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A Cooling-Drive Model for Sustainable Mega-Event Host Selection with Temperature-Activated Carbon Emission

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Abstract. To conduct the economic and environmental impacts of sport event, this study develops carbon emission model in an objective way by examining the possible host cities of major sport event. Two types of carbon emissions are taken into account in model, namely, operation and transportation. Energy consumption model will consider the volume of the venue, temperature of the location, period of the game, and energy consumption. Transportation carbon emissions is forecasted based on the city level statistics of driving and flying. To apply the carbon emission model in this study, the researchers will choose six former Super Bowl hosts and three possible new hosts for the upcoming games. However, a grey-prediction modeling approach will be applied due to the lack of sufficient data. In general, the findings suggest that the least carbon emission city is Philadelphia. The reasons for this ranking include climate, geographic location, and energy composition of the city. This emission prediction model can also be applied to different events, such as NBA All-Star Game which involves only one venue and World Games which uses several venues at once. Furthermore, scenario analysis finds that the use of electric cars could decrease the NBA All-Star Game emissions by 15.2%, while solar energy use in the World Games would reduce the emissions by 12.8%. Finally, climate, travel distance, and energy composition have been identified as the key factors of emission prediction for each category respectively. Thus, Philadelphia should host the Super Bowl in 2029.

Keywords: carbon emissions, site selection model, sporting events, sustainability, grey prediction

1. Introduction

Large sporting events, like the Super Bowl increase economic benefit but also increase our environmental costs from transportation, energy consumption at venues, accommodation, etc. In response to the growing importance of sustainability, organizations are increasingly utilising a variety of quantitative method to assess their environmental impacts. The absence of horizontal comparability of environmental criteria in current site-selection frameworks highlights importance of reliable quantitative methods. This study aimed to achieve two main goals: (1) build a scalable

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model that allows the quantification and comparison of various environmental footprints for large sporting events which can provide evidence in the assessment of current or future host cities and (2) assess drivers of carbon emissions per event type that could lead to intervention planning.

2. Literature review

Several leading organizations have developed frameworks to assess the environmental footprint of large sporting event. As an example, the Green Sports Alliance's "Play to Zero Guide" identifies energy, water and waste as key focus areas, measuring performance through reduced greenhouse gas emissions and potable water use. Likewise, ENGIE Impact's sustainability framework covers everything from waste management to energy use to material recovery to operations approach and community impact. Moreover, ISO 20121 defines a whole range of environmental issues including resource utilization, material selection, circularity, emissions reduction, climate change, and biodiversity preservation [1].

Despite their comprehensive nature, these frameworks possess significant limitations. Primarily, event-level incompatibility complicates cross-case comparison; most utilize multi-criteria ratings with heterogeneous weighting systems, which obscures direct comparisons. Moreover, while organizations often emphasize improvement, the fail to provide empirical data regarding actual impacts. Reports typically enumerate qualitative actions rather than specifying the percentage of environmental burden mitigated, thereby limiting the potential for outcome-based reporting. Finally, transparency remains a critical concern, as many reports omit standardized calculation methodologies, primary data sources, or evidence of third-party verification. The prevalence of ambiguous terminology, such as "green" or "zero waste," further suggests a prioritization of marketing objectives over scientific rigor.

This deficiency highlights the need for a model based on quantifiable environmental impacts. Since carbon emissions can be measured relatively easily and are an important part of most sustainability indicators, they serve as a common comparative metric. Because climate, geography, transport infrastructure and energy matrices play pivotal roles in determining carbon footprints, metrics such as these provide a means for much more methodical comparison.

3. Methodology

3.1. Carbon emission-based modeling framework

Carbon emissions allocated to major large sporting events are performed over two main areas: venue operations and transportation. Climatic conditions determine HVAC (heating, ventilation and air conditioning) demand; geography and infrastructure dictate travel distances; the local energy matrix governs the carbon-intensity per unit of energy consumption.

3.2. Venue operation carbon emissions

Venue operations necessitate significant electrical consumption, primarily driven by HVAC (heating, ventilation, and air conditioning) systems and lightning requirements. Total energy demand is estimated by quantifying these two critical variables.

HVAC Energy Consumption E_{HVAC} :

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$$E_{HVAC} = \alpha \times A \times (T_{out}\text{-}T_{in}) \times t \quad (1)$$

Where:

- A = venue floor area (m²)
- T_{out}-T_{in} = temperature differential between outdoor ambient and indoor setpoint (°C)
- t = event duration (hours)
- α = empirical coefficient (kWh/m²·°C·h), derived from U.S. Energy Use Intensity (EUI) [2]data for public assembly buildings (50.8 kBtu/ft² annually, converted to appropriate units)

Lighting Energy Consumption E_{light} :

$$E_{light} = P_d \times A \times t \div 1000 \quad (2)$$

where:

- P_d = lighting power density for public assembly spaces (1.0 W/ft², converted to kWh/m²) [3]
- A = illuminated area (m²)
- t= lighting duration (hours)

3.3. Transportation-related carbon emissions

We calculate transportation emissions by multiplying mode share, passenger counts, travel distances, and standardized emission factors. For the US today, about 86% of trips are done in a private car and 10% by air. Other transport modes have been purposely omitted from this analysis either due to limited availability of empirical data.

Number of travelers by mode:

$$X_i = X_{audience} \times P_i \times P_{visitor} \quad (3)$$

where:

- X_i = visitors using travel mode i
- P_i = proportion choosing mode i [4]
- $X_{audience}$= total spectators
- $P_{visitor}$ = proportion of spectators traveling from outside the host city

The travel distances are computed as the average of mean distance between the host city and other major urban centers nearby. For air transportation, it is based on the mean flight distance in the U.S. domestic market equal to 1,333 km [5] from empirical airline data.

- Total distanceR_i by mode i:

$$R_i = X_i \times r_i \quad (4)$$

where r_i = average distance per passenger for mode i .

Total transportation emissions:

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$$E_{traffic} = E_{airplane} + E_{car} \tag{5}$$

$$E_{airplane} = R_{airplane} \times N_{airplane} \tag{6}$$

$$E_{car} = R_{car} \times N_{car} \times 1/4 \tag{7}$$

where N_i = carbon emission factor for mode i (per passenger-km for air, per vehicle-km for car), and the factor 1/4 accounts for average car occupancy of 4 passengers.

4. Results

To model the carbon emission for the specific Super Bowl, the result is calculated by six past host cities and three potential candidates: This methodology incorporate venue specifications, climate conditions, accessibility metrics and energy consumption profiles are used to calculate total emissions resulting from both the operations and transportation.

4.1. Comparative emission profiles

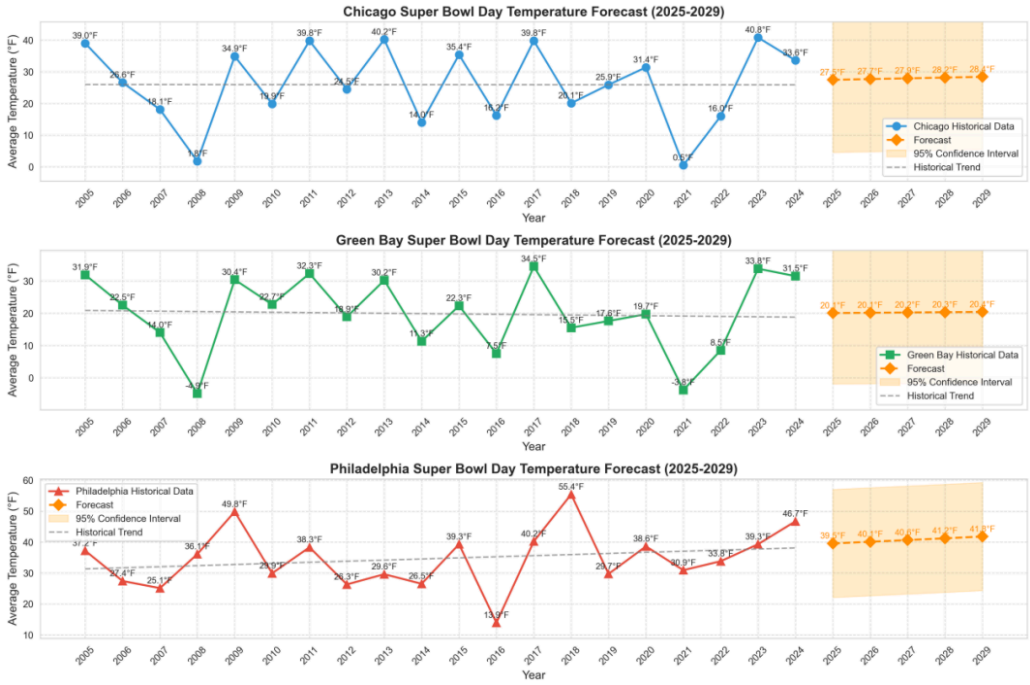


Figure 1. Temperature predictions of cities (2025-2029)

The grey prediction model (see Figure 1) was used to predict February temperatures and attendance figures in the long history of Super Bowls, which resulted in a mean accuracy of 99.73% for candidate host cities over February years through 2029. The subsequent outputs show wide variation in estimated emissions:

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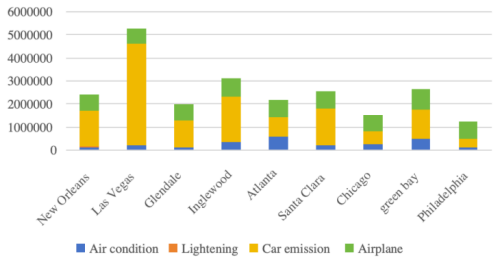


Figure 2. Emissions comparison across all cities

Philadelphia has the lowest emissions profile of all the cities in our sample (see Figure 2), driven by three main characteristics. This means that first, the energy demand for cooling of venues is reduced, as Philadelphia has a temperate climate. Second, mileage driven by visitors is minimized because of its physical location within the central Northeastern corridor. Third, the diversification of regional energy supplies will reduce the carbon intensity of electricity consumption.

4.2. Key determinants of emission variation

With these caveats in background, the following two explanations of emissions are extracted from the analysis:

• Municipalities with milder winter climate will have lower indoor climate regulation energy requirements, and so a related reduction in operational emissions. The factor matters particularly for large sports complexes.

• Many of these cities also fall within larger metropolitan clusters which results in reduced average transit distances for both vehicle and air travel, dramatically reducing carbon emissions associated with transportation.

• A cleaner power generation method brings to lower carbon emissions.

5. Discussion

Three scenarios (Super Bowl, NBA All-Star Game and World Games) were created to analyze the impacts of short-term changes in infrastructure availability, energy supply and transportation patterns on carbon outputs using Philadelphia, San Francisco and Birmingham as case studies.

Scenario 1: We assume that 30% of internal combustion engine vehicles are replaced by electric vehicle. Energy use was estimated to be 190 Wh/km, based on the Electric Vehicle Database data, and carbon emissions factors were applied according to their region.

Scenario 2: we assume the expansion of solar energy that a 10% increase in solar energy generation and 10% decrease in natural gas.

Scenario 3: we assume the highway efficiency improvements that the 10% improvement in distances traveled overall due to optimized transit patterns.

Table 1. Emission changes by scenario and event type

Scenario	Event	Original Total Carbon Emissions	New Carbon Emissions	Change Rate	Absolute Change
Electric Vehicle	Super Bowl	1,207,609	1,163,577	-3.60%	44,032
	NBA All-Star Game	16,221,174	13,749,966	-15.20%	2,471,208

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Table 1. (continued)

Solar Power	World Games	36,856,766	36,613,428	-0.70%	243,338
	Super Bowl	1,207,609	1,156,969	-4.20%	50,640
	NBA All-Star Game	16,221,174	15,000,619	-7.50%	1,220,555
	World Games	36,856,766	32,138,392	-12.80%	4,718,374
More efficient highways	Super Bowl	1,207,609	1,167,810	-3.30%	39,799
	NBA All-Star Game	16,221,174	15,005,643	-7.50%	1,215,531
	World Games	36,856,766	36,661,155	-0.50%	195,610

Table 1 shows the key findings below:

• Integrating electric vehicles yields the largest emission reductions for NBA All-Star Game given that transportation is the biggest contributor to the emissions profile.

• When the carbon drivers of venue operations have a more significant impact, solar energy expansion is shown to be effective at decreasing emissions in the context of a World Games.

• Improvements in highway efficiency result in very small reductions in emissions for every category of events.

• At least with a long-term view, low-impact, regional energy system optimization is arguably the best lever for decarbonization because it minimizes venue operations and transportation impacts simultaneously through transportation electrification.

6. Conclusion

We provided a standardized approach for site selection using climate control and ambient lighting as well as travel to the venue—including effect of pertinent variables. Our analysis suggests that the ideal city for hosting of a Super Bowl has certain environmental and infrastructure traits. A low-carbon village ideally combines a moderate climate to minimise energy demand of the venue itself, an optimal geographic location to reduce spectator transit distances and a clean-energy infrastructure to mitigate its carbon intensity.

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