Supplementary Information for

# A framework for assessing climate costs and economic benefits of major entertainment events

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## Supplementary Methods

### Coldplay surplus estimation

Two datasets were used for the Coldplay surplus estimation: a supplemented dataset obtained from Pollstar, and an original dataset collated from the resale website *Viagogo*. Face value prices were obtained from *Pollstar*, an information publishing firm that tracks concert statistics. This dataset provides the following information for each of the 32 concerts:

- Date (dd/mm/yyyy)
- Venue (name, location)
- Number of tickets sold (#)
- Sold out status (yes/no)
- Face value price range, i.e. prices of least and most expensive tickets (€)

Note that the *Pollstar* data does not provide the necessary ticket categorization to reflect price discrimination (i.e. prices and quantities per ticket category). We therefore supplemented this dataset by using the ten upcoming Coldplay concerts (08-09/2025) in the *Wembley Stadium* as approximation. This approximation is robust, since the *Wembley* concerts can be seen as the same product as the 2024 European concerts – they are all part of the *Music of the Spheres World Tour*, thus have the same setlist (i.e. song selection) and production (i.e. stage layout, special effects, concert duration)[1]. For full transparency, certain *Wembley*/UK-biases may subsist: Coldplay as UK-based band may enjoy even greater popularity in their home country, which may be further aggravated by high UK incomes compared to other European countries. *Wembley* offers four ticket categories (seating A, B, C; Standing), illustrated in Supplementary Figure 1. We assume prices for the three seating categories are equally distributed across the range. We then applied the relative price differences between ticket categories (%-ratio to highest ticket price) from *Wembley* to ticket price ranges per concert from *Pollstar*. VIP-tickets and *Infinity-Tickets* are excluded.

Limited amount (exact quantities not disclosed) of tickets with random category allocation offered for €20 to improve accessibility. Supplementary Figure 2 summarizes ticket prices and ratios.


Supplementary Figure 1 | *Wembley Stadium* layout (Wembley 2025)


| | A | B | C | Standing |
|---|---|---|---|---|
| **Stadium layout category** | Level 5 (501-552) | Level 2 (201-252) | Level 1 (101-142) | Pitch standing |
| **Price per ticket (£)** | 57.75 | 126.50 | 195.25 | 112.75 |
| **Ratio to highest price ticket (%)** | 30% | 65% | 100% | 58% |

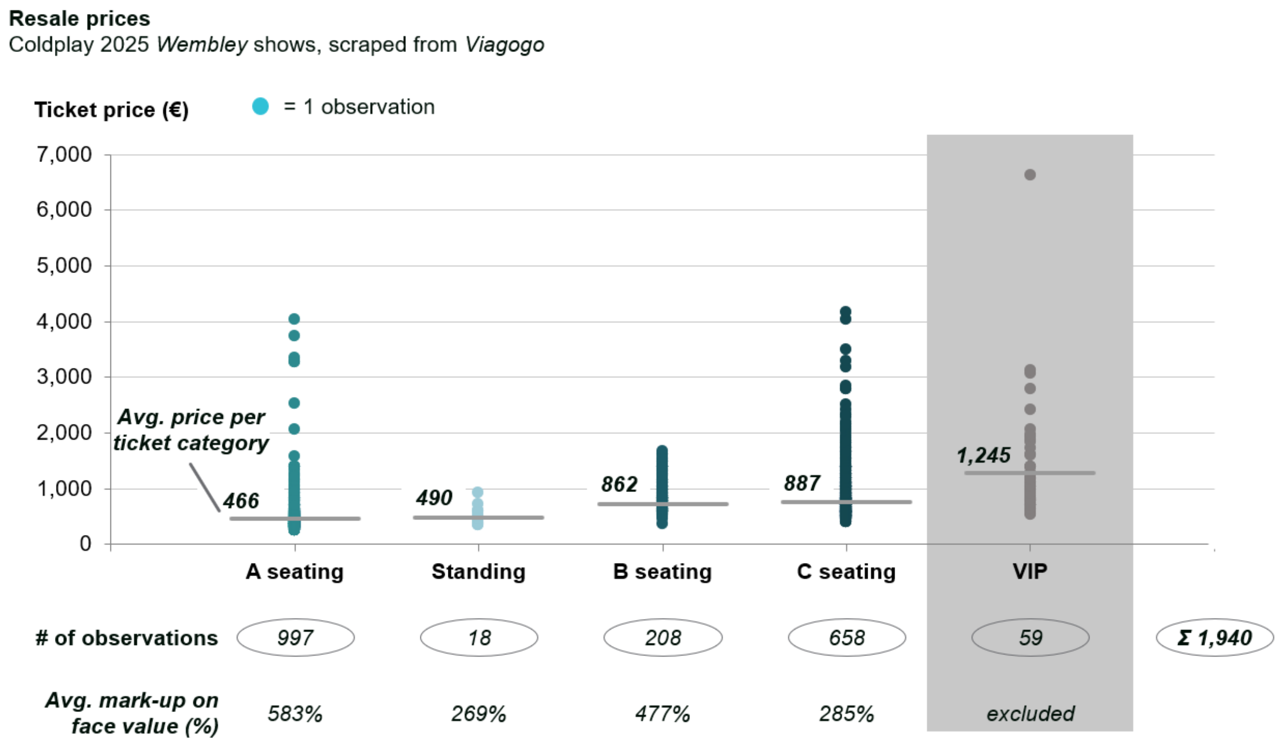
Supplementary Figure 2 | Face value ticket data of Coldplay concerts 2025, *Wembley* (Author illustration based on Coldplay 2025)

We obtained the seating versus standing splits for each concert from individual venue websites. If not available, we applied averages from venues that disclose such information. Lastly, we assumed an equal split of seating tickets (i.e. 1/3 of seating tickets in A, B, C). Supplementary Figure 3 summarises the enhanced face value data.

| Country | City | Date | Venue | # Tickets sold total | # Tickets seats | # Tickets standing | Sold out | € Ticket price low | € Ticket price high | € Ticket price A seats | € Ticket price B seats | € Ticket price C seats | € Ticket price standing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Greece | Athens | 08.06.2024 | Spiros Louis | **69,739** | 56,839 | 12,900 | Yes | 20.00 | 142.00 | 42.00 | 92.00 | 142.00 | 82.00 |
| Greece | Athens | 09.06.2024 | Spiros Louis | **69,739** | 56,839 | 12,900 | Yes | 20.00 | 142.00 | 42.00 | 92.00 | 142.00 | 82.00 |
| Romania | Bucharest | 12.06.2024 | Arena Națională | **52,710** | 42,960 | 9,750 | Yes | 21.06 | 133.38 | 39.45 | 86.42 | 133.38 | 77.02 |
| Romania | Bucharest | 13.06.2024 | Arena Națională | **52,710** | 42,960 | 9,750 | Yes | 21.06 | 133.38 | 39.45 | 86.42 | 133.38 | 77.02 |
| Hungary | Budapest | 16.06.2024 | Puskás Aréna | **55,590** | 46,706 | 8,884 | Yes | 18.56 | 121.73 | 36.00 | 78.86 | 121.73 | 70.29 |
| Hungary | Budapest | 18.06.2024 | Puskás Aréna | **55,590** | 46,706 | 8,884 | Yes | 18.56 | 121.73 | 36.00 | 78.86 | 121.73 | 70.29 |
| Hungary | Budapest | 19.06.2024 | Puskás Aréna | **55,590** | 46,706 | 8,884 | Yes | 18.56 | 121.73 | 36.00 | 78.86 | 121.73 | 70.29 |
| France | Lyon | 22.06.2024 | Groupama Stadium | **54,880** | 44,728 | 10,152 | Yes | 20.00 | 150.00 | 44.37 | 97.18 | 150.00 | 86.62 |
| France | Lyon | 23.06.2024 | Groupama Stadium | **54,880** | 44,728 | 10,152 | Yes | 20.00 | 150.00 | 44.37 | 97.18 | 150.00 | 86.62 |
| France | Lyon | 25.06.2024 | Groupama Stadium | **54,880** | 44,728 | 10,152 | Yes | 20.00 | 150.00 | 44.37 | 97.18 | 150.00 | 86.62 |
| Italy | Rome | 12.07.2024 | Stadio Olympico | **62,943** | 57,198 | 5,745 | Yes | 20.00 | 160.00 | 47.32 | 103.66 | 160.00 | 92.39 |
| Italy | Rome | 13.07.2024 | Stadio Olympico | **62,943** | 57,198 | 5,745 | Yes | 20.00 | 160.00 | 47.32 | 103.66 | 160.00 | 92.39 |
| Italy | Rome | 15.07.2024 | Stadio Olympico | **62,943** | 57,198 | 5,745 | Yes | 20.00 | 160.00 | 47.32 | 103.66 | 160.00 | 92.39 |
| Italy | Rome | 16.07.2024 | Stadio Olympico | **62,943** | 57,198 | 5,745 | Yes | 20.00 | 160.00 | 47.32 | 103.66 | 160.00 | 92.39 |
| Germany | Düsseldorf | 20.07.2024 | Merkur Spiel-Arena | **48,467** | 39,664 | 8,803 | Yes | 20.00 | 150.00 | 44.37 | 97.18 | 150.00 | 86.62 |
| Germany | Düsseldorf | 21.07.2024 | Merkur Spiel-Arena | **48,467** | 39,664 | 8,803 | Yes | 20.00 | 150.00 | 44.37 | 97.18 | 150.00 | 86.62 |
| Germany | Düsseldorf | 23.07.2024 | Merkur Spiel-Arena | **48,467** | 39,664 | 8,803 | Yes | 20.00 | 150.00 | 44.37 | 97.18 | 150.00 | 86.62 |
| Finland | Helsinki | 27.07.2024 | Olympic Stadium | **44,508** | 32,224 | 12,284 | Yes | 20.00 | 155.00 | 45.85 | 100.42 | 155.00 | 89.51 |
| Finland | Helsinki | 28.07.2024 | Olympic Stadium | **44,508** | 32,224 | 12,284 | Yes | 20.00 | 155.00 | 45.85 | 100.42 | 155.00 | 89.51 |
| Finland | Helsinki | 30.07.2024 | Olympic Stadium | **44,508** | 32,224 | 12,284 | Yes | 20.00 | 155.00 | 45.85 | 100.42 | 155.00 | 89.51 |
| Finland | Helsinki | 31.07.2024 | Olympic Stadium | **44,508** | 32,224 | 12,284 | Yes | 20.00 | 155.00 | 45.85 | 100.42 | 155.00 | 89.51 |
| Germany | Munich | 15.08.2024 | Olympiastadion | **70,064** | 59,863 | 10,201 | Yes | 20.00 | 150.00 | 44.37 | 97.18 | 150.00 | 86.62 |
| Germany | Munich | 17.08.2024 | Olympiastadion | **70,064** | 59,863 | 10,201 | Yes | 20.00 | 150.00 | 44.37 | 97.18 | 150.00 | 86.62 |
| Germany | Munich | 18.08.2024 | Olympiastadion | **70,064** | 59,863 | 10,201 | Yes | 20.00 | 150.00 | 44.37 | 97.18 | 150.00 | 86.62 |
| Austria | Vienna | 21.08.2024 | Ernst-Happel-Stadion | **62,850** | 40,736 | 22,114 | Yes | 20.00 | 180.00 | 53.24 | 116.62 | 180.00 | 103.94 |
| Austria | Vienna | 22.08.2024 | Ernst-Happel-Stadion | **62,850** | 40,736 | 22,114 | Yes | 20.00 | 180.00 | 53.24 | 116.62 | 180.00 | 103.94 |
| Austria | Vienna | 24.08.2024 | Ernst-Happel-Stadion | **62,850** | 40,736 | 22,114 | Yes | 20.00 | 180.00 | 53.24 | 116.62 | 180.00 | 103.94 |
| Austria | Vienna | 25.08.2024 | Ernst-Happel-Stadion | **62,850** | 40,736 | 22,114 | Yes | 20.00 | 180.00 | 53.24 | 116.62 | 180.00 | 103.94 |
| Ireland | Dublin | 29.08.2024 | Croke Park | **82,300** | 69,100 | 13,200 | Yes | 20.00 | 209.75 | 62.04 | 135.89 | 209.75 | 121.12 |
| Ireland | Dublin | 30.08.2024 | Croke Park | **82,300** | 69,100 | 13,200 | Yes | 20.00 | 209.75 | 62.04 | 135.89 | 209.75 | 121.12 |
| Ireland | Dublin | 01.09.2024 | Croke Park | **82,300** | 69,100 | 13,200 | Yes | 20.00 | 209.75 | 62.04 | 135.89 | 209.75 | 121.12 |
| Ireland | Dublin | 02.09.2024 | Croke Park | **82,300** | 69,100 | 13,200 | Yes | 20.00 | 209.75 | 62.04 | 135.89 | 209.75 | 121.12 |

Supplementary Figure 3 | Summary of face value ticket data for Coldplay's European Tour

Our secondary data source, regarding resale prices, was comprised of 1,940 resale offers for the ten *Wembley* concerts. These observations were taken directly from *Viagogo*, a leading resale platform[2]. We then mapped these to the categories and excluded VIP-tickets. Finally, we calculated average resale prices and derived relative mark-ups on face value per category (Supplementary Figure 4). On average, ticket prices increase in line with quality and follow Thompson's 2024[3] categorisation into outer seats (A), Standing, inner seats (B, C), and VIP. Expensive tickets in C are the front rows – the best seats[4].




Supplementary Figure 4 | Resale ticket data (author illustration of *Viagogo* data)

**World Cup surplus estimation**

To perform an ex-ante analysis for the World Cup, it was necessary to estimate both the face-value and resale ticket prices. To estimate the former, the 2022 World Cup prices were updated for inflation to 2025 dollars (see table S2). This was in line with FIFA's previous pricing strategy: updating the 2018 World Cup prices for inflation into 2022 dollars provides face-values in close agreement with the reported 2022 prices (see table S7). To estimate the latter, markup-rates were determined by observing the secondary market for a range of sporting events and then applied to the face-value prices. Secondary ticket prices were taken from resale sites including Live Football Tickets, Ticketmaster, and Viagogo. Primary ticket prices were collected directly from a pricing document published by the club or organising competition, with the exception of the one observed Club World Cup match, for which primary prices had to be calculated via observed "standard tickets" on Ticketmaster. In order to estimate TS, it is necessary to determine the cheapest face-value price required to cover the private costs of the event (TS = Resale Price – Cheapest Face Value Price). Because FIFA has historically offered a segment of underpriced tickets to increase fan accessibility, our cheapest estimated face values could not serve as the cover price. To determine these values for the 32 and 48 team tournaments, FIFA's reported operational costs were divided by the number of tickets expected to be sold. These values are presented in table S1.

Table S1 | Minimum ticket price to cover operational expenses

| *Format* | *Operational Cost (millions 2025 USD)* | *Expected Number of Tickets (millions)* | *Minimum Ticket Price* |
|---|---|---|---|
| 32-Team Tournament | 468 | 4.23 | $110.55 |
| 48-Team Tournament | 1,152.7 | 6.88 | $167.57 |

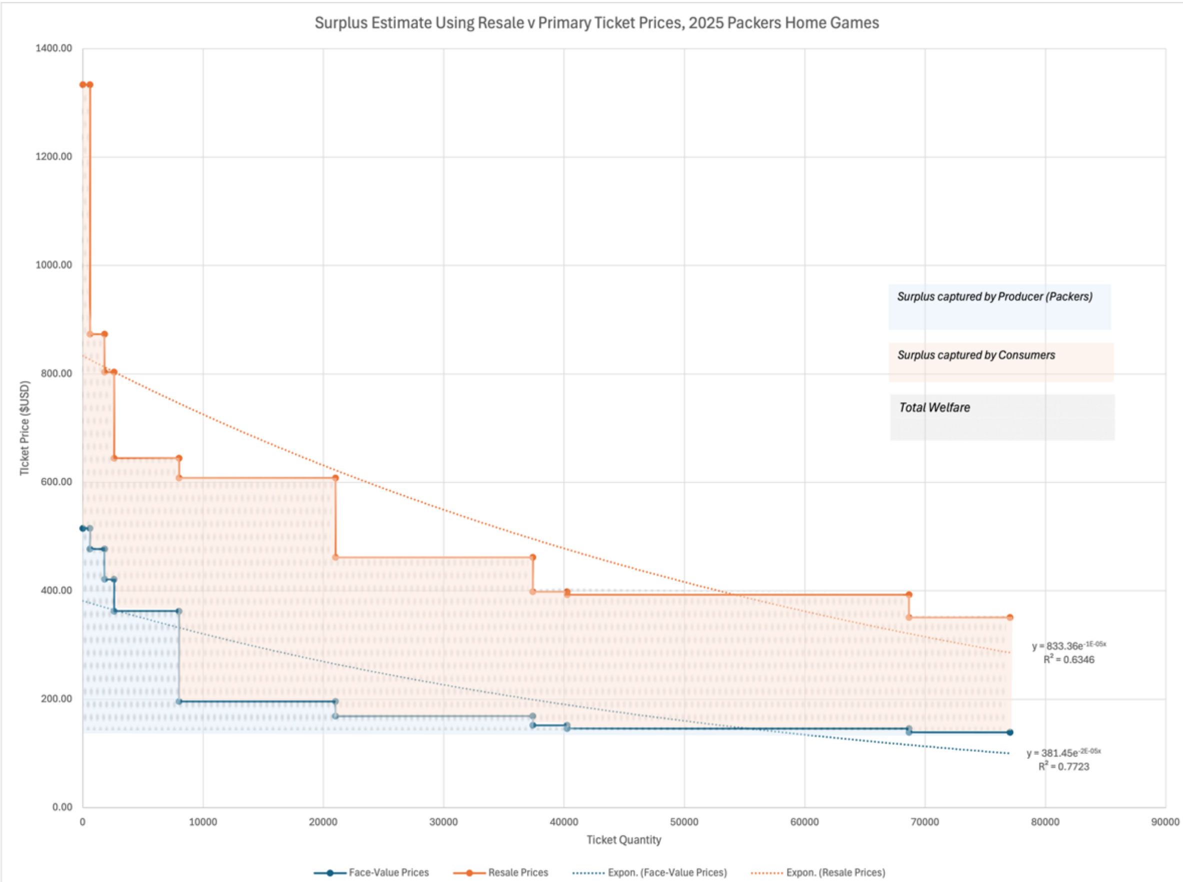
In total, 37,835 observations were collected from 35 games across seven different competitions. A full list of the observed games and their associated CS is presented in Table S4. Of the competitions selected, the NFL represents the clear focus, with 24 of the 34 analysed games coming from this competition, or around 87% of all observations (n = 32,484). This over-representation is the result of two main factors. Firstly, due to the timing of this research, a full season's worth of resale observations was available for three teams who had published their face-value prices (the Green Bay Packers, The San Francisco 49ers, and the New York Jets). Secondly, given that the 75% of the 2026 World Cup games will be hosted in the United States, performing the bulk of the analysis within the U.S. sporting market robustly captures regional WTP.

| Table S2 \| Estimated 2026 World Cup pricing scheme based on 2022 World Cup prices adjusted for inflation | | | | | | |
|---|---|---|---|---|---|---|
| *Tournament* | *Match Type* | *Category 1* | *Category 2* | *Category 3* | *Category 4* | *Accessibility Tickets* |
| 2022 WC Listed Prices | Opening Match | $618 | $439 | $302 | $55 | $55 |
| | Group Matches | $220 | $165 | $69 | $11 | $11 |
| | Round of 16 | $275 | $206 | $96 | $19 | $19 |
| | Quarterfinals | $425 | $288 | $206 | $82 | $82 |
| | Semi-finals | $955 | $659 | $357 | $137 | $137 |
| | 3rd place match | $425 | $302 | $206 | $82 | $82 |
| | Final | $1606 | $1002 | $604 | $206 | $206 |
| 2026 WC Estimated Prices | Opening match | $679 | $483 | $332 | $60 | $60 |
| | Group Matches | $242 | $181 | $75 | $12 | $12 |
| | Round of 16 | $302 | $226 | $106 | $21 | $21 |
| | Quarterfinals | $468 | $317 | $226 | $91 | $91 |
| | Semi-finals | $1051 | $725 | $393 | $151 | $151 |
| | 3rd place match | $468 | $332 | $226 | $91 | $91 |
| | Final | $1766 | $1102 | $664 | $226 | $226 |

In a similar vein, the second-most represented competition within the data set is the NBA Finals, with the four home games of the Oklahoma City Thunder representing around 7% of the total observations (n = 2490). The NBA finals were also selected because they represent a very different kind of event than regular season NFL games, being the highest stakes games played in an NBA season in a winner takes all series more akin to the format of a knockout-style tournament such as the World Cup. The difference between these two sporting events is represented dramatically in the average markup percentage of the competitions, with the NFL games having an average markup of 95% and the NBA Finals an average markup of 1,040%, with an associated average surplus of $23.1m and $48.3m, respectively. Some of this discrepancy may be explained by relative scarcity, since NBA stadiums have a capacity of around 20,000 while NFL stadiums typically seat 70,000 or more. However, given the impact of competition on WTP, it seems clear that the relative stakes of the competition drive an increase in markup rates[5,6]. An example of this analysis can be seen in Table S3, which estimates the average total surplus of Packers home game using resale data from all home games across the 2025 season. The results of this analysis are represented graphically in Supplementary Figure 5.

Of course, while the NBA and the NFL are apt choices for analysing the U.S. sporting market at large, both of these competitions differ importantly from the World Cup – they are different sports. In order to gain a sense of WTP for football in the U.S., the Club World Cup (CWC) provided the best candidate for comparison. Analysis on the CWC game between Atletico Madrid and PSG revealed a markup rate of around 96%, a number that is in close agreement with the overall NFL average of 95%. Notably, however, the total surplus was lower for the CWC game than for NFL games, at around $14.1m and $23.1m, respectively. Thus, while the relative markup percentage was similar, the overall willingness to pay was lower.

| Table S3 \| Total welfare estimate for average Packers home game | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Ticket Category* | *Approx # of Tickets* | *Face Value Price ($)* | *Average Resale Price (WTP, $)* | *Consumer Surplus per Ticket ($)* | *Total Surplus per Ticket ($)* | *Avg Markup (%)* | *Observations (n)* | *Consumer Surplus* | *Producer Surplus* | *Total Surplus* |
| 9 | 8,400 | 139 | 351 | 212 | 212 | 152% | 168 | 1,778,870 | - | 1,778,870 |
| 8 | 28,400 | 146 | 393 | 247 | 254 | 182% | 2,533 | 7,000,856 | 198,800 | 7,199,656 |
| 7 | 2,850 | 152 | 398 | 246 | 259 | 186% | 127 | 701,376 | 37,050 | 738,426 |
| 6 | 16,400 | 169 | 462 | 293 | 323 | 232% | 1,658 | 4,801,859 | 492,000 | 5,293,859 |
| 5 | 13,000 | 196 | 608 | 412 | 469 | 338% | 1,344 | 5,357,909 | 741,000 | 6,098,909 |
| 4 | 5,400 | 363 | 645 | 282 | 506 | 364% | 420 | 1,522,861 | 1,206,900 | 2,729,761 |
| 3 | 800 | 421 | 803 | 382 | 664 | 478% | 69 | 305,941 | 225,600 | 531,541 |
| 2 | 1,200 | 477 | 873 | 396 | 734 | 528% | 114 | 475,471 | 405,600 | 881,071 |
| 1 | 600 | 515 | 1,333 | 818 | 1,194 | 859% | 48 | 490,972 | 225,600 | 716,572 |
| TOTALS | 77,050 | - | - | - | - | 253% | 6,481 | $22,436,114 | $3,532,550 | $25,968,664 |




Supplementary Figure 5 | Total welfare of average Green Bay Packer's home game. Total welfare is the area under both resale and face-value prices. Producer surplus is the area under the higher priced face-value tickets and the cheapest ticket price. Consumer surplus is the area under the resale prices and above the face-value prices.

The remaining observations within the dataset were spread across seven games in three competitions (n = 1067). All of these were European football competitions, with five of the six taking place in the UK (n = 890) and one taking place in Germany (n = 176). Although these are not within the region where the World Cup is taking place, observing a segment of the European football sporting market was important to provide a rounded picture of WTP for football. This is especially true in light of the fact that it is estimated that 40% of the international attendees at the 2026 World Cup will be of European origin [7,8]. The markup percentages for these games ranged from 98% for the second round of the Champions League knockout matchup between Aston Villa and Club Brugge to 587% for Liverpool v. PSG in the same stage of that competition. The associated total surpluses for these two matches $4.2m and $24.9m, which again demonstrates the drastic effect that the level of competition can have on willingness to pay and therefore total surplus.

One important note for the consumer surplus analysis of games within the European market is the presence of ticket resale legislation. In the UK, the resale of football tickets by unauthorised entities (i.e. not approved by the organisers of the match) is illegal under section 166 of the Criminal Justice and Public Order Act 1994[9]. Despite this, however, so-called "black-market" resale continues to proliferate[10]. This is further evidenced by the number of observations within this paper's dataset which were taken from ostensibly unauthorised ticket resale platforms such as Live Football Tickets and Viagogo (n = 1067, approximately 3% of all observations). Notably, in November 2025, the UK government introduced legislation that will ban the resale of tickets above the original cost[11], meaning that this will no longer be a viable method for estimating WTP in the UK. The consumer surplus, total surplus, and resale markup percentages for every game analysed are presented in table S4. Note that, due to the format of the competitions and the timeline of this research, it was occasionally necessary to collect data only 48 hours or less before the start of the event. Although it is not possible to account for this post-facto, the events have been colour coded by their date of collection in the interest of transparency.

Table S4 | Consumer surplus, total surplus, and markup percentage for all analysed games

| *Competition* | *Game* | *Consumer Surplus ($)* | *Total Surplus ($)* | *Average Markup %* |
|---|---|---|---|---|
| Champions League | Aston villa v Club Brugge | 3,923,919.56 | 4,158,911 | 98% |
| Champions League | Liverpool v PSG | 23,952,971.09 | 24,927,481 | 587% |
| Club WC | PSG v Atletico | 12,046,742.04 | 14,117,914 | 95% |

| | | | | |
|---|---|---|---|---|
| FA Cup | Final | 47,236,066.14 | 55,106,630 | 322% |
| Nations League | Portugal v Spain | 14,126,461.85 | 20,319,908 | 300% |
| NBA Finals | Game 1 | 32,864,696.92 | 35,695,697 | 752% |
| NBA Finals | Game 2 | 36,565,735.99 | 39,406,240 | 832% |
| NBA Finals | Game 5 | 49,732,151.70 | 50,211,982 | 1093% |
| NBA Finals | Game 7 | 65,402,608.90 | 68,256,199 | 1428% |
| NFL | Jets v Browns | 4,088,620.14 | 13,190,682 | 35% |
| NFL | Jets v Dolphins | 5,053,160.31 | 14,094,845 | 38% |
| NFL | Niners v Titans | 8,986,339.65 | 19,292,917 | 43% |
| NFL | Jets v Panthers | 4,912,036.06 | 13,902,821 | 45% |
| NFL | Jets v Falcons | 4,664,991.33 | 13,064,955 | 49% |
| NFL | Niners v Cardinals | 10,505,150.27 | 22,723,900 | 50% |
| NFL | Niners v Panthers | 9,775,621.44 | 19,989,292 | 50% |
| NFL | Niners v Jags | 10,521,866.23 | 22,740,616 | 51% |
| NFL | Niners v Falcons | 11,512,393.00 | 23,009,956 | 56% |
| NFL | Jets v Patriots | 6,836,676.16 | 15,986,363 | 59% |
| NFL | Jets v Bills | 8,853,289.39 | 19,008,666 | 63% |
| NFL | Niners v Seahawks | 13,588,366.44 | 23,568,927 | 68% |
| NFL | Jets v Cowboys | 10,686,823.42 | 21,167,287 | 73% |
| NFL | Niners v Rams | 15,973,986.98 | 25,746,716 | 83% |
| NFL | Niners v Bears | 19,716,066.57 | 29,280,177 | 99% |
| NFL | Jets v Steelers | 17,727,437.28 | 28,969,562 | 116% |
| NFL | Packers v Ravens | 15,339,105.14 | 18,871,655 | 118% |
| NFL | Packers v Panthers | 16,768,979.01 | 20,301,529 | 130% |
| NFL | Packers v Vikings | 20,891,850.34 | 24,424,400 | 162% |

| | | | | |
|---|---|---|---|---|
| NFL | Packers v Bears | 22,716,274.26 | 26,248,824 | 173% |
| NFL | Packers v Bengals | 27,195,065.30 | 30,727,615 | 208% |
| NFL | Packers v Commanders | 31,723,986.11 | 35,256,536 | 209% |
| NFL | Packers v Lions | 30,837,242.04 | 34,369,792 | 234% |
| NFL | Packers v Eagles | 35,087,913.85 | 38,620,464 | 247% |
| WC Qualifying | England v Albania | 7,829,950.79 | 10,439,857 | 184% |
| WC Qualifying | England v Latvia | 5,843,617.07 | 6,851,834 | 147% |

| Data Collection Colour Key |
|---|
| Data collected < 48hrs before event |
| Data collected 48hrs-1wk before event |
| Data collected 1-2wk before event |
| Data collected 2wk-1mo before event |
| Data collected >1mo before event |

To calculate the total surplus associated with the World Cup, it is first assumed that markup rates for the tournament will be roughly in line with the markup rates observed in the observed sporting competitions. Making this assumption allows us to estimate the resale price by applying these markups to the face-value prices of the WC tickets. To account for the difference in demand for more competitive games, the matches were divided into group-stage, knockout, and semis/final. Markup rates were chosen for each of these subcategories by taking the $50^{th}$, $68^{th}$, and $95^{th}$ percentile markup rates from the total distribution of observations (n = 37,825). Thus, the markup rates applied to the group-stage, knockout, and semis/final are 67%, 101%, and 651%, respectively. The $68^{th}$ percentile value was also applied to the opening match and the third-place game, since these are priced differently by FIFA and do not fit neatly into the other categories.

**World Cup GHG model**

We created a new greenhouse gas estimation for the 2026 World Cup for both a 32-team and 48-team scenario by updating and modifying FIFA's use of the GHG protocol. The results of our model are an estimated total emission of 3,636,5942t $CO_2$-e for the former scenario and 4,230,400 t $CO_2$-e for the latter. The emissions by source category and their difference from the 2022 World Cup are presented in table S5.

Table S5 | Emissions estimate by category, 2022 and 2026 World Cups

| *Emissions Category* | *2022 FIFA Ex-Post Emissions (tCO2e)*[8] | *2026 32-Team Emissions Estimate (tCO2e)* | *2026 48-Team Emissions Estimate (tCO2e)* | *Difference Between 2026 Scenarios (tCO2e)* |
|---|---|---|---|---|
| Permanent venue construction | 657,164.00 | - | - | - |
| Accommodation | 536,740.00 | 179,182 | 287,237 | 108,054 |
| Temporary construction | 164,161.00 | 190,967 | 190,967 | - |
| Electricity | 57,200.00 | 30,767 | 40,484 | 9,717 |
| Food and beverages | 47,946.00 | 47,946 | 77,912 | 29,966 |
| Production of energy carriers | 26,233.00 | 26,233 | 42,629 | 16,396 |
| Materials and merchandise | 26,135.00 | 26,135 | 42,469 | 16,334 |
| Water | 11,741.00 | 11,741 | 19,079 | 7,338 |
| Diesel | 11,431.00 | 11,431 | 18,575 | 7,144 |
| Leased facilities | 7,898.00 | 7,898 | 12,834 | 4,936 |
| Logistics | 4,115.00 | 4,115 | 6,687 | 2,572 |
| Cooling | 3,224.00 | 4,144 | 6,735 | 2,590 |
| Water | 2,493.00 | 2,493 | 4,051 | 1,558 |
| Waste water | 734.00 | 734 | 1,193 | 459 |
| Refrigerants | 457.00 | 457 | 743 | 286 |
| Media and broadcasting | 406.00 | 406 | 660 | 254 |
| Process emissions | 10.00 | 10 | 16 | 6 |

| | | | | |
|---|---|---|---|---|
| International travel | 2,205,698.00 | 2,831,306 | 3,067,123 | 235,817 |
| Inter-city Travel | - | 233,150 | 366,065 | 132,915 |
| Intra-City Travel | 44,572.00 | 27,478 | 44,940 | 17,463 |
| TOTAL | 3,808,358.00 | 3,636,594 | 4,230,400 | 593,806 |

For the past three World Cups in Brazil, Russia, and Qatar, FIFA has conducted its own greenhouse gas inventory, employing the GHG Protocol developed by the World Resource Institute (WRI). This is a standardised method of GHG accounting, and it is has been used in a sporting context by both FIFA and other sports[14,15]. FIFA's three most recent World Cups, which took place in 2014, 2018, and 2022, respectively, were estimated to generate GHG emissions of 2.7, 2.1, and 3.6 Mt $CO_2$-e [14,16,17]. Additionally, for the 2022 edition of the tournament, FIFA conducted an ex-post greenhouse gas inventory for the first time, updating some of their ex-ante assumptions with empirical data collected during the tournament. This resulted in an increase of 200,000 t $CO_2$-e, raising the overall estimation for the 2022 World Cup in Qatar to 3.8 Mt $CO_2$-e[8].

Given FIFA's reliance on the widely used methodology of the GHG Protocol, particularly in the 2018 and 2022 tournaments, we adopted the approach of modifying their existing model as needed in order to generate an estimation for the 2026 event. In both of their 2022 ex-ante and ex-post inventories. To build a 32- and 48-team model for the 2026 tournament, we began by splitting these categories into those whose underlying assumptions are likely to be constant between the 2022 and 2026 tournaments and those whose underlying assumptions would need to be updated for 2026. Those which were determined to have constant underlying assumptions were held equal between the 2022 and 2026 32-team format. Any category which was determined to have significantly different underlying assumptions between the 2022 and 2026 editions was then modelled using a mixture of data from FIFA's 2014, 2018, and 2022 reports and governmental agencies. The emissions categories were then further refined into those that would need to be scaled for a 48-team tournament and those that would remain the same between and 32-team and a 48-team tournament. Categories which were determined to be scalable were multiplied by a factor of 1.625 to achieve the 48-team emissions. This factor of 1.625 comes from the percentage increase in the number of games between the two tournament sizes. Categories which were deemed not to be scalable were either held constant between the two tournament sizes in the case of categories with 2022 assumptions or modelled in the case of categories updated for 2026 (see table 2 in the main text). The process for the modelling of each of these categories is outlined individually below.

Travel represents the largest portion of emissions associated with the FIFA World Cup, constituting 51% of FIFA's GHG estimation in 2022 and 74% in 2018, or 1.9 Mt $CO_2$-e and 1.6 Mt $CO_2$-e, respectively[8,14]. As such, the overall emissions estimation is highly sensitive to the assumptions underlying the travel emissions category. Our model decomposes travel into three subcategories – international, inter-city, and intra-city. It is worth noting that the inter-city category was absent from the Qatar GHG estimation, as the tournament was entirely staged within the city of Doha and its immediate surroundings. The major assumptions underlying these three components of travel are presented in turn.

Firstly, in order to determine the number of international, inter-city, and intra-city travellers attending the World Cup, it is necessary to calculate the overall number of spectators expected to attend. To find this number, each host stadium's capacity was multiplied by the number of games it is expected to host. For a 32-team tournament, the total expected number of spectators is 4.2 million, while a 48-team tournament is estimated to draw a total of 6.9 million spectators. Of these, approximately 80% will attend in the US, 11% in Mexico, and 9% in Canada.

Importantly, however, the overall attendee number does not reflect the number of *unique* attendees. To calculate this number, the total number of spectators was divided by the average number of games per attendee. For the 32-team format, the total number of spectators was divided by 2, while in the 48-team format it was divided by 3. The total number of unique spectators is estimated to be 2.1 million and 2.3 million for the 32 team and 48 team formats, respectively. Thus, the assumed increase in the number of matches per spectator results in a relatively modest overall increase in unique number of spectators between the two formats, around 8%. This assumption represents a key driver of the overall emissions estimation – if the number of events per spectator is held constant at 2 across tournament sizes, unique spectators at the

48 tournament is equal to 3.4 million, or an increase of 63%. Similarly, if the number of events per spectator is held at 3 across tournament sizes, then the disparity between the two tournaments is 63%, as this would imply 1.4 million spectators in the 32-team format. An 8% increase in the number of unique spectators is reasonable assuming that people will attend more games given the increase in availability. With this number determined, it is possible to estimate emissions associated with attendees. The domestic/international split and assumption source can be found in table S6.

Table S6 | Domestic international split and assumptions, 48 teams

| *Attendee Type* | *% International* | *% Domestic* | *Assumption Source:* |
|---|---|---|---|
| General public | 58% | 42% | FIFA 2022 Ex-post Table 23[8] |
| Hospitality | 58% | 42% | FIFA 2022 Ex-post Table 23[8] |
| Group sales customers | 58% | 42% | FIFA 2022 Ex-post Table 23[8] |
| V/VIPs | 58% | 42% | FIFA 2022 Ex-post Table 23[8] |
| Media | 50% | 50% | FIFA 2018 Inventory Table 12[16] |
| FIFA, SC and Q22 staff | 100% | 0% | FIFA 2018 Inventory Table 12[16] |
| PMAs | 91% | 9% | Share of Tournament Slots |
| Referees | 91% | 9% | Share of Tournament Slots |
| Tournament-time workforce | 0% | 100% | FIFA 2018 Inventory Table 12[16] |
| Volunteers | 5% | 95% | FIFA 2018 Inventory Table 12[16] |

To determine the emissions generated from travel the following general formula was followed:

$$\text{Travel Emissions} = N_{tm} \times E_{tm} \times D \qquad \textit{f.s.1}$$

Where $N_{tm}$ is the number of travellers per travel mode, $E_{tm}$ is the emissions factor per passenger distance by travel mode, and D is equal to distance. It was assumed that all international travellers travelled to the tournament by air with the exception of those originating from the Central America & Caribbean region for matches in Mexico and the U.S., where it was assumed 3% would travel by car and 2% by bus given their proximity to Mexico and the southern United States. The flight type was then broken into economy, business, first class, and charter (private), with rates by attendee category taken from FIFA's ex-post estimate. The emissions factors used were taken from DESNZ's 2025 emissions factors dataset, with the exception of charter flights, for which an independent report on private jets was used[18,19].

To determine the distance travelled, we calculated the average flight distance from at least two airports in each origin region to an airport in each host nation. Once the number of travellers per mode, travellers per distance, and emissions factor were established, emissions were calculated for each region visiting each host nation. These were then summed to give the overall international travel emissions and then doubled to account for two-way travel. A condensed example of this calculation for one region (European travellers to the U.S., 48 team assumptions) can be seen in table S7. The emissions factors used are displayed in table S8. Long-haul emissions factors were used for all international air travel with the exception of attendees from the Central America and Caribbean region, for which short-haul domestic values were used. Applying this method results in international travel emissions of 2.8 Mt $CO_2$-e for the 32-team format and 3.1 Mt $CO_2$-e for the 48-team format.

| Table S7 \| International travel emissions for European spectators traveling to the U.S. under a 48 team format | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Attendee Category* | *International Attendees* | *European % of Int Attendees* | *# European Attendees* | *# Economy Flights* | *# Business Flights* | *# First Class Flights* | *# Charter Flights* | *Avg Regional Flight Distance (km)* | *Total Emissions (KG CO2e)* |
| General public | 788732 | 36% | 283707 | 283707 | 0 | 0 | 0 | 7,292 | 293,030,810 |
| Hospitality | 65728 | 36% | 23642 | 18914 | 4728 | 0 | 0 | 7,292 | 336,98,026 |
| Group sales customers | 157958 | 36% | 56818 | 56818 | 0 | 0 | 0 | 7,292 | 58,684,934 |
| V/VIPs | 1060 | 36% | 381 | 0 | 0 | 381 | 0 | 7,292 | 1,575,379 |
| Media | 2132 | 36% | 758 | 758 | 0 | 0 | 0 | 7,292 | 783,116 |
| FIFA, SC and Q22 staff | 2437 | 100% | 2437 | 0 | 2437 | 0 | 0 | 7,292 | 7,299,497 |
| PMAs | 3546 | 36% | 1261 | 0 | 0 | 0 | 1261 | 7,292 | 11,951,104 |
| Referees | 591 | 36% | 210 | 0 | 210 | 0 | 0 | 7,292 | 629,379 |
| Tournament-time workforce | 0 | 0% | 0 | 0 | 0 | 0 | 0 | 7,292 | 0 |
| Volunteers | 183 | 36% | 65 | 65 | 0 | 0 | 0 | 7,292 | 67,124 |
| *TOTAL #* | *1,022,368* | | 369279 | 360262 | 7376 | *381* | *1,261* | - | *296,442,440* |

| Table S8 \| Flight emissions factors for world cup travel calculations | | |
|---|---|---|
| *Flight Type* | *Emissions Factor (KG CO2-e / passenger.km)* | *Source* |
| Short-Haul Economy | 0.14825 | DESNZ 2025[18] (includes well to tank) |
| Short-Haul Business | 0.22236 | DESNZ 2025[18] (includes well to tank) |
| Long-Haul Economy | 0.14165 | DESNZ 2025[18] (includes well to tank) |
| Long-Haul Business | 0.41077 | DESNZ 2025[18] (includes well to tank) |
| Long-Haul First Class | 0.56658 | DESNZ 2025[18] (includes well to tank) |
| Private Jet (Charter) | 1.3 | Transport and Environment Report[19] |

To calculate inter-city travel, attendees were first split into domestic and international inter-city travellers. To calculate international inter-city travellers, it was assumed that 50% of general public international attendees would make one intercity trip during the course of the tournament in the 32-team format and 1.5 trips during the course of the 48-team tournament (half of the number of games attended for each tournament size). For FIFA staff and media, a ratio of 75% was assumed. For players and referees, it was assumed that 100% would make a number of trips equal to the average number of games that a team in the tournament plays, which are 4 and 4.3 in the 32- and 48-team formats, respectively. To calculate domestic inter-city emissions, it was assumed that inter-city travellers would make two inter-city roundtrips in the 32-team format and three inter-city roundtrips in the 48-team format.

The form of travel was also differentiated between domestic and international attendees. For the former, data from the US Bureau of Transportation was used to calculate the ratio of travel between flying, driving, bussing, and rail[20]. Around 79% of the total passenger miles in the US in 2023 were travelled by motor vehicle, 14% by air, 6% by bus, and only 1% by rail. To determine the mode of transport for the international attendees, assumptions from FIFA's 2018 report were updated. We assumed that 67% will fly, 27% will drive, 3% will bus, and 3% will take inter-city rail. The rationale behind the use of differing modes of transit for domestic and international attendees is that domestic attendees are more likely to have access to a car than international attendees who would need to rent a vehicle. Inter-city flight distance was assumed to be equal to the average flight distance within the U.S. from the Bureau of Transportation (1,513 km)[21]. Inter-city drive distances were calculated by taking the average distance between stadiums within the same tournament region (Western = 715km, Central = 874km, Eastern = 890km, average = 826km). Trips equal to or longer than the average flight distance were excluded from this calculation under the assumption that attendees would then choose to fly. Using DESNZ's 2025 emissions factors for flight, the average petrol car, coach (inter-city bus), and heavy rail, inter-city emissions were calculated to be 233,150 t $CO_2$-e and 366,065 t $CO_2$-e for the 32 and 48 team formats, respectively.

For intra-city travel, we assumed that all attendees would undertake a roughly equal amount of intra-city travel. First, we calculated the average distance between the airport and the stadium to be 27km. This is taken as the baseline travel distance for intra-city travel. This number was multiplied by two to account for round-trip travel, and then multiplied by the number of events attended, meaning that the average general public attendee was assumed to travel 108 km in the 32-team format and 162km in the 48-team format.

We differentiated the mode of transport between the international and domestic attendees. For domestic attendees, the split in transit mode was calculated using the same Bureau of Transportation Data excluding flight. This provided an estimated split of 92% motor vehicle, 7% by bus, and 1% rail. For the international attendees, FIFA's 2022 ex-post data from Qatar was used to determine the mode of transit: 35% travelled by car, 6% by bus, and 59% by the metro (light rail). Again, DESNZ's 2025 emissions factors were used to calculate the overall emissions associated with these transit modes and distances, resulting in an estimation of 27,478 t $CO_2$-e for the 32-team and 44,940 t $CO_2$-e for the 48-team model.

Summing the constituent parts of travel (international, inter-city, and intra-city), the 48-team 2026 World Cup is expected to generate approximately 3.49 Mt $CO_2$-e from travel alone. If the tournament were being held in the previous, 32-team format, this number would be 3.09 Mt $CO_2$-e. This represents a 12% increase in travel. For context, the 2022 World Cup was estimated to generate around 2.2 Mt CO2-e[8]. The increase to the tournament's size and geographic scope mean that the planned 2026 World Cup will result in a 59% increase in travel emissions over the previous tournament.

Emissions associated with accommodation were particularly high at the 2022 World Cup, constituting roughly 14% of the total or 536,740 t $CO_2$-e. In order to model the emissions for the 2026 World Cup, the overall attendance figures described above were combined with FIFA's assumptions regarding the number of nights per attendee in order to determine the total number of hotel nights. To determine the associated $CO_2$-e emissions, emissions factors were taken from Cornell's Hotel Sustainability Benchmarking Index (CHSB) 2024[22]. CHSB is a resource that is published yearly by the Nolan School of Administration Department within Cornell University and compiles a rich set of data on differing hotel types globally. This is the same resource that FIFA used to estimate the accommodation emissions for Qatar in 2022, and has been referenced in several peer reviewed works investigating the environmental impact of hotels[23,24]. Importantly, this resource provides emissions factors by hotel type, including two-, three-, four-, and five-star establishments, which are the categories into which FIFA sorts attendee types. The nights per attendee type for the team tournament are presented in table S9 and S10 along with the associated emissions factor. Guest nights for staff and workers were found by multiplying the 32 team values by 1.36, which represents the increase in the number of days of the tournament. Pulling these assumptions together achieves an overall accommodations emissions estimate of 179,183 t $CO_2$-e in the 32-team format and 287,237 t $CO_2$-e in the 48-team format.

Table S9 | Hotel accommodation details by attendee category, 32-Team

| *Attendee Category* | *Nights Per Event Attended* | *Total Guest Nights Per Attendee* | *Accommodation Type* | *U.S. Emissions Factor (kg CO2e per occupied room)*[22] |
|---|---|---|---|---|
| General public | 3 | 6 | 2-/3-Star Hotel | 16 |
| Hospitality | 4 | 8 | 4-/5-Star Hotel | 43 |
| Group sales customers | 3 | 6 | 2-/3-Star Hotel | 16 |
| V/VIPs | 4 | 8 | 4-/5-Star Hotel | 43 |
| Media | N/A (assumed) | 45 | 4-/5-Star Hotel | 43 |

| | | | | |
|---|---|---|---|---|
| FIFA, SC and Q22 staff | N/A (assumed) | 33 | 4-/5-Star Hotel | 43 |
| PMAs | N/A (assumed) | 51 | 4-/5-Star Hotel | 43 |
| Referees | N/A (assumed) | 50 | 4-/5-Star Hotel | 43 |
| Tournament-time workforce | N/A (domestic) | 0 | 2-/3-Star Hotel | 16 |
| Volunteers | N/A (assumed) | 33 | 2-Star Hotel | 14.2 |

Table S10 | Hotel accommodation details by attendee category, 48-Team

| *Attendee Category* | *Nights Per Event Attended* | *Total Guest Nights Per Attendee* | *Accommodation Type* | *U.S. Emissions Factor (kg CO2e per occupied room)*[22] |
|---|---|---|---|---|
| General public | 3 | 9 | 2-/3-Star Hotel | 16 |
| Hospitality | 4 | 12 | 4-/5-Star Hotel | 43 |
| Group sales customers | 3 | 9 | 2-/3-Star Hotel | 16 |
| V/VIPs | 4 | 12 | 4-/5-Star Hotel | 43 |
| Media | N/A (assumed) | 61 | 4-/5-Star Hotel | 43 |
| FIFA, SC and Q22 staff | N/A (assumed) | 45 | 4-/5-Star Hotel | 43 |
| PMAs | N/A (assumed) | 69 | 4-/5-Star Hotel | 43 |
| Referees | N/A (assumed) | 68 | 4-/5-Star Hotel | 43 |
| Tournament-time workforce | N/A (domestic) | 0 | 2-/3-Star Hotel | 16 |
| Volunteers | N/A (assumed) | 45 | 2-Star Hotel | 14.2 |

One major departure between the 2022 and 2026 editions of the World Cup is the significant amount of construction that the former required. Overall, construction of the venues in 2022 resulted in 657,000 t $CO_2$-e, which included the construction of seven completely new stadiums[8]. In stark contrast, the 2026 World Cup will be played entirely in existing stadiums. Although some minor renovations will need to be made to a number of these stadiums, only one requires the addition of extra seating capacity. Accordingly, the construction emissions are estimated to be significantly lower for the 2026 tournament, coming out to 191,000 t $CO_2$-e. These are split into temporary venue construction and temporary facility construction, detailed below.

Temporary facility construction refers to the construction of transient structures such as the FIFA fan zones and media zones. It is assumed that this portion of temporary construction will be on par with previous editions of the tournament. As such, the temporary facility construction from the previous three tournaments (164,558 $CO_2$-e in 2022, 91,792 in 2018, 111,500 in 2014) were averaged for an estimated emissions of 122,617 t $CO_2$-e in the 2026 World Cup. It is conservatively assumed that these emissions will remain constant across the 32 and 48 team formats.

For the 2026 World Cup, temporary venue construction refers to the upgrades that are being made to stadiums in order to host World Cup games that will be reverted once the tournament has ended. These include the installation of grass in eight of the sixteen host stadiums, and the temporary expansion of the Capacity of BMO field in Toronto, Canada. To estimate the former, a study was identified that compares the lifecycle emissions associated with both grass and turf sports fields[25]. Given the temporary nature of this installation, only the construction emissions of the lifecycle estimate were used, which amount to about 513t $CO_2$-e per installation. Summed across eight stadiums, the installation of new fields is estimated to result in around 4,104t $CO_2$-e. For the installation of temporary seating at BMO field, the total temporary construction emissions of the 2022 WC were divided by the number of installed seats in order to generate a per seat emissions factor of 3.8t $CO_2$-e per seat. This factor was then multiplied by the number of temporary seats being installed at BMO field, roughly 17,000, which generates estimated emissions of 64,247t $CO_2$-e. Thus, overall, temporary venue construction is estimated to create around 68,351t $CO_2$-e. Again, it is assumed that the construction for the 32 and 48-team tournaments would have been equal, and thus this number is held constant between the two formats.

To calculate electricity and cooling, it was first assumed that the total amount of electricity used in a 2026 32-team counterfactual would be roughly equivalent to the 2022 World Cup. Starting from this assumption, the total electricity use was then back-calculated using a combination of DESNZ's 2019 emissions factors and Qatar's own 2019 emissions factors, which were the emissions factors used by FIFA in their 2022 calculations[26,27].

For electricity, the total electricity emissions from the 2022 world cup, around 57,200t $CO_2$-e, were divided by the Qatar emissions factor combined with DESNZ's transmission and distribution emissions factor, which totalled around 0.65 kg $CO_2$-e per kilowatt hour (kWh). This leads to an estimated total electricity use at the 2022 World Cup of 87,931,761 kWh. Total kWh were multiplied by the US average emissions factor, which was taken from the US EPA's emissions hub, and results in of 30,767t $CO_2$-e[28]. To calculate the 48-team estimate, the total electricity usage was first increased by a factor of 1.625 to account for the increase in the number of games and then multiplied by the same EPA emissions factor of 0.35 kg/kWh, resulting in 40,484t $CO_2$-e.

Cooling emissions were calculated in a similar manner, dividing the 2022 cooling emissions by the 2019 heating and steam emissions factor from DESNZ to arrive at an estimated 18,311,939 kWh. Increasing this usage by 1.625 for the 48-team estimate, these numbers were then multiplied by the EPA's 2025 heating and steam emissions factor to achieve 32- and 48-team estimates of 4,144 and 6,735t $CO_2$-e.

## Coldplay GHG model

The four main steps for the Coldplay GHG estimation are GHGP: Scoping and boundary setting, data collection, baselining, scaling up. For step one (scoping), we compiled a list of activities to quantify, based on Bottrill et al. (2007)[29] and others – 13 activities are included, two excluded (Supplementary Figure 6).

| # | Cluster | Activity | Scope | Method | Main source to include/ exclude activity in scope |
|---|---|---|---|---|---|
| 1 | Venue operations | Electricity | Scope 2 | Per concert | Bottrill et al. 2008 (assessed); AGF 2023 (assessed) |
| 2 | Venue operations | Gas | Scope 2 | Per concert | Bottrill et al. 2008 (assessed); AGF 2023 (assessed) |
| 3 | Band and crew | Air travel | Scope 3 | Itinerary-based | Bottrill et al. 2008 (assessed); AGF 2023 (assessed) |
| 4 | Band and crew | Road travel | Scope 3 | Itinerary-based | Bottrill et al. 2008 (assessed); AGF 2023 (assessed) |
| 5 | Band and crew | Accomodation | Scope 3 | Itinerary-based | AGF 2023 (assessed); Botrrill et al. 2008 (mentioned) |
| 6 | Band and crew | Freight | Scope 3 | Itinerary-based | Bottrill et al. 2008 (assessed); AGF 2023 (assessed) |
| 7 | Audience travel | Air travel | Scope 3 | Per concert | Brennan et al. 2019 (assessed); Bottrill et al. 2008 (assessed); AGF 2023 (assessed) |
| 8 | Audience travel | Road travel | Scope 3 | Per concert | Brennan et al. 2019 (assessed); Bottrill et al. 2008 (assessed); AGF 2023 (assessed) |
| 9 | Audience travel | Public transport travel | Scope 3 | Per concert | Brennan et al. 2019 (assessed); Bottrill et al. 2008 (assessed); AGF 2023 (assessed) |
| 10 | Audience travel | Accomodation | Scope 3 | Per concert | Bottrill et al. 2008 (assessed); AGF 2023 (assessed) |
| 11 | Tickets | Print | Scope 3 | Per concert | Bottrill et al. 2008 (assessed); AGF 2023 (assessed) |
| 12 | Tickets | Digital | Scope 3 | Per concert | Bottrill et al. 2008 (assessed); AGF 2023 (assessed) |
| 13 | Audience consumption and waste | Waste | Scope 3 | Per concert | Lovei et al. 2010 (assessed); AGF 2023 (assessed); Bottrill et al. 2008 (mentioned) |
| x | Audience consumption and waste | Food and drink | Scope 3 | Excluded | *Mentioned in Botrrill et al. 2008, but excluded* |
| x | Audience consumption and waste | Merchandise | Scope 3 | Excluded | *Mentioned in Botrrill et al. 2008, but excluded* |

Supplementary Figure 6 | GHG assessment activity scoping

Following steps two and three (data collection and baselining), we defined a GHG quantification logic for each of the 13 included activities, which we then populated with data from various sources[29–32] - multiple data points were collected and averaged to add robustness. Essentially, we developed a quantity structure for an activity of an individual concert, that we subsequently convert into $CO_2$ emissions via *DESNZ* GHG conversion factors. In step four (scaling up), we aggregate this baseline across all 32 concerts. Supplementary Figure 7 shows calculations for activity 7 (audience air travel) as an example. All calculations are available in the supplementary data sheet.

| Data point | Unit | Comment | Source |
|---|---|---|---|
| 10.3% | *% of audience travelled via plane* | Survey result (n=135 - two festivals in Scotland) | Brennan et al. 2019 |
| 12.5% | *% of audience would travel >500 miles* | Survey result (n=2,000 - UK concertgoers) | KIA 2024 |
| 10.0% | *% of audience would travel via plane* | Survey result (n=2,000 - North American concertgoers) | Delfino & Sherrier 2021 |
| 7.0% | *% of audience travelled via plane* | Survey result (n=35,284 - various concerts in North America) | REVERB 2024 |
| 9.0% | *% of audience travelled via plane* | Survey result (n=1,000 - music fans across North America) | Price4Limo 2023 |
| **9.8%** | ***% of audience travelled via plane*** | **Average** | |
| 60,697 | *# of people per show* | Average audience size per concert | Pollstar 2024 |
| 5,919 | *# of people travelled via plane* | | |
| 1,130 | *km average European flight 2023* | Average distance of 10.2m European flights 2023 (incl. domestic & cross-border within Europe) | Eurocontrol 2024 |
| **6,688,175** | ***km travelled via plane*** | **Total passenger km** | |
| 0.18592 | *kg CO2 / km / passenger* | GHG conversion factor: Average passenger CO2 intensity (mix economy and business) | DEFRA 2025 |
| 2 | | Round trip (x2) | |
| 2,486,931 | *kg CO2* | | |
| **2,487** | ***t CO2*** | **PER CONCERT** | |
| 32 | *# concerts* | # of Coldplay's 2024 European concerts | Pollstar 2024 |
| **79,582** | ***t CO2*** | **FULL TOUR** | |

Supplementary Figure 7 | GHG quantification for Coldplay activity 7, audience air travel.[18,31,33–37]

We used the above method for all activities where emissions are driven by number of concerts. However, activities under *band and crew* (activities 3-6) follow a different logic, since these emissions are not driven by number of concerts per se but by tour routing and itinerary. For example, when Coldplay performs four concerts in a row in one city, no band and crew travel emissions are generated, except accommodation. Similarly, no accommodation emissions are generated during tour breaks (except arrival and departure), when band and crew travel home and remain there until the next concert. We assumed such breaks for the three weeks between Lyon and Rome, and two weeks between Helsinki and Munich. Consequently, we quantify activities 3-6 through an itinerary-based approach:

- Air travel (3): Flight routing determined, distances obtained from *AirMilesCalculator.com*, core crew assumed to fly commercial business class, extended crew road travel (except flight necessary, then economy class), distance travelled converted into $CO_2$ through *DESNZ* emissions factors
- Road travel (4): Road travel routing determined, distances obtained from *GoogleMaps.com*, number of vehicles determined by allocating extended crew members to night liner buses with capacity of 16 people, distance travelled converted into $CO_2$ through *DESNZ* emissions factors
- Accommodation (5): Number of nights in hotel per city calculated based on itinerary and converted into $CO_2$ through *DESNZ* emissions factors
- Freight (6): Road travel routing determined, distances obtained from *GoogleMaps.com*, number of vehicles determined as 63 by averaging data points from similar large-scale international tours (*Coldplay* 2022 >50 trucks, *Coldplay* 2016/17 30 trucks, *Taylor Swift* 2024 90 trucks, *U2* 2009 120 trucks, *AC/DC* 2024 22 trucks), distance travelled converted into $CO_2$ through *DESNZ* emissions factors

We assume crew size as 230 in total, consisting of 50 core (band, personal entourage as e.g. assistants, stylists) and 180 extended (e.g. technicians, managers) – based on an estimate from an operations manager involved in Coldplay's tours[38]. This is broadly in line with similar large-scale international tours and tends to increase over time (2024 *Taylor Swift* >200; 2015 *Taylor Swift* 125; 2009 *U2* 174; 2016 *Paul McCartney* 130).

## Supplementary Discussion

### World cup pricing scenarios

As noted, due to the timing of this research, it was necessary to estimate the face-value prices of the 2026 World Cup. This was done by updating the 2022 World Cup prices to 2025 dollars. This was in line with FIFA's previous pricing strategy: updating the 2018 World Cup prices for inflation into 2022 dollars provides face-values in close agreement with the reported 2022 prices (see table S11). However, FIFA has altered its pricing strategy in the time since this analysis was performed. Face-value prices are significantly higher than estimated, in some cases exceeding our estimated WTP (see table S12).

| Table S11 \| 2022 World Cup estimated prices v. reported Prices | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Game type | 2022 Estimated Prices (2018 Updated to 2022 USD) | | | | Actual 2022 Prices (Reported 2022 USD) | | | |
| | Cat 1 | Cat 2 | Cat 3 | Cat 4 | Cat 1 | Cat 2 | Cat 3 | Cat 4 |
| Opener | 641 | 455 | 256 | 60 | 618 | 439 | 302 | 55 |
| Group | 245 | 192 | 122 | 24 | 220 | 165 | 69 | 11 |
| Ro16 | 286 | 216 | 134 | 42 | 275 | 206 | 96 | 19 |
| Q.F. | 425 | 297 | 204 | 71 | 425 | 288 | 206 | 82 |
| S.F. | 874 | 559 | 332 | 84 | 955 | 659 | 357 | 137 |
| Third Place | 425 | 297 | 204 | 71 | 425 | 302 | 206 | 82 |
| Final | 1,282 | 827 | 530 | 131 | 1,606 | 1,002 | 604 | 206 |

Additionally, while FIFA has announced that they will be not be using dynamic pricing per se, they have stated that they will alter the face-value prices manually to meet demand. It is unclear how these changes will impact demand, and subsequently mark-up rates. Preliminary listings of tickets on the secondary market suggest that resale prices may be much higher than originally estimated, but it is difficult to determine if these are reliable data because, at the time of writing, there is significant uncertainty about whether FIFA has released all of the available tickets[12]. Such manufactured scarcity could drive up the resale prices of the currently listed tickets past typical WTP. One piece of evidence that suggests this could be the case is that resale prices for some group games is higher than for the round-of-32 elimination matches. One would expect the knock-out games to be priced higher due to their higher stakes and lower availability. Preliminary listings were collected from VividSeats on the 13th of April 2026: the group game average resale price was $2,800 (n = 324), and the r-o-32 average resale price was $1,900 (n = 298).

Table S12 | Reported face-value tickets versus estimated face values and WTP. Red indicates an estimated WTP lower than the listed face-value price

| Match Type | Average Reported Face-Values (2025 USD)[13] | | | | Estimated Face-Values (2025 USD) | | | | Estimated Resale Price, WTP (2025 USD) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| - | Cat 1 | Cat 2 | Cat 3 | Cat 4 | Cat 1 | Cat 2 | Cat 3 | Cat 4 | Cat 1 | Cat 2 | Cat 3 | Cat 4 |
| Average Opener | 2,102 | 1,490 | 860 | 428 | 679 | 483 | 332 | 60 | 1,368 | 973 | 669 | 122 |
| Average Group | 513 | 386 | 178 | 103 | 242 | 181 | 75 | 12 | 402 | 302 | 126 | 20 |
| Average R16/R32 | 582 | 441 | 214 | 166 | 302 | 226 | 106 | 21 | 608 | 456 | 213 | 43 |
| Average Q.F. | 1,345 | 915 | 578 | 327 | 468 | 317 | 226 | 91 | 942 | 638 | 456 | 182 |
| Average S.F. | 2,673 | 1,848 | 690 | 438 | 1,051 | 725 | 393 | 151 | 7,893 | 5,443 | 2,948 | 1,134 |
| Third Place | 1,000 | 715 | 360 | 165 | 468 | 332 | 226 | 91 | 942 | 669 | 456 | 182 |
| Final | 6,370 | 4,210 | 2,790 | N/A | 1,766 | 1,102 | 664 | 226 | 13,268 | 8,278 | 4,990 | 1,701 |

Due to this uncertainty, we determined that we would use our original estimated face-value prices to determine WTP. This decision is warranted on at least three grounds. Firstly, as noted, it is unclear how the changes will alter mark-up rates, making it difficult to establish a well-founded markup scheme. Secondly, FIFA's sudden departure from their previous pricing strategy, coupled with uncertainty over the practice of dynamic pricing, suggests that future World Cups will likely see a return to a pricing strategy more in line with previous additions of the tournament. Thirdly, and perhaps most importantly, it is unlikely that these changes will meaningfully impact the overarching conclusion of our analysis, which is that net benefits are high. If the resale prices are indeed significantly higher, it implies that total surplus is higher, and that net benefits remain positive even as the SCC increases. For robustness, we have calculated several additional welfare scenarios using FIFA's listed face-value prices and a range of mark-up rates. These are presented in table S13.

Table S13 | Additional welfare scenarios using FIFA pricing[94] and Moore mean SCC[99]

| *Face-Value Prices* | *Markup Scheme (%ile)* | *32 team TS ($)* | *48 team TS ($)* | *32 Team NW ($)* | *48 Team NW ($)* |
|---|---|---|---|---|---|
| Author Estimation | 50th,68th,95th | 2,149,341,586 | 2,327,077,733 | 1,473,060,627 | 1,540,369,337 |
| Reported FIFA[13] | 50th,68th,95th | 6,604,452,686 | 7,740,921,596 | 5,928,171,727 | 6,954,213,200 |
| Reported FIFA[13] | 50th,68th | 3,673,396,368 | 4,809,865,278 | 2,997,115,409 | 4,023,156,882 |
| Reported FIFA[13] | 50th,68th,75th | 3,792,944,147 | 4,929,413,057 | 3,116,663,188 | 4,142,704,661 |
| Reported FIFA[13] | None (WTP = Face) | 1,779,714,446 | 2,096,970,050 | 1,103,433,487 | 1,310,261,654 |

As can be seen, using FIFA's current face-value prices with our original mark-up scheme applied to the differing game types results in a NW estimation 4x as high in the 48-team scenario. It seems likely that this is an implausible outcome. Firstly, it is possible that FIFA has correctly estimated the maximum WTP and is engaging in perfect price discrimination. In this case, resale tickets will not be marked up at all, and FIFA will capture all of the potential CS. Assuming that the minimum price necessary to cover the private costs of the event is equal to $168 (derived by dividing operational costs by number of tickets) this would mean that FIFA would be capturing $2.10b worth of surplus, relatively close to our original estimation of $2.33b. It is also possible that FIFA has over-estimated the WTP, meaning that face-value prices will fall. In this case, FIFA will still capture most or all of the total surplus, but the magnitude of the TS will be smaller. Thirdly, it is possible that WTP is even higher than projected, meaning that resale tickets will still be marked up. In this case, the Total Surplus estimate would be significantly higher, even in the scenario where only the 50$^{th}$ and 68$^{th}$ percentile markup rates are applied. Yet, in all modeled scenarios, net welfare will be equal to or higher than our estimation, meaning that our conclusion that the event is climate viable under a central SCC value remains valid. Our analysis should therefore be seen as a conservative estimate of the total surplus. This conservatism is warranted given the noted uncertainty on the impacts that FIFA's policy changes will have.

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