Advancing Sport Ecology:
From Conceptual to Normative and Evaluative Frameworks

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Abstract

Sport ecology is an emerging academic discipline that has been gaining traction since 2016. It exists as an interdisciplinary and interconnected view on the dynamics of sports and the environment. Sport ecology sits primarily in a conceptual stage, with preliminary developments into a normative one - or how sustainable sports should look and perform, from the release of sporting sustainability reports and strategies. The focus of this major research paper will be how to move sport ecology beyond a conceptual framework, into a more substantive normative and evaluative one. The analysis of the paper is both quantitative and qualitative from the conceptual framework to derive the quantification of how sports ecology fits into a normative and evaluative frame. The quantitative analysis contains a scoring evaluation of mega sporting events on a scale of 1-5. The case studies used in the scoring analysis will be the Vancouver 2010 Olympics and the 2026 FIFA world cup. This evaluation will introduce sport ecology as more than an academic subdiscipline, but as an evaluation tool for sporting organizations and policy makers. This paper will broaden the meanings and dynamics of sport ecology and ways in which to advance it from being just a conceptual emerging academic subdiscipline.

Keywords: Sport Ecology, Climate Change, Sustainability

Foreword

This major research paper satisfies the requirements of both the MES and Business and Environment Diploma from the Schulich School of Business, as it is an interdisciplinary with emphasis on climate change, policy, systems-thinking, community-based sustainability, and has strong links to business organization and decision-making. The research conducted for this paper is both qualitative and quantitative in approach and is based on past, current, and future research through sustainability reporting, policy, internships, and experiential learning opportunities. The major research paper examines the roles that certain sporting organizations are taking to address the normative framing of sport ecology as well as how to use sport ecology as an evaluative tool for sporting organizations and policy. The MRP is grounded on the learning objectives established within the POS. It develops an understanding of the connection of sports to the climate crisis and the role of the United Nations Sustainable Development goals within sporting sustainability reporting. It also examines how sustainability can be advanced through renewable energy adoption, standards, and sustainable design of sporting venues. This would include green roofs and living walls, renewable energy systems, energy demands, and sustainable systems design. This MRP also considers the carbon footprint and emissions from travel, fan accommodations, waste generation, and energy use, where reduction potentials are discussed to reduce the carbon footprint. This exists from circular economy principles, sustainable was management, and sustainable sporting governance. These are connected to knowledge expansion from courses of ecological footprint informatics and applications, environmental policy, sustainability reporting and disclosure, and waste management/circular economy, as well as experiential learning from being an ESG research intern for the PSO of Skate Ontario and the sustainability in the foodservice & sports pilot program lead for Leaders in Environmentally Accountable Foodservice (L.E.A.F). The paper also advances sport ecology beyond a conceptual framework into a normative and evaluative tool for decision-making and event implementation. Using case studies of the Vancouver 2010 Olympics and the 2026 FIFA World Cup, the MRP applies sport ecology concepts as evaluative criteria to assess both sustainability and its associated outcomes.

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Section 1: Introduction to Sport Ecology

Sports foster a sense of identity, community, belonging, and provide a platform for communication and collective action. They bring together many individuals to daily sporting practices and events as fans, athletes, coaches, officials, volunteers, and staff. Sport ecology is an emerging academic field that is starting to bridge the connections between sports, the environment, and sustainability practices. The current definition of sport ecology is the study of the interconnections and effects between sports and the environment (McCullough et al., 2020). Sport ecology has been broken down into various subtopics which include the effects of climate change on venues and athletes, sustainability initiatives, renewable energy use, biodiversity loss and land-use, energy used and consumed at events, the various wastes generated, sustainable sporting governance structures, and the carbon footprint.

Sports are not only major contributors to climate and environmental change but are also vulnerable to it. Extreme weather events, shifting seasonal patterns, warming temperatures, declining snow availability and reliability, biodiversity loss, and water scarcity are affecting all aspects of sports. These impacts affect sporting event calendars, the safety of all individuals present, the durability and climate-proofing of infrastructure, and the impacts of long-term event planning.

While sport ecology is currently mapping the interconnections between sports and the environment, it remains at a conceptual level. There is opportunity to advance the field of sport ecology by developing a normative and evaluative framework that can be employed in planning and decision making around major sports events. This would include the capacity to assess the sustainability of sport at the organizational level (normative framing – what makes sport sustainable) and the use of selected case studies of mega-sporting events (evaluative framing)

where a sport ecology framework can contribute to assessment of the sustainability initiatives implemented into future mega-sporting events. Using selected criteria and categories such as sustainable sporting governance, the carbon footprint, energy used and consumed, and waste generation, sport ecology can move from a conceptual level to a normative and evaluative tool for policy makers and sporting organizations. The normative and evaluative framing will allow scholars, practitioners, governing bodies, the public realm, and sporting organizations to assess and implement sustainability initiatives and emission reduction potentials into sports and sporting events. This would contextualize further the interconnected nature of sport ecology and how it is being affected by climate change.

This paper will begin by discussing the history, background, importance, and evolution of sport ecology, followed by the explanations of various subtopics that exist within the conceptual framing. The next section will discuss how sport ecology sits within a normative framework, followed by the final section that will discuss how sport ecology can be moved into a practical evaluative framework. This evaluation will use selected criteria of; sustainable sporting governance; the carbon footprint; energy used and consumed; and waste generation to assess sustainability implementation at future mega-events by using selected case studies to shape the evaluation. The case studies used will be the Vancouver 2010 Olympics, and the 2026 FIFA World Cup. The conclusion of this analysis will assess progress and identify gaps that exist with sport ecology. It is intended that this work will encourage sporting governance and organizations to establish a sustainable mega-sporting event that addresses climate change and wider sustainability concerns.

1.2 Evolution of Sport Ecology

Sport ecology emerged from the green sports movement. It first started to take shape in the 1990s within the conceptual scholarship of sport management and has been explored in a disjointed manner through literature reviews, academic texts, and within siloed research. Practitioners have explored the ways that sports have impacted the environment through the lenses of sport sustainability that covers sustainability practices, corporate social responsibility, and the influence of sports on environmentally conscious behaviours (McCullough et al., 2020). The ways in which sport sustainability was used within sporting academic research before the coined term sport ecology was introduced, was based primarily only on the study of sport and the natural environment (McCullough et al., 2020), rather than the complexities connected to sustainability initiatives and the climate crisis.

This is where the emerging academic discipline of sport ecology began to develop. Sport ecology is not solely about sustainability and environmentalism but also includes research on sport experiences and the natural environment (McCullough et al., 2020). This demonstrates that this academic discipline does not just operate within the realm of climate change, sport, and sustainability, but also branches out to other social sciences and beyond. In the context of this major research, however, the discussions will be focused on the environment, sustainability initiatives, and links to climate change that shape and create the academic discipline of sport ecology.

Sport ecology literature has grown since 2010. A qualitative study examining articles regarding sports and the environment published between 2007 and 2017 (McCullough et al., 2020) concluded that conceptual sport ecology publications increased by 311%. It included categories of management, spectator and fan behaviours, facilities management, and the

evaluation of social sustainability (McCullough et al., 2020). Broadly, sport ecology research has evolved by grounding concepts of the environmental impact of sports and the environmental impact on sports (McCullough et al., 2020). Studies of fan engagement and education have contributed significantly to the evolution of sport ecology, as it has introduced concepts of climate action and awareness and sustainable practices from all individuals that are present in and within a sporting event space. Subtopics within this academic discipline include the carbon footprint, energy used and consumed, the generation of wastes, sustainability initiatives, biodiversity loss and land-use changes from the implementation of mega-events, water usage, pollution sources, health effects on athletes and members, and sustainable sporting governance.

While academic scholarship has helped to establish the conceptual framework of sport ecology, practical initiatives are also contributing to its growth. For example, in 2016, there was the launching of Green Sports Day, which occurs annually on October 6th (Green Sports Alliance, n.d.), which re-shaped sport ecology from theory to practical applications. Green Sports Day was implemented as a national initiative with the partnership of the Green Sports Alliance to address climate and sustainability concepts within the sporting realm, supported by the Obama administration. Green Sports Day is both a celebratory and collective learning day to provide action and awareness over the interconnections of sport ecology, so all members of the sporting community (athletes, coaches, fans, academics, practitioners, sporting companies, etc.) could come together to discuss the various climate and sustainability commitments that their local sporting teams and venues are implementing.

There are still gaps within the evolution and implementation of sport ecology which is why this paper is important - to demonstrate how sport ecology is developing into normative sporting and how selected criteria can further develop into the evaluation of mega-sporting

events to ensure that alignment with climate goals and targets are met for the implementation of future sporting events.

1.3 Research Gap and Objectives

Despite the growth in the academic literature and application of sport ecology, much of the research remains at a conceptual level. There are very few frameworks that evaluate the sustainability performance of sporting organizations and mega-sporting events using consistent measures. Sustainable sport should be more than conceptual in scope, and more attention needs to be given to how sporting organizations are introducing this academic discipline into normative discussions. Since global warming is affecting sports, there must be more attention given to describing and using sport ecology as both a normative and evaluative tool. Sport ecology can evolve into a tool for governance to assess mega-events to promote and ensure sustainability and climate commitments are met.

This research aims to advance sport ecology from a conceptual to a normative framework and evaluative tool. The research will be developing a qualitative and quantitative evaluative framework using four conceptual indicators of: sustainable sporting governance; the carbon footprint; energy used and consumed; and waste generation. The criteria will be applied to the case studies of the Vancouver 2010 Winter Olympics and the 2026 FIFA world cup to assess the validity of the sustainability commitments and the alignment to border climate goals.

The central question in this research is how can sport ecology evolve from a conceptual field of study into a normative and evaluative framework for assessing the sustainability performance of mega-sporting events?

Section 2: Research Design and Methodology

This major research paper and its analysis will utilize a mixed-methods design combining qualitative and quantitative approaches. The qualitative data used will be from sustainability and climate focused documents and reports available to the public consisting of governing documents, policy frameworks, peer-reviewed literature, sustainability reports, and organizational sustainability guidelines. The quantitative approach will be a scoring system within the evaluation framework to assess the sustainability of selected mega-sporting events.

The qualitative approach is appropriate to examine conceptual principles of sport ecology, it can provide the framework into how the advancements can be achieved into both a normative and evaluative sense for mega-sporting case studies, as well as how sporting governance and organizations are addressing sustainability in sport. This approach allows an in-depth study into sport ecology by examining policies, sporting governing structures, and sustainability and climate targets and commitments. This research examines how sustainability initiatives and environmental commitments that are framed, implemented, and potentially communicated within sporting organizations and mega-sporting event sustainability reporting. The qualitative design also contributed to the analysis of sustainability reports, governance documents, and policy frameworks that are developed by sporting organizations. These reports and sustainability guidelines assist in the knowledge expansion of sport ecology concepts. It will provide insights into how environmental and sustainability commitments are structured and how sustainability is incorporated within all stages of a sporting event.

The quantitative scoring system will allow practitioners and sporting organizations to understand how important implementing sustainability initiatives are to reducing overall emissions and aligning with sporting governance goals. It will contribute to how sport ecology

can be advanced beyond a conceptual framework and into a normative and evaluative tool for sporting governance and policy makers. The scoring framework is intended as a comparative evaluation tool, rather than focusing on the absolute measurement of sustainability.

The evaluation table scoring system in the evaluation section of the paper is influenced by sustainability scoring systems such as LEED (Leadership in Energy and Environmental Design) and the sustainability model of the International Organization for Standardization (ISO). This evaluation framework with a scoring mechanism demonstrates how sport ecology criteria can ensure benchmarks are established in both sustainable sporting infrastructure and event management. The ISO version 20121 is a beacon for sustainable event management, which guides organizations to integrate sustainability in all phases of event planning to execution (International Organization for Standardization, 2024). The ISO 20121 is a pivotal resource that pushes events to be more ethical, eco-friendly, and socially conscious, as it follows ESG guidelines and responsibility (International Organization for Standardization, 2024). LEED has different levels of certifications and different ranges of scores. There is a total of 110 points awarded that are grouped into 8 categories that measure sustainability, or green buildings (Green Badger, 2022). The scorecard can be used as a guide, to assist with the decision-making processes within all phases from design to implementation (Green Badger, 2022). Thus, the five point scoring system was selected as it provides a differentiation between levels of sustainability integration while remaining simple and transparent for analysis.

The scores that have been assigned in the evaluation framework are as follows:

1) the presence of sustainability guidelines and sustainable governance structures;

2) the indication or implementation of emission targets, reduction strategies, and key performance indicators;

3) the availability of data from sustainability reports or benchmark targets;

4) the alignment with international sustainability standards; and

5) any other sustainability initiatives that are contributing to sustainability (such as local procurement or sustainability programming).

This scoring methodology helps sport ecology to move from an academic discipline focused on definitions and the implementation of sporting sustainability reports, to an evaluative framework that can help support decision making, policy creation and development, and potentials for mega-sporting event analyses.

Here is a summary table for quick understanding of the scores assigned in the evaluation framework section:

Score	Interpretation
1	Minimal sustainability targets and commitments, weak sustainable sporting governance, and limited data availability
2	Some sustainability initiatives, partial implementation of sustainability targets and goals, and some general sustainability and/or target reporting
3	Moderate amounts of sustainability initiatives with measurable targets and partial alignments with sustainable sporting governance standards
4	Strong sustainability targets, initiatives, and goals, emission reduction targets, and multiple data sources
5	Strong sustainability integration, strong alignments to international standards and climate goals, and public sustainability documents provided

The limitations of this evaluation framework are that the scoring system is interpretive and is dependent upon the availability of publicly accessible sustainability reports and documents. Because this scoring system is based on LEED certification and ISO 20121

standards, the system is not formally concrete. It is a new way of interpreting data both quantitatively and qualitatively to advance the field of sport ecology.

Since FIFA 2026 has recently finished it's matches (July 19th), portions of the analysis rely on projected and forecasted sustainability initiatives and outcomes rather than measurable post-event statistics. Future research could further refine the evaluation framework by incorporating other weighing metrics, environmental impact assessment matrix tools, and additional comparative mega-event case studies.

2.2 Case Study Selection

The research will be using case studies to explore how sport ecology can be shaped and moved beyond normative and conceptual frameworks. The analysis will focus on two megaevents: the 2010 Vancouver Winter Olympics; and the 2026 FIFA world cup. These events were chosen, as they are two examples where sporting governance structures put sustainability and environmental responsibility at the forefront of event implementation and delivery. The Vancouver 2010 Winter Olympics illustrates a historical and past event that incorporated both sustainability and environmental commitments within all stages of the planning process. The 2010 Olympics is an example that is commonly used, as it is an example of how sports were beginning to adapt to sustainability initiatives and climate commitments.

The 2026 FIFA world cup demonstrates the evolution of sport ecology and is a gateway into how sporting events are continually improving on sustainability considerations. This example is a modern example of climate and sustainability implementation at the mega-event stage and is receiving a lot of attention. The comparison of these two case studies will evaluate the effectiveness of the sustainability commitments, how they are implemented, and what are the

outcomes. This will then contribute to the discussion of how sport ecology concepts can be utilized as a policy evaluation tool for future mega-sporting events.

2.3 Evaluation Criteria

Sport ecology has been shaped into an interdisciplinary field that studies the interconnections of sport and the environment (McCullough et al., 2020), while trying to improve sustainability within the sporting sector. Early research primarily focused on the environmental impacts associated with sports, while more recent research has been on how sporting organizations, governing bodies, and mega-events can contribute to climate action, sustainability, and environmental stewardship. Sport ecology has developed into normative and analytical dimensions that provide a foundation for evaluating sustainability in sports.

In a normative sense, sport ecology has established a guide on how sports should adapt to environmental and climate challenges. These include environmental stewardship, sustainability, and the management of natural resources (McCullough et al., 2020). The normative element recognizes the importance of environmental responsibility within sporting governance and policy development. This dimension of sport ecology provides the foundation for assessing whether sporting organizations are implementing sustainability into decision-making, operations, and planning.

Sport ecology is evolving in analytical directions as well. It provides structure for examining actors, institutions, governance, and policies that affect environmental performance in sporting activities (Mallen, 2023). From this sense, sport ecology helps to understand how sustainability initiatives are implemented, monitored, and evaluated. It enables assessments of strengths, opportunities, and areas for improvement.

This study develops four criteria to analyze sustainability within mega-sporting events. The four criteria are: (1) Sustainable Sporting Governance; (2) Carbon Footprint; (3) Energy Used and Consumed; and (4) Waste Generation. These criteria help to describe and analyze the institutional and decision-making processes involved in hosting mega-events.

The first criterion of Sustainable Sporting Governance establishes how sporting organizations establish, implement, and monitor sustainability commitments through their own governing structures and reporting systems. The International Skating Union and the International Olympic Committee are examples of organizations that are measuring their own sustainability performance. Advancing sustainability in sporting governance ensures a foundation for voluntary sustainability reporting and accounting within a universal framework to measure all environmental impacts on sports.

The second criterion is the Carbon Footprint that measures all indirect and direct GHG emissions that stem from sporting operations and events. Included in these are fan and athlete transportation, accommodations, and operational performance at an event. This is a measurable indicator for sustainability reporting and shaping strategies to reduce overall emission generation.

The third criterion of energy used and consumed is key to analyzing the sustainability of energy sources at venues. This includes the use of renewable energy sources, energy efficient design and construction, and operational energy consumption levels. As sports are introducing more renewable energy alternatives and building standards (like LEED), this becomes an important indicator for sustainability within venue operations.

The fourth criterion of waste generation examines how sporting events are managing their waste streams with diversion strategies for both material and non-material items. Material

wastes include those of plastics, foods, textiles, and equipment, whereas non-material wastes include those of noise and light pollution. Sporting organizations are starting to develop more waste management, recycling, and circular economy standards to reduce environmental impacts.

These four criteria thus provide a framework for assessing sustainability within all stages or a sporting event. This framework translates the normative aspects of sport ecology into measurable outcomes that can be used as an evaluation tool for other events. The four criteria hold the analytical perspective of sport ecology, as it examines governing structures, institutional processes, and environmental outcomes that influence the overall sustainability performance of the event. These criteria are the foundation for the case study comparative analysis of Vancouver 2010 Winter Olympic Games and the 2026 FIFA World Cup that is explained in section 4.

Section 3: Development of Sport Ecology Frameworks

Sports and sporting events generate vast amounts of emissions, which reinforces their relevance within climate change discussions. Since the Intergovernmental Panel on Climate Change released its sixth assessment report stating that we must keep our emissions below 1.5 degrees compared to pre-industrial levels (Intergovernmental Panel on Climate Change, 2023), it is imperative that sports take the necessary steps to align with climate goals and sustainability targets. This section will be dedicated to using the four criteria of sustainable sporting governance; carbon footprint; energy used and consumed; and waste generation as representations to analyze and evaluate sustainability of sporting events.

The development of these criteria will provide the foundation for the comparative case study analysis present in section 4. The application of this framework to the Vancouver 2010 Olympics and the 2026 FIFA World Cup will demonstrate the evolution of sport ecology through both governance and environmental performance across two significant international mega-

sporting events. This demonstrates that sport ecology can be used as both a normative and analytical tool for the implementation of future mega-sporting events.

3.1 Sustainable Sporting Governance

Sustainable governing structures are important to consider as it determines how certain environmental impacts (such as the carbon footprint, energy used and consumed, and wastes generated) are regulated, managed, and reduced. Within the context of sport ecology, the sustainable sporting governance concept refers to the policies and decision-making processes that guide sustainability practices and initiatives across both sports and sporting events (Government of Canada, 2025). Including sustainable sporting governance as a criterion, sport ecology can be moved beyond the outcome-based assessments and into an evaluative framework for policy makers.

The government of Canada recognizes the importance of sustainability and sports. They acknowledge that there is a gap within reporting that holds sporting governance accountable for emissions. Even if many organizations are starting to introduce sustainability strategies, they are often voluntary and lack standardized reporting frameworks, which can raise concerns over greenwashing, transparency, and accountability. The government of Canada states that there has been little to no effective monitoring of compliance in sports under existing governance rules (Government of Canada, 2025). Other sporting governing bodies such as the International Olympic Committee, Canadian Olympic Committee, The International Skating Union, and Green Sports Alliance have created sustainability and climate benchmarks for their own sports to bridge the monitoring compliance gap. Using sustainable sporting governance as a comparative case criterion for the Vancouver 2010 Olympics and 2026 FIFA World Cup will provide conclusions

of governing structures, reporting practices, and accountability mechanisms that can influence overall sustainability outcomes.

The Canadian Olympic Committee is a sporting governing body that helps to shape the delivery of sports across Canada. As a sports leader in Canada, they recognize that they have a role to play in pursuing climate action and reducing their carbon footprint, as critical actions need to be taken to preserve sporting environments for future generations (Canadian Olympic Committee, 2025).

The COC is achieving sustainable sport through the adoption of a strategic climate action plan to translate climate goals to climate actions. Commitments to translating these goals into action include reducing the overall carbon footprint of emissions by 50% by 2030, achieving net zero by 2040, and introducing a sustainability mindset to all, so that the sporting community across Canada can become climate actors by transforming the way sports are delivered (Canadian Olympic Committee, 2025).

The International Skating Union which is the international sporting governance of winter skating sports (figure skating and speed skating) has created three documents to ensure that events are conducted with both sustainability and climate commitments. The documents created were the ISU Vision 2030, which discusses how the skating community can commit to climate targets and sustainability initiatives, while maintaining growth and excitement for the sport (International Skating Union, 2023); the ISU sustainability strategy includes ESG framings of evaluation in both figure skating and speed skating events (International Skating Union, 2023); and the ISU sustainability guidelines which implement sustainability standards for the operation of events. The documents recognize the sport of skating is being jeopardized due to ice melts that are threatening outdoor arenas and access to natural ice, with urgency surrounding reducing

carbon emissions and conserving water, so that both indoor and outdoor rinks will continue to operate for future generational use (International Skating Union, 2023).

The ISU Vision of 2030 highlights what skating sports can do to achieve emission reduction goals, while aligning with climate targets. This document has 12 steps that spell out GO ISU (International Skating Union, 2023). Each letter in the GO ISU stands for growth, opportunity, innovation, safeguarding, and unity (International Skating Union, 2023). Within these steps, the ISU discusses environmental sustainability, where they commits to sustainability via the creation and implementation of their own sustainability mission and vision, commitments to the Sports for Nature Framework to help achieve nature-based solutions across skating sports and provide guidelines on both building and maintaining eco-friendly ice rinks and provide sustainability manuals for event organizers (International Skating Union, 2023).

Finally, the ISU has also presented a document referring to 5 eco-tips which include listed objectives for ice rinks, nature, transport, waste, and food (International Skating Union, 2023). One major eco-tip is for skating events to use renewable energy sources and innovative technologies (International Skating Union, 2023). This is important, as renewable energy adoption will encourage further reductions of emissions and align with broader climate targets. Other notable mentions of the eco-tips are reducing carbon footprints, prioritizing low carbon transport, reductions in single-use plastics, and reducing, reusing, and recycling materials (International Skating Union, 2023).

The International Olympic committee has been committed to sustainability since the 1990s for both Summer and Winter Olympic Games. These initiatives and commitments have been increasingly apparent since the Vancouver 2010 Olympics and have made their way into both the Milano Cortina Winter Olympic Games and the 2026 FIFA World Cup. Their efforts are

aligned with an aim to minimize their carbon footprint and to maximize positive influences across social, environmental, and economic spheres (International Olympic Committee, n.d).

The IOC's climate action framework follows three main pillars of reduce, compensate, and influence (International Olympic Committee, 2021). In October 2021, the IOC committed to reducing both direct and indirect emissions by 30% by 2024 (this was achieved) and 50% by 2030 and to compensate more than 100% of residual emissions for the environment. (International Olympic Committee, 2021). The International Olympics committee also releases sustainability reports, where they are committed to comprehensive and transparent reporting on their sustainability activities, which are aligned with the highest global standards and goals (International Olympic Committee, n.d.).

The latest sustainability report released from the IOC was from 2020-2024. Within the report, there were mentions of Tokyo 2020, Beijing 2022, and Paris 2024 games (International Olympic Committee, 2025). Highlights included the Tokyo 2022 Olympics having 99% of procured items that were reused or recycled and showcased hydrogen for powering of the Olympic village, Beijing 2022 having natural carbon dioxide refrigeration in ice venues, and Paris 2024 with venues operating with 100% renewable energy sources and a total 54% reduction in total carbon emissions (International Olympic Committee, 2025). The IOC releasing public sustainability reports is an important piece within sustainable sporting governance.

The Green Sports Alliance is a collaborative governing network that is advancing sustainability targets and initiatives across the sporting industry. They are known as the largest, most influential, drivers of environmental and social responsibility across the global sporting industry (Green Sports Alliance, n.d.). They host the Green Sports Alliance Summit, Play to Zero, Green Sports Day, and various educational materials (Green Sports Alliance, n.d.).

Play to Zero is an important framework released by the Green Sports Alliance. This sustainability toolkit is for Green Sports Alliance members to guide progress towards net zero energy, net zero water, zero waste, and a resilient future (Green Sports Alliance, n.d.). The program offers a benchmark, where sporting organizations can transform their sustainability efforts into measurable impacts, a roadmap, and targets that are compared against other industry leaders to help identify opportunities for improvement. The framework engages spotting community members by offering a space for climate education and awareness to continually engage fans to want to get involved into sustainability (Green Sports Alliance, n.d.).

The Green Sports Alliance is pushing for sustainable sporting governance in the sporting realm. Dozens of stadiums, professional sports teams, and universities have signed on to the Green Sports Alliance to commit to the UN Climate action principles to reduce climate impacts, educate for climate action, and promote environmental stewardship and sustainable and responsible consumption (Crawford, 2020). The Green Sports Alliance is advancing sports in a sustainable direction, as it is an organization that is environmentally focused with members around the sporting world that are committed to creating awareness and change for sustainable sporting (Crawford, 2020).

Together, these organizations demonstrate various approaches to sustainable sporting governance. The Canadian Olympic Committee emphasizes strategic climate commitments, the International Skating Union focuses on operational guidelines for sustainable event delivery, the International Olympic Committee strengthens accountability measures through reporting mechanisms, and the Green Sports Alliance promotes collaboration and voluntary benchmarking opportunities across the sporting sector.

Sustainable sporting governance represents an important criterion because differences in governance structures, accountability mechanisms, and reporting standards help to explain why sporting events achieve different sustainability outcomes.

However, there must be a transition from voluntary initiatives and reporting standards to mandatory ones, so that all sporting events and organizations will align with climate commitments and will continually reduce global emissions and greenhouse gases. Addressing these gaps is crucial for all sports to align with global and climate targets.

3.2 The Carbon Footprint

The carbon footprint is a crucial indicator for understanding the environmental implications of sporting activities. This measurement helps to understand the sources of emissions that are associated with sporting infrastructure, transportation, and fan engagement.

The sports sector is responsible for approximately 350 million tonnes of total carbon emissions per year (Sharma, 2023). The carbon footprint is composed of either direct (scope 1 and 2 emissions) or indirect (scope 3 emissions), and are attributed to an organization, activity, product, or life cycle (Wilby et al., 2022). Scope 1 emissions are known as those that are from owned and controlled sources (such as fugitive and combustion emissions) and Scope 3 are those that are all indirect emissions (such as air travel) (Bernoville, 2025). For example, the Rio Olympics produced 3.6 million tonnes of carbon dioxide into the atmosphere, as more than 500,000 individuals travelled to the games. (Orr, 2024). For further context, the carbon footprint of travel by sporting fans accounted for more carbon and carbon equivalents than 26 countries with a population of around 10 million (Orr, 2024). With an individual average footprint of about 18 tonnes of carbon (Orr, 2024), the carbon footprint for individuals attending and participating

at the event demonstrates the urgency of climate change and the importance of emission reductions.

The FIFA World Cup in Qatar had roughly 5 billion people globally watching both in person and online, releasing an estimated 3.63 million tonnes of carbon dioxide equivalents (Sharma, 2023). These emissions came from scope 1 and 3 emissions relating to travel (1.9 million) and accommodations (728, 403) (Sharma, 2023). In 2019, the carbon footprint of a Formula One race was estimated at 256, 551 tonnes of carbon dioxide equivalents. The origins were logistics (movement of sporting materials and equipment), the functioning of the cars in the race, and travel of participants (Sharma, 2023). These examples demonstrate the impact of certain mega-sporting events on carbon emissions.

However, sports don't only exist at the mega-event level, but also at a local and grassroots level. Local and grassroots level sports are harder to quantify in emissions but are attempted to be quantified by provincial or country reporting standards. For example, a study that was conducted in Germany in 2018 demonstrated that for all individual sporting activities, the carbon footprint was 1006 Kg, whereas individuals participating in team sports was 514 Kg (Wicker, 2018). Another example of a local assessment of the sporting carbon footprint comes from professional football games in Austria (Rapid Vienna- largest football club in Austria). This study provided data from 3317 responses, where the calculation of the total GHG emissions at a home game was 99,548 kg, or 6.0 kg per spectator (Herold et al., 2024). Other findings from this study concluded that 42% of spectators arriving by car released 72% of GHGs and 53% using mass transit emitted 27% (Herold et al., 2024). The carbon footprint from sports that arise from fan engagement and participation can vary considerably and can be shaped from various factors, as listed in the examples provided.

The carbon footprint of sports and sporting events extends further than just the total emission footprint from local and mega-events, or from the footprint of travel and fan engagement. The emissions that arise from venue construction are also important to note. The emission releases are due to the different materials that are used, as different materials generate different levels of carbon emissions (Xuan et al., 2025). For example, at the mega-event level, the construction is more than just at the sporting venue level, but at the accommodation level for all members. At the Olympic games, you need to construct athlete villages, appropriate sporting infrastructure to house certain sports that are not practiced in the area, and even roads that connect the spaces (Prince, 2021). The intent of the sporting governance and the infrastructure implementation is to encourage revitalization of the area, but they often end up leaving an environmental mark (Prince, 2021).

The Olympic village at the Rio Olympics, for example, generated 1.6 million tonnes of carbon emissions from the construction of the various accommodations. The preparation for the infrastructure development for the 2014 World Cup held in Brazil generated 1.4 million tonnes of carbon dioxide emissions (Prince, 2021).

Sporting venues are beginning to consider sustainability, through the LEED certification process and from the government of Canada through the Green and Inclusive Buildings (GICB) program (Government of Canada, 2024). The support of the GICB is through the plan's first pillar on the reduction of greenhouse gas emissions, increasing energy efficiency, and helping to develop higher resistance to climate change and its associated effects (Government of Canada, 2024). The aim is to retrofit existing buildings or construct new ones that have an overall goal of helping Canada move to net-zero by 2050 (Government of Canada, 2024).

LEED stands for leadership in energy and environmental design. A point system is used to track the environmental aspects of buildings to make them green and sustainable (Anderson, 2024). The LEED certification process is important aside from just environmental design. It also improves ESG credentials (Anderson, 2024). For example, The Toronto Pan Am Sports Center is one event space that hosts mega-sporting events that is LEED certified. The designation of the LEED standard was rated at a gold level for the TPASC center as of 2009 (Canadian Green Building Council, 2020). The TPASC center is home to recreational spaces and the Canadian Sport Institute of Ontario, where amateur, professional, and recreational athletes come together to practice sports. Highlights of this building includes recyclable materials used in construction (30%), 100% of the property's irrigation needs are met using non-potable rainwater. There are 1,854 solar panels, and LED lighting (Canadian Green Building Council, 2020).

The City of Whitby is another example of the completion of a sustainable sporting venue (2026). This venue will be an accessible net-zero carbon facility after federal investments of $25 million from the GICB program (Government of Canada, 2024). The Cowan Center in the City of Kitchener is known to be one of the most environmentally sustainable recreation facilities in Canada, as it is pursuing certification under Canada Green Building Council as a Zero Carbon Building Standard Design, which is the highest level of certifications for zero carbon buildings in Canada (City of Kitchener, n.d.). Highlights of the sustainability aspects of this building include a geothermal cooling and heating system and solar panels, with features that will reduce roughly 43 tonnes of carbon annually (City of Kitchener, n.d.).

To further reduce emissions within sporting spaces, the use of both green roofs and living walls can provide this opportunity. Since both living walls and green roofs are created from the use of various plant species, they can sequester carbon emissions through plant biomass and

substrate. There have not been a lot of studies conducted on the effectiveness of how much carbon is sequestered through living walls (Charoenkit & Yiemwattana, 2016). The Toronto Pan Am Sports Center has a green roof that covers roughly 5,632 metres squared (30%) of roof space (Canada Green Building Council, 2020) but does not disclose how much carbon is being sequestered from the roof. This presents an opportunity for the sport ecology realm to add both green roofs and living walls into sporting event spaces. Not only will it sequester carbon but also provides an opportunity for sports to document and record the benefits that these are important features that should be included.

A personal example comes from an international figure skating event hosted by the International Skating Union in Luxembourg. Aside from the emissions associated with air travel to the venue, this event aligned with the sustainability strategy from the International Skating Union and committed to carbon footprint reductions. The event space encouraged the use of public transit as the only method of transportation to-and from the event. This reduced the overall carbon footprint and encouraged sustainable modes of transportation. The city center was also a car free zone, where only pedestrians and foot traffic could occur to access the spaces. The accommodation space for athletes and other stakeholders was in proximity to various training networks and to the city core, so that all sporting community members would be working together to reduce the overall carbon footprint of the event. More sporting events should follow suit to this example, as it is a model example of how sporting events can and are molding to the normative framework of the carbon footprint of sport ecology.

The carbon footprint criteria show how sport ecology is evolving through emissions accounting, renewable energy transitions, and sustainable venue design and operation. LEED certification demonstrated that renewable energy adoption has reduced venue-based emissions

and examples from sporting organizations, mega-sporting, and international figure skating events have shown that appropriate measures are being taken and implemented to reduce the overall carbon footprint. For sports to truly align with global climate targets, further mandatory carbon accounting measures must be implemented so that more sustainability reports can be generated.

3.3 Energy Used and Consumed

The energy used and consumed at sporting events can be linked to the total carbon footprint but is a standalone criterion that can both explain and shape the framework of sport ecology. Facilities that host major sporting events contain thousands of spectators and require energy sources from electricity for lighting, HVAC (for heating and cooling the internal environment), and broadcasting equipment and services (Owens, 2023). Energy used and consumed at sporting events fall under Scope 2 emissions, which is an emission source that is not generally reported on nor focused on within sport ecology research. Scope 2 emissions are indirect emissions that fall into the category of the consumption of purchased electricity, steam, heating, and cooling services, from a utility provider (Bernoville, 2025).

The National Football League (NFL) and Major League Baseball (MLB) consume energy in large amounts from concession stands, lighting, HVAC, broadcasting operations, and security systems (Hollister, 2026). It is estimated that the average electricity that is used per NFL game is equivalent to roughly 10,000-20,000 kWh and has an estimated use per season consumption of 515+ million kWh (Hollister, 2026). The MLB operates its events for half the year, which creates a long-term energy footprint, with the average electricity used per game is 10,000-20,000 kWh with an estimated use per season of 20-30+ million kWh (Hollister, 2026). Not only do outdoor sporting facilities and major event spaces require a lot of energy to operate during peak demands, but so do indoor sport as well

Winter sports that are performed inside arenas (such as figure skating, hockey, and speed skating) also require a large amount of energy. In 2014, Statistics Canada generated a report accounting for the energy used and consumed within arenas across Canada, named the Survey of Energy Consumption of Arenas (Statistics Canada, 2014). The results of the survey indicated that across a total of 2,182 arenas, roughly 17.2 million gigajoules of energy were used and consumed (Statistics Canada, 2014) with suggestions that Ontario arenas are those that require the most energy to operate. Arenas across Ontario accounted for roughly 40% of total energy consumption, with the highest representation of regional energy of 1.64 Gj per meter squared of ice facility coverage (Statistics Canada, 2014). This data demonstrates that all operational procedures in arenas (lighting, heating, cooling, etc.) are energy intensive.

Broadcasting equipment used at sporting events is another aspect to large energy consumption patterns. Broadcasting equipment consists of cameras, microphones, speakers, jumbotrons, drones, and cabling to connect viewers to live streaming of events. Streaming services are the most energy intensive, as they require extensive data from data centers for processing and transmission, which adds large amounts of energy consumption (Zandvliet, 2026). For example, streaming a one-hour video in Europe is equivalent to 55 grams of released carbon emissions (Zandvliet, 2026). The concept of broadcasting and the release of quantified data within sporting events is another gap and opportunity for sport ecology's conceptual and normative framework to explore.

A shift to renewable energy by stadium operators would serve the sporting community by reducing the demands on local energy grids and reducing the potential of other environmental externalities (Wanless et al., 2024). The Toronto Pan Am is a prime example of energy savings. 1,854 solar panels were installed on the roof which can generate up to 593 kW per hour, which in

turn reduces energy consumption by roughly 10-15%. The combination of LED lighting and renewables reduced energy demand by 80%, and geothermal energy sources reduced water and energy demand by 40% (Canada Green Building Council, 2020).

More renewable energy sources at sporting stadiums have been incorporated to reduce energy demands. The MetLife stadium has 1,350 solar panels arranged into a solar ring to power LED lighting, display systems, and everyday electricity needs (Wanless et al., 2024), Wind power and the incorporation of wind turbines at the Lincoln Financial Field (Wanless et al., 2024), and hydropower at Ron Tonkin field uses an Inpipe hydropower system that generates energy from the communities water pipe to power the stadiums lights, concession stands, and electric vehicle charging stations (Wanless et al., 2024). These examples demonstrate how sporting venues and operations are becoming normative with energy reductions.

Green roofs, living walls, and building-integrated photovoltaics can further reduce energy demands. Living walls are passive techniques to improve building energy performance, where significant amounts of heat can be prevented from entering and being trapped, which results in reduction of energy for both heating and cooling services (Charoenkit & Yiemwattana, 2016). For example, the green facades produced by both green roofs and living walls influence their thermal properties by producing a shading effect, which in turn, reduces solar radiation that enters the building envelope (Charoenkit & Yiemwattana, 2016). Through the shading effect, a reduction in heat transfer occurs from both the absorption and reflection of solar radiation by the plants and substrate. They can also affect cooling further by dissipating heat through the loss of water by transpiration and evaporation (Charoenkit & Yiemwattana, 2016). The incorporation of green roofs and living walls into the design and construction of sporting venues, will reduce energy demands, especially through heating and cooling services.

Building integrated photovoltaics are a renewable energy alternative that can be used within building envelopes, and in combination with the green roofs and living walls to further reduce energy demand. Building envelopes play a significant role in energy consumption, and the introduction of building-integrated photovoltaics within the building's skin will reduce energy demand (Farghaly & Hassan, 2019). BIPV systems not only provide reductions in energy consumption but introduce environmental benefits such as the decreased usage of fossil fuels and overall carbon emission release (Farghaly & Hassan, 2019). For example, a BIPV unit that is installed with a total area of 508.08 metres squared with the cell efficiency of 20.8%, energy reduction can be upwards of 7% (Farghaly & Hassan, 2019). The implementation of BIPV in combination with green roofs and living walls is an ideal combination to further reduce energy demands.

Energy used and consumed moves beyond simple reductions in energy use. It is an important criterion as it captures the operational systems that help to achieve environmental performance. From renewable energy integration into sporting venues, living walls, green roofs, and building integrated photovoltaics, reducing energy intensity is integral to achieving sustainable sporting. Minimizing energy consumption across all interconnected dimensions of sport ecology is critical to advancing and aligning with climate commitments such as net-zero and Paris Agreement targets.

3.4 Waste Generation

Sports and sporting events generate large amounts of wastes from all members present from event planning to execution. These wastes include plastics and single-use plastics, food, textiles and equipment, and noise and light pollution. This section will demonstrate how the

concept of waste generation is shaping normative sport ecology and how proper waste management at sporting events is adding to circularity.

Plastic wastes from sporting events exist as single-use plastic bottles and in food and beverage packaging materials. Plastics are used around the world, as it is a cheap and versatile material to produce (International Olympic Committee, 2026). Globally, we have produced a total of 9 billion tonnes of plastics since the 1950s, where roughly 79% is still left in our environments, polluting landfills and littering the oceans and countrysides, where 50% of the plastic wastes are single use in material (International Olympic Committee, 2026). Many sporting events that are hosted at large stadiums and arenas use thousands of plastic cups, bottles, and wrappers to serve fans and all participants (Schulze, 2025). With many fans and individuals present at a sporting event, the volume of plastic wastes can be enormous, and can end up in our landfills if not properly disposed of.

Aside from plastics served at an event, synthetic turfs can cause plastic wastes as they are released in the form of microplastics. The synthetic turfs that are used for soccer games and matches release tiny plastic fibers when they break down from pounding of the players feet while running, where they break off from the turf and get into our water, storm drains, and landfills (Schulze, 2025). Once the plastic materials end up in both our waterways and landfills from the plastic release of the artificial turf, the process of breaking down the plastic materials causes emissions to rise, as warming temperatures from the sun breaks it down and increases the risk of bacterial issues, microplastic release, and potential algal blooms (Mallen, 2023).

The 2015 Canada Winter Games generated 16% of plastic wastes and 55.7 tonnes of plastic were produced from the 2018 World Cup (Zafari et al., 2025). For further context into the connections to rising emissions and climate change, 99% of plastics are made from fossil fuels,

with an estimated release of carbon accounting for 3.8% of total greenhouse gas emissions (International Olympic Committee, 2026). These examples demonstrate that plastic waste is strongly correlated to sports, rising emissions, and waste generation.

The International Olympic Committee (IOC) has released a policy document that discusses the plastic wastes that are generated from sporting events. The document is called Plastic Game Plan for Sport (International Olympic Committee, 2026). This document shares the importance of reducing the plastic footprint via proper final disposal. It describes 5 different steps to action which includes reduce (working with suppliers to redesign or remove packaging altogether), reuse (choosing reusable materials - such as cups, plates, cutlery, and reusable bottles), replace (alternative materials), redesign (proper recycling), and remind (spread the awareness to encourage other community members to act sustainably) (International Olympic Committee, 2026). Since this organization has released the policy document it is in effect at every Olympic Games, other sporting organizations should implement their own plastic sustainability strategy. If more sporting organizations implement a reporting standard or policy document that is in effect at every event, then sports will become sustainable and action will be taken to reduce our overall sporting plastic footprint.

Food waste is not only a concern for the sporting industry, but is also a global concern, as there can be waste from production to consumption to final disposal. These wastes can be avoidable or unavoidable, originate from organic foods, and can be discarded in beverage form. Total food wasted in Canada is roughly equal to 47% of purchases (Second Harvest, 2024). When discussing sports, food and beverages wastes are produced in large quantities, as they play a vital role in helping engagement levels and experiences for attendees at sporting events (Ko et al., 2025). The sporting industry is connected to the tourism sector, with data showing that 40%

of foods and beverages that were produced on site are wasted, where a growing concern of individuals (50%) are recognizing the importance of food and beverage wastes at sporting events (Ko et al., 2025).

The Tokyo Olympics is an example of a mega-sporting event that generated food and beverage waste in large quantities. This mega-event took place in 2022 and wasted 300,000 meal boxes that were to be distributed between coaches, athletes, staff, officials, operators, etc., which resulted in an economic loss of $5.6 million (Ko et al., 2025).

Scotiabank Arena has overarching sustainability and food waste goals. This venue recognizes that food wastes are generated in large amounts. In 2009 the venue diverted over 500 metric tonnes of organic materials to surrounding partnered farms, where the organic wastes were converted into clean soil (Maple Leaf Sports & Entertainment, 2026). Scotiabank Arena also achieves food waste and food diversion rates by partnering with Second Harvest, where food that was uneaten was donated as surplus (Maple Leaf Sports & Entertainment, 2026). For further specifics, the Toronto Maple Leafs have helped to divert food waste since 2009 to roughly 74%, with 60% diversion rates of food wastes monthly (Johnston, 2025). This not only addressed the concerns of food waste, but also food insecurity that can result from the improper practice of diversion strategies.

Green Sports Alliance is helping other major sporting teams to address food wastes. This organization suggested the National Hockey Leagues (NHL), National Football Leagues (NFL), Major League Baseball (MLB), and Major League Soccer (MLS) conduct lifecycle assessments on how food wastes are impacting sporting venues and beyond. The methodologies from this suggested would include both design and portion control to procurement and sourcing, improving kitchen efficiencies with the availability of on-site composters, food recovery,

donation, and processing strategies (Johnston, 2025). The manager of public affairs for the NHL stated that they are the first professional sporting league to mandate a food donation service within its 30 franchises (Johnston, 2025). Sporting organizations should adopt standardized food waste diversion targets with United Nations Sustainable Development Goals as a guiding framework. to address the complexities of food wastes generated from sporting events. Despite these initiatives food waste in sports remains underreported and inconsistent, voluntary, and not regulated.

Textiles and sporting equipment waste are another waste stream in sports. Textiles and sporting equipment wastes are generated from daily training practices to competition day(s). As a former National and International figure skater for Canada, the context of textile and equipment wastes are not thought of and assessed when discussing the interconnections to the environment. Within figure skating, there are various textiles and equipment wastes. These include the use of tape to keep laces and boot stability in place when training or competing, disposal of broken laces, wear and tear of helmets, Swarovski crystals from outfits that have fallen off from use, broken down boots (discarded after broken down completely), and athletic apparel that has been damaged from daily use or from accidents. These wastes create and shape the sport of figure skating and its functional equipment sources, as they are formed from fossil fuel-based products and decompose and release microplastics into the surrounding environment.

Textile and equipment waste in figure skating contributes indirectly to certain environmental pressures, like greenhouse gas emissions that are associated with both the production and disposal of synthetic materials. The reason as to why figure skating uses primarily fossil fuel-based products and generates these types of wastes is because the materials use plastics which provides affordability, adaptability, and durability (Schulze, 2025). Little

research has been examined in sport ecology literature regarding figure skating and textile and equipment wastes.

The sport of soccer in the UK is one of many sports that generate large amounts of these wastes. For example, the UK discards roughly 2.45 million tonnes of textile wastes from Liverpool and 1.95 million tonnes from Manchester United soccer teams, where a third of this ends up in either landfill or incineration (Ghosh, 2024). The project labelled Game Changers is an awareness campaign that is focused on the hidden costs and problem of athletic apparel wastes (Ghosh, 2024). The project works with local community members and eco-conscious suppliers to transform certain athletic apparel surpluses into reusable products (such as tote bags or backpacks). The aim of Game Changers is to inspire collective action to reduce the overall environmental impact of textile wastes (Ghosh, 2024).

Since athletes need running shows for dryland training purposes, shoe brands are those that are at the forefront of the awareness campaign. For example, the Swiss company named “on” (also known as cloud on shoes) are designing shoes that can be reused and recycled. The specific shoes that are beginning to use little materials and increase reuse rates are called Cyclon trainers. They are created from biomaterials that are naturally occurring (such as various forms of beans) (Collacott, 2024). Since they are made from natural materials, they can be composted and biodegraded back into the soil. Thus, these examples provide insights into how the normative framing of sports and textiles are entering the sporting landscape conversations.

Noise and light pollution should be included within the waste generation as non-material sources. Noise pollution has numerous health impacts. These include hearing loss, elevated heart rate and blood pressure, insomnia, irritability, stress, and reduced workplace productivity (Rocha et al., 2025). A sporting stadium that is close to communities can have benefits of quick access to

entertainment, consumption of amenities, and can have aesthetic properties (Hyun, 2021). However, there are downsides to having a large sporting venue in proximity to housing developments, or in areas that are next to natural spaces. Noise and congestion are main costs brought from the sporting facility (Hyun, 2021) and disruptions to habitats and biodiversity occur from both the associated noise and light pollution, which can affect migration and mating patterns.

Light spill is a term that explains the connections of environmental and social implications of light pollution. Light spill (or light trespassing) happens when sporting venue lights send illumination outside of a specified area. This means instead of concentrating light on the specific sport or event space, light beams produce stray beams that are projected into the night sky (skyglow), negatively affecting the neighborhoods, wildlife, and surrounding properties (Thomason, 2025).

In South Korea (Metropolitan city of Gwangju), there was a restoration project that converted an older baseball stadium into a newer updated one (Hyun, 2021). This stadium was restored directly less than 400m from an urban settlement of 914 homes (Hyun, 2021). The downside of the proximity to this venue was that it forced various property owners to file a complaint for noise and light pollution against the baseball team, only a year after opening (Hyun, 2021). NASCAR produces sound levels that are 900 times higher than the allowable daily noise occupation, which is normally only around 85 decibels (Anzola, 2023). This sport also provides various sources of light, as the races that are held in the evening contribute to skyglow and various light beams. Stadium floodlighting that is used for nighttime broadcasting in events like NASCAR contribute to light pollution, especially from skyglow and light trespass.

A company called DarkSky International is addressing light pollution and its effects on all sporting community members (Jaco, 2025). It is a sports lighting program that was launched in 2018 to implement rigorous light control standards, with focus on LED lighting (Jaco, 2025). This company helps to improve lighting efficiencies that includes remote scheduling and dimming of lights to conserve energy, protects wildlife with lighting services that are designed to avoid disrupting the natural rhythms of plants and animals, and adheres to lighting regulations with reduction of neighbourly complaints at top of mind (Jaco, 2025). Since this example demonstrates how lighting services like DarkSky International are addressing light pollution, then it should be mandated that all outdoor fields implement technological advances like this one to conserve energy and reduce light pollution spills. Noise pollution is less documented and reported on than light pollution. This should be included in a list of important factors that create waste generation, as they are non-material and can provide negative effects to individuals. According to the WHO (World Health Organization), exposure to sound levels of 80 dB or higher can produce negative health effects, such as hearing loss (Baghan, 2022).

Waste generation and the associated environmental externalities within sports goes beyond visible material sources but connects to non-material sources as well. While food waste, plastic waste, and textile wastes represent large material waste streams, the management of these are inconsistent and remain focused on diversion rather than both diversion and prevention. Nonmaterial wastes tend to be overlooked even if there are significant impacts on human health and biodiversity. This section thus represents a potential limitation within the framework of sport ecology, where focus is on direct emissions, and not indirect emissions.

As shown throughout this section, initiatives by sporting organizations and governing bodies demonstrate the potential for more sustainable practices, yet are still voluntary,

fragmented, and not standardized. A more comprehensive approach is required, which includes circular economy principles, the incorporation of both material and non-material waste streams, and stronger alignment with climate goals and sustainability targets. Addressing these gaps is essential to moving sport ecology forward to ensure that sports contribute meaningfully to long-term environmental and climate sustainability.

Section 4: Sport Ecology as an Evaluative Framework and Mega-Event Case Studies

This section applies the evaluative framework that was developed in sections 2 and 3 to two international mega-sporting events of the Vancouver 2010 Olympics and the 2026 FIFA World Cup. Using the four criteria, this section will introduce how all stages of an event can implement and execute projected or expected sustainability initiatives.

Applying this framework to these case studies will allow a comparison of sustainability of each event, while identifying progress and opportunities for future improvement. The evaluative framework helps to assess environmental commitments that are reflected from governmental and institutional forces, leading to potential measurable environmental outcomes. The comparison of these events demonstrates how sport ecology can be implemented as an evaluative framework to support future sustainability initiatives and decisions. It also illustrates how sustainability governance and environmental performance have been received between Vancouver 2010 and FIFA 2026. This will help to highlight the increasing implementation of sustainability initiatives and programming of future international mega-sporting events.

4.2 Case Study Summaries

The Vancouver 2010 Winter Olympics was one of the first mega-events to be committed to sustainability in all event processes, as it aligned with the growing attention and concerns from the International Olympic Committee over climate impacts and sports (Holden et al., 2008). There was a total of 17,273 volunteers, a total of 906,907 Gj of energy used, 35,059 tonnes of carbon dioxide equivalents released, and roughly 62 sustainability initiatives set in place (Vancouver Organizing Committee, 2010). This mega-sporting event was committed to sustainability by managing the social, environmental, and economic impacts and opportunities in hopes of producing long-lasting benefits both locally and globally, especially from the monitoring and compliance of environmental assessment standards for venues, villages, and facilities (Vancouver Organizing Committee, 2010).

The governance structure consists of reporting standards for accountability and transparency, as well as an ESG based corporate sustainability policy which included roughly 34 key performance indicators (KPIs) (Vancouver Organizing Committee, 2010). Notable achievements in ESG aspects included the launching of a carbon offset program (where targets of 15% in emissions reductions, via the offsetters 2010 carbon legacy portfolio), the use of 100% renewable energy technologies across venues (through LEED certifications and the use of electrical grids), climate action and awareness via public signage and advertisements, and the diversion of almost 77% of wastes from landfills (Vancouver Organizing Committee, 2010). This event also incorporated social aspects, such as the distribution of roughly 5,000 tickets to inner-city and Indigenous communities (Vancouver Organizing Committee, 2010) to make the games as accessible and affordable as possible. Thus, the Vancouver 2010 Olympics is the pioneer to

introducing sport ecology concepts into a shifting normative and evaluative lens, where all major games proceeding this have continued to implement sustainability targets and measures.

The FIFA World Cup is known to be the biggest single-sporting event in the world (Fédération Internationale de Football Association, 2025), aside from the Olympic Games, and has implemented sustainability initiatives since the FIFA World Cup of 2014 that was held in Brazil. The 2026 FIFA World Cup differs from the Vancouver 2010 Olympics, as it represents a forward-looking and complex sustainable model of mega-events. This event is forward looking, as it is the first event in 90 years where matches will be held across Canada, the United States, and Mexico (Fédération Internationale de Football Association, 2025). The sustainability initiatives that are embedded in this event speaks to climate change, human rights, diseases, and disabilities, and is aligned with both the International Organization of Standardization (International Organization of Standardization, 2024), and the United Nations Sustainable Development Goals, where climate and sustainability targets and benchmarks are the central component to how FIFA operates (Fédération Internationale de Football Association, 2025). This mega-event emphasizes the sustainable sporting governance processes by requiring cities to implement their own environmental plans, develop greenhouse gas inventories, and adopt circular economy principles (Fédération Internationale de Football Association, 2025). However, concerns could arise over proper documentation and reporting, as different host cities might have different priorities and/or benchmarks, even if FIFA has developed an environmental forum for communication and focal points for host cities (Fédération Internationale de Football Association, 2025). Since this event has not occurred, the sustainability and climate performance remains at a suggestive and qualitative level, rather than quantitative, as there are no sustainability reports nor measurable targets and data sets.

4.3 Cross-Case Evaluation Table and Analysis

The evaluation table below represents the summary of a cross-case comparison of the two mega-event case studies of Vancouver 2010 and FIFA 2026. This table demonstrates how the sport ecology criterion of sustainable sporting governance, the carbon footprint, energy used consumed, and waste generation, can be used as an evaluative tool for policy makers and sporting governance for the implementation of both current and future sustainable mega-events. This table is demonstrating both quantitative and qualitative results that have been translated into a scoring system, which was outlined in the methodology section. The section following the table will be describing how each score was developed according to the sport ecology criterion being measured.

Criterion	Vancouver 2010 Winter Olympics	Score (1-5)	FIFA 2026 World Cup	Score (1-5)

Sustainable Sporting Governance	- ESG pillar system and sustainability governance model creation - 34 Key Performance indicators - Corporate Sustainability Policy - Environmental assessment compliance for venues, villages, and facilities - Reporting standards and signage for widespread climate action and awareness	**4.5**	- Alignment with International Organization for Standardization (ISO 20121) - Alignment with the UN Sustainable Development Goals for measurable targets - ESG pillar system model - Environmental Forum for all host cities to connect and track environmental plans - Develop a programme to support and contribute to climate action projects	**4.0**

Carbon Footprint	- 35,059 tonnes of direct emissions - 268,000 tonnes of indirect carbon equivalent emissions - BC clean energy technologies to offset emissions - Launching of Carbon management program (15% reductions) – Carbon Offsetters - 62 sustainability innovations - International GHG protocol for compiling inventory of carbon emissions	**4.0**	- Create and develop a GHG inventory - Procurement of products that lower overall carbon emissions - Increase fan use of mass transit and low emission vehicles in FIFA fleet - Increase cycling or walking from accommodations to venue spaces	**3.0**

Energy Used and Consumed	- 906,907 total Gigajoules - 100% renewable energy use and integration via electricity grids - LEED certification for venues (minimum silver) - Improved operational performances via energy efficiencies	**4.5**	- Monitor and support the achievement of green building standards (LEED) - Identify projects that increase energy efficiency and the use of renewable energy sources	**3.5**
Waste Generation	- 3,144.1 tonnes of wastes diverted - 77% diversion rate from landfills - Zero Waste Challenge to divert 85% of wastes from landfills - Appropriate separation of waste streams with signage for proper disposal	**4.5**	- Implement requirements and guidelines to reduce waste flows and to follow circular economy principles - Implement sorting, repurposing, composting, and recycling of materials - Reduce food wastes at events from various mechanisms	**4.0**

Information for this table, aside from the scoring system was compiled from both (Vancouver Organizing Committee, 2010) and (Fédération Internationale de Football Association, 2025)*

Sustainable sporting governance

The Vancouver 2010 Winter Olympics received a score of 4.5, as there were extensive sustainability governance structures and measuring targets, which included 34 key performance indicators, corporate sustainability policies, and alignment with environmental assessment compliance (Vancouver Organizing Committee, 2010). This event has demonstrated integration of sustainability measures and outcomes into all aspects of a mega-sporting event execution. A score of 5 was not given, as it is hard to evaluate the long-term sustainability impacts (if the venues have improved by adding more sustainability initiatives, etc.).

The 2026 FIFA World Cup received a score of 4 due to the alignment with ISO 20121 standards, ESG pillar system model, and commitments to the United Nations Development goals as a measurable target indicator (Fédération Internationale de Football Association, 2025). This mega-event has also established environmental forums across all host cities of Mexico, Canada, and the United States, and has proposed to assist and develop future climate action projects. Since the event has not occurred, the evaluation is primarily based on forecasted sustainability outcomes of the event rather than actual measurable outcomes from post-event data.

Carbon Footprint

Vancouver 2010 has received a score of 4.0 for this section due to the launching of BC clean energy technologies, the 15% reduction strategy from the carbon management program, and from the development of a GHG inventory for compiling emissions (Vancouver Organizing Committee, 2010). However, a higher score for this category (such as a 4.5 or 5) was not achieved, as it still released a lot of emissions, notably 268,000 tonnes of indirect carbon emissions and 35,059 tonnes of direct emissions (Vancouver Organizing Committee, 2010).

FIFA 2026 received a lower score of 3.0 for the carbon footprint, as the goals and targets are primarily in development or suggested phases. This mega-event has some great initiatives

such as the increase of public transit, creating a comprehensive GHG inventory, and a push for local procurements of goods and services (Fédération Internationale de Football Association, 2025), but the score is reflected from the absence of post-event emissions and actual concrete statistical targets.

Energy Used and Consumed

Vancouver 2010 received a score of 4.5, as it incorporated 100% renewable energy technologies across all venues and had various LEED certified buildings with energy efficiency improvements (Vancouver Organizing Committee, 2010). This event received this score and not a perfect one, as the LEED certification of each building could have been at least Gold in standard for excellent energy savings and environmental design.

FIFA 2026 received a lower score of 3.5, as the commitments were like that of Vancouver 2010. The focus is on the achievement of receiving LEED certifications across venue spaces, projects that increase energy efficiency, and the use of renewable energy sources (Fédération Internationale de Football Association, 2026). However, the score is reflected upon the lack of benchmark targets for LEED certification (silver or high, for example), and the minimum target of renewable energy adoption (such as at least 70% use of renewable energy).

Waste Generation

Vancouver 2010 received a score of 4.5 as this mega-event had measurable goals and targets such as 77% diversion rates, zero waste challenges, and educational materials for all members of the sporting event to abide by (Vancouver Organizing Committee, 2010). The score of 5 was not achieved, as there could have been a higher diversion rate achieved and more waste diversion categories present in the report to determine what worked and didn’t.

FIFA 2026 received a score of 4.0 as it implemented requirements and guidelines to divert wastes and follow circular economy principles, reduction of food wastes at the event, and implement proper sorting mechanisms for all members (Fédération Internationale de Football Association, 2025). Measurable targets and forecasted outcomes from the event would have increased the score, as the reflection is due to strong sustainability planning commitments and not actual evidence.

4.4 Political and Governance Influences of Sustainability Performance

While the evaluation framework above shows the differences in sustainability performance between FIFA 2026 and Vancouver 2010, these outcomes are shaped by the governance and political contexts of event operations. The sustainability outcomes are not just determined by environmental and sustainability initiatives, but are also influenced from institutional structures, accountability matrices, and decision-making processes at all stages of event planning to implementation.

The Vancouver 2010 Olympics operated under a centralized governance structure composed and led by the Vancouver Organizing Committee (VANOC). Sustainability initiatives were integrated in the decision-making processes through the inclusion of a corporate sustainability policy, environmental management system, and the use of a measurable outcome to monitor overall performance stemming from 34 key performance indicators (Vancouver Organizing Committee, 2010). The sustainable sporting governance aspect was implemented at all event stages from support of various members, such as the Human Resources Committee and an external advisory committee to ensure a sustainable event was executed (Vancouver Organizing Committee, 2010). Because of these steps and collaborative efforts, sustainability

considerations and initiatives were embedded at every step of event execution. The governance structure that helped to shape the delivery of Vancouver 2010 allowed the event to move beyond just commitments and into measurable actions of emission reductions, renewable energy adoption, and waste diversion strategies (Vancouver Organizing Committee, 2010). The political landscape surrounding Vancouver 2010 also strengthened sustainability implementation. Sustainability at this event was not just an environmental objective, but an initiative to prove accountability to various governments, various stakeholders, and the public realm. Sustainability reporting integration, environmental assessment compliance standards, and measurable performance indicators allowed the organizing committee (VANOC) to demonstrate that public investments in venues, infrastructures, and event logistics, aligns with broader ESG objectives (Vancouver Organizing Committee, 2010). Sustainability functioned as an environmental commitment and a governing tool to increase investments, transparency, and public engagement.

Vancouver 2010 also showed how sustainability outcomes can be influenced by political parties and institutions. Both Provincial and Municipal governments, the International Olympic Committee, and VANOC operated within a coordinated environment where the sustainability initiatives can be integrated in all stages of event delivery (Vancouver Organizing Committee, 2010). The alignment of the IOC, governments, and VANOC reduced the potential for governance fragmentation, which allowed renewable energy adoption, carbon management programs, and waste diversion strategies into measurable outcomes in the development of sustainability reporting.

On the other hand, FIFA 2026 has a more complex governance structure that influences certain decision-making processes. FIFA 2026 will be held across three countries and 16 host cities, which requires more coordination amongst local governments, organizing committees,

stadium operators, and local stakeholders (Fédération Internationale de Football Association, 2025). To ensure transparency, FIFA's Sustainability commitment and Human Rights Strategy helped to establish sustainable governance, environmental, social, and economic pillars while requiring that each host city develops their own focal points from stadiums to share information to identify solutions and report progress (Fédération Internationale de Football Association, 2025). However, FIFA does recognize its own limitations with accountability and implementation of sustainability initiatives, as different host cities have their own environmental plans and political contexts (Fédération Internationale de Football Association, 2025).

The political dynamics with FIFA 2026 are more complex. FIFA 2026 required coordination amongst three national governments (Canada, USA, and Mexico) and 16 host cities. Even though FIFA provided overarching sustainability goals and commitments, environmental forums, and reporting expectations for host cities, the implementation of these fell on local governments, venue operators, and organizing committees that each operated within different political and regulatory environments (Fédération Internationale de Football Association, 2025). Sustainability reporting for this event varies according to local policies and existing environmental commitments.

The governing arrangement for this event thus creates a challenge regarding possible reporting standards and consistency. While their objectives of the event align with UN SDGs and ISO 20121 standards, individual host cities have significant influence over environmental and sustainability initiatives that are monitored or implemented (Fédération Internationale de Football Association, 2025). The jurisdiction has a large influence, as some may prioritize climate actions and sustainability initiatives, whereas another might place emphasis on economic development and tourism.

These sustainable governance differences between both events helps to demonstrate and justify the variation in scores. Vancouver 2010 had a higher score due to the centralized government structure, measurable sustainability indicators, and post-event reporting, which allowed documentation of both environmental and sustainability performance. In comparison, FIFA 2026 represents a governance model that is highly complex with cross jurisdictional coordination, planning, and sustainability commitments depending on host city contexts. Even though FIFA 2026 shows a strong alignment with sustainability frameworks such as ISO 20121 and the UN Sustainable Development Goals, much of the outcomes are forecasted until the post event reporting is completed and disseminated (Fédération Internationale de Football Association, 2025). Therefore, the lower scores that were assigned to FIFA are not to be interpreted as weaker in sustainability outcomes, but as a reflection for challenges associated with evaluation both environmental and sustainability performance before implementation, as well as across jurisdictions.

From a sport ecology perspective, the developed evaluation framework shows how environmental performance and sustainability initiatives can be included in governing decision-making processes throughout all stages of an event. Sport ecology can be used as more than a conceptual or normative framework, but as a practical evaluation tool that assists in guiding, implementing, and monitoring sustainability performance. The centralized governance model implemented during Vancouver 2010 provides a strong example for future mega-events to follow to strengthen their own environmental and sustainability performance. As the normative framing of sports is beginning to advance, the integration of sport ecology concepts into governance frameworks may provide the forward pathway towards more measurable and environmentally conscious events that will align with international climate and emission goals and targets.

Section 5: Conclusion and Future Directions

Sport ecology is emerging as an important academic discipline that is interdisciplinary in scope. It examines the relationship between sports, the environment, climate change effects, and sustainability practices. Even though this academic discipline has developed through normative discussions, the existing academic literature is still highly focused on defining and measuring baseline data of the environmental aspects of sports rather than developing tools to evaluate sustainability performance. This major research advances sport ecology beyond a conceptual framework by demonstrating how it can exist and function as a normative and evaluative framework for sporting organizations, coaches, athletes, policy makers, and within the planning to execution phases for mega sporting events.

The research shows that sport ecology is developing and evolving into a normative framework via the implementation of sustainability reports and strategies, sustainable governing structures, and climate commitments. Sustainable sporting governance, carbon footprint reduction and mitigation strategies, renewable energy adoption, and waste diversion initiatives are becoming central components of a definition of sustainable sporting. Examples explored through the paper from the International Olympic Committee, the Canadian Olympic Committee, the International Skating Union, and the Green Sports Alliance illustrate how the sporting sector is aligning with broader climate goals and sustainability targets. However, analysis shows that much of the advances in sustainability reporting are voluntary, inconsistent, and lack standardized reporting mechanisms. This represents one of the major gaps within the continual development of sport ecology.

The major research paper also demonstrated how sport ecology can be implemented as an evaluative tool through the development of a qualitative and quantitative table using the central four criteria of sustainable sporting governance, the carbon footprint, energy used and consumed, and waste generation. The application of these criteria to the two mega-event case studies of the Vancouver 2010 Olympics and FIFA 2026 showed how these concepts can be translated into measurable sustainability indicators for future mega events. The comparative analysis of this section highlighted that Vancouver 2010 represented a sustainability performance-based model that is supported by measurable outcomes stemming from post-event sustainability reporting, whereas FIFA 2026 showed a sustainability planning-based model focused on projected initiatives. This comparison was important, as it shows that sport ecology can be used to evaluate sustainability performance before, during, and after mega-sporting events.

The research also identified limitations and future research directions and opportunities. Gaps remain within reporting and evaluation of environmental impacts within waste generation of sports, particularly regarding food waste, textiles and equipment waste, broadcasting emissions, and noise and light pollution. Future research should refine evaluative frameworks towards more robust standardized systems with additional case studies across different sports and regions to demonstrate further how sport ecology can exist in broader contexts.

This major research thus argues that sport ecology does not exist nor should exist only as a conceptual or normative framework, but also as an evaluative one. The increasing impacts of climate change on sports and their associated environmental impacts requires stronger systems of accountability, governance, and evaluation. Advancing sport ecology into both normative and evaluative frameworks provides opportunities for sporting organizations and policy makers to advance sustainability into all stages of sporting operations. Sport ecology has the potential to

become an important tool for sustainability practices within sports which can support climate action and shape the future of sporting delivery from grassroots daily training to mega-sporting events.

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