Environmental Impact Assessment Review 91 (2021) 106645

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

journal homepage: www.elsevier.com/locate/eiar

The carbon footprint of a knowledge organization and emission scenarios for a post-COVID-19 world

Sami El Geneidy [a,b], Stefan Baumeister [a,b,*], Valentino Marini Govigli [c,d], Timokleia Orfanidou [e,f], Venla Wallius [a,b,e]

[a] School of Business and Economics, P.O. Box 35, University of Jyväskylä, 40014, Finland
[b] University of Jyväskylä, School of Resource Wisdom, P.O. Box 35, 40014, Finland
[c] University of Bologna, Department of Agricultural and Food Sciences, Via G. Fanin, 50, Bologna 40127, Italy
[d] European Forest Institute, Mediterranean Facility (EFIMED), St. Antoni M. Claret, 167, 08025 Barcelona, Spain
[e] European Forest Institute, Bioeconomy Programme, Yliopistokatu 6 B, FI-80100 Joensuu, Finland
[f] Department of Bioproducts and Biosystems, Aalto University, Vuorimiehentie 1, FI-002150 Espoo, Finland

A R T I C L E I N F O

Keywords:
Carbon footprint
Knowledge organization
Indirect emissions
Mitigation
Carbon offsetting
Travel
COVID-19 pandemic

A B S T R A C T

The looming climate crisis requires an immediate response, in which organizations, as major contributors, should play a central role. However, these organizations need appropriate tools to measure and mitigate their climate impacts. One commonly applied method is carbon footprint analysis. Carbon footprint analyses have been conducted for various types of organizations, but knowledge organizations, such as universities and research institutes, have received far less attention, because their carbon footprint is often less visible and can be easily underestimated. This study is based on the carbon footprint analysis of one multinational knowledge organization. This analysis then helped identify the major sources of climate impacts in other such knowledge organizations. These are mainly indirect emissions (Scope 3) and to a large extent (79%) travel-related emissions. Based on these findings, three scenarios for a post-COVID-19 world were developed and analyzed. The results from the first two scenarios showed that despite a reduction in business travel and employees working from home, Scope 3 and travel-related emissions would remain the largest contributor. Only in the unlikely case of the third, non-recovery scenario did the share of travel-related emissions drop, turning heating into the largest contributor. In addition to measuring the carbon footprint, the study discusses potential mitigation strategies knowledge organizations could apply to reduce their carbon footprint. The focus is on how to avoid and reduce emissions, but new forms of carbon offsetting are also addressed. Based on the findings, a mitigation policy framework and recommendations for further research are proposed.

1. Introduction

Climate change is the defining issue of our time. The steadily increasing greenhouse gas (GHG) emissions in the Earth's atmosphere will have unprecedented global and local impacts on the environment, societies, and economies in the near and long-term future (IPCC, 2014, p. 8). The Intergovernmental Panel on Climate Change (IPCC, 2018) states that fast, wide-ranging and unprecedented changes in society are essential if we are to limit global warming to 1.5 °C. In the last decade, GHG emissions increased by about 1.5% per year, with the 20 largest economies of the world accounting for 78% of global GHG emissions (UNEP, 2019a). Furthermore, UNEP (2019a) reported that even if all countries fulfilled the Paris Agreement commitments, the world is heading towards a 3.2 °C rise in global temperature, which will lead to irreversible socioecological consequences.

An immediate response and action are needed on all levels: individuals, cities, regions, countries and organizations. Wright and Nyberg (2017) see a central role for organizations, in particular. They argue that because organizations have a role in the production of GHGs, they also have great potential to mitigate them with innovative solutions. In order to better manage GHG emissions and identify which emissions reductions measures are the most effective, organizations

* Corresponding author at: School of Business and Economics, P.O. Box 35, University of Jyväskylä, 40014, Finland.
E-mail addresses: sami.s.elgeneidy@jyu.fi (S. El Geneidy), stefan.c.baumeister@jyu.fi (S. Baumeister), Valentino.Govigli@efi.int (V.M. Govigli), Cleo.Orfanidou@efi.int (T. Orfanidou), Venla.Wallius@efi.int (V. Wallius).

https://doi.org/10.1016/j.eiar.2021.106645
Received 21 January 2021; Received in revised form 7 July 2021; Accepted 11 July 2021
Available online 29 July 2021

need to obtain a better understanding of where those GHG emissions occur (Eurostat, 2020).

GHG emissions are far more visible in manufacturing and among service providers, but they can hardly be traced within organizations that operate in the so-called knowledge industry. These organizations, referred to here as knowledge organizations, include education, science, consulting, finance, insurance, and communications. A large body of research exists on the GHG emissions of manufacturing industries and service providers, yet the impacts of knowledge organizations have received far less attention. Previous research has mainly focused on the GHG emissions of universities (Larsen et al., 2013; Ozawa-Meida et al., 2013; Wynes and Donner, 2018), mostly neglecting other types of knowledge organizations. Our study, instead, is based on an internationally operating research institute based in Europe with offices in various European countries as well as in Asia.

One way to determine the GHG emissions of an organization is the calculation of its carbon footprint. An organizational carbon footprint can include, for example, the use of vehicles, the energy consumption of buildings, transportation and business travel of employees, the consumption of goods and services, and other direct and indirect activities (Awanthi and Navaratne, 2018). Previous studies and reports have found that the emissions of knowledge organization consist mostly of indirect, consumption-based emissions (Larsen et al., 2013; Ozawa-Meida et al., 2013; Wynes and Donner, 2018; UNEP, 2019b). A carbon footprint is an adequate tool for identifying consumption-based emissions at the organizational level and allows guidance for mitigating emissions. Pertsova (2007) highlighted the importance of quantitative assessment in environmental modelling, and noted the wide use of carbon footprint as an emerging concept for action against global warming.

This paper aims to estimate the carbon footprint of an organization in the knowledge service sector. After identifying the carbon footprint, it is possible to understand what the most important emissions sources are and how to mitigate them. Through our analysis, we found that most emissions arise from indirect activities (Scope 3; see Section 2.1 for a definition of different scopes). This leads to the questions of how to mitigate such emissions when the organization might not have direct influence over the activities. In addition, we took the novel COVID-19 crisis into account and developed three scenarios to assess (a) how the pandemic has influenced the carbon footprint of knowledge organizations and (b) where the focus of mitigation should be placed in a post-COVID-19 world. The three scenarios take into account the expected changes in business travel patterns as well as the increased use of home office in a post-COVID-19 world. For scenario 1 we assumed a reduction in business travel by 19%. For scenario 2, we assumed a 36% reduction, and for scenario 3, the so-called non-recovery scenario, we assumed business travel will remain as low as it has been during the pandemic, down by 93%. In terms of the increased use of home office, we assumed that in a post-COVID-19 world employees will work two out of five days remotely.

The findings of this study are novel because they quantify some of the hidden environmental impacts of knowledge organizations and provide suggestions for improvement that are relevant for all types of knowledge organizations. We present a framework that can guide knowledge organizations to mitigate their carbon footprint. Understanding the emissions structure and mitigation of knowledge organizations might also prove useful for other entities, such as those in the service sector, where most emissions are produced indirectly, driven by the consumption of products and services.

2. Theoretical background

2.1. Carbon footprint assessment and methods

Carbon footprint is a tool for quantifying emissions. According to Wiedmann and Minx (2007), it is "a measure of the exclusive total amount of carbon dioxide (CO_2) emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product". The carbon footprint can be calculated for a product, person, activity, event, or, as in this study, an organization. The carbon footprint is generally expressed in CO_2 equivalents (CO_2-eq), meaning that GHG emissions other than carbon dioxide (methane, nitrous oxide and fluorinated gases) are converted into CO_2-eq based on their potential to contribute to global warming (Weidema et al., 2008; Wiedmann and Minx, 2007). Emissions in organizational carbon footprint calculations can be divided into three categories, or "scopes" (Harangozo and Szigeti, 2017; WBCSD and WRI, 2011). Scope 1 emissions include direct emissions from the activities, products and processes under the control of the organization or owned by it. Scope 2 emissions include indirect energy (purchased heating and electricity) emissions. Scope 3 includes any further indirect emissions and is often the biggest contributor to an organization's carbon footprint (Harangozo and Szigeti, 2017; WBCSD and WRI, 2011).

Although the carbon footprint is a widely used tool that is relatively easy to comprehend, it has faced criticism for oversimplifying environmental impacts because it only takes into account GHG emissions, not toxic emissions to land and water, for example. For this reason, it might not fully represent an organization's sustainability (Laurent et al., 2012; Weidema et al., 2008). Calculating carbon footprints for products has multiple standards, so system boundaries and other methodological choices of carbon footprint calculations can vary, leading to differing results (Ng et al., 2013; Padgett et al., 2008; Pandey et al., 2011). This applies to less standardized organizational carbon footprint calculations as well. In general, the carbon footprint analysis of an organization should pursue accounting for all direct emissions (Scope 1), indirect energy emissions (Scope 2), and other indirect emissions (Scope 3) within the set boundaries and limitations of the assessment (Harangozo and Szigeti, 2017).

There are three key approaches to calculating an organizational carbon footprint: traditional process-based life cycle assessment (process-LCA), environmentally extended input–output analysis (EEIO), and hybrid-LCA (Nakamura and Nansai, 2016), also known as the hybrid economic input–output-based approach (EIO) (Onat et al., 2014). Process-LCA is a 'bottom-up approach' estimating the emissions that take place at each stage of a given system while the EEIO is a 'top-down' approach evaluating the linkages between economic consumption and environmental impacts (Kitzes, 2013). The biggest distinction between process-LCA and EEIO is that process-based approaches normally neglect financial flows, e.g. purchased services (Suh et al., 2004). EEIO also allows easier replication and comparability between organizations, yet it fails to allow comparison between different products and services of the same industry (Kitzes, 2013; Suh et al., 2004). The hybrid EEIO-LCA (or hybrid-LCA) is a combination of process-LCA and EEIO analysis that is typically used to optimize the strengths of each method (Crawford et al., 2017).

2.2. Knowledge organizations and their carbon footprints

The use of knowledge for the creation of goods and services plays a paramount role in modern knowledge economies. These economies revolve around the concept of knowledge, which characterizes the production, use and diffusion of all economic activities involved (Hadad, 2017). Within these economies, knowledge organizations can be defined as the agents "which provide the underlying infrastructure and processes that enable a knowledge market to function" (Simard et al., 2007). Knowledge organizations represent two main types of actors: (i) those who invest in knowledge (i.e. a university), and (ii) those who apply knowledge in the production, usage and distribution of goods and services (i.e. a knowledge-based company; Karlsson et al., 2009).

White et al. (2012) further classify knowledge organizations according to their structural characteristics. They identify open innovation, education, knowledge management, creativity, and a solid IT infrastructure as the main pillars that characterize any major agent playing a substantial role in the knowledge economy. However, knowledge organizations can also be apprised according to subsequent and interlinking stages. Simard et al. (2007) identify nine different stages of each knowledge service system: (i) generate content, (ii) transform content into products and services, (iii) manage the knowledge flow, (iv) use it internally, (v) transfer it, (vi) add value, (vii) use it professionally as well as (viii) personally, and (ix) evaluate it.

Estimating the carbon footprint of knowledge organizations requires identifying the primary activities of the organization' responsible for the production, usage and distribution of knowledge. Using Simard et al.'s (2007) classification, we can identify the following major activities that account for the majority of any knowledge organization emissions:

- Employees' office hours and employees' internal meetings (Generate knowledge content)
- Business travels to attend conferences and meetings, employees' office hours (Transform knowledge content in products and services)
- Organization of events and production of dissemination and communication materials (Knowledge transfer)

During the last decade, various companies and organizations have taken the initiative to calculate their own carbon footprints. Universities have been especially active in calculating their carbon footprints and publishing the results in scientific journals (e.g. Larsen et al., 2013; Letete et al., 2011; Ozawa-Meida et al., 2013). Indirect (Scope 3) emissions generally form a large share of the emissions especially for knowledge organizations (Larsen et al., 2013; Ozawa-Meida et al., 2013; Wynes and Donner, 2018; UNEP, 2019b).

Mobility, which is a part of the indirect emissions of a knowledge organization, is generally a key component in the carbon footprints of universities, knowledge organizations, and more generally, to science as a whole (e.g. Achten et al., 2013; Glover et al., 2018; Wynes and Donner, 2018). Air travel typically has the biggest impact and, thus, the biggest mitigation potential. Achten et al. (2013) found that for a PhD study, videoconferencing could have reduced the carbon footprint by 44%. Wynes and Donner (2018) estimated that business-related air travel at a Canadian university contributed to 63% to 73% of the university's carbon footprint. Despite air travel's relatively large environmental impact, it is not always taken into account in the sustainability strategies and recommendations of universities (Glover et al., 2018). Meanwhile, Ozawa-Meida et al. (2013) calculated that procurement, at 38%, was the biggest contributor to a UK university's carbon footprint, while travelling was slightly less important as a source of emissions, with 11% coming from staff and student travels, and a further 18% from commuting. Using EEIO analysis, Larsen et al. (2013) calculated that the carbon footprint of a Norwegian university was 92 kt of CO_2-eq in 2009, or 4.6 t per student. Energy, buildings, and equipment were the biggest contributors, at 19% each. Travel accounted for 16% of the total carbon footprint. Another example is the United Nations (UN), where the estimated average carbon footprint per employee is 7 t of CO_2-eq (UNEP, 2019b). Of the total carbon footprint, 42% came from air travel and 12% from other transportation. However, there are significant differences between different UN entities and organizations, and air travel is a significantly more important source of emissions in, for example, the United Nations Environment Programme (UNEP) than it is in United Nations International Children's Emergency Fund (UNICEF), ranging from 85% of total emissions in the former to 35% in the latter (UNEP, 2019b).

However, comparing different studies on a detailed level is difficult and rarely sensible, because the methods and focus points vary significantly. Not all carbon footprint calculations fully take Scope 3 emissions (indirect emissions in the value chain) into account, and all business-related travel might not be included due to lack of data (Wynes and Donner, 2018).

2.3. Expected impacts due to COVID-19 pandemic

Previously, mobility has been identified as a key contributor to the carbon footprint of knowledge organizations. For this reason, the novel COVID-19 crisis can be understood as a game changer because it has a significant impact on business travel, and it is expected that business travel will not fully recover in a post-COVID-19 world. According to estimates made by Sharfuddin (2020), in a post-COVID-19 world business travel will decrease considerably and be replaced by virtual meetings. Ioannides and Gyimothy (2020) even speak of a paradigm shift in business travel. Zahra (2021) assumes that as organizations and employees have become used to working from home during the pandemic, they will be less likely to return to regular business travel as in the past. The pandemic has shown that online communication is an effective working tool while also being far less expensive. A recent survey among 1414 business travelers conducted by YouGov (2021) for the European Climate Foundation found that 42% of the participants expect to travel less due to increased use of video conferences during the pandemic. In the same survey, 22% of the participants claimed that they will replace more than half of their business travel with videoconferencing. A recent article in The Wall Street Journal (2020), citing leading airline industry experts, estimated that 19% to 36% of all business travel will not return. Alon (2020) further postulates that new technological solutions, such as augmented and virtual realities, could enhance the quality of online meetings in the long term.

Nevertheless, the pandemic has also led to an increase in working from home and this is expected to continue in a post-COVID-19 world. Sharfuddin (2020) estimates that companies will encourage employees to work more from home in the future, with them being present for three out of five workdays per week. This will mean a reduction in the need for office space, heating, and electricity and a decrease in employees' commutes, which will further reduce the carbon footprint of knowledge organizations.

3. Data and methods

In this study, we calculated the carbon footprint of a knowledge organization. At the request of the organizational management and to maintain confidentiality, the case organization remains anonymous in this paper. The case organization is a multinational organization with five offices in Europe and additional project offices in Asia. At the time of data collection, the organization had 125 employees. The data for the carbon footprint assessment were collected between July and December 2019 in various regional offices of the organization. To get a full picture of annual emissions the data collected was mostly based on 2018 consumption figures and accounts. The studied institution represents a knowledge organization because of the scope of its activities: producing and communicating knowledge for policymakers.

To account for the environmental impacts of the knowledge organization's monetary and physical consumption, a hybrid EEIO-LCA (sometimes called hybrid LCA) model was used in this study (similar to Larsen et al., 2013 and Onat et al., 2014). Process-LCA is the most commonly used method (Junnila, 2006; Suh et al., 2004), but a hybrid EEIO-LCA is more appropriate for knowledge organizations because it extends the system boundaries to include monetary consumption. Furthermore, the level of detail required for a traditional LCA cannot usually be achieved when calculating the carbon footprint of a knowledge organization, where indirect emissions play a greater role. EEIO-LCA is thus less time- and labor-intensive and requires less effort than the conventional approach does (Suh et al., 2004; Junnila, 2006; Nakamura and Nansai, 2016). Heinonen and Junnila (2011) identified the main disadvantages of an EEIO-LCA as the high level of industry aggregation, potential temporary (differences in inflation and currency) and regional (different industrial structures) stats, and model asymmetries as well as the hypothesis of domestic import production (Suh et al., 2004; Suh and Huppes, 2005; Junnila, 2006).

In this study, the hybrid EEIO-LCA model was hybridized in terms of heating, flights and commuting emissions, which were calculated using emission factors based on process-based LCA information. In these categories, the results are limited because the process-based emission factors do not take into account all the indirect emissions related to a process (Kitzes, 2013; Suh et al., 2004). All other categories were calculated utilizing the EEIO database EXIOBASE (Stadler et al., 2018), with openLCA software (GreenDelta, 2021). openLCA makes it possible to carry out simple EEIO-based calculations, such as carbon footprint analyses, with EXIOBASE without the need for manual calculations and EEIO handling. For a summary of the model and categories included, see Fig. 1.

In the EEIO analysis, environmental impacts are calculated based on economic activities representing consumption (Kitzes, 2013). EEIO-based approaches are widely utilized and can be used in analyzing virtually any environmental impacts, not just carbon footprints. The goal of EEIO analysis is to identify and quantify embodied (upstream) environmental impacts caused by downstream consumption (for an introduction, see e.g. Kitzes, 2013; Leontief, 1970; Schaffartzik et al., 2014). Different environmental account databases and input–output tables can be used for EEIO analysis in analyzing the impacts of certain processes and products. Global databases, such as Eora, EXIOBASE, GTAP and WIOD, are generally used in order to acquire harmonized and detailed data (Kitzes, 2013; Stadler et al., 2018). In this study, the main input–output database was EXIOBASE. For organizational carbon footprint analysis, EXIOBASE performs well compared to other databases because of its high sectorial detail, including around 200 different product categories, and free usage (Stadler et al., 2018).

EXIOBASE is a multiregional, environmentally extended supply-use table and input–output table created for EEIO analyses (Stadler et al., 2018). Supply-use tables of EXIOBASE are monetary, meaning that the inputs need to be expressed as financial units, even though the newest hybrid version of the database also includes physical units (Merciai and Schmidt, 2018). EXIOBASE version 3 covers 44 countries, 200 products, 662 material and resource categories, and 417 emission categories (Stadler et al., 2018). EXIOBASE 3 includes base years of 1995 to 2011. In this study, we used the year 2011 in order to have the most up-to-date data. openLCA with EXIOBASE 3.4 and ecoinvent 3.4 databases were utilized for emissions calculations. Direct use of emissions factors either from national accounts or more specific sources were also used.

3.1. Energy

Data for energy (heating and electricity) usage came mostly from external stakeholders, because the organization does not own its office premises. Thus, the energy calculation methods for each office differed. For a summary of energy production types, consumption figures, emission factors and their sources, see Appendix 1. Heating and cooling emissions in the Spanish office were considered zero because heating and cooling were generated by geothermal energy. Heating emissions in the German office were calculated using the German district heating emission factor (0.28 t CO_2/MWh; BAFA, 2019). Heating emissions in

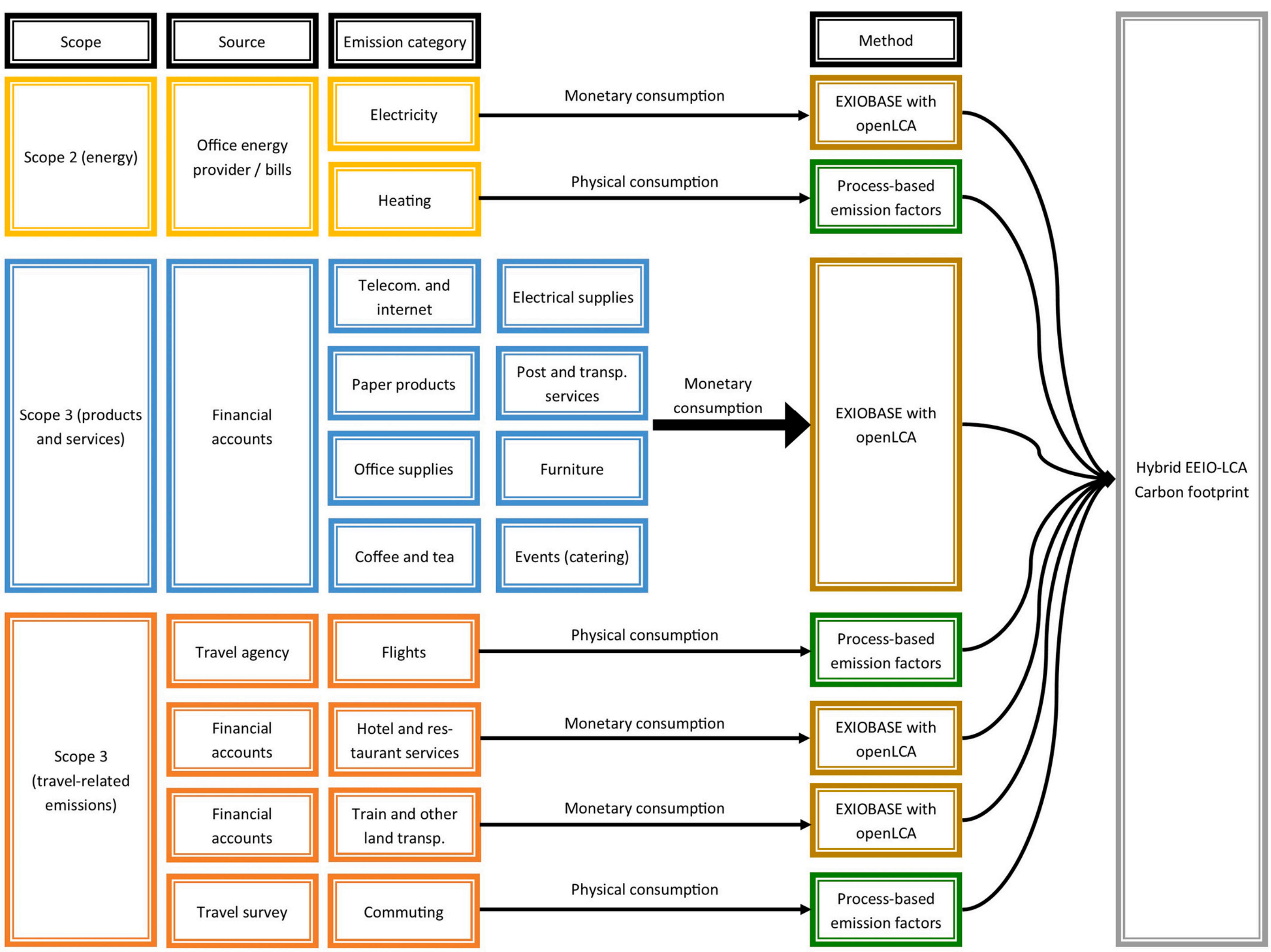


Fig. 1. Flowchart summarizing the data and methods of the study.

the French office were estimated by using the 2019 emission factor for burning oil (heating and lighting on domestic scale, 2.54 kg CO_2-eq/liter) for businesses based in the UK (DEFRA, 2020), because information about French emissions factors were not available. In the case of the Finnish office, energy consumption figures were given for the whole office building, which includes other organizations' offices as well. This means the organization's share of the energy use had to be estimated based on received information about the area occupied by the different offices in the building. Heating emissions were calculated with an emission factor (0.13 t of CO_2/MWh) provided by the local power plant. Heating emissions factors for the German and Finnish offices only considered carbon dioxide emissions, instead of carbon dioxide equivalent emissions, thus the numbers might not be strictly comparable. These emission factors were nevertheless used because more accurate data could not be found.

Electricity emissions in all offices were calculated with openLCA and EXIOBASE by utilizing electricity bills or by converting electricity consumption to monetary units. Conversion factors can be found from Appendix 1. The electricity source was considered to be an average national electricity mix, with the exception of the Finnish office where a renewable electricity mix was used. Furthermore, electricity consumption in the German office was not available, so an estimation based on the electricity use in other offices had to be made.

Energy-use information about other offices (Belgium and Asia) was not available or only a few staff members occupied the offices. In this case, they were considered of low importance in terms of total emissions and were left out from this analysis.

3.2. Products and services

Financial data from 2018 were utilized to obtain a general picture of how many products and services are consumed by each unit of the organization. Table 1 presents the names of financial accounts used, along with their respective categories from the EXIOBASE database, to calculate the organization's carbon footprint. Connecting a financial account with a respective EXIOBASE category was not straightforward in all cases (in Table 1, see e.g. financial account Office supplies and Short Term Equipm and Furniture). Some estimations of the possible content of the account had to be made based on observations and discussions with procurement officers.

Using EXIOBASE with openLCA requires identification of the country of final consumption, so a country was specified for each organizational project account based on the assumed location of the project office. The CML 2001 baseline (Guinée et al., 2002) was used as the impact method, because it includes Global Warming Potential (GWP) for 100 years. Prices were fixed to match inflation from the EXIOBASE baseline year (2011) by using the euro area harmonized indices of consumer prices (Eurostat, 2020). Aggregated EU-level inflation data were used, because all of the offices were based in the EU. Other conversions to prices have not been made.

Table 1
Name of accounts and representative categories in EXIOBASE.

Financial account name	EXIOBASE category (Stadler et al., 2018)
Coffee, tea	Beverages
ADP Supplies	Electrical machinery and apparatus
Events catering	50% Beverages, 50% Food products
Office supplies	1/3 Electrical machinery and apparatus, 1/3 Paper and paper products, 1/3 Rubber and plastic products
Short Term Equipment & Furniture	50% Furniture; other manufactured goods, 50% Office machinery and computers
Hotel/accommodation	Hotel and restaurant services
Restaurant Meals	
Courier Services	Other land transportation services
Group Transportations	
Journals	Paper and paper products
Paper (copy, printed)	
Printed Materials	
Mail	Post and telecommunication services
Phone, Fax, Datatran	
Internet	
Leasing	Renting services of machinery and equipment without operator and of personal and household goods
Tickets (land transportation estimate)	80% Railway transportation services, 20% Other land transportation services

3.3. Travel-related and commuting emissions

Travel data were collected from the financial accounts (land transportation) and travel agency (flights). The organizational travel agency had readymade and detailed data about flight emissions. Their calculations were considered reliable for the purpose of this study because the calculations are based on DEFRA's GHG conversion factors on flight emissions (for the latest version, see DEFRA, 2020).

A travel and commuting survey was conducted within the organization, primarily to determine commuting emissions and some additional information related to employees' commuting and travel behavior and opinions. The data were collected between August and September 2019 by distributing an electronic survey to all employees in the organization. The survey was answered by 78 out of the 125 employees, a response rate of 62%. The responses were well balanced between the three major offices and in terms of employees' gender, age, education and duration of employment as shown in Appendix 2.

For commuting emissions, respondents reported their primary mode of transport to work, the travel distance (home–office–home) and the average number of trips per week. Employees commuting with a car were also asked additional questions regarding the vehicle type (size, production year and fuel type). OpenLCA with ecoinvent 3.4 database was utilized to calculate emissions and IPCC 2013 GWP was used as the impact assessment method. Walking and biking were considered as emission-free modes of transportation. Appendix 3 provides the survey questions used in this study.

To assess the extent to which individual sociological characteristics affect travel and transport choices and emissions, two linear regression models were run. The first model aimed to capture any significant statistical relationship occurring between individual commuting transport choices and a series of independent variables (e.g. gender, age, education, office location, number and times spent in commuting trips, and obstacles to choosing more sustainable commuting options). The second model captures the effect on the individual's willingness to reduce work-related flights of a series of sociological characteristics (as above) as well as employee perceptions of virtual communication tools, travel necessity, carbon footprint reporting, and more. Additional information on the regression models can be found in Appendix 4.

3.4. Post-COVID-19 scenarios

In order to account for the impacts of the COVID-19 pandemic on the carbon footprint of knowledge organizations, three post-COVID-19 scenarios were created. The scenarios are based on the data collected from the studied organization. The three scenarios take into account the expected changes in business travel patterns as well as the increased use of home offices in a post-COVID-19 world. The Wall Street Journal (2020) has estimated that 19% to 36% of business travel will not return, so we assume the following: a reduction in business travel by 19% for scenario 1, and a reduction of 36% for scenario 2. Scenario 3 is based on the drop in business travel during the pandemic, meaning a non-recovery scenario where business travel falls by 93%. This scenario is based on the 2020 flight travel data provided by the studied organization, which saw a decrease of 93% in flights during 2020. These reductions in business travel will have a direct impact on the following emissions categories: flights, hotel and restaurant services, train and other land transportation, events (catering) as well as telecommunications and the internet. For the last category, we assumed an increase of the same percent because it replaces business travel while we expect a decrease for all the other categories depending on the scenario. In terms of employees working from home, we assume that in a post-COVID-19 world employees will work only three out of five days (60%) in the office and the remaining two days (40%) from home, as estimated by Sharfuddin (2020). We therefore assumed a decrease of emissions of 40% for the following emissions categories: heating, commuting, electricity and paper products. For the remaining emissions categories we did not assume any changes in our three post-COVID-19 scenarios. Table 2 below provides a detailed overview of how our assumptions have affected the different categories based on the three scenarios.

4. Results

4.1. Emissions of a knowledge organization

The estimated total carbon footprint of the studied organization in 2018 was 644,137 kg CO_2-eq, which equals 5135 kg CO_2-eq per person. The categories that contributed the most to the carbon footprint were flights (62%), heating (12%) and hotel and restaurant services (7%) (Table 3). Most emissions belong to Scope 3 (87%), with only 13% of emissions belonging to Scope 2. No Scope 1 emissions have been detected in this study.

After we determined the total carbon dioxide equivalent emissions of the knowledge organization, we found that the largest part of emissions created by the studied organization were related to travel. While flights, at 62%, were found to be the largest emissions category, those combined with other travel-related activities, such as hotel and restaurant services, commuting as well as train and other land transportation add up to 79%, so almost four-fifths of the organization's total emissions. Because travel-related emissions make up the largest share of a knowledge organization's carbon footprint but also represent the greatest potential for emissions reductions through changes in travel behavior, the second part of our study focused on travel-related emissions and potential mitigation strategies.

4.2. Emissions by offices

Of total organizational emissions, 34% can be allocated to the Finnish office while the Spanish office and the German office account for 24% and 21% of total emissions, respectively. Smaller offices in Europe and Asia account for 21% of the total emissions altogether.

Emissions per activity were studied further in the three biggest offices: Finnish, Spanish and German offices. There are some notable differences in the shares of emissions per activity between offices (Fig. 2). Flights are the biggest source of emissions in all offices: 69% in Spain, 54% in Finland, and 48% in Germany. Heating in the Spanish office does not create emissions, because geothermal energy is considered to be emission free, while in the German office it accounts for 26% of total emissions and 15% in the Finnish office. Commuting is an important source of emissions for the Finnish office (13%), whereas in Spain and in Germany it accounts for approximately 2% of total emissions. The share of hotel and restaurant services varies between 5 and 9% and land transportation between 4 and 6%.

Table 2
Changes in emissions by category based on the three scenarios.

Emissions category	Changes in emissions by scenario		
	Scenario 1	Scenario 2	Scenario 3
Flights	−19%	−36%	−93%
Heating	−40%	−40%	−40%
Hotel and restaurant services	−19%	−36%	−93%
Commuting	−40%	−40%	−40%
Train and other land transport.	−19%	−36%	−93%
Telecommunication and internet	+19%	+36%	+93%
Events (catering)	−19%	−36%	−93%
Electrical supplies	0%	0%	0%
Electricity	−40%	−40%	−40%
Paper products	−40%	−40%	−40%
Post and transport. Services	0%	0%	0%
Office supplies	0%	0%	0%
Furniture	0%	0%	0%
Coffee and tea	0%	0%	0%

4.3. Travel-related emissions

In the travel-related carbon footprint, flights accounted for 79% of the total travel-related emissions. In terms of distance, most kilometers were flown on economy class medium- and long-haul flights followed by business class long-haul flights. However, most emissions per passenger kilometer (pkm) were produced by long-haul business class flights (210 g CO_2-eq) and economy short-haul domestic flights (147 g CO_2-eq). In comparison, economy class medium-haul flights produced on average only 87 g CO_2-eq per pkm, while for economy class long-haul flights it was only 72 g CO_2-eq.

Here the domestic short-haul flights between the organization's Finnish office and the capital stand out. Helsinki-Vantaa, as Finland's only international hub airport, is the gateway for international flights to and from Finland. In 2018, altogether 161 flights were taken that included a short-haul flight between the Finnish office and Helsinki in order to connect to a destination outside of Finland. In addition, 21 flights were taken as a domestic flight only to the capital Helsinki. All of these were return flights, so altogether 364 short-haul flights were taken between Helsinki and the Finnish office.

In addition to taking a closer look at the recorded travel-related emissions, a travel and commuting survey was conducted among employees to better understand their travel behavior and to discuss mitigation possibilities. The survey focused on long-distance work travel as well as commuting to work.

4.3.1. Long-distance work travel survey

The travel survey showed that for international travel most employees travelled by airplane (81%), followed by train (8%) and car (1%) while 10% did not travel internationally at all. For domestic travel, the train dominated with 67%, followed by car (8%), airplane (5%) and bus (1%). The remaining 19% of respondents did not travel domestically for work.

Respondents also answered a set of three questions related to their most recent long-distance work trip of more than 200 km taken by airplane or car. The first question was whether they think this trip could have been avoided. The majority (86%) thought that the trip could not have been avoided. The main reason provided by the participants was the benefits of face-to-face contact, which are experienced differently than those of virtual meetings. These benefits included better interaction in terms of networking, informal discussion, building trust and team building. Some trips were also for fieldwork or organizing an event that could not be avoided. Because so many meetings are already organized online, meeting at least from time to time offline was seen as acceptable. Some respondents, however, also mentioned that not all meetings would need to take place face to face.

In a second question, participants were asked whether they think it would have been possible to choose another mode of transportation. Here, 59% thought it was not possible, while 38% saw it as a possibility. Participants justified their answers mainly by mentioning a significant increase in travel time when changing transportation modes. Other reasons mentioned were higher costs as well as the lack of options.

In the third question, participants were asked whether they had carbon-offset the emissions generated by their trip. A vast majority of the respondents (81%) did not compensate for their trip. They justified their responses by saying that carbon offsetting was not part of the organization's policy and thus participants were not willing to pay for to offset business trip with their own budget. Furthermore, some participants stated they had not simply thought about it, that it was not

Table 3
Total emissions and share of emissions for each category for the 2018 baseline and the three COVID-19 scenarios.

Emissions category	Total emissions (kg CO2-eq)							
	2018 Baseline		Scenario 1 (19%)		Scenario 2 (36%)		Scenario 3 (93%)	
Flights	397,670	62%	322,113	64%	254,509	60%	28,125	18%
Heating	76,629	12%	45,877	9%	45,977	11%	45,977	29%
Hotel and restaurant services	42,686	7%	34,576	7%	27,319	6%	3019	2%
Commuting	34,305	5%	20,583	4%	20,583	5%	20,583	13%
Train and other land transport.	29,986	5%	24,289	5%	19,191	5%	2121	1%
Telecommunication and internet	13,646	2%	16,239	3%	18,559	4%	26,327	17%
Events (catering)	13,206	2%	10,697	2%	8452	2%	934	1%
Electrical supplies	9623	1%	9623	2%	9623	2%	9623	6%
Electricity	6418	1%	3851	1%	3851	1%	3851	2%
Paper products	5945	1%	3567	1%	3567	1%	3567	2%
Post and transport. Services	5303	1%	5303	1%	5303	1%	5303	4%
Office supplies	4937	1%	4937	1%	4937	1%	4937	1%
Furniture	3582	0%	3582	0%	3582	1%	3582	2%
Coffee and tea	201	0%	201	0%	201	0%	201	0%
Total emissions	**644,137**	**100%**	**505,537**	**100%**	**425,653**	**100%**	**158,150**	**100%**
Scope 1 emissions	0	0%	0	0%	0	0%	0	0%
Scope 2 emissions	83,047	13%	49,828	10%	49,828	12%	49,828	31%
Scope 3 emissions	561,090	87%	455,709	90%	375,825	88%	108,322	69%
Travel-related emissions	504,647	79%	401,560	80%	321,602	76%	53,848	34%
Emissions reductions compared to 2018 Baseline	–	–	138,600	−22%	218,484	−34%	485,987	−75%

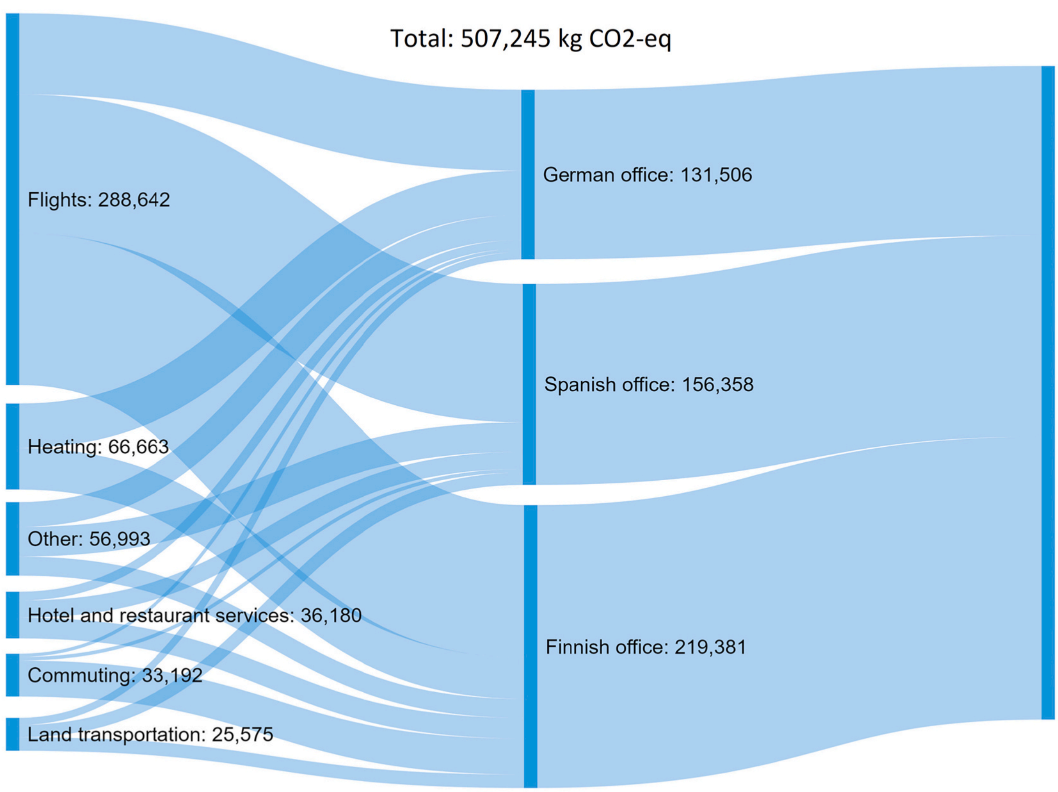


Fig. 2. Total emissions by office and emission category (excluding smaller offices in Europe and Asia).

available from the airline they flew with, or questioned the effectiveness of carbon offset schemes.

Finally, the participants discussed potential barriers they might face with the current travel policy of the organization and to name any potential solutions for reducing climate impacts related to work travel. The largest barrier was seen in how the policy focuses not on climate impacts but on reducing travel times and costs. No information about alternatives is provided. In terms of solutions on how to reduce impacts, carbon offsetting and the increased use of virtual meetings were mentioned the most. In addition, a change in organizational culture towards encouraging and rewarding train travel as well trying to use trains at least on parts of the trip was emphasized. Most employees would be willing to switch air travel to land travel when the journey lasts a maximum of six hours. Furthermore, 40% of the participants agreed that virtual communication tools cannot provide a good alternative to face-to-face meetings, while 39% disagreed with such a statement, and 21% neither agreed nor disagreed. This result could possibly differ from the current employee opinions regarding virtual meetings, which have been commonly used due to the COVID-19 pandemic. The regression model shows that those employees who have a positive view on virtual communication tools have rejected flights when they had the possibility. In addition, employees who value organizational flexibility regarding longer but more sustainable journeys tend to be more willing to reduce work-related flights (Appendix 4).

4.3.2. Commuting to work survey

The commuting survey found that most respondents commute by bicycle (35%), followed by car (23%) and public transport (17%). The average distance for a round trip to the office is 12.5 km. Most participants (42%) indicated they spend 15 to 30 min on their daily commute, 29% between 31 and 60 min, 9% over 60 min and the remaining participants less than 15 min or do not commute at all, working from home. Some differences between the individual offices could be found. Most staff members working in the German office commute by bike, while in the Spanish office most use public transport or walk and in the Finnish office most workers drive by car.

When workers were asked for reasons they chose certain transportation modes, travel time, convenience and flexibility followed by health reasons were mentioned the most. Environmental reasons and costs were mentioned to some extent. About half of the participants (51%) indicated that they would be willing to reconsider their commuting mode in case there would be no restrictions (e.g. time, flexibility, costs) with 65% selecting an environmentally friendlier mode (e.g. switching from car to bicycle) while the remaining 35% would opt for a less environmentally friendly mode (e.g. switching from public transport to car). The results of the regression model indicate a statistically significant effect of commuting distance and different office location on individual commuting transport choices. Employees closer to office locations and from the German and Spanish offices (compared to the French and Finnish offices) have the tendency to use more sustainable commuting modes (e.g. walking or biking vs. cars; Appendix 4).

In addition, respondents also named any possible ways the organization could support them in choosing more sustainable commuting modes. A frequent suggestion was financial support for using public transport, bicycle purchases or bicycle maintenance. Other ideas mentioned were the provision of office bikes and bike maintenance services. More support for home office and flexible working hours as well as organizing car pools was also mentioned.

4.4. Post-COVID-19 scenarios

The results of the three scenarios in Fig. 3 showed that a reduction in business travel by 19% and employees working from home for 40% of their working time could reduce the carbon footprint of the studied organization by 22%. Once the reduction of business travel increases to 36%, the carbon footprint could even be lowered by 34%. Nevertheless, despite a significant reduction in business travel and the 40% reduction in emissions from commuting due to the increased rate in employees working from home, the total share of travel-related emissions in both scenario 1 and scenario 2 remains as high as in the calculated carbon footprint for 2018, which was 79%. For scenario 1, the share even increased to 80% while in scenario 2 it only dropped to 76%. Even in a post-COVID-19 world where travel-related emissions are expected to decrease, for knowledge organizations travel-related emissions will remain the largest contributor to the carbon footprint and should therefore be actively addressed. Only in scenario 3, where no recovery of business travel was assumed (93% less than in 2018), did the share of travel-related emissions of the total carbon footprint drop, to 34%, turning heating into the largest contributor to the carbon footprint.

5. Discussion

5.1. The carbon footprint of a knowledge organization

The results of our study show that most of the carbon footprint in a knowledge organization stems from indirect, Scope 3 emissions. According to Harangozo and Szigeti (2017), Scope 3 emissions are usually the biggest contributor to an organization's carbon footprint and several studies on the carbon footprints of knowledge organizations, such as universities, are aligned with our results, indicating the importance of indirect emissions (ETH Zurich, 2018; Larsen et al., 2013; Letete et al., 2011; Ozawa-Meida et al., 2013; UNEP, 2019b). In terms of mitigation, organizations usually have the most control over their direct emissions (Scope 1), while it is much more difficult to control indirect emissions (Scope 2 and 3). This indicates that knowledge organizations would have very little control over their carbon footprint. However, based on our findings, we argue that with changes in travel behavior and policies, knowledge organizations could take control over their emissions. The largest share of the carbon footprint was generated by travel-related emissions (79%), with air travel accounting for 62% of the organization's total carbon footprint. Our findings are hereby in line with previous studies that found that emissions related to air travel represent a major share in the carbon footprint of knowledge organizations. The UN, for example, estimated that its emissions related to air travel were 42%. In some organizations within the UN system they were even higher: UN Volunteers was at 59% and the Convention on Biological Diversity had as much as 97% (UNEP, 2019b). According to a study by the SEI (2019), an organization similar in size and structure to the organization in this

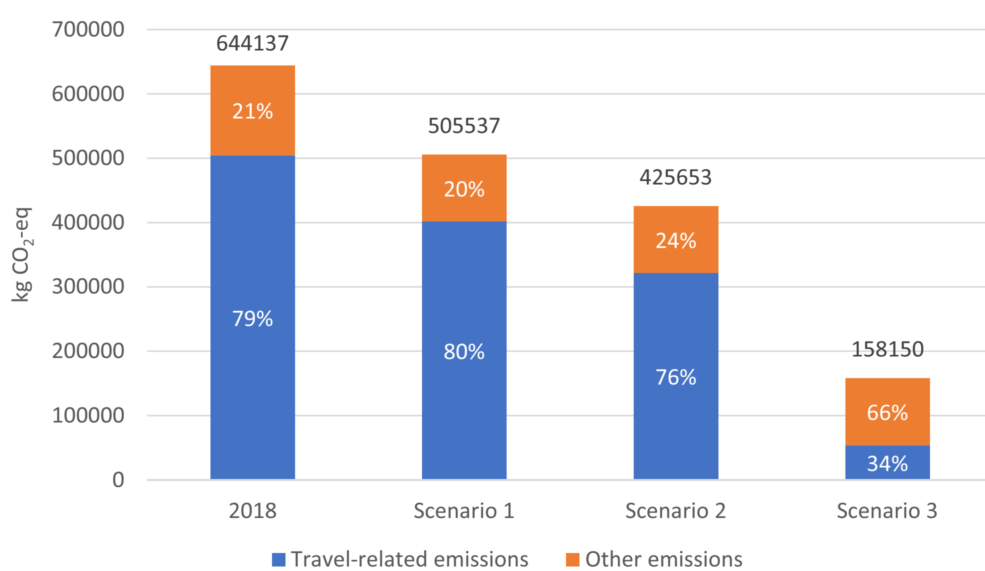


Fig. 3. Share of travel-related emissions by scenario.

study, it had emissions related to air travel per full-time employee of 4390 kg CO_2-eq, which is only slightly above those of our case organization, with 3787 kg CO_2-eq.

5.2. Expected impacts due to COVID-19 pandemic

Based on our scenarios, the total emissions of knowledge organizations are expected to drop due to the reduced amount of business travel. Nevertheless, based on the most likely scenarios (1 and 2) travel-related emissions will remain the largest contributor to the carbon footprint of knowledge organizations. Therefore, in order to reduce the carbon footprint of knowledge organizations, the focus of mitigation in a post-COVID-19 world should remain on travel-related emissions. Only in the unlikely event that travel-related emissions remain on the same level as they were during the pandemic (scenario 3) would other emissions categories gain more importance. In scenario 3, heating would become the single largest contributor, with 29% of the total emissions, raising the importance of Scope 2 emissions, which were negligible in the other scenarios. However, in scenario 3, the carbon footprint would already have decreased 75%, which once again stresses the significant contribution of travel-related emissions to the overall carbon footprint of knowledge organizations.

5.3. Mitigation strategies

In terms of mitigation, the most efficient way to reduce the carbon footprint of a knowledge organization would be to significantly cut or halt all travel, as has been the practice during the COVID-19 pandemic (presented in scenario 3). Prior to the pandemic, however, this did not always seem possible, as the results showed. At that time, the majority of employees (86%) thought their last trip could not have been avoided. Though fieldwork cannot easily be replaced with online tools, many face-to-face meetings and events such as conferences can, as the COVID-19 crisis has shown. Another measure to reduce emissions is the choice of transportation mode, such as avoiding or reducing air travel. A majority of employees did not think their last trip could have been avoided, but at least 38% of employees saw this as a possible solution. One simple measure is to avoid domestic flights, especially where alternatives such as good train connections exist. A large share of domestic trips within the case organization are already made by train (67%), yet many domestic feeder flights were used in Finland. There is a well-established railway connection between the Finnish office and downtown Helsinki as well as to Helsinki-Vantaa Airport, which provides door-to-door connections equal to that of aircraft (Baumeister, 2019). Based on Baumeister (2019), who studied the emissions reduction potential of replacing domestic flights in Finland with land-based transportation modes such as trains, the emissions for a one-way flight from the organization's Finnish office to Helsinki are 70.05 kg CO_2-eq. By train, they are only 8.77 kg CO_2-eq. If all flights had been replaced by train travel, 22,307 kg CO_2-eq could have been saved, which is 6% of the organization's total flight emissions. Here emissions could be easily reduced by replacing flight trips with train travel.

Another simple measure to reduce flight-related emissions is to cut down the amount of premium class flights, as their emissions are significantly higher than flying in economy class. According to Bofinger and Strand (2013), the emissions created by a flight in business class are on average 2.3 times higher than those in economy class and even 6.9 times higher in first class. Reducing work-related travel would not only cut down the emissions created from air travel and emissions of land-based travel modes but would also reduce the emissions created from hotel and restaurant services. These emissions can be significant, as they accounted for 7% of the total emissions of the studied organization. It has also been shown that frequent business travel can affect work–life balance (Liese et al., 1997; Striker et al., 2001; Lirio, 2014; Saarenpää, 2015). For example, in the World Bank the filing rate of medical claims among male travelers was 80% higher than it was among their non-travelling counterparts, and 18% higher among female travelers (Liese et al., 1997). Saarenpää (2015) found international business travel can affect work–family balance, with this imbalance producing negative mental and practical outcomes for travelers and their families.

Furthermore, the results also showed the important role the travel policy of an organization plays in efforts to reduce emissions. A travel policy that takes into account climate aspects could strongly encourage employees to choose alternative modes of transportation and think thoroughly about the importance of the trip. Previous studies have shown that manager support can be an important factor for employee's pro-environmental behavior (Blok et al., 2015; Lo et al., 2013; Ramus and Steger, 2000; Siu et al., 2013). A decision-tree and a pre-travel survey could, for example, help to choose and identify important trips, as practiced by the Tyndall Centre for Climate Change Research (2015). Similarly, the Stockholm Environment Institute (SEI, 2019) asks each of their offices to independently monitor flight emissions and develop environmental action plans; while ETH Zurich (2019) has implemented a voluntary carbon tax on its departments, and a similar approach has been implemented by the University of California, Los Angeles (UCLA, 2019) where a carbon mitigation fee is charged for each flight. Monitoring and justification of emissions, and encouraging employees to choose alternative modes of transportation are important parts of a travel policy aiming to take into account climate-related aspects (some example policies: LUCSUS, 2018; Tyndall Centre for Climate Change Research, 2015).

Finally, a surprisingly large share of the carbon footprint, 5%, of the studied case organization stemmed from commuting to work. Although it is the employee's individual choice how to commute to work, an organization can use incentives and support to motivate employees in choosing more sustainable modes of commuting. In our study, employees showed a strong willingness to reconsider their mode of commuting and a large share was interested in switching to environmentally friendlier modes.

After avoiding and reducing emissions, carbon offsetting or compensation can be a partial and temporary solution to achieve carbon neutrality. However, many challenges remain with conventional carbon offsets in the implementation and success of projects. These range from additionality and emission reduction estimates (Cames et al., 2016) to the fundamental issue of claiming that one tonne of additional emissions is “neutralized” by one tonne's worth of emission reduction units (Becken and Mackey, 2017). However, some of these issues and risks could be mitigated by overcompensation of emissions, in which case one tonne of emissions would be offset, for example, by two tonnes' worth of emission reduction units.

In addition to conventional carbon offsetting, often undertaken through external carbon offsetting providers, some knowledge organizations have been implementing alternative offsetting methods, known as internal offsetting. For example, ETH Zurich's (2019) carbon tax revenues are not used for conventional carbon offsets. Instead, the revenues are invested internally in “teaching, research and fostering young talent, with a focus on CO_2-reducing themes”. Similarly, the Air Travel Mitigation Fund of UCLA (2019) is used to support “local on-campus projects resulting in lasting, measurable carbon reduction in order to mitigate air travel emissions”. The University of Oregon and Yale University have also studied and piloted the implementation of carbon tax/charges, focused on flights and energy use (Kuang and Sternberger, 2017; Yale University, 2016). Moreover, these internal mechanisms could influence organizational and individual decision-making, as flights and fossil energy would have a higher price (Yale University, 2016). Internal offsetting could be a useful alternative for knowledge organizations, where they could be further extended. Organizations could use internal funds to mitigate organizational emissions, investing the internal funds into alternative business travel modes, local renewable energy and sustainable procurement solutions. However, the structure and collection method of the fund and the effect on financial performance would require careful consideration, depending on the

Table 4
Policy framework for mitigating the travel-related emissions of a knowledge organization.

Avoid	
Stop travelling	• Avoid all unnecessary travel • Implement more online meetings • Continue practices from COVID-19 lockdown
Avoid premium class flights	• Emissions can be 2.3 times higher flying in business class • Emissions can be 6.9 times higher flying in first class
Reduce	
Choice of transportation mode	• Reduce trips by aircraft, especially domestic flights • Reduce trips by car • Travel more by train or long-distance bus
Improve travel policy	• Policy needs to take into account climate impacts • Provide more information and flexibility in terms of alternative travel modes • Include carbon offsetting
Support employees in commuting	• Create incentives and support employees in selecting less carbon-intensive commuting modes • Offer more opportunities to work from home
Offset	
Carbon offset (external)	• Carbon offset through verified external offset providers • Overcompensate to account for risks
Carbon offset (internal)	• Carbon offset by investing in internal offsetting projects

structure of the organization.

5.4. Mitigation policy framework

Based on our findings and the above discussed mitigation strategies, we propose the following policy framework to mitigate the travel-related emissions of a knowledge organization (see Table 4). The priority should be avoiding emissions by stopping travelling and avoiding flights in premium class. We see these as the most effective ways of mitigation. Second priority should be given to reducing emissions through the choice of transportation modes, an improved travel policy and encouraging employees to use greener commuting. Finally, as a last resort and for remaining emissions, offsetting carbon emissions both externally and internally should be considered.

6. Conclusion

By assessing the carbon footprint of a knowledge organization, we found that indirect emissions (Scope 3) and travel-related emissions dominate. We used our findings to propose a mitigation policy framework for knowledge organizations to reduce their travel-related carbon footprint. This framework builds on three major activities: avoiding and reducing emissions while offsetting the remaining ones. It is commonly argued that organizations have little control over indirect emissions, but our framework demonstrates that knowledge organizations, whose carbon footprint is mainly based on indirect emissions, can use simple policy changes to effectively take control of their emissions. Though our study focused on knowledge organizations, the framework presented here can also be applied to any other type of organization that wants to mitigate travel-related emissions.

Even though our study shed some new light on the carbon footprints of knowledge organizations and discussed potential mitigation strategies, it also has some limitations. First, our results are based on only one case organization, which limits the generalizability of our findings. The studied organization had no Scope 1 emissions. The strong focus on travel-related emissions might also be misguided, because the share of those emissions can vary significantly between organizations, as previous studies have shown. Furthermore, the lack of availability of some data sources (e.g. energy-related emission factors or CO_2-eq) concerning the studied organization and some of the assumptions that had to be made during the calculation process, such as when EXIOBASE categories had to be matched with the financial accounts of the organization, might have led to errors in the estimation of the carbon footprint. In addition, the information provided by EXIOBASE was based on 2011 emissions, making the data somewhat outdated. The carbon footprint might also not present the full picture of environmental sustainability. Biodiversity impacts and toxic emissions, for example, have not been addressed. Finally, the travel survey, despite its good response rate, had a limited amount of participants, which restricts further statistical analyses.

Future studies could draw more attention to indirect emissions other than travel-related ones, because in some knowledge organizations their share might be significantly higher but also more difficult to mitigate. Research studies could also further explore the potential of internal carbon offsetting in organizations, which have yet to receive much attention in the literature. Finally, this study was mainly conducted prior to the COVID-19 crisis, so future work could also investigate the impacts the crisis has had on the carbon footprint of organizations, especially for work-related travel and commuting in a post-COVID-19 world.

Author statement

Sami El Geneidy as the first author was responsible for the conceptualization, data curation, formal analysis, methodology and he was involved in writing of the original draft. Stefan Baumeister, Ph.D. as the second author was involved in the conceptualization, formal analysis, methodology and in writing the original draft. Stefan was also responsible for the supervision and validation of the process. Valentino Marini Govigli, Ph.D., Timokleia Orfanidou and Venla Wallius were involved in the writing of the original draft and helped with the conceptualization of the study. All authors contributed equally to the reviewing and editing of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. A summary of key information related to office energy consumption and emissions

Office location	Emission category	Energy production type	Consumption (kWh)	Conversion factor to monetary units	Emission factor	Unit	Emission factor source
Finland	Electricity	Nordic renewable electricity mix (hydro and wind, Nordic Energy Research, 2017)	175,436	46.77 €/MWh (Nordpool, 2018)	Hydro: 0.37 Wind: 0.20	kg CO_2-eq/€	EXIOBASE (Stadler et al., 2018)
	Heating	Biomass, peat and biogas	247,674	No conversion done	0.13	t CO_2/MWh	Local power plant
France	Electricity	French electricity mix	9978		0.19		

(continued on next page)

(*continued*)

Office location	Emission category	Energy production type	Consumption (kWh)	Conversion factor to monetary units	Emission factor	Unit	Emission factor source
				0.07025 €/kWh (average of 2018 prices, Eurostat, 2021)		kg CO_2-eq/€	EXIOBASE (Stadler et al., 2018)
	Heating	Oil	3923 (liters)	No conversion done	2.54	kg CO_2-eq/l	DEFRA, 2020
Germany	Electricity	German electricity mix	83,000	0.2707 €/kWh (SWB, 2019)	0.10	kg CO_2-eq/€	EXIOBASE (Stadler et al., 2018)
	Heating	German district heating mix	123,090	No conversion done	0.28	t CO_2/MWh	BAFA, 2019
Spain	Electricity	Spanish electricity mix	67,360	0.123 €/kWh (from electricity bill)	0.23	kg CO_2-eq/€	EXIOBASE (Stadler et al., 2018)
	Heating	Geothermal	104,133	No conversion done	0	None	None

Appendix B. Commuting and travel survey background statistics ($n = 78$)

Variables	Statistics
Responses across offices	Office location 1: 27 (35%) Office location 2: 22 (28%) Office location 3: 21 (27%) Office location 4: 4 (5%) Office location 5: 3 (4%) Office location 6: 1 (1%)
Gender	Female: 39 (50%) Male: 39 (50%)
Age	18–24: 3 (4%) 25–34: 26 (33%) 35–44: 28 (36%) 45–54: 11 (14%) 55–64: 8 (10%) Prefer not to say: 2 (3%)
Highest education completed	Bachelor's degree: 11 (13%) Master's degree: 48 (62%) Doctoral degree: 18 (23%) Other: 1 (1%) Prefer not to say: 1 (1%)
Duration of employment	0–1 year: 22 (28%) 2–4 years: 24 (31%) 5–10 years: 19 (24%) 10+ years: 13 (17%)

Appendix C. Survey questions

Background questions:

1. Gender
   a. Female
   b. Male
   c. Other
   d. Prefer not to say
2. Age
   a. Under 18
   b. 18–24
   c. 25–34
   d. 45–54
   e. 55–64
   f. Age 65 and older
   g. Prefer not to say
3. Highest education completed
   a. Bachelor's degree
   b. Master's degree
   c. Doctoral degree
   d. Prefer not to say
   e. Other
4. Employing office
   [interviewee could select one of the different offices where the organization is located].
5. Duration of employment until now

   a. 0–1 year
   b. 2–4 years
   c. 5–10 years
   d. 10+ years
   e. Prefer not to say
6. Status of employment/Working time
   [e.g. 70% or 100%, without the percentage "%" character].

Questions related to commuting emissions:

7. What is the primary mode of transport you take to work (on a typical day)?
   a. Single occupant car (driving alone)
   b. Car share (e.g. with family)
   c. Carpooling (service)
   d. Bicycle
   e. Electric bicycle
   f. Train
   g. Tram/subway
   h. Bus
   i. Local public transport (if e.g. bus + subway or walk + tram)
   j. Moped/Scooter
   k. Walk/Run
   l. Motorcycle
   m. Taxi
   n. I mostly work from home/0 days a week at the office
   o. Other
8. Please estimate the daily distance used to travel with the primary mode of transport (home–office–home) (kilometers/day). If you previously answered "I mostly do home office", put 0 here.
9. Please estimate the average number of trips (1 trip = home–office–home) per week. If you previously answered "I mostly work from home", put 0 here.
10. Please provide some of the main reasons for choosing your primary mode of transport
11. In case you did not choose a car as your primary mode of transport, you can skip to question 14. If you chose a car as your primary mode of transport, please specify the type of fuel used.
    a. Petrol
    b. Diesel
    c. Electric
    d. Hybrid
    e. Not applicable
    f. Other
12. In case you did not choose a car as your primary mode of transport, you can skip to question 14. If you chose a car as your primary form of transport, please estimate the production year of the car.
    a. 1992 or older
    b. 1996–1999
    c. 2000–2004
    d. 2005–2008
    e. 2009–2013
    f. 2014 or newer
    g. Not applicable
13. In case you did not choose a car as your primary mode of transport, you can skip to question 14. If you chose a car as your primary form of transport, please estimate the size of engine/car. Detailed evaluation is not necessary here.
    a. Small
    b. Medium
    c. Large
    d. Not applicable
14. On average, how much time do you spend daily commuting to work (home–office–home)?
    a. less than 15 min
    b. 15–30 min
    c. 31–60 min
    d. more than 60 min
    e. Home office
15. How much money do you spend on your weekly commute?
    a. Basically none
    b. less than €10
    c. €11–25
    d. €26–50
    e. €51–100

   f. more than €100
   g. Home office
16. Which one of these vehicles would you most likely use to commute to work if you didn't have money, time or other limitations?
   a. Car
   b. Car pooling
   c. Bus
   d. Train
   e. Tram/Subway
   f. Bicycle
   g. Electric bicycle
   h. Walk/Run
   i. Moped/Scooter/Motorcycle
   j. Other
17. What are the main obstacles you face (if any) in choosing your most appealing commuting option?
   a. Time
   b. Money
   c. Convenience
   d. Physical health
   e. Distance from home to office
   f. Lack of options/knowledge
   g. No obstacles
   h. Other
18. Can you think of any ways how [name of organization] could support you in choosing a more sustainable commuting option?
19. What is your most common mode of transportation for international work travel?
   a. Plane
   b. Train
   c. Bus
   d. Car
   e. Ferry
   f. No travel experience so far
   g. Other
20. What is your most common mode of transportation for national work travel?
   a. Plane
   b. Train
   c. Bus
   d. Car
   e. Ferry
   f. No travel experience so far
   g. Other
21. If you don't have work travel experience (national or international) by plane or car, you can skip to question 27. Think about the most recent long-distance (>200 km) work trips you took by plane or car. Do you think it could have been possible to avoid travelling?
   a. Yes
   b. No
   c. Not applicable
22. Please justify your answer. Why was it/was it not possible?
23. If you don't have work travel experience (national or international) by plane or car, you can skip to question 27. Think about the most recent long-distance (>200 km) work trips you took by plane or car. Do you think it would have been possible to use another mode of transportation?
   a. Yes
   b. No
   c. Not applicable
24. Please justify your answer. Why was it/was it not possible?
25. If you don't have work travel experience (national or international) by plane or car, you can skip to question 27. Think about the most recent long-distance (>200 km) work trip you took by plane or car. Did you compensate for the emissions of the trip (e.g. by paying a carbon offsetting fee)?
   a. Yes
   b. No
   c. Not applicable
26. Why did you/did you not compensate for the emissions of the trip?
27. What are the barriers you face with [name of organization] and travel agency's policies and practices, which make it difficult for you to make environmentally sustainable choices?
28. Please state your opinion on the following statements. Remember that the following statements are only related to work travelling.
   [Strongly Disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree, NA]
   a. Virtual communication methods do NOT generally provide a good alternative to physical “face-to-face” meetings
   b. I carefully consider the purpose of each trip before making the travel decision
   c. I have chosen not to fly even though flying would have been quicker or cheaper
   d. I have chosen not to fly even though flying would have benefited my work

e. It would be difficult for me to carry out my work/research if I did not fly
f. From a general perspective (not the organization perspective), flying less would negatively affect my career prospects
g. In most cases, I am expected to be physically present by the organization or other collaborators

29. Please state your opinion on the following statements
[Strongly Disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree, NA]
a. As an employee of [name of the organization], I would be ready to reduce flying even if it meant fewer meetings, conferences, international collaborations etc.
b. I would be interested in voluntarily reporting and getting feedback about my work-related carbon footprint
c. Support from the organization in terms of being flexible about the increased journey time would encourage me to use land travelling options
30. As an employee of [Organization name], I would be ready to switch air travel to land travel even if it meant…
a. 0–2 h more travel time (compared to flight)
b. 3–6 h more travel time (compared to flight)
c. 7–10 h more travel time (compared to flight)
d. 11–15 h more travel time (compared to flight)
e. 1–2 days of travelling
31. What are the main BARRIERS of land travel in your opinion (compared to air travel)?
a. Time
b. Price
c. Flexibility
d. Services during travel
e. Comfort while travelling
f. Complexity of booking tickets
g. Transfers during the trip
h. Reliability of schedules
i. Ease of working while travelling
j. Baggage allowance
k. No barriers
l. Other
32. What are the main BENEFITS of land travel in your opinion (compared to air travel)?
a. Time
b. Price
c. Flexibility
d. Services during travel
e. Comfort while travelling
f. Reliability of schedules
g. Ease of working while travelling
h. Easier transitions in the departure and arrival destinations (center to center vs. airport to airport)
i. Chance to enjoy landscapes and views
j. Baggage allowance
k. Environmental sustainability
l. No benefits
m. Other
33. Here you can provide any additional comments and feedback you might have about the survey.

Appendix D. Commuting and travel survey regression models

To assess the extent to which individual sociological characteristics affect travel and transport choices and emissions, two regression models were run:

1. The first model aimed to capture any significant statistical relationship occurring between employees' commuting transport choices and a series of independent variables. Due to the nature of the dependent variable (ordered categories), this relationship was explored using an ordered logit regression and quantified using relative odds ratios.
2. The second model captures the effect on the employees' willingness to reduce work-related flights of a series of sociological characteristics (as above) and additional employee perceptions.

The list of the dependent and independent variables of both models are reported in the table below. Backward stepwise regression analyses were used to find the most parsimonious model with each outcome. Model results were tested for normality (OLS) and collinearity. All analyses were performed using the programming software R (R Core Team, 2020).

Model	Dependent variable	Independent variables
1. Drivers of employees' community transport choices (Ordered logit model)	Commuting mode carbon footprint (question 7), recategorized as follows: Home office = 0; Walk/Run =1, bicycle = 2; electric bicycle = 3;	Gender (q.1); age (q.2); education (q.3); Office location (q.4); employment duration (q.5); commuting distance (q.8); number of

(*continued on next page*)

(*continued*)

Model	Dependent variable	Independent variables
	Train, Tram/subway, Bus, and Local public transport = 4; moped, Motorcycle = 5; car share, Carpooling = 6; Single occupant car =7[a]	commuting trips (q.9); commuting time (q.14); total number of obstacles while commuting (q.17).
2. Drivers of employees' willingness to reduce work-related flights	Willingness to reduce work-related flights, quantified as follows: Strongly Disagree = −2, Disagree = −1, Neither agree nor disagree =0, Agree =1, Strongly agree = 2 (q.29: *As an employee of [name of the organization], I would be ready to reduce flying even if it meant fewer meetings, conferences, international collaborations* etc.)	Gender (q.1); age (q.2); education (q.3); Office location (q.4); employment duration (q.5); virtual communication tools acceptance (q.28); consideration of trip purpose (q.28); chosen not to fly even if quicker/cheaper (q.28); chosen not to fly even if would have benefitted work (q.28); difficult to carry out work/research without flying (q.28); impact on career prospects (q.28); expected to be physically present (q.28); report work related carbon footprint (q.29); flexible support from the organization (q.29); barriers of land travel (q.31); benefits of land travel (q.32).

[a] For respondents choosing hybrid options (e.g. walking and bus), only the means of transport with the highest pollution potential was chosen.

The full results of both regression models are hereby reported:

Results of the ordered logit regression model on drivers of employees' community transport choices.

Explanatory variable	Model coefficient	t value	Odds ratio	95% CI	*p*(>|t|)
Spanish office	−1.956	−3.361	0.14	0.04; 0.43	<0.001 ***
German office	−1.866	−3.231	0.16	0.05; 0.47	<0.001 ***
Commuting distance	0.073	3.711	1.08	1.04; 1.12	<0.001 ***
Number of commuting trips	0.196	1.484	1.22	0.94; 1.59	0.137
Obstacles while commuting	0.384	1.603	1.47	0.92; 2.38	0.109
Cut = 1[a]	−2.740	−3.116	–	–	<0.001 ***
Cut = 2[a]	−1.095	−1.345	–	–	0.178
Cut = 3[a]	0.801	0.998	–	–	0.318
Cut = 4[a]	1.085	1.349	–	–	0.177
Cut = 5[a]	2.150	2.636	–	–	<0.001 ***
Cut = 6[a]	2.580	3.117	–	–	<0.001 ***
Cut = 7[a]	4.271	4.598	–	–	<0.001 ***

Starting AIC: 280.6; final AIC: 268.8. Significance levels: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.
Cragg and Uhler's pseudo R^2: 0.444; *d.f.:* 5 and 70.

[a] Cut points representing the different levels of the ordered logit model.

The results of the ordered logit regression model indicate that, holding all other variables constant, employees living 1 extra km/day further away from the office location have 8% higher odds of choosing a more polluting commuting mode ($p < 0.001$). Additionally, this model shows an effect of different office locations on individual commuting transport choices, with the odds of an employee choosing a more polluting commuting mode being 86% and 84% lower when employees belong to the Spanish ($p < 0.001$) and German offices ($p < 0.001$) with respect to the baseline (Finnish office).

Results of the multiple regression model 2 on Drivers of employees' willingness to reduce work-related flights.

Independent variable	Estimate	SE	*t* value	*p*(>|t|)
Intercept	0.151	0.557	0.271	0.788
Education [Master's degree]	0.728	0.398	1.828	0.075
Education [Doctoral degree]	0.303	0.422	0.719	0.476
Employment duration	0.186	0.118	1.577	0.122
Virtual comm. Tools acceptance	−0.258	0.101	−2.554	0.014*
Consideration of trip purpose	−0.204	0.136	−1.499	0.141
Chosen not to fly even if would have benefitted work	0.375	0.123	3.064	0.004**
Flexible support from the organization	0.269	0.091	2.974	0.005**

Starting AIC: 132.1; final AIC: 119.0. Significance levels: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.
R^2: 0.566; d.f.: 7 and 41.

The regression model performed shows that employees who have a negative view of virtual communication tools ($p = 0.014$) tend to be more reluctant to reduce work-related flights. Conversely, employees who have rejected flying when they had the possibility ($p = 0.004$) and value organizational flexibility regarding longer but sustainable journeys ($p = 0.005$) are more willing to reduce work-related flights.

References

Achten, W., Almeida, J., Muys, B., 2013. Carbon footprint of science: more than flying. Ecol. Indic. 34, 352–355. https://doi.org/10.1016/j.ecolind.2013.05.025.

Alon, I., 2020. COVID-19 and international business: a viewpoint. FIIB Busin. Rev. 9 (2), 75–77, 10.1177%2F2319714520923579.

Awanthi, M., Navaratne, C., 2018. Carbon footprint of an organization: a tool for monitoring impacts on global warming. Proc. Eng. 212, 729–735. https://doi.org/10.1016/j.proeng.2018.01.094.

BAFA, 2019. Merkblatt zu den CO2 Faktoren. Energieeffizienz in der Wirtschaft – Zuschuss und Kredit. Retrieved from: https://www.bafa.de/SharedDocs/Downloads/DE/Energie/eew_merkblatt_co2.pdf?__blob=publicationFile&v=2.

Baumeister, S., 2019. Replacing short-haul flights with land-based transportation modes to reduce greenhouse gas emissions: the case of Finland. J. Clean. Prod. 225, 262–269. https://doi.org/10.1016/j.jclepro.2019.03.329.

Becken, S., Mackey, B., 2017. What role for offsetting aviation greenhouse gas emissions in a deep-cut carbon world? J. Air Transp. Manag. 63, 71–83. https://doi.org/10.1016/j.jairtraman.2017.05.009.

Blok, V., Wesselink, R., Studynka, O., Kemp, R., 2015. Encouraging sustainability in the workplace: a survey on the pro-environmental behaviour of university employees. J. Clean. Prod. 106, 55–67. https://doi.org/10.1016/j.jclepro.2014.07.063.

Bofinger, H., Strand, J., 2013. Calculating the carbon footprint from different classes of air travel. World Bank. https://doi.org/10.1596/1813-9450-6471.

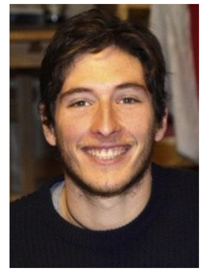
Cames, M., Harthan, R., Füssler, J., Lazarus, M., Lee, C., Erickson, P., Spalding-Fecher, R., 2016. How additional is the clean development mechanism?. In: Analysis of the Application of Current Tools and Proposed Alternatives. Öko-Institut e.V Retrieved

from: https://ec.europa.eu/clima/sites/clima/files/ets/docs/clean_dev_mechanism_en.pdf.
Core Team, R., 2020. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from: https://www.R-project.org/.
Crawford, R.H., Bontinck, P.-A., Stephan, A., Wiedmann, T., Yu, M., 2017. Hybrid life cycle inventory methods – a review. J. Clean. Prod. 172, 1273–1288. https://doi.org/10.1016/j.jclepro.2017.10.176.
DEFRA, 2020. Greenhouse Gas Reporting: Conversion Factors 2020. Retrieved from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020.
ETH Zurich, 2018. Sustainability Report 2017/2018. Retrieved from: https://ethz.ch/content/dam/ethz/main/eth-zurich/nachhaltigkeit/Berichte/Nachhaltigkeitsbericht/ETHzurich_Sustainability_Report_2017_2018_web.pdf.
ETH Zurich, 2019. Air Travel Project. Retrieved from: https://ethz.ch/en/the-eth-zurich/organisation/executive-board/vice-president-human-resources-and-infrastructure/mobilitaetsplattform/air-travel.html.
Eurostat, 2020. Harmonised Index of Consumer Prices (HICP) — Overview. Retrieved from: https://ec.europa.eu/eurostat/web/hicp.
Eurostat, 2021. Electricity Prices for Non-Household Consumers - Bi-Annual Data (from 2007 onwards). Retrieved from: https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_205/default/table?lang=en.
Glover, A., Strengers, Y., Lewis, T., 2018. Sustainability and academic air travel in Australian universities. Int. J. Sustain. High. Educ. 19 (4), 756–772. https://doi.org/10.1108/IJSHE-08-2017-0129.
GreenDelta, 2021. openLCA – the Life Cycle and Sustainability Modeling Suite. Retrieved from. https://www.openlca.org/openlca/.
Guinée, J.B., Gorrée, M., Heijungs, R., Huppes, G., Kleijn, R., de Koning, A., van Oers, L., Wegener Sleeswijk, A., Suh, S., Udo de Haes, H.A., de Bruijn, H., van Duin, R., Huijbregts, M.A.J., 2002. Handbook on life Cycle Assessment. Operational Guide to the ISO standards. I: LCA in Perspective. IIa: Guide. IIb: Operational Annex. III: Scientific Background. Kluwer Academic Publishers. ISBN 1–4020–0228-9, Dordrecht, 2002, 692 pp.
Hadad, S., 2017. Knowledge economy: characteristics and dimensions. Manag. Dynam. Knowledge Econ. 5 (2), 203–225. https://doi.org/10.25019/MDKE/5.2.03.
Harangozo, G., Szigeti, C., 2017. Corporate carbon footprint analysis in practice – with a special focus on validity and reliability issues. J. Clean. Prod. 167, 1177–1183. https://doi.org/10.1016/j.jclepro.2017.07.237.
Heinonen, J., Junnila, S., 2011. Metropolitan carbon management - a hybrid-LCA approach. In: 2011 2nd International Conference on Environmental Science and Technology, ICEST 2011, Singapore, 26–28.2.2011 (pp. VI13-VI17). (International Proceedings of Chemical Biological and Environmental Engineering; Vol. 6). Asia-Pacific Chemical, Biological & Environmental Engineering Society (APCBEES).
Ioannides, D., Gyimothy, S., 2020. The COVID-19 crisis as an opportunity for escaping the unsustainable global tourism path. Tour. Geogr. 22 (3), 624–632. https://doi.org/10.1080/14616688.2020.1763445.
IPCC, 2014. Climate change 2014: synthesis report. In: Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland. https://doi.org/10.1046/j.1365-2559.2002.1340a.x, 151 pp.
IPCC, 2018. IPCC, 2018: summary for policymakers. In: Masson-Delmotte, V., Zhai, P., Pörtner, H.O., Roberts, D., Skea, J., Shukla, P.R., Waterfield, T. (Eds.), Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. World Meteorological Organization, Geneva, Switzerland. https://doi.org/10.1017/CBO9781107415324, 32 pp.
Junnila, S., 2006. Empirical comparison of process and economic input-output life cycle assessment in service industries. Environ. Sci. Technol. 40 (22), 7070–7076. https://doi.org/10.1021/es0611902.
Karlsson, C., Börje, J., Stough, R., 2009. Human capital, talent and regional growth. In: CESIS Electronic Working Paper Series Paper No. 191, JIBS and CESIS. School of Public Policy. Retrieved from: https://static.sys.kth.se/itm/wp/cesis/cesiswp191.pdf.
Kitzes, J., 2013. An introduction to environmentally-extended input-output analysis. Resources. 2, 489–503. https://doi.org/10.3390/resources2040489.
Kuang, H., Sternberger, K., 2017. University Air Travel & Internal Carbon Taxation. Retrieved from: http://cassites.uoregon.edu/econ/wp-content/uploads/sites/4/2017/06/Sternberger-Kuang_Thesis17.pdf.
Larsen, H., Pettersen, J., Solli, C., Hertwich, E., 2013. Investigating the carbon footprint of a university - the case of NTNU. J. Clean. Prod. 48, 39–47. https://doi.org/10.1016/j.jclepro.2011.10.007.
Laurent, A., Olsen, S., Hauschild, M., 2012. Limitations of carbon footprint as Indicator of environmental sustainability. Environ. Sci. Technol. 46 (7), 4100–4108. https://doi.org/10.1021/es204163f.
Leontief, W., 1970. Environmental repercussions and the economic structure: an input-output approach. Rev. Econ. Stat. 52 (3), 262–271. Retrieved from. https://www.jstor.org/stable/1926294.
Letete, T., Mungwe, N., Guma, M., Marquard, A., 2011. Carbon footprint of the University of Cape Town. J. Energy Southern Africa 22 (2). https://doi.org/10.17159/2413-3051/2011/v22i2a3208.
Liese, B., Mundt, K., Dell, L., Nagy, L., Demure, B., 1997. Medical insurance claims associated with international business travel. Occup. Environ. Med. 54 (7), 499–503. https://doi.org/10.1136/oem.54.7.499.
Lirio, P., 2014. Taming travel for work-life balance in global careers. J. Glob. Mob. 2 (2), 160–182. https://doi.org/10.1108/JGM-06-2013-0028.
Lo, S., van Breukelen, G., Peters, G., Kok, G., 2013. Proenvironmental travel behavior among office workers: a qualitative study of individual and organizational determinants. Transp. Res. A Policy Pract. 56, 11–22. https://doi.org/10.1016/j.tra.2013.09.002.
LUCSUS, 2018. Travel Policy. Retrieved from: https://www.lucsus.lu.se/sites/lucsus.lu.se/files/lucsus_travel_policy.pdf.
Merciai, S., Schmidt, J., 2018. Methodology for the construction of global multi-regional hybrid supply and use tables for the EXIOBASE v3 database. J. Ind. Ecol. 22 (3), 516–531. https://doi.org/10.1111/jiec.12713.
Nakamura, S., Nansai, K., 2016. Input–output and hybrid LCA. In: Finkbeiner, M. (Ed.), Special Types of Life Cycle Assessment. LCA Compendium – The Complete World of Life Cycle Assessment. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-7610-3_6.
Ng, T., Chen, Y., Wong, J., 2013. Variability of building environmental assessment tools on evaluating carbon emissions. Environ. Impact Assess. Rev. 38, 131–141. https://doi.org/10.1016/j.eiar.2012.07.003.
Onat, C.N., Kucukvar, M., Tatari, O., 2014. Scope-based carbon footprint analysis of U.S. residential and commercial buildings: an input–output hybrid life cycle assessment approach. Build. Environ. 72, 53–62. https://doi.org/10.1016/j.buildenv.2013.10.009.
Ozawa-Meida, L., Brockway, P., Letten, K., Davies, J., Fleming, P., 2013. Measuring carbon performance in a UK University through a consumption-based carbon footprint: De Montfort University case study. J. Clean. Prod. 56, 185–198. https://doi.org/10.1016/j.jclepro.2011.09.028.
Padgett, P., Steinemann, A., Clarke, J., Vandenbergh, M., 2008. A comparison of carbon calculators. Environ. Impact Assess. Rev. 28, 106–115. https://doi.org/10.1016/j.eiar.2007.08.001.
Pandey, D., Agrawal, M., Pandey, J., 2011. Carbon footprint: current methods of estimation. Environ. Monit. Assess. 178, 135–160. https://doi.org/10.1007/s10661-010-1678-y.
Pertsova, C., 2007. Ecological Economics Research Trends. Nova Publishers.
Ramus, C., Steger, U., 2000. The roles of supervisory support behaviors and environmental policy in employee "Ecoinitiatives" at leading-edge European companies. Acad. Manag. J. 43 (4), 605–626. https://doi.org/10.2307/1556357.
Saarenpää, K., 2015. Stretching the borders: how international business travel affects the work–family balance. Community Work Fam. 21 (1), 1–16. https://doi.org/10.1080/13668803.2016.1170666.
Schaffartzik, A., Sachs, M., Wiedenhofer, D., Eisenmenger, N., 2014. Environmentally extended input-output analysis. Soc. Ecol. Work. Paper 154. Retrieved from: http://folk.ntnu.no/daniemor/pdf/Schaffartzik_IntroToEEMRIO.pdf.
SEI, 2019. Environmental Policy. Travel Emissions. Retrieved from: https://www.sei.org/about-sei/organization/governance/environmental/.
Sharfuddin, S., 2020. The world after COVID-19. Round Table 109 (3), 247–257. https://doi.org/10.1080/00358533.2020.1760498.
Simard, A.J., Broome, J., Drury, M., Haddon, B.D., O'Neil, R., Pasho, D., 2007. Understanding Knowledge Services at Natural Resources Canada. Canadian Forest Service Publications. Retrieved from: https://d1ied5g1xfgpx8.cloudfront.net/pdfs/27338.pdf.
Siu, H., van Breukelen, G., Peters, G.-J., Kok, G., 2013. Proenvironmental travel behavior among office workers: a qualitative study of individual and organizational determinants. Transp. Res. A 56, 11–22. https://doi.org/10.1016/j.tra.2013.09.002.
Stadler, K., Wood, R., Bulavskaya, T., Södersten, C., Simas, M., Schmidt, S., Tukker, A., 2018. EXIOBASE 3: developing a time series of detailed environmentally extended multi-regional input-output tables. J. Ind. Ecol. 22 (3), 502–515. https://doi.org/10.1111/jiec.12715.
Striker, J., Dimberg, L., Liese, B., 2001. Stress and business travel: individual, managerial, and corporate concerns. J. Organ. Excell. 20 (1), 3–10. https://doi.org/10.1002/1520-6734(200024)20:1%3C3::AID-NPR2%3E3.0.CO;2-U.
Suh, S., Huppes, G., 2005. Methods for life cycle inventory of a product. J. Clean. Prod. 13 (7), 687–697. https://doi.org/10.1016/j.jclepro.2003.04.001.
Suh, S., Lenzen, M., Treloar, G.J., Hondo, H., Horwath, A., Huppes, G., Jolliet, O., Klann, U., Krewitt, W., Moriguchi, Y., Munksgaard, J., Norris, G., 2004. System boundary selection in life-cycle inventories using hybrid approaches. Environ. Sci. Technol. 38 (3), 657–664. https://doi.org/10.1021/es0263745.
SWB, 2019. Stadtwerke Bonn, Energiepreise. Retrieved from: https://www.stadtwerke-bonn.de.
The Wall Street Journal, 2020. The Covid Pandemic Could Cut Business Travel by 36%-Permanently. Retrieved from: https://www.wsj.com/articles/the-covid-pandemic-could-cut-business-travel-by-36permanently-11606830490?cx_testId=3&cx_testVariant=cx_2&cx_artPos=4#cxrecs_s.
Tyndall Centre for Climate Change Research, 2015. Tyndall Travel Strategy. Retrieved from: https://tyndall.ac.uk/sites/default/files/tyndall_travel_strategy_2015_v1.pdf.
UCLA, 2019. Air Travel Mitigation Fund. UCLA Sustainability. Retrieved from: https://www.sustain.ucla.edu/airtravelfund/.
UNEP, 2019a. Emissions Gap Report 2019. Retrieved from. http://www.unenvironment.org/emissionsgap.
UNEP, 2019b. Greening the Blue Report 2019. The UN System's Environmental Footprint and Efforts to Reduce it. Retrieved from: https://www.greeningtheblueport2019.org/.
WBCSD, WRI, 2011. Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard. World Business Council for Sustainable Development and World Resource Institute. Retrieved from: https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.

Weidema, B., Thrane, M., Christensen, P., Schmidt, J., Løkke, S., 2008. Carbon footprint: a catalyst for life cycle assessment? J. Ind. Ecol. 12 (1) https://doi.org/10.1111/j.1530-9290.2008.00005.x.
White, D., Gunasekaran, A., Ariguzo, G., 2012. The structural components of a knowledge-based economy. Int. J. Busin. Innov. Res. 7 (4), 504–518. https://doi.org/10.1504/IJBIR.2013.054872.
Wiedmann, T., Minx, J., 2007. A definition of "carbon footprint". Science. 1 (1), 1–11. https://doi.org/10.1088/978-0-750-31040-6s.
Wright, C., Nyberg, D., 2017. An inconvenient truth: how organizations translate climate change into business as usual. Acad. Manag. J. 60 (5), 1633–1661. https://doi.org/10.5465/amj.2015.0718.
Wynes, S., Donner, S., 2018. Addressing Greenhouse Gas Emissions from Business-Related Air Travel at Public Institutions: A Case Study of the University of British Columbia. Department of Geography, University of British Columbia. Retrieved from: https://pics.uvic.ca/sites/default/files/AirTravelWP_FINAL.pdf.
Yale University, 2016. Yale University's Carbon Charge: Preliminary Results from Learning by Doing. Retrieved from: https://carbon.yale.edu/sites/default/files/files/Carbon_Charge_Pilot_Report_20161010.pdf.
YouGov, 2021. YouGov Survey Results. Retrieved from: https://docs.cdn.yougov.com/c9qjhkrrpk/Marketing%20data%20tables%20-%20GSCC.pdf.
Zahra, S., 2021. International entrepreneurship in the post Covid world. J. World Bus. 56 (1), 101143. https://doi.org/10.1016/j.jwb.2020.101143.

Sami El Geneidy holds a Master's degree in Corporate Environmental Management from the University of Jyväskylä. Currently Sami is working at the University of Jyväskylä as a Doctoral Researcher in the School of Resource Wisdom (JYU. Wisdom) and the Jyväskylä School of Business and Economics (JSBE). In his research work, Sami is studying how carbon and biodiversity impact accounting can be integrated to financial accounting, and how to best mitigate and offset impacts in organizations.

Stefan Baumeister, Ph.D. is a post-doctoral researcher at the University of Jyväskylä, School of Business and Economics and works as a teacher, supervisor and instructor in the Corporate Environmental Management Master's Degree program. Stefan's research interest centre around climate change mitigation, sustainable consumption and the transportation sector. His research has appeared in leading journals of his field such as Transport Policy, Journal of Transport Geography, Sustainability Science or Journal of Cleaner Production. Stefan acts also an editorial board member of Wisdom Letters.



Valentino Marini Govigli, Ph.D. works as a researcher at the University of Bologna. Valentino holds a Ph.D. in Forest and Cultural Ecology. Valentino's work lies in the intersection between Environmental Economics, Human Geography, and Rural Sociology applied to the forest and agriculture sectors. He uses both qualitative and quantitative tools in three main fields of research: (i) stakeholder preferences and consumer behavior analysis in natural resource management and agro-forestry production models, (ii) evaluation of cultural and intangible ecosystem services, (iii) social innovation brokerage and multi-actor engagement.

Timokleia Orfanidou is a junior researcher in the Bioeconomy Programme at the European Forest Institute. She is a Ph.D. student at Aalto University and holds an M.Sc. in Civil Engineering (Architectural Engineering) from the Technical University of Denmark as well as a B.Eng. in Civil Engineering from Greece. She works in the fields of resource-efficient and sustainable buildings and products, LCA and SIA, and the forest-based circular bioeconomy. In the recent years, her interest lied in the climate change mitigation potential of wood use in construction, and the LCA of forest products.

Venla Wallius is a junior researcher in the Bioeconomy programme of the European Forest Institute. She holds a M.Sc. degree in Economics and Business Administration (Corporate Environmental Management) and an M.Phil. Degree in Environmental Science and Technology from the University of Jyväskylä, Finland. Currently, she is doing her postgraduate (Ph.D.) studies, focusing on stakeholder perceptions of wood-based products in bioeconomy transition.