

Effects of Internet-based multiple-site conferences on greenhouse gas emissions

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ABSTRACT

There is a growing consensus that ICT can contribute to the reduction of anthropogenic greenhouse gas (GHG) emissions, both by increasing the efficiency of existing processes and by enabling substitution effects to usher in more energy efficient patterns of production and consumption. While, however, many studies based on theoretical reduction potentials have been presented, in practice it has only been possible to cite a few examples of such reductions thus far.

This article presents the results of a field experiment for one particular domain in which ICT can be substituted for more carbon-intensive technologies: using advanced videoconferencing technology to reduce intercontinental conference travel and thus travel-related GHG emissions. We organized a large resource management conference simultaneously on two continents and assessed the emissions caused by the attendees' travel and by the additional ICT equipment utilized to connect the two venues. We further assessed, based on a survey, the emissions in the alternative scenarios of holding the conference at either one of the places, and the satisfaction of the participants with the two-site conference format.

The results show that reductions of 37% and 50% in travel-related GHG emissions were attained as compared to the single-site alternatives, although more people took part than in any of these alternatives. At the same time, the attendees' experience was clearly positive, showing that the multiple-site format can serve as an acceptable alternative to the traditional one-site format of holding an international conference.

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1. Introduction

Information and Communication Technologies (ICT) are increasingly envisioned as enablers of a reduction of anthropogenic greenhouse gas (GHG) emissions. The European Commission, for example, recently stated that “the continued growth of the European economy [...] needs to be decoupled from energy consumption [...] Information and Communication Technologies have an important role to play in reducing the energy intensity and increasing the energy efficiency of the economy” (European Commission, 2008).

As we have argued in Hilty et al. (2009) and Coroama and Hilty (2009), assessing the energy efficiency induced by ICT is methodologically challenging for several reasons. The baseline scenario, for one, as it expands into the future, is inherently speculative. Furthermore, allocation issues are raised by the fact that ICT almost never induces efficiency on its own, but only

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in a suitable technological, political, or organizational context. Despite such difficulties, there are several well-known estimates of ICT's potential to induce energy efficiency and thus a reduction in anthropogenic GHG emissions, e.g. the report of the Global eSustainability Initiative (GeSI), which puts forward an overall reduction potential of 7.8 Gigatons CO₂e¹ by 2020, if all specific potentials of ICT were tapped (GeSI, 2008).

These ICT-induced reductions are expected to appear due to the following main reasons: firstly, as a result of improved energy efficiency in the domains of smart engines, buildings, or logistics; secondly, due to ICT-supported novel paradigms for the generation and distribution of electricity (i.e., smart grids); and thirdly due to substitution effects, where ICT would partly replace energy intensive activities (GeSI, 2008; Hilty, 2008). A substitution effect is – in this context – defined as a reduction of the environmental impact of providing a function, where the reduction is caused by replacing the process providing the function by an ICT service, either in part or completely.

This article investigates a special case of substitution effect, the replacement of work-related travel by videoconferencing technology. Three sorts of working travel are suitable for such a substitution:

- Work commute can be replaced by *teleworking* or *telecommuting* (Mokhtarian, 1991; Kitou and Horvath, 2003), which means that an employee or contractor works from home and is remotely connected with his or her business, usually via the Internet.
- Business meetings can be replaced by *virtual business meetings*, where the meeting parties are separated from each other at two or more locations connected via audio- or videoconferencing, including wireless business meetings (Toffel and Horvath, 2004).
- The travel to large international conferences can be partly replaced by videoconferencing as well (Hischier and Hilty, 2002).

While (GeSI, 2008) estimates a worldwide GHG reduction potential of 0.5 Gigatons CO₂e per year through the partial substitution of videoconferencing for work commute and business meetings, not much attention has been given to conference travel so far. Building on the work of Hischier and Hilty (2002), who analyzed several ways to reduce the amount of GHG produced by the travel of attendees to a conference, we focus on a promising conference format that has not been investigated empirically before: the multiple-site conference, i.e., holding a conference simultaneously at multiple geographically distributed sites connected via videoconferencing. While both the hypothetical assessment of this format given in Hischier and Hilty (2002) and our field study refer to academic conferences, we believe that the results can be generalized to any type of international event where large groups of people meet for the purpose of presenting and discussing audiovisual content.

Our research question is: can the GHG emissions caused by an international conference be significantly reduced by organizing the event at multiple sites in order to reduce the average travel distance of the attendees?

To approach the question, an advanced videoconferencing technology was deployed in our field experiment. The technology used goes far beyond simple webcam-and-screen systems and is rather an instantiation of Steuer's 'TelePresence' concept (Steuer, 1995). The assumption behind substituting this technology for a part of the conference travel is that a conference organized at several sites fulfills from the attendees' perspective roughly the same set of functions as a traditional single-site conference. We tested this hypothesis of functional equivalence through a participant survey, yielding a largely positive result.

2. Related work

Except for the early work by Hischier and Hilty (2002), not much attention has been given to partly virtualizing international conferences by connecting several venues through TelePresence systems. Most of the literature on substituting ICT systems for travel focuses on the effects of *telecommuting* or *virtual business meetings*. We summarize this work here although the results are not comparable to those of our study. This related work, however, shows clearly that the type of substitution matters: not all types of replacing travel by ICT services lead to a net reduction of GHG emissions. This underlines that it is necessary to investigate the multiple-site conference format as a particular case.

Takahashi et al. (2006) analyzed the environmental effects of replacing business trips with videoconferencing, complementing the Life Cycle Assessment (LCA) with a 'value factor' for the kind of communication, as a virtual meeting is different from a face-to-face meeting. Even reducing its value by this factor, which was calculated to be 0.6 of a face-to-face encounter, the virtual meeting was only responsible for 20% of the emissions of the business trip for which it was substituted (0.4 tons CO₂ instead of 2 tons). Later, the authors compared the effects for countries with differing energy mixes and transportation habits (Takahashi et al., 2008).

For all of Australia, a replacement of a third of the business trips through high-quality TelePresence systems was estimated to reduce emissions by 2.4 Megatons CO₂e (Mallon et al., 2007). If 30% of business trips worldwide were replaced by teleconferencing, an estimated reduction of 500 Megatons CO₂e would result (GeSI, 2008). Toffel and Horvath (2004)

¹ The unit "ton" and multiples of it refer to metric tons in this text. The unit "ton CO₂e", as cited from GeSI (2008), refers to the emission of greenhouse gases equivalent to 1 ton of carbon dioxide with respect to their global warming potential. Greenhouse gases include carbon dioxide, methane, perfluorocarbons, nitrous oxide, and others.

estimate that CO₂ emissions for a business meeting will be lower by 1–3 orders of magnitude if travel is replaced by wireless teleconferencing.

For *telecommuting*, however, estimates of future energy reduction potentials have been critically questioned. After a review of relevant studies, Fuchs concludes: “Working at home can have negative environmental effects, e.g. people can’t go shopping on the way home from work, but might take an extra trip by car from home to shops and supermarkets” (Fuchs, 2008). A study conducted by Marletta et al. even concludes that teleworkers drive, on average, more kilometers per day than conventional workers (Marletta et al., 2004).

While they stand to reason for *teleworking*, such objections have not been raised for virtualized business meetings and conferences, where the reduction potential seems realistic. We will therefore present our field study of the multiple-site conference and later resume this discussion, analyzing how our type of substitution relates to these objections.

3. System under study and methodology

This section first presents the conference we used for the field experiment. A discussion of the system boundaries follows, taking into account the fact that the travel of attendees is the dominant source of environmental impact for a conference. The section closes by presenting the methods used for the assessment of GHG emissions for the two-site conference and for the hypothetical alternatives.

3.1. The R’09 Congress and the World Resources Forum

The conference consisted of two back-to-back events, the 8th scientific congress R’09 on resource efficiency and resource management, and the first World Resources Forum. The conference was organized between September 14th and 16th in both Davos, Switzerland, and Nagoya, Japan, by our institute and the EcoTopia Science Institute at Nagoya University.

Our field study hence refers to a two-site conference, which is a special case of a multiple-site conference. To which extent this format can be scaled up to more than two sites mainly depends on the time differences among the sites involved, which already posed a challenge in our two-site experiment.

It would have been impossible to run through the whole conference program at both sites due to the seven-hour time difference between them. Instead, the Japanese morning workshops started independently, followed by the common 4-h slot (3 pm–7 pm in Japan and 8 am–12 am in Switzerland). The days concluded with the Swiss workshops of the afternoon program. During the common slot, all plenary sessions were shared between the two sites via Cisco’s ‘TelePresence’ system. This system provides Full-HD image quality of 1920 × 1080 pixels. Four such systems were continuously in use: two for the main conference hall and two in the lounges so that attendees could spontaneously and informally interact during coffee breaks. From the two main hall systems, one was used to transmit the speaker’s image, and the other to project at each site the other venue’s audience on a 5 × 3 m screen (see Fig. 1). By these means, we tried to create a common ‘virtual auditorium’ and thus a community feeling across the sites.

3.2. System boundaries

Hischier and Hilty (2002) introduced a list of sources of the environmental impact of an academic conference:



Fig. 1. Transcontinental plenary session, from the perspective of the Davos audience. The remote audience is projected on a large screen, creating together with the local audience a ‘virtual auditorium’.

- conference organization (conference secretariat, website, program committee meetings),
- conference materials (call for papers, program booklet, other dispatches, proceedings, additional printed material, conference bag), and
- participants' activities (conference venue, hotel stay, and travel activities).

The authors assessed the environmental impact of 10 of these 12 sources in their case study of a traditional (one-site) conference. They left aside, due to a lack of data, the environmental impact of the conference venue and the hotel rooms.

Given our research question as defined in the introduction, the *absolute* environmental impact of the two-site conference is not relevant for our study, but the *difference* between its impact and the impact of traditional one-site conference. This comparative analysis is thus simpler because some of the above-mentioned sources of environmental impact can be assumed to be equal in all scenarios and can therefore be ignored.

It is, however, a methodological challenge to account for the possible occurrence of *rebound effects*. The rebound effect, which was first observed in energy markets (Khazzoom, 1980), denotes the paradox that efficiency gains can lead to more consumption of a resource instead of less, or at least to a reduction that is smaller than expected. Generally speaking, as less of a resource is needed to produce the output, the cost per unit of output becomes lower (in monetary terms, in terms of time or other types of effort) and the increased demand stimulated by the lower price may outweigh the resource reduction per unit (Binswanger, 2001; Hilty et al., 2006). In our conference example, the aim was to reduce travel energy demand and related emissions by offering two conference sites on different continents. As a result, travel to the conference becomes cheaper (both time- and money-wise) on the average. Cheaper travel to the conference would probably induce additional demand, i.e., more people would attend the conference. This, in turn, would mean not only more travel; it would also imply more conference materials and other sources of environmental impact.

However, the results from Hirschier and Hilty (2002) are clear with respect to the dominant cause of the environmental impact of a conference. From all activities analyzed by the authors, only one of them, the travel of attendees to the conference, was responsible for 96.3% of the impact. As the conference under study was a typical international conference with no noteworthy particularities of relevance for its environmental impact, we regard this result as representative for international conferences in general. This conclusion – that more than 90% of the impact is due to the travel of attendees – was further robust with regard to the impact assessment method used. Hirschier and Hilty (2002) used two widely accepted methods of aggregating different environmental impacts, Eco-Indicator'99 (Goedkoop and Spriensma, 1999) and the Swiss Eco-points method based on ecological scarcity (Brand et al., 1997), which yielded no difference with regard to this conclusion. Focusing on one type of environmental impact, GHG emissions, even strengthens the dominance of travel as a source of impact.

Due to this unambiguous result we can safely ignore the consequence of a potential rebound effect for *all non-travel activities*. The production of the conference bag, for example, resulted in an insignificant environmental damage as compared to the travel of attendees (Hirschier and Hilty, 2002). Even if more bags had to be produced due to the increased number of attendees in the case of a multiple-site conference, their environmental impact was still negligible as compared to the travel of attendees.

Novel to a multiple-site conference, however, is the ICT equipment needed to connect the sites. In addition to the ICT equipments used in any conference, such as computers and projectors, a multiple-site conference has to deploy the entire TelePresence-related infrastructure. This consumes energy, as does the Internet transmission at the bandwidth needed. In another publication (currently in preparation) we show however that the entire ICT infrastructure utilized to connect the two sites was responsible, under the most pessimistic assumptions, for 165 kilograms (kg) CO₂ – three orders of magnitude below the amount of GHG caused by the travel of attendees. Its impact thus turns out to be negligible as well for the comparison of our scenarios.

3.3. Assessing the travel emissions

This section presents the methods used to assess the travel emissions caused by the two-site experiment as it was organized (the AS-IS-scenario), as well as the assumptions made for the two hypothetical cases of organizing the conference traditionally at one of the two sites.

We will concentrate on CO₂ emissions (as opposed to CO₂e, see footnote 1 above), since GHGs other than CO₂ are usually neglected in a context where no agriculture or chemical production is involved. We are aware of the uncertainty of even assessing the pure CO₂ emissions of a trip from A to B. Sources of uncertainty are in our case the route taken, the means of transport involved, and the emission factor of each individual means of transport. This implies that our results should be interpreted with some care, using only very large differences to support conclusions. We will, however, discuss the uncertainties that are not of general nature, but specific for our study, in some detail in Section 3.3.2 below.

3.3.1. Assessing the travel emissions for the AS-IS-scenario

After the two-site conference, we invited all attendees to participate in an online-survey, asking about their travel to the conference, as well as about their perception of the conference format. The response rates were 43.4% for Nagoya ($N = 66$) and 59.2% for Davos ($N = 225$).

In order to assess participants' travel emissions, we invited them to describe the legs of their journey to the conference and the respective means of transportation. To avoid likely mistakes if attendees were to compute themselves the length of

each leg of their journey, we did not ask for absolute distances but for a description of their travel based on geographical points. A typical description was, for example, “airplane New York–Paris; airplane Paris–Zurich; train Zurich Airport–Davos”.

From the detailed descriptions of their journeys provided by attendees, we computed for each participant the distance traveled on each leg of the journey, as follows: For air travel, the mileage calculator provided by WebFlyer (www.webflyer.com/travel/mileage_calculator/) was used. For car travel, the distance between two cities was computed by the free navigation tool Google maps (maps.google.com). For train journeys, as no suitable distance calculators could be found, road distances were used as a very close approximation.

In the next step, data from the ‘ecoinvent’ life-cycle inventory database was used to assess the cumulated GHG emissions of the individual journeys. Ecoinvent is the world’s leading supplier of transparent lifecycle inventory (LCI) data, which is provided and updated by a consortium of Swiss research institutes, including ETH, the Swiss Federal Institute of Technology, and Empa, the Swiss Federal Institute of Materials Science and Technology (www.ecoinvent.org). The ecoinvent database indicates the following CO₂ emissions per passenger-kilometer (pkm): 0.17 kg for long-haul flights, 0.11 kg for short-haul flights, 0.24 kg for car travel, and 0.0083 kg for train rides.

3.3.2. Assessing the emissions for the alternative scenarios

We examined the two hypothetical alternatives: a conference that would have been organized in Davos only, and one organized in Nagoya only. In order to assess the travel-related GHG emissions of the alternatives, we asked the participants at each site whether they would also have attended the conference, had it been hosted at the other site only.

Thereby, we made following assumptions (presented here for the ‘Davos-only’ scenario):

- (1) All Davos attendees would have kept taking part, had the conference been organized in a traditional manner in Davos only.
- (2) The Nagoya attendees would have acted exactly as they told us in the questionnaire with regard to traveling to Davos.
- (3) No further attendees, who in the AS-IS-scenario took part neither in Davos nor in Nagoya, would have attended the conference.
- (4) In calculating the alternative route to Davos (for participants who in the AS-IS-scenario went to Nagoya but would have taken part in Davos as well), we made the conservative assumption: participants from within 1000 km of Davos would have traveled by train to the conference. Further-away attendees would have taken the train to the closest international airport, and from there a direct flight to Zurich international airport, from where they would have taken the train to Davos.
- (5) As only 32.7% of the Nagoya attendees answered this question, we extrapolated from this sample to all attendees in Nagoya with regard to both attendance and average travel distance to Davos.

For the ‘Nagoya-only’ scenario, we made analogous assumptions to those described above for the ‘Davos-only’ scenario. Assumption 4 becomes “In calculating the alternative route to Nagoya (for participants who in the AS-IS-scenario went to Davos but would have taken part in Nagoya as well), we made the conservative assumption: participants from within Japan would have traveled by train to the conference. International attendees would have taken the train to the closest international airport, and from there a direct flight to Nagoya international airport, from where they would use local public transport to the conference center”.

Assumption 1 seems realistic to a large degree, as it only says that participants at a venue would have kept attending if the conference had been organized at that venue only. Assumption 2 is more questionable, as attendees might have acted differently in reality than they answered to the questionnaire. It is, however, a difficulty inherent in assessing a hypothetical scenario, and we have no better clues than the answers of attendees themselves. Assumption 3 seems again quite solid. To assumption 4, there are two observations to be made. Firstly, it is the most conservative one possible, i.e., the most optimistic one regarding CO₂ emissions. Many flights are not direct but with stopovers, over longer routes, as flights are often bought minimizing the costs and not the distance. Moreover, for a Nagoya-only conference, many international attendees would probably fly to the larger and more frequently used Narita airport in Tokyo rather than to Nagoya airport. Some people would travel, even long distances, by car or taxi, and not by train. Finally, for some of the routes (such as Oceania-Europe), the assumption of direct flights is even impossible, as no commercial aircraft can cover such a distance in one leg. Secondly, it should be noted that we are only able to compute the alternative route because we know from a previous question (referring to the travel in the AS-IS-scenario) from where the individual attendees traveled to Davos or Nagoya. For the alternative scenarios, we assume they would have started their travel to the alternative site from the same point.

Finally, assumption 5 was chosen due to the lack of a better alternative. In reality, there might be large variation – to both directions – between the subset of attendees who answered the questionnaire and those who didn’t.

Accordingly, there are three sources of uncertainty in the assumptions made for the alternative scenarios:

- the non-response bias, which describes the potential differences in opinions between respondents and non-respondents to a questionnaire, rendering extrapolations from the former to the latter inaccurate;
- whether attendees would – with respect to traveling to the remote site – behave as they answered in the questionnaire; and
- which would have been the travel means and route that they would have chosen to get to the alternative site.

Whereas the first two sources may have created variations in either direction, and we were not able to reduce those uncertainties, in the third case we systematically chose the most conservative assumption, leading to the smallest CO₂ emissions of the travel under study.

3.4. Functional equivalence and attendee satisfaction

As mentioned in the beginning, one essential issue in our study was to address the functional equivalence – or at least functional similarity – of a multiple-site conference compared to a traditional conference. Comparing the environmental effects of two alternatives only makes sense if sufficient functional similarity can be assumed. The concept of functional unit was defined for this purpose by the LCA standard (formerly ISO14041, now ISO14044), which states: “Comparisons between systems shall be made on the basis of the same function(s), quantified by the same functional unit(s)” [International Organization for Standardization, 2006](#).

When replacing traditional interaction forms with novel means of communication enabled by ICT, though, the functional equivalence of the two seems rather difficult to assess. [Hischier and Reichart \(2003\)](#) already encountered this issue when comparing the environmental impacts of receiving the daily news through traditional media versus the Internet. In their case, the challenge was caused by the multifunctionality of the Internet access and the thus-related difficulty in choosing a meaningful functional unit ([Hischier and Reichart, 2003](#)). In our case, the problem relates to multifunctionality as well. Not only the *replacing* system (the TelePresence-enabled multiple-site conference) is multifunctional, however, but also the *replaced* system (a traditional conference). A conference accomplishes numerous functions, one’s formal presentation of ideas being just one of them. Other functions include networking, social bonding, generating ideas during informal interaction (for example, at coffee breaks), and also profession-unrelated functions such as tourism or cultural enrichment.

Obviously, a conference with multiple venues will not be able to perform all these functions to the same extent. It could, however, try to fulfill them to some extent and compensate for the losses by accomplishing other functions better. As noted in [Hilty \(2008\)](#), “The concept of functional equivalence can be misleading [...] when virtual and real alternatives have to be compared”. And further: “We think that people do telework not because TelePresence is functionally equivalent to, but because it is different from, physical presence! We think that virtual substitutes for physical processes will never be functionally equivalent to the physical processes, but will always have some advantages and disadvantages as compared with physical processes” ([Hilty, 2008](#)).

For such cases, ISO’s technical report ISO/TR14049 states that equivalence of products can also be determined by user acceptance ([International Organization for Standardization, 2000](#)). Our survey therefore asked the attendees in Switzerland and in Japan about their experiences with the two-site conference. The results will be presented after the results of the travel emissions assessment.

4. Results: travel emissions

4.1. Travel emissions for the two-site experiment

175 of the 372 attendees in Davos (47%) described their detailed journey to the congress venue. Determining, as described above, for each individual attendee the number of passenger-kilometers for each means of transport and aggregating them for all respondents results in the first row of [Table 1](#). Extrapolating this data to 372 attendees results in the second row, and multiplying these figures with emission values for the different means of transport yields the estimated total emissions the travel of Davos attendees was responsible for, 83.74 tons CO₂.

In Nagoya, not only did fewer (159) people participate in the conference, but among them there was also a lower response rate of 32.7% to the travel-related questions. [Table 2](#) presents, analogously to above, the passenger-kilometers over all the means of transport used by respondents, as well as the extrapolation to all Nagoya-attendees. They caused the total emissions of 35.08 tons CO₂ with their travel to the conference. The total amount of travel emissions to both conference sites was roughly 119 tons CO₂.

4.2. Travel emissions for the ‘Nagoya-only’ scenario

Had the conference been organized in Nagoya only, only 37 out of the 175 respondents in Davos would have taken part in the conference. Assuming for each of these participants the same point of departure as they had for Davos, but with a new

Table 1

Travel distances to the Davos venue and corresponding CO₂ emissions. Data for both the 175 respondents, as well as extrapolation to the total of 372 Davos attendees.

Type of transport	Short-haul flight	Long-haul flight	Train	Car	Total
Travel distance for 175 respondents (pkm)	61,222	231,000	76,152	17,240	385,614
Extrapolation to 372 attendees	130,140	491,040	161,877	36,647	819,704
kg CO ₂ /pkm	0.16634	0.10576	0.0082994	0.24045	–
Emissions (kg CO ₂)	21,648	51,932	1343	8812	83,735

Table 2

Travel distances to the Nagoya venue and corresponding CO₂ emissions. Data for both the 52 respondents, as well as extrapolation to the total of 159 Nagoya attendees.

Type of transport	Short-haul flight	Long-haul flight	Train	Car	Total
Travel distance for 52 respondents (pkm)	15,132	81,520	11,050	1012	108,714
Extrapolation to 159 attendees	46,269	249,263	33,788	3094	332,414
kg CO ₂ /pkm	0.16634	0.10576	0.0082994	0.24045	–
Emissions (kg CO ₂)	7696	26,362	280	744	35,082

Table 3

Travel distances and emissions for Davos attendees who would have traveled as well to Nagoya, for the 'Nagoya-only' scenario. Data for the 37 (out of 175) 'yes'-respondents, as well as extrapolation to 79 out of 372 total Davos attendees.

Type of transport	Short-haul flight	Long-haul flight	Train	Car	Total
Travel distance for the 37 'yes' respondents (pkm)	0	683,820	2302	964	687,086
Emissions (kg CO ₂)	0	72,321	19	232	72,572
Extrapolation to 79 out of 372 attendees (pkm)	0	1453,606	4893	2049	1460,548
Emissions (kg CO ₂)	0	153,733	41	493	154,267

destination Nagoya, results in the first row of Table 3. As most Davos attendees were Europe-based, their travel to Nagoya would unsurprisingly have meant above all a large number of passenger-kilometers on intercontinental flights.

Extrapolating the result to the total of 372 Davos attendees results in: 79 attendees who would have traveled to Nagoya, causing the amount of travel shown in the third row of Table 3, and a total of 154.27 tons CO₂ travel emissions. On the other hand, the entire travel to Davos would have been saved, as Davos would not have existed as a conference site. In total, the travel in the 'Nagoya-only' scenario would have produced the 35.08 tons of CO₂ that the Nagoya attendees of the AS-IS-scenario would have kept producing, plus the 154.07 new tonnes from Davos attendees in the AS-IS-scenario, who would have traveled to Nagoya as well.

4.3. Travel emissions for the 'Davos-only' scenario

Proportionally, many more of the Nagoya attendees would have traveled to a Davos-only conference. From the 52 who answered the travel-related questions, almost half would have traveled to Davos. Extrapolating to the 159 attendees in Nagoya results thus in almost as many participants who would have traveled to the remote site (76 as compared to the 79 before).

As most participants in Nagoya were Asia-based, the travel distance and the emissions that these supplemental intercontinental travels to Davos would have induced are similar to the ones of the 'Nagoya-only' scenario – about 1.5 million pkm on long-haul flights, and corresponding 151.14 tons CO₂ (Table 4). The total emissions would have been roughly 235 tons CO₂, including the 83.73 tons from the 372 Davos attendees who would have kept taking part in the conference.

4.4. Interpretation of the results

Summarizing the data above, the Davos–Nagoya conference had a total of 531 participants, 372 in Davos and 159 in Nagoya. Their travel caused 119 tons of CO₂ emissions, 84 tons to Davos and 35 tons to Nagoya. In the 'Davos-only' scenario, 448 attendees (372 plus 76 from the Nagoya public) would have induced with 235 tons (the former 84 tons plus new 151 tons), almost the double CO₂ emissions of the AS-IS-scenario. In the 'Nagoya-only' scenario, a considerably reduced number of 238 attendees would still have been responsible for more emissions than those of the AS-IS-scenario. Apart from the 35 tons that would still be caused by the 159 participants, the 79 new attendees would cause an additional 154 tons. The horizontal axis of Fig. 2 shows the numbers of participants for the three scenarios.

Let us now view our field experiment from the perspective of substitution effects, as defined in Section 1. From this slightly different perspective, a single-site conference (i.e., either the 'Nagoya-only' or the 'Davos-only' scenario) is taken as the baseline and hypothetically replaced by the two-site Davos–Nagoya conference.

Table 4

Travel distances and emissions for Nagoya attendees who would have traveled as well to Davos, for the 'Davos-only' scenario. Data for the 25 (out of 52) 'yes'-respondents, as well as extrapolation to 76 out of 159 total Nagoya attendees.

Type of transport	Short-haul flight	Long-haul flight	Train	Car	Total
Travel distance for the 25 'yes' respondents (pkm)	0	466,680	8954	0	475,634
Emissions (kg CO ₂)	0	49,356	74	0	49,430
Extrapolation to 76 out of 159 attendees (pkm)	0	1426,964	27,379	0	1454,343
Emissions (kg CO ₂)	0	150,916	227	0	151,143

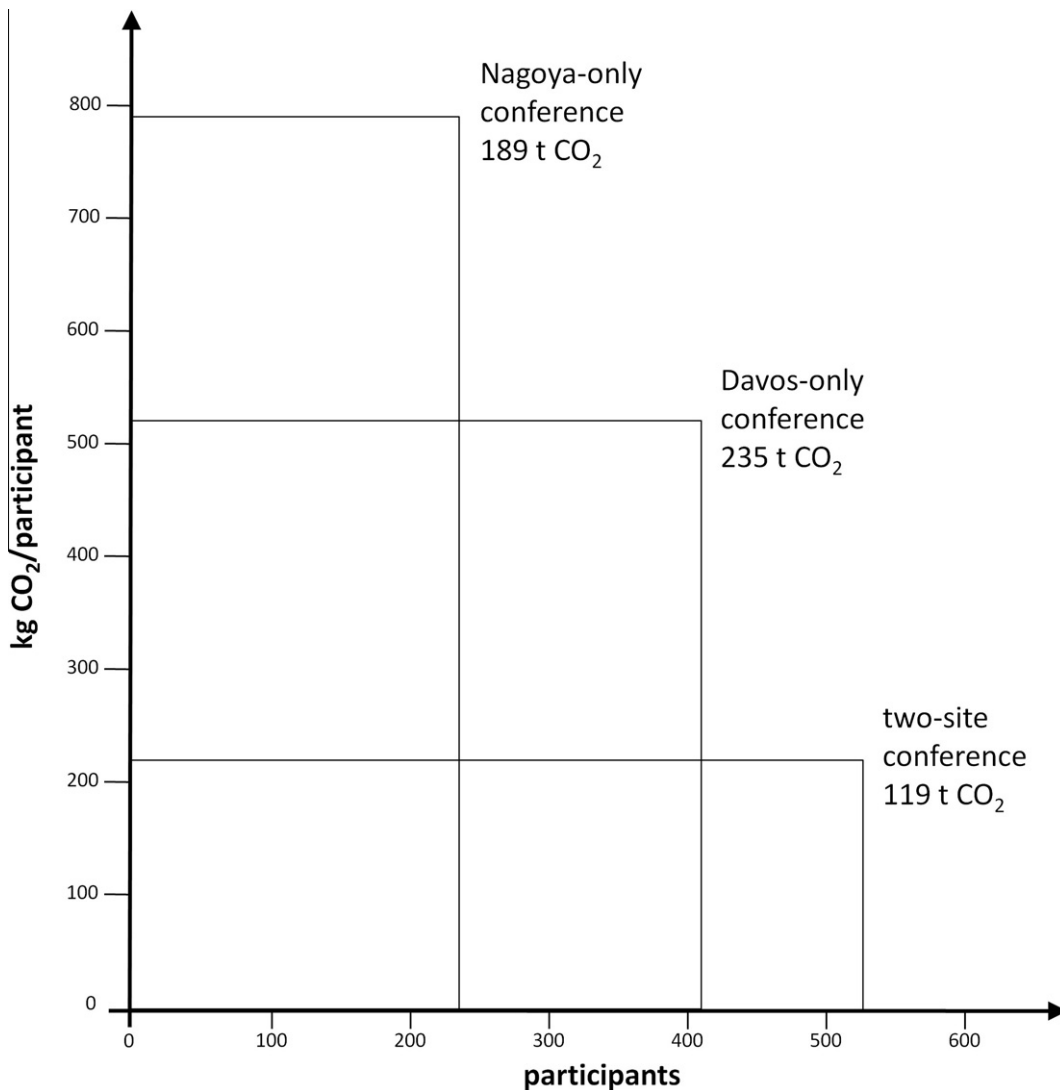


Fig. 2. Number of attendees and per-capita emissions in the three possible scenarios for the conference: the AS-IS-scenario with venues in Davos and Nagoya, as well as the 'Davos-only' and 'Nagoya-only' scenarios. The surface of each rectangle represents the respective scenario's overall travel emissions. The multiple-site conference saved travel emissions as compared to both traditional alternatives, despite more overall attendees.

As compared to the Davos-only conference, the Davos–Nagoya experiment substituted 76 trips to Nagoya for 76 trips to Davos (namely those of the Nagoya participants who would have taken part in Davos as well). Moreover, it induced 83 trips to Nagoya (the 83 corresponding attendees who would not have gone to Davos, but did actually take part in Nagoya). These 83 represent the rebound effect of the two-site conference, if viewed as a substitute for the Davos-only scenario. However, due to the fact that most of the 76 trips replaced would have started in Asia, the savings due to them (151 tons CO₂) are much larger than the emissions caused by all 159 trips to Nagoya, which are responsible for only 35 tons CO₂. Hence, despite allowing more participants to take part, the overall impact of attendees' travel has almost been reduced to half, from 235 tons to 119 tons. The per-capita emissions are reduced to less than a half, from 524 kg to 224 kg CO₂ (vertical axis of Fig. 2).

Viewing the Nagoya–Davos experiment as a replacement for a Nagoya-only conference, we see the rebound effect was much larger, but still not overwhelming. In addition to the 79 attendees who would have also found their way to Japan, another 293 were able to participate in the conference, more than doubling the total number of attendees. Overall reductions in travel emissions are thus not as large as above, but still considerable. The 79 avoided trips to Japan, most of them intercontinental, would have cost 154 tons CO₂, while the 79 trips substituted for them together with the 293 induced trips were only responsible for 84 tons. Below the line, this means a reduction of 70 tons (from 189 to 119 tons). Per participant, though, there is a reduction factor of 3.5, as the 224 kg induced on average by every attendee of the two-site conference compare to the 794 kg for the baseline (the replaced Nagoya-only conference).

Table 5

Satisfaction levels of attendees in Davos. Numbers in columns 2–5 indicate the valid percent among the respondents who experienced the respective feature. Column 6 shows the percentage of participants who did “not use” the feature from the total number of respondents.

Davos (N = 190) (in %)	Very satisfied	Fairly satisfied	Less satisfied	Not satisfied	Not used
Presentations transmitted from Japan	46.8	37.6	14.0	1.6	2.1
Interactive Q&A sessions (presenter in Japan)	29.5	47.2	20.5	2.8	7.4
Sensing the presence of the audience in Nagoya	24.9	51.4	15.7	8.1	2.6
Spontaneous cross-site discussions (e.g. during coffee breaks)	31.0	43.7	21.4	4.0	33.7

Our research question can now be answered: despite a medium to large rebound effect in the number of attendees (which had the benefit of broadening participation in the conference), it was possible to substantially reduce the GHG emissions caused by the conference by organizing it at multiple sites, thus reducing the average travel distance of the attendees. The question of whether a multiple-site conference is a suitable replacement for a traditional event, though, still has to be answered by assessing the attendees' acceptance of the new format.

5. Results: attendee satisfaction

Apart from providing the data for the travel-induced emissions, our survey assessed the two-site conference experience of the participants as well. This part of the survey was necessary to test the functional equivalence as described in Section 3.4.

When asked about their experience with the video-transmission, 84.4% of the Davos respondents were very or fairly well satisfied with the plenary presentations transmitted from Japan (Table 5). In Nagoya, this number was even higher at 95.8% (Table 6). The differences between the two groups were not significant ($X^2 = 4.585$; df: 3; $p = .205$).

In addition to the projection of the speaker and his or her slides, we connected both main halls with a transmission of the audience at the other venue, for two reasons: Firstly, to offer interactive Q&A sessions with both audiences, independently of where the speaker was physically located; secondly, to create the feeling of a shared conference. In the survey, 76.7% of the Davos and 91.5% of the Nagoya participants indicated that they were very or fairly well satisfied with the interactive Q&A sessions (Tables 5 and 6). The difference between the two groups was not significant ($X^2 = 6.254$; df: 3; $p = .100$). The feedback to the plenary presentations and the interlinked Q&A sessions was predominantly positive.

The idea of linking both audiences with a transmission of the remote auditorium was appreciated as well: 76.2% of the Davos respondents were very or fairly well satisfied with the experience of *sensing the presence of the audience in Japan* (Nagoya: 89.4% very or fairly well satisfied about sensing the presence of the Swiss audience). The differences were not significant ($X^2 = 6.912$; df: 3; $p = .075$).

In the coffee break area, we had two TelePresence round tables installed, which were intended to enable participants to quickly get in touch with smaller groups of attendees at the other venue. While it was possible to observe some interesting encounters at the round tables (“It was very interesting to see some group from the Nagoya side having pictures with a group from the Davos side”), 33.7% of the Davos participants answered they did not use these systems. Still, those who used them were very content with the experience: 74.6% of the respondents in Davos who communicated with the Japan participants were very or fairly well satisfied with this spontaneous cross-site discussions. In Nagoya, satisfaction with the round tables was higher (81.4% very or fairly well satisfied), while 23.2% did not use these tools.

The participants were further asked to assess the novel form of virtual and interactive conference with regard to several aspects on a –3 to +3 rating scale. As Table 7 shows, the Davos participants rated high the positive environmental effect (score: 2.11), as well as the cost and time efficiency (mean scores 1.83, and 1.85, respectively).

Generally, conferences are opportunities to socially interact and network. We expected that the virtual conferencing mode would have a rather negative impact on these aspects. Surprisingly, the Davos respondents still rated the social interaction as well as the “networking” item positively (mean scores 0.98 and 0.80, respectively).

The group of Davos participants who would have traveled to Nagoya if necessary scores significantly higher on the indicator “Experience of different cultures” (mean score of 1.72, as opposed to 1.19 for those who would not have flown; $t = -2.117$, $p = .036$). These respondents also rate the social interaction and networking significantly higher than the others (social interaction: 1.23, as opposed to 0.85: $t = -2.755$, $p = .006$; networking: 1.23 against 0.69; $t = -2.119$; $p = .035$). One possible interpretation is that among this group, culturally interested people are represented more strongly. Thus even

Table 6

Satisfaction levels of attendees in Nagoya. Numbers in columns 2–5 indicate the valid percent among the respondents who experienced the respective feature. Column 6 shows the percentage of participants who did “not use” the feature from the total number of respondents.

Nagoya (N = 56) (in %)	Very satisfied	Fairly satisfied	Less satisfied	Not satisfied	Not used
Presentations transmitted from Switzerland	56.3	39.6	4.2	0.0	14.3
Interactive Q&A sessions (presenter in Davos)	42.6	48.9	8.5	0.0	16.1
Sensing the presence of the audience in Davos	38.3	51.1	10.6	0.0	16.1
Spontaneous cross-site discussions (e.g. during coffee breaks)	23.3	58.1	18.6	0.0	23.2

Table 7

Opinions of attendees in Davos about the conference's impact on various factors. Mean score on a seven point scale: from +3 = strong positive influence to -3 = strong negative influence.

Opinions of Davos attendees on a -3...+3 rating scale	Would have traveled to Nagoya (N = 39)	Would not have traveled to Nagoya (N = 149)	Total Davos (N = 190)
Quality of content	1.77	1.51	1.56
Environmental impact (positive influence = less impact)	2.08	2.12	2.11
Social interaction	1.51	0.85	0.98
Networking	1.23	0.69	0.80
Cost efficiency of participation	1.85	1.83	1.83
Time efficiency of participation	1.77	1.87	1.85
Experience of different cultures	1.72	1.19	1.30

the virtual contact to the other culture could have influenced their positive rating of the item “cultural experience”. Table 7 summarizes the answers of the attendees in Switzerland.

For the Japanese respondents, the time and cost efficiency of participation was of significantly lower importance on the 5% level (time efficiency: mean score 1.42, $t = -2.484$, $p = .014$; cost efficiency: mean score 1.05, $t = -4.249$, $p = .000$). “Networking” and “Social interaction” were rated more positively in Nagoya than in Davos. While the differences were significant for the item “Networking,” they were not for “Social interaction” (Networking: $t = 2.606$, $p = .010$; Social interaction: $t = 1.505$, $p = .134$). Table 8 summarizes the answers of the attendees in Japan.

At the end of the questionnaire, we asked the participants about future similar conferences. A great majority of the respondents stated that two-site conferences were a viable approach for the future (93.7% “totally agree” or “rather agree” in Davos, 89.2% in Nagoya). The – mostly positive – comments of attendees about the future viability of multiple-site conferences included: “Absolutely yes because the flights and the travel put out so much CO₂ and other carbon emissions that it is valuable to have virtual conferences”, or: “It surely contributes to less traveling and thus the environmental impact of the conferences”. As several participants noted, though, there were limitations as well: “It surely contributes to less traveling and thus the environmental impact of the conferences. A little (but just personal) disadvantage is that if you want to meet someone personally, you will probably travel to the same place wherever it is. On the other hand, it can increase attendance and make the conferences accessible for more people”.

6. Discussion

The research question of our study was: “Can the GHG emissions caused by an international conference be substantially reduced by organizing it at multiple sites in order to reduce the average travel distance of the attendees?”

For our field experiment, the answer is clearly affirmative. Despite a strong rebound effect, the overall CO₂ emissions caused by the travel of attendees were significantly reduced by the two-site conference format compared to any of the single-site alternatives. Allowing more attendees to take part while lowering the overall energetic costs meant that the reductions per participant were even higher – by a factor of 2.3 and 3.5 as compared to a ‘Nagoya-only’ and ‘Davos-only’ conference, respectively.

Despite the possible non-response bias and the uncertainty inherent in hypothetical questions, the result of this field experiment was unequivocal. A critical question, though, is whether and if so, to what extent the result can be generalized to other types of conferences.

To achieve the same kind of savings as in our experiment, international conferences, typically attended by participants from different continents, are well-suited candidates. Reducing even a small number of intercontinental flights is the safest

Table 8

Opinions of attendees in Nagoya about the conference's impact on various factors. Mean score on a seven point scale: from +3 = strong positive influence to -3 = strong negative influence.

Opinions of Nagoya attendees on a -3...+3 rating scale	Would have traveled to Davos (N = 25)	Would not have traveled to Davos (N = 27)	Total Nagoya (N = 52)
Quality of content	1.68	1.48	1.58
Environmental impact (positive influence = less impact)	2.00	1.59	1.80
Social interaction	1.43	1.15	1.29
Networking	1.36	1.37	1.36
Cost efficiency of participation	1.00	1.11	1.05
Time efficiency of participation	1.36	1.48	1.42
Experience of different cultures	1.21	0.63	0.93



Fig. 3. The two audiences are placed in a 90° angle, and the speaker faces each audience at 45°.

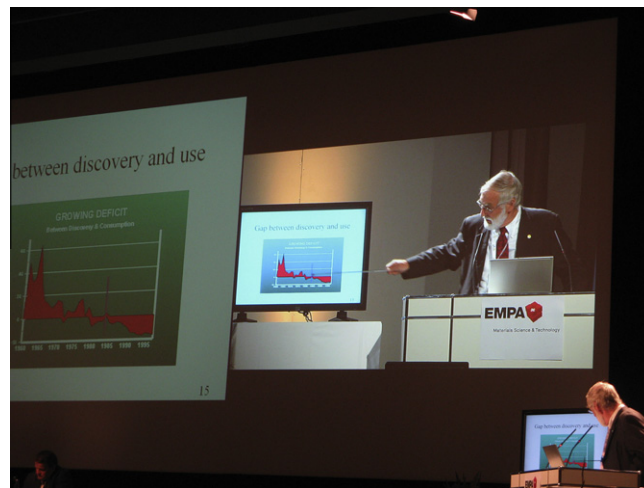


Fig. 4. A screen that displays the slides is placed next to the presenter, who is encouraged to point to it rather than to the large projection surface behind. In this picture, Dennis Meadows uses the technique while presenting in Davos. The two large images behind him were sent to Nagoya as well, one showing the slides only and the other showing the speaker pointing to the smaller monitor. It turned out that due to this set-up, both audiences could easily read the pointing gestures, which are an essential part of a presentation.

way to ensure that even a relatively large local rebound effect can be absorbed, and that the CO₂ emissions of the multiple-site conference will be lower than those of the traditional conference they are replacing. Spreading a conference over two or more continents, however, confronts the organizers with inherent challenges. There will typically be a time difference of some hours to cope with. As in our experiment, it helps if the conference has a part of the content which is of rather local importance. This content can be placed in the hours that cannot be used jointly, leaving the interactive part of the conference focusing on the content of general interest.

In order to ensure a high-quality link between the sites, following points proved to be important in our experience:

- having at least 2 video channels, one for the speaker, and one for the audience;
- using exclusively full-HD equipment for these video channels: full-HD cameras, TelePresence systems, and projectors;
- deploy echo-canceling techniques for the audio transmission between the two sites; and
- synchronize at each site the incoming audio and video signals – due to several reasons, primarily because of the lag introduced by the echo canceling algorithms on the audio channel, audio and video will be de-synchronized.

In order to offer the attendees a community experience across sites, the following features have proven helpful:

- projecting the audience from each site in such a way that the audiences can see each other, and the speaker can see the remote audience(s) as well as the local one, as showed by Fig. 3;

- placing a large screen displaying the slides next to the presenter, and asking presenters to point to this screen, as shown in Fig. 4 – then, remote audiences are able to follow the presenter highlighting specific details on slides;
- encouraging cross-site Q&A sessions – we started each such session with a question from the remote site;
- having cameramen filming the audience instead of static cameras – during Q&A, zooming in on the questioner makes the remote audience(s) and the remote presenter engage much better in a dialog;
- offering TelePresence “wormholes” also greatly improves the exchange across sites – we had one such connection in the coffee break areas, where attendees could informally engage in a chat and have the coffee “together”, and one placed in a quiet corner for more formal group meetings.

When organizing a similarly sized conference in such a way, one can expect CO₂ emission reductions by roughly a factor of 2–4 per capita and a factor of 1.5–2 in absolute terms. It would be too speculative to gross this up to a global emission reduction potential, because there are no reliable data on the annual number of events that would qualify for such a substitution.

As seen from the attendees' individual perspective, an intercontinental roundtrip of 20,000 km causes 3.4 tons CO₂, which is almost half of the average human's annual emission (Intergovernmental Panel on Climate Change, 2007). A multiple-site conference thus keeps the promise of substantially reducing the GHG intensity of this type of activity, even if rebound effects and other third-order effects (Erdmann and Hilty, 2010) are accounted for.

As the vast majority of attendees was satisfied with the conference experience, the two-site experiment did indeed provide a functionally similar substitute for a traditional conference organized at one site only. A substitute that reduced the conference's overall environmental impact, while at the same time broadening participation by offering an – on average – more time- and cost-efficient attendance.

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