiative, which was co-founded by UNEP (UNEP, 2012).

The 2014 FIFA World Cup in Brazil marked another milestone. FIFA announced a \$20 million investment to make it the first World Cup with a comprehensive sustainability strategy, addressing green stadiums, waste management, carbon emissions reduction and offsetting, renewable energy and climate change. The tournament's estimated carbon dioxide emissions totalled 1.4 million tons. FIFA pledged to offset 331,000 tonnes of carbon, including 80,000 tonnes from fans who entered a contest to make their travel

carbon neutral. The event was described as a “stepping stone” towards sustainable World Cups, with environmental protection becoming a mandatory requirement for hosting from 2018 onwards (Matthews, R. 2014a and b).

Operational adaptations: Heat policies, scheduling and athlete safety

Beyond infrastructure, sports organisations developed operational strategies to protect athletes from worsening climate conditions. Heat stress emerged as a primary concern across multiple sports (Racinais *et al.*, 2015). Extreme heat events were becoming more frequent and intense, negatively impacting many aspects of organised sport. Elevated temperatures were found to negatively affect memory, eye-hand coordination and concentration, all of which meant poorer sporting performance. Heat waves could significantly worsen human health. The Climate Institute (2015) reviewed heat policies across sports and found vast differences among them, even within particular sports. In Australia and around the world, extreme weather had led to deteriorating conditions at sporting events. Athletes, coaches, sports administrators and commentators increasingly spoke up about the need for consistent, evidence-based heat policies.

Scheduling emerged as a critical adaptation lever. Climate change was producing recurring disruptive events that might shake sport organisations out of inertia regarding scheduling. The feasibility of hosting endurance events like the Olympic marathon required consideration of climate projections, hourly climatic characteristics of host cities and adaptation measures. Some sports began exploring rescheduling as both a mitigation and adaptation strategy. Athlete training and preparation also required adjustment. Research demonstrated that well-trained athletes had individual tolerance to increase approximately 0.9°C higher than untrained individuals. However, even elite athletes faced limits.

Greening operations: Energy, water, and waste management

Parallel to climate adaptation, sports organisations pursued operational greening that simultaneously reduced environmental footprints and built resilience. By 2010, these efforts had gained significant momentum across multiple sports and regions. The Indian Premier League partnered with the United Nations Environment Programme to compensate its games' emissions and green its operations, from waste management to energy efficiency and water conservation. UNEP assisted the IPL in achieving climate neutrality through renewable energy introduction and emissions compensation (UN, 2010). The partnership represented a first-of-its-kind initiative by any sporting body in India. The Punjab Cricket Association hosted the first-ever carbon-neutral cricket

match, implementing rain harvesting systems, water recycling, solar power panels and waste separation.

The 2010 Commonwealth Games in Delhi showcased green infrastructure (Uppal, 2009). The Thyagaraj Stadium was built with the latest green building technologies, featuring solar energy for lighting, rainwater harvesting, and a sewage treatment plant with a two-lakh-litre-per-day capacity. The stadium produced its own power, with its solar plant providing electricity to over 1,000 households, while treated effluent water irrigated lawns (PTI, 2010). An Ecological Code was unveiled covering six environmental categories - Land, Energy, Air, Water, Carbon and Waste with tangible targets to ensure the event was carbon neutral.

Major League Baseball demonstrated leadership in environmental data transparency. In 2010, MLB became the first professional league to track and share environmental data. The Philadelphia Phillies committed to purchasing 100 percent renewable energy for the calendar year. Such initiatives reflected a growing recognition that sports organisations could reduce operational costs while demonstrating environmental responsibility. The IOC's 2014 World Environment Day initiatives highlighted how athlete advocacy could drive community-level adaptation. Projects like “Love Your Coast” in Papua New Guinea used athletes as role models to inspire young people to protect fragile coastlines and waterways. Project Litefoot in New Zealand, led by Olympic champion Barbara Kendall, aimed to transform community sports infrastructure to make it collectively electricity independent, water neutral and zero waste by 2025. Beyond environmental benefits, the initiative freed up money for investment into sport.

Net zero sports

“Net zero,” as a formal climate target term, did not enter mainstream sports vocabulary until later in the 2010s. However, the underlying concept, achieving a balance between emissions produced and emissions removed or offset, has clear antecedents in sport typically framed at the time as “carbon neutrality.” One of the earliest documented cases was the University of Florida's athletic programme, which in 2009 became the first collegiate athletics department in the United States to claim a fully carbon-neutral season. Working with the nonprofit Neutral Gator, the university offset its athletics programme's roughly 2,500-ton carbon footprint through local weatherization projects and natural area restoration in low-income sectors of Gainesville, alongside the construction of the country's first Platinum LEED-certified athletic facility (University of Florida, 2009).

At the mega-event level, FIFA pursued similar goals during this period. For the 2010 South Africa World Cup, FIFA offset roughly 243,000 tonnes of the tournament's estimated 2.2 million tonnes of emissions by investing in climate-neutral development projects

across host locations, while cautioning that carbon offsetting was not yet standard practice across the sports industry but was gaining traction through the visibility of high-profile organisations (UNEP, 2012). This built on FIFA's larger sustainability commitments for the 2014 Brazil World Cup, where it pledged offsets covering a substantial share of the event's carbon footprint as part of a stated ambition to make environmental responsibility a mandatory requirement for future host nations.

Taken together, these initiatives represent an early, largely voluntary and offset-driven precursor to today's more rigorously defined net zero sports commitments. They lacked the standardised accounting, science-based emissions targets and independent verification that define net zero frameworks. Nonetheless, they established the foundational idea, later refined into net zero methodology, that sporting institutions could and should take responsibility for quantifying and neutralising their environmental impact.

Conclusion

The progressing period marks a decisive turning point in how the sports industry understood its relationship with a changing climate. What began as scattered acknowledgments of environmental vulnerability evolved, within roughly half a decade, into a recognisable field of practice spanning technological innovation, infrastructure design, institutional policy and grassroots advocacy. Winter sports, as the most immediately and visibly exposed sector, led this transition. The stark imagery of Sochi 2014 crystallised for a global audience what climate scientists had already been documenting for years: that snow-dependent sport was losing its most basic operating condition. The response, dominated by snowmaking infrastructure, demonstrated both the ingenuity and the limits of technological adaptation. Snowmaking bought time, but at a cost of secure water access, heavy energy demand and capital investment that smaller resorts and developing winter sport regions simply could not sustain, foreshadowing a two-tier system in which climate resilience would increasingly correlate with financial resources rather than sporting merit alone.

Beyond winter sport, the extreme heat events at the 2014 Australian Open and the operational strain surrounding the 2014 FIFA World Cup in Brazil confirmed that no discipline, summer or winter, indoor or outdoor, could consider itself insulated from climatic disruption. This broadening of concern prompted a parallel evolution in institutional response. The mega-event became, in effect, a testing ground for adaptation at scale: London 2012's carbon footprint tracking and zero-waste-to-landfill commitments, FIFA's \$20 million sustainability investment and carbon offset pledges, and Delhi's Thyagaraj Stadium with its fly ash construction, rainwater harvesting and solar generation collectively signalled that environmental performance was becoming as central to event legacy as athletic achievement itself.

The IOC's rhetorical positioning of environmental responsibility as a third pillar of Olympism, alongside sport and culture, reflected this shift from peripheral concern to institutional mandate.

Equally significant, though less visible than stadium infrastructure, were the operational and behavioural adaptations that emerged during this period. The recognition that heat stress measurably impaired athlete cognition, coordination and safety pushed administrators toward evidence-based heat policy, even as the Climate Institute's 2015 review found troubling inconsistency in how such policies were applied across and even within sports. Scheduling adjustments and athlete training protocols represented early, if uneven, attempts to build physiological and logistical resilience into competition itself. Meanwhile, initiatives like the IPL's partnership with UNEP, the Punjab Cricket Association's carbon-neutral match and Major League Baseball's environmental data transparency showed that greening operations and climate adaptation were becoming mutually reinforcing rather than separate agendas.

Yet for all this progress, technological fixes risked entrenching the very fossil-fuel dependency that drove the underlying crisis. Commitments frequently outpaced measurable outcomes and the sports most fundamentally tied to specific climatic conditions, natural snowpack, stable temperature bands, predictable precipitation, faced a ceiling beyond which no amount of incremental adaptation could preserve their traditional form. This tension between adaptive capacity and climatic limits is the defining legacy currently and proved that sport was capable of responding to environmental threat with genuine innovation, while simultaneously revealing that response alone would not be sufficient. The unresolved question this period leaves behind, whether sport can move from adaptation toward meaningful mitigation of the crisis it also contributes to, would come to define the industry's climate reckoning for the decade that followed.

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