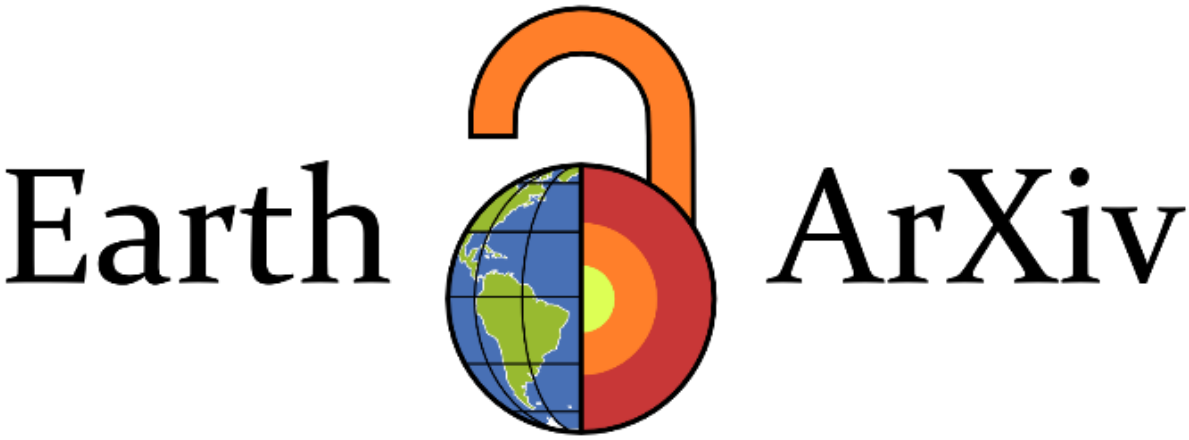

Doing conferences differently: a decentralised multi-hub approach for ecological and social sustainability

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Abstract

Conferences are invaluable for career progression, offering unique opportunities for networking, collaboration, and learning. However, there are challenges associated with the traditional in-person conference format. For example, there is a significant ecological impact from attendees' travel behaviour, and there are social inequities in conference attendance, with historically marginalised groups commonly facing barriers to participation. Innovative practices that enable academic conferences to be 'done differently' are crucial for addressing these ecological and social sustainability challenges. However, while some such practices have emerged in recent years, largely due to the COVID-19 pandemic, little research has been done on their effectiveness. Our study addresses this gap using a mixed methods approach to analyse a real-world decentralised multi-hub conference held in 2023, comparing it to traditional in-person conference and fully online conference scenarios. The decentralised multi-hub format consists of local in-person hubs in different locations around the world, each with a unique local programme developed around a shared core global programme; there is no single centralised point of control. We calculated the CO_2 emissions from transport for each scenario and found the decentralised multi-hub conference had significantly lower emissions than a traditional in-person conference, but higher emissions than a fully online conference. We also interviewed 14 local hub organisers and attendees to gain their perspectives about the ecological and social sustainability benefits of the decentralised multi-hub format. We found that the more accessible and inclusive format attracted a more diverse range of attendees, meaning that the benefits attributed to conference attendance were able to be shared more equitably. These findings demonstrate the ecological and social sustainability benefits of doing conferences differently, and can be used as further evidence in the argument to help transition conferences to a more desirable state in terms of ecological and social sustainability.

Author summary

Conferences are very important for career progression but at the same time they create negative ecological and social impact. For example, flying to a traditional in-person conference causes high carbon emissions which negatively impact the environment. Socially, there are many people who are unable to attend conferences because they do not have funding, are disabled, or have children/parents to care for (among other reasons) and this affects their career. We need to do things differently to both minimise the ecological impacts and be more inclusive to allow more people to gain the benefits of attending. In this study we looked at a decentralised multi-hub conference format which allowed people to gather in groups in different places around the world to share the same core programme, instead of all travelling to a single place. We found the carbon emissions were approximately 2 percent of a traditional in-person conference, and it was more inclusive because 50-85 percent of people would not have been able to attend an in-person conference in a central location.

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Introduction

Conferences are essential for academics. They facilitate a direct and effective exchange of ideas, findings, practices and methods, and create opportunities for collaborations (1-3). In addition to sharing perspectives and challenging assumptions with a diverse range of attendees in cross-cultural dialogue, there are other benefits that accrue from regular conference attendance. For example, chairing a conference or being on an organising committee, being invited to speak as a keynote or expert panellist, or simply presenting one's research at a conference can all provide unique opportunities to build one's curriculum vitae, and establish and strengthen relationships that contribute to career progression (4). This is especially true for early career academics, who can benefit from regular conference attendance to improve their profile by presenting their work, and make their way in the highly competitive world of academia(2, 3, 5, 6). Conferences can also lead to journal publications and other forms of productive outputs (which are widely used metrics for career promotion), increased job satisfaction, performance and motivation, and a sense of belonging within an academic community (7-11). Moreover, conferences can incorporate satellite sessions that address broader societal issues, further expanding the scope of discourse and fostering a sense of shared responsibility.

However, traditional in-person conferences raise concerns with regard to ecological and social sustainability. They often concentrate resources in privileged locations that have good transport links and established infrastructure, such as the main tourist destinations, and there is a significant ecological impact from attendees' travel behaviour as many choose to (or, especially for those from long-haul destinations, need to) fly (12, 13). Furthermore, these traditional conference practices often perpetuate the structural and systemic social injustices

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that are deeply embedded within academia (4). For example, many studies have identified inequities in conference organisation, high profile speaking roles and attendance, with historically marginalised groups commonly facing barriers to participation (4, 14-16).

New event design practices are therefore important for delivering academic conferences while addressing both social and ecological sustainability concerns (17), and in so doing provide benefit for our disciplines and society at large. There have been analyses of CO_2 emission savings achieved by moving from traditional in-person to virtual or other alternative format conferencing, and studies positing how such a move also improves inclusion (12, 14, 18). To date, however, there has been little work carried out using a holistic approach to explore the ecological and social sustainability benefits of these alternative formats, that incorporates the perspectives of those both organising and attending these conferences.

This paper seeks to address this gap in our knowledge. We adopt a mixed methods approach to gain more nuanced insights into ecological and social sustainability within a decentralised multi-hub conference format, as compared with two other common conference formats: a traditional in-person conference, and a fully online conference. First, using a real-world decentralised multi-hub neuroscience conference delivered in 2023 as a case study, we calculate the real CO_2 emissions saved as a result of reduction in long-haul air travel. Second, we interview conference organisers and attendees of that decentralised multi-hub conference, exploring how they experience and interpret these issues. The results provide evidence of the sustainability benefits that can be achieved by doing conferences differently through the decentralised multi-hub conference format. Importantly, our findings more broadly point to the existence of a significant disconnect between the understandings and experiences of conference participants and the practices of academic associations. We therefore hope this

paper will act as a catalyst for further conversations and action as we work towards better academic practices.

The remainder of the paper is structured as follows. We begin by situating the paper within the relevant academic literature. We then introduce the research context and present details of the real-world decentralised multi-hub conference that we will use as the case study. This model can be adapted for use in a wide range of disciplines from the physical and social sciences to business, arts and humanities. Next, we describe the study methodology before presenting the results of our analyses. We emphasise the carbon emission savings compared to traditional in-person and fully online conference format, and discuss the accessibility, inclusion and equity aspects of social sustainability. We conclude that decentralised multi-hub conferences offer a viable alternative to traditional in-person and fully online conferences: they offer a means of reducing negative ecological impacts and providing more equitable access to the benefits of conference attendance, while at the same time still offering the face-to-face social element that attendees desire.

Literature review

Conferences and sustainability

The practices associated with traditional centralised in-person conferences are difficult to reconcile with both ecological and social sustainability. Even if they are generally viewed as essential for career advancement (6, 19, 20), these conventional conference formats pose significant sustainability challenges. Most obviously, traditional in-person conferences require participants to fly to a single location, which typically generates several tons of CO_2 per person (13, 21-23) and represents the largest source of conference-related carbon emissions (24). Conferences also have other negative ecological impacts: for example,

consider air conditioning, meat consumption, non-locally sourced food, beverages and other products, the use of plastic, the ubiquitous ‘conference bag’ with its disposable contents, and the printing and transport of posters in plastic tubing (18, 25, 26). These factors seriously challenge the ecological sustainability of the traditional in-person conferencing model.

In terms of social sustainability, conference attendance (including organising committee roles, keynote and similarly high-profile roles, or presenting one’s work in a session) has been found to have long-term benefits for career progression, job satisfaction and sense of belonging. Regarding events more generally, Smith (27, p. 111, emphasis added) stated that “sustainable development requires long-term benefits that are distributed *equitably*”. However numerous studies have found that the benefits of academic conferences are not distributed equitably, as barriers to attendance exist for many historically under-represented groups within academia (28). This includes women, BIPOC (Black, Indigenous and people of colour), migrant scholars, those from the Global South, early career, precarious, first-in-family, members of the disability and LGBTQIA+ communities, and/or low or no-income academics (29). Indeed, Hanser (30) notes that conferences are often a silent struggle for belonging for academics from these groups. Conference organisers, hosts, and other attendees who engage in exclusionary practices and microaggressions emphasise the ‘outsiderness’ of historically marginalised academics (15, 16, 31, 32). Where conferences are not inclusive (i.e. where they are exclusionary), they are not equitable, and thus not socially sustainable.

Exclusionary practices include, but are not limited to, the choice of conference chair and organising committee members, selection of keynote and other high-profile roles (where these academics are under-represented), the structuring of registration fees (costs may be prohibitive for students, low/no income academics or those on precarious contracts, especially where catering and social events are not included in the registration fee),

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inaccessible venues (for people with disabilities), host destination politics (particularly for LGBTQIA+ and Muslim academics, but also for those that require visas to enter the destination country) and lack of consideration given to those with caring responsibilities, and other needs such as dietary or religious requirements (28, 31, 33, 34).

Alternative models of conference delivery

The advent of virtual conferencing, which became more prevalent during COVID-19, is one practice that has opened the possibility for academic conferences to address social and ecological sustainability concerns. It has the potential to revolutionise inclusivity and equity by making these events more widely accessible to academics worldwide, facilitating a sense of belonging and community for historically marginalised groups (13, 26, 35, 36). In addition, virtual conferencing offers an opportunity for those attendees who do not wish to attend in-person for moral issues (such as concern for the environment) to be able to still present their work and engage in meaningful discussion with colleagues (13, 37).

That said, virtual conferences cannot fully replicate the richness of in-person interactions, which play an important role in ‘breaking the ice’ and fostering serendipitous collaborations (34). In addition, in collectivist cultures (most Asian/Pacific countries), the interests of the group are more important than those of the individual and it is important to conform to social norms (38); in a virtual conference setting this can manifest in not feeling comfortable asking a question in front of other attendees. Virtual conferences may also leave people feeling isolated and disconnected from the broader academic community through ‘Zoom fatigue’ and multitasking during virtual conferences which leads to disengagement (13, 18). Another challenge faced by many is the speed and reliability of internet connectivity required to engage fully (34).

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To overcome some of these limitations, recent years have witnessed the rise of hybrid conferences which offer both in-person and virtual participation options – with virtual participants usually attending individually from their home location. The format of hybrid conferences is highly diverse, using a wide range of governance schemas. For instance, some organisations maintain a centralised governance structure with a single presidency, centrally determined programme and a tightly coordinated schedule across locations. Examples of hybrid conferences include that of the Organisation for Human Brain Mapping (OHBM), Tourism and Leisure Studies Research Network, European Group for Organisational Studies (17), South Pacific Educators in Vision Impairment, the International Conference on Music Perception and Cognition, and the 2024 American Geophysical Union conference which is the largest earth and space scientist event in the world, attracting over 25,000 attendees (12). Others adopt a distributed decision-making model (39, 40). One example is Brainhack Global, held regularly since 2017. It opens up a two-week global window for any type of local research organisation around the world to participate and run their own ‘hackathon’, a creative project-oriented type of event.

An alternative multi-hub model of conferencing has now emerged, with participants convening in person to a number of deliberately selected locations (hubs) spread around the world at a given time to attend an online live broadcast (13, 18). Conferences delivered in this format include the 2024 iteration of the Royal Geographic Society (with the Institute of British Geographers) conference, the Neuromatch computational neuroscience conference which evolved from virtual to multi-hub format over the course of the COVID-19 pandemic (41), and the 2023 CuttingGardens conference which is the focus of this paper (42). The multi-hub approach to conference delivery helps maintain the in-person social interaction, thereby addressing the most frequently mentioned limitations of virtual meetings – and it has

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the additional benefit of minimising long-haul air travel which in turn reduces ecological impact.

Among the various models of multi-hub conferences though, it is important to note that there is a high variability in the ability for each hub to determine content or make it locally relevant – many, such as the Royal Geographic Society and Neuromatch, are still run centrally (we could classify these as ‘centralised’ multi-hub conferences) which means hubs have little autonomy. It is also important to note that some of the conferences that implemented the hub format during the height of COVID-19 (for example, the American Geophysical Union and OHBM) have now reverted back to traditional in-person iterations or have downscaled to a simpler hybrid offering (as predicted by Kinakh (25)). This perhaps reflects the additional amount of work the multi-hub format required from the organisers (18).

Research context

Introducing the case study conference

As an international network of over 2,000 members, the CuttingEEG association has been organising scientific events in the field of neuroscience for over 10 years. They operate under the guiding principles of sharing knowledge globally and building competence locally: their mission is to promote best scientific practice, and to connect scientists worldwide by hosting events that showcase cutting-edge methods applied to neurophysiology. As part of this mission, and as a way to address the aforementioned ecological and social sustainability concerns generated by traditional in-person conferences, the CuttingEEG collective implemented a decentralised multi-hub conference format, a hybrid approach with hubs located around the world and no single location from which it was run. Importantly for this paper (and discussed further below), they did not wish to provide the ‘same’ experience for

participants across locations: there was also no centrally dictated content or strictly defined format for each of the local hubs to follow. Rather, each of the local hub organisers was empowered to tailor their offering to meet the interests, specialisations and needs of participants. They called it ‘CuttingGardens’, a play on their name, and the first edition was held in late 2023. They believed this approach could reduce the carbon footprint, increase inclusivity, and develop new rules to open up the field to perspectives less centred on WEIRD (Western, Educated, Industrialised, Rich, and Democratic) countries. The conference was created with a threefold objective, namely, to:

1. Reduce long-haul travel – organisers sought to highlight the importance of minimising attendees’ and speakers’ need to fly, to lower the ecological impact of the conference.
2. Empower local groups – hubs could strengthen bonds with their local disciplinary communities while simultaneously engaging with the global community, attending the same lectures and asking live questions to the same international speakers at no cost.
3. Give autonomy – organisers took advantage of the autonomy in local organising committees to advertise cultural diversity, supporting them all to operate differently.

Local hub organisers were recruited through a call to the CuttingEEG community's mailing list, and advertising at preceding meetings allowed gathering a wide array of local hubs. The widest possible global representation was systematically encouraged using welcoming language in advertisements, and in-person contact with potential organisers. However, it must be noted that despite these efforts no interest was forthcoming from Australasia or Asia. Over four days, 21 local hubs with 730 in-person and 300 online attendees were involved in CuttingGardens 2023 (129 lectures with 42% women speakers, 53 tutorials, 137 posters, see detailed report in the associated online resource repository

https://doi.org/10.5281/zenodo.14281570). The hubs were located in: Los Angeles (USA), Havana (Cuba), Montréal (Canada), Santiago and Talca (Chile), Oro Verde (Argentina), Donostia/San Sebastian (Spain), Bournemouth and London (England), Dundee (Scotland), Caen and Lyon (France), Gent (Belgium), Nijmegen (the Netherlands), Frankfurt, Regensburg and Münster (Germany), Genova (Italy), Belgrade (Serbia), Haifa (Israel), Tehran (Iran). Each local hub was called a “Garden”, and the people responsible for organising them were called “Gardeners”. 122 "Gardeners" participated, 52% of whom were women.

The decentralised multi-hub conference format

We now provide an overview of the format for decentralised multi-hub conferencing adopted for the delivery of the CuttingGardens 2023 conference. We acknowledge that this multi-hub format is not unique and the logistics and organisational details have already been covered by Parncutt, Lindborg (18), particularly around the issue of time zones which we will return to in the conclusion. Thus, here, we focus on the conference design elements (specifically the governance and programme structure) that contributed to its success that may be of value to others considering adopting the decentralised multi-hub format for their conference.

1. Governance structure

This decentralised multi-hub conference framework was based on a two-tiered governance structure, with separate financial accounting:

Central governance: There was a central team (working together but from different locations across Europe and the Americas) responsible for developing a shared core programme (33% women speakers), unified communication and website platforms, some practical ‘à la carte’ tutorials, and information about how to establish a local hub. The resources prepared by the

central governance team ensured high-quality programming was made accessible to any internet-connected location, providing a strong foundation for a successful conference and simplifying/encouraging participation (see as an example the “Gardener’s Starter's Guide” in the associated online resource repository https://doi.org/10.5281/zenodo.14281570).

Local governance: In accordance with the overarching goal of empowerment, local hub organisers had the autonomy to devise their own unique conference programme while staying within the overarching framework of the conference. They could choose to complement the main programme with locally relevant activities like poster sessions, talks, workshops, or social gatherings.

Financial governance: Finances were separated transparently into global and local expense categories. All costs related to global aspects (such as hiring a professional organiser, arranging plenary talks, acquiring licenses for technical tools) were borne by the central governance body. Attendees paid a nominal membership fee to join the CuttingEEG association – this income was used towards the global costs (the fee was waived on demand for low/no income participants). Hubs were responsible for their own local expenses and were able to charge their own registration fee separate from, and in addition to, the CuttingEEG membership fee.

2. Programme structure

In the decentralised multi-hub conference format, a two-tiered approach was also taken to organising the programme: a synchronous global programme and autonomous local programmes.

Synchronous global programme: To foster a sense of global community among attendees and set the tone for the conference, it was important to develop a common synchronous

programme of activity broadcast live to all locations. The central governance team chose how many of these synchronous sessions to include in the programme, and what the content should be. Developing in this way ensured it featured the most cutting-edge topics in the field. In keeping with the ethos of the conference, the central governance team ensured these sessions were delivered by speakers from different parts of the world, highlighting the expertise present at a range of local hubs. Broadcasting each presentation live from the speaker's closest local hub also reduced travel emissions and provided an opportunity for smaller local hubs to host a featured speaker. This in turn fostered a more inclusive and geographically diverse event. Other studies have noted that different time zones can cause challenges with scheduling synchronous global programmes in an online conference (14, 18). However, while noting these difficulties, CuttingGardens 2023 was timetabled with a trade-off such that conference attendees at *most* local hubs could participate in *most* of the synchronous global programme sessions, creating a shared experience for attendees worldwide for a period of 4 hours (Fig 1). We will return to this point later in the conclusion.

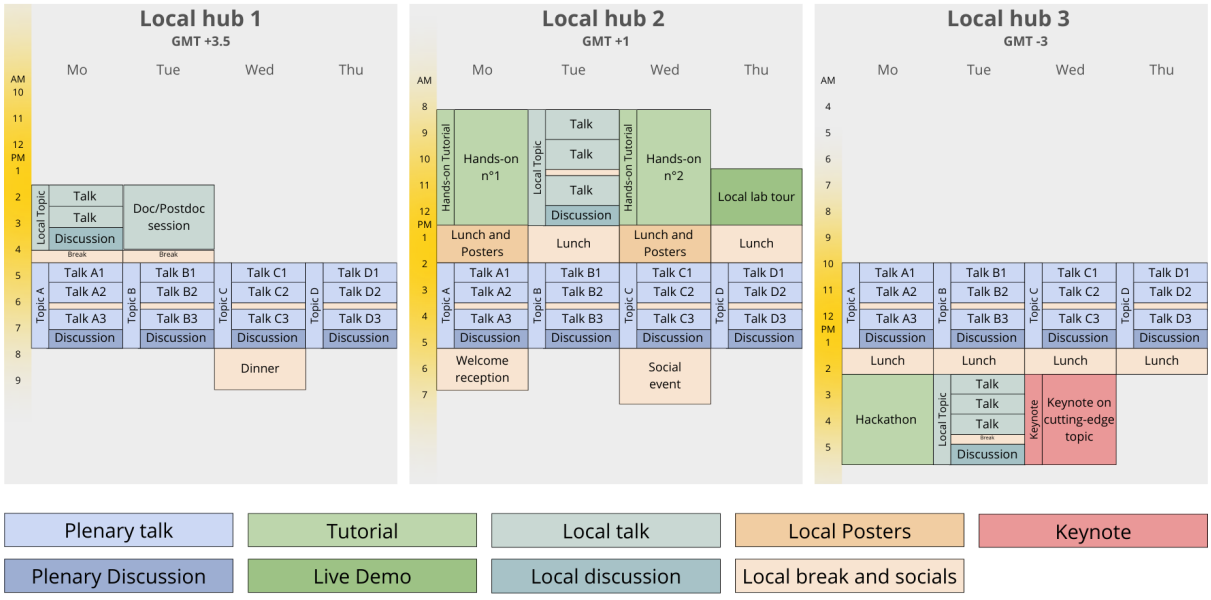

Fig 1. Three generic examples demonstrating the integration of local hub programmes, shown in local hub time, with a synchronous global programme (in blue). Actual programmes are available on the CuttingGardens 2023 website. (Source: Authors)

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To consolidate this shared experience and enhance the community-building aspect, a key element of the global programme was to elicit local discussions among attendees while also enabling them to engage with the global speakers. After each presentation, a short 'camera-off' break allowed local hubs to hold discussions amongst their attendees to identify their most relevant questions for the speaker, and/or vote for the most relevant questions posed by other hubs. A small subgroup of the central governance team was responsible for selecting which questions to address in a live online Q&A session following the break; the remainder were forwarded to the speaker to provide answers in a live document which was shared with all attendees after the conference.

Autonomous local programme: The decentralised multi-hub conference framework enabled each local hub to develop its own autonomous programme around the global programme to foster local initiatives and enhance global connections (Fig 1). They could choose to broadcast their own content live to their community, and could also share this via the global video feed of the conference. The central governance team called for proposals to host a local hub, which enabled local hub programming to be incorporated into the global programme (as discussed above, speakers in the global programme were able to present from their closest local hub). It also meant they could benefit from the global communications and visibility. Standardised activity definitions and associated icons were developed so that a common understanding and language could be used – each local hub could choose which activities they wished to offer, and the related icons were displayed next to their listing on the global conference website (Table 1).

Attendee hub A local hub with a gathering of people who attend the live global programme together are called Attendee hubs. To qualify as an Attendee hub, a location only needs a streaming device (e.g. computer), a good internet connection, and a space to gather and follow the talks.	

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Speaker hub Local hubs that host one or more in-person lecture(s) are called Speaker hubs. These locations need to provide a physical space to host the talk(s), as well as the ability to stream it to all the other local hubs.	
Tutorials hub Local hubs that host local training sessions are called Tutorial hubs. This can be: 1) A hands-on session. This requires local Teaching Assistants and a dedicated space for the attendees to work on their own laptops. 2) A demo session. This is a shorter session with a live demo from the main tutor. It only requires a broadcasting system.	
Posters hub Local hubs can also organise poster sessions. These need an appropriate infrastructure (e.g., room, poster stands, etc.), as well as a submission platform for attendees. Local hubs have autonomy to decide the format and content of posters.	
Satellite Local hubs may also organise any type of satellite event, such as additional workshops, talks/presentations, hackathons, social events, visits to local lab(s).	

Table 1. Standardised activity definitions and associated icons. (Source: CuttingEEG, 2023)

As a result, the CuttingGardens 2023 local programmes were diverse. For instance, one local hub was held at a venue where attendees mixed with support staff and local colleagues who were not attending the conference, in dedicated communal spaces. The local organisers used this opportunity to create a conference that challenged attendees and local personnel about the climate emergency and systemic oppression, collaborating with a national art company to develop an installation in the garden. This additional temporary setup took the form of a kitchen with cooks on site (short supply food, vegetarian), a coffee bar, a cafeteria under the awning, a communal dishwashing area and an exhibition on climate change questioning the role of scientists in and outside the lab, open to both attendees and local personnel.

Another local hub organised a very well-attended public lecture with two goals - to promote electroencephalography and science to the public and to give back to the local community that finances their public university. Other local activities included field trips to laboratories

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and research centres, tutorials, symposia, presentations, workshops, posters, a roundtable on Women Leading Neurosciences, a ‘getting to know you’ session where researchers presented their labs (their research teams, equipment and topics) rather than their research, special sessions for postgraduate students and postdocs, plus social events such as welcome drinks, guided city tours, beach walks and conference dinners.

Methods

We used a mixed methods approach to compare the ecological and social sustainability of the decentralised multi-hub conference format with two other common conference formats: a traditional in-person conference, and a fully online conference. To provide evidence for ecological sustainability we used quantitative methods to calculate comparative CO_2 emissions for each of these three scenarios. This was supplemented with qualitative data gained from semi-structured interviews with local hub organisers and conference attendees, where their views of both ecological and social sustainability were sought. This study was reviewed and approved by the Lincoln University Human Ethics Committee (HEC) under approval number HEC2024-36. All participants were over the age of 18, and written informed consent was obtained from them prior to their involvement in the study. All interview material has been anonymized to protect participant privacy. We detail our methods below.

Data collection

Quantitative data collection

To estimate the CO_2 emissions of passenger transportation for CuttingGardens 2023 attendees, a post-conference online survey was conducted. Attendees were asked which hub

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they attended, where they travelled from, and how; a free-text box allowed them to add comments. Participation in the survey was voluntary.

From 727 attendees who attended via a hub, a total of 247 responses were collected, out of which 228 were considered valid, resulting in an overall response rate of 31% (Table 2). A total of 18 responses were excluded from further analysis. This included 14 who reported attending online, 3 who reported using “other” transport modes such as a mixture of local transportation and online attendance, and one who provided a comment that their travel would have occurred anyway for family reasons, and believed it should not be taken into account for the carbon footprint of the conference.

As only the city of respondent origin was collected, rather than suburb, the distance to the respective local hub yielded zero for six local hubs (Los Angeles, Havana, London, Münster, Talca, and Tehran) as all respondents lived within the city. These hubs were therefore excluded from the analysis.

Local hub	**Attendees**	**Responses**	**Proportion (%)**
Belgrade; Serbia	19	8	42
Bournemouth; UK	20	6	30
Caen; France	50	4	8
Dundee; Scotland	30	3	10
Frankfurt Am Main; Germany	90	32	36
Genova; Italy	45	32	71
Gent; Belgium	30	14	47
Havana; Cuba	15	2	13
London; UK	10	6	60
Los Angeles; USA	50	4	8
Lyon; France	100	38	38
Montreal; Canada	50	6	12
Muenster; Germany	10	2	20
Nijmegen; The Netherlands	25	6	24
Oro Verde; Argentina	16	16	100
Regensburg; Germany	7	7	100
Donostia/San Sebastian; Spain	40	14	35
Santiago; Chile	95	20	21
Talca; Chile	10	3	30

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Tehran; Iran	15	5	33
Total	**727**	**228**	**31**

Table 2. Distribution of responses by local hub. (Source: Authors)

Qualitative data collection

Semi-structured interviews were chosen for their ability to generate rich, nuanced data about the topic while allowing some flexibility for deeper questioning and exploring other related areas as necessary (43). After gaining ethics approval from the second author's university, recruitment emails were sent to the central governance team's database of local hub organisers and attendees. As a diverse range of perspectives was sought, interviewees were subsequently selected based on role, local hub size, range of offerings and location. A total of 14 interviews were held: seven with local hub organisers and seven with attendees, from a total of 12 local hubs. Interviews were conducted online and recorded for note-taking purposes. They ranged in length from 21 to 45 minutes, averaging 34 minutes. One was conducted asynchronously via email. In addition to general questions about their experience of the decentralised multi-hub format, more specific questions were asked about what ecological sustainability measures they took (local hub organisers) or observed (attendees), and their perceptions of social sustainability (using terms such as accessibility, equity and inclusion) at the conference compared with both traditional in-person and fully online conferences.

Data analysis

Quantitative data analysis

We used the arc distance between cities to calculate travel distances as extracted from the post-conference survey responses, and R version 4.4.2 (44) to perform all computations

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presented here. The scripts are available on the associated online resource repository (https://doi.org/10.5281/zenodo.14281570). To estimate transportation-related CO_2 emissions, the emission factors as reported in Table 3 were used.

Transportation means	Corresponding nomenclature from source	Emission factor (kg CO_2eq / km)
Feet		0.0000
Bike		0.0000
Train	International Train	0.0370
Metro or Regional train	Metro	0.0040
Intercity Coach or City Bus	Bus.Intercity	0.0306
Plane	Medium Haul	0.1875
Car	Unknown Engine Car	0.2156

Table 3. Emission factors extracted from original detailed data, specific to French transportation devices. See https://apps.labos1point5.org/documentation. Click on the British flag (top right corner) for English translation. Condensation trails during flights are ignored in aircraft emission factors. Note that for the Car transportation means, the emission factor assumes a single passenger in the vehicle. (Source: Mariette, Blanchard (45))

In all cases, the estimated equivalent CO_2 emissions (CO_2eq) of transporting a given attendee was obtained by multiplying the distance from the city they reported travelling to the local hub from by the respective emission factor for the reported means of transport. We created three scenarios in order to compare the attendee transportation footprint of CuttingGardens 2023 as it took place with two alternative formats: a traditional in-person conference and a fully online conference.

Scenario 1: CuttingGardens

The *CuttingGardens scenario* corresponds to the actual conference as it took place in 2023, with attendees travelling to a local hub where the core global programme was broadcast and a unique local programme offered. In this scenario, we estimated CO_2 emissions based on the results of the attendee survey. We used a random resampling method (bootstrap with 1000 resampling iterations) to estimate the transportation emissions of all attendees despite incomplete data due to missing survey responses. Computations were based on the subsample

of participants who responded to the survey in each local hub (no responses from Havana, Los Angeles, London, Münster, Talca and Teheran). For each local hub and each bootstrap iteration, we randomly picked the actual number of attendees (Attendees column of Table 2), with replacement from the survey responses (Responses column of Table 2). The CO_2 emissions were computed based on the respondents' reported mode of transport. We performed these random picks 1000 times, and the average and standard deviation of the estimated total emissions are reported in Table 5. In addition, the CO_2 emissions from live streaming for the 21 different hub locations were computed using Equation 1 described below in Scenario 3.

Scenario 2: Traditional In-Person

The *Traditional In-Person scenario* estimated CO_2 emissions that would have occurred if exactly the same CuttingGardens 2023 attendees had instead travelled to a single location to attend a traditional in-person conference instead of their local hub. Each of the local hubs in turn was used as the single conference location in a series of simulations (i.e. we carried out a simulation whereby all attendees travelled to Caen, France, another simulation whereby all attendees travelled to Santiago, Chile, and so on for each of the 21 local hubs). The same resampling procedure as above was used. To keep geographical consistency with the original conference, resampling was still performed per local hub.

We used the distance to that single location to determine a likely transportation means. All travel below a certain distance D was assumed to be done by train, and all travel above that distance was assumed to be done by plane. We computed the total CO_2eq emissions for this scenario with D ranging from 300 km (all attendees living closer than 300 km from the location travel by train, others by plane) to 1500 km (all attendees living closer than 1500 km from the location travel by train, others by plane).

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Scenario 3: Fully Online

Finally, in the *Fully Online scenario*, we estimated the emissions of live streaming the full online content of the conference (48 hours of content available after the event) to all attendees using methods provided by the Carbonalyser tool made by the Shift Project. We estimated the amount of data transferred during one hour of video from the platform used during the conference (Crowdcast.io) and found that 2.7 GB data was transferred during this hour. In addition, we also made the following assumptions for this simulation: one participant per terminal using a laptop computer on a Wi-Fi network located in Europe. We followed the same methodology as the Carbonalyser tool documented in the full report of the Shift Project. In the formula below, the total CO_2 emissions attributable to streaming (TI) is equal to the energy required for one terminal, multiplied by the number of users (NU), multiplied by the average world intensity factor (IF, the average amount of CO_2 emitted to produce 1kWh of electricity). The energy required for one terminal is itself the sum of the energy necessary to power the terminal locally (DEI) for a given duration (UD) plus the energy required to store (DCEI) and transfer (NEI) the amount of streamed data (DS).

$$TI = IF * NU * (UD * DEI + DS * (DCEI + NEI))$$

Table 4 explains these values:

		Unit	Value	Comment	Source
TI	Total Impact	kg CO_2eq			
IF	Intensity Factor	kg CO_2eq/kWh	0.519	Average world Intensity Factor	
NU	Number of Users	person	727		
UD	Usage Duration	min	48 * 60	Total duration of streamed content	48 hrs of video watched on Crowdcast
DEI	Device Energy Impact	kWh/min	3.19E-04	For a standard laptop computer (2018)	Lean ICT Materials Forecast model by The Shift Project
DS	Data Size	Bytes	129.6E09	Total size of streamed data	At 2.7 E09 B /hour

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DCEI	Data Centre Impact	Energy	kWh/Byte	7.20E-11	1 PB ~ 72 MWh	Lean ICT Materials Forecast model by The Shift Project
NEI	Network Impact	Energy	kWh/Byte	1.52E-10	Local Wi-Fi network	Lean ICT Materials Forecast model by The Shift Project

Table 4. Formula components for estimating the total impact of streaming. (source: Carbonalyser tool made by the Shift Project)

Qualitative data analysis

The interviews were subjected to reflexive thematic analysis, an iterative process of reading and re-reading the interview transcripts and notes to identify recurring themes (46). An inductive approach was taken to the analysis; this is where the themes are linked to the data itself, rather than trying to make them fit with a predetermined coding frame. In this case, words or phrases related to any aspect of ecological and social sustainability were initially highlighted as being of interest. These were then coded, and similar codes grouped together into themes. These themes were subsequently consolidated into higher order, more abstract themes with shared meaning, and the codes cross-checked for internal consistency and theme coherence (46).

Results

Ecological sustainability at CuttingGardens 2023

In this section we firstly discuss the individual components that comprise the CO_2 emissions calculations (transport and live streaming). We then provide an overall assessment of the

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three scenarios and supplement this with the interview findings. Of note, the computed emissions due to live streaming are only a fraction of those due to transport.

The average estimated CO_2 emissions from transport for each local hub in the *CuttingGardens scenario* are shown in Table 5; there are no transport emissions to present from the *Fully Online scenario* as it was assumed all attendees participated online.

Local hub	Avg CO2 emissions (10^3 kg)	Std dev (10^3 kg)	No. participants
Belgrade; Serbia	2.481	1.101	19
Bournemouth; UK	1.755	0.789	20
Caen; France	1.818	0.164	50
Dundee; Scotland	0.304	0.029	30
Frankfurt Am Main; Germany	1.115	0.151	90
Genova; Italy	1.093	0.155	45
Gent; Belgium	2.451	1.010	30
Lyon; France	1.715	0.230	100
Montreal; Canada	3.269	0.657	50
Nijmegen; The Netherlands	0.232	0.051	25
Oro Verde; Argentina	0.079	0.061	16
Regensburg; Germany	0.095	0.031	7
Donostia/San Sebastian; Spain	2.382	0.598	40
Santiago; Chile	3.184	0.374	95
Total	**21.973**	**1.980**	**617**

Table 5. Average CO_2 emissions (kg) per local hub in the CuttingGardens scenario, over bootstrap iterations. Only cities for which we have survey data are listed. Std dev column corresponds to the standard deviation of the resampled data. (Source: Authors)

For the *Traditional In-Person scenario*, the estimated CO_2eq emissions in simulations where each local hub acted as the single conference location for all attendees are shown in Fig 2. In this scenario the total CO_2 emissions range from a minimum of 892 tons CO_2eq (equivalent to almost 900 return trans-Atlantic flights) if all participants travel to Caen (France) and take the train for any distance below 1500 km, and a maximum of 2617 tons if all participants travel

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517 to Talca (Chile) and take the plane for any distance above 300 km. These two values reveal
518 the wide range of possible emissions depending on the choice of location for a traditional in-
519 person conference. Noteworthy, the simulation reveals minimal differences between all
520 Western European local hubs. This highlights both the considerable contribution of long-haul
521 air travel to emissions, and the availability of low carbon transportation options for travel
522 across Europe where the majority of CuttingGardens 2023 attendees were from.

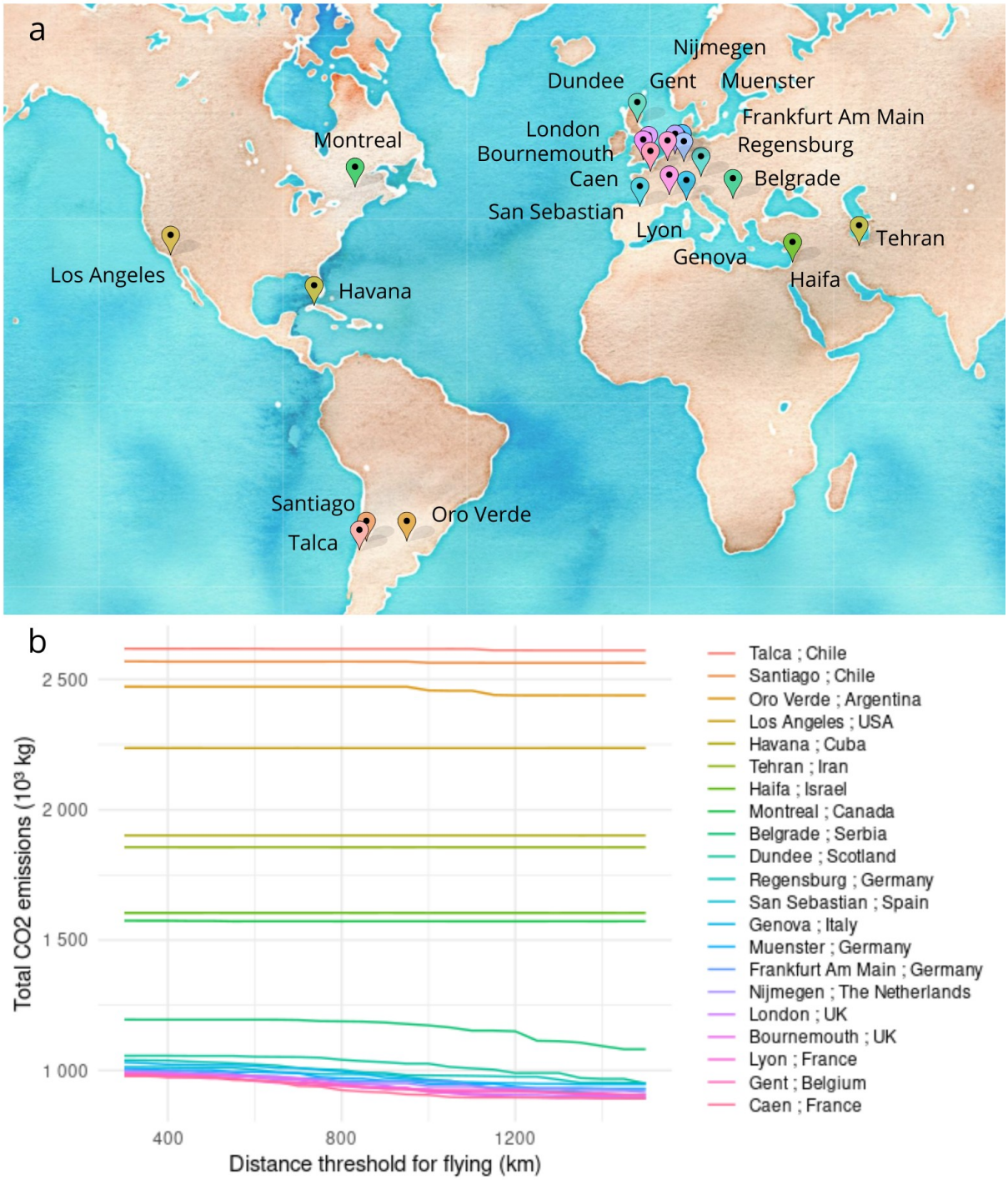

Fig 2. Conference CO_2 equivalent emission simulations for the *Traditional In-Person* scenario. (a) Map showing the locations of all hubs. The colours of the individual locations correspond to the line colours in (b). (b) Total CO_2 emissions as a function of distance threshold. The locations are sorted by average emissions across distance thresholds for flying, and match the order of the lines in the graph. (Source: Authors)

The total CO_2 emissions from live streaming content on a single screen at all 21 local hubs in the *CuttingGardens scenario* was calculated as follows:

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$$TI = 0.519 * 21 * (48 * 60 * 3.19e-4 + 129.6e9 * (7.2e-11 + 1.52e-10))$$

$$TI = 0.326 \times 10^3 \ kg\ CO2eq$$

This emission value is ignored in Tables 5 and 6 because it represents only a small fraction of the estimated emissions due to travel.

For the *Fully Online scenario*, the emission was computed using 727 as the number of users:

$$TI = 0.519 * 727 * (48 * 60 * 3.19e-4 + 129.6e9 * (7.2e-11 + 1.52e-10))$$

$$TI = 11.300 \times 10^3 \ kg\ CO2eq$$

The *Traditional In-Person scenario* was assumed to have no live streaming content. Under the best conditions then (in which all attendees at the same local hub use a single stream), we can see that streaming emissions in the *CuttingGardens scenario* are 34 times lower than those of the *Fully Online scenario*.

Table 6 presents the total simulated CO_2 emissions across each of the three scenarios. Perhaps unsurprisingly, the *Fully Online scenario* performed best in terms of ecological sustainability using CO_2 emissions as a proxy, while the *Traditional In-person scenario* was the worst. The *CuttingGardens scenario* created approximately twice the emissions of the *Fully Online scenario*, but only about 2 percent of the emissions of the *Traditional In-Person scenario* (with the least estimated emissions hub in Caen). A large part of the *Fully Online scenario* emissions is due to electricity consumption, however it is important to note here that electricity generation in some locations may come from low-emission renewable energy sources. This is not the case for other sources of CO_2 emissions, especially long haul travel.

Scenario	**CO_2 emissions (10^3 kg)**	**Standard deviation (10^3 kg)**
1. CuttingGardens	21.973	1.980
2. Traditional In-Person (maximum: Talca, Chile)	2,617.748	1.737
2. Traditional In-Person (minimum: Caen, France)	924.356	2.604
3. Fully Online	11.300	NA

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Table 6. Comparison of CO_2 emissions for each scenario. (Source: Authors)

Lastly, while we focused on transport and live streaming, the findings from the interviews highlighted ecologically friendly initiatives such as vegetarian catering, recycling, bringing their own name badges, reduced/no printed material, and reusable crockery/cutlery. Interviewees believe these actions helped to reduce the ecological footprint of their local hub. One local hub implemented a food waste strategy whereby they confirmed people's attendance a few days before. This meant they were able to "order the amount of food as close as possible as what was needed", and they also encouraged attendees to bring their own container to take any leftover food home. However, the interviewees all recognised that these measures made little difference relative to total carbon emissions of the conference. They believed that the decentralised multi-hub conference format had just one significant benefit for ecological sustainability: flying had been substantially reduced or, in the case of long-haul flying, ceased altogether – this supports the results of the carbon emissions calculations presented above.

Social sustainability at CuttingGardens 2023

In this section, we present evidence from the interviews of how the decentralised multi-hub format contributed to social sustainability. Two main themes were identified in the analysis: accessibility and inclusion; and equity.

Accessibility and inclusion

Interviewees reported that the decentralised multi-hub format of CuttingGardens 2023 allowed a more accessible and inclusive conference than a traditional in-person conference. Arguably the groups that benefited most were students, researchers from the Global South

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and others on low incomes, as registration fees and travel costs were reduced. These verbatim quotes are illustrative of what was said:

> *First, I like the inclusivity like because I think there was a there was a [local hub] in Havana. As far as I know, and in South America, and usually these are places where rarely researchers come from [to an in-person conference] (Interviewee #9)*

> *I like for different reasons, since for example, sometime in the in the conference, not all people can travel. People sometimes doesn't have a fund money to go. So I think that this kind of the conference is very democratic and the gives the possibility to all people to join. (Interviewee #3)*

While a number of interviewees agreed that a fully online conference may be even more accessible and inclusive, they pointed out that meeting in-person added something intangible to the conference experience that could not be replicated online. As one interviewee reflected, the decentralised multi-hub conference format offered a good compromise, helping reduce CO_2 emissions and barriers to attendance, but still providing important in-person contact and experience:

> *I still think that the benefit of lowering the barrier of attendance really outweighs the potential con of not meeting [all together in a single location]… Especially because we had this small group of very engaged people and the discussions were actually super interesting and very engaged. And some days I would just leave at six, really tired from the day, and they were still drawing on the board and discussing things. So I think that you would not get that from a fully online conference. And I think it was still good at like giving the feeling that you shared something or you shared the experience with some other people, which in terms of memory, I think is quite important and that I don't think you would get with the fully online. (Interviewee #2)*

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Funding is a significant barrier to conference attendance for researchers globally: numerous interviewees commented that, had the conference been somewhere held in Europe (the most likely destination for an in-person CuttingEEG conference), many attendees would not have been able to participate. Indeed, when prompted, interviewees estimated that between 50 and 85 percent of those who attended their local hub would have been excluded.

Several interviewees also noted that even where conference funding was available, researchers were encouraged to prioritise attendance at conferences that were tightly aligned to their work or area of expertise – there was little opportunity to attend conferences that were of interest but in less strongly relevant or allied fields. Therefore some interviewees felt that the lower cost of participation allowed a more diverse range of attendees:

> *There were people from EEG side, but on [a different topic]. So that might have been for us was a special point in our program, but is not usually the case. So usually people from these topics they tend to go to cluster in other conferences. (Interviewee #1)*

> *Due to company funding I could maybe have gone [if CuttingGardens 2023 had been held in Paris and therefore cost more], but unlikely, as there were other more relevant conferences that I would have been supported to go to as a priority. (Interviewee #10)*

Relatedly, one local organiser deliberately hosted their hub in a “neutral” venue on campus rather than in a disciplinary space. They believed this attention to reducing power dynamics created a more accessible environment that promoted diversity, contributing to a broader mix of attendees that in turn facilitated cross-disciplinary communication:

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So it was kind of good to have, you know, people gather somewhere, which is where it is neutral otherwise maybe some engineering students would not be that, you know, maybe reluctant to go to the Faculty of [XYZ] for conference because they would maybe think this is not for us. (Interviewee #12)

Another traditionally under-represented group that benefited from the decentralised multi-hub CuttingGardens 2023 format was the disabled community, with a number of interviewees noting the local hubs' smaller size enabled them to better manage challenges such as neurodiversity or social anxiety:

On a very personal level, I have some issues with processing too much sound in the crowd and I just get overwhelmed very easily. And then my brain just shuts off. And on that level, it's just nicer to have for example, a poster conference in a room with well 20 to 50 posters instead of I don't know, 100. And even then, it's a bit much, but... (Interviewee #9)

I'm not like the person that goes the most, the social events in general, I feel too exhausted with like the conference… And especially because like as I say, I didn't attend the online part, so it was more half a day, so it's like really less for the brain to process in term of information. (Interviewee #11)

As discussed earlier in the paper, people with caring responsibilities often find conference attendance challenging. One of the local hubs recognised this and provided childcare, but as this interviewee with a baby says, even being able to attend partially online was valuable:

I have a baby now, and then… I have the feeling that I'm less productive and then I miss some conference because we cannot afford to go for one week. We cannot afford to spend 2-3 days [outside of home] and then just to leave the baby for the [other

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> *parent] or vice versa. So knowing it online it's easier and also for the jet lagging. (Interviewee #7)*

Three of the interviewees acknowledged that needing to apply for a visa can be a problem for people from some countries – and that the processing can take a long time and be expensive. Some of them had personally experienced this with traditional in-person conferences themselves in the past, but having local hubs effectively alleviated this issue.

Equity

Being able to attend a global conference at a local hub conferred significant benefits, particularly for those who presented their research, whether in poster form, panel discussion, workshop, demonstration or oral presentation. There was very much a sense of community created at both local and global levels, and the visibility it facilitated was valued:

> *Well, this this was interesting for us because if it were fully online, we still wouldn't have that kind of sense of a community gathering… in having it in person had some additional charms to it on the local level, but still at the same time feeling that you're part of a global community and also enabling participants who presented their work at the local [hub] to be visible by the global [audience]. (Interviewee #12)*

Likewise, Interviewee #8 said a benefit was “offering the opportunity of people here to broadcast their own talks much more broadly” noting that a decentralised multi-hub model allowed “international content and richness.”

The connections made at the local hubs were also beneficial, as this Principal Investigator observed with one of the students in their lab:

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I think [my student] benefited a lot from a workshop that we had, organised by the local community doing EEG there with certain software that after that she started using that to analyse data and actually this started to kind of I wouldn't say a very fruitful collaboration, but she could rely on people in [city] for some advices about data analysis and stuff like that (Interviewee #6)

For some interviewees, the benefits of the conference lasted well beyond the conference itself, with a number of new relationships and collaborations forming:

A small 'reading' group has been formed, meeting monthly to discuss our work – thus creating lasting networking legacy, creating a community in [country]…we are not in a big group with a lot of money so for us is very important to create a network. (Interviewee #3)

We kept in touch with colleagues from all participating institutions - they exchanged information on upcoming events and attended each other's events, they exchanged training materials, gave lectures and workshops. (Email from local hub organiser)

Also I've been invited to other conferences after this. This so from thanks to people that I knew during the [local hub]. (Interviewee #1)

Thus in terms of social sustainability, the benefits were more equitably distributed with a wider range of attendees. This was due to the fact that the decentralised multi-hub CuttingGardens 2023 format was more accessible and inclusive than a traditional in-person conference, but still with the advantages of a sense of community that is difficult to replicate in a fully online conference environment.

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Discussion

The purpose of this study was to analyse how a real-world decentralised multi-hub conference, as run, addressed the ecological and social sustainability concerns attendant with traditional in-person conference formats. It has provided both quantitative and qualitative evidence that a viable alternative exists to both the traditional in-person and fully online conference formats which is not only more ecologically sustainable but also more accessible, inclusive and equitable - thus enabling the benefits of conference organisation, keynote speaking and attendance to be realised by a wider range of attendees.

To explore the ecological implications, we used post-conference survey responses to gather attendees' actual travel data. We developed two alternative scenarios to compare the decentralised multi-hub conference attendees' CO_2 emissions: a traditional in-person conference and a fully online conference. Our analysis assumed that all attendees who participated in the decentralised multi-hub conference would have travelled to the single location in-person meeting, and found that expected CO_2 emissions are considerably lower for the decentralised multi-hub conference than for a traditional in-person conference. While this assumption may have resulted in an overestimation of the difference between the two scenarios, it is nevertheless an interesting upper bound of CO_2 emission reductions that could be achieved for a conference of this size. This was largely due to the reduction in long-haul travel engaged in by attendees, as the majority were able to utilise low carbon transportation (i.e. not plane or private car) to travel to their local hub. However, and unsurprisingly, CO_2 emissions were still twice as high as if the conference had been held fully online, and this ratio is likely to increase as more electricity suppliers switch to renewable sources.

The results from the traditional in-person scenario reveal that gathering the whole attendance at any single European local hub would have generated lower CO_2 emissions than at any non-

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European local hubs (Fig 2). This is perhaps unsurprising as it mirrors the location of the CuttingGardens 2023 attendees. As discussed below however, this solution would have excluded many attendees and thus reduced the social sustainability. In contrast, in this paper, we argue that the decentralised multi-hub conference is a viable solution to go beyond such a narrow carbon-centered perspective by addressing sustainability more comprehensively.

The analysis of interview data found that, in addition to reducing CO_2 emissions via reduced travel, local hubs took a number of other measures to improve ecological sustainability (such as vegetarian and local catering, not using plastics, recycling). Our evaluation of the ecological sustainability of the conference is restricted solely to calculations of travel-related CO_2 emissions, as this is the largest contributor to conference carbon emissions (18), and the estimated video streaming emissions. A more comprehensive analysis could take into account the amount and type of waste, meal composition, and local commuting and we acknowledge that this is a limitation of the study. Moreover, another limitation is that the CO_{2eq} calculations did not take into account whether the energy supply was renewable or not, and more generally, could present a biased summary of the complexity of environmental impact.

Social sustainability was evaluated using semi-structured interviews with conference organisers and attendees. For those that we spoke to, the ability to meet with people in-person was a key benefit of the multi-hub approach as it created a sense of community and belonging – an important factor in social sustainability within the context of academic conferences (3, 9, 15, 16, 30). They perceived this as being vital, and something that would not have been possible with a fully online scenario (13, 18, 34). The evidence suggests that the local hubs were invaluable in facilitating this feeling of belonging for attendees, and the ability to participate in a global programme with opportunities for live discussions contributed to feeling part of a much larger, global community (13, 26, 35, 36).

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The more accessible and inclusive format allowed a diverse range of attendees to participate, meaning that the benefits attributed to conference organisation, keynote speaking and attendance were able to be shared more equitably, thus contributing to social sustainability. Short-term benefits have already been seen, such as early career researchers expanding their professional networks, research groups being formed for future collaboration, and people being invited to speak at other conferences and events by someone they met at the conference – these are all activities that build one's curriculum vitae and assist career progression (1-4, 6). For the 50-85 percent of people who would not have been able to attend an in-person conference in a central location, for a range of reasons including socio-economic status, disability, neurodiversity, visas, and/or other disciplinary priorities, this is important. This finding thus supports the work of Wynes, Donner (47) who argued that frequent and/or long-haul travel is not necessary for career success.

Conclusion

These findings show CuttingGardens 2023 to be a successful instance of a decentralised multi-hub format, demonstrating once again the feasibility of organising events with this type of structure (18). That said, further refinements could be made to the model to improve ecological and social sustainability, and we offer four suggestions.

First, we mentioned earlier that there were no local hubs in Australasia and Asia despite efforts to recruit local organisers. While we have no hard data about the reasons for this, we speculate that it may have been a result of a sparsity of personal networks in those areas, or a perception that the time zone differences would result in the need for midnight attendance. Thus when considering where local hubs could be developed, it is important for any central governance team to adopt an approach that takes the oft-overlooked Australasia/Asia time

zone into account – we direct readers to the work of Parncutt, Lindborg (18) in this regard, as they present a comprehensive model for global time zone conferencing with hubs. This model enables 8 hours of global programming per day, rather than 4 hours as in the CuttingGardens 2023 experience reported on here. While it undoubtedly causes more logistical challenges, it would also enable a more inclusive and equitable conference, with more opportunities for international communication.

Second, local hubs should be encouraged wherever there are sufficient resources (organisers, venues, technology, participants) while at the same time being mindful of any plans to host another local hub nearby. An important learning is the potential for a particularly popular location (e.g. a renowned institute) to ‘drain’ participants from a lesser-known location that had already planned their venue. Continued efforts in coordinating nearby locations are necessary to also avoid participants having false expectations regarding the size of the local hub they are attending. Third, for a decentralised multi-hub conference to be successful in achieving goals of social sustainability, a focus on encouraging the participation of local hubs from non-WEIRD communities is vital.

Finally, the central governance team could incorporate specific social sustainability best practices into the resources they create to help people organise their local hub. This could include (but is not limited to) making sure conference communications and websites are designed for screen-readers, providing guidelines for developing presentations for visually impaired attendees, having synchronous transcription and/or translation for presentations, and including pronouns (28, 33, 48, 49).

We would like to conclude by making one final very important observation: there appears to be a serious disconnect between academic associations/organisations and their membership regarding conference practices. As this study has shown, people who have participated in a

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multi-hub conference are enthusiastic about its ecological and social sustainability benefits. Yet the majority of academic associations persist with the problematic, deeply entrenched traditional in-person format. The reasons for this are unclear, but there may be a number of factors at play. We argue that ignorance can no longer be a justification: the evidence of the ecological unsustainability of traditional in-person conferences (particularly those involving long-haul travel) is irrefutable (12, 18, 22-24), and numerous studies have detailed the range of social inequities perpetuated by in-person conferences (3-5, 15, 16, 32). However, anecdotally at least there is a perception that alternative formats (even simply live-streaming content or allowing virtual presentations in a hybrid format) are too difficult or costly to implement. We do not deny that a decentralised multi-hub conference format requires more consideration than the traditional in-person model (18) – but at a time when the effects of climate change are becoming more undeniable, and more universities and research institutions around the world are facing financial constraints (50-53) and reducing funded conference attendance in response, we must act. We therefore call for academics across all disciplines to push for radical change, to align their values with their academic practices, to stop the hypocrisy embedded within academia (50), and make decentralised multi-hub conferences the norm in their field rather than the exception.

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