SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2024
ORGANIZATION AND MANAGEMENT SERIES NO. 210

ANALYSIS OF THE ENVIRONMENTAL IMPACT OF TRAINING SERVICES FROM THE ORGANIZER'S PERSPECTIVE – A CASE STUDY BASED ON SECONDARY DATA

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Purpose: The purpose of this paper is to analyze the life cycle assessment (LCA) of training services and compare the environmental impacts of online and on-site training.
Design/methodology/approach: The research uses a life cycle assessment methodology to evaluate and compare the environmental impacts of online and on-site training across various categories. The analysis focuses on key areas such as acidification, climate change, freshwater ecotoxicity, resource depletion, and ozone layer depletion.
Findings: The study found that online training generates a lower environmental impact across all analyzed categories. For acidification, online training shows a 23% lower impact compared to on-site training, where 63% of emissions originate from energy production and 15% from participant transportation. Regarding climate change, online training results in 21% fewer greenhouse gas emissions due to the absence of transport and catering-related impacts. Freshwater ecotoxicity for online training is 60% lower, primarily due to the lack of emissions related to food preparation. Resource depletion for online training accounts for 73% of the impact of on-site training, with electricity being the main contributor. For ozone layer depletion, online training generates only 19% of the impact compared to on-site training.
Research limitations/implications: The study highlights the need for further research into the environmental impact of meals consumed during online training and standardizing perspectives for both training models.
Practical implications: The findings demonstrate the importance of online training as a more sustainable option, particularly in reducing the environmental impact associated with transportation and catering. Organizations can implement online training to minimize their environmental footprint. However, it is essential to consider specific quantitative assumptions and varying parameters resulting from the particular training practices, which may differ from those described in this study.
Social implications: This research contributes to the estimation of an organization's carbon footprint, particularly in Scope 3, within the category of purchased goods and services. It highlights the need for further studies to enhance understanding and provide detailed insights into this aspect.

Originality/value: This paper provides a novel comparison of the environmental impacts of online versus on-site training, offering valuable insights for organizations, policymakers, and educators seeking to implement more sustainable training practices.
Keywords: life cycle assessment, on-line training, on-site training, environmental impact, sustainable.
Category of the paper: Research paper, case study.

1. Introduction

Managing environmental impacts has become one of the key challenges for contemporary organizations, particularly in the context of global actions towards sustainable development. As ecological awareness grows, an increasing number of organizations are striving to analyze the environmental impact of various aspects of their operations, including services such as training. The impact of purchased training on climate change is often considered in the carbon footprint assessment of many organizations, particularly within Scope 3, Category 1: "Purchased goods and services".

A comprehensive analysis of the environmental impacts of a given product or service across all stages of its lifecycle—from raw material acquisition to implementation processes—is achievable through the application of Life Cycle Assessment (LCA). This methodology is recognized as a robust tool (Neramballi et al., 2020). In recent years, as organizations increasingly recognize the importance of sustainable development, LCA has gained popularity in the context of services. This highlights the necessity of adapting assessment methods to the unique characteristics of the service sector (Lindgreen et al., 2022).

Training services, as a significant element of the educational and development sector, pose unique challenges in the context of environmental assessment. Their intangible nature requires identifying and quantifying factors such as emissions associated with participant transportation, energy consumption in training facilities, and the use of office materials (Martín-Garín et al., 2021). Research indicates that different forms of training delivery—on-site, remote, and hybrid—can vary significantly in their environmental impact, making LCA particularly relevant in this context (Chaudhary, Dey, 2020).

Promoting sustainable development within organizations requires not only appropriate strategies but also the involvement of all stakeholders, which is crucial for achieving positive environmental and social outcomes (Marciszewska, 2024). Therefore, analyzing the impact of services, including training services, becomes essential for understanding their environmental implications and making informed decisions in project management in the context of sustainability.

This article aims to conduct a Life Cycle Assessment (LCA) of training services, considering the specific stages of their delivery and identifying key sources of environmental impact. It focuses on a comparative analysis of on-site and remote training to determine which format has a lower environmental footprint. Applying the LCA approach to training services provides valuable insights for both organizers and participants, supporting decision-making aligned with sustainable development principles. In this way, the article contributes to advancing knowledge about the environmental dimension of the service sector and represents a step toward systematically incorporating LCA into analyses of intangible products (Akyol et al., 2018).

2. Context and research problem

Training services, both on-site and online, are a significant component of educational and business activities, yet their environmental consequences are often underestimated or entirely overlooked. The growing prominence of online training, perceived as more environmentally sustainable, raises questions about the actual differences in their environmental impact compared to traditional on-site training. The key research problem, therefore, lies in estimating the differences in environmental impact between these two training formats and identifying the most significant factors contributing to their ecological footprint.

Research in this area is relatively limited, but existing findings suggest that online training may have a significantly lower environmental impact, primarily due to the elimination of participant travel and reduced consumption of physical resources such as paper or catering. For example, Rath et al. (2020) indicate that transitioning to remote education can lead to a reduction in greenhouse gas emissions from transportation by over 80% compared to traditional teaching methods. Similarly, research by Laurent et al. (2012) emphasizes that the environmental impact of on-site education is highly dependent on local conditions, such as the energy sources used in training facility infrastructure.

Key aspects of the research problem

To accurately assess the environmental impact of both forms of training, it is essential to collect and analyze data covering all stages of their life cycle. Particular attention should be given to the following aspects:

- Preparation stage (production): Organizing training involves activities such as sending emails, making phone calls, and preparing training materials (printed or digital). These actions can vary in terms of emissions depending on the training format.

- Duration of the training: Differences in the length of training sessions can affect energy consumption, both in physical training rooms and in the devices used for online training.
- Participant travel: For on-site training, greenhouse gas emissions associated with participant transportation are a key component of environmental impact. Different modes of transportation (trains, combustion-engine cars, hybrid vehicles) generate varying levels of emissions.
- Training resources: Organizing on-site training necessitates the provision of printed materials, catering, and maintaining suitable conditions in the training room (e.g., heating, lighting). In online training, these resources are replaced with digital materials, which also have their own environmental footprint.
- Infrastructure and technology: Online training relies on digital platforms and devices, which generate additional energy consumption, though to a lesser extent than the infrastructure required for on-site training.

Research challenges

The analysis of the environmental impact of training services faces several significant challenges:

- Data incompleteness: Information regarding individual emissions, particularly related to participant travel, is often imprecise or difficult to estimate.
- Variability of local conditions: Differences in energy sources, climatic conditions, and transportation infrastructure can significantly affect the results.
- Systemic complexity: Comparing two distinct training models requires a detailed Life Cycle Assessment (LCA) that accounts for all stages of impact.
- Participant diversity: Participants may use various modes of transportation and have different habits regarding infrastructure usage, making data standardization challenging.

This study addresses an existing gap in the literature on the environmental impact of training services by focusing on a comprehensive comparison of on-site and online formats using the LCA methodology.

3. Research methodology

The research methodology is based on the application of Life Cycle Assessment (LCA) to compare the environmental impact of two types of training: on-site and online.

The declared functional unit for the study is the provision of on-site and online training for 20 participants, taking into account the assumptions outlined in Chapter 4.

The analysis process was divided into the following steps:

1. Defining system boundaries.

   Within the analysis, the following were considered:

   – Preparation stage (organization, communication, printing of materials).
   – Participant transport in the case of on-site training.
   – Resource and energy consumption during training delivery (e.g., electricity, catering).
   – Digital distribution of materials and certificates for online training.

2. Data collection.

   Data on key environmental parameters were obtained from:

   – Actual operational data (e.g., kilometers traveled, energy consumption).
   – Assumptions based on market standards (e.g., transport emissions per kilometer).
   – Available environmental databases, such as Ecoinvent and Agribalyse.

3. Modeling and calculations.

   – Models and estimates were applied to energy consumption during office work, email correspondence, and phone calls.
   – Models and estimates were also applied to participant travel, preparation and distribution of training materials, and the delivery of on-site and online training.
   – Process modeling in SimaPro was based on indicators from Ecoinvent and Agribalyse. The indicator for electricity consumption reflects the energy mix in Poland (location-based).

4. Results analysis.

   The results are presented in a comparative format, highlighting key differences in the environmental impact between on-site and online training. The analysis includes indicators such as acidification, climate change (including biogenic, fossil fuel, and land use change sources), freshwater ecotoxicity (divided into inorganic, organic, and other factors), eutrophication (marine, freshwater, and terrestrial environments), ionizing radiation, land use, photochemical ozone formation, resource use (fossil fuels), and water use.

This methodology allows for a comprehensive comparison of both training models, identifying areas with the highest environmental impact and providing recommendations for their optimization.

4. Description of data and assumptions

4.1. Training preparation

Firstly, the electricity consumption in an office room over 10 hours was analyzed. The total energy consumption for this period amounted to 10.9 kWh, with the dominant components being electric heating (10 kWh) and lighting, which required 0.4 kWh of energy, assuming the use of four LED bulbs for 10 hours. Energy consumption by a computer operating at 50 W for 10 hours accounted for 0.5 kWh (Latif, 2015; Han et al., 2013).

It was assumed that as part of the preparatory activities for training, 25,000 emails needed to be sent. The total energy consumption associated with this activity was 629.25 kWh. This includes three main components: data transmission, data storage in the cloud, and energy consumption during email reading and writing. Data transmission for an average 2 MB email, assuming that transferring 1 GB of data consumes 5 kWh, amounted to 245 kWh. Storing the same data in the cloud, with an average annual consumption of 7 kWh/GB, added another 342.5 kWh. Energy consumption during laptop use (2 minutes for writing and reading an email) amounted to 41.75 kWh (Tayari, Burman, 2018; Lessard et al., 2017).

The energy consumption associated with making 50 phone calls was 8.975 kWh. This includes 8.35 kWh of energy consumed by smartphones during the calls and 0.625 kWh attributed to the operation of network infrastructure, assuming a data transfer rate of 0.5 MB/min and average network energy consumption of 5 kWh/GB (Carvalho et al., 2020; Kim et al., 2021).

These analyses provide a detailed overview of the energy costs of office and communication activities and can serve as a basis for further research into energy efficiency and carbon footprint reduction in office and remote work.

4.2. Participants' travel to the training venue

The analysis considered the distribution of participants in on-site training: 10 participants travel by private car, and another 10 use rail transport. The total number of participants is 20, and the total distance traveled by participants in both scenarios was estimated accordingly.

For private car travel, it was assumed that 10 participants each travel an average of 10 km. This results in a total distance of 100 km (10 participants × 10 km). Car travel is associated with shorter distances, corresponding to local commutes.

In the train travel scenario, it was assumed that 10 participants each travel an average of 300 km, resulting in a total distance of 3000 km (10 participants × 300 km). This mode of transport is associated with longer commutes.

The total distance traveled by 20 participants is therefore 3100 km, of which 100 km involves cars (assumed to use diesel fuel) and 3000 km involves trains (Coutaz et al., 2018; Bano, Sehgal, 2020).

4.3. Training materials

The process of preparing and distributing training materials was divided into several stages: presentation preparation, printing materials, and sending files in PDF format. Preparing the presentation required 8.5 hours of work on a laptop, including content creation and saving the document in two formats: PowerPoint and PDF. The laptop's energy consumption amounted to 0.425 kWh, while data exchange involving 200 MB added another 1 kWh, resulting in a total of 1.425 kWh (Pano, 2017; Phillips et al., 2011).

For printing the presentation, it was assumed that each of the 20 participants in the on-site training would receive a 100-page presentation, totaling 2000 pages.

The distribution of training materials involved sending a 10 MB PDF file. The data transmission process via the Internet, consuming 5 kWh per GB, required 0.0488 kWh per file, amounting to 0.976 kWh for sending the file to 20 participants. Storing the same file in the cloud for one year, with an energy consumption of 7 kWh/GB, required 0.0684 kWh per file, totaling 1.368 kWh for 20 files. Additionally, preparing and reviewing materials before the training, which took 5 minutes of laptop use, consumed 0.0042 kWh per user, resulting in a total consumption of 0.084 kWh.

The total energy consumption for the preparation, distribution, and handling of training materials amounted to 2.428 kWh, including data exchange and long-term cloud storage of files. This analysis highlights the energy costs of remote work and digital content distribution (Al-Ghamdi, Bilec, 2015; Muñoz-González et al., 2021).

4.4. Conducting training on-site

The analysis of energy consumption during an 8-hour on-site training session in a 35 m² room included all key elements requiring electricity. The total energy consumption was estimated at 55.6 kWh, based on standard equipment and training conditions.

Lighting the room with LED bulbs at 10 W/m² for a total area of 35 m² consumed 2.8 kWh over the 8-hour session. Electric heating, operating at 100 W/m² to maintain a comfortable temperature, accounted for 28 kWh. The projector, operating at 300 W, consumed 2.4 kWh, while air conditioning, with a power of 1500 W, consumed 12 kWh (Cassola et al., 2022; Heddeghem et al., 2014).

Computer equipment included laptops for the trainer and coordinator, each operating at 50 W, consuming 0.4 kWh each. Additionally, 20 participant laptops, running throughout the session, consumed 8 kWh. The room's sound system, including a microphone and speakers at 200 W, consumed 1.6 kWh. These findings highlight key areas of energy consumption during on-site training sessions, showing that air conditioning, heating systems, and participant equipment represent the largest shares. This analysis can serve as a basis for optimizing energy use in similar scenarios (Zhang et al., 2010; Ferdous, 2023).

The analysis also evaluated the demand for coffee and related energy consumption, considering two scenarios: serving coffee with milk and coffee without milk. In both cases, 25 cups of coffee, each 200 ml, were considered. Each cup required 7 g of ground coffee, totaling 175 g for the entire event. In the scenario with milk, each cup contained 100 ml of coffee and 100 ml of milk, requiring 2.5 liters of milk for the event. The scenario without milk involved serving only black coffee, increasing the water demand to 5 liters.

The energy consumption of the coffee machine, assuming 0.1 kWh per liter of coffee prepared, was 0.25 kWh for coffee with milk and 0.5 kWh for black coffee, proportional to the required water quantity (Menezes et al., 2012; Shan, Cao, 2017).

4.5. Conducting online training

An analysis of energy consumption was conducted for an 8-hour online training session involving 20 participants and one trainer. The assessment considered all key elements related to the use of electronic devices and data transmission via a video conferencing platform. The total energy consumption was estimated at 219.24 kWh.

The main sources of energy use included the operation of laptops, cameras, microphones, and data transfer. A total of 21 laptops (20 participants and 1 trainer), each operating at 50 W for the entire training duration, consumed 8.4 kWh. Cameras and microphones, essential for interaction during the training, consumed 0.84 kWh, assuming a power requirement of 5 W per person.

The largest share of energy consumption was attributed to the video conferencing platform, related to data transmission. It was assumed that each participant used an average of 2 GB of data over 8 hours, resulting in a total data transfer of 42 GB for all participants. With an energy consumption rate of 5 kWh per GB of data transfer, the platform's operation accounted for 210 kWh (Zhang et al., 2011; Vartholomaios et al., 2023).

This analysis highlights the significant impact of data transmission on energy consumption in online training sessions, emphasizing the critical role of internet infrastructure in the energy balance of such events. These findings can be used to optimize resources and plan effective and environmentally friendly solutions for organizing virtual meetings (Kim et al., 2020; Yuan, Yan, 2012).

5. Analysis of LCA results of the training service

The results of the Life Cycle Assessment (LCA) analysis compared two training service delivery variants: online training and on-site training. The results encompass environmental impact categories consistent with the Environmental Footprint 3.1 methodology. The analyzed impacts pertain to the life cycle stages associated with energy production and materials used during the organization of the training sessions.

Table 1.
LCA results for online and on-site training services

Impact category	Unit	Szkolenie on-line	Szkolenie on-site
Acidification	mol H+ eq	5,47E+00	7,07E+00
Climate change	kg CO2 eq	7,72E+02	9,73E+02
Climate change - Biogenic	kg CO2 eq	3,68E-01	1,38E+01
Climate change - Fossil	kg CO2 eq	7,71E+02	9,23E+02
Climate change - Land use and LU change	kg CO2 eq	2,46E-01	3,66E+01
Ecotoxicity, freshwater - part 1	CTUe	8,87E+02	2,23E+03
Ecotoxicity, freshwater - part 2	CTUe	1,11E+03	1,79E+03
Ecotoxicity, freshwater - inorganics	CTUe	1,94E+03	2,47E+03
Ecotoxicity, freshwater - organics - p.1	CTUe	5,72E+01	1,07E+03
Ecotoxicity, freshwater - organics - p.2	CTUe	3,60E+00	4,72E+02
Particulate matter	disease inc.	7,51E-06	2,93E-05
Eutrophication, marine	kg N eq	5,91E-01	1,24E+00
Eutrophication, freshwater	kg P eq	1,01E-01	1,04E-01
Eutrophication, terrestrial	mol N eq	6,65E+00	1,48E+01
Human toxicity, cancer	CTUh	3,44E-07	4,61E-07
Human toxicity, cancer - inorganics	CTUh	9,86E-08	1,43E-07
Human toxicity, cancer - organics	CTUh	2,46E-07	3,18E-07
Human toxicity, non-cancer	CTUh	8,67E-06	9,82E-06
Human toxicity, non-cancer - inorganics	CTUh	8,60E-06	9,33E-06
Human toxicity, non-cancer - organics	CTUh	7,47E-08	4,90E-07
Ionising radiation	kBq U-235 eq	9,60E+00	3,10E+01
Land use	Pt	1,66E+03	8,08E+03
Ozone depletion	kg CFC11 eq	2,86E-06	1,48E-05
Photochemical ozone formation	kg NMVOC eq	1,92E+00	2,91E+00
Resource use, fossils	MJ	8,88E+03	1,21E+04
Resource use, minerals and metals	kg Sb eq	1,62E-05	4,44E-04
Water use	m3 depriv.	1,03E+02	3,34E+02

5.1. Acidification

Acidification refers to the emission of gases such as sulfur oxides (SOx) and nitrogen oxides (NOx), which react with water in the atmosphere to form "acid rain", leading to soil and water acidification and negatively impacting ecosystems.

Online training generates 5.47 mol H^+ eq, which is lower compared to 7.07 mol H^+ eq for on-site training. For on-site training, electricity production accounts for 63% of this impact, rail transport of participants contributes 15%, and food preparation accounts for 22%. In the case of online training, 100% of the impact in this category is associated with electricity consumption.

The higher level of acidification in on-site training is primarily due to the intensive use of electricity and emissions related to participant transport and food preparation. Sustainable practices in energy use and catering could significantly reduce this impact.

5.2. Climate change

Climate change refers to the emission of greenhouse gases, such as carbon dioxide (CO_2) and methane (CH_4), which contribute to global warming, leading to rising sea levels, desertification, and climate changes that affect ecosystems and humans.

Online training generates 7.72×10^2 kg CO_2 eq, which is lower compared to 9.73×10^2 kg CO_2 eq for on-site training. For on-site training, electricity production accounts for 65% of this impact, participant transport generates 20%, and food preparation contributes 15%. In the case of online training, 100% of the impact in this category is associated with electricity consumption.

The higher level of greenhouse gas emissions in on-site training is primarily due to the reliance on electricity with a high carbon footprint, as well as emissions from participant transport and food preparation. Adopting more sustainable practices in energy sourcing and catering could significantly reduce this impact.

5.3. Ecotoxicity of freshwater

Freshwater ecotoxicity measures the potential risk of harmful effects of chemical substances on organisms living in freshwater ecosystems.

For online training, the total impact is 8.87×10^2 CTUe, approximately 40% of the impact compared to 2.23×10^3 CTUe for on-site training. In the case of on-site training, electricity production accounts for 32% of the total impact, participant transport for 10%, and food preparation for 58%. Among the food-related impacts, lunch contributes the largest share (30%), followed by dried fruits (6%), cake (6%), sandwiches (7%), and juice (5%).

For online training, 100% of the impact on freshwater ecotoxicity is associated with electricity consumption.

The high level of freshwater ecotoxicity for on-site training is primarily due to emissions from electricity production and food preparation processes. Online training, with a significantly lower contribution to this category, is a more sustainable option, particularly in the context of reducing food- and transport-related emissions.

5.4. Resource consumption

Resource use refers to the exploitation of non-renewable materials such as fossil fuels, minerals, metals, and water, which can lead to their depletion.

For online training, the total resource consumption is 8.88×10^{3} MJ, approximately 73% of the impact compared to 1.21×10^{4} MJ for on-site training. In on-site training, the largest share of resource use comes from electricity production, accounting for about 60% of the total impact. Rail transport contributes 20% (also related to energy use), while the remaining 20% is primarily associated with food preparation, including meat production, processing, and product transport. For online training, 100% of the impact in this category is associated with electricity consumption.

The higher level of resource consumption in on-site training is primarily due to greater energy demands and the intensive use of natural resources in catering-related processes. Online training, with a lower contribution to this category, offers a more sustainable alternative in terms of reducing resource exploitation. However, it is important to note that this analysis, from the organizer's perspective, does not account for meals and beverages consumed during online training. Considering different perspectives would provide a more comprehensive understanding of this impact.

5.5. Ozone layer depletion

Ozone layer depletion is associated with the emission of gases, such as chlorofluorocarbons (CFCs), that destroy ozone in the stratosphere. A thinner ozone layer allows harmful UVB radiation to penetrate, increasing the risk of health issues such as skin cancer.

The impact on the ozone layer for online training is 2.86×10^{-6} kg CFC11 eq, approximately 19% of the impact compared to 1.48×10^{-5} kg CFC11 eq for on-site training. For on-site training, electricity consumption accounts for about 16% of the total impact, while the remaining impact is primarily due to emissions from food preparation processes and transportation. For online training, 100% of the impact in this category is linked to electricity consumption.

The significantly higher emissions from on-site training are due to the use of energy with a large environmental footprint and emissions from catering processes. Online training, with about five times less impact, represents a more sustainable solution in this category.

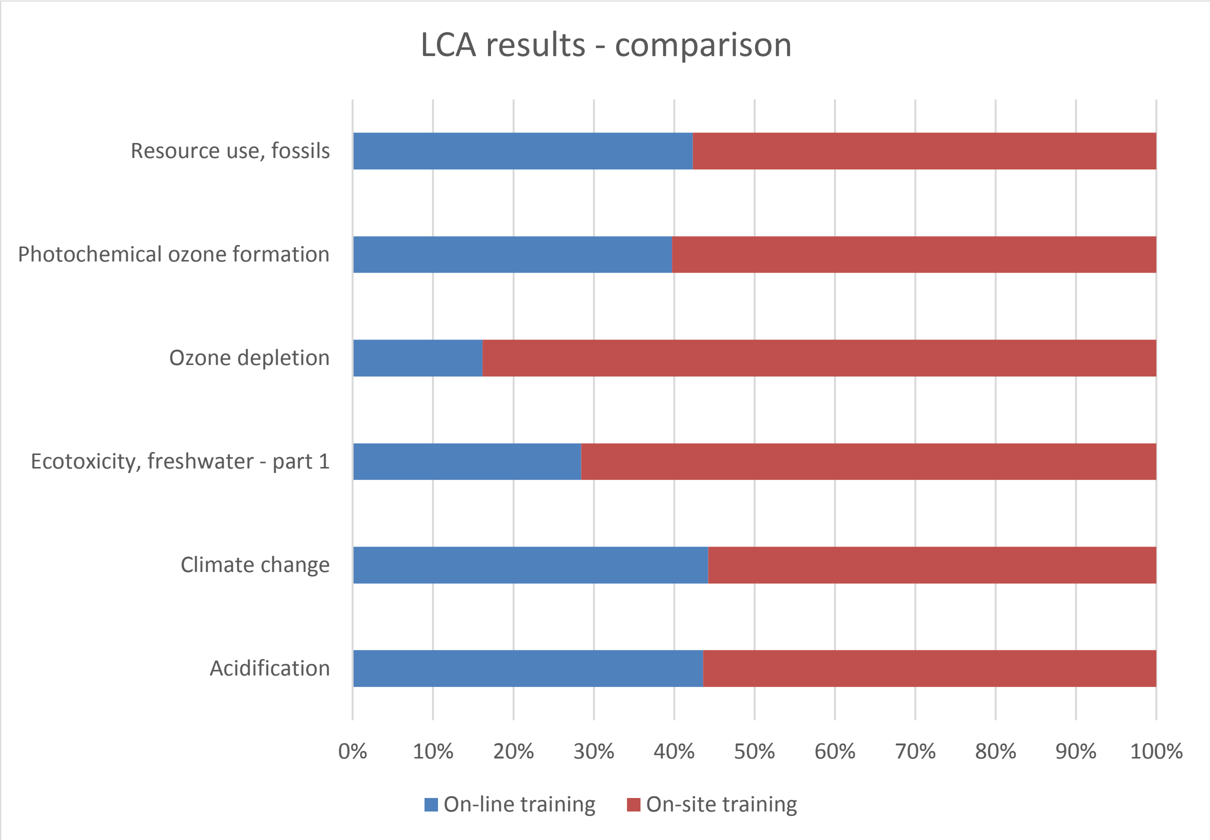

Figure 1. LCA Results - Comparison of online and on-site training services across selected impact categories.

6. Summary

In the tested analytical model, online training generates a lower impact on acidification, climate change, freshwater ecotoxicity, resource use, and ozone layer depletion compared to on-site training. This highlights the potential for implementing more sustainable practices in energy management and catering. Examples of such practices include using renewable energy sources, optimizing participant transportation (e.g., selecting training locations closer to participants' residences), and choosing local and seasonal food products, which can significantly reduce their environmental impact.

Additionally, it is important to consider various perspectives in environmental impact analyses to obtain a more comprehensive understanding, including the consideration of meals and beverages consumed during online training. References for further exploration of this topic may include studies on sustainable development in education, the environmental impact of training, and best practices for energy and resource management in the context of event organization.

Future research should account for the full scope of consumption, including the potential impact of meals consumed during online training, to provide a more holistic view of the environmental effects of both models. Implementing the recommended practices can significantly improve the sustainability of training sessions, regardless of their format.

Acknowledgements

This paper was financed from the resources of the Silesian University of Technology, project no BK-264/ROZ1/2024 (13/010/BK_24/0081).

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