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ORIGINAL ARTICLE

Sustainability of international research: evidence from an H2020 European project

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Abstract

Greenhouse gas emissions reduction is a critical topic in the scientific community, as researchers strive to produce knowledge for the betterment of society. However, it is important to acknowledge that researchers themselves engage in activities that have a significant environmental impact. Group meetings and conferences are under the spot due to their extensive contribution to emissions through travel, catering, hosting, and other event-related activities. To address this issue, our work aims to conduct an environmental diagnosis of an ongoing H2020 European project, focusing on the impacts associated with the periodical group meetings organized in each country involved. We also sought to evaluate researchers' stance on online meetings and collected environmental and personal opinions through dedicated online forms. Results show that while travel is the primary contributor to emissions, catering, meeting structures, and hosting support should not be overlooked. Conference location and availability of public transportation also play a crucial role in the final impact of the event, as they affect directly the 87% share of emissions due to travels. Besides, using local distributors and reducing hotel stays (representing about 5% of the final impact) may reduce the potential environmental burden of these events. On the other side, besides the obtained positive feedback from online meetings, in-person activities are still more effective for reinforcing human bonds and collaborations.

Keywords Life cycle assessment · Sustainable project · European project · Carbon footprint · User acceptance · Sentimental analysis

Introduction

Over the past few decades, scientific research has made remarkable progress in various fields of knowledge, exploring innovative pathways in all human activities and needs. With the advent of online platforms and journals, scientists can now access a vast store of insights with ease. However, despite the convenience of online resources, most scientists still consider in-person meetings as an essential and stimulating tool, primarily due to the networking, social interaction, and traveling opportunities they offer (Bonnett 2006; Bossdorf et al. 2010; Alberts 2013; Porpiglia et al. 2020). One of the significant challenges of today's research community is to reduce the environmental footprint of anthropogenic activities and pave the way toward sustainable development, which is clearly impacted by human behavior from a variety of perspectives (Pisello et al. 2015). Unfortunately, scientific research produces extended impacts on the environment (Holden et al. 2017; Abbott 2020; Kier-Byfield 2020). The environmental burden of events and meetings has been an object of interest to several academics concerned about emissions and behavior patterns. Some scholars suggest limiting the number of in-person gatherings to those strictly necessary, rethinking locations and transportation, among other actions to reduce their environmental footprint.

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The literature provides several editorials with reflections and opinions about this topic (Green 2008; Ponette-González and Byrnes 2011; Boreman 2013). Several frameworks and standards guide the sustainability of meetings and events, as reported by Cai et al. (2014). Among them are the ISO 20121:2012 (event sustainability management systems) (ISO Central Secretariat 2012) and the Green Globe Certification (Green Globe Ltd 2015). The same authors highlighted the importance of the Green Meeting Standards established by the Convention Industry Council (CIC), the Accepted Practices Exchange (APEX), and the American Society for Testing and Materials (ASTM). These standards provide specifications for evaluating and selecting matters related to meetings, events, conferences, and shows.

Numerous studies have been conducted to assess the environmental impact of events, categorized by type, size, and data sources. These studies analyze the effects of various aspects such as travel, accommodations, food services, and the site activities before, during, and after the event (promotional items and marketing). Based on these categories, Edwards et al. (2016) conducted a study on two sports events hosted by the University of Arizona, attended by 60,000 people. The study found that primary data collection is crucial, and traveling was responsible for most of the carbon dioxide emissions, accounting for around 80% of the 2400 metric tons of CO_2-eq emitted in 2012 and 1900 metric tons of CO_2-eq in 2013. Accommodations were responsible for approximately 18% of the total emissions. The Homecoming events were responsible for the equivalent of 39.62 $kgCO_2$-eq per person in 2012 and 31.50 $kgCO_2$-eq in 2013 (Edwards et al. 2016).

Similarly, Desiere (2016) tracked the carbon footprint of a congress in Ljubljana (in 2014) attended by 646 participants from over 40 countries. The study focused on transportation emissions, concluding that each participant emitted about 500 $kgCO_2$-eq. The authors suggested that selecting a more central location and encouraging the use of trains instead of airplanes could significantly reduce emissions.

Stroud and Feeley (2015) emphasized the crucial role of selecting an appropriate location in reducing the overall emissions of a conference. The authors analyzed the travel distances for four international conferences with 200–400 participants and found an average of about 9564 km. The results showed that each attendee contributed on average to 2.5–3.0 tons of CO_2-eq. However, by simply changing the conference venue from Germany to the UK (London), the authors found a reduction of about 200 $kgCO_2$-eq per person. In another study, Hall (2007) designed four different scenarios for an Annual International Conference and calculated the emissions according to the Tyndall Centre for Climate Change Research formula. The estimated emissions from air displacement were 7.725×10^5 $kgCO_2$-eq for 357 participants or 2163 $kgCO_2$-eq per person.

Spinellis and Louridas (2013) assessed the carbon footprint of conference papers by collecting all available data from Scopus and crossing it with additional information from ISI Web of Science. They then classified the papers based on conference location and traveler origin. The researchers found about 1.17 million conference papers in 2008, which were associated with 9.39×10^8 $kgCO_2$-eq emissions, corresponding to 0.23% of emissions from international flights in that year. The findings highlight the significant environmental impact of the scientific community on our society.

Neugebauer et al. (2020) investigated the paradox of sustainability in conferences through life cycle assessment (LCA), including preparation, execution, traveling, and finishing activities related to a 3-day international conference. The authors also quantified the emissions related to hospitality, such as accommodation and catering services. The estimated carbon footprint was 4.55×10^5 $kgCO_2$-eq, i.e., 570 $kgCO_2$-eq per participant.

In a similar study conducted by Hischier and Hilty (2002), the effect of different measures to reduce the environmental impact of a 3-day international conference was investigated. Although the study did not consider the impact of accommodations and meeting site structure due to lack of information, it revealed that reducing promotional items and printed material had a positive effect despite more than 95% of the environmental impact derived from traveling. In addition, the centralized meeting scenario reduced from 80,000 $kgCO_2$-eq to about 45,000 $kgCO_2$-eq considering simultaneous decentralized meetings.

In a more recent study, Toniolo et al. (2017) investigated and confirmed the validity of the LCA method in measuring the potential environmental impacts of an event. The study accounted for all materials, energy, and water used before, during, and after the event, as well as waste products. However, traveling was not considered. By doing so, the authors managed to appreciate and compare minor impacts usually dominated by transportation, e.g., accommodation, and food services. In addition, the calculations demonstrated the importance of emissions related to energy use and materials employed for organizing these meetings.

Numerous studies have shown that traveling has a significant impact on the environmental performance of conferences, events, and meetings. Indeed, flights produce large amounts of greenhouse gases (GHG)—primarily carbon dioxide from burning fuel. Therefore, the location of an event is a crucial factor to consider when planning. In recent years, researchers have explored the possibility of resorting to online meetings as a partial substitute for in-person gatherings to reduce the overall environmental footprint of research. For instance, Periyasamy et al. (2022) estimated that physical meetings can impact 55 times more than virtual ones.

The topic gained even more attention after the COVID-19 pandemic forced gatherings to be replaced by virtual ones

(Bottanelli et al. 2020; Porpiglia et al. 2020; Periyasamy et al. 2022). However, the actual feasibility of this new form of research is still under debate. While there is an expectation of a reduction in environmental burdens, there are also concerns about the loss of human connection in the virtual environment (Porpiglia et al. 2020; Arul Vallarasi and Regi 2022). Tables 10 and 11 in Appendix provide a summary of research papers that delve into the impact of events and meetings, specifically focusing on the emissions attributed to science-related activities. Literature can be divided into three distinct lines of study. First, several papers evaluate the ecological aspect of these practices. A second group of papers discusses the social impacts of modifying the status quo. Finally, researchers have written open letters on the subject.

The present study aims to assess the environmental impact of an ongoing European project, the SWS-Heating, which aims to create a new seasonal thermal energy storage system using an innovative sorbent storage material embedded in a compact multimodular sorption unit. The project involves 16 organizations, including universities and companies in seven European countries, with five board meetings concluded by March 2020. This work explores the intersection of social and environmental impacts, covering ecological and social perspectives of international project meetings. The authors aim to improve the environmental performance of these meetings without any negative consequences on their social role. Most literature assesses only one of these sustainability aspects at a time. The findings of this study will provide valuable insights into the overall sustainability of international research meetings and support coordinators in the strategic planning of future projects to optimize their productivity and ecological footprint.

Research methodology

In this work, we conducted a comprehensive sustainability assessment of the first five board meetings of the SWS-Heating European project (Grant Agreement No. 764025). Our assessment focused on two key areas: (i) environmental footprint from a life cycle perspective and (ii) user acceptance through language processing analysis. To do so, two dedicated online forms were designed and distributed to meeting organizers and participants between February and

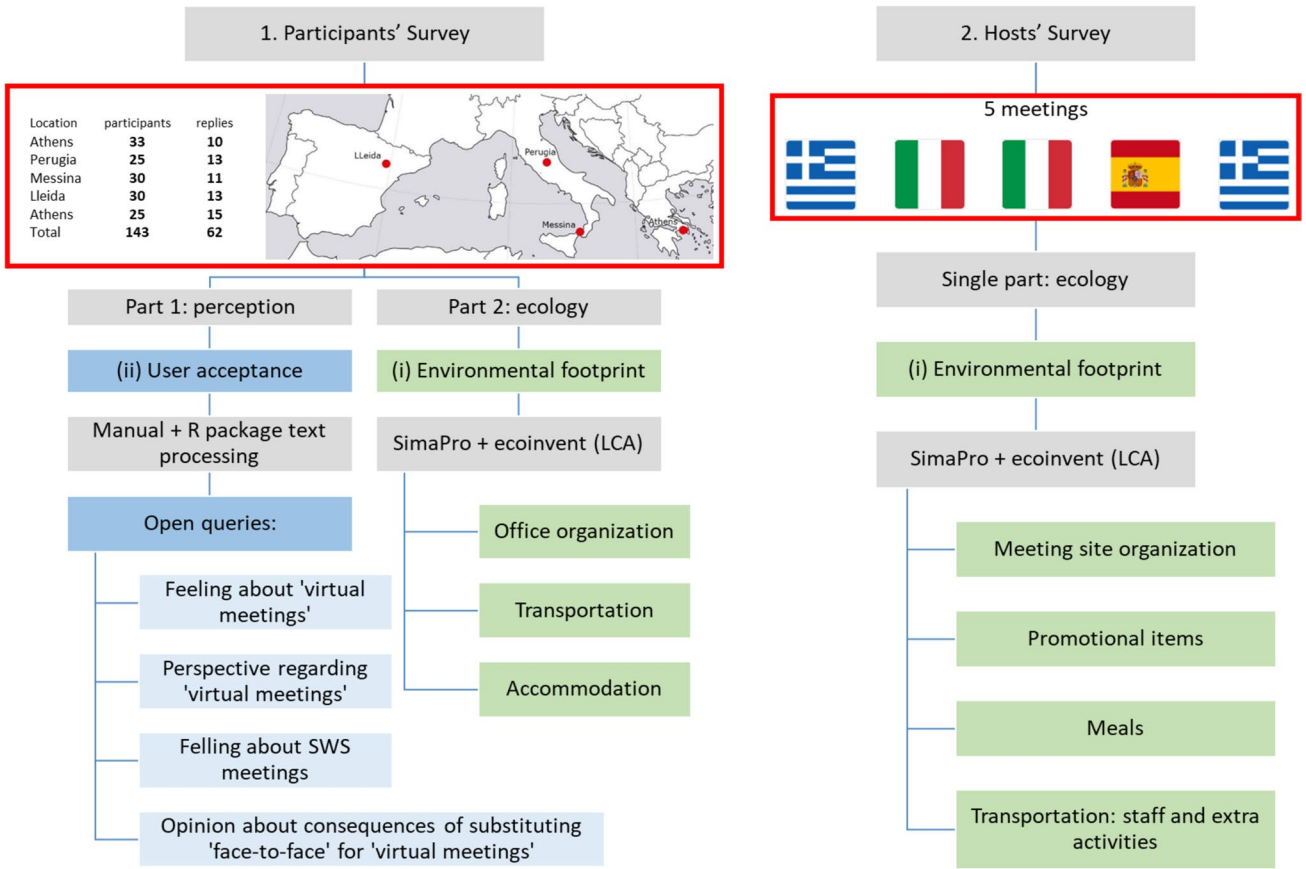

Fig. 1 The overall flow of the research analysis

May 2020 (see Fig. 1). The utilization of online surveys has raised concerns about the potential impact of unequal Internet connectivity and technology (Fabiani et al. 2021). Despite these concerns, we determined that this approach was suitable given the specific group of participants and the onset of the pandemic. The obtained responses were thoroughly analyzed and are presented in Fig. 2.

Elaboration of the questionnaires

Participants' questionnaires

The participants of the SWS-Heating group meetings were asked a series of qualitative and quantitative questions, which can be found in Supplementary Material 1. The survey was divided into two parts. The first part consisted of open-ended questions that focused on personal perception of virtual meetings, projections for face-to-face meetings, and opinion about the SWS-Heating project meetings. The second part of the survey covered personal information, including eating habits, accommodation preferences, travel standards, and specific questions about participation in work meetings and social activities. Each group meeting was assessed separately, using a dichotomous question, followed by detailed multiple-choice and short open-ended questions.

Hosts' questionnaires

The organizers of each group meeting were asked to complete a second survey, which was divided into four sections, and primarily consisted of open-ended questions (refer to Supplementary Material 2 for details). The first section of the survey focused on promotional items provided during the meeting, including details on the type of item, its source, delivery method, and packaging. The second section inquired about food services, including catering and restaurant selection, using open-ended and multiple-choice questions. The third section of the survey asked about building facilities, equipment, and waste management, using both open-ended and dichotomous queries. Finally, the organizers were asked to report any transportation arrangements for secondary activities, such as dinners or visits.

Environmental impact assessment

The environmental impact assessment utilized data gathered from the surveys to analyze the impact of various factors, such as transportation, accommodations, building energy, printed materials, consumables, and meals provided during the event (including coffee breaks, lunch, and dinners). The information is presented in Figs. 3 and 4. In cases where survey data were insufficient, secondary data were obtained through a comprehensive literature review. The study was conducted using the LCA framework standardized by ISOs 14040 and 14044 (International Organization for Standardization 2006a, b). "Goal and scope" outlines the aim and approach of the study, while "Functional unit and boundaries" defines the functional unit and the system boundaries. The life cycle inventory for six activity groups is presented in "Life cycle inventory". Finally, the results are presented in "Results" using a single-point method for transparency and simplification. The results include a comprehensive impact assessment for organizing the meeting as well as individual guests.

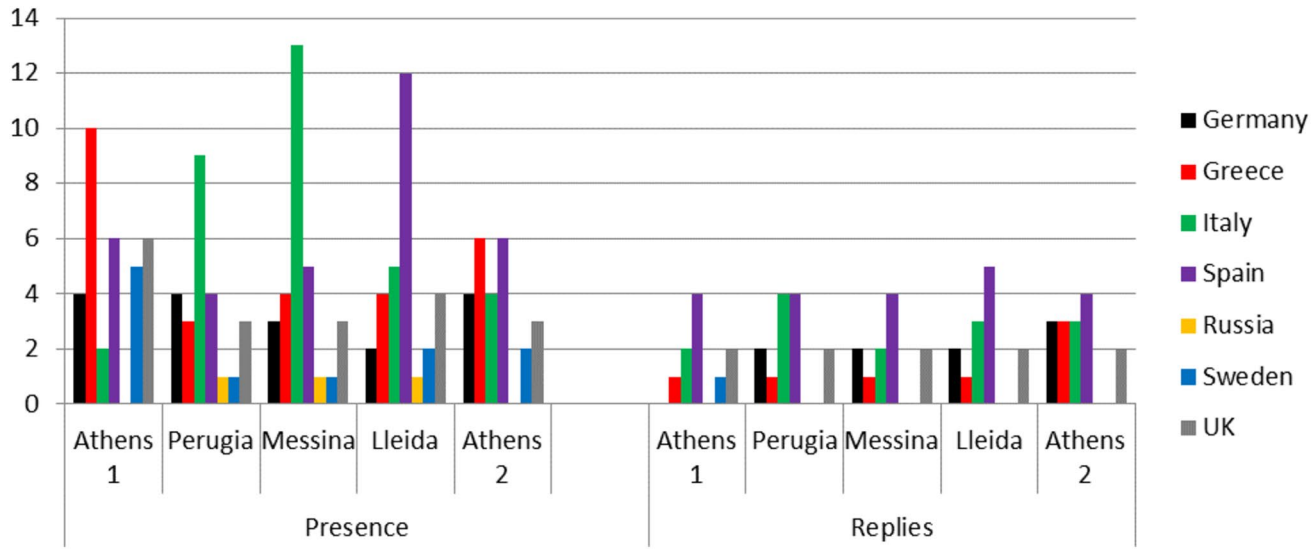

Fig. 2 Participants' presence in each meeting (Athens 1, Perugia, Messina, Lleida, and Athens 2) and collected replies divided by country

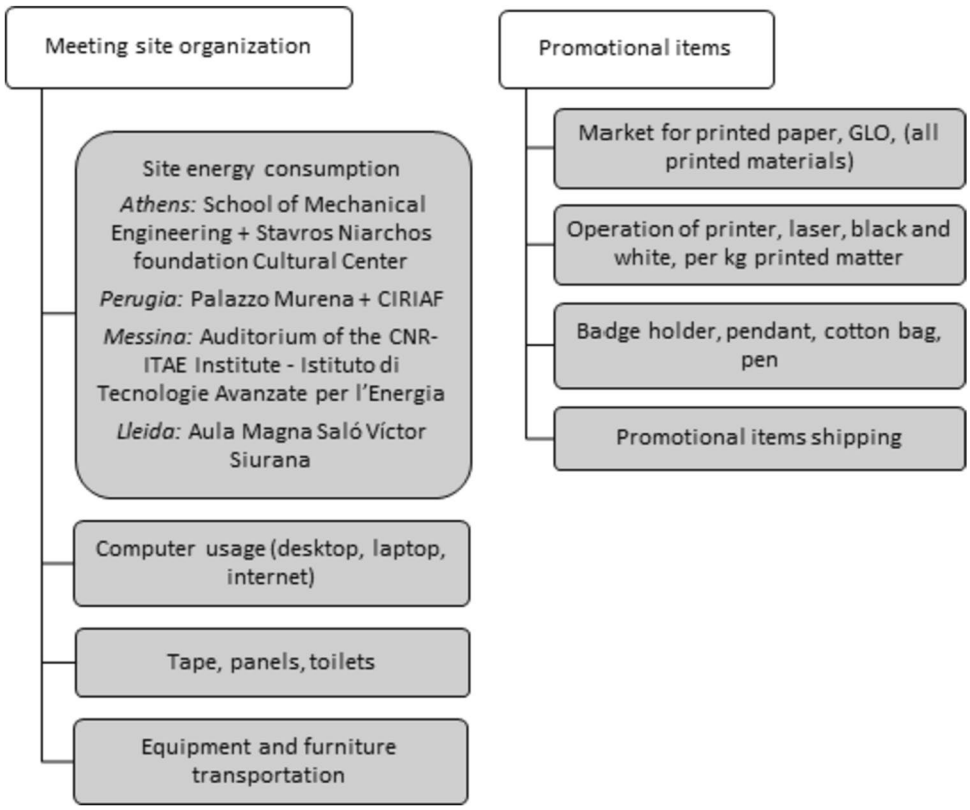

Fig. 3 Study boundaries for the hosts' comprehensive emissions

Goal and scope

The purpose of the environmental analysis is to assess the potential environmental impacts resulting from five meetings of the ongoing SWS-Heating European project. This evaluation considers all aspects of the meetings, including planning, meeting site requirements, meals, materials, accommodations, and transportation from a cradle-to-grave perspective. Furthermore, this study aims to raise awareness within the scientific community about their environmental footprint and resource depletion habits.

Functional unit and boundaries

The functional unit of this study is the sum of all inputs and outputs associated with the conduction of five 2-day-long board meetings in four different European cities: Athens (Greece), which hosted two meetings, as well as Perugia (Italy), Messina (Italy), and Lleida (Spain). By presenting the results for each meeting separately, this research aims to evaluate the differences and provide valuable insights for future events. It is important to note that this study did not consider the additional technical meetings taken in Messina in September 2018, Athens in March 2019, and Malmo in January 2020 where the technology was being implemented.

The boundaries of our study excluded the construction and infrastructure of the facilities. Unfortunately, we were unable to model waste and water collection systems due to inaccuracies in the replies and a lack of information regarding the water network from the sites. Additionally, we did not make specific distinctions regarding the food's origin and preparation methods due to the system complexity and the lack of information.

To evaluate the environmental burdens related to the SWS-Heating group meetings, the Simapro version 8.4.0.0 software and the ecoinvent database were used (Wernet et al. 2016). In addition, the Agribalyse 3.0 (Agence de la Transition Ecologique 2020) data were included for missing food items. The impact assessment in terms of comprehensive and individual emissions using the single-point Global Warming Potential (GWP) method for the horizon of 100 years developed by the Intergovernmental Panel on Climate Change (IPCC 2013 V1.00) was used. This method relates greenhouse gas emissions in the air to climate change, which impacts the ecosystem, human health, and resources (PRé-Consultants 2020). The final impact is expressed in $kgCO_2$-eq as in most studies as CO_2 emissions' estimation is essential for benchmarking.

Life cycle inventory

This section presents and discusses the life cycle inventory separated by activity. The ecoinvent market specification refers to the processes from a specific location (different

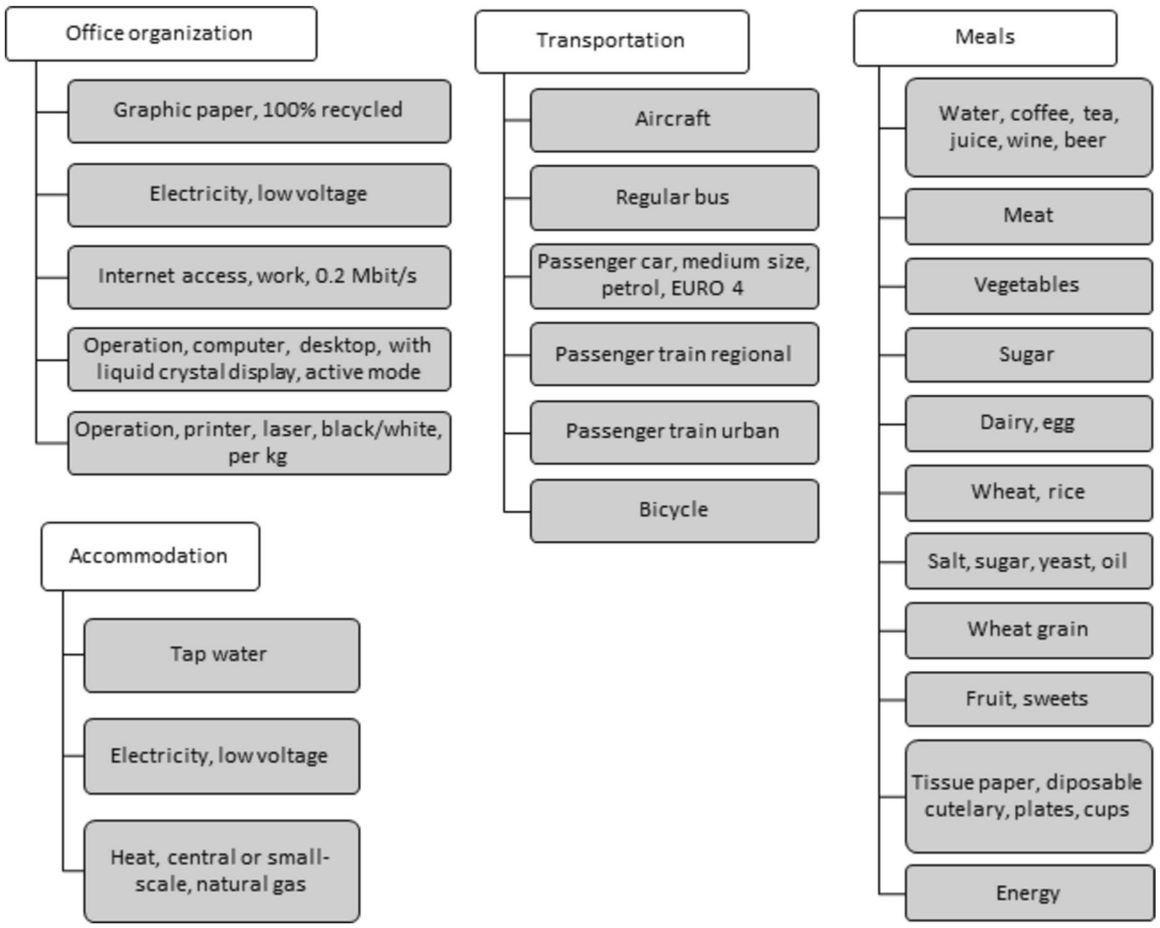

Fig. 4 Study boundaries for the participants, and individual emissions

production countries) and includes average transportation and eventual losses. Country-specific data were preferred for this study. However, when these are unavailable, the selection follows the sequence: European, Swiss, or Global datasets..

Transportation Tables 1 and 2 present a comprehensive transportation inventory. The data were collected in a systematic manner, as illustrated in Fig. 5, and categorized according to the mode of transportation, including aircraft, buses, cars, trains, and bicycles. The distances traveled by air were calculated using the Great Circle Mapper website (meco media & communication GmbH 2008). Table 3 displays the distances between the airports and the meeting center, as reported by survey respondents. The means of transportation used to travel to and from the airport were

Table 1 Transportation inventory

Transportation means	Geography	1	2	3	4	5	Total	Unit
Market for passenger aircraft	Global	33,642	15,743	29,440	18,750	38,512	136,087	Person km
Market for regular bus	Global	250	502	678	3	346	1778	Person km
Market for passenger medium size car, petrol, EURO 4	Global	2750	5289	3377	2526	3133	17,074	km
Market for passenger regional train	Switzerland	70	689	432	1444	500	3134	Person km
Market for passenger train urban	Switzerland	37	–	–	–	–	37	Person km
Market for transport bicycle	Global	–	–	–	–	20	20	Person km

The numbers from 1 to 5 indicate the specific meeting: 1 = Athens; 2 = Perugia; 3 = Messina; 4 = Lleida; 5 = Athens, second meeting

Table 2 Accommodation inventory divided per hosting country

Location	Input	XENIOS data	Total number of nights					Total per event	Unit
			1	2	3	4	5		
Greece	Energy heating	64 kWh/m^2	23	–	–	–	28	282	kWh
	Energy electricity	110 kWh/m^2	23	–	–	–	28	484	kWh
	Water	0.433 m^3/m^2	23	–	–	–	28	22	m^3
Italy	Energy heating	76 kWh/m^2	–	24	23	–	–	308	kWh
	Energy electricity	139 kWh/m^2	–	24	23	–	–	564	kWh
	Water	0.189 m^3/m^2	–	24	23	–	–	9	m^3
Spain	Energy heating	154 kWh/m^2	–	–	–	21	–	279	kWh
	Energy electricity	133 kWh/m^2	–	–	–	21	–	241	kWh
	Water	0.553 m^3/m^2	–	–	–	21	–	12	m^3

The numbers from 1 to 5 indicate the specific meeting: 1 = Athens; 2 = Perugia; 3 = Messina; 4 = Lleida; 5 = Athens, second meeting

also determined based on survey responses, with options including bus, car, or train. The distances traveled by the participants were calculated using Google Maps, considering the shortest route possible based on the itinerary provided by the respondent. For travel to accommodations, meetings, and event dinners, we considered the position of a central hotel, events location (specified by the host), eventual visits according to the agenda, and the means of transportation reported by the participant.

Unfortunately, most of the participants did not specify the type of car used. Therefore, we assumed the process market dataset for medium-sized passenger cars, petrol, category EURO 4, based on references from the literature (De Camillis et al. 2010; Neugebauer et al. 2020). Distances between cities assumed the regional passenger train dataset in Switzerland, while distances inside cities were calculated based on the passenger train urban dataset. Moreover, since no detailed information was available, the distance covered by bicycle was estimated in two-daily 5 km trips, for 2 days.

Accommodation Table 2 presents the inventory section that focuses on the number of overnight stays reported during the meeting. Interestingly, despite the meeting's duration being 2 days, most participants stayed for 3 days. One person even reported an extended visit to Lleida. The attendees lodged in centrally located three- or four-star hotels, but unfortunately, most of them did not provide the exact names of their hotels, making it difficult to determine their locations. Consequently, the hotels' energy consumption (electricity and heating) and water standard consumption were derived from the XENIOS project (Dascalaki and Balaras 2004). XENIOS is the only reference that reports data from audited buildings in Italy, Spain, and Greece, making it highly compatible. To calculate the energy consumption, a room of 4.5 m × 7 m (31.5 m^2) was assumed in each case, based on an executive room according to Neufert (2019).

Office organization This section of the inventory considers all impacts that arise from office activities related to meetings attended by the participants. These activities include printing (energy, ink, and paper), computer work, and Internet use, as outlined in Table 4. The printing services considered recycled paper printed on both sides, as reported by the participants. For computer work and Internet use, we estimated 2 h of work dedicated to the meeting preparation over a period of 5 days, based on the indications provided by the University of Perugia team.

Meeting site organization The preparation of the meeting site (as outlined in Table 5) involves all the necessary activities required to ensure that the site is ready for the event and the following 2 days. To determine the resources required for promoting the event and marking the building, we relied

Table 3 Car distance from the city center to the main airport hub assessed by Google maps

Meeting city	Airport	Distance	Unit
Athens	Athens International Airport	34	km
Perugia	Rome International Airport	200	km
Messina	Catania Fontanarossa Airport	109	km
Lleida	Barcelona International Airport	157	km

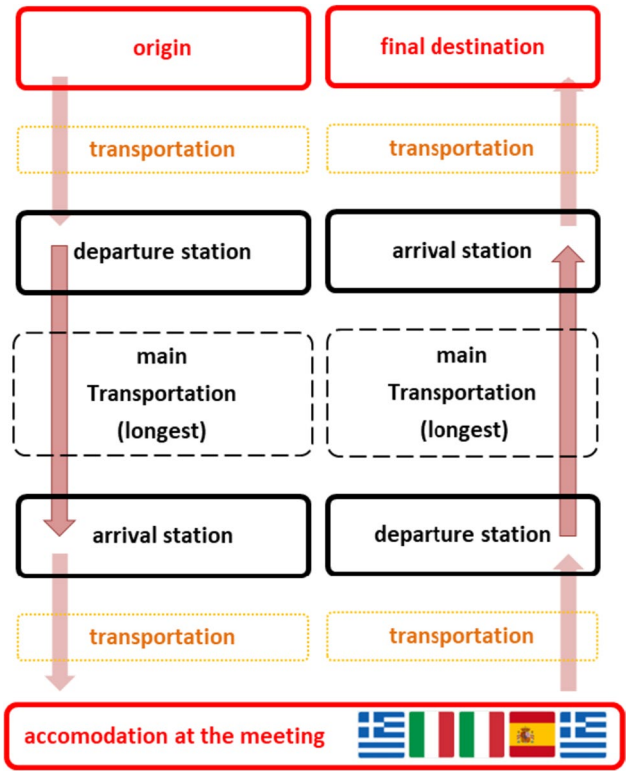

Fig. 5 Mapping scheme for transportation. The section was mandatory, and the interview could skip the steps that did not apply

on data provided by the hosts and specific compositions found in the literature (Toniolo et al. 2017). Additionally, the University of Perugia's organizing team provided data on the use of hygiene materials which were taken as reference.

The meetings were held in various locations, including the School of Mechanical Engineering (75 m^2) and Stavros Niarchos foundation Cultural Center (64 m^2) in Athens, Palazzo Murena (115 m^2) and Centro Interuniversitario di Ricerca sull'Inquinamento da Agenti Fisici (52 m^2) in Perugia, 'Auditorium of Istituto di Tecnologie Avanzate per l'Energia' (75 m^2) in Messina, and 'Aula Magna Saló Víctor Siurana' (170 m^2) in Lleida. Unfortunately, the hosts were unable to provide information on the energy consumption of these buildings. Therefore, we estimated the non-residential energy consumption to be 280 kWh/m^2 based on data from the Buildings Performance Institute Europe (Economidou et al. 2011). It is important to note that several factors can influence the final energy consumption, including construction technology, internal temperature setpoint, and user behavior. Additionally, the organizations reported the number of computers used (desktop or laptop), and we included the transportation of 50 kg of paper by light commercial vehicle (considering the database input Europe without Switzerland) corresponding to the material printed outside the institutions (graphic services). A total of 3.3 km was considered for Perugia, 2.4 km for Messina, and 1.5 km for Lleida. Furthermore, we took into account the Internet access and computer operation per attendee, as well as standby mode during coffee breaks. During lunch and site visit periods, all personal equipment was considered to be in off mode. Finally, we assumed 45 h of computer work for each organization based on the University of Perugia team's experience.

Promotional items This section pertains to the promotional items that were reported by the hosts. These items include posters, lists of attendees, agendas, blocks of notes, and brochures. We also considered the packaging and transportation as reported by the hosts. However, since we had no detailed information about the items like badges, pens, and cotton bags, the amounts were estimated based on the University of Perugia case and simplified in the model as in Table 6.

Meals The model considered the specific catering profile, menu description provided by the hosts, and observations made during the event. Therefore, the inputs were simplified, as reported in Table 7. In addition to ecoinvent, emissions for various items, such as tea, coffee, pork, cheese, wine, sausage, ham, egg, beer, fish, and yeast, were collected from the French database Agribalyse 3.0 (Agence de la Transition Ecologique 2020). It is worth noting that none of the 62 participants had any special dietary requests.

To estimate energy and water data inputs, the study by Neugebauer et al. (2020) was used, which considered two coffee breaks and two lunches served to 800 people. The overall energy consumption of the restaurants was calculated based on the CIBSE Guide F for a typical practice in a restaurant with a bar (Filippín and Larsen 2009). The menu considered was designed based on the Italian balance diet requirements (SINU—Società Italiana di Nutrizione Umana 2014) representing Mediterranean countries. However, it is important to note that the menu does not replicate the real complexity of all the ingredients in this diet. Additionally, it is not possible to reproduce the precise portions and preparation methods, storage techniques, and waste patterns as they were.

Researchers' stance evaluation

The purpose of this study was to evaluate the environmental and social impacts of a global, interdisciplinary, and multicultural project. To gather qualitative feedback on virtual meetings, participants were asked to share their thoughts and impressions through open-ended questions (as explained in "Participants' questionnaires"). While natural language can provide valuable insights, it can be difficult to analyze quantitatively. Therefore, we utilized a two-stage language processing approach. First, we manually analyzed the responses to identify the overall sentiment of the participants' dissertations. Then, we applied a multi-stage natural language processing (NLP) procedure to verify the main results using established statistical methods.

For the NLP analysis, we parsed and tokenized all responses to obtain a unique set of alphanumeric characters separated by blanks and punctuation marks. This allowed us to identify the primary terms (or tokens) in the text and create a list of unique terms (or types) representing the reference vocabulary of the collection. We then carried out additional pre-processing procedures to reduce language variability and eliminate possible noise in the data set. This included converting all characters to lowercase, deleting all numbers, and correcting all misspelled terms. We also applied lemmatization to reduce language variability at a morphological level, transforming each inflected term into its canonical form. Finally, we pruned the vocabulary by deleting message stop-words and removing the most common words in the English language to avoid non-informative

Table 4 Office organization inventory

Input	Geography	1	2	3	4	5	Total per event	Unit
Market for Graphic paper 80 g/m^2, 100% recycled	Global	0.28	0.35	0.33	0.36	0.36	1.67	kg
Desktop computer operation, liquid crystal display	EU without Switzerland	100	130	110	130	150	620	h
Market for Internet access, 0.2 Mbit/s	Global	100	130	110	130	150	620	h
Printing operation, laser black/white	EU without Switzerland	0.56	0.70	0.66	0.72	0.71	3.33	kg

The numbers from 1 to 5 indicate the specific meeting: 1 = Athens; 2 = Perugia; 3 = Messina; 4 = Lleida; 5 = Athens, second meeting

Table 5 Site meeting organization inventory

Item	Input	Geography	1	2	3	4	5	Total per event	Unit
Tape and poster	Market for phenolic resin	Global	0.012	0.012	0.012	0.012	0.012	0.06	kg
	Market for polypropylene, granulate	Global	0.048	0.048	0.048	0.048	0.048	0.24	kg
	Market for polyvinylidene chloride, granulate	Global	0.0008	0.0008	0.0008	0.0008	0.0008	0.004	kg
Hygiene	Market for paper, wood free, uncoated	Europe	0.0098	0.0098	0.0098	0.0098	0.0098	0.0491	kg
	Market for tissue paper	Global	160	160	160	160	160	800	g
	Market for polypropylene, granulate	Global	10	10	10	10	10	50	g
	Market for soap	Global	0.3	0.3	0.3	0.3	0.3	1.5	kg
Computer	Market for Internet 0.2 Mbit/s	Global	–	10.25	20.5	11.5	–	42.25	h
	Market for operation, desktop w/ liquid crystal display	Global	–	10.25	20.5	11.5	–	42.25	h
	Market for Internet videoconference, 0.7 Mbit/s	Global	396	256.25	307.5	345	214.6	1519.4	h
	Market for operation, laptop, 68% active work	Global	396	256.25	307.5	345	214.6	1519.4	h
	Operation, laptop, standby mode	EU w/out Switzerland	82.5	25	30	90	66.7	294.2	h
Building energy	Market for electricity, low voltage	Spain	–	–	–	349.4	–	349.4	kWh
	Market for electricity, low voltage	Greece	221.7	–	–	–	221.7	657.8	kWh
	Market for electricity, low voltage	Italy	–	256.2	230.1	–	–	486.3	kWh
Transp.	Processing light commercial vehicle	EU w/t Switzerland	–	80	60	30	–	170	kgkm

The numbers from 1 to 5 indicate the specific meeting: 1 = Athens; 2 = Perugia; 3 = Messina; 4 = Lleida; 5 = Athens, second meeting

terms. After completing the initial analysis, we further processed the textual content as structured data within the R environment. Our goal was twofold: (i) to gain insight into the general sentiment expressed by participants regarding online group meetings, and (ii) to evaluate the frequency and distribution of words across the corpus, along with their most common connections.

To achieve this, we utilized a dedicated language processing analysis within the 'tidy tool' ecosystem in R. We selected a word and emotion connection, also known as the 'NRC lexicon,' which was constructed and later validated using crowd-sourcing and categories of words and their associations with eight basic emotions corresponding to four polar opposites (anger, fear, anticipation, trust, surprise, sadness, joy, and disgust) (Plutchik 2001) and two sentiments (negative and positive) (Mohammad and Turney 2010). To measure frequency distribution, we calculated the correlation factor among the different words in the previously processed corpus and the PageRank centrality of each node. The PageRank centrality is a crucial parameter that takes into account the number of links received by the node, the link propensity of the linkers, and the centrality of the linkers (Page and Brin 1998). In other words, a node is considered essential if it is linked to other important nodes and links parsimonious nodes, or if it is highly linked.

Results

Environmental impact assessment

The organization of the five group meetings resulted in a total of 1377 $kgCO_2$-eq emissions. This breaks down to approximately 120 $kgCO_2$-eq for promotional products and 1257 $kgCO_2$-eq for the meeting site activities. In more detail, 84% of the emissions produced by the meeting site and organization are due to the energy consumed by the buildings. When divided by the total amount of participants (143), the emission per capita is about 9.6 $kgCO_2$-eq.

Regarding the estimation of the average individual emissions produced by each meeting participant, the main results are summarized in Fig. 6, which is divided into impacts due to transportation, accommodation, organization, and meals. The emissions obtained from these categories add up to 28,088 $kgCO_2$-eq. Specifically, 1259 $kgCO_2$-eq is due to accommodation, 24,299 $kgCO_2$-eq is due to transportation, 61 $kgCO_2$-eq is due to office organization, and 2468 $kgCO_2$-eq is due to meals. Therefore, we can estimate that, on average, each participant emitted about 455 $kgCO_2$-eq.

Transportation is the primary contributor to emissions, accounting for a staggering 86.5%. Meals and accommodations follow making up 8.8% and 4.5%, respectively. Within transportation, air travel is responsible for a whopping 73% of CO_2 emissions, while passenger cars account for 26% (refer to Fig. 7). When we consider the combined impact of both hosts and visitors, the total emissions per participant amount to 463 $kgCO_2$-eq. This translates to a comprehensive environmental impact of approximately 66,161 $kgCO_2$-eq across all five meetings.

The results per meeting were separated and are reported in Table 8. Once again, the impact of transportation on the meeting's performance is clearly visible. However, a fascinating insight regarding the different locations can be observed in terms of meals and meeting sites. It is interesting to note that the higher emissions during both Athens meetings can be partially attributed to the impact of the Greek energy mix, as demonstrated in Table 9. In fact, the impact is almost 50% of the total for the meals. Furthermore, when it comes to meeting site emissions (as depicted in Fig. 8), it was discovered that using a larger conference room had a significant impact on Lleida's environmental performance. This impact corresponds to 24.3% of the emissions for this specific activity.

Table 6 Promotional items inventory

	Input	Geography	1	2	3	4	5	Total per event	Unit
Badges	Market for ethylene vinyl acetate copolymer	Global	–	400	–	240	–	640	g
	Market for extrusion, plastic film	Global	–	400	–	240	–	640	kg
	Market for nylon 6	Global	–	596	–	358	–	954	g
Banner	Market for vinyl acetate	Global	–	0.47	–	–	–	0.47	kg
Ecobag	Market for textile, woven cotton	Global	–	3100		–	–	3100	g
Pen	Market for polyethylene, low density, granulate	Global	–	250	175	–	–	425	g
Printed material	Market for printed paper	Global	0.04	8.88	0.17	5.97	0.04	15.11	kg
	Operation printing, laser black/white	EU without Switzerland	0.02	4.77	0.08	3.50	0.02	8.40	kg
Transp.	Transport, freight, light commercial vehicle	EU without Switzerland	–	165	120	75	–	360	kg km

The numbers from 1 to 5 indicate the specific meeting: 1 = Athens; 2 = Perugia; 3 = Messina; 4 = Lleida; 5 = Athens, second meeting

Table 7 Meals, packaging, and catering products

Input	Geography	1	2	3	4	5	Total per event	Unit
Drinking water, at plant	Europe	18.2	17.8	15.4	14.4	19	84.8	l
Beer	France	7.5	3.9	3.3	3.9	7.5	26.1	l
Wine	France	5.75	4.625	4.125	4.125	3.125	21.8	l
Coffee	France	2.73	2.67	2.31	2.16	2.85	12.7	l
Juice	France	11.7	12.28	10.73	9.85	10.6	55.2	l
Tea	France	7.5	7.5	6.3	5.9	10.6	37.8	l
Market for pig meat	France	–	1.3	–	–	–	1.3	kg
Market for red meat, live weight	Global	3.03	2.50	2.20	0.00	3.03	10.75	kg
Fish	France	5.33	1.80	3.30	0.00	3.75	14.18	kg
Market for onion; tomato; zucchini; green asparagus	Global	1.78	2.50	2.20	2.30	1.78	10.55 of each	kg
Market for wheat grain	Global	5.27	6.54	5.66	5.60	4.88	27.96	kg
Market for sodium chloride	Global	0.10	0.12	0.11	0.11	0.08	0.52	kg
Market for sugar from beet	Global	1.68	1.99	1.72	1.71	1.56	8.65	kg
Yeast	France	0.05	0.05	0.04	0.05	0.03	0.21	kg
Egg	France	4.08	4.42	3.87	4.10	2.43	18.9	kg
Ham	France	0.5	0.975	0.825	2.95	1.125	6.38	kg
Sausage	France	2.8	3.475	3.025	2.95	2.375	14.63	kg
Cheese	France	3.30	4.45	3.85	3.60	3.50	18.7	kg
Market for rice	Global	2.68	2.96	2.64	2.64	1.00	11.92	kg
Market for vegetable oil, refined	Global	0.46	0.50	0.44	0.46	0.25	2.11	kg
Market for melon	Global	2.50	1.30	1.10	1.30	2.50	8.7	kg
Market for pineapple	Global	1.05	1.20	1.10	1.00	0.00	4.35	kg
Market for cream from cow milk	Global	0.48	0.63	0.56	0.49	0.23	2.38	kg
Market for cow milk	Rest of the world	2.51	2.74	2.42	2.50	1.25	11.42	kg
Market for butter from cow milk	Global	0.98	1.51	1.27	1.15	1.65	6.56	kg
Market for strawberry	Global	0.40	0.78	0.66	0.52	0.90	3.26	kg
Market for tissue paper	Global	0.14	0.13	0.11	0.10	0.19	0.67	kg
Market for polystyrene	Global	1.35	0.85	0.72	0.78	1.48	5.16	kg
Market for polycarbonate	Global	0.25	0.13	0.11	0.13	0.25	0.87	kg
Market for polypropylene, granulate	Global	0.42	0.39	0.33	0.31	0.57	2.02	kg
Market for polyethylene, low density, granulate	Global	0.30	0.16	0.13	0.16	0.30	1.04	kg
Market for tap water	EU w/o Switzerland	2.13	2.61	2.28	2.24	1.74	11.00	kg
Market packaging glass, white	Global	4.22	3.39	3.03	3.03	2.29	24.2	kg
Market for polyethylene terephthalate, granulate, bottle grade	Global	0.59	0.58	0.50	0.46	0.67	2.81	kg
Market for liquid packaging board container	Global	0.22	0.23	0.20	0.19	0.20	1.04	kg
Aluminum, secondary, ingot, from beverage cans, at plant/RNA	North America	0.35	0.18	0.16	0.18	0.35	1.23	kg
Market for tap water	EU w/o Switzerland	1386	1869	1617	1512	1470	7854	l
Market for cork slab	Global	0.04	0.03	0.02	0.03	0.03	0.16	kg
Processes								
Market for electricity, low voltage	Greece, Spain, Italy	308.7	307.8	268.4	250	285	–	kWh
Market for heat, central or small-scale, natural gas	EU w/o Switzerland	315	292.5	247.5	234	427.5	1516.5	kWh

The numbers from 1 to 5 indicate the specific meeting: 1 = Athens; 2 = Perugia; 3 = Messina; 4 = Lleida; 5 = Athens, second meeting

Life cycle interpretation

In agreement with the literature presented in "Introduction", traveling contributes significantly to the environmental burdens produced by the project meetings. In fact, our calculations have estimated that a total of 24,299 $kgCO_2$-eq are emitted, with 17,806 $kgCO_2$-eq coming from air transport alone, which equates to 287 $kgCO_2$-eq per person, i.e., approximately 62% of the overall emission. These findings confirm the importance of considering the impact of air travel, even for relatively short distances within Europe. The obtained shares are in line with the reported literature (Desiere 2016; Neugebauer et al. 2020), which highlight the crucial role of meeting location in the environmental sustainability of a project, rather than the number of participants. Therefore, it is clear that the impact of air transport must be a key indicator to be estimated. However, recent research has raised concerns about the accuracy of the SimaPro characterization factors under the IPCC method. Specifically, it has been argued that these factors do not consider the increased effects caused by the emission of GHG at high altitudes (Jungbluth and Meili 2019), primarily due to the considerable uncertainty regarding this calculation.

A new scenario was developed to assess the impact of the database used for the simulation model. The first modification involved changing the type of bus from a regular bus to a trolleybus (database input 'Transport, regular bus {GLO}| market for, Alloc Def, U' to 'Transport, trolleybus {GLO}| market for, Alloc Def, U'), resulting in a 6% reduction in emissions.

The second modification involved substituting a more generic input for a medium-sized petrol car (database input 'Transport, passenger car, medium size, petrol, EURO 4 {GLO}| market for, Alloc Def, U' to 'Transport, passenger car {RER}| market for, Alloc Def, U'). The newly selected input considers a mix of different sizes, EURO classification, and fuels, such as gas, diesel, petrol, and electricity, and produces 12% emissions' reduction.

Finally, the alternative scenario considered more localized data for passenger aircraft, considering an exclusive European set, rather than a general intracontinental and intercontinental dataset, resulting in a 23% increase of emissions mainly due to the fuel geography. This highlights the importance of database selection and improving details when approaching transportation. The contributions related to accommodation, materials, communication, and food were less significant to the overall environmental footprint of the SWS-Heating project

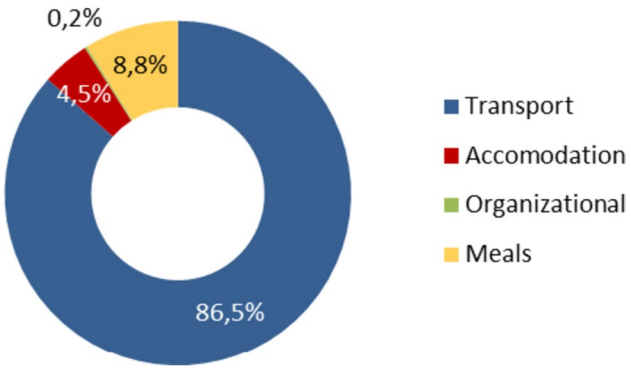

Fig. 6 Emissions in $kgCO_2$-eq for 62 entries are divided by meeting activity

meetings. However, they still represent a non-negligible source of pollution. Among these activities, the energy (electricity and heating) consumption associated with meals accounted for 63% of their total emissions.

Regarding the food provided during the meetings, Fig. 9 shows the CO_2-eq emissions associated with one kilogram of each item in the menu reported by the hosts according to the ecoinvent (Wernet et al. 2016) and Agribalyse 3.0 (Agence de la Transition Ecologique 2020). The emissions can vary based on production methods, product origin, and other factors, which can add uncertainty to the results. To provide some context, a study by Clune (2019) examined the environmental impact of various food items in terms of embodied CO_2 by constructing a Food Global Warming database. The author estimated that field-grown fruits and vegetables have emissions of about 0.40 $kgCO_2$-eq/kg, while grains, cereals, and pulses have emissions of 0.51 $kgCO_2$-eq/kg. Poultry has an average of 3.71 $kgCO_2$-eq/kg, non-ruminants have about 5.72 $kgCO_2$-eq/kg, and ruminants have an average of 26.61 $kgCO_2$-eq/kg. It is important to note that the environmental burden attributed to food can be characterized by a large amount of uncertainty due to several assumptions.

Accommodation is a crucial factor in our model, ranking third in terms of relevance. Our survey results revealed that 84% of participants stayed in four-star hotels, while 13% opted for three-star hotels, and only one person stayed in a five-star hotel. It is worth noting that all hosts were assumed to stay at their homes, so their impact was excluded from these percentages. Numerous literature studies have highlighted the importance of electricity and heating consumption in hotel stays. For instance, Santamouris et al. (1996) conducted an audit of 158 hotels in Greece to study energy

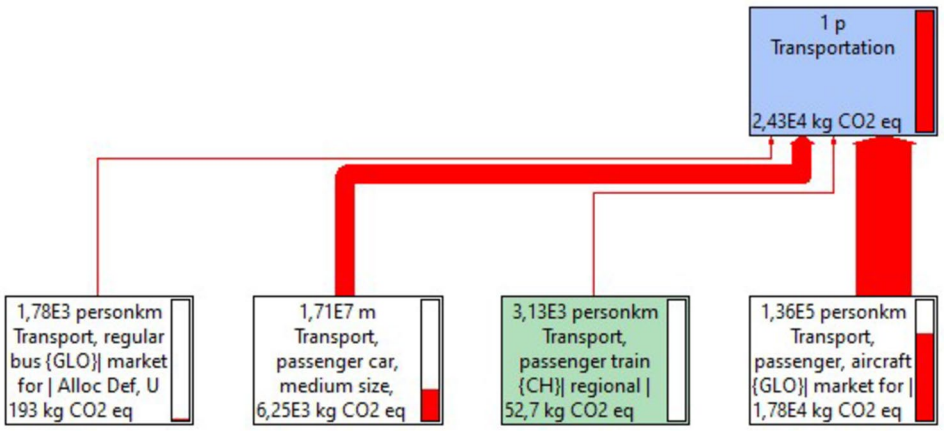

Fig. 7 Emissions in $kgCO_2$-eq are divided by the mean of transportation

Table 8 Total emissions calculated per meeting and per activity

	Persons	Athens 1	Perugia	Messina	Lleida	Athens 2
Transport	62	5436.8	4061.0	5168.5	3402.0	6231.5
Accommodation	62	277.5	227.1	217.7	199.2	337.8
Organizational	62	9.9	12.9	10.9	12.9	14.8
Meals	143	629.1	484.0	416.7	329.5	614.0
Meeting site	143	282.9	190.6	179.7	295.5	266.1
Promotional	143	0.1	102.7	1.0	15.8	0.1
Average $kgCO_2$-eq/person		600.1	361.9	510.6	299.4	474.2

Table 9 Total consumption per country, emissions according to the energy mix, and total emissions

	kWh	CO_2/kWh	Tot CO_2-eq
Spain	521.6	0.50	259.4
Greece	443.4	1.10	486.6
Italy	486.3	0.64	309.5

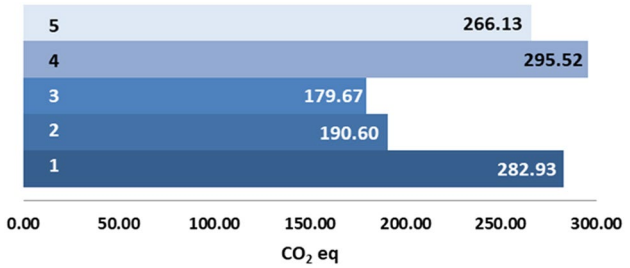

Fig. 8 Sum of emissions in CO_2-eq per 'meeting site' related activities. (The numbers from 1 to 5 indicate the specific meeting: 1 = Athens; 2 = Perugia; 3 = Messina; 4 = Lleida; 5 = Athens, second meeting)

consumption reduction solutions. They found that the average annual consumption was 273 kWh/m^2, second only to the hospital sector. Similarly, Beccali et al. (2009) studied the hotel sector in Sicily (2002) and classified the samples by clusters according to the hotels' categories. They discovered that the CO_2 emissions by overnight stay were 4.69, 7.05, and 15.77 kg for one-, two- or three-, and four- or five-star hotels, respectively. The resulting average was 9.17 $kgCO_2$-eq, which is very similar to the 10.58 $kgCO_2$-eq considered in our calculations, which did not differentiate between hotel categories. Despite the building performance, many services that are related to the hotel category, occupant behavior, size, and others can increase the potential impacts of this activity (De Camillis et al. 2010). Concerning meeting organization and promotional products, the highest shares of the impacts are associated with electricity and heating consumption and printing. However, they only contribute narrowly and marginally to the comprehensive impact of the event.

Researchers' stance interpretation

Manual language processing

The initial inquiry into participants' feelings about virtual meetings yielded a generally favorable response, particularly for straightforward topics and smaller working groups, as it can expedite the decision-making process. However, five respondents expressed caution, emphasizing that face-to-face meetings are irreplaceable and more suitable for complex discussions.

The interviewed participants were not entirely convinced about replacing face-to-face meetings with virtual ones. Most of them believe that virtual meetings are appropriate only in specific situations. The more confident participants (three of them) emphasized the need for technological improvements to make virtual meetings more effective. The group unanimously agreed that face-to-face meetings were valuable to the project's development.

Finally, participants expressed concerns about the consequences of substituting face-to-face meetings with virtual ones in a European project like SWS-Heating. Most people considered the possibility of misunderstandings, delays, and networking losses as potential side effects. Only two participants considered virtual meetings feasible once people get used to them, but with reservations.

Automated language processing

Figure 10 shows the results of the NRC classifications of the analyzed text. These findings support the impression derived from manual processing and are consistent with the results of Kim et al. (2022) from a virtual medical conference. Indeed, the NRC results indicate that over 82% of the investigated words are positive. The most common sentiment toward online meetings is trust, accounting for 37%, followed by anticipation at 19%, and joy at 18%. These emotions have a high degree of similarity in positive sentiment, according to the wheel model from Plutchik (2001). To gain a better understanding of the general opinion about online meetings in European projects, a closer look at the open answers of the meeting participants is necessary. The stronger correlations among the words were filtered and visualized in a network. The dimension of the node denotes its Page Rank centrality, and the color of the word gives the number of its repetitions, while the thickness of the line gives the intensity of the correlation (see Fig. 11). For example, Fig. 11a considers a minimum number of repetitions of 3 and a minimum correlation of 0.45. In this case, four different groups of words can be detected.

The bottom left group in Fig. 11a is densely packed with many connections among most of the nodes, characterized by high correlations. Indeed, most of these nodes share a similar centrality value and are equally important and connected. This group indicates a strict correlation among words like "short," "conversation," "partners," "faster," "communicate," "positive," "focused," "solving," and "directly." This suggests that most meeting participants consider online meetings as a faster and more direct way to interact with other partners. Additionally, the presence of terms like "task," "specific," "tool," and "project" indicates that online meetings are also seen as a valuable tool for efficiently and rapidly solving specific problems. Moving to the bottom right group, we see fewer terms, but the words "person,"

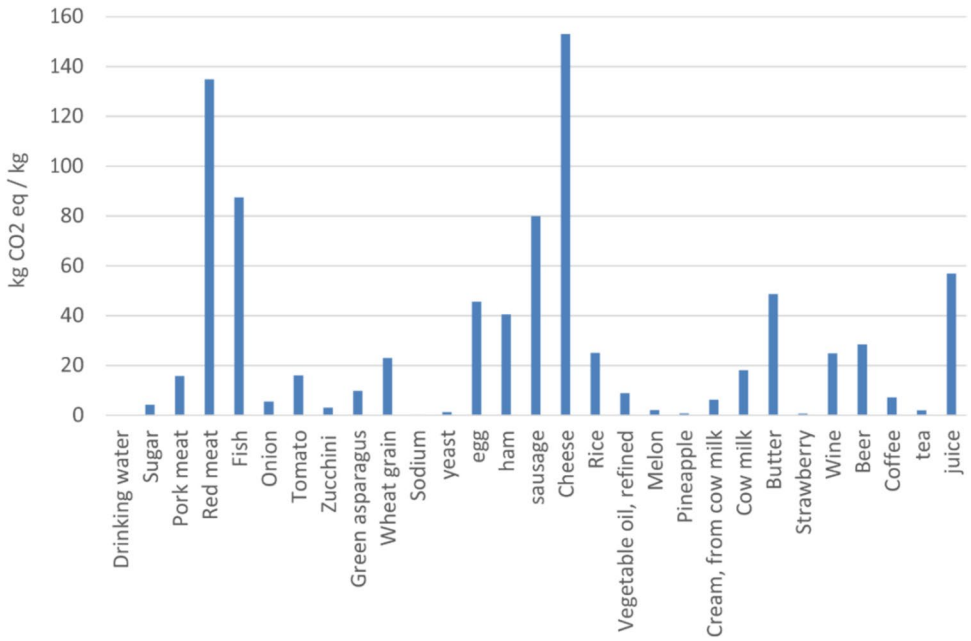

Fig. 9 Comparison of kgCO_2-eq emissions per kg of food

"help," "difficult," "aspect," and "issue" have higher centrality values. This suggests the opinion that the most challenging issues should be discussed in person. The two smaller groups at the top of Fig. 11a, on the other hand, show a significant correlation between the pair "opinion–involved" and the pair "misunderstanding–communication". However, due to the poor number of significant connections with other words, it is difficult to evaluate these strong correlations. Figure 11b shows the word network obtained by considering a minimum number of repetitions of 4 and a minimum correlation of 0.35. In this case, only the two main groups described before can be noticed.

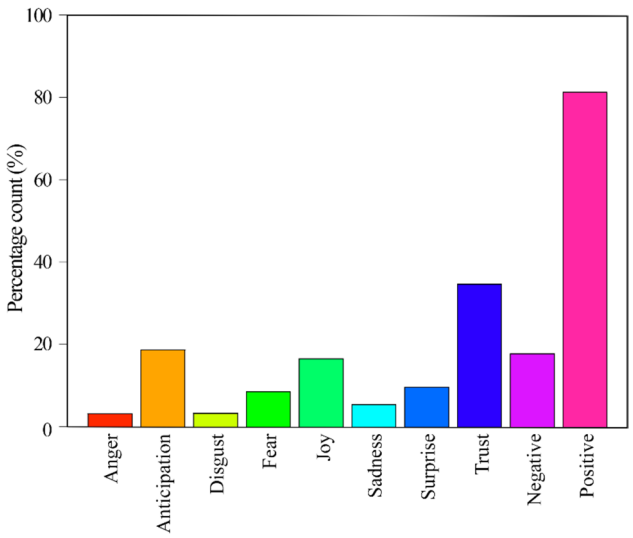

Fig. 10 Classifications of the participants' words in the reference NRC lexicon categories

Discussion

Limitations of the study

The LCA is a simplification based on reality. This work attempts to reconstruct and report past events that occurred in different geographies and timeframes, which can add complexity to the model. As a result, the assessment is limited to the details provided by the organizers and participants of the event. To limit uncertainties in the model, this study made assumptions and estimations based on the literature, consolidated database, and expert experience. When information was not provided, it was estimated using secondary data from existing literature. However, it is important to note that the lack of information regarding actual building energy and water consumption, total waste produced by organizations, and energy flows related to all activities should be considered. Overall, events would benefit from the environmental calculations before their execution, starting from the planning stages and continuing throughout the event. Post-meeting evaluations show high levels of uncertainty, even if, for instance, some high-impact activities such as traveling are traceable by receipts.

On the other hand, NLP is a powerful tool that enables computers to comprehend text in the same way humans do. However, it is not without its limitations and challenges. One of the most important obstacles is contextual understanding,

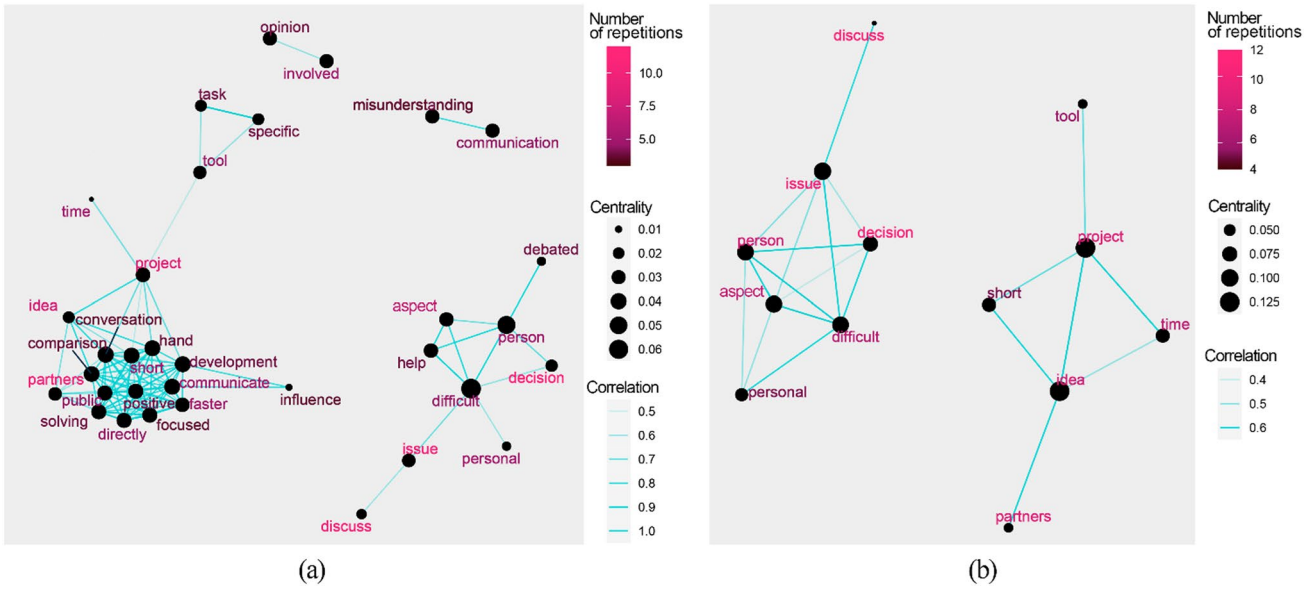

Fig. 11 Word networks based on the correlation of word counts considering only connections with **a** a correlation greater than 0.45 and a word frequency of at least 3 repetitions and **b** a correlation greater than 0.35 and a word frequency of at least 4 repetitions

where the same word or phrase can have different meanings depending on the context. Another limitation is detecting irony and sarcasm, which often use words and phrases that, strictly by definition, may be positive or negative but connote the opposite. Ambiguity, whether lexical, semantic, or syntactic, is also a significant concern in NLP, referring to sentences and phrases that can have multiple interpretations. To address these issues, future research could limit some of these issues using supervised machine learning and model pre-training. However, this would require many domain-specific corpora and expensive computational resources.

Finally, using online surveys for retrieving the information for the LCA and the NLP is intriguing but susceptible to under-coverage issues due to uneven Internet connectivity and technology distribution. Nevertheless, in this study's case, which involved researchers participating in project meetings, it was deemed acceptable. Future research could replicate this study outside of a single European project, combining in-person and online questionnaires and employing different and more advanced sampling and data collection techniques.

Integration of different sustainability perspectives

The investigation presented here delves into the overall sustainability of international research and provides intriguing insights that could benefit from an organic interpretation. By integrating considerations about environmental sustainability and participants' opinion mining, we can gain a more comprehensive understanding of the topic at hand. In today's world, researchers have the luxury of using online platforms to access a vast amount of information and share ideas without having to meet face-to-face in a specific location. However, in-person meetings still play a crucial role in research projects.

Despite this, manual interpretation and the text-mining investigation carried out in this work suggest that most researchers have a positive outlook of online meetings. They are considered an effective way to discuss specific issues that need to be addressed rapidly within the project's tasks. However, in-person meetings are still perceived as the most appropriate solution for addressing complex issues that require face-to-face interaction. This finding is also supported by Straus and McGrath (1994). Sniezek and Crede (2002) conducted a study comparing decision-making processes in in-person groups to technology-assisted meetings. They found that there were no significant differences related to the quality of the decisions. Most distinctions were related to the participants' perception of confidence in the outcomes of the meetings.

From an environmental point of view, as demonstrated in "Environmental impact assessment" and according to similar literature studies (Desiere 2016; Neugebauer et al. 2020), traveling has the highest environmental impact. Even though all SWS-Heating project meetings were organized within Europe and among European participants, most attendees traveled by airplane, resulting in 287 $kgCO_2$-eq emissions per capita. However, other activities related to accommodation, materials, communication, and food also contributed to the overall environmental footprint of the meetings, albeit to a lesser extent than transportation.

To provide a more detailed breakdown, *per capita* emissions were calculated for each meeting. The first Athens meeting resulted in 600 $kgCO_2$-eq, Perugia in 362 $kgCO_2$-eq, Messina in 511 $kgCO_2$-eq, Lleida in 299 $kgCO_2$-eq, and the

last meeting at Athens 474 $kgCO_2$-eq. The 30% difference between the average emissions of Athens and Lleida can be attributed mainly to transportation and a smaller scale for meals. Most participants who responded to the first Athens meeting were from abroad, while most of the responses obtained for the meetings in Spain and Italy were from locals, resulting in a reduced environmental impact from air travel.

These combined findings represent good insights for optimizing the overall sustainability of scientific research. As such, we propose a novel management approach for European projects that leverages remote meetings in specific circumstances. This approach can significantly reduce the environmental impact of a project, facilitate the swift and effective resolution of minor issues, and ultimately improve the lifestyles of researchers. Moreover, project leaders worldwide could promote scheduled or online meetings as a partial substitute for in-person meetings, which should only be organized a few times per year to discuss the most controversial or crucial research topics. Additionally, meeting locations could be planned based on a preliminary impact that considers the most relevant impact activities, such as transportation. This approach can also coordinate other activities like site visits in the surroundings or courses to optimize time and displacement. Limiting emissions and offsetting unavoidable ones can help mitigate these impacts. However, it is essential to evaluate how this approach would affect the dynamic among participants from a social perspective.

Conclusions

In recent years, there has been a growing concern about the impact of human activities on the environment. As a result, environmental research has been working tirelessly to reduce the environmental footprint of all kinds of human activities. Researchers from all over the world have been collaborating and sharing their knowledge in multifaceted international research projects to achieve this goal. However, it has been observed that most of these activities also generate severe impacts, partly because of the many conferences and group meetings that are held. Therefore, this work aims to investigate the overall sustainability of an ongoing H2020 European project by examining the environmental burden produced by the group meetings and evaluating researchers' opinions about online events. To achieve this aim, we designed and carried out a dedicated online survey campaign during the project. The survey was completed by almost 70 respondents, including hosts and meeting participants. The results were first checked and classified, and then, the environmental burden due to transportation, accommodation, office organization, site meeting organization, promotional items, and meals was evaluated from a life cycle perspective, based on the data from the survey. Later, data were analyzed to assess researchers' stance on online meetings. The environmental investigation revealed the significant impact of transportation, particularly air travel, on the overall greenhouse gas emissions generated by the five SWS-Heating project meetings. While accommodation, promotional items, communication, and food had a smaller impact, they still contributed to emissions that cannot be ignored. The data collected during the investigation highlighted the potential for digitalization to reduce the environmental impact of paperwork and promotional items. However, the investigation also revealed the challenges of mapping processes that are not directly controlled by the hosts, such as food production and waste management.

The results of our study have highlighted that in-person meetings are the most effective tool for discussing complex issues and debating crucial topics related to a project. However, online meetings are also valuable for addressing specific issues within the project's confined tasks in a rapid and effective manner. To reduce the environmental impact of face-to-face meetings, strategies such as selecting an optimized site and offsetting measured emissions can be implemented.

Overall, online meetings have the potential to be a promising management tool for researchers and policymakers involved in international projects. They can improve problem-solving for specific issues and tasks within the project work frame. Additionally, integrating and coordinating online meetings with in-person meetings can reduce the environmental impact of international projects, especially when multiple countries are involved. As an alternative, hybrid meetings with participants on virtual platforms and in-person can be a feasible strategy for reducing emissions and costs, while also aiding in time management for participants. This approach has become even more relevant in the post-pandemic world, where remote work has become the norm.

Appendix: Summary of studies that connects environmental impact study related to events

See Tables 10, 11.

Table 10 Studies on the environmental assessment of events

References	Assessment method	Scope of impacts covered	Share of traveling in the total impacts of events/meetings	Range of the changes from various traveling scenarios	Data used for the assessment
Toniolo et al. (2017)	ReCiPe 2008	Environmental impacts associated with the assembly, disassembly, and use phase of an event, including issues reported by ISO 20121	Not included in this study, but previously estimated in 54% of the total ecologic impacts	Not applicable	Primary data were collected during the organization activities for the four steps of the life cycle
Parkes et al. (2016)	CO_2, CH_4, N_2O in kg CO_2-eq	Impacts associated with water and wastewater management during construction, operation, and post-event; fuel consumption associated with transporting construction materials, demolition waste, and visitors during and post the event; embodied emissions from materials and energy during the construction and operation of the event	Three post-event scenarios: Business as Usual, Commercial World, and High-Rise High Density. The highest emissions' share corresponds to construction materials (almost 50% scenarios 1 and 3) and transportation (nearly 60% for scenario 2)	Optimized traveling scenarios demonstrated that the total emissions could be reduced by 30–40% compared to baseline	Data for the construction and event phases are based on Olympic Delivery Authority reports. Scenarios and buildings operation based on literature
Stroud and Feeley (2015)	GHG emissions-based USA's Environmental Protection Agency	Impacts associated with attending to International Biogeography Society meetings	About 39% of the emissions are due to transportation	Almost 50% of transportation emissions are reduced selecting optimal locations	Georeferenced travel distances were estimated from the past four International Biogeography Society meetings
Castellani and Sala (2012)	Ecological Footprint and LCA Eco-indicator 99	Hotel structure including energy and fossil fuel consumption for travel, local mobility of tourists, and accommodation (stay, food, and waste)	70% overall impact is attributed to traveling by car	Not applicable	Primary data came from direct interviews with the hotel manager, bills, and tourist surveys. Secondary data came from local statistics, national and international databases
Neugebauer et al. (2020)	CML 2001 baseline v. Jan 2016 and USEtox version 2.1	Three-day international academic conference including preparation, webpage, and secretariat, and materials; conference execution, other activities, catering, hotel overnight and travel of participants	Impacts from travel are about 83%	The reduction of air travel (by extending the number of participants arriving by train) reduces by about 8% the GWP	Primary data were collected from the conference venue. Assumptions were based on the permanent conference committee information and authors' experience
Hischier and Hilty (2002)	Eco-Indicator'99	Direct environmental impacts caused by holding 3-day conference	Travel activities account for 96.3% of the total impact load. 6% of the participants are responsible for almost 60% of the emissions load due to long-distance flights	Hypothesis was reducing the conference materials; proceeding in CD ROM; holding a 100% virtual conference; decentralizing the meeting for three sites	Data were obtained from the Zurich participants list and earlier studies

Table 10 (continued)

References	Assessment method	Scope of impacts covered	Share of traveling in the total impacts of events/meetings	Range of the changes from various traveling scenarios	Data used for the assessment
Edwards et al. (2016)	TRACI 2 model	Impacts of travel, accommodations, food, energy, materials, and waste	Traveling environmental impact corresponds to 82% in 2012 and 78% in 2013	Impact decreases due to better information in 2013 the lower travel impact for 2013 can be attributed to 98% of the decrease in impact overall for Homecoming 2013	The data collection process was completed by student observers and supplemented with information provided by university departments, event organizers, and survey responses from attendees
Orsi (2012)	EcoPassenger tool and TRX Airline Carbon Emissions Calculator	Amount of CO_2 emitted on a roundtrip travel at the 2007 World Congress of the International Association of Landscape Ecology (IALE)	Total of 461 tons of CO_2, from traveling. Most participants caused emissions between 200 and 1000 kg (26.6%), 1000 and 2000 kg (22.2%), and even beyond 2000 kg (5.4%) of the emissions	Overall carbon emission would have dropped to 30% if participants been assigned to different venues	Database was built starting from the official list of participants
Spinellis and Louridas (2013)	Act on CO_2 Calculator Version 2.0	Emissions associated with scientists traveling to present their work at conference	Not applicable	Two factors seem to increase the CO_2 emissions associated with a conference location: distance and popularity	Conference location data obtained from conference paper bibliographic details (Scopus digital library over the period 1998–2008). This selection yielded a sample of 2.8% of the population's papers
De Camillis et al. (2010)	CML 2001	Accommodation services provided by a hotel located in Italy, from door to door: transport to the hotel, accommodation services, and transport back home (modular LCA approach)	Passenger transport from Northern Italy is the most significant aspect of the transport system (45% of the guests come from Northern Italy)	Not applicable	Primary data were collected onsite for the hotel services, questionnaires submitted to guests and an interview with the hotel manager
Ponette-González and Byrnes (2011)	Conservation fund carbon calculator	Emissions from transportation	Not applicable	The alternating schedule has a maximum CO_2 reduction of 49–74%, use of geography in the selection process: of 6–30%, reduced international participation of 25–56%, carbon offsets of 23–44%, reduction in meeting frequency of 50%, video-conferencing of 52%	Location data for all participants were compiled in a Geographic Information System (GIS) and calculated roundtrip distances to the host city

Table 10 (continued)

References	Assessment method	Scope of impacts covered	Share of traveling in the total impacts of events/meetings	Range of the changes from various traveling scenarios	Data used for the assessment
Achten et al. (2013)	IPCC 2007 GWP 100y	Desktop work, fieldwork, meetings, and conferences that lead to a PhD thesis	Mobility corresponds to 75% of the overall share	Video conferencing could have reduced 44% of the impacts	Foreground data compiled from real activities of the PhD candidate, the ICT, and the technical support services of the university. Energy data estimated from the literature
Desiere (2016)	GHG emissions	Emissions from transportation	Not applicable	Strategies to reduce the carbon footprint potential savings resulted in − 50% without participants from outside Europe; − 7% for a more central location (Stuttgart), − 13% for promoting public transport. The total reduction in CO_2 emissions − 70%	The roundtrip distance traveled by a conference participant was estimated as twice the shortest distance between the capital of their country of origin and Ljubljana
Bossdorf et al. (2010)	myclimate.org CO2 calculator for events	Local food for catering, disposable tableware, paper, participant's transportation, and others for a 3-day conference with 125 participants from 14 countries	66% of the total emissions were due to traveling	Holding a conference closer to the participants' and during a mild-temperature season can minimize flight mileages and energy use, and therefore extra costs for carbon offsetting	Primary data collected by inquiring
Hall (2007)	Tyndall Centre for Climate Change Research (2006)	Emissions of participants to the 2006 Annual Conference were calculated for different means of transportation including all carbon emissions, i.e., other travel, energy, business, and so on	International participation represents 95% of the emissions	Alternatives for mitigating conferences emissions: offsetting, reducing the frequency, limiting participation, and using other ways of disseminating research	Data obtained from participants traveling to the most recent RGS-IBG Annual Conference (2006)

Table 11 Studies on the assessment of the social aspects of events

Social	Outcomes virtual	Outcomes face-to-face	Insights
Sniezek and Crede (2002)	Virtual meetings had less in confidence in their decisions Virtual groups were more flexible regarding their beliefs	Face-to-face groups were more confident in their decisions	Few differences between medias in terms of accuracy; confidence; spoken turns and interpersonal interaction Study focused on the decision-making process (not outcomes)
Straus and McGrath (1994)	Worse performance on a fixed time task and lower productivity for tasks requiring agreement on outcomes Groups were satisfied with the media for generating ideas—typing messages was not disruptive Media did not interfere with the effectiveness of intellective assignments, but virtual meetings resulted in lower satisfaction More difficulty in understanding each other despite the register of the discussion	Differences in productivity favoring face-to-face groups Appropriate for tasks requiring more coordination Superior when productivity is a priority or when time is constrained Resulted in more ideas	Group work may involve multiple processes, such as generating ideas and judgment processes Few differences in the quality of the work completed All variables must be known to identify the proper use of communication media and effective group outcomes Future studies should investigate variants of the types of work and type of media
Kim et al. (2022)	Participants from outside of academia perceived the virtual conference more positively, while experienced participants were less positive Limited opportunities for interaction during the virtual conference Technological development facilitates the virtual mode—at the moment, there are some technical barriers Participants complained of the unfamiliar conferencing platform	Blended conference could solve the lack of social interactions among attendees Multi-hub could also be an alternative	Virtual meetings should remain popular even after the pandemic Synchronized and unsynchronized methods could answer all attendees' needs More experienced participants might need more support and/or are less comfortable with online interactions
Abbott (2020)	Virtual scientific meetings virtual to cut large carbon footprints caused by air travel Advantages for the personal life of the participants Scientists mentioned that it released the bureaucracy and costs involved in overseas conferences	Not applicable	Not applicable
Arul Vallarasi and Regi (2022)	Saves costs of traveling and meeting organization Flexibility for fixing time for the meeting More people can join and interact Virtual conferences increased the productivity	Face-to-face interaction is important: eye contact establishes a connection speaker—audience No interruptions due to connection issues Virtual conferencing could be hacked Sitting for a long time in front a PC is prejudicial to health	Not applicable
Bottanelli et al. (2020)	Virtual seminars and online groups maintain connections New faces can organize events at low cost No obligation to travel Possibility to create community-driven interaction spaces	Networking opportunities Formal and informal Interactions between researchers at different stages Unplanned meetings may create new opportunities	Conferences need to adapt to creating hybrid events with in-person

Table 11 (continued)

Social	Outcomes virtual	Outcomes face-to-face	Insights
Cohen et al. (2011)	Not applicable	Perception can have important behavioral implications 18 design characteristics were identified: 9 predicted perceptions of meeting quality Study validated and extended research showing that agenda, punctuality, facility, and meeting facilitator status relate to perceived quality	Not applicable
Leach et al. (2009)	Not applicable	Design characteristics are connected to perceived meeting effectiveness and attendee involvement Agenda, punctuality, and meeting facilities are relevant Meeting size does not affect relationships, but is associated with lower levels of involvement Meeting duration is not relevant unless the agenda is not completed	As involvement is important to perceptions of effectiveness, organizers need to promote involvement when the meeting size increases
Nagaraj et al. (2022)	Survey assessing perceptions regarding the formality of various meeting types and the importance of virtual conferencing etiquette practices was created Faculty rated wearing professional outfits and maintaining the camera on, and eye contact as important while video-conferencing from the bed was inappropriate	The lack of etiquette guidelines for virtual conferencing created frustrations during the pandemic	Faculty members have different understandings of 'formality' which leads to different expectations A large amount of faculty and residents hope to continue virtual or hybrid formats Authors propose a set of etiquette frames that for each institutional values
Porpiglia et al. (2020)	Virtual conferences using online technology were attractive and safe during the pandemic New digital platforms give more opportunities for exchange from remote and allow the creation of virtual communities Dedicated online platforms and apps could be greatly improved to allow more interactivity simulating a face-to-face conference	Face-to-face meetings were abruptly suspended creating disruption on education and economic damage Virtual mode has limitations: human contact, affections, and emotions are impossible to reproduce online Formal and informal interactions among scientific community and industries could be in danger For onsite participants, conferences should promote occasions to improve networking	Authors expect that after the pandemic both methods will co-exist maximizing the benefits Potential of the digital media should be incorporated leading to "hybrid" conferences
Wynes et al. (2019)	Reducing GHG emissions from air travel may be critical 'Green academics' create emissions as much as other professionals they should have greater responsibility or motivation to reduce their impacts No link between traveling emissions and productivity	Academics who advanced in their career and have higher salaries emitted more than their colleagues It might be possible that 'green academics' are more likely to conduct fieldwork, participate in international initiatives, also in remote areas	Possible initiatives could include offsets or mitigation charges

Table 11 (continued)

Editorial	Pro face-to-face	Cons face-to-face	Mitigation measures
Green et al. (2008)	In the past, conferences focused world attention on many topics and were source of inspiration and motivation No virtual event can replace face-to-face communication: being seen is more appealing and there is the possibility of learning about local issues Running conferences have a low effect on global warming Conferences are useful to meet colleagues and network, work, obtain feedback, and keep on track in the specialty	Climate change is accelerating: stop going to international conferences could make some difference—also as an example There are new ways of communicating saving time, money, and energy Speakers could be in their home auditorium and academics could join virtual networks with a chair to moderate the discussions Collaborators from abroad could be linked by video while key people could meet offline	Virtual conferences require a new mindset in which comfortable facilities would be provided and discussions with other colleagues facilitated The excitement of a foreign visit might be lacking, but the easy practicalities could compensate Conferences have to be economically viable, and most delegates want comfort Organizers could be pressed to promote real experiences to complement plenary sessions
Holden et al. (2017)	Conferences are often organized by a small local committee of researchers	Very few conferences offered carbon-offset options and only 9% advertised any mitigation action Most conference organizers considered the environmental impact of their meeting	Organizers asked for guidance to reduce the impact of future events Conferences should document and promote the actions to reduce environmental impacts Scientists should prefer conferences with sustainability policies Small investments have the opportunity to generate major positive impacts
Alberts (2013)	Week-long meetings are designed to promote informal discussions of frontier science Many lifelong friendships started during those events Science works better with trust between collaborators—which is hard to create from a distance Critical role that face-to-face scientific meetings play in stimulating a random collision of ideas and approaches	Scientists can reach a huge amount of information online Scientific meetings might become overly specialized as the knowledge expands	Avoid scientific meetings with no diversity of approaches Approach people with different backgrounds and interests
Biggin (2007)	Not applicable	Approach would be more effective if the scientific community reduces its own contributions to climate change Reducing their own footprint can demonstrate that the organizations are concerned about climate change and there is no prejudice regarding the effectiveness More people can participate increasing dissemination of research findings and interaction among members	Widespread video-conferencing in oral sessions at scientific meetings Include 'virtual poster Sessions' with live audio connections
Bonnett (2006)	Academics enjoy mobility It is cheap and easy to fly Scientific community value conferences A range of measures—including offsetting—is being implemented to reduce the environmental impact of international meetings	Air traffic accelerates global warming Global carbon offsetting business has triggered discussion being often questionable	Conferences are appreciated but a cultural shift is required Green Meeting Guide and Guide on Carbon Neutral Conferencing offer insights

Table 11 (continued)

Editorial	Pro face-to-face	Cons face-to-face	Mitigation measures
Grémillet (2008)	Dilemma between personal restraint against energy-demanding public involvement	Scientists are concerned about the environmental impact of their work Regular long-distance flying can easily triple their carbon footprint Industry would benefit from not attending distant meetings	Reduce carbon footprint by attending fewer scientific conferences Promote conservation with improved local academic training, local research, leaders, and reduced stays by foreign visitors
David (2003)	Virtual conferencing has the potential to reduce CO2 emissions Improved technology is making virtual meetings more 'real' New technology means that virtual conferences are not impractical and impersonal anymore	Face-to-face conferences will always have a place Important start-up cost for the technology and few locations in the developing world are currently able to meet the requirement of broadband network access	Some environmental conferences aimed to offset their emissions by funding tree-planting schemes. Others sourced electricity from renewable solutions, and others even buy carbon credits to offset conference-related emissions
Fisk (2016)	Promote insights from other researchers Discussion about potential research collaboration Power of scientific meetings in spurring creativity and collaboration among scientists to the benefit of society The article shares a positive personal experience that emerged from a conference	Not applicable	Not applicable
Kirchherr and Biswas (2017)	Conferences exist from the early days of academia Conferences feature elaborate social programs Participants can meet collaborators and broaden their knowledge Conferences with practitioners and academics frequently aspire to impact policies	High cost of hosting fancy academic conferences Conference grants are difficult to obtain and early career scholars struggle to attend academic conferences Conferences had no impacts and did not present novelties Most conferences are oversized	Early career scholars would benefit from conferences hosted in universities and also would not mind if those were partially virtual More rigorous peer-review of conference abstracts may improve the impact of those meetings
Boreman (2013)	Meetings provided opportunities to update in a specific field and interact with students and scientists Meetings provided employment opportunities Scientists should maintain a passion for learning Cutting travel to scientific meetings is not a new issue and creates isolation	Not applicable	Not applicable

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