Estimating and reducing the carbon footprint of academic travel

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Academic institutions that estimate their carbon footprint commonly observe that air travel is a large contributor to emissions[1]. Work-related travel of employees and students is part of an academic organization's carbon footprint and categorized as Scope 3 emissions (Scope 1 being "direct emissions" from sources that are owned or controlled by the organization; Scope 2 being emissions associated with purchased electricity; Scope 3 being everything else, including emissions associated with purchases, work-related travel etc.). As example, air travel was responsible for 12-27% of the carbon footprint of seven universities in The Netherlands [2]. These estimates corroborate results of a multi-country carbon-footprinting effort where work-related travel accounted for up to 20% of the carbon footprint of universities in Germany, Australia and the United States [1]. The large variation in the importance of travel for the total carbon footprint of institutions will in part be due to missing data, differences in calculations and the precision with which different sources of emissions can be estimated[1]. In addition, the nature of academic activities varies between institutions with some involving more travel than others. An institution of higher education that focuses on studying and advocating global health estimated that the majority of its total carbon footprint was due to air travel [3]. Despite considerable imprecision and heterogeneity, it is evident that air travel is an important contributor to carbon emissions of institutes of higher education[1-3] and of individual research activities[4]. Universities can cut emissions from energy use, for instance by insulating buildings, adopting energy efficient policies for data storage and lab practices, and switching to renewable and sustainable energy sources. Universities can also cut emissions from the products and services they purchase, for example by prioritizing plant-based food and beverages, and repairing and recycling equipment. These infrastructural and behavior change interventions are critical and in some cases are gaining momentum. However, it is also evident that air travel cannot be ignored as source of greenhouse gas emissions.

Measuring greenhouse gas emissions associated with air travel

Considerations on what emissions to include and uncertainties in estimates

When quantifying emissions associated with air travel, there are several things to consider. The most fundamental is probably what emissions are incorporated in travel-associated estimations. There is broad consensus that aviation contributes more to climate change than simply the CO_2 emissions from burning fuels[5]. The release of gases and participles into the upper troposphere (8-18 km altitude) and lower stratosphere (10-50 km altitude) impacts atmospheric composition through three processes, each with global warming potential. Firstly, there are direct emissions of CO_2 and water vapor, both radiatively active substances, whose impact on global warming is well characterized. Secondly, aviation results in the emission of chemical species that alter radiatively active substances such as NO_x which modifies ozone (O_3) and methane (CH_4) concentrations that in turn impact CO_2 and water vapor formation and heat retention. Thirdly, aviation emits substances that trigger the generation of aerosol particles that can have a warming effect through inducing changes in natural clouds that can trap heat [5]. Whilst cloud formation can have both a cooling and a warming effect, the latter dominates. Contrails of airplanes, for instance, can lead to the formation of cirrus clouds that have a significant net warming effect [6]. Whilst the global

warming potential of the second and third process are not as well quantified as direct CO_2 emission effects, they are highly relevant and best estimates of CO_2 equivalent emissions (CO_2e) of the three processes combined are 1.9-3 times that of CO_2 alone[7]. Estimators that ignore these impactful non-CO_2 effects, such as those presented on websites of some airlines as part of CO_2 compensation schemes [8], are incomplete and 'optimistic' about the climate impact of air-travel. Other uncertainties that are relevant for estimating flight-associated emissions are the type (and thereby efficiency) of the airplane, occupancy rate, exact flight route, and weather conditions such as wind force and direction. Whilst relevant variables, these factors are evened out in estimators that are based on average conditions.

Approaches and tools to calculate the carbon footprint of travel

There are numerous calculations in scientific articles on the carbon footprint associated with academic travel[7,9-15]. Many of these present the footprint of academic conferences. The most laborious estimates identified for each conference participant the reported or estimated airport of departure, their most likely travel route including connecting flights based on websites offering airline tickets, and the distance associated with each individual flight based on a geodesic (great circle) path [10,13]. A strength of this approach is that it allows incorporation of the differences in emissions between short haul flights, that are relatively inefficient due to excess fuel use during take-off, and more fuel efficient long-haul flights. Travel kilometers can be converted to emissions using established methods that incorporate or ignore non-CO_2 effects (**Figure 1**). To mitigate the labor intensiveness of this approach and make these calculations more accessible, online calculators have been generated that allow users to simply upload an excel or csv file with the cities of departure and the destinations [7,13]. These online calculators use the same geodesic path and CO_2e calculations but ignore the fact that some journey consist of multiple travel legs. Nevertheless, the differences between these approaches are generally small and not too relevant when a large number of flights is considered. The advantage of online tools for rapidly assessing travel-associated carbon emissions includes the option to easily explore different scenarios. One online planner for instance allows setting different thresholds for travel by train[7], another allows high resolution maps with travel routes to be generated and downloaded [13]. This rapid generation of maps and associated summary measures can for instance be used when a choice has to be made between meeting locations and where the consequences of different options for travel-associated emissions can be used in decision-making.

The carbon footprint of academic activities

Examples of conferences and a rule of thumb estimate

Academic conferences are probably the largest meetings of researchers and have been the focus of several efforts to estimate travel-associated emissions. The vast majority of carbon emissions associated with conferences are due to air travel. Catering, ground transportation and accommodation together account for 4-10% of total emissions, dwarfed by emissions associated with international travel [14,16]. To provide one example of a relatively large conference with a wealth of associated data, we present the 2019 edition of the annual conference of the European Society of Clinical Microbiology and Infectious Diseases that welcomed 13,663 participants in Amsterdam (**Figure 2**)[13]. Together, conference participants from six continents traveled a total of 85.9 million kilometers. When expressed as return trips to the moon, with an average distance of 384,400 km [17], this total distance is equivalent to 113 return trips to the moon. Using a calculator that included non-CO_2 emissions, this travel was estimated to result in 16,558 tons CO2e emitted[13]. For most audiences, carbon estimates are difficult to interpret. When

expressed relative to the annual emissions of average European households, the conference travel emissions were equivalent to the annual emissions of 1,160 European households. There have also been analyses on the amount of Arctic ice that is lost for each ton of CO_2 emitted, estimating that each ton equates to 3m^2 of Arctic ice lost [18]. When using this estimate, the conference emissions would result in the loss of 51,139 m^2 of Arctic ice, a surface area equivalent to approximately 7 soccer pitches. These extrapolations have to be used with caution since they come with uncertainty but are more likely to capture the imagination than tons of CO_2.

In addition to the environmental arguments for thoughtful travel, it can be argued that travel is not the most efficient way of spending time that, for the participants of the above-mentioned conference, could have been used for research, patient care or teaching. When calculating the time investment related to air travel by calculating the duration of flights and adding a realistic waiting time at airports for continental and intercontinental flights, it was estimated that the 13,663 participants spent a total of ~ 193,000 hours or 4,836 workweeks to travel to the conference venue [13]. There are numerous other examples of the carbon footprint of conferences and meetings, some of meetings as large as 52,000 participants[15]. The common finding here is that international conferences with participants from multiple continents typically have emissions in the range of 0.5-2 tons of CO_2e per conference participant [10,13,15,19]. In an opinion piece, this estimate was put in perspective indicating that if 7.8 million researchers worldwide each travel to one international conference per year, the emissions (~8 million tons of CO_2e per year) would be larger than the total carbon footprint of some nations[19].

Other reasons for academic travel

Whilst conferences are obvious examples of 'carbon-intensive' academic activities, there are more reasons for academic travel. One activity that has sparked some debate is the way by which funders organize grant reviewing processes. As an example, we present the carbon footprint associated with the process of selecting proposals for the European Research Council Starting Grants for early career researchers (ERC-StG; ~400 laureates each year). In 2019, applicants traveled a total of 1.8 million km for their 30-minute interviews while panel members traveled a total of 2.9 million km for two meetings, the first to select proposals for a full evaluation and the second for the actual selection of laureates. Carbon emissions combined to 1,519 tons of CO_2e each year [9]. During the years of COVID-19 associated travel restrictions, ERC-StG proposals were evaluated by virtual means. Once travel restrictions were lifted, the old modus operandi of in-person meetings was resumed with the exception that pitches and interviews of applicants were now done by virtual means, saving ~33% of emissions as well as substantial travel funds and time. There are numerous similar funding meetings where in-person meetings were temporarily replaced by eco-friendly virtual meetings during the COVID-19 pandemic, but have become in-person again subsequently. An unbiased and well-considered decision is important in these meetings; fellowships can be decisive for the careers of (young) researchers. This importance is sometimes used as argument for in-person panel discussions. At the same time, there is no evidence that the wrong decisions were made during the virtual panel meetings. In fact, several studies suggest that virtual meetings may allow for less biased [20] and more efficient interaction [21], especially in culturally diverse teams [22]. Whilst in-person meetings are superior for creative processes (as described in some detail below) [23,24], decision-making can be as good or potentially superior by virtual means [23]. This argues that virtual meetings can be considered in decision making processes like grant reviewing processes.

Approaches to reduce travel-associated carbon emissions

As highlighted in the travel policy of the Wellcome Trust, a major funder of research in the UK, there are three pillars in reducing the environmental impact of travel: i) minimizing the number of journeys taken by using (virtual) alternatives where possible; ii) choosing travel that has a lower carbon impact, where practical; and iii) offsetting carbon emissions of journeys that are still made[25]. We will discuss the first and last pillar in some detail. Regarding low carbon travel, there is an increasing number of institutions in Europe that impose a minimum distance required to fly and provide sustainable travel advice to promote low carbon travel [2] . Some tools to measure travel-related emissions and facilitate greener travel are listed in Box 1. Promoting travel by train or car for short distances is a feasible measure in Europe and other parts of the world where train connections are reasonably good. For destinations that can be reached within 7 or 8 hours by train, this mode of travel is mandatory at some European universities and recommended at others [2] although exceptions are regularly permitted. In addition to the inefficient train networks in large parts of the world, another relevant limitation of this measure is that long-haul flights often outnumber short-haul flights. Over 60% of flights by employees of Wageningen University in The Netherlands were intercontinental and long-haul flights account for a much larger distance traveled (84% of all flight kilometers at the University of Groningen came from long-haul flights). Whilst meaningful reductions can be achieved by low-carbon travel, this is unlikely to affect the majority of travel-associated carbon emissions. That brings us to the other two pillars.

Virtual alternatives to in-person meetings

Virtual conferencing has existed for many decades. Already in 1916, a virtual meeting of the American Institute of Electrical Engineers was organized. At that time, 5,000 attendees across four time zones called in for a meeting that was considered a triumph of engineering and that was covered in major newspapers. Despite this early success, it took another century for most academic societies to be attracted to, or perhaps to be forced to, virtual conferencing. During the period when COVID-19 related travel restrictions were in place, there was a steep rise in the number of virtual conferences that was organized [19,26,27]. It was quickly acknowledged that virtual conferences can be an environmentally friendly alternative to in-person meetings. It should be noted that also virtual meetings are not carbon neutral. The major driver of the ecological impact of virtual meetings is the use of electricity associated with servers for streaming content and computers that are used by meeting participants [11]. There have been several studies that calculated the carbon footprint of large virtual meetings in a direct comparison with in-person meetings. These studies conclude that virtual meetings have a 1,000-6,000-fold lower carbon footprint per meeting participant[9-11,13,28]. The wide range is partially explained by variation in the electricity mix of different countries. CO_2 emissions per kWh of electricity are considerably lower in countries where renewable energy sources are prominent, compared to those that currently still rely on fossil fuels for electricity[4]. With the rapid increase in renewable energy across the globe, it is very likely that the gap between the footprints of in-person and virtual meetings will become even larger in the near future. In addition, virtual conferences typically attract a broader and more diverse population that may not have attended meetings for financial reasons, difficulties in obtaining visa and care duties[14,27,29].

Whilst the environmental sustainability and accessibility benefits of virtual meetings are beyond dispute, in-person events are often considered more effective and enjoyable. Many academic societies that organize conferences explicitly advocate these conferences as prime opportunity to foster a sense of belonging to the society [13,30]; it is difficult to translate this feeling to a virtual format. On a social-level, in-person meetings with dinner and drinks and unexpected meetings are a great way to meet colleagues and allows building friendships and relationships. Dr Anthony Fauci, former director of the National Institute of Allergy and Infectious Diseases (NIAID) at the National Institutes of Health (NIH) in the USA, commented that his favorite Keystone Symposia meeting was

in Utah, USA in the early 1980s that he attended with his soon-to-be wife Dr Christine Grady [31]. At in-person meetings, participants can feel a sense of community, feel visible and acknowledged. Participants are able to participate in discussions and debates that are shaping their professional fields and contributions are recognized and maybe even celebrated. Where in-person conferences thus allow for both information sharing and social aspects, virtual conferences tend to primarily focus on information sharing and have largely failed to create a sense of community. Online formats that focus on sharing information where a few presenters broadcast their work to a passive audience fail to deliver on the social benefits. Whilst some elements of in-person meetings may be nearly impossible to cater for in online events, there are ample opportunities to innovate.

Building community online

To create interesting virtual meetings that participants enjoy, organizers need to build an engaged community. Some of the thoughts and recommendations below are already used in practice (but not published on) or are inspired by the book *Citizens* by Jon Alexander and Ariane Conrad [32]. Online conferences can improve to 'build community' and include multiple ways to engage participants. Here, it is important to consider that everyone is an active participant, not only invited speakers. Providing plenty of modes of participation for the community to get engaged during the virtual event is important. We list several examples. One interesting approach is to make presentations available several weeks prior to the event. Participants can then be prompted and encouraged to leave a comment or question for the presenters and incorporate this feedback into live discussion sessions in the main program; gatherings of Astronomers for Planet Earth (A4E) use YouTube for this. Organizers can also help people to connect and get to know one another. As very easy example, it is possible for registrants to introduce themselves using a digital sticky note or a video message that they post in the virtual conference space. At the beginning of a session, it is good practice to ask participants to say hello and share where they are connecting from in a chat box. During the conference, it is possible to explicitly value online contributions. One approach is to celebrate participants' contributions with gold, silver, and bronze medals voted on by fellow participants. For example, excellent presentations, innovative work, supportive mentorship can be awarded.

There are also many innovative virtual networking platforms that are specifically designed to humanize the online experience that was lacking in most of the hastily organized virtual conferences during the COVID-19 pandemic. Currently available innovations include 3D virtual conference environments with exhibiter boots, animated avatars for participants, games that are embedded in the social interaction space, spatial connect options and virtual tables where participants can join and benefit from private audio-video interaction. Developments are fast and opportunities for better online interaction and networking are improving rapidly. At the same time, younger generations are entering the academic playing field who grew up with a vibrant online social life; it is likely that these future academic leaders will be better adapt in using and enjoying virtual modes of social interaction.

Preparing a virtual event

When preparing a fully virtual or hybrid online and in-person event, it is important to make serious (time) investment. Whilst smaller events can sometimes be effectively organized using technologies that are already used in daily academic practices (e.g. Zoom, WebEx), professional conferencing platforms can improve the experience of (larger) meetings. It is beyond the scope of this chapter to review conferencing platforms. Heterogeneity in digital literacy of conference participants makes it important to help less adapt participants to navigate the online options. When preparing for an event, it is also important to consider the needs of the targeted community and provide fora that help address them. If a new technology or method is important in the field – work with experts to host online

training. If professional development is a critical topic – create a booking platform for networking that runs throughout the program. For these networking events, that can be short and take the form of online professional speed-dating, it can be valuable to ask leaders in the field to commit to a number of slots where they are available to meet with fellow participants. Learning about new opportunities is an important draw for people to attend conferences. Here, it is recommended to create an opportunities board in your virtual space. Before the event, one can ask funders, team leaders, editors, and research institutions to post information about forthcoming grants, job opportunities, calls for papers, visiting programs, etc.

It is also important to embrace some of the benefits or unique opportunities that virtual platforms bring. Using a voting option allows moderators to let the audience vote for questions to be discussed, improving the democratic element in academic discussions that can otherwise be dominated by the most vocal attendants. In addition, it is possible to let online sessions be followed by virtual breakout rooms where participants can continue the discussion with each other and a presenter. These small but valuable components can add great value to online gatherings. Given that virtual and in-person conferences will provide a different experience to users, it is important to explicitly celebrate the achievements and benefits of a successful virtual meeting (e.g. the number of participants and countries attending, the carbon emissions averted). This content works well on social media and can raise awareness about the event.

Practical challenges with virtual events

Time zones are sometimes mentioned as a challenge in virtual conferences. Whilst virtual meetings are free of nighttime travel and jetlag, managing time zones for a virtual event is highly important. Meeting organizers are accommodating time zones in various effective ways.

- The American Society of Tropical Medicine and Hygiene (ASTMH) Green Task Force host a monthly meeting, which alternates between Asia-friendly and Africa-friendly times. Each meeting is recorded and a transcript is generated and shared with all members.
- Climate Action Network in International Education (CANIE) and Astronomers for Planet Earth (A4E) organize their annual virtual congresses by scheduling each session twice during the program. Ensuring that most participants can attend during (or close to) normal working hours.
- A4E allows participants to watch presentations at any time, 2 weeks prior to the scheduled program. This allows participants to manage their own time and allows the actual meeting to focus on discussion rather than broadcasting presentations.
- Tufts University and London School of Tropical Medicine and Hygiene hosted a hybrid meeting in 2 different locations simultaneously. The keynote talks were held at a time that was convenient for both locations and discussion involved participants in both locations. The social events and other sessions took place locally, somewhat like the example of Chicago on Schier (see box below).

Another challenge that is regularly mentioned in relation to virtual events is the difficulty to focus and truly commit to the event. Multi-tasking by attending a conference and at the same time continue other daily activities is a threat to a valuable conference experience. Workplaces and team leaders should adopt a policy whereby staff participating in virtual conferences (whether scheduled during normal working hours or during the night) take time away from their normal work duties. They are effectively ‘out of the office’ as if they had travelled to attend a conference. This allows participants of online event to be disciplined and focus on the virtual event.

Hybrid events

In addition to fully virtual meetings, there is of course also the option of hybrid events. Since the forces online conferences during the COVID-19 pandemic, many (large) conferences have retained the option to attend virtually. Whilst this is laudable and allows eco-minded participants, as well as those with care (or other) duties to attend virtually, it also brings challenges. There is a risk of feeling like a second-rate participant if discussions are dominated by those present in person; an elegant option that is adopted by meetings of the European Centers for Disease Control (ECDC) and of Open Philanthropy, is to only discuss questions that are posted online. The conference illustrated in Figure 1 also allows for online participation. Possibly related to the fact that conference fees are nearly identical for online and in-person attendance, the online option is not very popular and accounts for only 6-8% of participants [13]. Whilst hybrid options can theoretically greatly reduce the carbon footprint of academic conferences [10 33], there is room for improvement to make them truly attractive.

When flying, is carbon offsetting an easy fix?

The third pillar of the Wellcome Trust travel policy is offsetting carbon emissions. One of the most common approaches to limit the climate impact of academic travel is indeed to compensate for CO_2 emissions through offsetting schemes. Whilst considered by some to be part of the solution and sometimes advocated or facilitated by meeting organizers to make meetings more environmentally sustainable [7,13], the approach also meets considerable criticism. Three commonly mentioned points of criticism are that i) prices that are used in offsetting schemes are unrealistically low; ii) the achieved emission reductions are often much lower than those promised; and iii) i) offsetting may create a situation where those who can afford to offset their emissions are no longer incentivized to reduce them.

So what is a realistic price for offsetting carbon emissions? Typical schemes that adhere to the Gold Standard, a Switzerland-based organization with relatively high standards in certified emission reductions, offer offsets in the range of €6-25 per ton of CO_2 emitted [34,35]. Assuming that these schemes achieve the promised emission reductions, some argue that this price is unrealistically low. The 2050 Foundation that investigates the true price of compensated emissions, argues that low-cost offsets are problematic. Low-cost offset programs are typically focused on avoiding additional emissions or actions that in the long run may remove CO_2 from the atmosphere such as planting trees or preventing forest loss. These offsets are much cheaper than the cost involved in directly neutralizing current emissions. The price of direct air capture and storage of CO_2, for instance, is in the range of €100-350 per ton CO_2 [36] and requires considerable infrastructure to be used at scale. There is also another ethical challenge in depending on cheap offsets that assume future benefits. Using cheap offsets today will deplete their availability for future generations and will make carbon offsetting in the future increasingly expensive. One may still argue that offsets are better than nothing, provided they work and do not incentivize more air travel.

Do carbon offsets deliver on their promise?

As indicated above, a common carbon offsetting mechanism is based on reducing emissions from deforestation and forest degradation. The central concept is that improved monitoring, conservation and management of forested areas can remove CO_2 from the atmosphere or prevent its emission into the atmosphere. There is limited rigorous

evidence for the performance of such schemes [37-39] and the robustness with which the impact of conservation efforts can be quantified is debatable. This quantification relies on scenarios and projections of deforestation and forest degradation in the absence of conservation efforts. In a recent study, the plausible impact of conservation efforts was estimated by comparing conservation areas with control areas that initially had similar characteristics and deforestation pressure [40]. From 26 analyzed project sites, the majority did not show significant improvements in conservation outcomes compared to control areas and for those where there was a beneficial impact, this impact was typically <10% of that what was projected and on which offsets were based [40]. This sobering performance has repeatedly been demonstrated [37-39], although there are also positive exceptions where impact was achieved [40]. There are several possible reasons for this poor performance of most carbon-funded forest conservation projects, including unrealistic (exaggerated) projections of deforestation in the absence of conservation and struggles to effectively implement conservation efforts. Directly planting trees would in some ways be better, or at least more direct, than preventing deforestation. Whilst there are high failure rates with tree-planting projects [41] and there are political and perhaps ethical challenges in planting trees in low-resource settings to offset carbon emissions from wealthy nations, the future will have to learn whether this type of offsetting can be improved to deliver on its promise [42].

Another common approach is the promotion and distribution of energy efficient cooking stoves. With 2.4 billion people worldwide who rely on kerosene or smoky solid fuels like wood or charcoal, cooking may be responsible for 2% of global greenhouse gas emissions [43] and is thus a logical area for sustainable improvement. Efficient stoves can reduce emissions through better combustion and, by their efficiency, require less fuel for the same heat. Most of the carbon offset initiatives that involve energy efficient cooking stoves aim to achieve impact by replacing stone fires or other inefficient stoves with improved firewood stoves. Only a minority of projects distribute stoves that rely on solar energy, electricity, natural gas, ethanol or certain pellets that reduce smoke formation sufficiently to be labeled clean by the World Health Organization (WHO) [44,45]. In an analysis of projects in 15 countries, Gill-Wiehl and colleagues quantified the usage of new stoves, the amount of cooking fuel that was used before and after obtaining the new stoves and the energy efficiency of the (new) cooking fuel. They conservatively estimated that the cookstove projects over-credited their impact approximately 9-fold. This was in part due to a net increase in overall cooking fuel consumption; the improved stoves made cooking easier and provided an extra (rather than replacement) of the original inefficient stove [45]. The authors indicate that it is important that offsetting projects that rely on energy efficient cooking stoves rely on stoves recommended by WHO [45]. At present, it is prudent to exert caution when interpreting the benefits and CO_2 emission reductions that are claimed by carbon offsetting schemes that promote and distribute energy efficient stoves.

Carbon offsets as 'get out of jail for free' card

Carbon offsets may be part of thoughtful travel, especially if realistic prices are used for offsets. There is, however, a concern that the feeling that damage can be neutralized may stimulate damaging behavior [46,47]. Testing whether this fear is justified is complicated. One interesting attempt to quantify behavioral changes that may be induced by offsetting environmental damage involved a randomized trial in a German your hostel. All guests received information on the electricity use and carbon cost of showering. Part of the guest received additional information that the hostel compensated all carbon emissions by financially contributing to an environmental project. The time that 7,350 guests used the shower was subsequently measured and compared. Guest who received information that the carbon costs were compensated, used the shower 5-15% longer [48], suggesting that damaging behavior may increase if there is a promise of offsetting this damage. Other studies similarly show that electricity consumption may increase when an offsetting scheme makes use 'guilt-free'[49].

In conclusion, the price per ton of CO_2 is likely to be too low in most current carbon offsetting schemes, schemes typically fail to achieve the impact that is anticipated or promised and there are indications that carbon offsetting may stimulate damaging behavior or, putting it more mildly, dampen the incentive to reduce emissions. Whilst at an individual level, emission compensation schemes can be part of a sustainable lifestyle, offsetting is currently not a solution to global warming that should distract from the need to reduce carbon emissions.

Concluding remarks: towards thoughtful academic travel

It is important to emphasize that science benefits from strong international collaborations and networks and equally important to acknowledge that for most people, there are evident advantages to in-person meetings and conferences. Virtual conferences and virtual meetings are – and in our opinion should be – advocated in a time when we have to drastically reduce our carbon emissions to prevent the worst of the climate crisis. Whilst a large consultation concluded that the vast majority (74%) of scientists also want virtual meetings to stay [29], it is important to be honest about the (current) shortcomings of virtual meetings. In-person meetings allowing for more enjoyable and bonding interactions. In addition, there is scientific evidence that creativity thrives better in direct personal interactions. A detailed study of human interaction, idea generation and decision making that directly compared in-person gatherings with videoconferencing, indicates that the latter may inhibit the production of creative ideas [23]. In contrast, decision-making and prioritization of ideas was at least as good, and possibly even more effective, online[23]. While the benefits of online and in-person are often contrasted, also in this chapter, this is a false dichotomy. There is good reason to combine virtual and in-person meetings and consider a future where both approaches are used in concert. Generating new ideas, brainstorming about new projects and building new collaborations clearly benefit from in-person interaction and this interaction should be catered for. At the same time, (smaller) meetings that are primarily organized to compare ideas or proposals and take decisions can often be organized efficiently online.

This chapter is also not a pledge against academic travel. Instead, it hopes to stimulate action and more thoughtful academic travel. If we acknowledge that in-person meetings and conferences have important roles in academic practices and that there is currently no good way of truly compensating carbon emissions, we can consider the frequency and scale at which these events should be organized. Some societies organize biennial conferences, others have established a system where in-person and virtual conferences alternate. Whilst location optimization models to select venues that minimize travel may often yield only small reductions in carbon emissions (<5%) [33], hub-and-spoke models and decentralized approaches where multiple regional venues are selected can have a much larger impact (reductions of 60-70% in some analyses [10 33]). The largest reductions are achieved by reducing the frequency and scale of in-person conferences. This would ideally be taken on by the conference organizers and there are initiatives where thousands of scientists call upon conference organizer to take this up as their responsibility [50]. Also at the level of institutes of higher education and (research) departments, it is possible to set carbon targets. This can translate in a maximum number of in-person participants to a given conference each year.

More generally speaking, it is important to define the objectives of travel when adopting a thoughtful travel approach. If visibility of the institute is one of the goals, a (small and potentially rotating) delegation of employees can be selected to attend a meeting. If a (junior) researcher hopes for international exposure and networking experiences at a conference abroad, it can be highly beneficial to combine this with a work-visit to a collaborating group in the same (or neighboring) country. If an established researcher is invited for a meeting, it may be possible to delegate a more junior colleague who generally travels less [51] and may benefit more from it. When networking and productive interaction with colleagues is the primary goal for traveling, smaller meetings are likely to be more productive than mega conferences [13] . There are numerous other examples of situations where a thoughtful approach to academic

travel is possible. With the creative minds in academia, there is every reason to be optimistic that the international character of science and environmental sustainability can go hand in hand.

Figure 1. Emission factors as a function of the distance flown. Emission factors are given in kilogram as dashed lines (CO_2) or solid lines (CO_2e). Travel is given per kilometer; calculations assume economy class travel and one continuous leg. Seven data sources are presented. Figure reproduced with permission of Didier Barret. Details are published elsewhere [7].

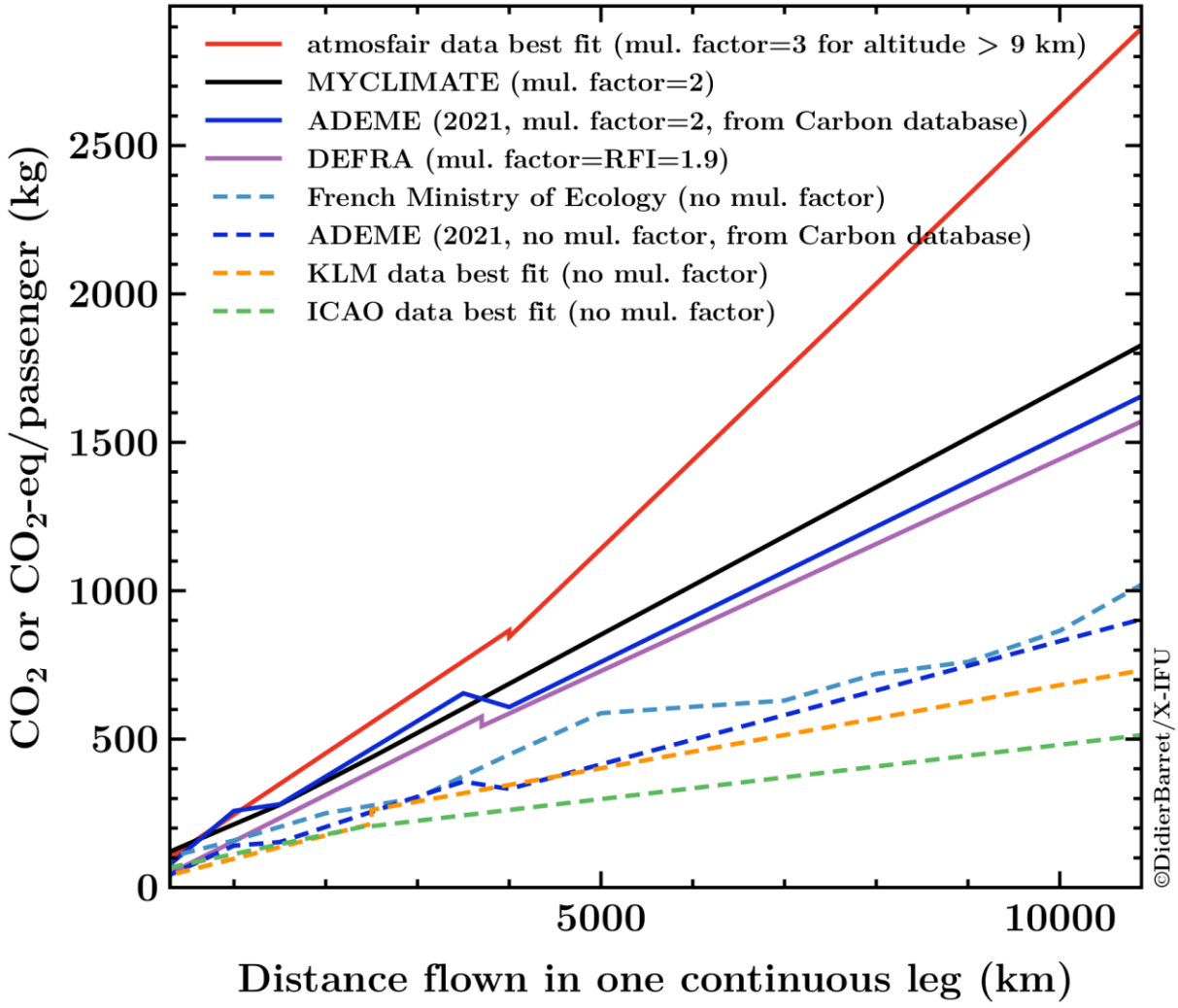
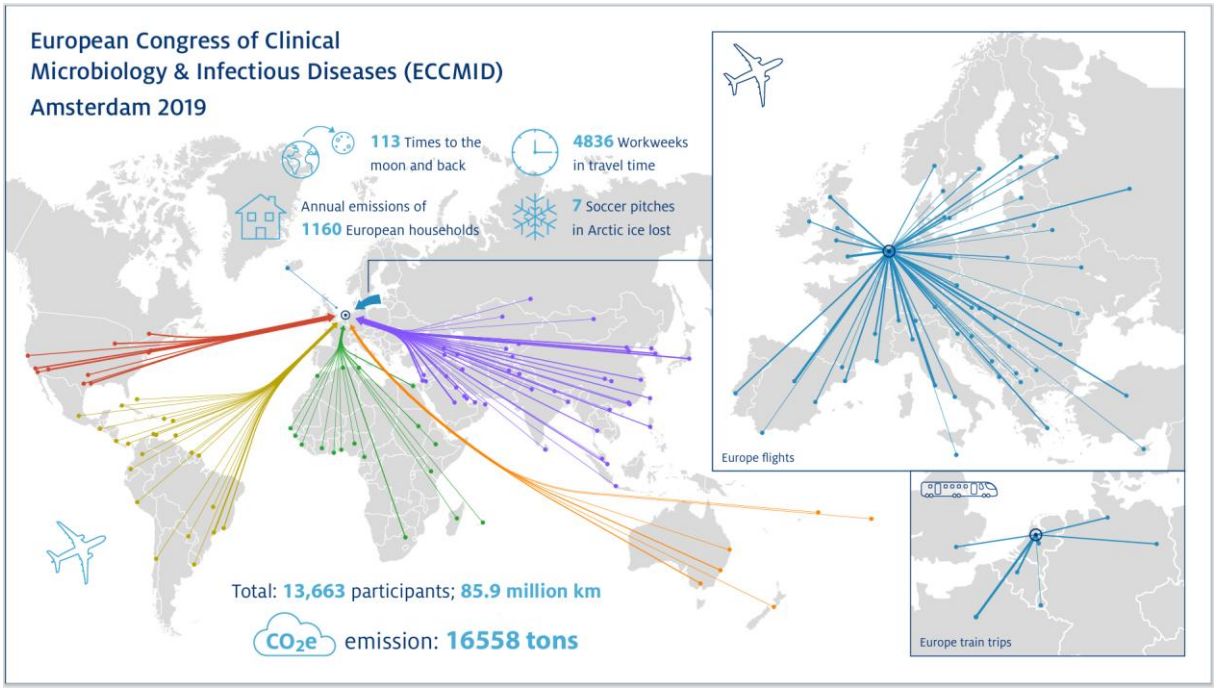


Figure 2. The travel carbon footprint of the 2019 European Congress of Clinical Microbiology & Infectious Diseases (ECCMID). The thickness of the line reflects the number of journeys, colors indicate the region of origin. The figure is reproduced with permission of the journal Clinical Microbiology and Infection. Details on the calculation are in the text of this chapter and in the original article [13]



Box 1. Tools to measure travel-related emissions and encourage lower carbon modes of travel.

Travel emissions calculator

Estimates the total emissions between a point of origin and destination for one or multiple travelers. https://travel-footprint-calculator.irap.omp.eu/home.html

Travel emissions calculator and map

Estimates the total emissions between a point of origin and destination for one or multiple travelers and generates a travel map and data summary. https://bousema-lab.shinyapps.io/travel_calculator/

Greenhouse gas emissions converter

Estimates the total emissions between a point of origin and destination and compares different modes of transport. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Global train travel guide - The Man in Seat 61

Provides information about train routes, train companies and how to purchase tickets. https://www.seat61.com/

Train journey planner for students - Go2Rail

Helps students to plan their European travel itineraries so that they can meet up on route travel together. https://www.go2rail.eu/

Box 2. **Inspiring examples**

A low-carbon international conference

Whilst many top quality medical conferences are international, much of the daily network of participants is national or regional. With that in mind, *Chicago on Schier* has been organized since 2012 as local hub on one of the Dutch islands. Each year, approximately 60 Dutch oncologists now choose to visit Schiermonnikoog instead of Chicago for the annual meeting of the American Society of Clinical Oncology (ASCO). The 4-day program on Schiermonnikoog lags one day behind the conference schedule in the US. In this manner, all content can be viewed on demand despite the time difference. The participants attend a plenary 'virtual ASCO', where the program committee makes a selection of sessions. In addition, there is room for interpretation, moderated in-depth discussion with (national) colleagues and a live connection with oncologists in Chicago. The scientific content is complemented with a social program in the evening to foster the conference feeling and allow for networking. The formula thus achieves both the knowledge dissemination and the networking objectives of conference while avoiding jetlag and the large carbon footprint associated with international air travel.

A prize for the research group that embraces Thoughtful Academic Travel

The Department of Cognitive Neuroscience of the Donders Institute in Nijmegen, the Netherlands has taken up the challenge of reducing air travel while retaining a strong international focus. Since 2022, the department undertakes concrete efforts to reduce air travel for the many successful research groups it hosts. Its impact is monitored by annual reporting of work-related travels, including the destination, the staff member who traveled and the means of transportation. This registration serves as an entry for the Sustainability Team Award, with the winning group receiving €10,000 for their lab budget. The assessment values virtual conference attendance, green transportation choices, flight equity across career stages, and improvements in emission reductions over time. The focus of this competition is not on 'no travel' but on 'thoughtful travel'. In addition, annual seminars are organized to raise awareness and encourage sustainable travel behavior. In the future, the group aims to introduce a flight tax for an institutional Sustainability Fund that will be used to support local green initiatives.

Social and low-carbon travel

The Climate Action Network for International Educators (CANIE) collaborates with conference organizers and engages participants to reduce the carbon footprint of conferences[52] . In 2022, CANIE members initiated the 'Travel With CANIE' campaign to encourage colleagues to use low carbon modes of transport to travel to the Forum on Education Abroad in Milan, Italy. CANIE successfully made this behavior change initiative fun, attractive, and social for participants, which are key elements to engaging people in changing habits[53]. CANIE set an emissions reduction target and asked participants to pledge their commitment with an online registration form. Using the hashtag #TravelWithCANIE they leveraged social media to engage their community, track, and report on progress against their target. Low carbon travellers posted updates and their smiling faces as they boarded trains and meet with colleagues along the way. Each year, the initiative is becoming more popular. Various conference organisers promote the effort on their website and low carbon travellers are celebrated at participating conferences. At the 2022 European Association for International Education conference, CANIE was bestowed with the President's Award. In 2024, the year of the Olympics, CANIE used social media to create their own winners' podium and awarded medals to the countries with participants making the greatest emissions savings. For two consecutive years, the campaign has exceeded their emissions reductions targets and the CANIE team set up a poll on social media to ask their community what their new, more ambitious target should be. CANIE's approach is an inspiring example of how collaborating with key partners and celebrating low carbon choices can be very successful.

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