TOWARDS SUSTAINABLE MEGA SPORTS EVENTS: CARBON FOOTPRINT ASSESSMENT OF THE 20th WINTER DEAFLYMPICS

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Abstract. It can be observed that states are considering energy usage and environmental factors in line with their sustainable development goals. The carbon footprint resulting from the consumption of energy resources is a quantitative indicator of the environmental impact. Mega sports events have significant impacts on environmental sustainability, and indoor winter sports events, in particular, are characterized by high energy consumption and carbon emissions. This study aims to examine the carbon footprint of the 20th Winter Deaflympics, which was attended by 930 participants from 34 countries. The research evaluates the carbon footprint by addressing emissions resulting from energy consumption (electricity, natural gas, water consumption) and transportation (airplane, bus) during the event. Sustainable practices for reducing the environmental impacts of Deaflympic sports events and recommendations for raising environmental awareness in international sports organizations are presented. Therefore, the importance of utilizing renewable energy sources, adopting sustainable facility construction strategies, and implementing environmentally friendly transportation policies is emphasized.
Keywords: *carbon emissions, deaf sports events, environmental impact, international sports organizations, transportation emissions*

Introduction

Sustainable development emerged as a critical paradigm for addressing the urgent environmental challenges in the world, as outlined in the report Our Common Future by the United Nations-affiliated World Commission on Environment and Development (WCED, 1987). In addition to this conceptualisation, several models have been developed to provide a clearer explanation of sustainability and sustainable development, including the Russian doll model (Levett, 1998), the three circle model (Giddings et al., 2002) and the triple pillar model (Purvis et al., 2019). The triple pillar model explains sustainability by representing the economic, social and environmental dimensions as three equally sized pillars, with sustainability symbolised as the roof over these pillars (Purvis et al., 2019). The three-circle model, on the other hand, represents the economic, social, and environmental factors as three equally sized circles, and argues that sustainability can be achieved through sufficient effort in the intersection where the circles overlap

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symmetrically. The three-circle model emphasises the environmental dimension by stressing the management of resources without harming the environment, while the economic dimension focuses on promoting the use of goods and services while avoiding the over-consumption of natural resources. The social dimension, in turn, emphasises responsible and conscious global citizenship over individualistic consumption patterns (Giddings et al., 2002). While these models differ in their approach to explaining sustainability through the economic, social and environmental dimensions, they share similarities in using the same three dimensions. This highlights the essential nature of these dimensions for the integrity of the models. However, environmental sustainability is more pronounced than the other factors.

Environmental sustainability, also referred to as the conservation of natural capital (Goodland, 1995), is defined as meeting human needs while preserving ecosystems (Morelli, 2011). In another study (Daly, 1990), environmental sustainability is described in terms of the consumption of nonrenewable resources, the disposal of waste and the production of sustainable products, with renewable resources, nonrenewable resources and pollution identified as key components. One of the measures and strategies employed to combat global warming and climate change is sustainable development. Within this framework, strategies include the prevention and reduction of ecological and carbon footprints. In recent years, one of the most prominent indicators used to measure sustainable development is the ecological footprint (Collins and Flynn, 2015; Kovshun et al., 2023). The ecological footprint represents the area required to reduce the consumption of current resources and the absorption of waste (Wackernagel and Rees, 1998; Akpanke et al., 2024). One of the key components of the Ecological Footprint is the Carbon Footprint. The carbon footprint measures the total amount of carbon dioxide emissions that result directly or indirectly from an activity or that accumulate over the life cycle of a product (Wiedmann and Minx, 2008). Thus, all human activities, including basic activities such as transport, heating and food consumption, as well as the products produced and consumed as a result of these activities, contribute directly or indirectly to the total carbon emissions that are generated, forming the carbon footprint. The carbon footprint includes not only the activities of individuals, but also those of societies, governments, companies, organisations, industrial sectors and, in short, all actors (Kaypak, 2013; Chitra, 2024). The relationship between sustainable development and carbon footprint in the context of sporting events has become an increasingly important issue in recent times. The sports industry has significant responsibilities due to its environmental impacts, such as high levels of carbon emissions (Triantafyllidis, 2018; Wicker and Thormann, 2024). Governments play a crucial role in shaping policies that regulate emissions and promote sustainability through frameworks such as the Paris Agreement (Seixas and Ferreira, 2021). Therefore, research aimed at understanding how to reduce the carbon footprint of sporting events is important in contributing to the achievement of sustainable development goals.

Sports organisations, as events within the sports ecosystem where the environmental impacts of human activities are evident, require scientific investigation into the ecological consequences of both large- and small-scale events, along with the adoption of strategic management approaches to mitigate these effects. Additionally, developing policies that promote alternative transport behaviours can help reduce the carbon footprint and support environmental sustainability (Triantafyllidis, 2018). Furthermore, calculating the carbon footprint of sporting events is a crucial step in understanding their environmental impact. For example, a study that calculated the carbon footprint of basketball teams in Turkey

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and Lithuania (Vienažindienė et al., 2023) reported that the total carbon emissions, based on travel distances, were calculated to be 53,029 tonnes. Such calculations can help sports organisations to develop strategies to reduce their environmental impact. For example, Dolf and Teehan (2015), who studied small-scale sporting events, conducted a carbon footprint analysis of spectator and team travel at university sporting events. The study highlights the significant contribution of long-distance air travel by spectators to the overall environmental impact. In this context, the study concludes that public policy should aim to develop strategies to reduce long-distance air travel. Promoting lower-emission transport options could be an effective way of reducing the carbon footprint of events. Another study focusing on individuals involved in small-scale sporting events (Wicker, 2019) examined the carbon footprint of active sports participants, with a focus on the heterogeneity of individual sports participation behaviour. The research revealed the impact of athletes' travel behaviour on carbon emissions and showed that individual sports generate more emissions than team and racket sports, with the highest emissions occurring in outdoor sports. This highlights the need to develop strategies to reduce the environmental impact of sporting events.

One of the most significant events in the sports industry is the mega sports event. As such, there is a considerable amount of research in the literature aimed at understanding and improving the sustainability of mega sports events. For example, a study by Pereira et al. (2017) highlights that the carbon footprint resulting from the international travel of mega sports event participants has a disproportionate impact on a global scale.

A review of the literature shows that organisations managing major sporting events have undertaken numerous sustainability initiatives to reduce the environmental impact of these events. For example, the International Olympic Committee (IOC), the world's largest sports federation, launched the Olympic Games Global Impact (OGGI) programme to measure the impact of the Olympic Games and set benchmarks for future games (IOC, 2006a). Subsequently, in 2006, the IOC published a voluntary 'Guide to Sport, Environment and Sustainable Development' (IOC, 2006b). The International Federation of Association Football (FIFA), in collaboration with the United Nations Environment Programme (UNEP), launched the Green Goal project to monitor and reduce the environmental impact of the FIFA World Cup. Through the Green Goal project, FIFA aims to achieve carbon offsetting, waste reduction and sustainable resource use in its operations (World Cup, 2006). In addition, the United Nations Climate Change (2018) published the Sports Framework for Climate Action report to encourage sports organisations to develop strategies to achieve climate neutrality in the events they organise. This report aims to raise awareness that every organisation or sporting event, regardless of size, has a climate impact and that everyone can take action to reduce it. These examples show that environmental sustainability initiatives are increasingly being adopted by major sporting events.

It is important to understand the greenhouse gas emissions caused by mega sporting events, particularly organisations such as the Deaflympics Winter Games, and to conduct studies aimed at reducing their carbon footprint. Sports events generate significant carbon emissions not only through the participation of athletes and spectators, but also through the organisation of the events, including transportation, accommodation and other services. Therefore, as suggested by previous international studies (Golob et al., 2015; Triantafyllidis and Davakos, 2019), it is essential to monitor and review these events in terms of sustainable development goals to ensure their sustainability. Such studies are

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believed to contribute to the development of public policies within the framework of sustainable development goals.

Methodology and data

According to the carbon footprint assessment protocols, directly generated emissions are classified as Scope 1, while emissions resulting from direct energy purchases are classified as Scope 2. Optional emissions related to supply chain processes are classified as Scope 3 (see *Figure 1*) (Huang et al., 2009; NSAA, 2012; Radonjič and Tompa, 2018).

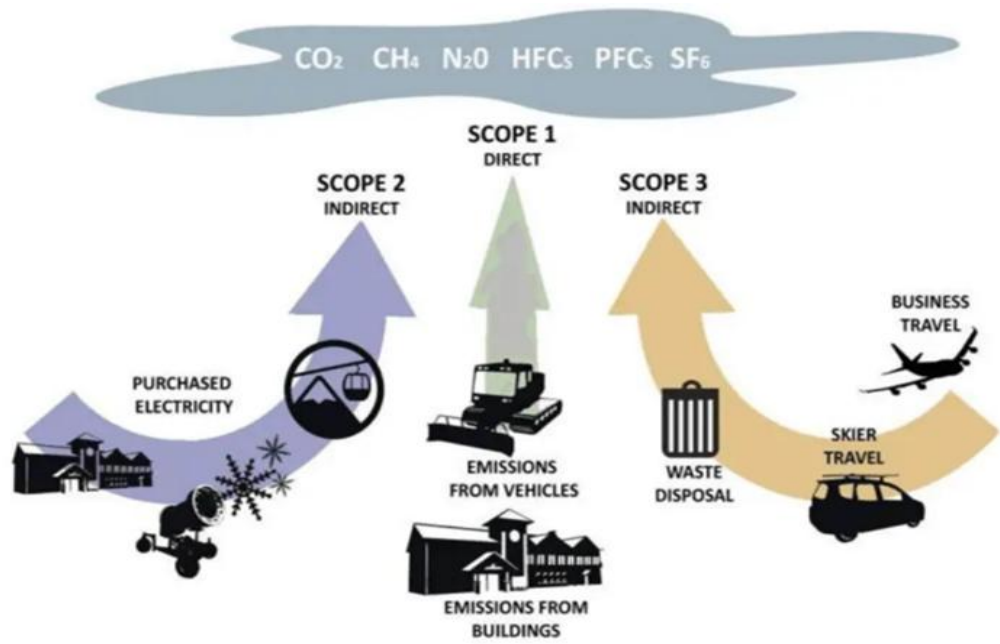

Figure 1. *Greenhouse gas emissions from winter tourism activities (NSAA, 2012)*

While emissions directly caused by industry are referred to as Tier 1 emissions (Matthews et al., 2008; Wang and Chen, 2018), the Tier 1 model was employed in this study to analyse data from four different sports facilities hosting six different sports. The model calculates emissions to the atmosphere resulting from the consumption of electricity, natural gas, and water purchased and/or used by these facilities. These emissions are classified as indirect, as they stem from the energy use of the sports venues. This study adopts a quantitative approach to estimate the carbon footprint generated during the 20th Winter Deaflympics.

Data collection process

This study examines the carbon footprints of the teams (countries) participating in the 20th Deaflympic Winter Games, held in Erzurum, Türkiye, from 2 to 12 March 2024, from different perspectives. The Deaflympic Winter Games involved 34 countries, 559 athletes and 371 technical staff. The data collection process in this study consists of three stages:

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- First stage: Information about the athletes and the travel routes of the countries was obtained from the Deaf Sports Federation through the Ministry of Youth and Sports of the Republic of Türkiye.
- Second stage: Natural gas, electricity and water consumption data of the sports facilities where the activities took place were provided by the Ministry of Youth and Sports of the Republic of Türkiye.
- Third stage: Information about the sports facilities where the activities took place, the accommodation details of the countries and the sports disciplines they participated in were obtained from the official website of the event, "20th Winter Deaflympics 2023".

Carbon footprint calculation process

In the context of the research, while **four items** are considered in the carbon footprint calculation, **six main stages** are addressed.

- For the 20th Deaflympic Winter Games, carbon emission factors were used for each mode of transport (plane, bus) during travel.
- In order to identify the consumption factors influencing carbon generation in the sports facilities where the activities took place, the natural gas, electricity and water consumption data of four different sports facilities were evaluated and the carbon emissions generated by these facilities were determined.
- Based on the data obtained, the emission factor provided by the Ministry of Energy and Natural Resources of the Republic of Türkiye was used for electricity consumption, while the emission values for natural gas, water treatment and distribution were taken from the UK's 2024 Greenhouse Gas Conversion Reports.
- The calculation of flight distances was conducted using the website "greatcirclemap.com", which utilises actual flight routes as opposed to the visually shortest paths depicted on conventional cartographical representations. With regard to the determination of distance values for intra-city transportation purposes, the "Google Maps" database was the source of the relevant data.

The first step in the data analysis process was to calculate electricity consumption, which falls under Scope 2. For this, the nationally accepted emission factor provided by the Ministry of Energy and Natural Resources of the Republic of Türkiye is approximately 0.442 kg per kilowatt hour (kWh) (Ministry of Energy and Natural Resources of the Republic of Türkiye, 2024). Using this factor, the carbon footprint was calculated by directly multiplying the amount of electricity consumed as it was illustrated in *Eq (1)*. To make the calculation clearer and easier to understand, the formula used in the calculation is shown below:

$$CO_{2,\ electricity} = E \times EF_{electricity} \tag{Eq.1}$$

where,

$CO_{2,\ electricity}$: Carbon emissions resulting from electricity consumption (kg CO_2),

E: The amount of electricity consumed (kWh),

$EF_{electricity}$: Emission factor of electricity generation (kg CO_2/kWh).

The second stage of the calculation is to determine the carbon footprint resulting from the use of natural gas, which falls under Scope 1. For this, the natural gas emission factor provided in the "UK Greenhouse Gas Reporting: Conversion Factors 2024" report. The

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carbon footprint was calculated by directly multiplying the natural gas consumption by this emission factor, resulting in the footprint expressed in kilograms as demonstrated in *Eq (2)*. According to the data, the accepted CO_2 equivalent emission factor per unit is 2.04140 kg/m³ (GOV.UK., 2024). The formula used in the calculation is shown below:

$$CO_{2,\ natural\ gas} = G \times EF_{natural\ gas} \quad \text{(Eq.2)}$$

where,
$CO_{2,\ natural\ gas}$: Carbon emissions resulting from natural gas consumption (kg CO_2),
G: The amount of natural gas consumed (m^3),
$EF_{natural\ gas}$: Emission factor of natural gas generation (kg CO_2/m^3).

The third stage of the calculation is to determine the carbon footprint of water use in sports facilities, which falls under Scope 3. The unit of measurement used is 0.18574 kg/m³, as calculated in the "UK Greenhouse Gas Reporting: Conversion Factors 2024" report was used as the unit of measurement. The formula used for the calculation is presented below as *Eq (3)*.

$$CO_{2,\ water} = W \times EF_{water} \quad \text{(Eq.3)}$$

where,
$CO_{2,\ water}$: Carbon emissions resulting from natural water consumption (kg CO_2),
W: The amount of water consumed (m^3),
EF_{water}: Emission factor of water treatment and distribution (kg CO_2/m^3).

The fourth step in the calculation is to determine the total carbon footprint. The analysis takes into account the electricity, natural gas and water consumption of the facilities. The formula used in the calculation is shown in *Eq (4)*:

$$CO_{2,\ total} = CO_{2,\ electricity} + CO_{2,\ water} + CO_{2,\ natural\ gas} \quad \text{(Eq.4)}$$

where,
$CO_{2,\ total}$: Total carbon emissions from consumption (kg CO_2),
$CO_{2,\ electricity}$: Carbon emissions from electricity consumption (kg CO_2),
$CO_{2,\ water}$: Total carbon emissions from water usage (kg CO_2)
$CO_{2,\ natural\ gas}$: Total carbon emissions from natural gas consumption (kg CO_2).

In the fifth step of the calculation, the total carbon footprint of transport was calculated based on the type of transport (airplane-bus). The emission factors used in the analysis were 0.17493 kg CO_2e/km for aircraft and 0.12909 kg CO_2e/km for city buses (GOV.UK., 2024). The formula used in the calculation is illustrated in *Eq (5)* and *Eq (6)*.

$$CO_{2,flight} = \sum_{i=1} \left(D_i \times EF_{flight,i}\right) \quad \text{(Eq.5)}$$

where,
$CO_{2,\ flight}$: Total carbon emissions from air travel (kg CO_2),
D_i: Distance of the flight from the country (km or miles),
$EF_{flight,\ i}$: Official aircraft emission factor for the relevant flight (kg CO_2/km).

$$CO_{2,\ \mathrm{vehicle}} = \sum_{j=1} \left(D_j \times EF_{vehicle,j}\right) \quad \text{(Eq.6)}$$

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where,
$CO_{2,\ vehicle}$: Total carbon emissions from vehicle use (kg CO_2),
D_j: Distance traveled by the vehicle within the city (km),
$EF_{vehicle,j}$: Official emission factor of the vehicle (kg CO_2/km).

In the sixth step of the calculation, the total carbon footprint of transport was calculated. The formula used in this calculation is presented below as *Eq (7):*

$$\mathrm{CF} = \frac{\sum \left[\left(\text{International Travel}_i * \text{Emission Factor}_i\right)\right] + \sum \left[\left(\text{Around the City Distance}_j * \text{Emission Factor}_j\right)\right]}{\text{Total number of country athletes and coaches}_n} \quad \text{(Eq.7)}$$

where,
$\sum_i$ (InternationalTravel)$_i$ $*$Emission$_i$: Total carbon emissions from flights,
$\sum_k$ (AroundtheCityDistance)$_j$ $*$Emission$_j$: Total carbon emissions from urban transportation,
$EF_{vehicle,j}$: Official emission factor of the vehicle (kg CO_2/km),
Total number of country athletes and technical person $_n$: Total number of athletes and technical personnel from each country.

Empirical results

This section presents the empirical results of the carbon footprint analysis for the 20th Winter Deaflympics. Data from electricity, natural gas, water consumption and transport were analysed to quantify the environmental impact of the event. The following tables provide detailed data on carbon emissions based on electricity, natural gas, water consumption and transport modes such as air travel and inner city bus services.

Table 1 provides information on the sports facilities and disciplines at the 20th Deaflympics Winter Games. Although the official event schedule was planned for February 2-12, 2024, due to preparation and training periods, disciplines such as Snowboarding and Curling began their activities earlier. Under the alpine discipline, the events included super-g, combined, giant slalom, slalom, and parallel slalom. For the curling and snowboarding disciplines, two different facilities were used to continue the activities.

Table 1. *Sports disciplines and facilities at the Deaflympics Winter Games*

No	Sports	Date	Facility Name
1.	**Alpine Skiing**	3-12 March 2024	Konaklı Ski Resort
2.	**Curling**	29 February-11 March 2024	Curling Hall-Short Track Hall
3.	**Futsal**	1-12 March 2024	Aziziye Indoor Sports Hall Erzurum Technical University Sports Hall
4.	**Cross Counry Skiing**	28 February-9 March 2024	Kandilli Cross Country Skiing & Biathlon Centre
5.	**Chess**	3-12 March 2024	Erzurum Youth Center
6.	**Snowboard**	28 February-8 March 2024	Konaklı Ski Resort-Palandöken Ski Resort

Source: 20th Winter Deaflympics 2023

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Table 2 provides information on the sports disciplines in which countries participated. In the games in which 34 countries took part, 16 different countries participated in futsal and chess, 11 in alpine skiing and curling, 8 in snowboarding and 5 in cross-country skiing.

***Table 2.** Countries participating in the Deaflympics Winter Games*

No	Sports	Country
1.	**Alpine Skiing**	Germany – Austria – France – India – Iran – Switzerland – Italy – Japan – Slovakia – Türkiye – Ukraine
2.	**Curling**	China – Croatia – Switzerland – Italy – Japan – Kazakhstan – Korea – Hungary – Poland – Türkiye – Ukraine
3.	**Futsal**	Germany – Brazil – Great Britain – Czechia – Armenia – Netherlands – Iran – Ireland – Spain – Switzerland – Italy – Japan – Kuwait – Poland – Thailand – Türkiye
4.	**Cross Counry Skiing**	China – France – Kazakhstan – Korea – Ukraine
5.	**Chess**	Germany – Bosnia and Herzegovina – Brazil – Armenia – Croatia – India – Italy – Kazakhstan – Latvia – Hungary – Uzbekistan – Poland – Serbia – Türkiye – Ukraine – Greece
6.	**Snowboard**	Austria – China – Italy – Japan – Kazakhstan – Korea – Türkiye – Ukraine

Source: 20th Winter Deaflympics 2023

Table 3 shows the natural gas, electricity and water consumption of four different sports facilities used at the 20th Deaflympics Winter Games. Looking at the natural gas consumption, the Curling Hall has the highest consumption rate (3.783,34 m³). The Erzurum Youth Centre came second with 1.185,8 m³, while the Kandilli Cross-Country and Biathlon Ski Centre came last with 551.28 m³. In terms of electricity consumption, the curling rink again used the most electricity (52.736,7 kWh). The Kandilli Cross-Country and Biathlon Ski Centre came in second with a consumption of 10.857,84 kWh, while the Erzurum Youth Centre and the Aziziye Sports Hall consumed 3.275,78 kWh and 2.194,47 kWh respectively. In terms of water consumption, the Aziziye Sports Hall (80 m³) is the largest user of water, followed by the Erzurum Youth Centre (50 m³) and the Curling Hall, with a minimal difference in consumption between the two. The Kandilli Cross-Country and Biathlon Ski Centre has the lowest water consumption among the sports facilities.

***Table 3.** Energy consumption of the sports facilities used in the Deaflympics Winter Games*

Facility Name	Amount of Natural Gas Consumption	Amount of Electricity Consumption	Amount of Water Consumption
Aziziye Indoor Sports Hall	605 m3	2.194,47 kwh	80 m3
Erzurum Youth Center	1.185,8 m3	3.275,78 kwh	50 m3
Curling Hall	3.783,34 m3	52.736,7 kwh	55 m3
Kandilli Cross Country Skiing&Biathlon Centre	551,28 m3	10.857,84 kwh	28,5 m3
Total	**6.125,42 m3**	**69.064,79 kwh**	**213,5 m³**

Source: Ministry of Youth and Sports of the Republic of Türkiye

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Looking at *Table 4*, we can see that a total of 930 participants, consisting of 559 athletes and 371 technical staff from 34 different countries, took part in the Deaflympics Winter Games. Italy had the highest number of participants with 78, followed by Türkiye with 74. The countries with the fewest participants were Pakistan with 1 athlete and Greece with 2 participants. The total distance travelled by air was 152.280,00 km, which is 3.5 times the circumference of the Earth, while the total distance travelled by local transport was 15,852 km. In terms of emissions from air travel, the countries with the highest emissions were Brazil (11.589,00 km), Japan (10.048,00 km), Korea (9.009,00 km) and Thailand (8.567,00 km). On the other hand, Türkiye, Greece and Ukraine had the lowest emissions. In terms of distances travelled by city buses, Kazakhstan (1282 km), Ukraine (1176 km) and China (1108 km) had the highest rankings. Countries with the lowest use of city buses were Kuwait, Bosnia and Herzegovina, India, Ireland, Spain, Mongolia, Uzbekistan, Serbia, Thailand and Greece.

Table 4. *Countries participating in the Deaflympics Winter Games and the distances covered*

No	Country/Teams	Athlete	Technical Team	Vehicle Type	Distance Traveled by Plane (km)	Distance Traveled by Bus (Inner-City) (km)
1.	Germany	25	19	Airplane-Bus	2.771,00 km	648
2.	Austria	6	10	Airplane-Bus	2.519,00 km	921
3.	Bosnia and Herzegovina	6	2	Airplane-Bus	1.972,00 km	126
4.	Brazil	31	13	Airplane-Bus	11.589,00 km	268
5.	Great Britain	14	10	Airplane-Bus	3.544,00 km	156
6.	Algeria	12	3	Airplane-Bus	5.292,00 km	226
7.	Czechia	14	6	Airplane-Bus	2.572,00 km	231
8.	China	37	25	Airplane-Bus	8.142,00 km	1108
9.	Armenia	4	3	Airplane-Bus	2.374,00 km	126
10.	France	5	7	Airplane-Bus	3.294,00 km	908
11.	Croatia	13	7	Airplane-Bus	2.212,00 km	201
12.	India	6	3	Airplane-Bus	5.620,00 km	126
13.	Netherlands	13	4	Airplane-Bus	3.267,00 km	632
14.	Iran	13	19	Airplane-Bus	2.186,00 km	549
15.	Ireland	9	3	Airplane-Bus	4.009,00 km	126
16.	Spain	25	10	Airplane-Bus	3.289,00 km	126
17.	Switzerland	9	9	Airplane-Bus	2.896,00 km	579
18.	Italy	42	36	Airplane-Bus	2.440,00 km	939
19.	Japan	37	30	Airplane-Bus	10.048,00 km	935
20.	Kazakhstan	25	18	Airplane-Bus	4.991,00 km	1282
21.	Korea	18	40	Airplane-Bus	9.009,00 km	937
22.	Kuwait	18	10	Airplane-Bus	3.183,00 km	62
23.	Latvia	2	1	Airplane-Bus	2.860,00 km	126
24.	Hungary	17	7	Airplane-Bus	2.100,00 km	393
25.	Mongolia	2	-	Airplane-Bus	7.041,00 km	126
26.	Uzbekistan	9	2	Airplane-Bus	3.705,00 km	126
27.	Pakistan	1	-	Airplane-Bus	5.015,00 km	349
28.	Poland	35	15	Airplane-Bus	2.284,00 km	845
29.	Serbia	4	1	Airplane-Bus	1.868,00 km	126
30.	Slovakia	2	4	Airplane-Bus	2.271,00 km	481
31.	Thailand	14	6	Airplane-Bus	8.567,00 km	126
32.	Türkiye	55	19	Airplane-Bus	698,00 km	640
33.	Ukraine	35	28	Airplane-Bus	1.752,00 km	1176
34.	Greece	1	1	Airplane-Bus	1.430,00 km	126
	Total	**559**	**371**	Airplane-Bus	**152.180,00 km**	**15.852 km**

Source: 20th Winter Deaflympics 2023

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Looking at *Table 5*, the curling rink has the highest carbon emissions in terms of natural gas and electricity consumption. On the other hand, the Aziziye Sports Hall has the lowest emission levels for both natural gas and electricity consumption. In terms of emissions from water treatment and distribution, the Aziziye Sports Hall has the highest rate, while the Erzurum Youth Centre has the lowest rate.

Table 5. *Emission amounts of the facilities used in the Deaflympics Winter Games*

Facility Name	Amount of Natural Gas Consumption	Amount of Electricity Consumption	Amount of Water Consumption
Aziziye Indoor Sports Hall	1.235,047 kg CO2	969.96 kg CO_2	14,8592 kg CO2
Erzurum Youth Center	2.420,69132 kg CO2	1447.89 kg CO_2	9,287 kg CO2
Curling Hall	7.721,668276 kg CO2	23,309.62 kg CO_2	10,2157 kg CO2
Kandilli Cross Country Skiing & Biathlon Centre	1.125,390192 kg CO2	4,799.17 kg CO_2	5,29359 kg CO2
Total	**12.502.796.788 kg CO_2.**	**30.526,64 kg CO_2**	**39.65549 kg CO2**

Table 6 shows the total emission amounts generated by the sports facilities from electricity, water, and natural gas sources. The curling rink accounts for 75% of the total emissions. The emission amounts of other sports facilities are significantly lower compared to the curling rink, with the lowest total emissions belonging to the Aziziye Sports Hall. The emission amount of 43.068,092278 kg CO_2 is equivalent to 43 tons of emissions.

Table 6. *Total emission amounts of the facilities used in the Deaflympics Winter Games*

Facility Name	Total
Aziziye Indoor Sports Hall	2.219,8662 kg CO_2
Erzurum Youth Center	3.877,86832 kg CO_2
Curling Hall	31.041,503976 kg CO_2
Kandilli Cross Country Skiing & Biathlon Centre	5.929,853782 kg CO_2
Total	43.068,092278 kg CO_2

In *Table 7*, the total carbon footprint from transport sources for the 20th deaflympics winter games, in which 34 countries participated, is 24.518,85 kg CO_2e with 559 athletes and a technical team of 371 participants, the total per capita emissions were 2.466,84 kg CO_2e. looking at the emissions caused by transport, it can be seen that the emissions from air travel are about 10 times higher than those from local transport in terms of emissions from air travel, the countries with the longest flight distances are Brazil (1,996.58 kg co_2e), Japan (1.757,76 kg CO_2e) and Korea (1.576,77 kg CO_2e). The country with the shortest flight is Türkiye (122,12 kg CO_2e) in terms of per capita emissions, Greece (250,15 kg CO_2e) and Ukraine (306,40 kg CO_2e) - which had 1, 2 and 9 participants respectively - have the highest emissions. meanwhile, Türkiye (2.77 kg CO_2e) with 74 participants, Ukraine (7.27 kg CO_2e) with 63 participants and Italy (7.03 kg CO_2e) with 78 participants have the lowest per capita emissions.

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Table 7. *Total carbon footprint generated by the athletes of participating countries in the Deaflympics Winter Games from airplane and bus transportation sources*

No	Country/Teams	Vehicle Type CF (kg)		Total CF (kg)	Per Person CF (kg)
		Airplane	Bus		
1.	Germany	484,78 kg CO_2e	83,65 kg CO_2e	568,43 kg CO_2e	12,92 kg CO_2e
2.	Austria	440,45 kg CO_2e	118,89 kg CO_2e	559,34 kg CO_2e	34,96 kg CO_2e
3	Bosnia and Herzegovina	344,95 kg CO_2e	16,27 kg CO_2e	361,22 kg CO_2e	45,15 kg CO_2e
4.	Brazil	1.996,58 kg CO_2e	34,60 kg CO_2e	2.031,18 kg CO_2e	46,17 kg CO_2e
5.	Great Britain	620,23 kg CO_2e	20,14 kg CO_2e	640,37 kg CO_2e	26,68 kg CO_2e
6.	Algeria	925,01 kg CO_2e	29,17 kg CO_2e	954,18 kg CO_2e	63,61 kg CO_2e
7.	Czechia	449,98 kg CO_2e	29,82 kg CO_2e	479,80 kg CO_2e	23,99 kg CO_2e
8.	China	1.424,17 kg CO_2e	143,03 kg CO_2e	1.567,20 kg CO_2e	25,28 kg CO_2e
9.	Armenia	415,30 kg CO_2e	16,27 kg CO_2e	431,57 kg CO_2e	61,65 kg CO_2e
10.	France	576,37 kg CO_2e	117,21 kg CO_2e	693,58 kg CO_2e	57,80 kg CO_2e
11.	Croatia	386,91 kg CO_2e	25,95 kg CO_2e	412,86 kg CO_2e	20,64 kg CO_2e
12.	India	982,99 kg CO_2e	16,27 kg CO_2e	999,26 kg CO_2e	113,03 kg CO_2e
13.	Netherlands	571,72 kg CO_2e	81,58 kg CO_2e	653,30 kg CO_2e	38,43 kg CO_2e
14.	Iran	382,39 kg CO_2e	70,87 kg CO_2e	453,26 kg CO_2e	14,16 kg CO_2e
15.	Ireland	701,09 kg CO_2e	16,27 kg CO_2e	717,36 kg CO_2e	59,78 kg CO_2e
16.	Spain	575,33 kg CO_2e	16,27 kg CO_2e	591,60 kg CO_2e	16,90 kg CO_2e
17.	Switzerland	506,79 kg CO_2e	74,74 kg CO_2e	581,53 kg CO_2e	32,31 kg CO_2e
18.	Italy	426,84 kg CO_2e	121,22 kg CO_2e	548,06 kg CO_2e	7,03 kg CO_2e
19.	Japan	1.757,76 kg CO_2e	120,70 kg CO_2e	1.878,46 kg CO_2e	28,04 kg CO_2e
20.	Kazakhstan	872,87 kg CO_2e	165,49 kg CO_2e	1.038,36 kg CO_2e	24,15 kg CO_2e
21.	Korea	1.576,77 kg CO_2e	120,96 kg CO_2e	1.697,73 kg CO_2e	29,27 kg CO_2e
22.	Kuwait	556,91 kg CO_2e	8,00 kg CO_2e	564,91 kg CO_2e	20,18 kg CO_2e
23.	Latvia	500,21 kg CO_2e	16,27 kg CO_2e	516,48 kg CO_2e	172,16 kg CO_2e
24.	Hungary	367,35 kg CO_2e	50,73 kg CO_2e	418,08 kg CO_2e	17,42 kg CO_2e
25.	Mongolia	1.231,45 kg CO_2e	16,27 kg CO_2e	1.247,72 kg CO_2e	623,86 kg CO_2e
26.	Uzbekistan	648,34 kg CO_2e	16,27 kg CO_2e	664,61 kg CO_2e	60,42 kg CO_2e
27.	Pakistan	876,91 kg CO_2e	45,05 kg CO_2e	921,96 kg CO_2e	921,96 kg CO_2e
28.	Poland	399,43 kg CO_2e	109,08 kg CO_2e	508,51 kg CO_2e	10,17 kg CO_2e
29.	Serbia	326,59 kg CO_2e	16,27 kg CO_2e	342,86 kg CO_2e	68,57 kg CO_2e
30.	Slovakia	397,33 kg CO_2e	62,09 kg CO_2e	459,42 kg CO_2e	76,57 kg CO_2e
31.	Thailand	1.498,76 kg CO_2e	16,27 kg CO_2e	1.515,03 kg CO_2e	75,75 kg CO_2e
32.	Türkiye	122,12 kg CO_2e	82,62 kg CO_2e	204,74 kg CO_2e	2,77 kg CO_2e
33.	Ukraine	306,40 kg CO_2e	151,81 kg CO_2e	458,21 kg CO_2e	7,27 kg CO_2e
34.	Greece	250,15 kg CO_2e	16,27 kg CO_2e	266,42 kg CO_2e	133,21 kg CO_2e
	Total	**26.609,81 kg CO_2e**	**2.402,05 kg CO_2e**	**24.518,85 kg CO_2e**	**2.466,84 kg CO_2e**

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Discussion

The Deaflympics, organized by the International Olympic Committee (IOC), is a multinational sporting event that involves individuals with hearing impairments. Austria first hosted the International Winter Silent Games in 1946, marking the start of these activities. While there is a wealth of research in the literature on sports organizations, there is a noticeable gap in studies that specifically focus on individuals with hearing impairments, particularly in evaluating the carbon footprint of international sports events within the framework of development goals and strategies. This gap significantly enhances the importance of this study.

The literature suggests that climatic conditions and intensive use of facilities are key factors contributing to high carbon footprint rates (Atalay, 2023; Atalay and Demir, 2024). In Perkumienė et al.'s (2024) study on the EuroLeague Men's Final Four, which uses a mixed research method, solutions are proposed to reduce the carbon footprint. In addition, Atalay (2022), in his study on the carbon footprint assessment of winter sports facilities, emphasises that activities should be carried out within the framework of environmental sustainability goals and that governments should develop sustainability policies accordingly.

As stated in the research, the generation of carbon emissions is not only influenced by the focus on facilities, but also significantly affected by human activities such as transportation, accommodation, food and beverage, and waste (Loewen and Wicker, 2021; Vienažindienė et al., 2023; McCullough et al., 2023; Safaa et al., 2023; Perkumienė et al., 2024). It has also been shown that a significant amount of emissions are generated by transport during international travel. In addition, the carbon footprint generated by travelling to training sessions is said to contribute to poorer well-being of individuals, while adopting an environmentally friendly approach is highlighted as offering greater benefits to both individuals and the environment (Wicker and Thormann, 2022). In their study “Estimated Carbon Footprint from Accommodation for the 2030 FIFA World Cup”, Pereira et al. (2020) suggest that an increase in the number of teams, combined with an increase in the number of tourists, will accelerate the carbon footprint by 24%. In order to reduce this rate, it is emphasised that host countries should be selected on the basis of their energy indicators.

In the extant literature on mega sport events, studies have highlighted the role of renewable energy technologies and low-carbon development associated with such events. These studies have emphasised the importance of constructive policies, industrial collaboration, and inter-event linkages. The enhancement of collaboration between environmental policies and public administration is regarded as imperative for addressing the climate crisis (Su et al., 2025). The study on the Nanjing Youth Olympics (NYO) indicates that an increase in energy intensity in the industrial sector has contributed to a reduction in per capita carbon emissions. Nevertheless, the elevated energy consumption of the transportation sector exerted an influence on the magnitude of the industrial sector and the configuration of the energy infrastructure, thereby engendering persistent emissions even in the aftermath of the Games (Zhang et al., 2022). The extant literature highlights the necessity of developing strategies to achieve the carbon-neutral goal of the 2022 FIFA Men's World Cup hosted in Qatar (Meza Talavera, 2019).

Therefore, the detailed evaluation of the countries, athletes and technical teams participating in the 20th Deaflympic Winter Games from 2 to 12 February 2024, the means of transport used (airplane and bus) and the sports facilities where the events took place, provides significant contributions to sustainable development (see *Tables 1, 2, 3*

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and 4). Looking at the countries participating in specific disciplines, it can be seen that countries such as Austria, Switzerland, Germany and Italy are involved in the Alpine discipline. The participation of Asian countries such as China, Kazakhstan and Korea in cross-country skiing and snowboarding highlights their investment in winter sports. The diverse participation of countries from different continents in futsal and chess demonstrates the global reach of these disciplines. Türkiye's participation in all sports except cross-country skiing highlights the importance of the policy of the Ministry of Youth and Sports of the Republic of Türkiye and the value placed on athletes, while also providing opportunities for hearing impaired people to achieve social benefits through sport.

According to the energy consumption of the facilities, including natural gas, electricity and water (see *Tables 5 and 6*), the Curling Hall has a high demand for heating and energy, while the natural gas consumption of the Kandilli Cross-Country Biathlon Ski Centre has the lowest emission levels. Based on these findings, it can be assumed that the carbon emissions in the curling hall are mainly due to the active use of the continuous cooling system, the provision of heated rooms in the changing rooms due to climatic conditions, as well as lighting, energy consumption and the duration of use of the facilities. On the other hand, for sports that take place in a natural environment (outdoors), energy consumption requirements are expected to be lower due to environmental factors. Therefore, the relatively low consumption levels at the Kandilli Cross-Country and Biathlon Ski Centre are expected to be normal.

Looking at the total number of delegations (athletes and technical staff) from each country, travel distances, use of local transport and carbon emissions per capita, it is clear that transport and the number of athletes play a significant role in determining emissions levels. Countries such as Brazil, Japan, Korea, China and Thailand naturally have higher carbon emissions due to their remote locations. However, long-distance travel with small delegations has a significant negative impact on per capita emissions. Countries with long flights, such as Mongolia (2 athletes) and Pakistan (1 athlete), have excessively high per capita emissions due to their small number of participants. In Europe, the proximity of countries results in lower carbon emissions due to travel distances, with Greece and Ukraine having lower carbon emissions. In addition, Türkiye has the lowest transport emissions of all the countries. This is mainly due to the large number of athletes representing Türkiye.

In terms of urban bus use, Kazakhstan and Ukraine have the highest carbon emissions due to the variety of activities in which they participate. Among the countries with the highest number of participants, Türkiye has the lowest emission potential. While it might be expected that the number of athletes would have a significant impact on bus-related carbon emissions, it is clear that the diversity of activities has a greater impact. When assessing the transport related carbon footprint, it is clear that distant countries and small delegations lead to a significant increase in emissions per athlete. Türkiye stands out due to its geographical advantage and has lower emissions.

Conclusion

This study presents a comprehensive assessment of the carbon footprint associated with the 20th Winter Deaflympics, highlighting the significant impact of transportation and facility-related energy consumption on overall emissions. The findings provide an in-depth understanding of the total emissions generated by mega sporting events,

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emphasising the critical role of geographical factors-such as participation levels and travel distances-in determining per capita emissions. The research emphasises the significance of adopting sustainable practices by proposing alternative solutions to reduce the environmental impact of international sporting events and promoting a more sustainable lifestyle.

In the case of carbon emissions from transport, the amount of emissions from flights is fixed for each flight. However, as the number of athletes from a country increases, the per capita emissions decrease. Long-haul flights contribute significantly to total carbon emissions, and this factor is considered to be one of the main causes of high carbon emissions. While emissions from long-haul flights cannot be avoided, it is recommended that for shorter flights or travel between nearby countries, train travel should be considered instead of air travel. In addition, direct flights should be preferred to connecting flights, and international participants should try to travel on the same flight rather than using different flights. The negative environmental impact of diesel fuel has influenced the increase in the number of electric vehicles. By focusing on minimising long-haul flights and promoting alternative, lower-emission modes of transport, such as rail, and optimising flight schedules (such as direct flights and shared flights for participants), significant reductions in transport-related carbon emissions can be achieved. This approach will contribute to the overall sustainability of international sporting events and help reduce the environmental impact of such large gatherings. The use of electric vehicles in the areas where events are held offers a significant opportunity to reduce the carbon footprint. As the use of electric vehicles becomes more widespread, it will also contribute to the international recognition of domestically produced electric vehicles. In the evaluation of sports facilities, energy consumption was found to be particularly high in facilities used for ice sports such as curling, ice hockey and speed skating. To reduce energy consumption and raise the strategic profile of facilities management, it is important to consider the physical infrastructure of the city when building new facilities and to prioritise the use of renewable energy sources. In the construction of facilities, the use of intelligent lighting systems and sensor-controlled showers could also contribute to water and energy savings. In the process of energy production and consumption within these facilities, the integration of solar panel systems and wind-powered energy solutions would significantly reduce electricity consumption, which is one of the largest contributors to energy use. One of the most important carbon offsetting activities is reforestation. Planting trees can help absorb carbon dioxide from the atmosphere, directly addressing the emissions generated by large events such as the Winter Deaflympics.

This study makes a substantial contribution to the existing academic literature on sustainability and carbon footprints in international mega sporting events. It should therefore be considered as part of the global sustainable development action goals. Consequently, it furnishes a thorough evaluation encompassing climate, environment, and sport on a global scale, proffering constructive recommendations for future practices.

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