Report on travel-related carbon emissions of DISC/PODC

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Context. This report has been written in September 2023. The authors are environmental co-chairs of DISC 2023. The main goal is to evaluate how the choice of locations impacts the CO2e emissions of the participants when traveling to conferences.

Structure of the document. Section 1 is an executive summary, for those interested in the key figures. Section 2 is the methodology section. In Section 3 we give more details about the results, and how sensitive they are to our methodology choices. In Section 4, we explore how a few modifications of the conference system would impact these numbers.

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1 Executive summary

The main result of this study is the following table of the average CO2 equivalent emissions per DISC/PODC participant of for the return trip to the location of the conference.[1]

Conference location	CO2e per participant (tons)
London	2.3
Madrid	2.6
Paris	2.1
Rome	2.5
Vienna	2.4
Berlin	2.4
Jerusalem	3.3
Augusta	3.4
New Orleans	3.8
Orlando	3.7
San Francisco	4.3
Toronto	2.9
Mexico City	4.6
Tokyo	5.7

As will be discussed later, the precise numbers have to be taken with a grain of salt, but for comparison between different locations, these are reliable.

[1] CO2 equivalents (CO2e) gather the impact of all green house gases in one number.

The take-home message here:

- Different locations correspond to very different average emissions per participants. To stay below 3 tons, the conference has to be on East Coast US/Canada or in Europe. (Note that 3 tons is already a lot more than the annual emissions of Paris' agreement.)
- Conference locations is a complicated topic, with many parameters, but the emissions should be one of the main criteria.
- Alternatives should be considered. We run simulations for scenarios where the 10% furthest participants are allowed to give the talk online, and simulations with two hubs. These do reduce the emissions significantly.

2 Methodology

This part has two purposes: explaining the methods to support our findings and providing some guidelines for people who want to do similar calculations (*e.g.* for another conference). Later in the document, we will justify our choices by a basic sensitivity analysis.

2.1 Data collection

Choice of scope. Our raw data are the lists of (affiliations of the) participants of past editions of DISC and PODC. Since it is a common belief that DISC and PODC have basically the same community, we looked for the data for the two conferences, and considered them as one.

The years for which we gathered participants lists are 2016, 2017, 2018, 2019, 2022 and 2023. Years before 2016 were not considered, since they might not be representative of the community today. We chose to exclude the data from 2020 and 2021, since the conference were fully or partially online these years, due to COVID. We expect that the participant lists of 2020-21 will contain people who would normally not attend these conferences, and are not part of the 'core community'. Of course, making the conferences available to these people as well is a separated discussion, beyond the scope of this report.

We were able to include PODC 2023, but not DISC 2023, since the registration had not closed at the time of writing, so we chose not to include this incomplete data. We note that PODC 2023 was part of FCRC, which most probably influences the set of participants. However, it is only one of our four PODC datasets, and PODC is planning to take part in FCRC every four years, so we thought it would be fair to include it.

Asking and getting the data. We contacted the general/local chairs for all of these years for both PODC and DISC. We could get all the lists for DISC (except 2023), but only 2018, 2019, 2022 and 2023 for PODC. (The chairs of the other years replied, but the data has been lost, or deleted for privacy reasons.)

These are the locations of these conferences.

- DISC 2016, Paris.
- DISC 2017, Vienna.
- DISC 2018, New Orleans.
- DISC 2019, Budapest.
- DISC 2022, Augusta.

- PODC 2018, London.
- PODC 2019, Toronto.
- PODC 2022, Salerno.
- PODC 2023, Orlando.

2.2 Data preprocessing

Basic anonymization. A first step was to remove the participants names from the files, since we only needed the affiliations, and affiliations are better than names in terms of privacy.

Affiliation standardization. A second step was to standardize the affiliations. Many places have different names, and it makes later steps more complicated. For example, *CNRS, IRIF* and *Université Paris Cité* refer to the same place. For each standardized affiliation, we looked for the country and city.

Clustering. For both computation and privacy purposes, we decided to group cities by areas. For each area, we chose a city, that would give its name to the area, and also be the city from which the distance estimates would be made. There are several constraints on this clustering:

- It should be fine-grain enough such that it does not induce too much error in the final carbon emissions estimates.
- It should be coarse enough to avoid privacy issues (recovering too easily the names of the participants from the areas). This allows to make the processed spreadsheet public.
- Ideally, the number of clusters is not too large, in order to save on distance computations (which requires a specific manual processing, see below).

In order to satisfy Item 1, the rule of thumb was that traveling inside the cluster would be much cheaper (in CO2) than between clusters, which typically means that people would not fly within a cluster. For a few participants, it was difficult to satisfy both Item 1 and 2. E.g. participants from Qatar or Iceland. We decided to remove them from the dataset. This corresponds to less than 1% of the participants.

In the end, our clusters correspond to the following 30 cities.

- Atlanta
- Bangalore
- Berlin
- Boston
- Calgary
- Chicago
- Dallas
- Denver
- Frankfurt
- Jerusalem
- London
- Madrid
- New York
- Nicosia
- Paris
- Phoenix
- Pittsburgh
- Rio de Janeiro
- Rome
- San Francisco
- Seoul
- Shanghai
- Singapore
- Stockholm
- Sydney
- Tokyo
- Toronto
- Vienna
- Zurich

2.3 Choice of cities for conference locations

Our goal is to evaluate how different carbon emissions are for various conference locations. We chose to evaluate the locations of the conferences of our data set, both for validating some of our simplifications (see later) and because conferences tend to return to close places (because this is where there is higher density of researchers from the community).

We also evaluated the locations for next years (either already decided or with current bids). Finally, we added Tokyo, San Francisco, and Jerusalem, since they are in areas that are popular for conferences, and do not appear yet in our list of locations.

The final list of 14 target cities is the following.

- Paris
- Vienna
- New Orleans
- Augusta
- London
- Toronto
- Salerno (Rome)
- Orlando
- Mexico City
- Madrid
- Tokyo
- San Francisco
- Berlin
- Jerusalem

2.4 Evaluation of CO2e emissions of traveling between two cities

What we count in this document are *equivalent CO2 masses* (CO2e), and do not correspond to actual CO2 emissions. The reason is that plane travel, in addition to its raw effects of releasing CO2, also contributes to global warming by releasing other substances including nitrogen oxides and water vapor, and releasing them at high altitudes [4]. For some details, see for example: Environmental effects of aviation on wikipedia.[2] For this reason, the environmental footprint of plane trips is usually expressed as an equivalent mass of conventional CO2 emissions.

We computed the estimated CO2e emissions of traveling from any of the 30 source cities to any of the 14 target cities, and back. This required some choices, that we believe do not impact the results in an important way. Below is the method we used.

- If there exists a train connection that would take less than 8 hours, we consider that the travel will be by train, otherwise by plane. (We made exceptions for Vienna-Berlin, because there is a convenient, direct 8h20 train, and Pittsburgh-Toronto that is 5 hours by car).
- For train the CO2e emissions were approximated by: 1 - evaluating the distance, taking Google maps distance by car (back and forth) and 2 - multiplying by the average CO2e emissions by kilometer for trains, for which we used 0.03 tons. In reality high speed train are mostly in the 0.006-0.012 regime, local train can reach up to 0.06. For details on this see for example: this Deutschebahn report.[3]
- For planes, we use `https://www.atmosfair.de/en/offset/` roundtrip estimates (for an average airline). This includes the indirect CO2 effects not just as a multiplicative factor 2 (an approximation recommended by Jungbluth and Meili [2] as a first order estimate), but makes this factor dependent of the flight altitude (as recommended as a next order accuracy therein). Additionally, atmosfair's calculator uses a database which analyzed the aircraft types, their fuel consumption and passenger loads typically flown on specific routes. We assume economy class for every participant.

2.5 Typical participants list

To evaluate emissions for future locations, we need a virtual participants list. An issue here is that depending on the locations, this list could be different. We used three populations: one for North America locations, one for Europe locations, and one for other locations. For the two first ones, we used the sums of the participants for the past conferences in the relevant area. For the third, since we miss data, we just use the sums of all participants from

[2]Full url: `https://en.wikipedia.org/wiki/Environmental_effects_of_aviation`

[3]Full url: `https://www.deutschebahn.com/resource/blob/6925828/f3c7c9bc0d0766230e64d0464f299b56/report_environmental-data.pdf`

our data. Note that since our end results are emissions per participants, it is not necessary to scale down these populations.

We noted that for some conference editions there were many participants from the host city, and for some a suspicious zero. We assume this corresponds to a local chair including the local organizers in registration or not. To make the impact of these differences smaller, we replaced the number of participants from the host city by the average over all years (including the year itself).

3 Results

Before we give detail our results, let us give other CO2e emissions per year, to get some references for comparison.

- Emissions per capita (world): 5 t CO2e.
- Emissions per capita (Europe): 8 t CO2e.
- Emissions per capita (USA): 15 t CO2e.
- Emissions for one car per year (12,000 km; middle class model): 2 t CO2e.
- Emissions for running an average fridge per year: 0.3 t CO2e.
- Annual emissions budget for one person for Paris'agreement: 1.5 t CO2e[4]

3.1 Main results

Let us restate our main results, the average CO2e emissions per participant for the 14 target cities. We estimate our margin of error to be below 10%, see the next section.

Conference location	CO2e per participant (tons)
London	2.3
Madrid	2.6
Paris	2.1
Rome	2.5
Vienna	2.4
Berlin	2.4
Jerusalem	3.3
Augusta	3.4
New Orleans	3.8
Orlando	3.7
San Francisco	4.3
Toronto	2.9
Mexico City	4.6
Tokyo	5.7

[4]See e.g. https://www.atmosfair.de/en/green_travel/annual_climate_budget/.

3.2 Sensitivity analysis

Typical participants list. For the conferences of which we received the participant data, we also calculated the CO2e emissions with the real participants list (after clustering) of that year. The difference between those outcomes and the typical participant lists is small: about 0-10%.

Removed participants. Since we removed very few participants (less than 1 %) this has a negligible effect.

Clustering. We aimed at creating clusters where, within a cluster, people take the train or other local low-emission transport. These emissions would have negligible impact when traveling to another cluster. This was relatively straightforward in Europe, since the density of participants is high there. Outside of Europe, we let the radius of the cluster grow until it contains a non-trivial amount of people. E.g., the participants from Los Angeles and San Francisco are clustered in San Francisco, although this trip would, according to our assumptions, always be taken by plane. We argue that this is not a big issue, since it concerns a way smaller number of participants. For comparison: we have an average of 15 participants per year clustered in Paris, and 4 in San Francisco.

In other words, our clustering is such that

$$\frac{\text{(additional local travel)} \cdot \text{(number of local participants)}}{\text{total emissions}} = \text{small}.$$

Ignoring 'the last mile'. In our calculations, we often ignored the last part of the journey, near the conference location. This means for example that we treat both Salerno and L'Aquila as 'Rome'. Rome is the closest airport to L'Aquila, and one of the closest airports to Salerno. The additional train/bus journey from there is negligible compared to any flight. Similarly, we treated Budapest as Vienna. These cities are a two-hour train ride apart, which again is negligible compared to any flights.

Train-plane cut-off. We assumed that participants would take the plane if a train ride would be more than 8 hours. This number is an educated guess based on conversations with community members. To see if it is in the right ballpark, we surveyed the DISC '23 participants. We received 36 answers, with a median of 10 hours and a average of 11 hours. Since the number of answers in very low, and perhaps biased by the pool of surveyed people, we are hesitant to draw any significant conclusions from this. We do want to conclude that 8 hours seems to be the right ballpark. We estimate that changing the number 8 slightly up or down by 2 hours will have an impact of less than 5%.

3.3 Other statistics

One of the other statistics that came out of the participant data is the number of participants. We note:

- average number of participants: 119;
- average number of participants when held in Europe: 128;
- average number of participants when held in North America: 107.

We also split out the country of origin. We round the percentage for a clear overview, hence they no longer add up to exactly 100%.

Participants origins	Participants in average	Participants if in Europe	Participants if in North America
Europe + Israel	54	60	45
Canada + USA	34	26	46
Middle and South America	1	1	1
Asia and Oceania	11	13	8

We admit that with only 5 European editions and 4 North American editions, these statistics are quite sensitive and have to be taken with a grain of salt. Our main conclusions are that the community is somewhat more European based than North American, and while we have a steady 10% of participants from Asia and Oceania, we have almost none from Middle and South America.

We note that this is not the only reason that emissions for Europe are lower. The other reason is that it is geographically more central. Just as a reminder, the Pacific Ocean is much bigger than the Atlantic. E.g., Tokyo-San Francisco is > 8000 km, while Paris-Toronto is 6000 km.

4 Estimation of some alternatives

4.1 Partially online and multi-location alternatives

In this section, we discuss possible measures and their effects on the carbon emissions.

Hybrid with 10% furthest participants online. A significant portion of the CO2e emissions come from few participants that are further away. A fully hybrid conference, with say 50% online participants, will have a much much lower environmental impact (see below). However, several senior community members have expressed that they oppose such fully hybrid conferences, because of organization overhead and degraded conference atmosphere. Instead, in this section, we explore what happens with a light hybrid set-up when participants who live far away from the conference location are allowed to attend/present online (just like people who could not get visas, for example). As an example, we let the furthest 10% of participants attend online[5]. This would have minimal impact on the feeling of the conference, while having significant impact on the CO2 emissions. Below, we average the CO2e emissions again per participant (including the online participants). Alternatively, this 10% can also publish in the proceedings without presentation. Of course the CO2e emissions for both policies are the same.

[5] Of course, by letting the average 10% attend online, instead of the 10% furthest, the cost would go down by 10%.

Conference location	CO2e per participant (tons) with 10% online participants	change	relative change
London	1.6	0.7	-30%
Madrid	1.9	0.7	-30%
Paris	1.5	0.6	-30%
Rome	1.8	0.7	-28%
Vienna	1.7	0.7	-28%
Berlin	1.7	0.7	-27%
Jerusalem	2.5	0.8	-25%
Augusta	2.6	0.8	-26%
New Orleans	2.9	0.9	-24%
Orlando	2.7	1.0	-26%
San Francisco	3.4	0.9	-21%
Toronto	2.1	0.8	-27%
Mexico City	3.6	1.0	-22%
Tokyo	4.9	0.8	-14%

Hybrid with 50% online participants. Just for comparison purpose, we computed the CO2e emissions for hosting a conference in Paris or Toronto with the furthest 50% of the participants attending online.

- Paris: 0.2 t CO2e/participant, i.e., −91%.
- Toronto: 0.5 t CO2e/participant, i.e., −84%.

Two hubs. A bigger change to the organization would be to organize the conference simultaneously in two locations, with an online connection between the two. Participants can then go to the closest location. As an example, we present here the case of hosting in Paris and Toronto. This would decrease the carbon emissions to

- 1.2 t CO2e/participant.

When we also have 10% online participation, it decreases further to

- 0.7 t CO2e/participant.

Note that a way to partially get the benefits of the two-hubs solution without the synchronization issues is to allow authors to present their paper in the next X years after publication.

4.2 Other alternatives

Carbon offset. Carbon offset consists in paying companies to "erase" carbon emissions, by investing in sectors that remove CO2 from the atmosphere (*e.g.* planting trees). Unfortunately, climate advocates seem to agree that the current system of voluntary carbon offsets is not working, and could potentially even be harmful. See for example, this Guardian article.[6].

[6] Full url: `https://www.theguardian.com/environment/2023/aug/24/carbon-credit-speculators-could-lose-billions-as-offsets-deemed-worthless-aoe`

Co-locating. Organizing a conference in the same city in the week before, after, or during another conference can also be used to decrease emissions. The challenge is finding conferences with a high enough participant overlap that this makes sense. Moreover, if the combination is so attractive that some people will show up that would not show up to the individual conferences, the gain is lost again. A rough estimate is that there is a 10-20% overlap between PODC and ICALP/STOC/SPAA. That means it would save half of the emission of that group, i.e., 5-10% of the entire conference. Although that is a significant dent in the emissions, it is a much smaller difference than the one between different conference locations.

Other measures. Finally, we would like to note that any measure that does not decrease the number of physical participants that come from afar has a very small impact on the carbon emissions of a conference. This includes for example the Extended Stay Support Schemes (see the specific pages on DISC 2023 website and ICALP 2022 website).[7]

5 Closing remarks

In our opinion, scientists should take a leading role in battling the climate crisis, both in research and as role models. As these numbers show, attending multiple conferences a year puts the carbon emissions of a researcher already at worse-than-average, while this is not even including private travel.

How much does picking a certain location help? If we average the emissions per participant for the nine editions of DISC and PODC for which we received the data, we obtain: 2.8 t CO2e. If we pick the best North America location (Toronto) and best Europe location (Paris) equally often, we obtain: 2.5 t CO2e, a decrease of -11%. And if we always pick the best location (Paris), we obtain: 2.1 t CO2e, a decrease of -25%. The latter is still significantly more than the climate compatible annual emissions budget (1.5 t CO2e/person).

Recommendations. We hope these computations help the community in making some difficult choices. We recommend the steering committees of DISC and PODC to develop a climate policy, which includes picking locations that correspond with where our community is centered, and seriously explore hybrid options.

We also recommend the steering committee to appoint a environmental chair each year, whose task is to compute the estimated environmental impact of that year's edition.

Further reading.

- For a discussion on mandatory attendance of conferences we suggest the Viewpoint Column of Antoine Amarilli (TCS4F) in the February 2023 edition of the bulletin of the EATCS.[8]
- Bousema et al. [1] calculated the emissions of the 2019 edition of the annual conference of the American Society of Tropical Medicine and Hygiene (ASTMH).
- Stroud et al. [6] calculated the emissions for four editions of the conference of the International Biogeography Society.
- Spinellis and Louridas [5] calculated the total emissions of scientific conferences, using the Scopus digital library.

[7] Full URLs: `http://www.disc-conference.org/wp/disc2023/disc-extended-stay-support-scheme/` and `https://icalp2022.irif.fr/?page_id=50#support`.

[8] Full URL: `http://bulletin.eatcs.org/index.php/beatcs/article/view/754/801`.

- Leochico et al. [3] survey the climate impact of academic conferences and alternatives more generally.

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