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Emissions from Air Travel and Major Football Tournaments

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ABSTRACT

Research Question: This paper explores the environmental impact of air travel during two international football tournaments– the Mens FIFA World Cup and UEFA European Championships – by estimating CO_2 emissions from the movements of competing teams. Specifically, we consider how travel associated with major international football tournaments has evolved over time.

Research Methods: We access data for 895 international football matches (June 1990 - July 2024). Our data focuses on the travel associated with players and management travelling to, and within, host countries and includes the movement of more than 16,000 people. Estimates of CO_2 emissions per passenger (per kilometre) are used to examine the environmental impact of travelling to host countries, and competing, during the tournament.

Results and Findings: Our findings are a first attempt to demonstrate the CO_2 emissions from team travel to and within major football tournaments. Despite improvements in aeroplane fuel efficiency, the carbon footprint from team travel has generally not been reduced. The decision to expand these tournaments, locate matches across large geographic areas, and use co-host countries has exacerbated this issue.

Implications: Our findings can support sustainability initiatives and could be adopted by both federations to curb CO_2 emissions which appear to undermine genuine attempts to become more environmentally friendly.

Keywords: Sustainability, event, sport, travel emissions, competition.

Word Count: *,***

Introduction

On the 2nd of June 2002, Paraguay and South Africa played the opening match of the FIFA World Cup in Busan, South Korea. While this match was largely uneventful, it does hold a significance; it is likely the tournament's highest ever carbon dioxide (CO_2) emitting match. The teams travelled a combined distance of more than 31,000 kilometres from their home countries to reach South Korea. Our calculations, explained in detail later, estimate that this movement produced more than 170 tonnes of CO_2 from air travel alone. This is approximately the electricity usage of 33 homes for an entire year (Environmental Protection Agency, 2023). While FIFA recently communicated its responsibility towards the environmental impact of the construction and operation of stadia at the 2022 Qatar World Cup (O'Rourke & Theodoraki, 2022), little attention has been placed on international travel to, or during, tournaments (Dolf and Teehan, 2015).

CO_2 emissions from travel have been calculated to contribute up to 83% of total emissions from a World Cup tournament (FIFA, 2013). This is not unique to football. Collins et al. (2012) examine how changes in travel behaviour affects the environmental consequences of major events by using Tour de France data. Dolf and Teehan (2015) note, in some cases, long distance travel may only involve a small portion of participants but it is the most effective area to target for mitigating the carbon footprint of sporting events. Collins & Roberts (2017) demonstrate how rugby and cycling impact the environment, with multi-day events and free entry resulting in a greater negative environmental impact. Also, the impact that travel, due to sport and sport tourism, has on the environment has been extended by Collins et al. (2012); Cooper (2020); Cooper & Alderman (2021); and Cooper & McCullough (2021).

Given that major sports events attract a range of stakeholders (media outlets, commercial enterprises, spectators etc.) contributing significantly to transport emissions in a concentrated

period, a reduction in transport emissions is an important step in the delivery of sustainable sports events. This is acknowledged by the United Nations' Sport for Climate Action Framework which calls for the halving of emissions by 2030 and the achievement of net zero emissions by 2040 (United Nations, 2023). To achieve this, there is first a need for increased monitoring and measurement of sustainable practices in sport (McCullough et al., 2019). This research seeks to contribute to this. Specifically, we consider how travel associated with major international football tournaments has evolved over time.

We use data from men's FIFA World Cup and UEFA European Championships tournaments to measure CO_2 emissions from travel over an extensive period. The findings are relevant for any sport or activity that requires qualifying teams or individuals to travel to a host country, and within the host country during their stay in a competition.[1]

We add to the nascent field of environmental sustainability in sport, building on the work of Pereira et al. (2017) who examine international team travel to FIFA World Cups based on the distances between the teams' capital cities and the capital city of the host nation. Our estimations are an attempt to assess how CO_2 emissions from team travel to and during major football events are changing. Our analysis is based on data at a most conservative level as it excludes travel to training camps both pre- and during the tournaments, and other travel activities. Thus, we aim to provide a baseline estimate.

The decision where to host international competitions is an important element of this research as FIFA and UEFA have significantly changed their hosting methods. These changes include expanding the number of teams, choosing locations further from their headquarters in Switzerland, hosting events in countries of significant landmass, the adoption of co-host practices, and the use of multiple city locations across a continent. Given the

[1] For example, Formula 1 racing would benefit from re-considering the location of major races as less than one per cent of CO_2 emissions are generated from the racing cars' fuel, with the transportation of teams and their equipment significantly increasing the sport's carbon footprint (King, 2013; Gammelsæter & Loland, 2023).

increased travel due to these changes, it is timely and important to examine the effect of tournaments on the environment.

The remainder of this paper is structured as follows; the next section provides a context and theoretical grounding for the research. It discusses how sports management research addresses sustainability concerns arising from the evolution of sporting events and the objectives of federations when hosting tournaments. We then discuss the data and methodology used before outlining the findings. A discussion follows. The final section concludes the paper.

Conceptual Framework

The management of sporting events, by their very nature, is dependent upon the natural world, yet these sports often contribute to environmental degradation (McCullough et al., 2016). This view is generally accepted (Inoue & Kent. 2012; Pfahl, 2011), however, it is only since the 1990s that sports strategies emerged to address environmental concerns.[2] Two initiatives have largely been targeted; reducing the ecological footprint[3] of sporting events and attempting to raise awareness of environmental issues globally. The degrees of success, under each initiative, vary across federations.

Trendafilova et al. (2013) claim organisers are reluctant to maximise their efforts for improved environmental sustainability for various reasons. These include financial constraints, lack of knowledge, absence of momentum or a lack of motivation to maintain the efforts. McCullough & Cunningham (2010) add that sport organisations have other goals than minimising their environmental impact. As a result, environmental initiatives are the

[2] The IOC's adopted environmental sustainability as the 'third pillar' of Olympism in 1994, to mark the 100-year anniversary of the foundation of the movement at Congress of Unity (Chappelet, 2013). The pillar placed the management of ecological concerns, and tacitly the impact of human behaviour on the environment, beside the original goals of the Olympic movement.

[3] An ecological footprint is a measure of human demands on nature, particularly in terms of the resources consumed and waste generated by human activity.

exception rather than the norm (McCullough & Cunningham, 2010; Hugaerts et al., 2022). McCullough & Cunningham (2010) acknowledge that passivity towards environmental matters might be the expected norm within sport organisations.

However, some organisations are starting to deviate from this norm (Trendafilova et al., 2013). There is evidence of both the Waves of Environmental Sustainability in Sport framework (McCullough et al., 2016) and the Triple Bottom Line (TBL) concept in action. Recent years have undoubtedly witnessed development of an awareness of the importance of environmental sustainability (first wave). Both FIFA and UEFA personnel are aware of environmental pressures, understand them and adopt positive environmental actions, as evidenced by their strategies. Increased knowledge of sustainability (second wave) within these organisations, the implementation of targeted actions and formalised strategic planning around sustainability has occurred (Hugaerts et al., 2022). Sustainability goals out to 2030 are fully integrated into the strategic planning of FIFA and UEFA (third wave) (United Nations, 2023). This wave is most relevant to our analysis as hosting decisions should be consistent with organisational strategy.

O'Brien & Chalip (2008) suggest sports events are now adopting the TBL, balancing economic with the promotion of social and environmental responsibility. Organizations that adopt this framework aim to contribute to the well-being of their communities and reduce their environmental footprint, while still being financially sustainable. While short run financial gains are understandably a target of sports federations, as revenues can be reinvested by back into the sport (FIFA, 2022a), many are now looking at the long run costs of their actions and attempting to align economic success with sustainability targets.

The consequences of this new form of sport management have had far reaching effects and acted as the catalyst for a new culture in sports events. Today, the United Nations' Sport for Climate Action Framework outlines specific climate goals for 2040 (United

Nations, 2023). The IOC, FIFA and UEFA are all signatories of this and adhere to the five principles; to implement consistent efforts to enhance environmental responsibility; lower overall climate impacts; provide education on climate action; encourage sustainable and responsible consumption; and support climate action through advocacy and communication (United Nations, 2023).

While the promotion of environmental and sustainability goals should be celebrated, McCullough et al. (2019) note the paradox exists between the goals of global sporting organisations and actions in the management of major sporting events. The motivation to earn financial rewards can cause the underestimation of negative environmental effects. This is coupled with overestimation of the economic and environmental benefits of an event (Kellison & Mondello, 2014). As suggested by McCullough et al. (2019), consideration of the environmental impact requires the identification of both direct and external effects of the entire life cycle of the event. Such an assessment would move international federations away from simple consideration of the 'bottom line', towards TBL, and place sustainability and environmental concerns, at the centre of the planning and management of sporting events.

Tournament Organisation and CO_2 Emissions

Between 1958 and 2006, FIFA adopted a rotation policy for hosting tournaments, with every second tournament held in Europe (once every eight years). This policy was abandoned after 2006. The reasons cited for this change in policy include the fact that broadcasting revenue is now more important than ticket sales (Deloitte, 2016; Wallrafen et al., 2020) and there is a desire to spread the game globally (FIFA, 2023a).

This policy change has had repercussions. The travel emissions generated by major tournaments is influenced by the distance between the participating countries and the host country, the distance between the host nation's stadia, and the mode of transport used to

travel. Furthermore, co-hosting and tournament expansion are two recent phenomena. Despite growing the number of teams travelling to major tournaments and dispersion of venues, both UEFA and FIFA state their wish for football to be environmentally sustainable under the United Nations Sports for Climate Action Framework (UEFA, 2023a; FIFA, 2022b). Our study assesses the validity of these commitments by comparing the travel emissions of both World Cups and European Championships from 1990 to 2024.

Both federations, now embed environmental concerns into their present strategies. Both UEFA's and FIFA's strategies state that they are committed to becoming carbon neutral by 2040. UEFA plans to achieve this by reducing direct and indirect carbon emissions from UEFA operations and events, and through circular economy initiatives such as zero plastic and food was across UEFA events (UEFA, 2024a; 56-57). FIFA's actions include using greater renewable energy, reducing the need for temporary power solutions prior and during tournaments, reducing business air travel in the preparation of events, the use of low emissions vehicles and greater monitoring of emissions (FIFA, 2024a). The 2022 World Cup aimed to "measure, mitigate and offset" greenhouse gas emission (FIFA, 2024b). For this reason, there has never been a more pertinent time to explore travel associated with major international football tournaments over time.

At a general level, Collins et al. (2009) offer a quantitative impact assessment of the environmental externalities of both the FA Cup Finals (using Ecological Footprint analysis) and World Rally Championships, and the Wales Rally of Great Britain. The authors argued that their methodologies were not perfect but noted that quantitative environmental impact assessments and the evaluation of major sporting events on an environmental basis will become widespread. Furthermore, Collins et al. (2007), Collins et al. (2012), Mallen et al. (2010), Mallen & Chard (2011) and Dolf & Teehan (2015) have significantly advanced our understanding of how sport events and organizations affect the environment. Travel

emissions are part of this discussion. In 2022, aviation accounted for 2% of global energy-related CO_2 emissions (International Energy Agency, 2023). As international football is a global sport, aviation travel is an inherent part of its operations. Athlete and spectator travel accounted for 83 percent of emissions at the World Cup in Brazil in 2014 (FIFA, 2013) and 74 per cent at the World Cup in Russia in 2018 (FIFA, 2016). In addition, Wicker (2020) highlights that travel for competitions generates stress for athletes and reduces their enjoyment from participation, which is vital to sustaining the recreational and health benefits of football.

Further rationale for this research is emerging based on the claims of major sporting organisations. For example, FIFA promoted the 2022 World Cup in Qatar as being carbon neutral. European countries submitted complaints against this to the Swiss Commission for Fairness in late 2022, with the outcome concluding that it should not be claimed that sustainability goals have been achieved (Themen, 2023). The Commission advised FIFA to refrain from making unsubstantiated claims in the future (Themen, 2023).

Data and Methodology

We access data from 895 men's football matches at the FIFA World Cup Finals and the UEFA European Championship Finals between June 1990 and June 2024. Data from both competitions are extracted from The Rec. Sport. Soccer Statistics Foundation (RSSSF, 2023a; RSSSF, 2023b) and includes all teams playing at the finals, squad sizes, dates, locations, and the number of games played during the tournament. We do not include spectator travel. While it may be possible to estimate the number of fans travelling, it is impossible to know each spectator's origin and whether later games at tournaments are populated by fans engaged in internal travel or those travelling from their country of origin. We, therefore,

know with certainty that the estimates we calculate are very conservative as fans often travel thousands of miles to support teams.

Tournament Overview

Table 1 presents data on stadia, teams competing, the number of games and the total number of players at these major tournaments. Over time, the number of players allowed to compete at major tournaments has risen. In 1990 and 1992, only 22 and 20 players, respectively, could be named in country squad lists. This increased to 22 players for all tournaments until 2002 and this number further increased to 23 squad players from 2002 to 2018. In 2020, the number of players allowed in a squad rose to 26.

TABLE 1 ABOUT HERE

Between 1990 and 2000, when a maximum of 22 players could play, we account for 10 staff members travelling with each team. This includes a manager/coach, assistant, goalkeeping coach, physio, kitman, doctor and other coaching staff. From 2002 to 2012, we raise this number to between 12 and 15 individuals as sports science and data analysis became more important to the game. From 2014 to 2018, this is raised to 18 travelling staff members, and we account for 20 travelling staff members for the tournaments in 2020, 2022 and 2024.

It is important to note that these estimates, and increases through time, are based on intuition. National team websites often list backroom staff, which regularly include 15 to 20 staff, however, we believe this number would have been lower historically. The increases are used to capture the role of performance analysts, data analysts, additional physio and coaching staff, scouting/opposition performance analysts, social media and communication staff and equipment managers. It is also true today that teams can travel with large ancillary support such as social media managers, marketing staff, catering, chefs, and kitchen staff, as well as others. We do not include these in our estimation as we are primarily focus on those

directly engaged in the tournament e.g. players, manager, coaching staff, etc. Of course, if support staff are included, the estimated CO_2 emissions would be much greater.

Again, we believe these estimates are conservative and do not include other supporting staff who may travel to matches, such as the Chief Executive Officer, Association President, secretarial staff, or honorary members. There are sometimes "second" chartered aircraft travelling to tournaments to deliver equipment, and we do not account for these. The final column "All" in Table 1 attempts to measure all players and playing staff at these tournaments.

Estimating Distances Travelled

The second data source is calculated using a Distance Calculator (see https://www.distance.to/)[4]. For consistency purposes, we assume all travel is completed by aeroplane. This includes both travel to the tournament, and internal travel. A team is assumed to leave their capital city and travel, by plane, directly to the destination of its first match and, subsequently, travel directly to its next match. We are aware that some internal travel is not conducted by aeroplane, as locations are close together, but for consistency purposes and so comparisons can be made across tournaments, aeroplane emissions are used for all travel. While these inflate the figures at times, the number of journey's misrepresented are likely to be few, with almost half related to Qatar 2022. Furthermore, we can't be sure what other modes of transport e.g. bus and rail are used and produce emissions. When the team of a host country is playing, we do not include travel to the first match. An overview of distances travelled at these major football tournaments is provided in Table 2. As expected, countries

[4] Utilizing the distance calculator we ascertain the distances between locations. This software allowed us to gather precise flight data and distances between two cities/airports, by inputting the airport code (IATA) and then recording the distance in kilometres between these locations.

further away from Europe, and those of larger geographic areas, report higher travel distances, with Brazil, South Korea/Japan and South Africa reporting the highest scores.

TABLE 2 ABOUT HERE

As one would expect, most travel made by countries competing in the FIFA World Cup or UEFA European Championship is incurred when travelling to the host destination. Traditionally, as most finalists are from UEFA member countries and Western Europe hosted every second tournament, the burden of travel on many teams travelling to the finals was small once every eight years. This changed in 2010, when South Africa became the first Confederation of African Football member to host the World Cup. Since then, the tournament has not returned to Western Europe and will not arrive back until 2030. Consequently, competing finalists often face greater travel distances when travelling to the finals in destinations such as Brazil, Russia, and Qatar.

To account for these differences, and the changing landscape of host countries over more than a decade, Table 2 also includes the volume of internal travel once teams have arrived at the host country. This allows for comparisons to be made across time, without the need to consider where the host country is located globally. Some useful insights can be made when internal tournament travel is compared to total travel. Most notably, we estimate 99% of team travel during the 2022 World Cup in Qatar was associated with arriving at the Middle East state. This is due to the concentration of the stadia used at the finals, with spectators often able to see more than one game per day during the group stage of the competition. FIFA's "Sustainability Strategy" includes a statement that "the compact nature" of the 2022 tournament in Qatar eliminated "long-distance travel between sites typically required", the direct effect of which is a reduction in carbon emissions (FIFA, 2022b).

On the contrary, Euro 2020 experienced the greatest necessity for internal travel due to UEFA's decision to host games across the European continent. This is followed by France

2016 where the organisers moved teams around the country when playing during both the group and knock-out stages of the competition. The 2002 FIFA World Cup in Korea and Japan is another interesting case. While long distances were required by many to reach east Asia, once on the ground, internal travel during the tournament accounted for just over 10% of all travel.

Estimating Emissions

The third group of data is the CO_2 emissions from air travel. Data are sourced from the European Environmental Agency (2009) and are triangulated with other open sources such as Our World in Data (2023) and Carbon Independent (2023). The data gathered cover the years 1990 to 2022 and estimates average long haul flight CO_2 emissions per passenger, per kilometre, controlling for improvements in fuel efficiency of aeroplanes. Combining this with the two other sources of data (tournament match information from RSSSF) and travel distances, we estimate the emission generated by each major tournament, by calculating:

$$Emissions_{i,j} = \sum_{i=1}^{N} (CO^2pPpKm)x(Dist)x(Staff)$$

Where: i is the tournament, j is the year, CO^2pPpKm is the average carbon emissions per passenger, per kilometre, *Dist* is the distance in kilometres from one city to the other and *staff* is the estimated number of people travelling as part of the plaing group. As discussed, this includes all directly involved members of the group such as players, managers, and coaching staff. Advances in technology, changes in airline fleets, and efforts to improve fuel efficiency may have led to a reduction in emissions as airlines and aircraft manufacturers are continually working to reduce their environmental impact.

It is important to note that considerable variation can exist when attempting to measure the amount of CO_2 emissions per passenger in this context. The amount of carbon

dioxide emissions produced by a plane per passenger, per kilometre, can vary depending on several factors, including the type of aircraft, the distance of the flight, the load factor (how full the plane is), and the specific airline's fuel efficiency. Short-haul flights tend to have slightly higher emissions per passenger-kilometre, while long-haul flights can be more efficient due to the higher cruise altitude and longer distances travelled.

Findings

We create a CO_2 emissions index from 1990 to 2024. This allows us to understand the evolution of tournament hosting and the subsequent CO_2 emissions from team travel. As we are not considering alternatives to air travel or CO_2 emissions, we do not use CO_2e. As mentioned, significant changes have occurred with the expansion of qualifying teams, the movement to host locations further from UEFA members, and the co-hosting of these tournaments. Our analysis is a first attempt to demonstrate the CO_2 emissions cost of these decisions, at a most conservative level. It is essentially the minimum impact that these events are having on CO_2 emissions. It is hoped that future research can add to the baselines presented here and add greater nuance to the estimations provided in this analysis.

Team Travel and CO_2 Emissions from 1990 to 2024

Despite improvements in aeroplane fuel efficiency over the course of the past three decades, FIFA and UEFA do not appear to be reducing their carbon footprint from team travel to major tournaments. Table 3 presents the total emissions from both competitions between 1990 and 2024. It is clear from the data that tournaments held in locations further from Western Europe (Korea, Japan, South Africa and United States of America) and those held in larger countries (Russia, Brazil) or across the European continent, require greater travel by qualifying teams and higher travel emissions.

TABLE 3 ABOUT HERE

Figures 1 and 2 display the mean and median distances travelled by teams within tournaments from 1990 to 2024. The mean and median CO_2 emissions are also displayed. For each of these variables, two figures are reported. One is based on total team travel and emissions, including travel to the tournament, and travel within the host location. The second, internal travel (IT), solely relates to travel undertaken during the rounds of the tournament. Using these two metrics allows us to determine whether the geographic location of the host country, or size of the host country (i.e., the distance between stadia), has the greatest influence on CO_2 emissions. All figures are reported on a per game basis.

From an environmental perspective, it would be most beneficial if the average CO_2 emissions (the broken line in the below figures) trended downwards to reflect improvement in fuel efficiencies over this period. However, it is clear from Figure 1 that the decision of where to host the World Cup has resulted in fluctuating levels of emissions. Total travel is greatest at the 2002 World Cup in Korea and Japan and resulted in an average of 31.5 tonnes of CO_2 emitted per game. Just 15% of these emissions are due to travel between the 20 stadia, with the remainder due to the travel required to the host countries to compete in opening group games. Emissions generated by the World Cup tournaments in South Africa (2010), Brazil (2014) and Qatar (2022) are also heavily influenced by travel to the tournament. The location of the host country is clearly an important factor as the tournaments in Italy, France and Germany resulted in relatively low average emissions per game due to their European location. The 2022 World Cup in Qatar resulted in the lowest within tournament emissions from travel due to the proximity of stadia to one another in this small country.

FIGURE 1 ABOUT HERE

FIGURE 2 ABOUT HERE

Figure 2 illustrates that average CO_2 emissions per game are far lower at the UEFA European Championships compared to the FIFA World Cup. Within tournament travel represents a greater portion of total travel when compared to World Cups. UEFA took the unique step of locating the 2020 European Championships across multiple cities to celebrate 60 years of the tournament. This was the highest emitting tournament, with almost 80% of team travel emissions a result of within tournament travel and far greater travel was required than when a single country or co-hosts were awarded the tournament. If organisers are serious about reducing their carbon footprint, this competition format should not be used again. The 2004 tournament in Portugal had the second highest average team travel emissions per game due to its peripheral European location. The most recent tournament in Germany produced relatively low CO_2 emission from travel, owing to the central European location and the fact the stadia are relatively close to each other.

Comparing France and Germany's Tournaments in 1998/2016 and 2006/2024

During the period of examination, both France and Germany hosted tournaments twice. France hosted the FIFA World Cup in 1998 and the European Championships in 2016. Germany hosted the FIFA World Cup in 2006 and the UEFA European Championships in 2024. Based on the observed movement of teams, Figure 3 presents comparisons between the first and second time these tournaments were hosted in each country. Again, data is presented on all team travel and internal team travel only. When only internal travel is examined, CO_2 emissions at the 2016 European Championships in France are higher than the FIFA World Cup hosted there in 1998, with an identical number of competing countries (24).

FIGURE 3 ABOUT HERE

The difference in Germany is negligible despite eight fewer countries competing at UEFA Euro 2024 compared to FIFA World Cup in 2006. This evidence suggests while air

travel is becoming more environmentally friendly, gains are eroded by increasing numbers of players, staff and countries competing, even in Western European hosts. The increased mean and median travel distance in France during the 2016 competition, when compared to 1998, demonstrates that teams are required to travel further distances during the tournaments' rounds.

To highlight some of these distances that teams travel, Table 4 presents data on games that required a combined distance of 20,000 kilometres by competing teams and lists internal travel where countries, having played at least one match in the host country, were required to travel a combined distance of more than 5,000 kilometres to play their next fixture. Five fixtures, all of which were at the 2002 FIFA World Cup in Korea and Japan, resulted in more than 140 tonnes of CO_2 emissions from team air travel.

TABLE 4 ABOUT HERE

The data presented in Table 4 also lists the games that produced the highest CO_2 once countries had arrived at the destination and the impact of hosting the 2020 European Championships across eleven different countries. This tournament included the 2nd, 4th and 6th biggest CO_2 emitting games. USA (1994) and Brazil (2014) make up the remainder of the list due to their expansive geographic size and wide distribution of stadia. The decision at the 1994 World Cup for Sweden and Russia to travel a combined distance of 6,544 kilometres from Texas and California respectively, to meet in Pontiac, Michigan less than a week later, is not a scheduling strategy that is consistent with achieving environmental goals. With the World Cup returning to the United States in 2026, and the heightening of environmental concerns since the last competition in 1994 and the United Nations' Sport for Climate Action Framework, we hope and expect fixture scheduling to change to avoid a repeat of this. This action may result in the 2026 World Cup reporting lower averages for both internal travel and

emissions per game than 1994. It may also avoid similar CO_2 emissions per game for internal travel reported at the 1994 competition - the highest reported in our data at 14.29 tonnes.

Discussion

Our work complements that of others in this area, including Pereira et al. (2017) and McCullough et al. (2016), to examine travel emissions– in our case "transport to/from event" – on major events. This evidence can be used as a starting point for developing environmental life cycle assessments of major events, suggested by Curran (1996). As noted by Eccles, Ioannou, & Serafeim (2014), governing bodies should identify where negative environmental externalities exist and seek to find solutions that make these sports more efficient and improve overall delivery.

It is worth emphasising that the total travel emissions generated at these tournaments are greater than these team-level estimates. While some of this may have been generated regardless (e.g. normal tourism on commercial flights), we believe much of the emissions are generated entirely by hosting tournaments. While we only assess measurable components of travel, the findings still serve to highlight the important role governing bodies play when awarding major events to a country. We now discuss some policy implications and considerations for the future.

Travel Reductions

We do not argue that teams should not travel. These tournaments require travel, but improved management of schedules is required. As noted by Dolf and Teehan (2015) "reducing travel" is achievable and will quickly reduce CO_2 emissions. However, the expansion of both tournaments has increased the number of games and travel and imposes an environmental cost. This trade-off should be carefully considered when FIFA and UEFA establish future strategic goals. As stated, both federations, now make environmental issues

part of their strategies and are seeking to reduce emissions. UEFA's decision to host UEFA Euro 2024 in a single country – Germany – and Euro 2028 in the British Isles, suggests alignment with this target. The decision to award the 2026 FIFA World Cup to three countries – Canada, Mexico and USA – will result in increased emissions relative to Qatar 2022. This will continue in 2030. Further consideration is required when awarding hosting rights from 2034 and beyond if environmental concerns are to be prioritised.

One way to overcome this is by altering fixture scheduling. For example, using individual cities to host a finals group of four teams. This would mean that teams only travel again if they qualify for the knockout stage. Teams who qualify for the knockout stage would then travel to a single location for all knockout games. This approach would reduce travel in the early stage of the tournament and limit internal movement during the later stages. This is how the 2019-20 UEFA Champions League ended, with the quarterfinals, semifinals and final all played in Lisbon, Portugal in August 2020 due to Covid-19.

At present, teams travel to different stadia during the tournament, due to the preferences of organisers. While many examples of this can be used, one of the best is illustrated by the World Cup in 2014. Between the 14th and 24th of June, England travelled from Manaus to Sao Paulo to Belo Horizonte, a combined distance of more than 4,000km. Had England played all their group games in one city, like they did at Euro 2020, CO_2 emissions from air travel for their second and third games would have been zero. As emphasized by McCullough & Cunningham (2010) and McCullough et al. (2016), organisers of these events need to be put under "social pressure" to alter this practice. Such pressure could be used to alter norms and behaviour, which is often very hard to change in society and in football (Hodgson, 1996; Butler and Butler; 2021), and encourage UEFA and FIFA to follow the three waves of environmental progress outlined by McCullough et al. (2016) and contribute to the TBL.

The number of stadia used within a tournament also impacts travel. UEFA have generally increased the number of stadia used, thereby increasing team travel. The 2020 tournament was held across 11 stadia resulting in the highest level of travel emissions ever reported at a UEFA European Championship. 16 stadia will be used across Canada, Mexico, and the USA, making the tournament the most geographically spread in the history of the World Cup. 24 different stadia – a record number for a FIFA World Cup – will be used in 2030. Despite a shift since 2002 away from increased stadia use, the next decade will see a reversal of this, with increased air travel an essential element of getting to these locations.

The Cost of Spreading the Game

The movement of games to countries away from the traditional European base has increased travel distances. Hosting tournaments and games in peripheral locations such as Japan, Korea, South Africa, Ukraine, Azerbaijan, Russia, and Qatar require long travel distances for many qualifying countries. However, when located in the host country, travel distances for internal games are largely consistent with European hosts (Table 3). The 2022 World Cup in Qatar reported the lowest CO_2 emissions per game when only internal travel is considered. This tournament generated relatively low mean emissions per match, due to short travel distance between stadia, making the Qatar tournament the most sustainable tournament ever when just internal movements are considered.[5] The same cannot be said of tournaments in USA, Brazil, and Russia. Long-haul flights, required to arrive to the host location, were then matched by further lengthy trips during the tournaments. As discussed, fixture scheduling is crucial and pro-environmental choices need to become the norm, in line with

[5] As coach or rail travel was used in Qatar the emissions produce may be lower than those estimated. Coach travel produces similar CO_2 emissions, but rail travel is lower. However, for consistency purposes across tournaments we estimate this as if air travel were used. As the differences travelled are small – with a mean of 63km – the differences are negligible. One caveat, however, is that unprecedented infrastructural investment was required for this tournament, and we do not measure any carbon emissions related to construction.

the three waves of environmental sustainability and TBL, for sporting organisations to reduce emissions as tournaments expand and become truly global.

Future Tournaments, Financial Success and Sustainability

The FIFA World Cup and UEFA European Championship Finals host locations have been announced up to 2032. All three tournaments – 2028, 2030 and 2032 – have a common theme – more than one host country. Euro 2028 will be shared by the United Kingdom and Republic of Ireland, while Euro 2032 will be co-hosted by Italy and Turkey. World Cup 2030 will take the unprecedented step of being hosted on three continents and six countries. The three opening games will be held in held in Argentina, Paraguay, and Uruguay to commemorate the 100th anniversary of the first World Cup (FIFA, 2023b) while the remainder of the tournament will be hosted by Morocco, Portugal, and Spain.

As articulated by McCullough et al. (2019:398), "for the FIFA World Cup, because air travel to mega events by spectators and participants is a large part of the carbon footprint of these mega events, studies should be considering national and international impacts on the environment". This scenario is not unique to football. The sports industry's commitments to sustainability are often not matched in practice (McCullough & Pelcher, 2018). While the financial aspect of these tournaments, and the critical nature of their success in allowing sports federations to remain viable is not irrelevant, a TBL approach means that sustainability and profitability are not mutually exclusive. Steps have been made in this direction in recent years, and further steps can be made. UEFA Euro 2024 produced the lowest emissions since 2008. Internal emissions at the World Cup in 2022 were a record low and revenue soared to almost €7 billion (FIFA, 2022a). Reducing travel within tournaments will help federations reach their sustainability targets and this should not impact profitability goals. Such an approach is the essence of TBL, and these organisations should create value not only for

shareholders but also for society and the environment. Future tournaments can be used to ensure both financial and sustainability goals are achieved. While these may not be possible in 2026 and 2030, future decisions should take this into account when decided on host countries.

Carbon Offsetting

This work provides conservative estimates regarding carbon offsetting strategies. Crabb (2018) directly appeals to the World Cup in Brazil in 2014 and debates the success of the "forestry-based carbon-offsetting project" which commenced following the tournament. Wicker (2019) and Wilby et al. (2023) measure the impact of sports participation on the climate by measuring carbon emissions. Our findings complement these studies and can be used to measure the minimum levels of offsetting required. Table 5 below provides some examples of the offsetting requirement of each of the last four FIFA World Cups and UEFA European Championships.

TABLE 5 ABOUT HERE

The data demonstrates three CO_2 offsetting equivalents for each competition since 2010. In total, more than 100,000 tree seedlings would need to be planted or nearly 7,200 of acres of forest created. This information can be used to direct future policy on offsetting. Additionally, we anticipate financial commitments to carbon offsetting will become commonplace within sporting organisations hosting major tournaments. UEFA Euro 2024 provides an example of this with UEFA (2024b) stating that €7 million was invested in grassroots German football in sustainable infrastructure as part of the association's climate fund, which attempts to counter necessary CO_2 emissions generated by the tournament.

Conclusion

A first step in managing any organisation's carbon footprint is to conduct a detailed measurement of emissions. This research is an attempt to do this for team air travel. This work can guide policy by providing baseline estimates, illustrating the carbon footprint of team movements at major football tournaments. Hosting decisions that result in large volumes of CO_2 emissions are not allowing UEFA and FIFA to advance their environmental goals. Considering the Sports for Climate Action Framework, sporting bodies should take the responsibility to promote environmentally friendly choices. This includes a reduction in internal travel during tournaments and the use of fewer stadia.

We demonstrate that locating tournaments close to most qualifying teams also significantly reduces the CO_2 emissions from team travel. Thus, there are clear scheduling implications for sustainability strategies. The findings generalise and are relevant for other major events that require international travel, with subsequent domestic travel as a tournament progresses. As noted by Paché (2020), proper intervention and planning are essential for leading authorities to minimise the carbon footprint of travel from major events in international football.

Sport's governing bodies have many objectives other than protecting the environment, which include developing the sport, ensuring inclusivity and being financially stable. However, a balance must be struck when managing these aims without damaging the environment. If this trade-off exists, effective carbon offsetting is required. Future research could consider hypothetical CO_2 emissions based on alternative competitions designs and scheduling constraints. Clearly, as we offer the most conservative estimates, additional data on fans and their travel patterns could build upon this attempt and add greater precision to observed emissions.

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Table 1. Major Football Tournaments Between 1990 and 2024

Year	Competition	Location	Stadia	Teams	Games	Players	All
1990	World Cup	Italy	12	24	52	528	768
1992	European Championship	Sweden	4	8	15	160	240
1994	World Cup	USA	9	24	52	528	768
1996	European Championship	England	8	8	31	176	256
1998	World Cup	France	10	32	64	704	1,024
2000	European Championship	Belgium/Netherlands	8	16	31	352	512
2002	World Cup	Korea and Japan	20	32	64	736	1,120
2004	European Championship	Portugal	10	16	31	368	560
2006	World Cup	Germany	12	32	64	736	1,216
2008	European Championship	Austria/Switzerland	8	16	31	368	608
2010	World Cup	South Africa	10	32	64	736	1,216
2012	European Championship	Poland/Ukraine	8	16	51	368	608
2014	World Cup	Brazil	12	32	64	736	1,312
2016	European Championship	France	10	24	51	552	984
2018	World Cup	Russia	12	32	64	736	1,312
2020	European Championship	Various	11	24	51	624	1,104
2022	World Cup	Qatar	8	32	64	832	1,504
2024	European Championship	Germany	10	24	51	624	1,104

Source: The Rec. Sport. Soccer Statistics Foundation (2023)

Table 2. Distances Travelled (Kilometres) at Major Football Tournaments

		All Travel					Internal Travel				
Year	**Location**	**Total**	**Mean**	**Median**	**Minimum**	**Maximum**	**Total**	**Mean**	**Median**	**Minimum**	**Maximum**
1990	Italy	112,130	2,156	488	123	15,821	18,005	360	227	123	1,114
1992	Sweden	10,406	694	513	241	2,021	4,150	277	266	241	513
1994	USA	307,684	5,917	3,573	306	22,157	104,851	2,621	2,606	306	6,544
1996	England	25,641	827	163	50	4,411	3,319	144	131	50	483
1998	France	169,753	2,652	832	9	20,837	35,108	731	746	9	1,530
2000	Belgium/Netherland	20,756	670	233	97	3,684	4,931	214	222	97	349
2002	Korea/Japan	368,393	5,756	1,010	98	31,337	37,148	774	649	98	1,638
2004	Portugal	38,760	1,250	317	0	5,745	6,402	207	119	0	963
2006	Germany	183,506	2,867	734	313	25,955	30,681	639	636	313	1,046
2008	Austria/Switzerland	24,459	789	268	95	3,770	9,030	393	235	95	1,412
2010	S Africa	334,715	5,230	1,603	215	22,945	61,592	1,283	1,315	215	2,798
2012	Poland/Ukraine	40,989	1,322	876	246	5,313	17,556	763	592	246	2,096
2014	Brazil	379,576	5,931	3,386	698	30,705	131,268	2,735	2,678	698	5,727
2016	France	70,663	1,386	1,114	188	3,907	39,317	1,008	995	188	1,557
2018	Russia	284,661	4,448	2,402	634	18,565	99,223	2,067	2,156	634	3,849
2020	Various	119,010	2,334	1,907	0	7,647	92,279	2,366	2,598	0	6,206
2022	Qatar	223,006	3,484	72	5	20,226	3,017	63	66	5	144
2024	Germany	46,652	914	674	148	5,339	20,046	542	579	148	902

Source: The Rec. Sport. Soccer Statistics Foundation (2023) and Distance.to (2023)

Table 3. Estimated CO^2 Emissions (Metric Tonnes) of Team Travel

			All Travel					Internal Travel				
Year	**Location**	**Games**	**Total**	**Mean**	**Median**	**Minimum**	**Maximum**	**Total**	**Mean**	**Median**	**Minimum**	**Maximum**
World Cup												
2002	Korea/Japan	64	2,015.81	31.5	5.53	0.53	171.48	225.25	4.69	3.83	0.53	25.12
2010	S. Africa	64	1,742.91	27.23	8.34	1.12	119.48	320.72	6.68	6.85	1.12	14.57
1994	USA	52	1,537.92	29.58	17.3	1.66	120.34	557.21	14.29	14.45	1.66	35.54
2014	Brazil	64	1,525.14	23.83	13.6	2.8	123.37	527.43	10.99	10.76	2.8	23.01
2018	Russia	64	1,073.74	16.78	9.06	2.39	70.03	374.27	7.8	8.13	2.39	14.52
2006	Germany	64	948.43	14.82	3.79	1.62	134.15	158.57	3.3	3.29	1.62	5.41
2022	Qatar	64	923.24	14.46	0.3	0.02	83.74	12.49	0.26	0.27	0.02	0.60
1998	France	64	785.21	12.27	3.85	0.04	96.39	162.39	3.38	3.45	0.04	7.08
1990	Italy	52	664.11	12.77	2.89	0.73	93.71	94.85	2.5	1.84	0.73	6.43
European Championships												
2020	Various	51	492.70	9.66	7.89	0	31.66	382.04	9.8	10.76	0	25.69
2016	France	51	272.34	5.34	4.29	0.72	15.06	151.53	3.89	3.83	0.72	6
2004	Portugal	31	220.62	7.12	1.8	0	32.70	36.44	1.58	1.57	0	5.48
2024	Germany	51	193.14	3.79	2.79	0.61	22.01	82.99	2.24	2.4	0.61	3.73
2012	Poland/Ukraine	51	167.46	5.4	3.58	1	21.70	71.72	3.12	2.42	1	8.56
1996	England	31	120.27	3.88	0.76	0.23	20.69	15.57	0.68	0.61	0.23	2.26
2008	Austria/Switzerland	31	104.13	3.36	1.14	0.4	16.05	38.44	1.67	1	0.4	6.01
2000	Belgium/Netherlands	31	94.03	3.03	1.05	0.44	16.69	22.34	0.97	1	0.44	1.58
1992	Sweden	15	55.32	3.69	2.73	1.28	10.74	22.06	2.01	2.11	1.28	2.73

Table 4: Matches with >20,000 km. Travel and Internal Travel of > 5000 km.

Year	Team 1	Team 2	Host	City	Combined Distance (km)	$C0_2$ Emissions (tonnes)
2002	Paraguay	South Africa	Korea	Busan	31,337	171.48
2002	Argentina	Nigeria	Japan	Ibaraki	31,328	171.42
2002	Uruguay	Denmark	Korea	Ulsan	27,453	150.22
2002	England	Sweden	Japan	Saitama	25,668	140.45
2002	Brazil	Turkey	Korea	Ulsan	25,630	140.24
2006	Australia	Japan	Germany	Kaiserslautern	25,955	134.15
2002	Italy	Ecuador	Japan	Sappaoro	23,100	126.40
2014	Russia	South Korea	Brazil	Cuiabá	30,705	123.37
2002	France	Senegal	Korea	Seoul	22,084	120.84
1994	Cameroon	Sweden	USA	Los Angeles	22,157	120.34
2010	Honduras	Chile	South Africa	Mbombela	22,945	119.48
2002	USA	Portugal	Korea	Suwon	21,646	118.45
2010	England	USA	South Africa	Phokeng	21,910	114.09
2002	Croatia	Mexico	Japan	Niigata	20,319	111.19
1994	Nigeria	Bulgaria	USA	Dallas	20,417	110.88
2010	Brazil	North Korea	South Africa	Johannesburg	20,302	105.71
2010	New Zealand	Slovakia	South Africa	Phokeng	20,124	104.79
1998	Argentina	Japan	France	Toulouse	20,837	96.39
2022	Uruguay	South Korea	Qatar	Al Rayyan	20,226	83.74
2014	Ivory Coast	Japan	Brazil	São Lourenço da Mata	20,634	82.91
				Internal Travel Only		
1994	Sweden	Russia	USA	Detroit	6,544	35.54
2021	Czech Rep.	Denmark	Azerbaijan	Baku	6,206	25.69
1994	Spain	Switzerland	USA	Washington	4,554	24.73
2021	Belgium	Portugal	Spain	Seville	5,935	24.57
2014	Cameroon	Croatia	Brazil	Manaus	5,727	23.01
2021	England	Denmark	England	London	5,414	22.41
2014	USA	Portugal	Brazil	Manaus	5,375	21.60
2014	Honduras	Switzerland	Brazil	Manaus	5,344	21.47
2014	Uruguay	England	Brazil	São Paulo	5,061	20.34

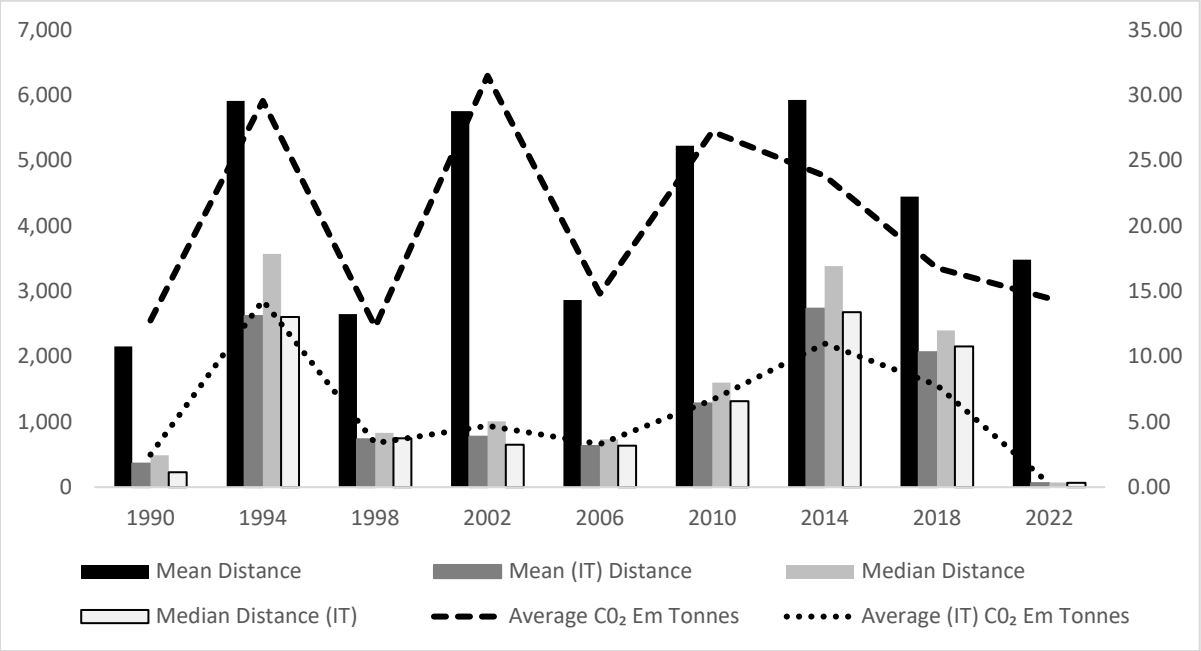
* Due to Covid-19 Euro 2020 was held in 2021.

Table 5: Carbon Emissions and Offsetting Requirements

			Carbon Offsetting Equivalent		
Year	Location	Total CO2 (tonnes)	Tree Seedlings Planted	Acres of Forest	Recycling (tonnes)
2010	South Africa	1,743	28,821	2,035	605
2012	Poland/Ukraine	167	2,761	195	58
2014	Brazil	1,525	25,216	1,780	530
2016	France	120	1,984	140	41.7
2018	Russia	1,074	17,759	1,254	373
2020	Various	493	8,152	576	171
2022	Qatar	923	15,262	1,078	320
2024	Germany	119	1,968	139	41.3

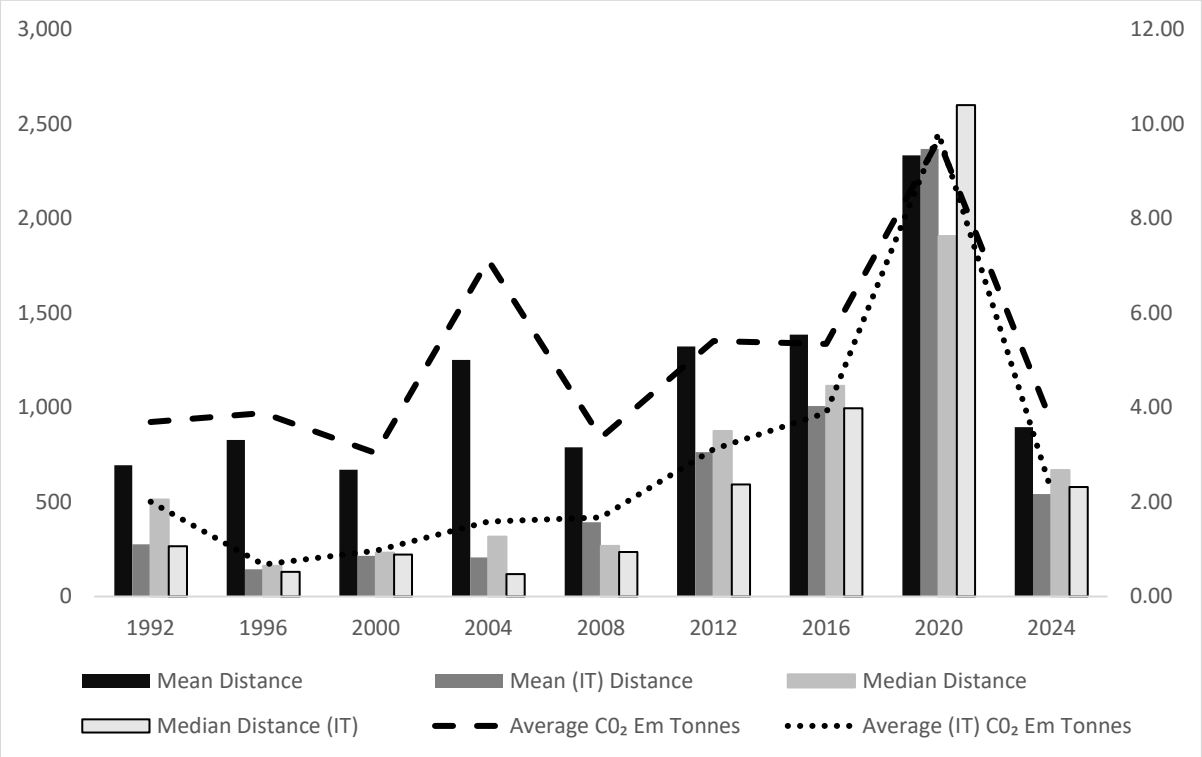
Source: Environmental Protection Agency (2023)

Figure 1. Team Travel (Kilometres) and CO^2 Emissions (Metric Tonnes) per Game at World Cups (1990-2022)



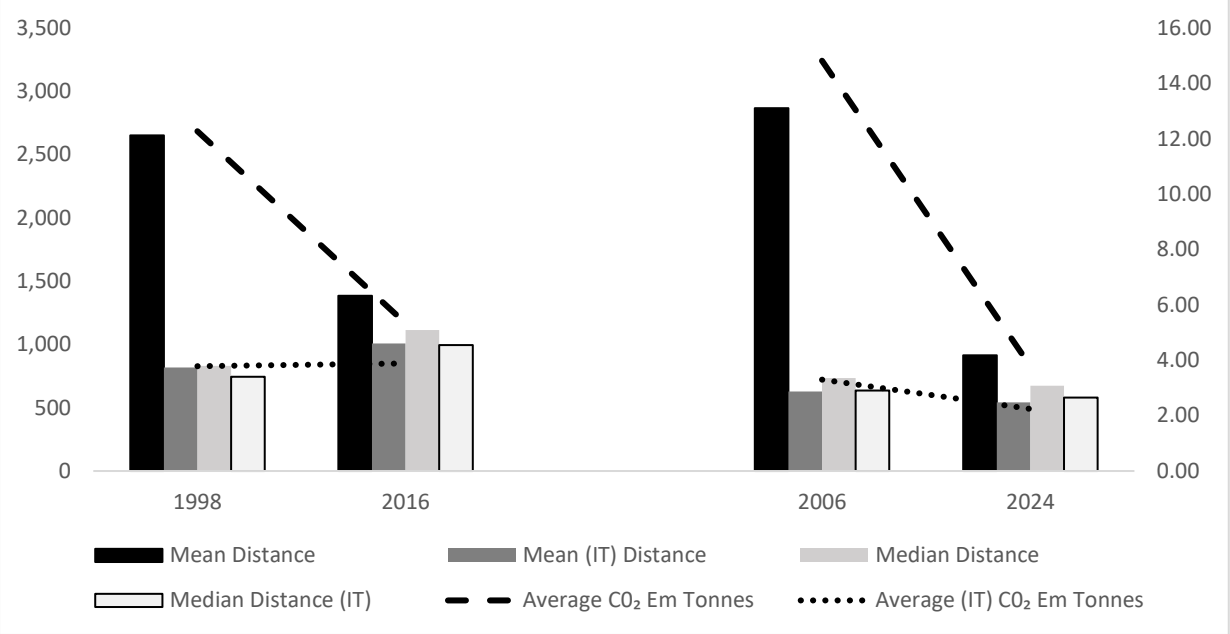
***** Average emissions values (metric tonnes) correspond to right-axis.

Figure 2. Team Travel (Kilometres) and CO^2 Emissions (Metric Tonnes) per Game at European Championships (1992 - 2024)



***** Average emissions values (metric tonnes) correspond to right-axis.

Figure 3: Comparing the same Host Countries - France (1998 and 2016) and Germany (2006 and 2024)



* Average emissions values (metric tonnes) correspond to right-axis.