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28th CIRP Conference on Life Cycle Engineering

# Comparison of the environmental impacts of online and classical conferences: the case of LCE 2020 and perspectives regarding the planetary boundaries

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## Abstract

International conferences such as CIRP LCE usually imply that their attendees travel around the world to reach the venue. Several online conferences have already been organised, but the year 2020 was particular because of the COVID-19 pandemics which obliged to cancel or modify dramatically all the events planned for the second quarter of that year. The CIRP Life Cycle Engineering conference was no exception and all arrangements made before March were cancelled or modified in order to host the conference online. This article presents the environmental impact assessment of the online conference and its comparison to the estimation of the impacts if the event had taken place in Grenoble (France), as initially planned. This study confirms that an online conference has lower environmental impacts than a classical conference, except for freshwater quality. The main contributors are the country energy mix of the audience for the online conference and the travel by plane for the classical one. This article also shows that online conferences might contribute to stay within the planetary boundaries. These results encourage to improve the study of the environmental impacts of online conferences and to highlight the hotspots to be improved.

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*Keywords:* Life Cycle Assessment; Event organisation; virtualisation; Planetary boundaries

## 1. Introduction

The beginning of the year 2020 was marked by the rapid spread of COVID-19 everywhere in the world. Especially, most of the European Union was in lock-down during spring, with important restrictions of travel and strict limitations of the number of people allowed to gather at the same place. The CIRP LCE 2020 conference which was supposed to take place in Grenoble, France, in May 2020 was impacted by this situation, like a high number of other events.

Considering this situation, it was decided in the beginning of March to transform the conference into an online event. The chosen option was to broadcast all the conference presentations and questions & answers sessions through four YouTube channels. The choice for this streaming service

provider was justified by its wide usage everywhere in the world, easiness, and reliability since it is designed for streaming an enormous amount of videos anywhere, anytime and is widely used.

The goal of this paper is to compare the environmental impacts of this online conference with the classical conference, if it had happened in Grenoble. This study was carried out following the structure the ISO 14040 standard about Life Cycle Assessment. Thus, the first section presents the goal and scope of this study; the second part describes the Life Cycle Inventory for both the online and classical conferences. Then, the results of the environmental assessment are presented, showing that virtual international events are relevant to reduce the impacts. A fourth section includes the interpretation of these results and their

discussions, notably in regards to social aspects and the planetary boundaries. Finally, conclusions are drawn.

## 2. Goal and scope definition

This study is an environmental screening using the method of Life Cycle Assessment to evaluate the environmental impacts of both conferences. Nevertheless, it follows the structure described in the ISO 14040 standard. Thus, the goal of this article is to compare the estimated environmental impacts of the LCE 2020 conference as it took place online, with the potential environmental impacts of a classical conference happening in Grenoble, as it was initially planned.

The functional unit can therefore be expressed as “*To present 135 papers, 6 keynotes and Q&A (Questions and Answers) sessions during 3 days to the 180 persons around the world who were registered to attend to the conference*”. In order to answer to this functional unit, two systems had to be considered: the online conference and the classical conference.

Elements considered similar (i.e. meals, building occupancy), even though differences should be possible, were not considered, in the absence of precise information and the few datasets in EcoInvent.

### 2.1. Online conference

The solution which had been chosen to host the conference was to ask the presenters to record a 10-minute presentation which was live streamed through YouTube, and to broadcast video calls with the speakers of a session. Four channels, corresponding to four parallel sessions were used: Life Cycle Assessment, Smart Manufacturing, Circular Economy, and Ecodesign [1–4]. Each channel streamed during four hours every day, during the three days that the conference lasted.

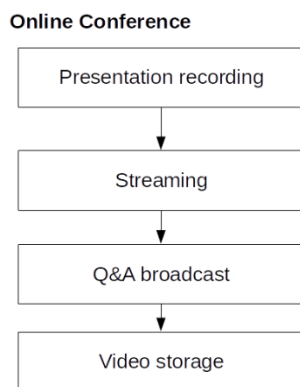


Fig. 1. Online conference system.

After the end of the conference, the videos remained stored and accessible on YouTube (Fig. 1). Most of the viewing time happened on the days of the conference. Nevertheless, the videos were left accessible and the follow-up showed that a little number of people watched them during the following month. In this study, we considered that the videos were accessible during one year.

Table 1. Information used for the online conference (calculated after [5-6]).

| Step                   | Item                | Value         |
|------------------------|---------------------|---------------|
| Presentation recording | Laptop              | 2h/speaker    |
|                        | Video uploading     | 100MB/speaker |
| Streaming              | YouTube Server      | 0.216Wh/s     |
|                        | WIFI Network        | 0.456Wh/s     |
|                        | Fixed Network       | 1.287Wh/s     |
|                        | Mobile Network      | 2.652Wh/s     |
|                        | Device - Smartphone | 1.87E-04Wh/s  |
|                        | Device - Laptop     | 1.77E-03Wh/s  |
| Q&A broadcast          | Video call service  | 0.216Wh/s     |
| Video online storage   | Storage             | 10E-06Wh/B/yr |

Since the servers still consume energy to make the videos available, this phase was also studied. Thus, for every step described in Fig. 1, the values given in Table 1 were taken into account. For the recording of the presentations, it was considered that the speakers used a laptop during 2 hours and that each video was a 100MB file for a 10-minute presentation.

For the streaming, the method developed by The Shift Project [5-6] was used to assess the amount of electricity consumed by the datacentres per byte and per unit of time, considering a bitrate of 3MB/s, the network (WIFI, fixed or mobile) and the devices (smartphone or laptop). For the datacentres, an allocation to create a YouTube electricity mix from their locations, as stated in [7], was done.

In the absence of much information about the video call system used for the Q&A sessions, it was considered that its consumption was similar to streaming with YouTube with a location of the datacentres in the USA.

### 2.2. Classical conference

In the case of the classical conference, the structure of the system was based on the initial planning, as illustrated in Fig.2. The arrival of the participants was considered, based on the location they gave during their registration. A search for the nearest airports and flight distances to Lyon airport was considered. The possible connections necessary for the actual trips were neglected, therefore the impacts of the flight is expected to be underestimated. Finally, transportation by train between Lyon and Grenoble was considered. During the conference, the energy and water consumption in the building where the event would have taken place was considered. Accommodations were not included in the absence of data for the participants and the hotels they would have booked.

Another important difference with the online conference was the social events which had been planned and could not be reproduced virtually. Finally, the departure of all the participants back to their home country was considered. The possible extension of their stay after the conference for sightseeing was unknown. The total number of participants which had been expected was 148, without the people from Grenoble. After calculations, the inventory was as indicated in Table 2.

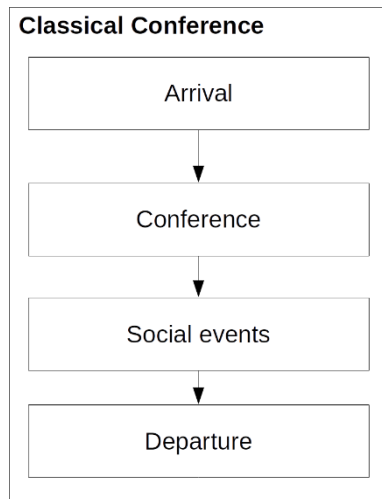


Fig. 2. Classical conference system.

Table 2. Information used for the classical conference.

| Step              | Item                    | Value            |
|-------------------|-------------------------|------------------|
| Arrival-Departure | Plane                   | 286,168p.km      |
|                   | Train                   | 14,800p.km       |
| Conference        | Electricity FR          | 20kWh            |
|                   | Tap water FR            | 22m <sup>3</sup> |
| Social events     | Transportation by tram  | 10p.km           |
|                   | Transportation by coach | 10p.km           |
| Departure         | Plane                   | 286,168p.km      |
|                   | Train                   | 14,800p.km       |

### 3. Lifecycle inventory

Data about the origin of the participants were used to identify the national electricity mixes to consider for the preparation and viewing of the videos. The Life Cycle Inventory and the hypotheses used for the calculations are described in this section.

#### 3.1. Online conference

YouTube enables to access a number of statistics about the videos. Thus, the quantities used to estimate the consumption of the online conference is based on these data. More specifically, the duration of visioning, the number of unique spectators, their geographical origin and the devices they used provided the relevant data to calculate the energy

consumption related to the access to the videos in each country, according to the electricity mixes included in the EcoInvent database. Then, the streaming time for the four channels during the three days of the conference was considered. This includes the viewing time by countries according to YouTube (Table 3).

Table 3. Duration of viewing per country (in hours).

| Location of views | Duration | Device  |      |        |        |
|-------------------|----------|---------|------|--------|--------|
|                   |          | Desktop | TV   | Mobile | Tablet |
| Belgium           | 43.01    | 34.78   | 0.61 | 6.26   | 1.33   |
| Germany           | 411.94   | 333.24  | 5.91 | 59.98  | 12.79  |
| Denmark           | 5.61     | 4.53    | 0.08 | 0.81   | 0.17   |
| Ecuador           | 13.03    | 10.54   | 0.18 | 1.89   | 0.40   |
| France            | 364.71   | 295.03  | 5.23 | 53.11  | 11.32  |
| Great Britain     | 43.08    | 34.85   | 0.61 | 6.27   | 1.33   |
| Guatemala         | 2.17     | 1.75    | 0.03 | 0.31   | 0.06   |
| Ireland           | 1.86     | 1.51    | 0.02 | 0.27   | 0.05   |
| India             | 3.18     | 2.57    | 0.04 | 0.46   | 0.09   |
| Italy             | 95.96    | 77.63   | 1.37 | 13.97  | 2.98   |
| Japan             | 72.87    | 58.95   | 1.04 | 10.61  | 2.26   |
| Malta             | 9.85     | 7.97    | 0.14 | 1.43   | 0.30   |
| Sweden            | 57.54    | 46.54   | 0.82 | 8.37   | 1.78   |
| Singapore         | 13.48    | 10.91   | 0.19 | 1.96   | 0.41   |
| Turkey            | 2.31     | 1.87    | 0.03 | 0.33   | 0.07   |
| USA               | 34.79    | 28.15   | 0.49 | 5.06   | 1.08   |

Then, the usage of the YouTube servers was assessed, considering the known locations of the datacentres to apply the most relevant electricity mix. The information was collected 2017 [7] and no more recent source could be found. The number of servers and their location is summarised in Table 4. From this information, an allocation of the share of electricity consumption was carried out in order to have a more precise electricity mix for the functioning of YouTube servers. However, it was not possible to consider the actual usage of the various servers for this precise application, or which servers were used.

Table 4. Location and number of YouTube datacentres.

| Location of datacentres | Number |
|-------------------------|--------|
| USA                     | 19     |
| EU                      | 12     |
| Russia                  | 1      |
| South America           | 1      |
| Asia                    | 3      |

It seems important to indicate that there is a high uncertainty about the reliability of these statistics, considering that some countries are not represented, whereas speakers whose location was clearly identified were known. In the

absence of a better source of information about the audience, they have been used nonetheless.

In order to estimate the environmental impacts, the calculation method by The Shift Project [5-6] was used. It provides a value for the energy consumption per byte of video streamed, including the streaming service provider, network and device used to watch the videos. However, the impacts of the materials used for the servers and equipment could not be found, except for the devices used by the audience. Table 5 summarises the inventory for the online conference and the energy consumption per byte of data and a share of the devices according to the proposed life span indicated in the document (equation 1).

$$E = \sum_i \text{File size} * \text{Number of views} * \text{Energy per byte} \quad (1)$$

Table 5. Life Cycle inventory of the online conference.

|                     | Energy consumption | Usage allocation |
|---------------------|--------------------|------------------|
| YouTube datacenters | 7.20E-11 kWh/B     | 0.21 Wh/s        |
| WIFI Network        | 1.52E-10 kWh/B     | 0.45 Wh/s        |
| Fixed Network       | 4.29E-10 kWh/B     | 1.28 Wh/s        |
| Mobile network      | 8.84E-10 kWh/B     | 2.65 Wh/s        |
| Smartphone          | 1.87E-04 Wh/s      | 913 h/yr         |
| Laptop              | 1.77E-03 Wh/s      | 2922 h/yr        |

### 3.2. Classical conference

For the classical conference, arrival and departure of the attendants were considered, as already showed in Table 2, according to the location of the registered participants before the announcement of the passage to an online conference. Mean distances by plane were considered to reach Lyon airport, which is the closest to Grenoble. The calculation was made with an online flight distance calculator [8]. Then, transportation by train for the last 100km was considered. For the conference itself, only an estimation of the electricity used for lighting, video-projectors and air conditioning could be used, in addition to an average consumption of tap water per person. Finally, for the planned social events, this study considered the transportation planned, and meals roughly estimated by 200g of red meat and 200g of various vegetables per person per meal, so as to have an overestimation of meals compared to the situation at home.

## 4. Results of the lifecycle impact assessment

The environmental assessment was carried out with SimaPro 8, using the ILCD method (Fig. 3). First of all, it is noticeable that the online conference has lower impacts than the classical conference on most indicators. The online conference represents less than 10% of the impacts of the classical conference for 7 indicators (climate change; ozone depletion; photochemical ozone formation; acidification; terrestrial eutrophication; marine eutrophication and land use); less than 30% for 2 (Particulate matter and ionizing radiation E); and between 70 and 80% for 4 (human toxicity

non-cancer effects; human toxicity cancer effects; ionizing radiation on human health, water depletion and mineral, fossil & renewable resource depletion). However, the online conference presents the highest environmental impacts for freshwater eutrophication, freshwater ecotoxicity.

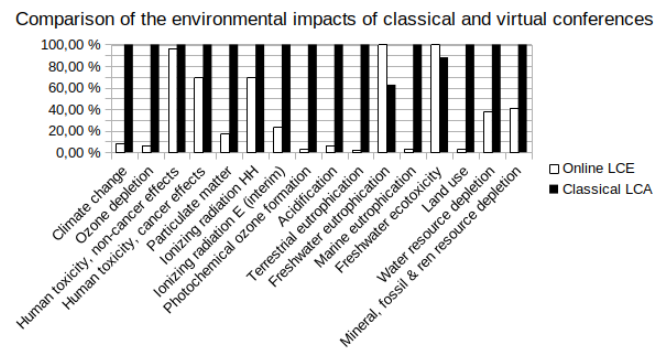


Fig. 3. Comparison of the environmental impacts of the classical and online conferences.

A closer look at the results showed that the main cause for this result was the electricity used in the country where the highest number of attendees watched the conference: Germany. More generally, most of the impacts of the online conference are due to the audience. Therefore, the overall environmental impacts of the event seem to depend mostly on the location of the viewers and their number; the streaming counting for 8.5%, according to the present hypotheses. As far as the classical conference is concerned, the majority of the environmental impacts are due to the flights to and from the venue.

## 5. Interpretation and discussion

The results of the environmental screening were unequivocal. However, other considerations need to be regarded in order to conclude about the relevance of online conferences. This aspect is discussed in the first subsection and is followed by a tentative consideration of the planetary boundaries in order to verify the environmental relevance of online conferences.

### 5.1. Discussion about the impacts of an online conference

The environmental impact assessment of information and communication technologies (ICT) is difficult, since the allocation of the impacts of hardware used for multiple functions does not present any clear solutions [9–10]. Furthermore, monitoring the audience of an online conference is imprecise although the service provider offers some statistics and could collide with privacy requirements. Nevertheless, the clear differences between both conferences enabled to answer that online conferences present an undeniable environmental superiority on classical international conferences. Before video storage compensates the benefits of not travelling by plane, the videos can be watched several hundreds of times during many years.

Considering the variety of devices used to watch the conference, it would have been extremely tricky to propose a

fraction of laptops, desktops, mobile phones or TV related to the 12 hours that LCE 2020 lasted. It might be reasonable to think that the impacts would not be different in both conference formats, where people use their laptops or phones extensively. Another important aspect which needs to be discussed is the social impacts of the conference. Indeed, apart for presenting researches in a paper and during a presentation, essential elements of classical conferences are the discussions, networking or project building among the participants. It is possible that such interactions had happened during LCE 2020. However, it was not possible to estimate precisely the expected reduction compared to a classical conference. Although it would be possible to consider the planned expenses for the events, the transfer with current locations of the participants would have required conducting a survey on this matter. It is also the informal gatherings and discussions which are the most difficult to assess. In addition, the cancellation of the event may have had an influence on some local businesses (hotels, restaurants, etc.). Rebound effects due to the money saved by the participants' institutions and spent for something else might increase the overall environmental burdens of the online conferences. A sensitivity analysis based on several scenarios for these expenses could be a way to assess them, such as acquisition of new computers, but other possibilities would need to be investigated.

In this study, the online conference had not been advertised, and it is reasonable to think that other events could attract many more viewers than the 180 registered participants considered in this study. In this case, the environmental savings would be partially compensated by the extra audience. Since, the audience electricity was the main impact, the results would evolve almost linearly and the online conference would become less relevant for an increase of attendance coherent with the results given in section 4: e.g. the audience could be multiplied by 10 to reach the impact of the classical conference on climate change, and only by 1.3 for toxicity.

For the classical conference, it was considered that the participants would come only for the duration of this event, and only for this purpose. A more realistic allocation for the time of travel would be essential to have a clearer idea of the impacts of the social events and the conference itself, and not to consider that anything could be done on these aspects. Furthermore, for the indicators where the differences are the narrowest, the relevance of online conferences would be questionable. Thus, the impacts on toxicity would be less obvious if it was considered that the attendant would stay around twice the duration of the conference for other reasons. However, the issue of the boundaries considered arises, and the definition of the responsibility of the conference as a cause for travelling may be more difficult than a matter of allocation: if someone had come to France for the conference and another meeting, which is the main reason? Would have this person travelled without the conference?

## 5.2. Relation to planetary boundaries

In 2009, Rockström et al. [11] defined nine planetary boundaries in order to rethink sustainability and provide a reference to the main bio-geo-chemical cycles of the Earth. These boundaries are: climate change, ocean acidification, stratospheric ozone depletion, interference with the global phosphorous and nitrogen cycles, rate of biodiversity loss, global freshwater use, land-system change, aerosol loading and chemical pollution. Exceeding the capacity of the planet for these indicators would therefore threaten the sustainability of life on Earth. From then, various authors sought to link these planetary boundaries to objectives for a sustainable society [12–14] or to apply them to LCA [15]. Although, these approaches imply the consideration of the whole human system, it would be helpful to have a way to consider the planetary boundaries when working on a single project and to be able to verify whether the said project contributes to respect them. In the case of this article, it was attempted to see whether switching from classical to online conferences would contribute to stay within the planetary boundaries.

In 2016, the European Union proposed normalisation factors to consider the planetary boundaries in LCA [16]. As a first approach, it is proposed here to use the ratio between planetary boundaries factors and current ILCD factors in order to obtain a coefficient. It would then indicate the number of times that the impacts of a baseline situation needs to be reduced to be compatible with the planetary boundaries. Thus, it may be possible to see whether the lower impacts of the online conference are enough in a world where the planetary boundaries would be aimed. Because there does not exist a planetary boundary determined for each indicator of the ILCD method, only those for which a value exists are calculated in Table 7.

Table 6. Normalisation factors in current ILCD method and according to planetary boundaries, after [9].

| ILCD impact category          | Unit                          | Normalisation factors |                      |
|-------------------------------|-------------------------------|-----------------------|----------------------|
|                               |                               | Current ILCD          | Planetary Boundaries |
| Climate change                | kg CO <sub>2</sub> eq/pers.   | 9.22E+03              | 9.85E+02             |
| Ozone depletion               | kg CFC-11 eq/pers.            | 2.16E-02              | 7.80E-02             |
| Photochemical Ozone Formation | kg NMVOC eq/pers.             | 3.17E+01              | 3.80E+00             |
| Acidification                 | mol H <sup>+</sup> eq/pers.   | 4.73E+01              | 1.45E+02             |
| Terrestrial Eutrophication    | mol N eq/pers.                | 1.76E+02              | 8.87E+02             |
| Freshwater eutrophication     | kg P eq/pers.                 | 1.48E+00              | 8.40E-01             |
| Marine Eutrophication         | kg N eq/pers.                 | 1.69E+01              | 2.90E+01             |
| Land Use                      | kg C deficit/pers.            | 7.58E+04              | 1.99E+04             |
| Freshwater Ecotoxicity        | CTUe/pers.                    | 8.94E+03              | 1.90E+04             |
| Water depletion               | m <sup>3</sup> water eq/pers. | 8.14E+01              | 9.93E+01             |

In addition, some coefficient may be inferior to 1 in the cases where the European impact does not exceed the

planetary boundary. Anyhow, with this tentative approach, as long as the coefficient for the conference is higher than the European one, it means that the online conference environmental performances are up to this particular planetary boundary.

In this example, there is still a need for improvements on the issues freshwater eutrophication and water depletion. One of the setbacks here is that several environmental issues would not be considered, such as freshwater ecotoxicity which was higher, as explained in the previous section. Finally, in this study, and with this simple consideration of planetary boundaries, it appears that the online conference is a good alternative, except for freshwater eutrophication and water depletion, as already seen in the comparison in section 4. However, this would require a full LCA with a deep sensitivity and uncertainty analysis to be certain of this observation. Furthermore, since the main contributor is the national electricity mix of some countries, the only solution to improve the results would imply to work on the overall system, which would be out of the scope of the organisers of a conference.

Table 7. Planetary boundaries coefficient and application to the conference.

| ILCD impact category          | Unit                          | Europe | Conference |
|-------------------------------|-------------------------------|--------|------------|
| Climate change                | kg CO <sub>2</sub> eq/pers.   | 9.36   | 11.70      |
| Ozone depletion               | kg CFC-11 eq/pers.            | 0.28   | 14.54      |
| Photochemical Ozone Formation | kg NMVOC eq/pers.             | 8.34   | 32.04      |
| Acidification                 | mol H <sup>+</sup> eq/pers.   | 0.33   | 13.81      |
| Terrestrial Eutrophication    | mol N eq/pers.                | 0.20   | 33.04      |
| Freshwater eutrophication     | kg P eq/pers.                 | 1.76   | 0.54       |
| Marine Eutrophication         | kg N eq/pers.                 | 0.58   | 25.11      |
| Land Use                      | kg C deficit/pers.            | 3.81   | 27.52      |
| Freshwater Ecotoxicity        | CTUe/pers.                    | 0.47   | 0.7        |
| Water depletion               | m <sup>3</sup> water eq/pers. | 0.82   | 0.22       |

## 6. Conclusion

This article presented an evaluation of the environmental impacts of the online LCE 2020 conference as it happened. The study is based on the available data and uncertainties remain. Nevertheless, it seems that online international conferences offer an interesting alternative, considering the high impacts of flights. More research about the influence of the audience and organisers' electricity mixes would be

necessary to better understand how it affects the results, and the impacts of the hardware would also need to be included.

Additional work about the planetary boundaries and how to include them in LCA studies would be essential, in order to use them to guide decisions while assessing a new product or service. However, it is crucial to keep in mind that actual solutions related to the planetary boundaries should take into account the bigger picture, and that a narrow solution may have unexpected consequences or too little effect.

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