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Assessing Strategies to Reduce the Carbon Footprint of the Annual Meeting of the American Academy of Ophthalmology

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Invited Commentary
Multimedia
Supplemental content

IMPORTANCE Greenhouse gas emissions associated with medical conferences have been associated with climate change, and the effects of climate change have been associated with an increased incidence of ophthalmic diseases. Identifying practical strategies associated with reducing these emissions may be warranted.

OBJECTIVE To assess greenhouse gas emissions associated with in-person and virtual meetings of the American Academy of Ophthalmology (AAO) and to conduct mitigation analyses to suggest strategies to reduce future emissions.

DESIGN, SETTING, AND PARTICIPANTS Quality improvement study in which attendee and conference data were used to estimate emissions from in-person (October 12 to October 15, 2019, San Francisco, California) and virtual (November 13 to November 15, 2020) AAO annual meetings for 35 104 attendees. The data were also used to perform mitigation analyses to assess whether meeting format alterations could be used to reduce future emissions. Data were analyzed from December 21, 2021, to April 18, 2022.

EXPOSURES Attendance at a selected meeting. Total attendance was 23 190 participants in 2019 and 11 914 participants in 2020.

MAIN OUTCOMES AND MEASURES Greenhouse gas emissions produced by the in-person meeting were estimated by calculating the equivalent metric tons of carbon dioxide (CO_2) associated with attendee transportation, attendee accommodations, and the conference venue. Emissions produced by the virtual meeting were estimated by calculating the equivalent metric tons of CO_2 associated with attendees' computer use, network data transfer, and video-conferencing server use. Mitigation analyses simulated the association of changing the meeting location and format with reductions in emissions.

RESULTS In this analysis, the 2019 in-person meeting produced 39 910 metric tons of CO_2 (1.73 metric tons of CO_2 per capita), and the 2020 virtual meeting produced 38.6 metric tons of CO_2 (0.003 metric tons of CO_2 per capita). Mitigation analyses showed that holding a single in-person meeting in Chicago, Illinois, rather than San Francisco, California, could be associated with transportation-related emissions reductions of 19% (emissions for the San Francisco meeting, 38 993 metric tons of CO_2; for the Chicago meeting, 31 616 metric tons of CO_2). Holding multiple in-person meetings in separate regions could be associated with transportation-related emissions reductions of as much as 38% (emissions for the San Francisco meeting, 38 993 metric tons of CO_2; for multiple meeting scenario 2, 24 165 metric tons of CO_2).

CONCLUSIONS AND RELEVANCE This study found that the AAO's 2019 in-person meeting was associated with substantially higher greenhouse gas emissions compared with the 2020 virtual meeting, primarily due to transportation-related emissions. Increasing the proportion of virtual participants, holding the meeting in locations chosen to minimize transportation-related emissions, or offering multiple regional meeting locations may reduce the carbon footprint of future meetings.

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Climate change and its effects are of growing interest among vision scientists. Most surveyed ophthalmologists have expressed concern, and climate change has been associated with increased rates of ophthalmic disease.[1-8] Recent articles have reported on the carbon emissions associated with ophthalmic surgery and efforts to reduce surgical waste, demonstrating an increasing self-awareness of the field's environmental impact.[8-10] This work explores carbon emissions associated with ophthalmic conferences.

Medical conferences are a substantial source of greenhouse gas emissions in the health care sector and are an appealing target for reductions because of the absence of regulatory hurdles, the lack of a need to alter existing infrastructure, and the avoidance of direct impacts on health care delivery. Previous articles have estimated the carbon footprint of conferences held by various medical specialties, including ophthalmology.[11-20] These analyses have focused on transportation-related emissions, and none have evaluated emissions associated with the conferences themselves or considered emissions associated with virtual participation. Understanding the sources of nontransportation emissions is particularly important when comparing in-person and virtual meetings.

The annual meeting of the American Academy of Ophthalmology (AAO) has historically high attendance, making it the seventh largest medical conference in the United States.[21] The 2019 annual meeting was held in person in San Francisco, California. In 2020, the COVID-19 pandemic prompted the transition to a virtual meeting. The abrupt shift in conference format provides a unique opportunity to compare the greenhouse gas emissions associated with in-person and virtual conference formats. The resulting findings may be useful in exploring strategies to reduce the carbon footprint of future meetings.

Key Points

Questions How do greenhouse gas emissions compare between in-person and virtual formats of the American Academy of Ophthalmology annual meeting, and what adjustments might be associated with reduced emissions?

Findings In this quality improvement study of 35 104 meeting attendees, the 2019 in-person meeting was associated with substantially higher estimated emissions compared with the 2020 virtual meeting, primarily due to transportation-related emissions. Mitigation analyses suggest that holding the meeting in optimal locations, offering multiple regional meetings, or offering virtual options may be associated with a reduced carbon footprint of future meetings.

Meaning This study found that adjustments to the meeting format may be associated with reduced meeting-associated emissions.

Methods

AAO In-Person Annual Meeting, 2019

The 2019 annual meeting of the AAO took place at the Moscone Center in San Francisco, California, between Friday, October 12, and Tuesday, October 15. Using AAO-provided data containing self-reported places of origin and hotel bookings for deidentified attendees, we estimated the conference's carbon footprint based on 3 factors: attendee transportation, attendee accommodations, and venue-based emissions. The attendee data set included domestic and international physicians, health professionals, spouses and guests, and industry exhibitors (n = 23 190). Attendees with inconsistent location information were excluded from the analysis (n = 65).

The term *greenhouse gases* refers to a mixture of gases that are each associated with atmospheric warming. Greenhouse gas emissions in this analysis are reported as the mass of carbon dioxide (CO_2) gas that would produce an amount of warming equivalent to that of the actual greenhouse gas mixture. Because neither human participants nor personal identifiable information was used for this study, institutional review board review or approval was not required. This study followed the Standards for Quality Improvement Reporting Excellence (SQUIRE) reporting guideline.

Transportation-related emissions were estimated as a combination of greenhouse gas emissions attributable to ground and air travel. All attendees' travel was assumed to originate at the closest commercial airport to their self-reported origin. The origin airport was determined with the OpenFlights Airports database and a combination of online tools for cases in which nearby commercial airports were not available in the OpenFlights Airports database (n = 16).[22] Attendees within a 48-km (30-mile) geodesic radius of San Francisco International Airport were assumed to make round-trip drives to the meeting via passenger vehicle on each day of their attendance, which was assumed to be 4 days. Attendees between 48-km (30-mile) and 240-km (150-mile) geodesic radii of the airport were assumed to make a single round-trip drive to the meeting via passenger vehicle. All other attendees were assumed to take round-trip, nonstop, economy class flights originating at their closest commercial airport and terminating at San Francisco International Airport. Driving-related emissions were calculated with the US Environmental Protection Agency guidelines on passenger vehicles.[23] Aviation-related emissions were calculated with the GoClimate Flight Emissions API, which uses a radiative forcing index of 2.[24,25]

Accommodations-related emissions were estimated as the sum of emissions attributable to electricity and natural gas use for each attendee's stay. Hotel quality correlates to energy intensiveness; thus, hotels were categorized as upper upscale, upscale, midscale, and economy according to information published by the Environmental Protection Agency or independent determination when necessary.[26] The total number of room-nights was assumed to exceed the number booked through the AAO because conference attendees were free to book rooms independently. Attendees within a 48-km (30-mile) radius were assumed to not require accommodations. All other attendees were assumed to use 4 room-nights during the course of the meeting. The difference in room-nights booked through the AAO and the estimated total was assumed to have a conservative distribution of 50% upscale and 50% midscale hotels. Electricity use and natural gas use were calculated with consumption rates published by the Environmental Protection Agency[26] and converted to CO_2 emissions by using published emissions factors, including those specific to the California electric grid.[27]

Venue-related emissions were estimated from the electricity use and natural gas use attributable to the conference venue. Electricity and natural gas consumption factors published by the Environmental Protection Agency[26] were multiplied by event space floor area to calculate utility consumption for each day.[26,28] Data provided by the AAO indicated the portion of days that the Moscone Center was used for the meeting, including extra nonconference days for event setup and breakdown. Full use of these utilities was assumed for conference days, and 50% use was assumed for nonconference days.

AAO Virtual Annual Meeting, 2020

The 2020 virtual meeting was held between Friday, November 13 and Sunday, November 15, 2020, with a total live meeting duration of 32 hours. Emissions attributable to the virtual meeting were calculated according to the number of total attendee-hours, and the proportion of active participation time (participation rate) was assumed to be 75%.[29] Deidentified attendance numbers published on the AAO website were used for this analysis.[30] The carbon footprint for the 2020 virtual meeting was calculated according to 3 factors: computer, network, and server-based emissions.[29,31] All attendees were assumed to have participated in the virtual conference by using a cloud-based video-conferencing service through a fixed-line (nonmobile) network on a personal laptop computer.

Computer-related emissions were estimated with the mean lifetime emissions of a personal laptop computer (340 kg of CO_2).[31] The mean lifetime emissions include those associated with electricity use by the computers, as well as emissions associated with the computers' production, shipping, and disposal. Computer-related emissions were calculated according to the percentage of total lifetime emissions attributable to their use during the virtual meeting.

Network-related emissions were calculated according to the emissions attributable to the aggregate amount of internet data transferred to facilitate the virtual meeting. The rate of transfer for internet data for Zoom conferences with high-definition video ranges from 1.2 to 3 megabits per second (Mb/s),[32] and a uniform transfer rate of 1.2 Mb/s was assumed. Because virtual attendance occurred internationally, total network-related emissions were calculated according to the aggregate data transferred and the 2020 median global internet carbon emission rate of 32.13 g of CO_2/GB.[33]

Virtual conferences require the use of servers to route data. Previous studies have assumed that a single server may host hundreds of webinar participants.[29,31] A ratio of 1:200 servers per participant was assumed. Based on a server power rating of 0.594 kW and the 2019 average global carbon intensity for electricity generation (0.475 kg of CO_2/kilowatt-hour [kWh]), total server-related emissions were estimated as the product of the server power rating, electricity generation, and duration of server use.[31,34]

Mitigation Analyses

Two mitigation strategies designed to reduce the carbon footprint of in-person conferences were explored. First, meetings in alternative locations were simulated to assess the sensitivity of the carbon footprint to meeting location. Assuming attendance remained the same as the 2019 in-person meeting, transportation-related emissions were estimated under the same methods after substituting the travel destination to major airports in locations previously used to host the AAO's annual meeting: Las Vegas, Nevada (Harry Reid International Airport), New Orleans, Louisiana (Louis Armstrong New Orleans International Airport), Chicago, Illinois (O'Hare International Airport), and Orlando, Florida (Orlando International Airport).[35] Additionally, a location-optimization algorithm was used to identify the meeting location that would minimize the carbon footprint of the 2019 in-person meeting, regardless of geography. This algorithm sampled points at random across the surface of the earth to identify a geographic region that minimized the aggregate travel distance across attendees, a proxy for transportation-related emissions.

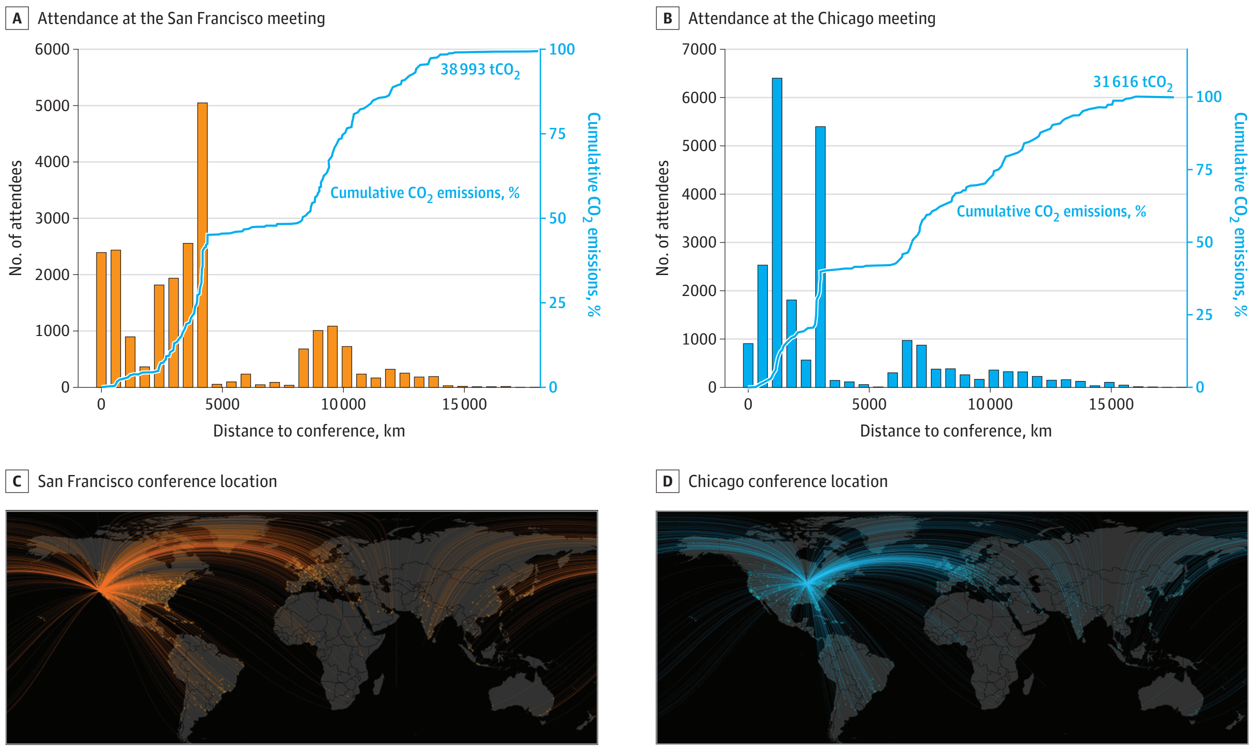
Second, multiple-meeting formats were simulated to assess the association of breaking up 1 large conference into multiple smaller conferences. Meeting locations were again limited to those previously used by the AAO. Transportation-related emissions were estimated under 2 scenarios assuming each attendee of the 2019 in-person meeting traveled to the closest alternative meeting. Scenario 1 estimated emissions that would result from splitting the annual meeting into 2 meetings held in the East (Chicago, New Orleans, and Orlando) and West (Las Vegas and San Francisco) regions of the United States. Scenario 2 estimated emissions that would result from splitting the annual meeting into 3 meetings. Emissions estimates are reported for the combination of cities resulting in the lowest transportation-related emissions. Analyses were performed with R, version 4.1.2 (R Project for Statistical Computing). Data were analyzed from December 21, 2021, to April 18, 2022.

Results

2019 In-Person Meeting Emissions

Transportation-related emissions were estimated at 38 993 metric tons of CO_2. **Figure 1**A and C compares the attendees' travel distances and their association with transportation-related emissions for the San Francisco meeting. Of the 23 125 attendees included in the analysis, 20 778 (90%) were assumed to use air travel, and 99.8% of the transportation-related emissions were attributable to this group (emissions of 38 931 metric tons of CO_2 for flights to San Francisco and 38 993 metric tons of CO_2 for total emissions from San Francisco travel). The remaining 0.2% of transportation-related emissions (emissions of 62 metric tons of CO_2 attributable to drivers to San Francisco) were from the 2347 attendees assumed to have driven. United States–based attendees (72% of attendance [16 720 US attendees and 23 125 total attendees]) produced 43% of transportation-related emissions (16 738 metric tons of CO_2) and had a per capita footprint (1.00 metric tons of CO_2) less than half that of the average international attendee (22 226 metric tons of CO_2; 3.47 metric tons of CO_2 per capita).

Figure 1. Travel Distances and Cumulative Transportation-Related Carbon Dioxide (CO_2) Emissions for Meeting Attendees



The 2019 American Academy of Ophthalmology (AAO) annual meeting was held in San Francisco, California, and the simulated meeting was held in Chicago, Illinois. Places of origin and geodesic distances to the conference for attendees to the 2019 AAO annual meeting and the simulated annual meeting in Chicago are shown. tCO_2 Indicates metric tons of carbon dioxide.

Of 23 125 included attendees, 21 768 were assumed to have required hotel accommodations. A total of 53 961 room-nights were booked through the AAO (82% upper-upscale [44 238 room-nights], 15.2% upscale [8201 room-nights], 2.8% midscale [1522 room-nights], and 0% economy), leaving an excess of 33 111 room-nights: 16 555.5 category 3 and 16 555.5 category 2 room-nights. Utility use was estimated at 3 399 513 kWh and 9478 MMBtu (1 000 000 British thermal units), emitting 837 metric tons of CO_2.

The Moscone Center was used for 5 conference days and an additional 7 days for event setup and takedown, resulting in an estimated equivalent of 8.5 full days. Utility use was estimated at 340 296 kWh and 688 MMBtu, emitting 80 metric tons of CO_2.

The total carbon footprint for the 2019 in-person meeting was estimated at 39 910 metric tons of CO_2 (1.73 metric tons of CO_2 per capita). Transportation accounted for 97.7% of total emissions (38 993 metric tons of CO_2 for all transportation emissions). Accommodations- and venue-related emissions accounted for 2.1% (837 metric tons of CO_2) and 0.2% (80 metric tons of CO_2), respectively.

2020 Virtual Meeting Emissions

A total of 11 914 people attended the 2020 virtual meeting. The carbon footprint of the virtual meeting was estimated at 38.6 metric tons of CO_2 (0.003 metric tons of CO_2 per capita). The largest source of emissions was associated with computer-related emissions (86.3%; 33.3 metric tons of CO_2), followed by network-related emissions (12.9%; 5.0 metric tons of CO_2) and server-related emissions (0.8%; 0.3 metric tons of CO_2). See the eFigure in Supplement 1 for calculations. If the 2020 virtual meeting had had the same number of attendees as the 2019 in-person meeting, this footprint would have been associated with 74.9 metric tons of CO_2, a 99.8% decrease from the 2019 in-person meeting (emissions of 39 910 metric tons of CO_2).

Alternative Location Analysis

Simulating single in-person meetings in alternative locations revealed that San Francisco was the least optimal location compared with any other previously used by the AAO (**Table**). The simulated Chicago meeting had the lowest carbon footprint and would have been associated with a 19% reduction in transportation-related emissions compared with the actual 2019 meeting (from 38 993 to 31 616 metric tons of CO_2). Figure 1B and D compares the attendees' travel distances and their association with transportation-related emissions for the simulated Chicago meeting. Furthermore, the location-optimization algorithm found that the top 3 meeting locations that minimized the aggregate travel distance were in northern Indiana, and the geographic area that encompassed the top 10 meeting locations included Chicago (**Figure 2**). The algorithm's result suggests more robust support for Chicago as an optimal location because it achieves a near theoretically maximal reduction in aggregate travel distance.

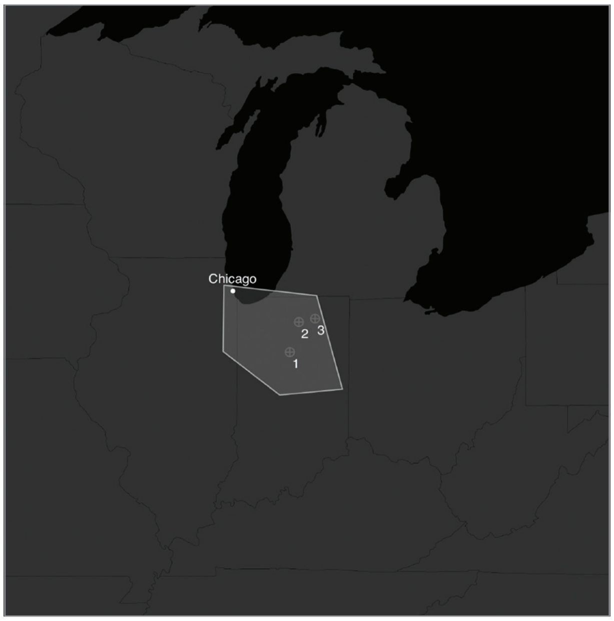
Table. Transportation-Related Carbon Dioxide Emissions of Simulated Alternative In-Person Meeting Locations Compared With the 2019 Meeting in San Francisco, California

Meeting location	Total transportation emissions, tCO_2	Per capita transportation emissions, tCO_2	Change compared with San Francisco, %
San Francisco, CA[a]	38 993	1.69	NA
Las Vegas, NV	37 167	1.61	−5
Orlando, FL	35 727	1.54	−8
New Orleans, LA	34 700	1.50	−11
Chicago, IL	31 616	1.37	−19

Abbreviations: NA, not applicable; tCO_2, metric tons of carbon dioxide.

[a] Indicates actual location of the 2019 in-person meeting.

Figure 2. Optimal Meeting Location Region Identified by the Location-Optimization Algorithm

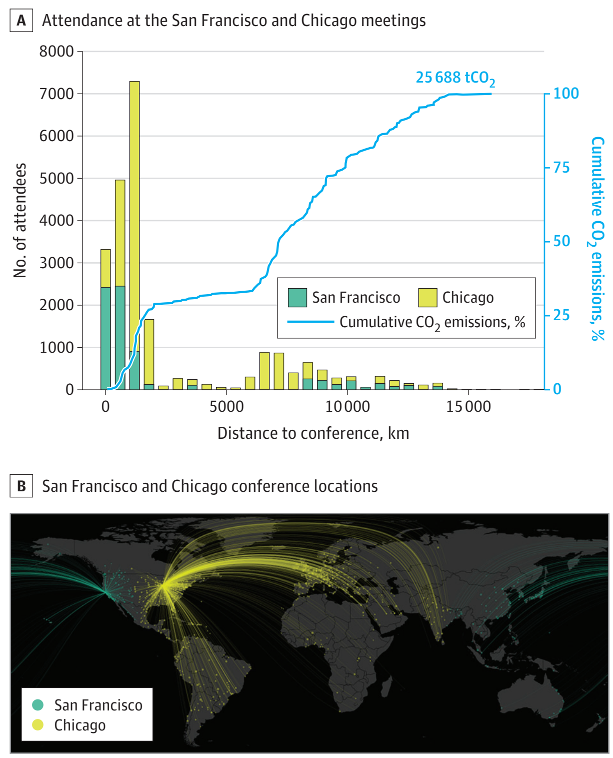


The gray polygon indicates a geographic area encompassing the top 10 meeting locations. The top 3 locations that minimized the aggregate geodesic distance are numbered 1 to 3 in descending order.

Multiple-Meeting Analysis

Total transportation-related emissions were estimated at 25 688 metric tons of CO_2 (1.11 metric tons of CO_2 per capita) for the 2-meeting format (scenario 1), with 69% of attendees (15 868 of 23 125) traveling to the Chicago location (18 810 metric tons of CO_2; 1.19 metric tons of CO_2 per capita) and 31% of attendees (7257) traveling to the San Francisco location (6878 metric tons of CO_2; 0.95 metric tons of CO_2 per capita). **Figure 3** shows attendee travel distances and their association with transportation-related emissions under scenario 1. Scenario 1 was associated with a 34% reduction in transportation-related emissions compared with the 2019 in-person meeting (from 38 993 to 25 689 metric tons of CO_2). Compared with the most optimal single meeting location (Chicago), scenario 1 would reduce emissions by an additional 19% (31 616 to 25 688 metric tons of CO_2). Adding a third meeting (scenario 2) provided marginal benefit, lowering emissions by an additional 4 percentage point change, from 34% (38 993 to 25 688 metric tons of CO_2) to 38% (38 993 to 24 166 metric tons of CO_2), compared with scenario 1, and by an additional 5 percentage point change, from 19% (31 616 to 25 688 metric tons of CO_2) to 24% (31 616 to 24 166 metric tons of CO_2), compared with the Chicago meeting.

Figure 3. Travel Distances and Cumulative Transportation-Related Carbon Dioxide (CO_2) Emissions for the Simulated 2-Meeting Scenario



Places of origin and geodesic distances to the conference for attendees to the simulated 2-meeting scenario with regional meetings in Chicago, Illinois, and San Francisco, California, are shown. tCO_2 Indicates metric tons of carbon dioxide.

Discussion

The total carbon footprint associated with the 2019 in-person meeting is estimated to be 39 910 metric tons of CO_2. Emissions for the average attendee of the 2019 in-person meeting were 1.73 metric tons of CO_2, which accounts for 39% of annual emissions for an average global citizen (4.478 metric tons of CO_2 per year) and 10% for an average US resident (17.58 metric tons of CO_2 per year).[36] To limit global warming to a maximum of 2 °C by 2100, it has been estimated that annual global per capita emissions should not exceed 1.61 metric tons of CO_2.[37] Under this assumption, our analysis suggests that merely attending the 2019 meeting may have caused participants to exceed their optimal annual carbon budget.

The estimated per capita emissions for the AAO annual meeting rank high among those reported for other medical conferences (range, 0.23-1.80 metric tons of CO_2; mean [SD], 1.19 [0.54] metric tons of CO_2).[11-18,20] The carbon intensiveness of the meeting may be due to the large proportion of international attendees and a location that necessitates long flights for many participants. Although the unique inclusion of nontransportation-related emissions was another factor, the proportion of emissions from these sources (2.3%) was relatively small. These findings emphasize the importance of attempting to reduce the attendee commute.

The carbon footprint of the 2020 virtual meeting is substantially lower, even when controlling for attendance. These findings are consistent with other published comparisons between in-person and virtual meetings[20,29,38] and suggest that holding virtual meetings could reduce emissions by several orders of magnitude. Whether the virtual meeting experience can serve as an adequate substitute for in-person participation remains unknown, and potential downsides include the loss of personal engagement and networking. However, due to the COVID-19 pandemic, virtual meetings have become increasingly common and are associated with high rates of participant satisfaction.[39-41] Additionally, an increased frequency of conference attendance does not appear to be correlated with academic productivity,[42] and virtual meetings have been associated with improved socioeconomic equity due to greater accessibility and reduced attendance costs.[39]

Careful location selection informed by the geographic dispersion of the attendance base might be another effective strategy for reducing conference emissions associated with travel. Changing the conference location should be minimally disruptive; it preserves the benefits of in-person attendance and would presumably necessitate few changes to the current conference format. Assuming a similar geographic distribution for future AAO meeting attendance, analyses show that holding meetings in locations such as Chicago may lead to emissions reductions of nearly 20%. Moreover, Chicago has been the site of previous annual meetings, so implementation may be straightforward. Emissions might be further reduced by offering multiple in-person meetings. This approach may reduce participant travel time and expenses and may allow for a more diverse set of conference venues and curricula given the reduced size. Although this may add to planning costs and administrative burden, it is possible that conference revenue would be enhanced through increased attendance given that, in aggregate, attendees would live closer to a meeting site. The potential association between altered attendance patterns and the meetings' collective greenhouse gas emissions was not considered in this analysis.

Limitations

The findings of this study are limited by the accuracy of emissions factors and the underlying assumptions. With the intention of being conservative, these analyses included only emissions sources for which data were available and would not have occurred in the absence of the meeting, which suggests that the carbon footprint of the meeting was substantially larger than estimated.

For example, the flights taken by attendees are unlikely to uniformly consist of nonstop economy fares. Nonstop flights are associated with fewer emissions, and itineraries with layovers may have as much as 63% more greenhouse gas emissions,[43] which suggests that emissions for the 2019 meeting were underestimated and that the benefit of holding meetings in Chicago may be greater than expected because O'Hare International Airport has the highest number of nonstop domestic and international flights in the United States.[44] Premium fares are also more carbon intensive because of reduced passenger density. It has been recommended that emissions associated with premium economy, business, and first-class fares be multiplied by factors of 1.5, 2, and 3, respectively,[45] and some first-class fares have been found to be associated with nearly 7 times more greenhouse gas emissions than the same economy class itineraries.[45,46] Other assumptions that may underestimate in-person emissions include the use of lower-tier hotels for bookings made outside of the AAO, the use of geodesic distance as a proxy for driving distance, and the lack of inclusion of emissions associated with the use of conference materials. The virtual meeting analysis is similarly constrained; however, given the relatively small footprint of the virtual meeting, the association is less consequential.

Conclusions

The overall value of a conference is difficult to quantify, but the benefit of an in-person meeting may justify its carbon cost. Alternatively, conference emissions could be associated with negative downstream effects that outweigh the sum of benefits conferred by conference activities. Ophthalmic conferences play a direct role in ocular health by advancing vision science; however, the effects of climate change have been associated with the development of ocular pathology, including angle closure glaucoma,[2] ocular infections,[5] uveitis,[5] and surface neoplasia.[2,5,6] Exposure to combustion-related particulate matter has also been associated with glaucoma,[47] atopy,[4] ocular surface disease,[4] and retinovascular pathology (including central retinal artery occlusion).[1,3] Furthermore, climate change may be associated with more frequent natural disasters and geopolitical conflicts, both of which have been associated with ocular trauma.[48-50]

This quality improvement study suggests that the AAO's 2019 in-person meeting was associated with substantially higher emissions compared with the 2020 virtual meeting, primarily due to transportation-related emissions. The findings from this study suggest that increasing the proportion of virtual participants, holding the meeting in locations chosen to minimize transportation-related emissions, or offering multiple regional meeting locations might reduce the carbon footprint of future meetings. Additional research is needed to evaluate the potential costs and benefits of these interventions. In the meantime, this work seeks to inform future decisions by providing both insight into the degree to which such conferences may be associated with climate change and practical strategies to reduce emissions without compromising conferences' benefits to vision science.

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