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Examining the Carbon Footprint of Conferences with an Emphasis on Energy Consumption and Catering

Viktoria Mannheim [1,*] and Judit Lovasné Avató [2]

[1] Department of Engineering Management and Enterprise, Faculty of Engineering, University of Debrecen, H-4028 Debrecen, Hungary
[2] Department of Methodology for Business Analysis, Institute of Quantitative Methodology, Budapest Business University, Alkotmány Str. 9-11, 1054 Budapest, Hungary; lovasneavato.judit@uni-bge.hu
* Correspondence: mannheim.viktoria@eng.unideb.hu

Abstract: This research study presents a comparison of an in-person and an online conference in terms of environmental impact and energy efficiency. The main goal of our research was to prepare a complete life cycle assessment of a two-day (15-h), 200-participant in-person and online conference based on different impact assessment methods. Life cycle assessments focus on the numerical determination of the decarbonization of conference consumption (lunch, dinner, food and beverage consumption during breaks), conference organization (discussions, correspondence, abstract booklet, registration package), travel, and infrastructure. The meals were examined by connecting the stages of preparation, cooking, consumption and end-of-life cycle as a cradle-to-grave analysis. We paid particular attention to the calculation of energy consumption. After carbon footprint comparisons, the areas with the highest impacts with pie diagrams were identified. Lastly, a SWOT chart and an SAP-LAP analysis diagram summarize the achievable objectives and challenges. In conclusion, there is no outstanding difference between the impact assessment methods for the carbon footprint investigation. Travel contributes 57% of the overall carbon footprint at in-person conferences, while the environmental impact of meals holds the second largest share, at 8.41 kg CO_2 equivalent/person/hour. Excluding meals and travel, the calculated carbon footprint is 0.362 kg CO_2 equivalent/person/hour (only considering the effect of preparation, organization, administration and registration package). Our initial hypothesis was that an online conference reduces decarbonization, which the results confirm.

Keywords: energy consumption; decarbonization; life cycle assessment; carbon footprint; in-person conference; online conference

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1. Introduction

There has been growing interest in creating more sustainable services in recent years. The European Union is working towards achieving carbon neutrality within the sustainable development goals' (SDGs) framework and the circular economy (CE). The question rightly arises: how can the decarbonization goals to reduce the loads of services be achieved, and through what methods?

Many studies [1–3] mention that life cycle assessment (LCA) is a popular tool for determining environmental impacts. However, the LCA studies are primarily concerned with determining the environmental impacts of products and technologies. Recent research works [4–6] range from the LCA of polyethylene shrink wrap to using municipal solid waste as recycled aggregates and to comparative analysis of building sustainability.

Despite the increasing focus on decarbonizing communication and information technologies, no research has been conducted on the impact of conferences based on the LCA method. However, scientific conferences are a priority for scientists, researchers and lecturers. The target audiences for conference services are mainly academics and corporate employees, who face various choices among academic and business stakeholders [7].

Conference tourism, as a subsector of Meetings, Incentives, Conferences, and Exhibitions (MICE), is one of the most significant segments of the tourism industry [8].

It also directly contributes to local markets' economic benefits and global markets' development [9]. Therefore, this research topic is currently gap-filling. It is novel in that it has not yet been examined and evaluated from an LCA perspective, which also examines the decarbonization of the conference service. In-person conferences offer social and economic advantages, such as reduced reliance on technology and enhanced communication through non-verbal cues. However, they come with travel and accommodation costs, logistics, and security risks. The experience of the venue enhances attendees' enjoyment and benefits the local economy, creating a more substantial economic impact on local entrepreneurs [10–14].

However, face-to-face interaction has become more critical since COVID-19, with the forced contact shift to virtual space. Online conferencing saves time and travel energy and is more cost-effective and convenient but requires information and communication technology (ICT) energy [9].

The organization and conduct of an in-person, online, or hybrid conference must be tailored to a wide range of expectations.

The potential risks for the two event types are parallel and different. There are challenges for both the face-to-face and online formats. The motivating factors for different generations to participate are different and need to be considered by organizers [14–16].

Grossmann and Krueger [17] published a new idea about the environment, known as the inverted U-shaped curve, which is becoming more popular in the economic sector and with the public. This trend is also seen in professional conferences, as the age range of participants changes [8]. The conference itself as a product will be considered a tourism service. This is because it fits well with the situation–actor–process and learning–action–performance (SAP-LAP) analysis framework [18].

The literature identifies three critical subsystems of conferences from an environmental point of view: travel, catering, and ICT tools [19–21]. In the context of travel, it is a good solution to advertise the event in a hybrid or online format instead of attendance [22–25]. In catering, reducing food waste, using short supply chain vendors, and using sustainable cooking techniques (sous-vide) can be good opportunities [26–28]. Previous research [29] found that the ICT created about 1.8–2.8% of global greenhouse gas (GHG) emissions. The emissions from virtual conferences were measured at 10.17 kWh [30]. Some studies examine research trends related to integrating innovative solutions and sustainable energy use or focus only on the energy use of electronic devices [31–33]. We have not yet found any research results on the role of ICT tools at conferences.

In the present study, we conducted a methodological review of the literature regarding the given research topic and modeling for in-person and online conferences. Based on the results of studies using a life cycle assessment approach, we sought to identify options for decarbonization.

The main goal of this research was to compare a two-day (total of 15 h), 200-participant in-person and online conference and to prepare complete life cycle assessments by comparing the carbon footprints and energy consumption values. This study was based on an international conference held in 2019 and a detailed life cycle inventory (LCI).

In the reviewed in-person conference, 25% of foreign participants arrived from Italy, Germany, India, Australia, Algeria, Iraq, and Belgium. The remaining individuals were citizens of Hungary.

Our initial hypothesis is that the transition to online conferences significantly reduces the carbon footprint of conference organizational processes by minimizing physical presence. When it comes to models for the decarbonization assessment of online conferences, mathematical, computer simulations, or other analytical tools come to the fore. Unlike these tools, we resorted to applying the LCA method, strengths–weaknesses–opportunities–threats (SWOT) and SAP-LAP analysis.

This research analyses the carbon footprints of the conference types using three life cycle impact assessment (LCIA) methods, focusing on event preparation, organization, energy and water use, travel, and infrastructure. The chosen methods align with those preferred by the Catena-X data ecosystem, although the CML 2016 method has been deemed obsolete in the latest Sphera (GaBi 10.6) LCA for Experts software. Nonetheless, it was included due to its use in previous research.

Following a methodological review, a detailed inventory analysis and life cycle impact assessments using Sphera LCA FE software, this study compares global warming potential and examines energy consumption in catering, organization, and attendance. To support our hypothesis, we employed SWOT analysis alongside situation–actor–process (SAP) and learning–action–performance (LAP) models. This research culminates in critical discussions and conclusions based on the findings.

2. Methodology

2.1. Life Cycle Assessment Method

The applied life cycle assessment methodology quantifies conference consumption (lunch, dinner, food and beverage consumption during program breaks), conference organization (discussions regarding the organization, correspondence, abstract booklet, registration package), energy consumption related to conference participation, and the travel's impacts. During this investigation, separate analyses were made of the meals consumed at the conference, the multi-course lunches and dinner, and the foods and drinks consumed in the pauses. The main meals were examined by connecting the stages of preparation, cooking, consumption, and end-of-life life cycle. When determining the conference's carbon footprint, we did not consider the environmental impact of hotel accommodation. Regarding travel, we calculated the global warming potential (GWP) depending on the different travel modes and transport distances.

During the software analyses, we followed the mandatory steps of the life cycle assessment (determination of system boundary, functional unit and allocation, definition of expectations regarding batch quality, data collection and inventory analysis based on actual plant and measured household data, impact assessment and interpretation).

In the first step of this research, we performed a cradle-to-grave life cycle assessment of the meals of one in-person and one online two-day conference and the catering services during the program breaks of the two conference days (four times in total). The whole life cycle of the examined lunch and dinner dishes was divided into four main stages: (1) preparation, (2) cooking, (3) consumption, and (4) becoming waste. The life cycle assessments lasted from the extraction of raw materials through the preparation, cooking and use (consumption) phases until the end of the life cycle. The life cycle stages of each product (meal) were illustrated in a single LCA plan for each meal portion separately during the software analyses, with a single LCA process in the background. For the 3-course lunch on the first day of the conference, we chose Cheddar cheese cream soup, Wiener schnitzel with Thai rice, and orange cream, and for dinner, we chose gnocchi with cheese sauce. On the conference's second day, we chose green pea cream soup, steamed fish with Thai rice and tomato salad for lunch. Dinner was not served on the second day of the conference given that the program ended at 4:00 p.m. Starting conditions during the conference meals are the following:

- The duration of the first conference day is 9 h.
- The second conference day's duration is 6 h.
- The conference has a total duration of 15 h. The first conference day features a 3-course lunch and dinner with pickles, plus two 15 min breaks.
- The second conference day features a 3-course lunch and two 15 min breaks.

In the second step, we determined the estimators of the carbon footprints occurring during the conference's organization.

In the third step, we determined separately the burden of traveling to the in-person conference. A separate calculation methodology was developed for travel. In this regard, we took into account that participants from foreign countries arrived at the conference venue by plane and train. However, Hungarian participants arrived at the city where the in-person conference was held exclusively by train and car. Therefore, separate carbon footprint values per functional unit kilometer for travel by plane, train, and car were determined. Subsequently, the individual carbon footprint values calculated based on transportation distances and modes of transport were summed up.

2.2. Life Cycle Inventory

The coherent life cycle inventory is based on 2022 data and follows the technique described in the ISO 14040:2006 and 14044:2006 standards [34,35]. It includes the material and energy supply of all the examined processes. Regarding the study of meals, we associated professional and food industry supplementary datasets with preparation and cooking data to establish a more accurate life cycle inventory for the studied products. In most cases, the data available in the database of the Sphera LCA for Experts software used by us do not take into account the following parameters: equipment, various auxiliary materials and additives, or the amount of energy used for heating and cooling; so, in the case of equipment, only their energy consumption was taken into account. When entering the input data to create the LCA processes within the software, we could only consider the parameters already included in the database. All other parameters were considered cut-off flows. Also, conference accommodation was treated as a cut-off flow during the analysis. The Saint Anna Restaurant in Berkenye (in Hungary) provided us with the large-scale kitchen data necessary for the inventory analysis of the in-person conference regarding lunch and dinner courses as they also deal with conference and wedding organizations. For each main course, we received the exact material and energy flow values for the preparation and cooking phases, which mainly included the following parameters: electricity supply for preparation and cooking; gas quantity used for cooking and water heating; electricity use, for example, for storing chilled meat, cod, cheese and cream; and the amount of drinking water for cleaning raw materials, for cooking, and for washing used dishes, plates and cutlery. We measured the material flows of the soups, desserts, and tomato salad using a kitchen scale in our homes, and we prepared the individual dishes. The material flows required for the online conference inventory analysis were identical to those of the in-person conference material flows for consistency and comparability. However, the water and energy flows used here were measured in our homes. The factors, input and output currents taken into account in the analysis were as follows:

- Number of participants.
- Travel distance and travel method.

- Energy consumption for the organization and running of the event (2 days—15 h duration of electricity consumption, lighting, electricity consumption of IT devices).
- Registration package.
- Catering (buffet service twice a day)—tea, orange juice, potato chips, oranges, sugar.
- Meals—1st day: lunch + dinner; 2nd day: only lunch.
- Travel methods and kilometers travelled.
- Water consumption, and paper towel consumption (when using the toilet).
- Amount of municipal solid waste and wastewater generated.

Table 1 summarizes the life cycle inventory of the raw materials in kilograms per portion for lunches on the two conference days and dinner on the first conference day.

Table 1. Life cycle inventory of raw materials in kilograms per portion for lunches on the two conference days and dinner on the first conference day.

Conference Day 1:/Lunch/Course I: Cheddar cheese cream soup Serving weight: 0.385 kg/person
Cheddar cheese: 0.15 Pasteurized cream (38–42%): 0.103 Rapeseed oil (Canola): 0.025 Fine wheat flour: 0.006 Salt: 0.001
Conference Day 1/Lunch/Course II: Vienna Schnitzel with Thai rice Serving weight: 0.433 kg/person
Beef (semi-boned): 0.12 Fine wheat flour, eggs and breadcrumbs: 0.0355 Thai rice: 0.25 Orange rings (for decoration): 0.02 Sunflower oil: 0.0882 Salt: 0.001
Conference Day 1/Lunch/Dessert: Orange cream glass Serving weight: 0.289 kg/person
Orange: 0.165 Pasteurized cream (38–42%): 0.0773 Sour cream: 0.045 Sugar: 0.01
Conference Day 1/Dinner: Gnocchi with cheese sauce Serving weight: 0.414 kg/person
Cheese: 0.15 Pasteurized cream (42%): 0.05 Potatoes: 0.167 Wheat flour: 0.0333 Rapeseed oil (Canola): 0.03 Salt: 0.01
Conference Day 2/Lunch/Course I: Green pea cream soup Serving weight: 0.388 kg/person
Green peas: 0.125 Carrot: 0.09 Pasteurized cream (38–42%): 0.05 Rapeseed oil (Canola): 0.02 Fine wheat flour: 0.002 Salt: 0.001
Conference Day 2/Lunch/Course II: Steamed fish with Thai rice Serving weight: 0.398 kg/person
Fish meat: 0.10 Thai rice: 0.25 Orange rings (for decoration): 0.02 Rapeseed oil (Canola): 0.03
Conference Day 2/Lunch/Salad: Tomato salad Serving weight: 0.250 kg/person
Tomato: 0.20 Rapeseed oil (EU): 0.05

The life cycle inventory for conference registration package only features the in-person conference; so, the relevant analyses were prepared only for this case. During the analyses, we assumed that all participants received the registration package during the in-person registration; so, the analysis was performed for 200 people. The contents of the package are as follows:

- Two-page program booklet (2 pieces of A4 size kraft paper, with black ink cartridge, total: 8 g).
- Globe-shaped stress ball made of eco-rubber; weight: 61 g/pc.
- Conference folder: a document folder made of recycled paper with a 20-page notepad, a ballpoint pen covered with recycled paper and self-adhesive marking (post-it) labels.
- Paper bag with ribbon flaps made of recycled paper (size: 22 × 28 + 10 cm)
- Wooden wine cup with glass insert and copper conference logo.

2.3. Life Cycle Impact Assessment Methods

During the life cycle impact assessment, the impact assessment methods shown in Table 2 can be used to determine the carbon footprint during the analyses (regarding determining carbon dioxide equivalents) in the LCA for Experts software.

Table 2. Possible impact assessment methods for decarbonization in the LCA for Experts software.

Name of Impact Assessment Method	Carbon Footprint [kg CO_2 eq.]
CML 2001—August 2016/Non-baseline CML	Global Warming Potential (GWP 100 years) with or without biogenic carbon
Impact 2002+ (I02 + v2.1)	Global warming 500 yr—Midpoint (kg CO_2 eq. to air)
EF 3. 0 and EF 3.1 (Environmental Footprint 3.0 and Environmental Footprint 3.1)	Climate Change—total, biogenic, fossil, and land use and land use change
EN 15804 + A2 (based on EF 3.1)	EN 15804 + A2 (EF 3.1) Climate Change—total, fossil, biogenic, land use and land use change
Impacts ILCD/PEF recom worldsteel mod v1.09	Climate Change midpoint, including or excluding biogenic carbon (v1.09)
IPCC AR6	IPCC AR6 GWP 20, 100, 500 including or excluding biogenic carbon IPCC AR6 GTP 50, 100 including or excluding biogenic carbon
ISO 14067 GWP (based on IPCC AR6)	GWP100, Aircraft emissions GWP100, Biogenic GHG emissions GWP100, Biogenic GHG removal GWP100, Emissions from land use change (dLUC) GWP100, Fossil GHG emissions
PCF IPCC	IPCC AR5 GWP 100 including biogenic carbon, including Land Use Change, no norm/weight
ReCiPe 2016 v1.1	Climate Change, incl. Land Use Change (LUC): endpoint (H) and midpoint (H), Climate Change, incl. or default, excl. biogenic carbon Endpoint (I)/Midpoint (I)
SBK Bepalingsmethode—January 2021 (NMD 3.3)	Climate change (GWP 100) Climate change (GWP 100), incl long-term emissions
TfS (Together for Sustainability)	TfS 1—GWP total, inc. biogenic carbon TfS 2—GWP total, excl. biogenic carbon TfS 3—GWP fossil
TRACI 2.1	Global Warming Air, excl biogenic carbon, incl LUC, no norm/weight Global Warming Air, incl biogenic carbon, incl LUC, no norm/weight Global Warming Air, LUC only, no norm/weight Global Warming Air, including or excluding biogenic carbon

During the life cycle assessments, the following impact assessment methods for the determination of the carbon dioxide equivalent in the software analyses, both for the face-to-face and online versions, were applied:

- CML 2016/Non-baseline, excluding biogenic carbon.
- IPCC AR6 GWP 100, excluding biogenic carbon (version August 2021).

- ISO 14067 GWP 100.

2.4. System Boundary

Regarding the system boundary and allocation of the life cycle assessment, the food and drinks served were examined within the cradle-to-grave system boundary, and the life cycle stages were determined as a function of the weight of the portions served. All environmental loads were allocated by mass allocation to the tested products and the generated waste. The material and energy flows used are related to the examined product output. The energy requirement was determined as a function of the energy content. Equipment and machines are outside the system boundary. In the preparation phase, we considered the energy storage of raw materials, which includes the energy values used to keep meat, fish, cream and cheese in the refrigerator. We incorporated these energy values into the preparation phase. We completely excluded the transport of the raw materials during our analyses since the individual ingredients do not come from the same place, and in this case, we would not have been entirely consistent in comparing the environmental impact of the served meals. The life cycle analysis also includes the wastewater flows from the washing process of the raw materials and the washing of dishes in the preparation and cooking phase, as well as the required input water flows, like the same in our previous research with regard to water currents.

Regarding the amounts of food waste generated, in connection with the consumption of the in-person conference lunch, we assumed that 15% of food waste would be generated during the consumption phase in the soup, 26% in the main course, and 5% in the dessert. Regarding the online conference lunch consumption, we assumed 5% food waste in the soup, 22% food waste in the meat main course, and 5% in the dessert. For both the in-person and the online conference dinners, we assumed 15% food waste for the main course and 5% waste for the salad. At the end of the life cycle, food waste from the production, cooking and consumption phases was disposed of in a municipal solid waste incinerator during our software analyses.

3. Results

3.1. Energy Consumption and Waste Generation for Conference Dishes

As mentioned earlier, a three-course lunch was served to the conference participants on the first day: Cheddar cheese cream soup, Wiener schnitzel with rice, and orange cream as dessert. We examined three energy flows for the entire preparation of the meals: water, natural gas, and electricity. Heated tap water was used as the water flow for washing utensils and cooking pots and used cutlery. The water was heated using a mixture of natural gas and electricity. Cold tap water was used for cooking on the gas stove. As a result, primarily, a more significant amount of wastewater from all life cycle stages as an output stream and used cooking oil in the cooking stage were received. Food waste is present as an output stream in all life cycle stages. However, regarding soup, while only 5% was generated in the case of the online conference, 15% was assumed for the in-person conference because we consume more economically at home. For the main course, these percentage consumptions were already higher, and for dessert, they were lower. Table 3 provides a summary of the energy consumption and generated waste streams regarding lunch on the first conference day for both types of conferences.

Table 3. Energy consumption and waste generation regarding lunch on the first conference day for both types of conferences (functional unit: 1 portion/person/hour).

Cheddar Cheese Cream Soup (Course I), Serving Weight: 0.385 kg			
Inputs	Water [kg]	Natural gas [kg]	Electricity [MJ]
In-person	4.50 tap water mix from EU for washing and cooking (of which the cooking water: 0.1)	0.0063 natural gas from EU	0.85 electricity grid mix (Hungary):
Online	4.50	0.0308	2.01
Outputs	Food waste from all life cycle stages [kg/portion]	Wastewater generated from preparation–cooking–consumption stages [kg/portion]	Amount of other waste [kg/portion]
In-person	0.058 (remaining consumption: 15%)	4.40	-
Online	0.0193 (remaining consumption: 5%)	4.40	-
Vienna Schnitzel with Thai rice (Course II), Serving Weight: 0.433 kg			
Inputs	Water [kg]	Natural gas [kg]	Electricity [MJ]
In-person	6.71 tap water mix from EU (of which the cooking water for rice: 1.14)	0.0283 natural gas from EU	1.87 electricity grid mix (Hungary):
Online	8.10	0.201	0.373
Outputs	Food waste from all life cycle stages [kg/portion]	Wastewater generated from preparation–cooking–consumption stages [kg/portion]	Amount of other waste [kg/portion]
In-person	0.11526 (orange peel from decoration: 0.001, peel: 0.018, consumption residue: 0.11246—26%)	5.57	0.0794 (used cooking oil)
Online	0.098 (orange peel: 0.001, peel: 0.018, consumption residue: 0.09516—22%)	6.99	0.0794 (used cooking oil)
Orange Cream Glass (Dessert), Serving Weight: 0.289 kg			
Inputs	Water [kg]	Natural gas [kg]	Electricity [MJ]
In-person	3.45 tap water mix from EU for washing	-	1.70 electricity grid mix (Hungary):
Online	3.45	0.0107	0.805
Outputs	Food waste from all life cycle stages [kg/portion]	Wastewater generated from preparation–cooking–consumption stages [kg/portion]	Amount of other waste [kg/portion]
In-person	0.0227 (orange peel: 0.0825, consumption residue: 0.01445—5%)	3.45	-
Online	0.0227 (orange peel: 0.0825, consumption residue: 0.01445—5%)	3.45	-

A similar concept was applied on the second conference day, where the lunch consisted of green pea cream soup, steamed fish with rice and tomato salad. Here, we also examined three energy flows for the complete preparation of the dishes: water, natural gas, and electricity. The concept of the input and output flows is identical to the concept known for the first conference lunch. The only difference is that no cooking oil was used for this menu item since the fish was prepared using sous-vide cooking technology and the percentage amounts of the generated food waste were different. Table 4 presents the energy consumption and food waste amount for lunch on the second conference day.

Table 4. Energy consumption and waste generation regarding lunch on the second conference day for both types of conferences (functional unit: 1 portion/person/hour).

Green Pea Cream Soup (Course I), Serving Weight: 0.388 kg			
Inputs	Water [kg]	Natural gas [kg]	Electricity [MJ]
In-person	4.50 tap water mix from EU for washing and cooking (of which the cooking water: 0.1)	0.0063 natural gas from EU	0.85 electricity grid mix (Hungary):
Online	5.00 (of which the cooking water: 0.1)	0.0595	2.01
Outputs	Food waste from all life cycle stages [kg/portion]	Wastewater generated from preparation–cooking–consumption stages [kg/portion]	Amount of other waste [kg/portion]
In-person	0.0682 (carrot peel: 0.01, consumption residue: 0.0582—15%)	4.40	-
Online	0.0294 (carrot peel: 0.01, consumption residue: 0.0194—5%)	4.90	-
Steamed Fish with Thai Rice (Course II), Serving Weight: 0.398 kg			
Inputs	Water [kg]	Natural gas [kg]	Electricity [MJ]
In-person	6.31 tap water mix from EU	0.043 natural gas from EU	1.21 electricity grid mix (Hungary):
Online	6.31	0.195	0.33
Outputs	Food waste from all life cycle stages [kg/portion]	Wastewater generated from preparation–cooking–consumption stages [kg/portion]	Amount of other waste [kg/portion]
In-person	0.0621 (orange peel from decoration: 0.01, consumption residue: 0.05963—15%)	5.20	-
Online	0.0621 (orange peel: 0.01, consumption residue: 0.05963—15%)	5.20	-
Tomato Salad (Salad), Serving Weight: 0.250 kg			
Inputs	Water [kg]	Natural gas [kg]	Electricity [MJ]
In-person	0.7 tap water mix from EU for washing and preparing	-	- electricity grid mix (Hungary):
Online	0.70	-	-
Outputs	Food waste from all life cycle stages [kg/portion]	Wastewater generated from preparation–cooking–consumption stages [kg/portion]	Amount of other waste [kg/portion]
In-person	0.0125 (consumption residue)	0.70	-
Online	0.0125 (consumption residue)	0.70	-

Dinner was only served on the first day of the conference given that the second day of the conference ended at 4 p.m. A single dish was selected for dinner: gnocchi with cheese sauce. We followed a similar concept for the inventory analysis as for the lunches based on the same energy flows. The preparation of gnocchi required a high input water flow. We used a Hungarian energy mix for both lunches and dinner. However, in addition to the removed potato peels, we assumed 15% of the remaining material was food waste during consumption for both conference types. Table 5 shows the energy consumption and wastes regarding dinner on the first conference day.

Table 5. Energy consumption and waste generation regarding dinner on the first conference day for both types of conferences (functional unit: 1 portion/person/hour).

Gnocchi with Cheese Sauce (Main Course), Serving Weight: 0.414			
Inputs	Water [kg]	Natural gas [kg]	Electricity [MJ]
In-person	10.60 tap water mix from EU (of which the added cooking water: 0.1 kg)	0.036 natural gas from EU	1.35 electricity grid mix (Hungary):
Online	10.60	0.0615	2.01
Outputs	Food waste from all life cycle stages [kg/portion]	Wastewater generated from preparation–cooking–consumption stages [kg/portion]	Amount of other waste [kg/portion]
In-person	0.0788 (potato peel: 0.0166, consumption residue: 0.06214—15%)	10.60	-
Online	0.0788 (potato peel: 0.0166, consumption residue: 0.06214—15%)	10.60	-

3.2. Energy Consumption for Catering Service

Table 6 show the energy consumptions and raw material weights for the catering service during the conference breaks taking into account both days and two different functional units. Functional units: (1) consumption per 1 participant for 4 program breaks/2 conference days/4 × 15 min = consumption/1 person/1 h; and (2) consumption per 200 participants for 4 program breaks/2 conference days/4 × 15 min = consumption/200 people/1 h. The average daily consumption assumed for a conference participant during the two program breaks per day: two servings (2 × 2 dL) of tea, two teaspoons of tea leaves, two teaspoons of sugar, 10 g of sliced oranges, 600 g of Cassava chips, and 4 dl of orange juice. Since the software database did not contain lemon, we used oranges to flavor the tea. For the four occasions, a total of 0.261 kg/person/1 h of municipal solid waste was generated by the used tea grass and orange peels. The following is the amount of waste for 200 people: 52.2 kg. During our analysis, we considered the packaging of potato chips, orange juice, granulated sugar, and tea as cut-off flows since we focused exclusively on consumable material flows. As for food and drink consumption during program breaks, we assumed that in the case of online conference participation, we consume the same food and drinks in our homes with the same material and energy flow inputs and municipal solid waste output.

Table 6. Energy consumption and raw material weights regarding catering for in-person and online conferences by different functional units.

Tea with Orange, Orange Juice and Cassava Chips Functional Unit: Consumption/1 Person/1 h		
Water [kg]	**Natural Gas [kg]**	**Electricity [MJ]**
0.80 tap water mix from EU ((use of water to make tea)	-	0.0576 electricity grid mix (Hungary) CASO HW 550 hot water dispenser
Weight of raw materials [kg]	Black tea: 0.0112 Sliced orange (for flavoring): 0.02 Potato chips (Cassava): 1.20 Orange juice: 0.96 Crystal sugar: 0.024	

Table 6. *Cont.*

Tea with Orange, Orange Juice and Cassava Chips Functional Unit: Consumption/200 Person/1 h		
Water [kg]	**Natural Gas [kg]**	**Electricity [MJ]**
160 tap water mix from EU ((use of water to make tea)	-	11.50 electricity grid mix (Hungary) CASO HW 550 hot water dispenser
Weight of raw materials [kg]	Black tea: 2.24 Sliced orange (for flavoring): 4.0 Potato chips (Cassava): 240 Orange juice: 192 Crystal sugar: 4.8	

3.3. Energy Consumption for Conference Organization

During the analyses, we assumed the conference was held in late summer; so, we did not account for heating and cooling. There were six meetings between the members of the Organizing Committee.

<u>Conference organization for 200 people:</u>

- Classroom lighting in a classroom of 20 students by neon tube six times during discussions: 6 × 1 h.
- Correspondence: 1–2 h of computer use over 60 working days, total: 60 × 1.5 h = 90 h. Website editing: 5 working days in 8 h: 40 h of computer use = 40 h × 0.08 kW = 3.2 kWh.
- Correspondence: 1.5 h/day × 60 days = 130 h = 10.4 kWh.
- Laptop consumption per hour: 0.08 kW (80 W).
- Classroom lighting (20 people) per hour, 40 sq.m.
- Neon tube: 10 pcs.
- Consumption of 1 neon tube: 36 W/h = 0.036 kWh, 10 360 W/h = 0.36 kWh × 6 times = 2.16 kWh.
- Total energy consumption: 15.78 kWh = 56.736 MJ.

3.4. Energy and Water Consumption for In-Person Conference

Providing technical background during the conference:

- Equipment: laptop, projector, lighting.
- Laptop consumption per hour: 0.08 kWh (80 W).
- For 15 h: 1.2 kWh.
- Projector consumption per hour: 0.08 kWh (80 W).
- For 3 p.m.: 1.2 kWh.
- 15 h of lighting in 1 large auditorium (200 people)/conf. day.
- Consumption of 1 neon tube: 36 W/h = 0.036 kWh.
- For 68 neon tubes for 1 h = 2448 kWh.
- For 68 neon tubes for 15 h = 36.72 kWh.
- For 15 h: 39.12 kWh = 140,862 MJ.
- Total electricity consumption: 54.9 kWh = 197.64 MJ.

Bathroom use during the conference:

- 2 sessions/person/day, 400 sessions/day, 800 sessions/conference. Water consumption/occasion: 3 kg/occasion. 2400 kg of water for tank flushing.
- Handwashing: 1 l/occasion, i.e., 800 kg of tap water/conference.
- Handwashing: 800 times/2 paper towels, total: 1600 paper sheets, 11 packs of folded hand towel sheets (1 pack: 150 sheets), 1650 sheets in total, weight of 1 sheet: 1 g, 1650 g/conf., 1.65 kg.
- Toilet paper: 600 times 1200 pieces of paper, 8 packs of paper, 1200 g, 1.2 kg.

- Paper waste: 1.2 kg.
- 1 g liquid soap: 1600 drops/2 days/200 people. Total: 1.6 kg of soap.
  Wastewater: tank flushing + hand washing: 3200 kg for 2 days for 800 people.
- Paper waste: 1.65 kg.

3.5. Energy and Water Consumption for Online Conference

Provision of technical background:

- Tools: laptop.
- Laptop consumption per hour: 0.08 kWh (80 W).
- For 15 h: 1.2 kWh.
- 15 h of lighting in 1 room by an LED bulb.
- Consumption of 1 × 60 W LED bulb: 9 W = 0.009 kWh.
- For 15 h: 0.035 kWh = 0.486 MJ.
- Total electricity consumption: 61,542 MJ.

Toilet use at home:

- 2 sessions/person/day, 400 sessions/day, 800 sessions/conference. Water consumption/occasion: 3 kg/occasion. 2400 kg of water for tank flushing.
- Handwashing: 1 l/occasion, i.e., 800 kg of tap water/conference.
- Hand washing: 800 times/towel used by everyone at home.
- Toilet paper: 600 times 1200 pieces of paper, 8 packs of paper, 1200 g, 1.2 kg.
- Paper waste: 1.2 kg.
- 1 g liquid soap: 1600 drops/2 days/200 people. Total: 1.6 kg of soap.
- Wastewater: tank flushing + hand washing: 3200 kg for 2 days for 800 people.
- Paper waste: 1.2 kg.

3.6. Decarbonization Results

The decarbonization results of the conferences are summarized in Tables 7 and 8 for one person and one hour. Given that, during the carbon footprint calculation, we initially determined separate carbon footprint values per functional unit kilometer and per person for air, train, and car modes of transport, only a summarized carbon footprint value for the in-person conference based on the known transportation distances and transport modes was presented. For this reason, Table 7 shows a single summary value for the trip regardless of the LCIA method. In the case of an in-person conference, travel accounts for 57 percent of the total carbon footprint.

Table 7. Carbon footprint values regarding in-person conference by different life cycle impact assessment methods in carbon dioxide kg equivalents.

	Carbon Footprint for the In-Person Conference Functional Unit: 1 Person/1 h		
	CML 2016 Excl. Biogenic Carbon [kg CO_2 eq.]	**IPCC AR6 GWP 100, Excl. Biogenic CO_2 (Version August 2021) [kg CO_2 eq.]**	**ISO 14067 GWP 100 [kg CO_2 eq.]**
Lunch, Day 1	4.068	4.213	2.612
Lunch, Day 2	0.7504	0.7711	0.5893
Dinner, Day 1	3.06	3.17	1.85
Catering	0.535	0.551	0.286
Registration gift package	0.355	0.357	0.24
Organization and Management	0.0077	0.00774	0.0042
Total	8.7761	9.06984	5.5815
Trip		11.912	

Table 8. Carbon footprint values regarding online conference by different life cycle impact assessment methods in carbon dioxide kg equivalents.

	Carbon Footprint for the Online Conference Functional Unit: 1 Person/1 h		
	CML 2016 Excl. Biogenic Carbon [kg CO_2 eq.]	**IPCC AR6 GWP 100, Excl. Biogenic CO_2 (Version August 2021) [kg CO_2 eq.]**	**ISO 14067 GWP 100 [kg CO_2 eq.]**
Lunch, Day 1	4.041	4.187	2.55
Lunch, Day 2	0.7374	0.7551	0.4815
Dinner, Day 1	3.12	3.23	1.86
Catering	0.657	0.673	0.324
Organization	0.00321	0.00323	0.00208
Total	8.55861	8.84833	5.21758

Figures 1 and 2 summarize the decarbonization values in percentage distribution. In Figure 1, organization and management include energy, water, paper towels, and liquid soap consumption (conference room technology and bathroom use combined).

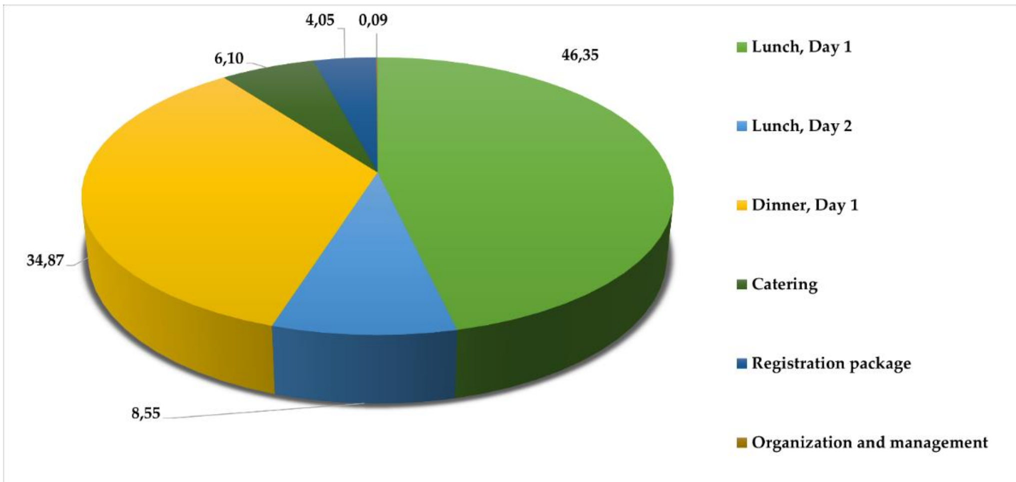

Figure 1. Decarbonization percentage distribution regarding in-person conference by CML 2016 excluding biogenic carbon impact assessment method (functional unit: person/hour).

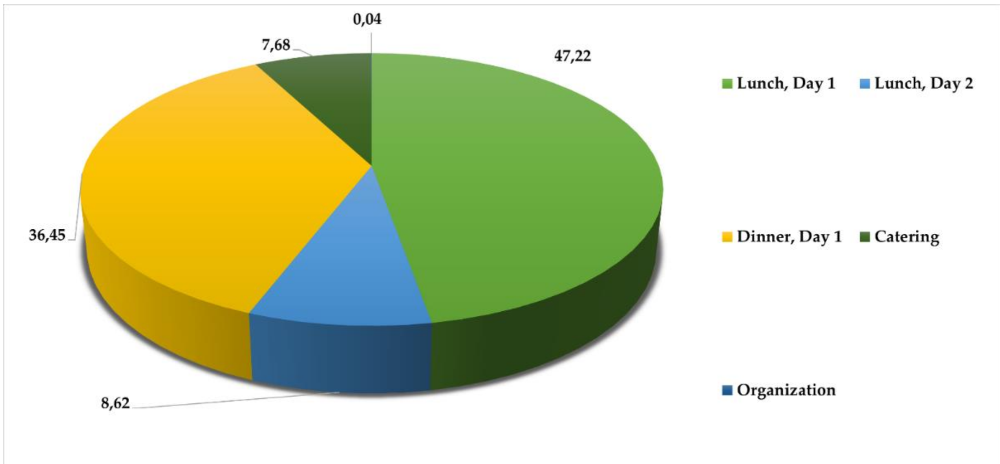

Figure 2. Decarbonization percentage distribution regarding online conference by CML 2016 excluding biogenic carbon impact assessment method (functional unit: person/hour).

The research results show that in-person and online conferences' carbon footprint values are similar. The data in Table 7 clearly show that the carbon footprint resulting from conference travel is extremely dominant: 11.912 kg CO_2 equivalent/person for 1 h (57% of the total conference impact) and 178.68 kg CO_2 equivalent/person for the entire conference. Meal impact (lunches, dinner and catering) represents the second largest environmental burden at 8.413 kg CO_2 equivalent/person/h. Ignoring the environmental impact of meals and travel, the decarbonization value is 0.3627 kg CO_2 equivalent/person/h including only preparation, organization, implementation and registration package in the case of an in-person conference.

4. Discussion

In our previous research studies [36,37], we developed comprehensive life cycle models for restaurant dishes, focusing mainly on end-of-life scenarios and comparing the environmental impacts of "sous vide" versus traditional cooking methods. Additionally, we explored and compared the environmental burdens of vegan, vegetarian, and traditional diets [38]. Our findings consistently indicate that the carbon footprint associated with the preparation phase of each meal is higher than that of the cooking phases [37,38]. This is largely due to the environmental impacts linked to the production of raw materials themselves. We have reached similar conclusions in our current work as well.

The life cycle assessments show that travel accounts for 57% of the total carbon footprint at in-person conferences. A significant reduction can be achieved by minimizing travel to reduce conference carbon footprints. However, hybrid solutions or decentralized conference organizations can also be effective strategies for decarbonization.

Another significant factor contributing to the carbon footprint of conferences is catering. The meals provided, including lunches and one dinner, have a notable impact. To mitigate this, choosing environmentally conscious dietary options and serving snacks that minimize waste instead of full-course meals can be effective strategies. Overall, the online conference is also realistic from environmental and energetic viewpoints.

After the environmental life cycle assessments, we conducted a strengths–weaknesses–opportunities–threats analysis of in-person and online conferences. The SWOT analysis is an effective tool for business analysis and strategic decision-making. It is helpful in the design and operational stages of technologies because while certain traits will emerge as opportunities in the planning stage, the same characteristics will lend themselves to an interpretation as strengths in the operational stage. It can also help with energy-related designs [39].

To make a conference as sustainable as possible, the main aspects to be taken into account in the different decisions are presented in the SWOT chart. It provides a clear overview of internal and external factors that can influence decision success. Figure 3 illustrates the results of the SWOT analysis after comparing the two types of conferences in four areas (strengths, weaknesses, opportunities, and threats).

Figure 3 summarizes the positive and negative aspects that can arise with the two types of conference organizations. The strengths of the in-person conference include the multiple channels of communication (the full range of verbal, vocal, visual, and non-verbal communicated information reaches from the communicator to the host), the experience of the location (geographical social characteristics of the accommodation and conference venue), the related economic stimulus and the reduction in seasonal fluctuations.

In contrast, an online event is more cost- and time-efficient (due to the absence of travel and other related services), more sustainable, more convenient, and safer (due to the lack of direct physical contact). The previous ones reverse the weaknesses of the two forms: the disadvantages of the present form are the accessibility of the location, the difficulty and environmental impact of the journey, the cost of accommodation, and the lower level of security. From the participants' point of view, the presence of the conference provides a better opportunity to build contacts and leisure and recreation opportunities; from the organizers' point of view, it increases job opportunities, the demand for transfer services and infrastructure development, and it provides a better chance for green and other marketing and related services.

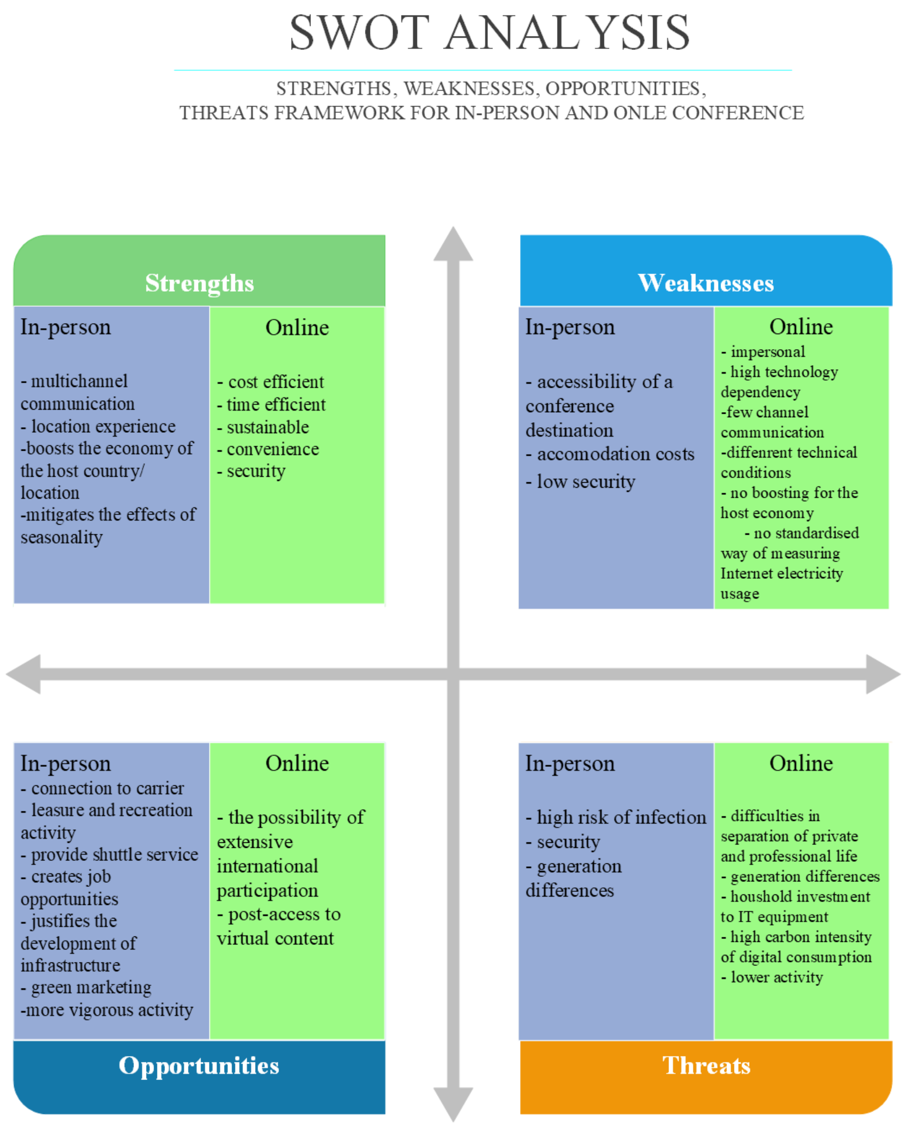

Figure 3. SWOT analysis of in-person and online conferences based on the results.

In contrast, the online format allows for broader international participation and more reliable access to the virtual content of the lectures. Threats include the higher health risk of attending a conference and the generational disadvantage of the higher age in the academic field. However, in the case of online conferencing, it should be taken into account that these participants may have difficulties in separating private and professional participation (due to the exact location), generational differences in skills in the use of ICT tools, which require high upfront investments from households, the high carbon intensity of digital content consumption and, finally, the tendency for participants to be less active in online conferencing.

Burkhanov et al. [40] proposed a situation–actor–process and learning–action–performance model of flexible system management to support sustainable development. A

SAP-LAP analysis diagram summarizes the ways to achieve the objectives and challenges identified in the SWOT analysis to illustrate our primary purpose and place for sustainability calculations. In Figure 4, the steps to achieve the set goal of organizing a sustainable conference were summarized in a SAP-LAP model.

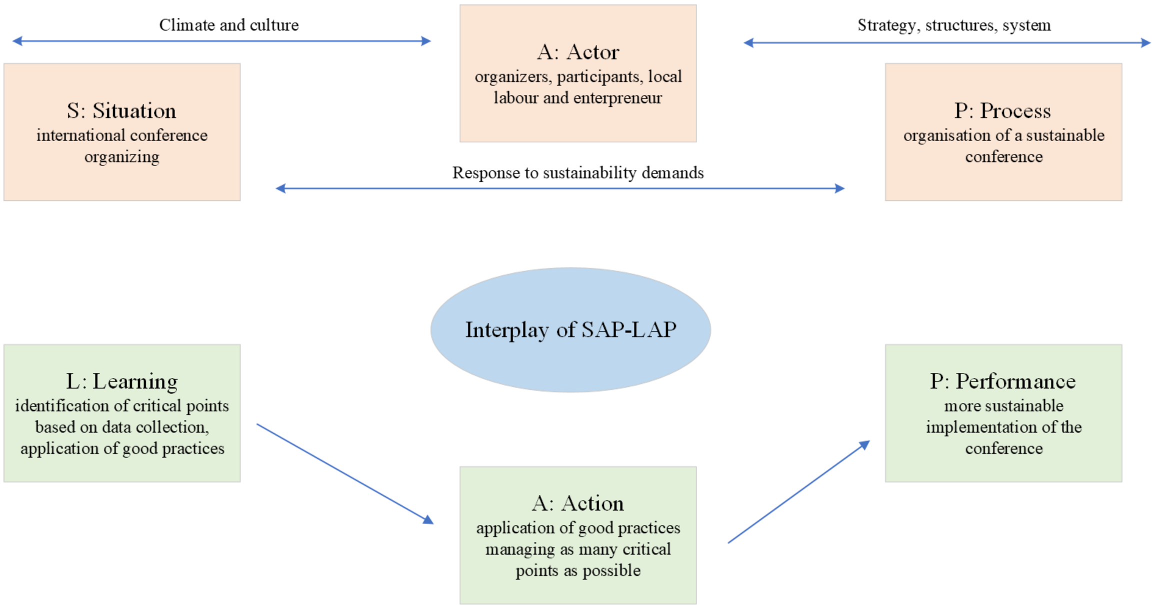

Figure 4. SAP-LAP analysis (situation–actor–process–learning–action–performance) framework for conferences.

The starting point for the SAP-LAP analysis is to organize a conference (S: situation) that is as sustainable as possible (P: performance). There is a growing awareness of sustainability issues, the importance of reputation and brand value, the need to comply with regulatory requirements, the stakeholders', participant (A: actor), expectations, and the potential cost savings of sustainable event management. Organizing a sustainable event can benefit the organizer because it builds reputation and "brand equity" (especially in the case of a recurring event) and can result in cost savings. The ISO 20121:2024 standard [41] regulates the organization of sustainable events. It helps to organize events in line with sustainability requirements (L: learning). It guides best practices in organizing events and regulating and controlling their social, economic, and environmental impacts. Different theoretical and practical approaches to implementing the ISO 20121:2024 standard have been developed (P: process). In terms of organizing events, the literature highlights three critical subsystems of conferences from an environmental perspective: travel, the use of information and communication technology tools, and catering (A: action)

The limitation of using these research results is that we considered several cut-off flows during the LCA analyses. We treated the packaging of raw materials used in meals (potato chips, orange juice, granulated sugar, and tea) as cut-off flows by focusing only on consumable flows. We did not consider the environmental impacts of the delivery of raw materials for meals and the transportation of conference administration packages. We excluded transport from our analyses because the individual ingredients come from different places. This inconsistency would affect our comparison of the environmental impact of the meals served. We excluded the impacts of accommodation during in-person conferences. Only for conference travel, the impacts were calculated depending on the different travel modes and transport distances in the case of an in-person conference. Taking these cut-off flows into account influences the applied LCA methodology and the system boundary. As a result, lower environmental impacts are obtained than if we also considered transport processes, transport distances and the load of the used fuels. We did not separately address the problem of online data transmission in the case of an online conference, which may also limit the use of the results.

In the future, the research results will offer new insights into energy consumption and decarbonization for the future for in-person and online conferences as services. The SWOT chart and the established SAP-LAP model help identify high-emission areas and can suggest sustainable strategies for decarbonization. Additionally, the result and the developed model can assist in assessing the carbon footprints of conference types by using simulations to estimate their environmental impacts.

In the future, we would like to conduct further research on comparing different types of conferences. We want to supplement our life cycle assessment results with Monte Carlo simulation, sensitivity and weak-point analyses. We did not specifically examine the phenomenon of participants attending the conference in person for only one day, which is quite common nowadays. We did not specifically discuss the hybrid conference opportunity. We would also like to address these issues in the future.

5. Conclusions

This research study aims to develop better scenarios for more sustainable conferences by examining their environmental impact throughout their life cycles. It supports sustainability while calculating the energy consumption and carbon footprint associated with in-person and online conferences.

Decarbonization can be achieved in various ways, including expanding alternative energy production, improving energy efficiency, advocating for electric transportation, advancing environmentally friendly consumption, and digitalization. Therefore, we focus separately and in detail on energy efficiency and consumption at the conference. By analyzing the environmental impact of the food served at conference events and optimizing its life cycle, we can maximize ecological benefits while minimizing food waste during preparation.

Various theoretical and practical ways of implementing the ISO 20121:2024 standard have emerged, ranging from corporate governance methods to online interfaces and artificial intelligence. For example, integrating artificial intelligence and other technologies into the event management platform is good practice for increasing security and the user's experience. In addition, an online presence is essential for any event in the digital age. Online conferences are more cost-effective and convenient (even for the participants) and are considered more sustainable and safer by the literature.

However, in-person conferences create optimal conditions for establishing and maintaining personal contacts and developing social networks to eliminate the disadvantages and increase the advantages of face-to-face conferences. In-person conferences have the disadvantages of higher travel costs, difficulties in accessing the venue, and higher costs (travel, accommodation and organization) and security risks.

Travel accounts for 57% of the total carbon footprint at in-person conferences. A significant reduction can be achieved by minimizing travel, mainly through online formats, to reduce carbon footprints in conferences, which yields the most substantial savings. However, hybrid solutions or decentralized conference organizations can also be effective strategies for decarbonization.

The SWOT chart identifies strengths, weaknesses, opportunities, threats, and recommendations for decarbonization measures. The developed SAP-LAP model helps make decisions, summarizing how to achieve the objectives and challenges identified by illustrating sustainability calculations. In the future, the models created by SAP-LAP analyses may play an increasingly important role and gain ground in more areas.

We hypothesized that transitioning to online conferences significantly lowers the carbon footprint of such events by reducing the need for physical attendance. The research results confirmed our assumed research hypothesis.

The European Union strives to achieve carbon neutrality in line with sustainable development goals and the principles of a circular economy. As a result, it is becoming increasingly important to understand the environmental impacts of various services through life cycle assessments in the future.

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Abbreviations

CE	Circular Economy
GHG	Greenhouse Gas
GWP	Global Warming Potential
ICT	Information and Communication Technology
LAP	Learning–Action–Performance
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MICE	Meetings, Incentives, Conferences and Exhibitions
SAP	Situation–Actor–Process
SDGs	Sustainable Development Goals
SWOT	Strengths–Weaknesses–Opportunities–Threats

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