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RESEARCH AND ANALYSIS

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Emission reduction potentials for academic conference travel

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Abstract

Air travel, including academic conference travel, is a major contributor to global greenhouse gas emissions and must be limited to achieve climate change targets. To model reduction potentials, we analyzed travel emissions for three global conferences of the International Society for Industrial Ecology. Travel emissions were 722–955 t CO_2e per conference and averaged 1.3–1.8 t CO_2e per attendee. A shift to land transport for short flights has a maximum reduction potential of only 5% because long-haul flights contribute most of the emissions. A carbon tax of 100$/t CO_2e could reduce emissions by 4–14% but students face the largest relative increase in the cost of conference attendance. Having the 10% of attendees who travel furthest attend virtually reduces conference travel emissions by 20–30%. A multi-site conference with two video-linked locations yields a reduction of 25–50%; a three-site conference yields a reduction of 46–75% and combined with a shift to land transport a reduction of up to 82%. A virtual conference would yield zero travel emissions. We conclude that the effectiveness of the reduction options mostly depends on how international the conference is and whether the longest flights are eliminated. We call on conference organizers, universities, academic societies, and funders to further develop, support, and implement multi-site and virtual conference models. This article met the requirements for a gold–silver JIE data openness badge described in http://jie.click/badges

KEYWORDS

air travel, carbon footprint, climate change, conference travel, industrial ecology, virtual conference

1 | INTRODUCTION

Restricting global warming to 1.5°C with no or limited overshoot is expected to require an emission reduction of 40–50% by 2030 compared to 2010 and, according to illustrative pathways, net-zero emissions by around 2050 (IPCC, 2018). In 2010, aviation was responsible for 11% of greenhouse gas (GHG) emissions from the transport sector and 1–2% of total anthropogenic GHG emissions (IPCC, 2014; Sims et al., 2014). Aviation is projected to grow at an annual rate of 5% (Schäfer & Waitz, 2014) and current national and international policies for the sector are unlikely to yield major emission reductions (Larsson, Elofsson, Sterner, & Åkerman, 2019).

Flying less may be necessary to meet climate change targets because other options are not sufficient. First, technological options for increasing efficiency, including the use of best available technology and improved air traffic management, cannot compensate for the expected growth in aviation (Schäfer & Waitz, 2014). Second, stabilization of emissions through the use of low-carbon fuels would be "very challenging" given competing land uses and the current state of the technology (Schäfer & Waitz, 2014). Third, carbon offsetting is problematic because of the uncertainty regarding effectiveness and the limited scope for carbon reductions in other sectors beyond their individual obligations (Becken & Mackey, 2017; Macintosh & Wallace, 2009).

The arguments for reducing flight emissions from academia have been outlined by authors in various research communities (Fraser, Soanes, Jones, Jones, & Malishev, 2017; Green & Drife, 2008; Le Quéré et al., 2015). Academics travel more by air than the average person because they conduct fieldwork and disseminate research findings; they collect data in remote locations and attend international conferences, workshops, and meetings. Academics, particularly in the field of the environment and climate change, risk losing credibility and effectiveness if they are perceived to have relatively large carbon footprints (Attari, Krantz, & Weber, 2019). At the same time, academia has the means and remit to develop and disseminate low-carbon conferencing practices.

Studies that quantify conference travel emission reduction options focus most often on optimization of a single conference location (Astudillo & AzariJafari, 2018; Desiere, 2016; Fois, Cuena-Lombraña, Fristoe, Fenu, & Bacchetta, 2016; Kuonen, 2015; Stroud & Feeley, 2015), followed by a shift to land transport (Desiere, 2016; Fois et al., 2016; Kuonen, 2015; Neugebauer, Bolz, Mankaa, & Traverso, 2020), multi-site conferencing (Coroama, Hilty, & Birtel, 2012; Hischier & Hilty, 2002; Orsi, 2012; Parncutt, Meyer-Kahlen, & Sattmann, 2019), and excluding long-distance flyers (Desiere, 2016) (an overview is provided in Table S2-1 in Supporting Information S2). Hischier and Hilty (2002) assessed a fully virtual conference, which is generally assumed to require a negligible amount of travel.

The literature does not provide a comprehensive insight into reduction options. First, more than half of the studies analyze conferences with a regional rather than global character, with a large majority of attendees from the same continent. These regional conferences feature relatively low travel emissions and relatively high reduction potentials for a shift to land transport or exclusion of long-distance flyers. Only Fois et al. (2016) study a shift to land transport for a global conference but, contrary to other studies, assume combined rail and air journeys (see Table S2-1 in Supporting Information S2). Second, since most studies cover only one or two interventions, the relative attractiveness of the interventions cannot be reliably inferred. Only one study compares three interventions, but for a regional conference (Desiere, 2016).

We analyze and compare five types of interventions for reducing travel emissions from a global conference. We identify the conference travel emission profiles and present the reduction potential of a shift to land transport, a carbon tax, exclusion of long-distance flyers, multi-site conferencing, and a virtual conference. Our estimate for multi-site conferencing takes a new approach: it is based on data from three single-site conferences, instead of one multi-site conference (Coroama et al., 2012; Parncutt et al., 2019) or single-site conference (Orsi, 2012). We focus on three conferences of the International Society for Industrial Ecology (ISIE) held at different locations from 2013 to 2017 and drawing about half of the attendees from outside of the continent where they were held.

2 | METHODS AND DATA

2.1 | The ISIE conferences

We studied the ISIE international conferences in Ulsan, South Korea (2013); Surrey, United Kingdom (2015); and Chicago, United States (2017). We selected these conferences because of data availability and because they cover the typical conference locations: East Asia, Europe, and North America. The Chicago 2017 conference was organized in collaboration with the International Symposium on Sustainable Systems and Technology (ISSST), which suggests an increase in attendance compared to a conference organized by the ISIE only; however, only 3% of attendees registered as ISSST members.

The biennial international conferences organized by the ISIE is the largest conference series dedicated to the field of industrial ecology. The field of industrial ecology has strong roots in engineering and overlaps with environmental science, environmental economics, ecological economics, and management. It entered the mainstream around 1990, launched its journal in 1994—the *Journal of Industrial Ecology*—and started the ISIE in 2001 (ISIE, 2015). In the same year, the first international conference was held in Leiden in the Netherlands, and every 2 years in a different location thereafter (ISIE, 2015).

2.2 | Emission estimates

To calculate emissions from conference travel, we first obtained the attendee lists, which included attendee affiliations. These lists had either been supplied to all attendees at the event, including to the authors, or were provided to us by the organizers. We used online public profiles of some attendees to clarify ambiguous entries (one attendee of the Surrey conference could not be matched and was left out of the analysis). In the second

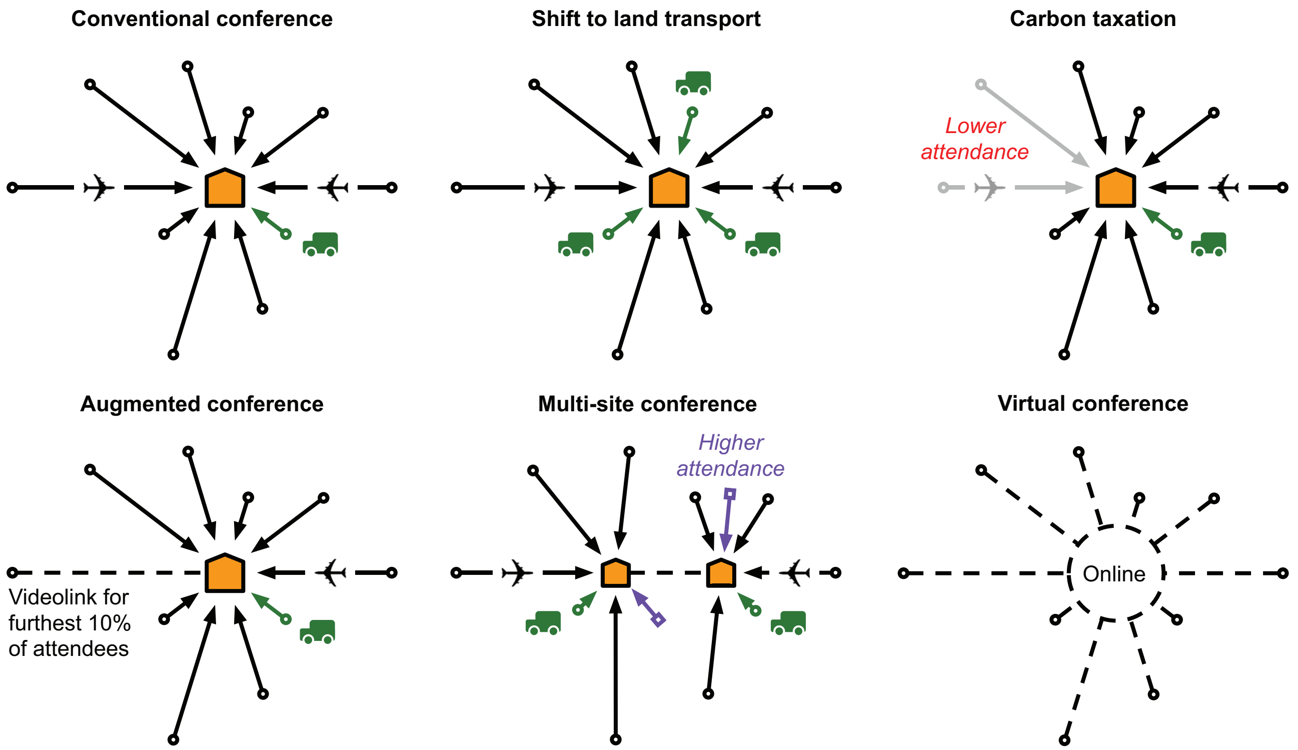

FIGURE 1 Emission reduction options for conferences

step, we matched the affiliations to cities and the cities to airports. Third, we calculated the great-circle distances from airport to airport (the shortest travel distance considering the earth's curvature). We assumed direct flights and left out the negligible travel distances to and from the airport. Fourth, we assumed that attendees at a great-circle distance of less than 550 km used land transport, based on data from Moeckel, Fussell, and Donnelly (2015) (see Supporting Information S2). We multiplied the great-circle distance with a "detour index" to account for the longer travel distance overland (Boscoe, Henry, & Zdeb, 2012). Finally, we multiplied the distances with GHG emission factors (BEIS, 2017). For air travel, the factors account for additional fuel use through deviations in the flight path. We assumed economy class travel and used factors that include additional radiative forcing due to emissions at high altitude. For land transport, we assumed equal fractions of rail and single-occupancy car transport—in between the likely modes for the Chicago conference (almost all car transport) and the Surrey conference (almost all rail transport). The travel distances per conference are included in Supporting Information S1; the modeling parameters are summarized in Table S2-2 in Supporting Information S2.

2.3 | Emission reduction options

2.3.1 | Overview

We modeled the travel emissions for five reduction options and used the emissions profile of the conventional conferences as a baseline for comparison. Figure 1 represents the travel pattern for a conventional conference and the change in travel pattern for each reduction option. First, a shift to land transport can replace short-distance flights. Second, a carbon tax discourages attendance, in particular of those far away. Third, an augmented conference encourages those furthest away to attend online. Fourth, a multi-site conference reduces travel distances and makes land transport feasible for more attendees. Fifth, a virtual conference reduces travel to zero.

The five reduction options are archetypes and can be combined in practice. For every option, we calculated the reduction potential as a range that represents likely outcomes. Wherever we indicate a parameter range, we used the upper and lower values to calculate the boundaries of the reduction potential range. In some calculations, various parameters were specified as a range: for example, to calculate the impact of a shift to land transport, we considered two travel distances beyond which attendees use air travel instead of land transport, and two values for the carbon intensity of land transport. The following sections describe the methods for each reduction option; a summary of the options is provided in Table S2-3 in Supporting Information S2.

2.3.2 | Shift to land transport

In the baseline estimate, attendees within a range of 550 km were assumed not to fly but to travel overland. Le Quéré et al. (2015) suggest that it is possible to avoid air travel for journeys up to 1,000 miles or approximately 1,600 km, with a focus on travel from the United Kingdom to continental Europe. Le Quéré et al. (2015) provide an example of the connection between London and Rome, which is approximately 1,600 km and takes 14–21 hrs by train. In many parts of the world, such long-distance journeys may require an overnight stay, though it should be noted that many academics are based in large and well-connected urban centers. For some conference locations, international land travel is not possible (including for Ulsan), but our interest is with average reduction potentials—not with the merit of specific locations. We chose two extremes to calculate the reduction potential: a threshold of 1,000 km combined with travel in single-occupancy cars, and a 1,600 km threshold combined with travel by rail. We conduct the calculation for all three conferences in our database.

2.3.3 | Carbon tax

We included a carbon tax in our analysis because it is a widely discussed policy instrument. We modeled the reduction in attendance and travel emissions as a result of a carbon tax on the airfare (which could be charged by, e.g., the conference organizer). We calculated the impact based on the price elasticity of demand for long-haul air travel for businesses purposes (Gillen, Morrison, & Stewart, 2007). We also calculated the impact of the carbon tax on the total cost of attendance for both students and non-student attendees. The calculation was based on the Chicago conference, for which reliable accommodation and conference fee cost data was available.

We used a standard carbon tax of 40$/t CO_2e based on a campus program at Yale University which used this price (Gillingham, Carattini, & Esty, 2017). This carbon price makes sense in the context of academic travel because it has already been implemented in the academic environment. Much higher rates per tonne of carbon have been used in other contexts (Smith & Braathen, 2015) and we included a second rate of 100$/t CO_2e. Our results represent the impact of a tax ranging from 40 to 100$/t CO_2e. We do not recommend any particular level of taxation but used these two rates to gauge the impact of a typical tax.

We calculated the total cost of attendance based on approximate airfares, accommodation prices, conference fees, and living expenses (see Table S2-4 in Supporting Information S2). The cost of accommodation was taken directly from the Chicago 2017 conference website based on the price ranges of recommended (block-booked) student accommodation and hotels. For the fees, we took the early-bird ISIE member rates for non-students and students. We assumed a typical stay length of seven nights and estimated the daily budget for items such as food to be 25–50$.

The airfares were calculated based on a literature estimate of fares for various distance groups (Morlotti, Cattaneo, Malighetti, & Redondi, 2017). We assumed plus and minus 25% variation in average prices between routes; we did not consider very cheap or very expensive fares, consistent with previous assumptions that all flights are direct flights (and therefore not the cheapest) and economy class (and therefore not the most expensive). Based on a review of the price elasticities of air travel demand, we applied an elasticity of −0.198 to −0.475 for "long haul international business" (Gillen et al., 2007).

2.3.4 | Conference types

We considered various alternative conference models inspired by a previous categorization (Le Quéré et al., 2015). First, an augmented conference would have video links and other online tools to increase participation. Le Quéré et al. (2015) argue this could enlarge the audience without increasing emissions. We take a different angle and estimate the potential benefits of using augmentation to encourage those travelling furthest to attend digitally instead and decrease total conference travel emissions. We model an augmented conference that encourages the top 10% emitters to attend from their workplace. We do not quantify an increase in attendance beyond the number of attendees that could be expected for a conventional conference.

Second, a multi-site conference would consist of simultaneous video-linked regional conferences in the main academic hubs. This enables all attendees to travel to the nearest conference and cuts out many of the long-haul flights that are normally required to gather everyone in a single location. A multi-site conference would require excellent telecommunication infrastructure and planning that considers time zones. Coroama et al. (2012) describe a two-site conference on resource management with shared 4-hr slots between Switzerland and Japan; Parncutt et al. (2019) report on a conference on music cognition with 4-hr slots that are shared between three of the four sites. We considered a conference with two sites (North America and Europe) and three sites (North America, Europe, and East Asia).

The calculation for the multi-site conference is based on the assumption that for each country, the same number of people that attended the closest of the most recent two (for the two-site conference) or three (for the three-site conference) ISIE conferences will attend the relevant site. To consistently combine data, we accounted for the growth in total conference attendance over time. For example, 30 attendees travelled from

Germany to the 2015 Surrey conference, which was closer to Germany than either Chicago or Ulsan, and the Chicago conference was 1.06 times bigger than the Surrey conference. For the multi-site conference, we expect $30 \times 1.06 = 32$ attendees to travel from Germany to a European site.

The allocation procedure leads to a significant increase in total conference attendance, which may exceed the demand for biennial conference attendance, and limits the emission reduction potential. To address the potential overestimation of attendance, we also modeled the reduction potential of a multi-site conference with no increase in attendance, by normalizing attendance to the size of the Chicago conference. The resulting range of the reduction potential is a function of the extent to which the multi-site conference draws more people than a conventional conference: the highest reduction potential is achieved when total conference size does not increase.

The allocation procedure for the multi-site conference assumes that conferences that are closer draw more attendees. For a few countries, the closest conference is not the most visited, which leads to a minor inconsistency in the allocation. At the level of the conference, this inconsistency is insignificant: for the three-site conference, allocation based on popularity instead of proximity would lead to a 1.9% higher upper estimate of attendance. We prioritized allocation based on proximity because an estimate based on popularity implies an upward correction based on unlikely occurrences of high attendance at far-away conferences (i.e., outliers).

The reduction potential of a multi-site conference depends on where the conventional conference would have been. For example, our two-site conference has a greater reduction potential when compared against the Chicago conference than the Surrey conference, because the Surrey conference had relatively low travel emissions. For the multi-site conferences, we therefore compared the emissions against the conventional conferences in all the relevant locations. Since the multi-site conference is normalized to the size of the Chicago conference, we had to also normalize the figures for the emissions from the Surrey and Ulsan conference (Chicago had 6% more attendees than Surrey and 56% more attendees than Ulsan).

Finally, a virtual conference consists of online engagement only and would reduce the amount of air travel to zero. Both the organization and attendance of the conference could take place in any number of locations, and the level of in-person engagement would be limited to local gatherings within cities or universities, between people who most likely already know each other. Such conferences have been organized in the past, among others under the label “nearly carbon-neutral” (NCN) (Hiltner, 2019). Consistent with the literature (Hischier & Hilty, 2002), we assume that such a conference requires no significant travel (beyond a potential commute) and do not conduct any further calculation for this type of conference.

3 | RESULTS AND DISCUSSION

3.1 | Conference emission profiles

Our first results are the travel emission profile of the three conferences. The total travel emissions from the Chicago 2017, Surrey 2015, and Ulsan 2013 conference were respectively 955, 765, and 722 t CO_2e. The number of attendees was 625, 588, and 401, which results in average emissions of 1.5, 1.3, and 1.8 t CO_2e per attendee. Our estimates of average travel emissions per conference attendee are in between estimates for other global conferences (Coroama et al., 2012; Fois et al., 2016; Stroud & Feeley, 2015). Figure 2 shows the distributions of emissions per attendee by matching the percentage of emissions with the percentage of travellers, sorted with the low-carbon travellers first (akin to a Lorenz curve). The figure reveals that the 10% least polluting travellers had an insignificant contribution to total emissions and that the 10% most polluting travellers (between the 90% and 100% mark on the horizontal axis) produced 20–30% of total conference travel emissions.

Figure 3 shows the emission profiles of the three conferences by region. The height of a bar reflects the average travel emissions for attendees from the relevant region, the width of the bar the number of attendees from that region, and the surface area the total travel emissions for the region. Countries were allocated to regions based on the classification by the United Nations (UNSD, 2017). The charts show that the home region contributes relatively few emissions: it supplies 44–52% of attendees, but they cause only 9–14% of travel emissions. The charts also reveal that some conference locations struggle to attract a regional audience: the Ulsan conference features a much smaller fraction of regional travellers with less than 1 t CO_2e travel emissions than the Surrey conference. This explains the 38% higher average emissions per attendee for Ulsan.

3.2 | Reduction potentials

In this section, we discuss the impact of the reduction options. Figure 4 summarizes the relative impact of the various reduction options in the order of their reduction potential, with the ranges covering any possible outcome in our lower and upper modeling estimate (the sensitivity of the outcomes to key parameters is therefore already integrated with our results). The detailed figures for each option are provided in Table S2-5 in Supporting Information S2 , including emissions, attendees, and relative reductions compared to one or more conventional conferences. Below, we discuss the results from the calculations for each option except for the virtual conference, which we assume yields no travel emissions at all.

First, a shift to land transport appears hardly effective. When all attendees within a distance of 1,000 km shift to land transport and rely exclusively on single-occupancy cars, the emissions *increase* by 2%. If all attendees within a larger distance of 1,600 km use land transport and travel exclusively by train, emissions can be reduced by just 5%. At the individual level, a shift to train travel can lead to significant reductions but since

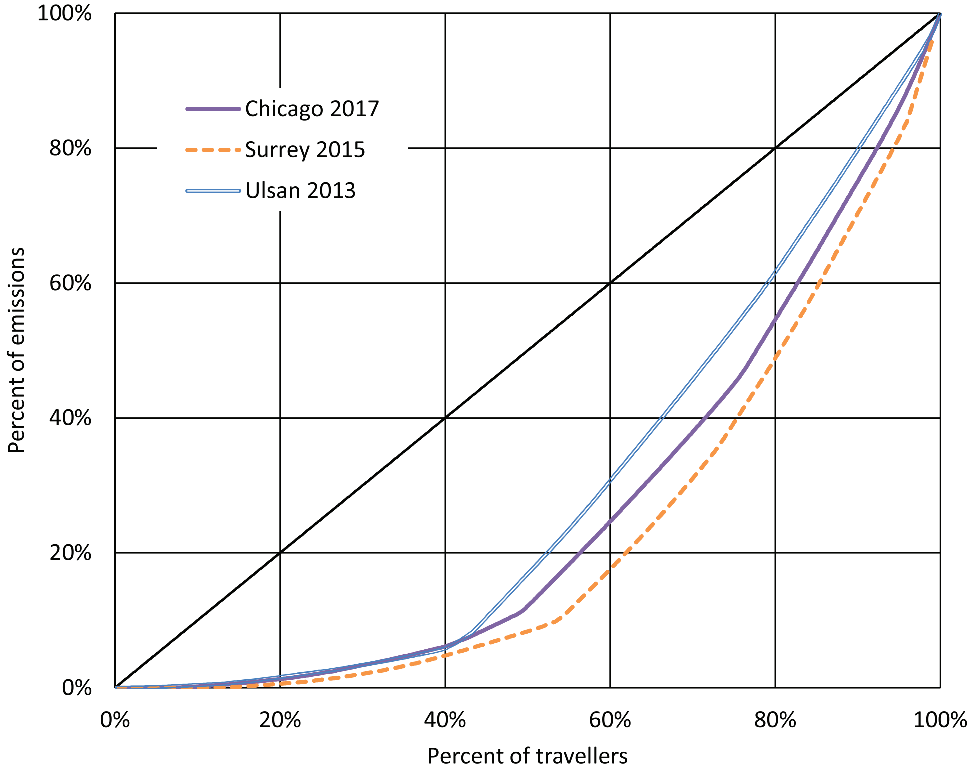

FIGURE 2 Distribution of emissions between travellers for three biennial ISIE conferences. Underlying data used to create this figure can be found in Supporting Information S1

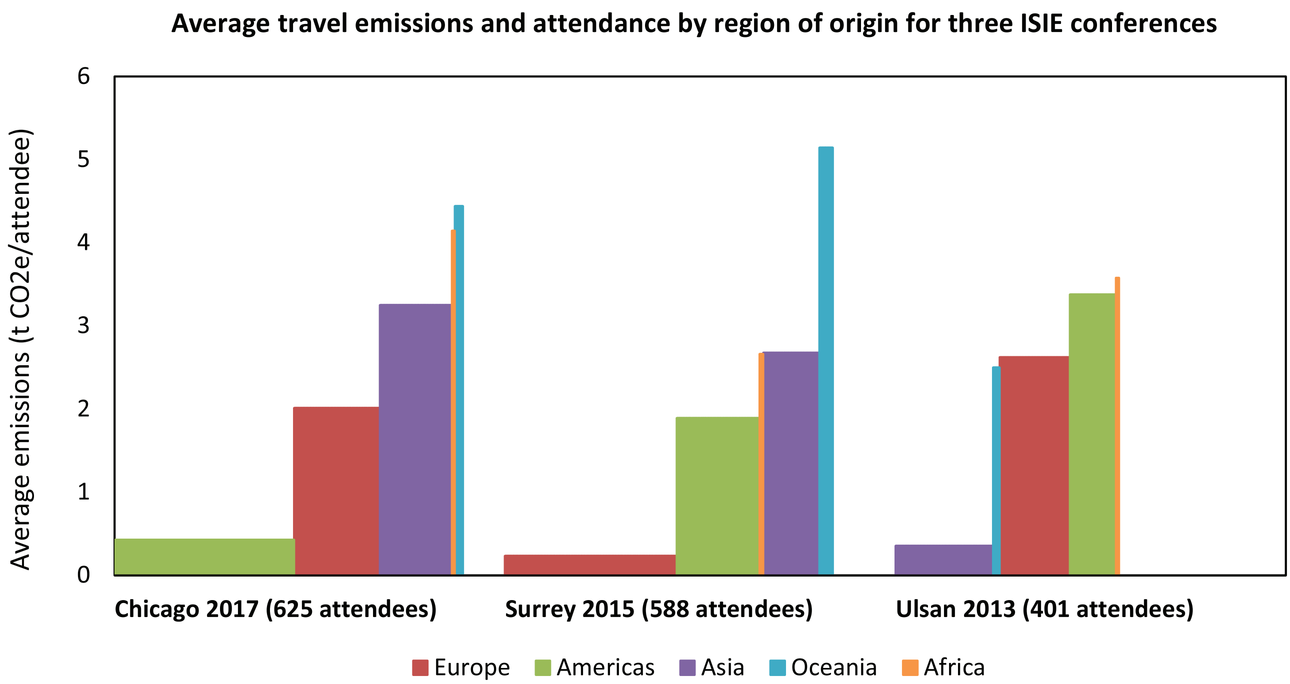

FIGURE 3 Distribution of emissions for three ISIE international conferences. The vertical axis shows average emissions per attendee by region of origin. The width of the bars reflects the number of attendees. Underlying data used to create this figure can be found in Supporting Information S1

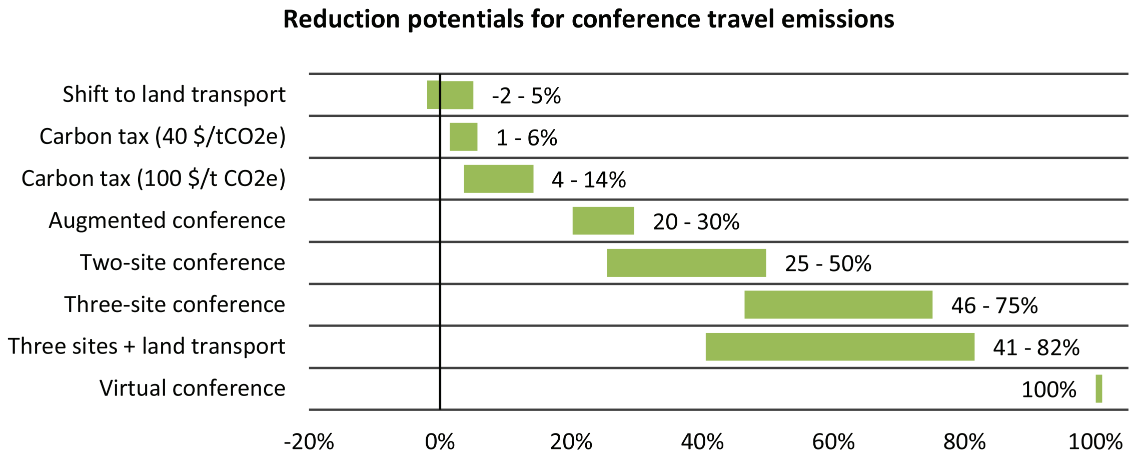

FIGURE 4 Relative reduction potentials for conference travel emissions. Underlying data used to create this figure can be found in Supporting Information S1

most emissions are caused by long-distance flyers, modal shift does little to reduce total conference travel emissions. For some conference locations, high-speed rail could make modal shift more effective, but even if everyone within a distance of 1,600 km used zero-carbon land transport, the total reduction would be 6–9%. Fois et al. (2016) suggest a reduction potential of up to 19% for a global conference but make the unusual assumption that attendees travel 2,000 km by train and then fly for the remainder of the journey. Analyses of regional conferences suggest reductions of 10% (Neugebauer et al., 2020), 13% (Desiere, 2016), and 33% for an all-European conference (Kuonen, 2015).

Second, a carbon tax of 40\$/t CO_2e yields a reduction of 1–6% and a carbon tax of 100\$/t CO_2e yields a reduction of 4–14%. The wide range is the consequence of the large uncertainty associated with the demand response to a change in airfares. A reduction of up to 14% of emissions is significant but, unfortunately, this reduction is achieved solely through a decrease in attendance. Taxation could be combined with augmentation of the conference (see next paragraph) to enable virtual participation of those not attending in person; offering an alternative is also likely to increase the effectiveness of the tax with more people foregoing physical attendance. We did not consider the effect of taxation on a shift to land transport, but this can be assumed to be negligible since the tax is relatively small for travel distances that allow modal shift.

Third, an augmented conference—with those attendees from far away only attending via video links—could see a reduction of 20–30% of emissions when the top 10% emitters do not attend the conference. Desiere (2016) finds a much larger reduction of 50% for a regional conference with 90% of attendees from the same continent (Europe). An augmented conference would need a mechanism, such as a carbon tax, to encourage long-distance flyers to attend virtually. Alternatively, a maximum travel distance could be imposed, derived from the travel distances of the top 10% emitters of past conferences. Currently, conferences are typically organized in the Northern hemisphere, and avoiding long flights would therefore systematically exclude attendees from large parts of the world. An augmented conference may be more acceptable when the conference location alternates between sites around the globe.

Fourth, a two-site conference—with regional conferences in North America and Europe—has a reduction potential of 25–50%. The maximum reduction is achieved when attendance does not increase, and when compared to a conventional conference in North America; the minimum reduction occurs when attendance increases by 26%, and when compared to a conventional conference in Europe. The literature suggests a similar reduction potential of 30–50% (Coroama et al., 2012; Orsi, 2012). For a three-site conference, we estimate a reduction of 46–75%, with participation increasing by up to 56%. Consistent with our findings, the literature suggests a reduction of 43% to 46% with no increase in participation (Hischier & Hilty, 2002; Orsi, 2012).

Finally, a multi-site conference could be usefully combined with modal shift since it features a large number of attendees that can feasibly take land transport. The three-site conference combined with modal shift yields a reduction of up to 82% assuming no increase in participation and only rail travel. A shift to land transport is counterproductive when it concerns only single-occupancy cars. The maximum reduction of 82% is not far from the 100% reduction achieved with a fully virtual conference, but the three-site conference allows attendees to still meet about a third of the other attendees in person. Compared to an augmented conference, which also benefits from cutting out long flights, the multi-site conference seems fairer because it demands an adjustment of all attendees and not just of those living furthest away.

3.3 | Inequity of a carbon tax

The carbon tax reduction option merits additional discussion because it can have inequitable effects. For student attendees with relatively low conference fees and accommodation costs, the carbon tax leads to a relatively large increase in the total cost of attendance. Figure 5 shows the

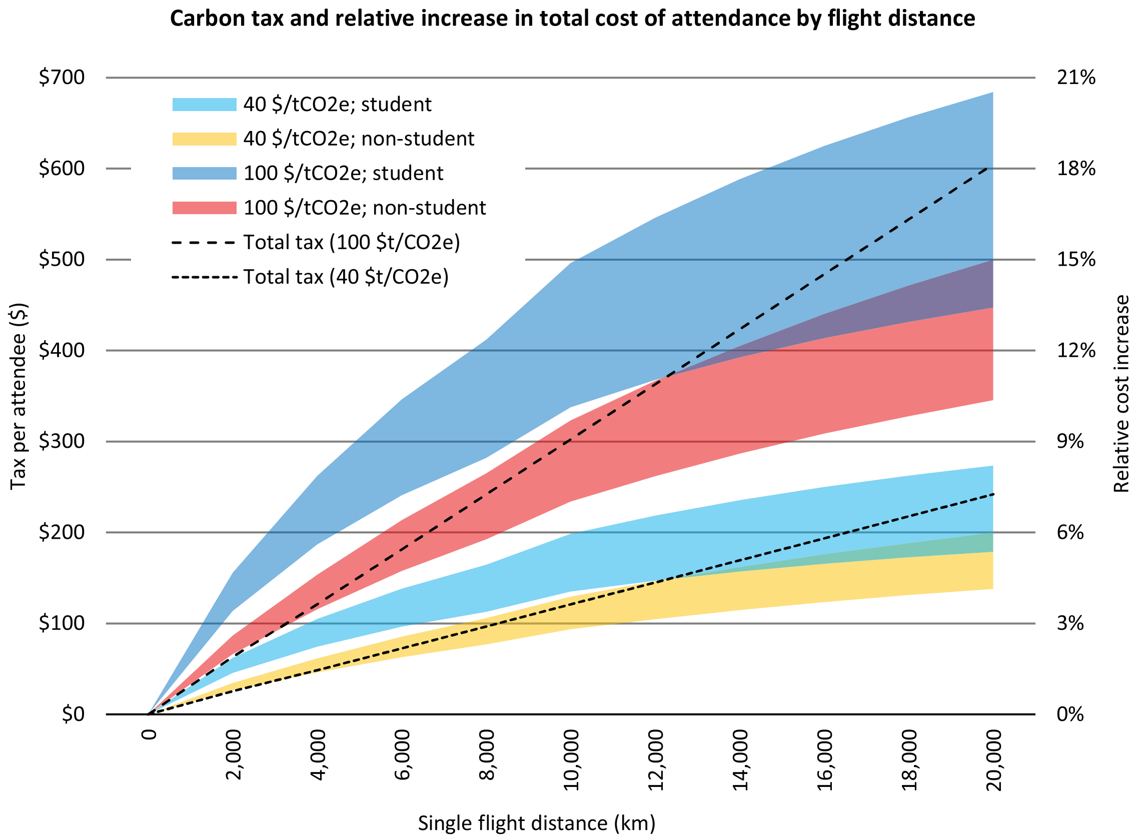

FIGURE 5 Tax per attendee (dotted lines, primary axis) and the relative increase in the cost of attendance (shaded areas, secondary axis). Underlying data used to create this figure can be found in Supporting Information S1

total carbon tax and the resulting relative increase in the cost of attendance as a function of the single flight distance. It shows the results for both students and non-students and two levels of taxation: 40$/t CO_2e and 100$/t CO_2e. For large travel distances, the airfare dominates the cost of attendance. At the same time, the tax is roughly proportional to the airfare (leaving aside the slight nonlinearity in the airfare price and carbon intensity). Taken together, the tax leads to a larger relative increase in the cost of attendance for larger distances.

Students spend less on accommodation and conference fees, but pay the same amount of tax, and therefore face a higher relative increase in the cost of attendance. For example, a student attendee flying from the Netherlands (Schiphol airport) to Chicago would have travelled approximately 6,600 km (one way) and faced a total tax of 80–200$. This would increase the overall cost of attendance by 3–11%. For a non-student flying from the same airport, the cost increase would be just 2–7%. As a result, the share of students that is deterred from attending is likely to be larger than the share of non-students that is deterred. In practice, the effect may be less pronounced than in our calculations since students may find cheaper tickets, in part because they may be more willing to adjust their travel dates and times to save expenses.

The unequal burden of a carbon tax can be addressed by using the tax revenues to compensate disadvantaged groups. In our case, this could consist of subsidizing non-airfare costs of attendees, such as the conference fee, to avoid attendees being worse off on average, or to compensate students specifically. Such a scheme would make the tax less effective, but not cancel it out altogether since long-distance flyers would still pay more tax than they get in subsidies. Another issue of fairness is spatial: some attendees have to pay higher taxes, besides higher airfares, simply because they happen to live further away and not because they made a fundamentally different decision. The burden is shared more fairly when each conference is held in a very different location (which is also true for the augmented conference).

3.4 | Face-to-face interaction

There are many costs and benefits to the various reduction options. Here, we focus on what is often considered the main challenge in reducing or substituting conventional conferencing: the loss of face-to-face interaction. Indeed, all options analyzed in this article that had a major impact implied a reduction in not only emissions but also face-to-face interaction. The loss of face-to-face interaction is problematic, as stated by one of the interviewees in a previous study (Nursey-Bray, Palmer, Meyer-Mclean, Wanner, & Birzer, 2019): "you do not go really to give the paper. You really go to meet the amazing people and you cannot do that remotely." Admittedly, even this article would not have existed without the various ISIE conferences where the authors met in person, conceived the idea, and presented the preliminary results.

Interestingly, one of the most effective reduction options—the multi-site conference—still offers much face-to-face interaction, especially if the total number of attendees increases. It is worth exploring whether the emission reduction justifies this limited loss of face-to-face interaction and the extent to which it can be compensated through innovative forms of digital engagement. Coroama et al. (2012) surveyed attendees of a two-site conference regarding transmitted presentations, interactive Q&A sessions, the sense of presence of the audience at the other location, and spontaneous cross-site discussions. Some respondents reported they did not use all features and a significant group (up to 34% in one location) did not engage in cross-site discussions. But, of the respondents that did engage, 79–96% reported to be "fairly" or "very" satisfied.

The challenging trade-off between face-to-face interaction and carbon footprint should not be a reason for inaction. First, there is no one-size-fits-all solution. We suggest that short conferences and meetings may be more easily replaced with virtual conferences, whereas multi-day global conferences with a strong focus on networking, such as the ISIE international conferences, would benefit greatly from the face-to-face interaction that is offered by multi-site conferences. Second, because of their novelty, alternative conference models have not yet been fully developed. For alternative conference models to reach the maturity of conventional conferences, they need to be tried out by many academic communities, and the earlier the transition process gains momentum, the sooner alternative conference models will achieve their full potential.

3.5 | Limitations and further work

Our analysis reveals significant reduction potentials for academic conference travel. We only considered direct emissions from fuel consumption—a comparison of full life cycle emissions (the footprint) of various options may lead to slightly different estimates. In particular, the inclusion of emissions from the use of digital technology could slightly reduce the relative advantage of digitization. However, travel is by far the largest contributor to the life cycle emissions of conference attendance (Hischier & Hilty, 2002; Neugebauer et al., 2020) and a more extensive assessment of life cycle impacts is unlikely to reach a different conclusion regarding the comparative climate benefits of virtual conferencing.

The generalizability of our findings is subject to three constraints. First, for the industrial ecology community, the reduction potentials may change when the spatial make-up of the industrial ecology community shifts, such as through the growth of industrial ecology in China. Second, our results are most relevant for global conferences and we recommend that conference organizers assess the approximate origins of their audiences before pursuing reduction options. For regional conferences, augmentation and a shift to land transport can be more effective than suggested in the present study. Third, the carbon intensity of flight and land transport may decrease in the future and possibly faster for land transport due to electrification of cars and expansion of high-speed rail, yielding greater benefits for a shift to land transport.

Further research should focus on three subjects. First, there are various potential co-benefits of low-carbon conferencing that deserve further scrutiny. Multi-site or virtual conferences are likely to be more inclusive because the costs of travel and attendance can be significantly lower and the addition of sites in the Global South could open the conference to underrepresented audiences. Besides, recording of sessions could improve conference experience by allowing attendees to catch up on sessions that were held in parallel. These and other potential co-benefits provide a window of opportunity for increasing the support for low-carbon conferencing.

Second, the scope of research should be expanded to include various academic events, the linkages between them, and the time scales at which they occur. A more holistic approach to academic travel can show how annual demand for interaction between academics can be met through strategic planning of various activities including conferences, workshops, fieldwork, and meetings. It may be possible to alternate conventional face-to-face meetings with low-carbon teleconferencing options to maintain a minimum level of personal interaction whilst reducing annual travel emissions. Besides, events could be (partly) substituted with permanent digital platforms for flexible interactions not bound by physical meeting dates (Le Quéré et al., 2015).

Finally, because we considered the feasibility of the various scenarios only briefly, we emphasize that further research is required to identify whether and how these options can be achieved. Given the urgency and nature of the challenge, it makes sense to combine research with practical action. There are already many initiatives by academics and universities, such as individual travel pledges and institutional travel policies. Our findings suggest a great reduction potential for multi-site conferences, consistent with earlier assessments (Coroama et al., 2012; Hischier & Hilty, 2002; Orsi, 2012; Parncutt et al., 2019), as well as for virtual conferences, and we urge conference organizers, and those who support and fund them, to develop multi-site and virtual conference models, evaluate experiences, and share recommendations and best practices.

4 | CONCLUSION

Our analysis identified the travel emission profiles of three ISIE biennial conferences and estimated the impacts of various reduction options. Our results are representative of global conferences with about half the attendees from the continent where the conference is held. The greatest reduction is achieved by a fully virtual conference, which would require no travel at all, followed by a combination of a three-site conference with simultaneous events in North America, Europe, and East Asia and a shift toward land transport. Major reductions can also be achieved through a multi-site conference without modal shift or with an augmented conference that allows attendees living furthest to attend through telecommunication links. Only a modest reduction is achieved when attendees of a conventional conference shift to land transport or pay a carbon tax of up to 100$/t CO_2e. Both the augmented conference and the carbon tax put an uneven burden on attendees, with student attendees and those having to travel furthest being worst off. A multi-site conference fairly distributes costs and benefits. However, its feasibility depends on the willingness of attendees to forego much of the face-to-face interaction, which in turn depends on how well the activities at the three sites are organized and linked. An advantage of the multi-site conference, besides the emission reduction, is the potential to attract more attendees with limited budgets due to the shorter travel distances. Based on our findings, we highly recommend to further develop and implement multi-site and virtual conference models.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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