Research article

Carbon footprint at institutions of higher education: The case of the University of Oulu

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A R T I C L E   I N F O

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A B S T R A C T

As an answer to the need to reduce greenhouse gas emissions, organizations are increasingly making efforts to account for their carbon footprint. While general guidelines for carbon footprint calculation exist, they usually do not consider special characteristics of organisations such as institutions of higher education. Case studies can act then as learning tools, and comparisons between applied methodologies can be used to develop best practices. However, a lack of case studies published in peerreviewed journals limits access to the calculation results. This work provides a case study for a Northern European institution to extend the pool of available calculation methodologies tested under real-life conditions. The carbon footprint calculation of the University of Oulu utilises a hybrid model, combining approaches of Environmentally Extended Input-Output Analysis and Life-Cycle Assessment. The focus of the work was to consider included scopes and categories of emissions that represent indirect and non-energy-related greenhouse gas emissions, such as commuting or procurement of research and laboratory equipment. In 2019, the institution’s emission inventory sums up to 19,072 t CO2e, with the highest share due to the use of district heat on campus. Another goal of conducting this research was to show the limitations researchers might encounter when analysing caused emissions on an organisational level, and how the calculated carbon footprint can help to identify the best mitigation measures and possibilities for universities to reach carbon neutrality. It was found that the availability of information and missing strategies for data collection are prominent limiting factors. Favourable mitigation measures include the implementation of energy-saving policies and improved policies for procurements.

1. Introduction

Due to climate change concerns, the assessment of emissions and the calculation of a carbon footprint have continuously gained attention, especially as a starting point for reducing one’s impact and eventually achieving carbon neutrality. Currently, there is a large gap between the sequestration ability of natural carbon sinks and the amounts of emissions released globally (European Parliament, 2019). Therefore, the mitigation of greenhouse gas (GHG) emissions is identified as one of the most important actions of climate change mitigation (IPCC, 2014).

The reduction of emissions and reaching carbon neutrality are implemented by various organisations, institutions, countries, and other associations on national and international levels. The European Union, for instance, pledged in the European Green Deal to achieve net-zero emissions by 2050 with deep decarbonisation covering all sectors (European Union, 2019). The plan acts as a pathway for all EU member states, while the countries are also partially adopting their own commitments. For example, Finland is aiming at reaching carbon neutrality already by 2035 (Finnish Government, 2020). Following that goal, a working group of Finnish universities (UNIFI) published several theses for a sustainable future for higher education institutions in Finland, including the recommendation to act as forerunners and realise carbon neutrality in 2030 (UNIFI, 2020).

The UNIFI theses highlight the exceptional role institutions of higher education can take toward carbon neutrality as trailblazers and pioneers. The consensus in the academic world seems to be that institutions of higher education have the responsibility to become forerunners for climate-friendly practices and should aim at sustainable practices on
their premises and in their operations. Reaching carbon neutrality is an integral part of that endeavour (see, for example, Getzinger et al., 2019; Gómez et al., 2016; United Nations, 2012). As places for education and research, universities also have the possibility to achieve progress independently from national laws or mandatory obligations. Adopting new technologies and practices supported by their research and encouraging younger generations in developing a consciousness for sustainability and climate-friendly actions are possible pathways. Universities adopting official commitments towards carbon neutrality would help to spread the message to other organisations or even to governments, showing the willingness to act and fight climate change (Disterheft et al., 2012; Gómez et al., 2016; Udas et al., 2018; UNIFI, 2020).

The carbon footprint as a form of greenhouse gas emission inventory provides the possibility to define a baseline for institutions of higher education aiming for carbon neutrality. However, due to missing specific guidelines that address the characteristics of universities, case studies are an important source when deciding on the methodology to be utilised. The general method for assessing emissions of a higher education institution might be already quite well researched but applied case studies that are openly accessible around the world will help to further develop the methods and increase the transparency of the calculations, a notion that is also stated by other research groups that assessed a university’s carbon footprint (Clabeaux et al., 2020; Yañez et al., 2019).

Furthermore, the discussion of appropriate mitigation measures in the context of the institution’s location and characteristics will provide an additional perspective to the number of already existing case studies.

The objective of this paper is to describe the carbon footprint calculation process at the University of Oulu, Finland. In accordance with the recommendations of UNIFI, the University of Oulu has committed to being carbon neutral by 2030, with the intermediate goal of halving emissions by 2025 from the 2019 level. The carbon footprint of the university was calculated for the base year as a first step on the path towards carbon neutrality, covering a wide spectrum of the university’s activities. The assessment is carried out based on popular calculation methods and includes commonly chosen scopes of emissions. Following the results, the best options for mitigation measures and possibilities to achieve carbon neutrality on campus, as well as the encountered limitations and difficulties are discussed. The question to explore is what a university can learn from creating a greenhouse gas inventory with the purpose of developing an emission reduction pathway.

2. Literature review

2.1. Carbon footprint as a tool for carbon neutrality

Carbon neutrality is the net-zero balance of greenhouse gas emissions for a certain system. The pathway towards this goal consists of first accounting and managing one’s own emissions and secondly counter-measure their impact. To support these goals, it is necessary to rely on an appropriate measurement tool: the carbon footprint, an emissions accounting or inventory record (Pandey et al., 2011). As stated by Wiedmann and Minx (2007), the carbon footprint assesses all greenhouse gas emissions caused by and related to the activities of a system. This includes emissions directly caused by the investigated system, as well as certain indirect emissions depending on the chosen system boundaries (Wiedmann and Minx, 2007). The completeness of measuring the released emissions is a key principle, intending to show the total quantity of emissions - resulting in the carbon footprint being mainly presented in a mass unit (Harangozo and Szigeti, 2017).

In addition to carbon dioxide, other included greenhouse gases are mainly methane, nitrous oxides, and fluorocarbons (HFC and PFC) (IPCC, 2014). To account for that, emission inventories mainly utilise the term ‘CO2 equivalents’ (CO2e). The result of such an assessment will help to identify the major sources of emissions, which can be used as a starting point for planning effective mitigation measures for greenhouse gas emissions (Awanthi and Navaratne, 2018). In addition, it can be used to track the progress of reduction and therefore help to follow up on climate-related goals and action plans (Awanthi and Navaratne, 2018). Both aspects mark the carbon footprint as an important tool on the pathway toward carbon neutrality.

The most widely used guidelines for the calculation of a carbon footprint are the GHG Protocol Standards developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), as well as the Publicly Available Specification (PAS) guidelines published by the British Standards Institution (BSI) and standards mapped out by the International Organisation for Standardisation (ISO) (Gao et al., 2014). On an organisational level, the GHG Protocol Corporate Standard (WRI and WBCSD, 2004) or ISO 14064–1 (ISO, 2018) should especially be noted.

In general, there are two different main approaches for the calculation methods depending on the object of investigation as stated by Gao et al. (2014). For product-based calculations on a smaller scale, the methodologies are primarily based on the process of a Life Cycle Assessment (LCA). When assessing the emissions of an organisation, company, or institution, the guidelines suggest an approach that is more inspired by an Environmentally Extended Input-Output Analysis (EEIOA) (Gao et al., 2014). Independent thereof, the different methodologies might also be applied in relation to the different characteristics of the assessed emissions depending on their origin and cause of release.

For the calculation of the carbon footprint, emissions are usually allocated to scopes and categories. A popular classification is presented by the GHG Protocol Corporate Standard published by WRI and WBCSD (2013). Their guideline proposed the division of the emitted greenhouse gases into three scopes. The first represents the directly caused emissions, for example, due to the onsite burning of fossil fuels, while scopes 2 and 3 include the indirect emissions. The former only accounts for energy-related, indirect emissions, meaning those that were caused during the generation of the energy purchased by the object of investigation. All other indirect, non-energy-related emissions are collected in scope 3, including emissions caused by business travels or handling of waste (WRI and WBCSD, 2004).

Fig. 1 illustrates the defined scopes of emissions following the value chain of a company or organisation as used by the GHG Protocol Corporate Standard.

2.2. Commonly applied methodologies for calculating the carbon footprint of an educational institution

Institutions of higher education are encouraged to adopt goals to reach carbon neutrality in the near future to provide exemplary pathways for potential followers. The carbon footprint can hereby act as an important tool, not only for identifying the largest emitters but also to help raise awareness among staff members and the student body on the different impacts created by everyday-actions on campus. This applies to all activities from research and education to administrative issues. A study by Loyarte-Lopez et al. (2020) found that a regularly conducted assessment of emissions and subsequent communication of the results was responsible for a better understanding of the impacts created by waste and energy consumption, due to the better tangibility of the subject when supported by the calculation of a carbon footprint. This could open possibilities to reform habits and include more environmental-friendly practices in daily working schemes (Loyarte-Lopez et al., 2020).

While there are currently guidelines available for the calculation of the carbon footprint on an organisational level, the standards are not specifically tailored to the needs of higher education institutions. In their study, Robinson et al. (2018) pointed out, that a university differs from a company mainly in regard to its functions and the required infrastructure to satisfy them. A teaching and learning environment requires other resources than a company in the service or industry sector. As an example, the University of Turku (2020) stated that they
had to develop their own concept for calculating the emissions of research equipment. Considering the unique characteristics of universities in comparison to companies, it is necessary to adapt the more generic standards. Several universities have tackled this question in recent years, developing their own methodologies and presenting different approaches.

In addition, there have been various methodology reviews published in scientific journals detailing the approaches used for a carbon footprint assessment at institutions of higher education. Notable is, for example, the research conducted by Robinson et al. (2018), Helmers et al. (2021), as well as Valls-Val and Bovea (2021). However, their work also reveals that the availability of case studies in form of peer-reviewed articles varies between different regions. As pointed out by Helmers et al. (2021), case studies from Northern Europe are hard to come by if the focus is on published journal articles. This betrays the fact that there is a growing awareness at Finnish universities to push for carbon neutrality. The missing of specific guidelines for educational institutions makes it harder to follow a uniform calculation approach that enables the comparison of results between various universities. Using a more coordinated approach could provide more transparency, as well as context to published carbon footprints, which is the reason why this case study aimed to follow prevalent methods of previously published carbon footprint calculations.

### 2.2.1. Scopes of emissions

Popular regulatory frameworks and international guidelines for the calculation of organisational carbon footprints are especially the Greenhouse Gas Protocol Corporate Standard (WRI and WBCSD, 2004) and ISO 14064-1 (ISO, 2018). In general, the GHG Protocol Corporate Standard seems to be the most favoured guideline used as a basis for the calculation at higher institutions of education (HEI) (Kiehle, 2021; Valls-Val and Bovea, 2021). Probably due to the absence of a university-specific, internationally recognised standard, universities tend to also adopt the methodologies of earlier published case studies or define their own rules. Even when citing one of the international standards as the main guideline, the institutions often choose to follow partly individual allocations (Helmers et al., 2021).

With the GHG Protocol Corporate Standard (WRI and WBCSD, 2004) being the mainly applied guideline, the requirements for emissions to be included in scopes 1 and 2 are clearly specified. However, the framework is not as strict for scope 3 and allows the optional adoption of individually chosen indirect, non-energy-related emissions. This results in the fact that universities seem to decide based on their own experiences which emissions to include in their final carbon footprint. Due to the characteristics of a higher education institute, scope 1 can include the consumption of fuel by the university’s car fleet, as well as some emissions caused by the direct combustion of fossil fuels on campus. Scope 2 might consist of the purchased electricity, (district) heat, water consumption, and if applicable the purchased (district) cooling. A widely adopted category for scope 3 are the emissions related to business travel (Valls-Val and Bovea, 2021), even though the extent to which they were calculated varies. Including travelling by plane is a common choice, while other modes of transport or even hotel overnight stays are not considered as often (Kiehle, 2021). The calculation of emissions related to the procurement of materials and equipment needed for research purposes or the general functioning of the university is popular, too. Especially categories such as paper, laboratory chemicals and electronic equipment (Valls-Val and Bovea, 2021), as well as furniture and office supplies (Kiehle, 2021) are taken into account. Emissions related to the handling of waste are another often-calculated category (Valls-Val and Bovea, 2021), followed by the maintenance of properties and facilities, referring to the cleaning of premises and the repair or construction of buildings (Kiehle, 2021).

Furthermore, the commuting of staff members and students is seen to...
have a significant impact on the overall carbon footprint of an HEI and is therefore often included in the calculation process (Valls-Val and Bovea, 2021). However, student commuting is more often neglected compared to the impact of the employees’ commuting (Helmers et al., 2021). Emissions related to the operation of restaurant services on campus are less often considered, but still adopted by a notable number of institutions (Kiehle, 2021; Valls-Val and Bovea, 2021). Especially for the emissions related to commuting or restaurant services on campus, one of the main reasons given for intentionally scouring out certain emission categories is the opinion that those belong to the individual footprints of staff and students. Therefore, it is not considered to be part of the carbon footprint on an organisational level, as seen, for example, at Turku University of Applied Science (Paikkari, 2020) or the University of Leeds (Townsend and Barrett, 2015).

In addition to the more commonly adopted emission sources, there are a few which are only included very rarely. One of those categories refers to the amount of greenhouse gas emissions caused by an institution’s investment portfolio as adopted by the University of Jyväskylä, Finland (El Genedey et al., 2021). Although their calculations show the considerable impact of these specific emissions, current methodology reviews do not mention other universities that consider them for their carbon footprint assessment (see Valls-Val and Bovea (2021), Helmers et al. (2021) or Robinson et al. (2018)).

2.2.2. Approaches and tools for the calculation

One popular method for conducting the calculation of a university’s carbon footprint is a hybrid model based on two different methodologies for assessing environmental impacts: Life-Cycle Assessment (LCA) and Environmentally Extended Input-Output-Analysis (EEIOA). It enables the possibility to combine the most beneficial practices of each approach and fit the calculation model to the characteristics of the university. Several universities already applied this method successfully, for example, the University of Eastern Finland (Eskelinen, 2021), the University of Jyväskylä (El Genedey et al., 2021), the University of Castilla-La Mancha (Gómez et al., 2016), the University of Leeds (Townsend and Barrett, 2015), as well as the De Montfort University (Ozawa-Meida et al., 2013) and the Norwegian University of Science and Technology (Larsen et al., 2013).

The calculation of indirect, energy-related emissions, as well as directly caused emissions, is using the same methodological basis as an LCA. The approach is described as identifying the activity data of a certain action and multiplying it with the appropriate GHG emission factor (EF), a coefficient used to convert activity data to GHG emissions. The method inspired by the EEIOA is mainly utilised in relation to emissions associated with the procurement and acquisition of equipment for research, laboratories, and education. The required information for this type of calculation is provided by financial accounts. This data, meaning the money spent for a specific purchase, is then subsequently multiplied by an emission factor in kilograms of CO₂ per spent unit of money.

In addition to those two main methodologies, especially the analysis of travelling and commuting data is often accompanied by surveys and questionnaires (see, for example, Birla Institute of Technology and Science Pilani (Sangwan et al., 2018), Shikshana Prasarak Mandal’s Sir Parashurambhau College (Kulkarni, 2019), De Montfort University (Ozawa-Meida et al., 2013), University of Jyväskylä (El Genedey et al., 2021) and University of Talca (Yañez et al., 2019). Furthermore, some institutions have seen to conduct their assessment of emissions in the framework of more elaborate models. This is, for example, the case with the harmonised model of the Energy Institute in Croatia (Juric et al., 2019) or the multiregional hybrid model from the Spanish University of Castilla-La Mancha (Gómez et al., 2016).

Combining different methods into a hybrid approach makes it possible to fit the calculation model to the characteristics of the university. The utilisation of an EEIOA-based approach, especially for procurement categories, is seen as beneficial for conducting an annually recurring calculation (Kiehle, 2021). Based on financial data, which is usually available every year, the calculation might be repeated with less effort than when utilising other methods. This could be useful in controlling the progress of an institution according to its goals for the reduction of emissions. In addition, an EEIOA-based methodology was found to be less time-consuming and more detailed (Larsen et al., 2013), as well as better in covering the whole operations on campus compared to an LCA-based assessment (Townsend and Barrett, 2015). On the other hand, following the procedure of a Life-Cycle Assessment allows the utilisation of pure consumption data (Ozawa-Meida et al., 2013), which is for example beneficial for energy-related emissions or in case no expenditure information is available (Kulkarni, 2019). With the LCA method, it might also be easier to follow up on indirect emissions associated with activities that might be overlooked when using only financial accounts (Alvarez et al., 2014).

There seems to be a considerable number of institutions preferring the mixed approach and the identified benefits speak in favour of assessing emissions based on a hybrid model. Following this method, scope 1 and 2 emissions would mainly be calculated based on activity data and appropriate EFs, while especially categories featuring procurement and purchased equipment would rely on financial accounting data and fitting EFs (Kiehle, 2021).

3. Material and methods

3.1. University of Oulu

The University of Oulu is situated in Northern Finland (Fig. 2) and had around 13,500 registered students plus about 3400 staff members in 2019. Two main campuses are situated in the city of Oulu, splitting the eight faculties into two areas; the Medical Faculties are located near the hospital in Kontinkangas, while the other faculties are based on the Linnanmaa campus (see Fig. 3). The University offers study programs on all levels, for example in the fields of technology, education, medicine, and science. Especially research and education in the technological and industrial sectors are major branches of the institution. In addition to the two larger campus areas in Oulu, there are also several smaller research units belonging to the University of Oulu located in different parts of Northern Finland, for instance, a geophysical observatory in Sodankylä or a biological research station in Oulanka National Park. While the institution is receiving funding mostly from public sources, the model can be described as ‘private like’, based on the university not being state-owned. Education is tuition-free for students coming from the European Economic Area.

![File: Fig. 2. Map of Finland’s location in Europe. Oulu is marked by the red pin. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)](image-url)
3.2. Calculation approach

The calculation of the University of Oulu’s carbon footprint followed the hybrid-model approach. Aside from the obligatory scopes 1 and 2 as defined in the Greenhouse Gas Protocol Corporate Standard (WRI and WBCSD, 2004), the following scope 3 categories were chosen to be included in the assessment: business travels with all modes of transportation and overnight stays, commuting of staff and students, restaurant services, procurement of equipment for education, research and laboratories, the handling of waste and the management of the buildings on campus. Data related to the consumption of energy and the upkeeping of the properties were mainly calculated and provided by the university’s property management company. Information needed for the remaining emission categories was gathered by the university’s carbon footprint working group. The carbon footprint will be presented in tonnes of CO$_2$ equivalents, following the global warming potential approach (IPCC, 2014) for all greenhouse gases.

3.2.1. Scope 1: Direct emissions

All emissions ($E_{\text{GHG}}$) allocated to scope 1 were calculated based on an LCA approach, meaning the multiplication of activity data ($AD_i$) and appropriate EFs. The following formula was used for the calculation:

$$E_{\text{GHG}} = AD_i \times EF$$

(1)

Contributing direct emission sources are the vehicles owned by the university, as well as direct fuel combustion on campus.

3.2.1.1. University’s car fleet. In 2019, the university’s car fleet consisted of ten transporter vans, nine diesel-driven cars and four plug-in electric vehicles. Emissions for the car fleet were calculated based on the driven kilometres in a year multiplied by the EF for the specific car type, used fuel, and fabrication year (see Appendix, Table A). Information about the individual cars was obtained from campus service, while the EF was taken from the LIPASTO emissions database (VTT Technical Research Centre of Finland Ltd., 2017), which provides data specifically for Finland.

Transporter vans contributed to the carbon footprint with a total mileage of around 67,480 km in 2019, while diesel cars and plug-in hybrid vehicles accounted for about 83,150 km and 31,200 km, respectively.

3.2.1.2. Direct fuel combustion. The university’s medical campus operates a steam generator on its premises which causes direct emissions. The generator combusted light fuel oil and its impact was assessed by combining the yearly consumption of the fuel in MWh and the appropriate EF (see Table A). The total yearly fuel consumption of the steam generator sums up to 1117 MWh.

3.2.2. Scope 2: Indirect, energy-related emissions

Scope 2 encompasses the indirect emissions ($E_{\text{GHG}}$) caused by the utilisation of district heating, cooling, the usage of water, and the purchased electricity. The main approach used for the calculation is the multiplication of consumption data ($CD_i$) and appropriate EFs (see Table A), which also account for local circumstances. The following equation was used for the calculation:

$$E_{\text{GHG}} = CD_i \times EF$$

(2)

Information for this section of the carbon footprint was mainly acquired from the university’s property management company.

3.2.2.1. Electricity. All agreements the university contracted from electricity providers ensure the usage of electricity entirely generated from renewable energy sources. For that reason, the EF used for the electricity consumption on all premises equals zero, resulting in no emissions being allocated to the University’s carbon footprint. This emission factor is based on the allocation method utilised by the Finnish national electricity transmission grid operator Fingrid Oyj, 2021 and supported by the national statistical institution in Finland (Statistics Finland, 2022). Both services assign an emission factor of 0 t CO$_2$e to renewable energies and electricity generated via nuclear power plants. Only operational emissions, meaning the ones caused during the generation of electricity, are considered and not the full life-cycle emissions of the employed power plants and fuels. The University consumed 23,389 MWh of electricity in 2019.

3.2.2.2. District heating. The main heating source used on campus is district heat. The EF for the district heat supply was defined in consultation with the provider based on the primarily used fuels, which are peat, wood, and non-recyclable waste. Smaller research units belonging to the university but located outside of the city use a variety of different heating sources. The respective consumption of light fuel oil and wood was accounted for with their appropriate EFs (see Table A). Premises with an electric heating system fall under the purchase of electricity generated with renewable energy sources and a resulting EF of zero. Emissions caused by heating were calculated by multiplying the consumption of the heating source in MWh with the respective EF. Total district heating consumption on campus accounted for 34,448 MWh in 2019, while about 777 MWh of light fuel oil and 25 MWh of wood was used at the smaller premises.

3.2.2.3. Water consumption. The carbon footprint of the water consumed on campus premises is based on the supply of clean water and the handling of wastewater. Due to the lack of specific information on the amount of wastewater, the same volume as the consumed clean water was assumed for the calculation. The amount of water in m$^3$ was multiplied with the appropriate EF (see Table A), representing both clean water and wastewater handling, to obtain the caused emissions. The yearly consumption for both types of water is estimated at 53,106 m$^3$, respectively.

3.2.2.4. Cooling. Emissions caused by cooling were assessed based on the used refrigerants on the premises of the two main campus areas. The data was provided by the property management company.
3.2.3. Scope 3: Indirect, non-energy-related emissions

In contrast to the previous scopes, indirect-non-energy-related emissions were not calculated solely based on an LCA approach. A couple of categories were assessed based on financial data, following an EIOA approach.

3.2.3.1. Business travel. Business travelling encompasses travelling in a job-related context by staff members of the University of Oulu. Included modes of transport are trains, airplanes, and rental cars. The emissions \( E_{\text{GHG}} \) were calculated based on booked travelling distances (TD) for each mode of transport, respectively, using the following formula:

\[
E_{\text{GHG}} = \text{TD} \times \text{EF}
\]  

For the usage of rental cars, the travelled distances (316,440 km in 2019) were paired with a generic EF for an average passenger vehicle used in Finland in travelled km per kg of CO\(_2\)e, published in the LIPISTO emission database (VTT Technical Research Centre of Finland Ltd., 2017), as no specific information about the type of rented vehicles was available. Appropriate EFs for the Finnish trains were taken from an analysis of business travels done by the University of Jyväskylä, Finland (Alvarez Franco, 2021). The study specifically accounted for the characteristic of the local train company in Finland, which is mainly utilising electrical trains running on 100% renewable energies (Alvarez Franco, 2021). In total, trains were used for 854,530 km of business travel.

Flights were categorised in relation to their length and allocated to EFs provided by the Y-HILLARI calculation tool developed by the Finnish Environment Institute (SYKE, 2021), where the information was based on specific flight paths undertaken by Finnish airline Finnair in 2019: National short-haul flights are based on the route Helsinki to Oulu, while medium-haul flights refer to the route Helsinki-Paris and long-haul flights are modelled after the flight between Helsinki and Tokyo. Around 19, 592, 670 km of air travel were accumulated by the University’s employees in 2019. Short-haul flights accounted for 30%, while medium- and long-haul flights had each a share of about 35%.

The emissions caused by hotel overnight stays were calculated based on the price of a hotel stay per night. The number of nights \( n_{\text{nights}} \) spent in hotels (1608 nights in 2019), as well as the average fee of 100€ per night \( \text{P}_{\text{nights}} \), was obtained from official reports collected by campus services. A daily EF (kg CO\(_2\)e/€) was assigned to the overall value of invoices and the emissions were calculated with the following formula:

\[
E_{\text{GHG}} = n_{\text{nights}} \times \text{P}_{\text{nights}} \times \text{EF}
\]  

All EFs used for assessing the emissions caused by business travel are listed in Table A (Appendix).

3.2.3.2. Property maintenance. Building-related emissions include non-energy-related emissions allocated to maintenance repairs, construction and cleaning activities happening on the campus premises. The carbon footprint of constructions and repairs was directly reported by the property manager, while the impact of the cleaning service was calculated based on procurement costs of utilised cleaning supplies \( C_{\text{CS}} \) – around 158,236 € in 2019 and an EF in kg CO\(_2\)e/€ using the following equation:

\[
E_{\text{GHG}} = C_{\text{CS}} \times \text{EF}
\]  

3.2.3.3. General procurements. The category of general procurements includes an unspecified assortment of purchased laboratory equipment, furniture, educational materials, and office supplies, as well as large-scale research equipment. Due to a lack of available information, the calculation of emissions related to the purchase of said equipment was solely based on financial accounts provided by the university’s financial service and follows an EIOA approach. Procurement costs \( C_{\text{p}} \) were combined with a general EF in kg CO\(_2\)e/€ for procurements based on estimations utilised by other Finnish universities in their carbon footprint calculation (Table A, see for example Eskelinen, 2021; Tolvanen, 2021). The equation is displayed in the following:

\[
E_{\text{GHG}} = C_{\text{p}} \times \text{EF}
\]  

The procurements are divided into two main categories depending on their total investment costs. Equipment with investment costs of more than 5000 € was subject to depreciation. This mainly concerns large-scale research equipment and leads to the allocation of the initial investment costs over 5 years. Therefore, not all costs of equipment bought in 2019 were accounted for in the carbon footprint of that year, but depreciation sums from the previous years (2015–2018) were added as well. The total investment sums spent by the University in different procurement categories are listed in Table 1.

3.2.3.4. IT-equipment. The assessment of emissions related to laptops and mobile phones was carried out based on the number of purchased items \( n_{\text{IT}} \) in 2019, their expected service life \( a \), and annual cradle-to-grave life-cycle emission factors \( \text{EF}_{\text{LC}} \) per item retrieved from manufacturers of the typically purchased products at the University. Those EFs were divided by the potential usage time of an item and then applied as an annual factor (see Table A). IT equipment bought during the previous two years was added as well to the carbon footprint of 2019 based on the expected service life of 3 years. In 2019, 605 laptops and 59 mobile phones were acquired by the University.

\[
E_{\text{GHG}} = n_{\text{IT}} \times \frac{\text{EF}_{\text{LC}}}{a}
\]  

3.2.3.5. Printing paper and printed books. Paper provided by the printing service on campus was accounted for based on the total weight of the utilised sheets of paper \( n_{\text{p}} \) and a cradle-to-grave EF for printing paper in kg CO\(_2\)e/kg of paper (Table A), therefore following an LCA approach. In 2019, 21,803 kg of paper was consumed at the University of Oulu.

\[
E_{\text{GHG}} = n_{\text{p}} \times \text{EF}
\]  

Printed books and other printed publications, for example, acquired by the university library were added to the carbon footprint based on the total investment sum \( C_{\text{b}} \) in a specific EF for book purchases developed by the University of Eastern Finland (Eskelinen, 2021):

\[
E_{\text{GHG}} = C_{\text{b}} \times \text{EF}
\]

### Table 1

Costs of the University of Oulu’s procurements per category in 2019.

<table>
<thead>
<tr>
<th>Procurement category</th>
<th>Total costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research &amp; Laboratory equipment</td>
<td>Under 5000 € procurement cost per item: 3,059,350 €</td>
</tr>
<tr>
<td></td>
<td>Over 5000 € procurement cost per item (including depreciations from 2015 to 2018): 5,737,458 €</td>
</tr>
<tr>
<td>Office supplies &amp; educational materials</td>
<td>842,089 €</td>
</tr>
<tr>
<td>Book material</td>
<td>428,122 €</td>
</tr>
<tr>
<td>Other procurements</td>
<td>1,682,886 €</td>
</tr>
</tbody>
</table>
3.2.3.6. Waste management. Emissions allocated to waste management encompass the GHG emissions caused by the transport and treatment of the waste. Considered waste fractions include biowaste, paperboard, scrap metal, glass, paper, and batteries, as well as mixed waste, wood, e-waste and hazardous waste. The treatment emissions were calculated based on the produced waste in tonnes per year (m) and a treatment emissions factor in kg CO$_2$/tonne (EF$_{TM}$), respectively. The impact of transportation was assessed following the number of waste collections (n$_{t}$), the amount of waste in tonnes (m), the transport distance in km (d) and the transportation EF in kg CO$_2$/km (EF$_{TP}$). Apart from carton and paper waste, the following equation is used:

$$E_{GHG} = m \times EF_{TM} + m \times d \times n_{t} \times EF_{TP}$$  \hspace{1cm} (10)

Due to the different data available for paperboard and paper waste, the transport-related emissions were based on an EF per tonne of waste (EF$_{CP}$):

$$E_{GHG} = m \times EF_{TM} + m \times EF_{CP}$$  \hspace{1cm} (11)

EFs published by the calculation tool Y-HILLARI (SYKE, 2021) were used for the calculation (see Table A). A total amount of 789 t of waste was produced on campus in 2019; Table 2 presents the obtained data in more detail.

3.2.3.7. Restaurant services. The carbon footprint of restaurant services only refers to the impact of the food sold on campus, while energy consumption necessary for the restaurants’ operations is part of scope 2. The required information was directly obtained from the restaurant operators. Depending on the type of available data, the calculation follows two different approaches. The first method relied on the number of sold meals (n$_{M}$), the number of sold cups of coffee (n$_{C}$) and EFs for different types of food (EF$_{M}$, meal with or without meat) published by the University of Helsinki’s calculation tool Hiilifiksu (University of Helsinki, 2019) and an EF for a cup of coffee (EF$_{C}$):

$$E_{GHG} = n_{M} \times EF_{M} + n_{C} \times EF_{C}$$  \hspace{1cm} (12)

The second approach utilised the amounts of raw materials ordered in kg (m$_{RM}$), which were subsequently multiplied by EFs for each food category (EF$_{RM}$, see Table A):

$$E_{GHG} = m_{RM} \times EF_{RM}$$  \hspace{1cm} (13)

3.2.3.8. Commuting. The commuting of staff and students was analysed with the help of a survey, where people were asked to state their primary mode of transportation, their main workplace, as well as their one-way commuting distance and the usual number of days they commute to the campus. The questionnaire was made available to all employees and students at the University, meaning it was sent via mailing lists and published under the internal network’s news sections. The service used for creating the survey was the online tool ‘Webropol’. The questions included in the questionnaire can be seen in the supplementary material.

To allow an uncomplicated answering and a straightforward analysis of the acquired data, most of the questions were multiple-choice. The main categories of interest were passenger vehicles, public transportation (bus and train) and non-fuel transportation (on foot, bicycle, and E-bikes). To be able to identify the most suitable EF for passenger vehicles, the survey also asked about the vehicle’s year of manufacturing and the fuel used. The survey questions can be found in the supplementary material. The questionnaire aimed at mapping commuting habits under normal or pre-pandemic circumstances when no remote work recommendation was in place.

However, a calculation solely based on surveys among the employees and students at the university may result in uncertainties due to low response rates or questionable truthfulness of respondents (Clabeaux et al., 2020; Helmers et al., 2021). To address these issues, the questionnaire used for the calculation was only one part of the approach. In addition, anonymised postal codes of home addresses of all registered students and employees were provided by campus services and sorted into categories according to the approximated one-way commuting distance between the postal area and the campus locations (e.g., 1–5 km, 6–10 km). The shares of different transportation modes for each commuting distance, as gathered from the survey, were then extrapolated to the whole community following the postal code data. This approach aimed to compensate for a low, but still representative feedback rate for the questionnaire of around 10% of all students and staff members. Similar answering rates have been observed, for example, by Yañez et al. (2019). The daily commuting distances were multiplied with EFs for each mode of transportation in g CO$_2$/passenger-km (taken from VTT Lipasto (VTT Technical Research Centre of Finland Ltd., 2017)) and combined with the average number of working days per year on campus. The following equations were used for the calculation:

$$E_{D-M} = d_{a} \times EF_{M} \times t \times n_{D-M}$$  \hspace{1cm} (14)

$$E_{D} = \sum_{M} E_{D-M}$$  \hspace{1cm} (15)

$$E_{G-H} = \frac{E_{D}}{n_{D}}$$  \hspace{1cm} (16)

$$E_{G-H} = n_{U} \times \sum_{O} E_{D}$$  \hspace{1cm} (17)

with EF$_{D-M}$ Emissions per distance and transportation mode. D$_{a}$ Daily commuting distance. EF$_{M}$ Emission factor for specific transportation mode. T Commuting days per year. n$_{D-M}$ Number of survey participants per distance and transportation mode. E$_{O}$ Emissions per distance category. E$_{O}$ Average emissions per person per distance category. n$_{D}$ Number of survey participants per distance category. n$_{U}$ Number of total staff and students with specific commuting distance. E$_{G-H}$ Total commuting emissions.

4. Results

4.1. Commuting survey

The survey was conducted in the autumn of 2021 at the University of Oulu and targeted all staff members and students. The main questions revolved around commuting habits under normal/pre-pandemic circumstances. Around 10% of the university’s community answered the questionnaire.

It was revealed that a large majority of people working or studying on one of the two main campuses live not further than 5 km away from their work or study place. The shares of the different distance groups are shown in Fig. 4. Especially for shorter distances, the bicycle seems to be

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### Table 2: Types and amounts of waste produced at the University of Oulu in 2019.

<table>
<thead>
<tr>
<th>Type of waste</th>
<th>Amount of waste in tonnes</th>
<th>Transport distance in km/ year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biowaste</td>
<td>164.3</td>
<td>82,154</td>
</tr>
<tr>
<td>Iron scrap</td>
<td>13.6</td>
<td>66</td>
</tr>
<tr>
<td>Mixed waste</td>
<td>402.4</td>
<td>113,484</td>
</tr>
<tr>
<td>Wood waste</td>
<td>42.6</td>
<td>213</td>
</tr>
<tr>
<td>Electronic waste</td>
<td>4.7</td>
<td>24</td>
</tr>
<tr>
<td>Batteries</td>
<td>0.3</td>
<td>48</td>
</tr>
<tr>
<td>Hazardous waste</td>
<td>20.7</td>
<td>11,777</td>
</tr>
<tr>
<td>Glass</td>
<td>12</td>
<td>6967</td>
</tr>
<tr>
<td>Paper</td>
<td>49.9</td>
<td>–</td>
</tr>
<tr>
<td>Carton &amp; Cardboard</td>
<td>78.6</td>
<td>–</td>
</tr>
</tbody>
</table>
the preferably chosen mode of transportation (around 47%). However, cars running on fossil fuels are still prominently used as soon as the commuting distance is getting longer, with around a quarter relying on their own passenger vehicles. The most used fuel is gasoline, followed by diesel, but also around 12% of all car users are driving electric or plug-in hybrid vehicles (see Fig. 5). The age of the used vehicles differs considerably between the occupation of the survey participants: Employees usually drive cars manufactured after 2014 (EURO 6 emission standard), while students tend to use older cars which are on average over 10 years old and respond to EURO emission standards 3 to 4. Public transportation, mainly buses, is only used by approximately 14% of the survey’s participants, and mainly by students, while commuting on foot is considered a valid option by 13%, depending on the distance. Separated results for employees and students are shown in Table 3.

The obtained answers show that, in 2019, the average commuting days per week amounted to 3.6 days for students and 4.1 days for staff members. Considering the general number of work weeks per year based on holidays and semesters (employees: 48 weeks, students: 31 weeks), the average number of working days per year spent on campus was determined as 196 for staff members and 111 for students.

4.2. Carbon footprint of the University of Oulu

The total amount of emissions associated with the University of Oulu sums up to 19,072 t CO$_2$e for the year 2019. For better comparability with other universities, the carbon footprint can also be presented as 1.129 t CO$_2$e/person regarding the number of students and staff members (16,900), as well as 0.124 t CO$_2$e/m$^2$ considering the area in use by the University (153,413 m$^2$). Fig. 6 shows the visualisation of the carbon footprint and Table 2 displays the results in greater detail.

The emissions related to the purchase of district heating have currently the highest impact, as they account for around 40% of the total carbon footprint. Those emissions are followed, with a large difference, by the impact of procurements with a share of around one-fifth. Business travel and restaurant services sum up to shares of around 9% and 13%, respectively. Commuting of staff and students has a lower share compared to business travelling, but with around 8% it is still significant. Construction and maintenance of properties account for about 5%. The remaining categories are in comparison much smaller and seem to make up almost negligible fractions. Most of the total amount of emissions is caused by activities related to the two main campus areas. Greenhouse gases emitted by smaller units have a very low impact overall.

5. Discussion

5.1. Included scopes of emissions

The definition of appropriate scopes of emissions and, therefore, also the definition of system boundaries is challenging. By deciding what kind of operations are on campus and which emissions should be included or scoped out in the assessment, the ones conducting the calculation have a high influence on the outcome and are required to proceed with circumspection. As the widely adopted guidelines already require the calculation of all scope 1 and 2 greenhouse gas emissions and provide a concise explanation of what they entail, difficulties are primarily found in the third scope. Universities usually seem to define for themselves which emission sources are relevant or not.

<table>
<thead>
<tr>
<th>Commuting</th>
<th>Mode of transportation</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>University’s employees</td>
<td>Passenger vehicle</td>
<td>33.4</td>
</tr>
<tr>
<td></td>
<td>Public transport</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>Non-fuel transportation</td>
<td>57.5</td>
</tr>
<tr>
<td></td>
<td>Biking</td>
<td>49.5</td>
</tr>
<tr>
<td></td>
<td>Walking</td>
<td>8.0</td>
</tr>
<tr>
<td>Students</td>
<td>Passenger vehicle</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Public transport</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Non-fuel transportation</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>Biking</td>
<td>45.5</td>
</tr>
<tr>
<td></td>
<td>Walking</td>
<td>18.5</td>
</tr>
</tbody>
</table>
Although some case studies specifically exclude emissions related to commuting (Townsend and Barrett, 2015; Udas et al., 2018) and restaurant services (Paikkari, 2020; Suominen, 2020), these categories are seen by the authors of this article as important parts of the carbon footprint of an institution of higher education. It is found that the characteristic of a university does not warrant the decision to allocate those emissions to the individual footprints of staff and students. For companies and other industrial organisations with the sole focus on production or providing specific services, the employees might not be the most relevant issue when assessing emissions. Therefore, individual actions, like the choice of transportation for commuting or the consumed food, could be excluded. However, a university is made up of people - research and education are the primary purposes of such an institution, resulting in a focus on students and employees. To exclude emissions perceived as individual choices would not acknowledge this context.

Furthermore, while for instance the mode of transportation is decided by the student or the staff member, the university can influence those decisions by providing appropriate infrastructure or motivation by supporting, for example, the utilisation of public transport or bicycles. In addition, employees, as well as students, can often be required to either work from campus or attend obligatory events. Thus, commuting is a direct consequence of their occupation at the university and the related emissions should be allocated to the institution. Recent methodology reviews also indicate that emissions due to commuting can have a major impact depending on the structure and location of the institution (Valls-Val and Bovea, 2021; Yanez et al., 2019) and excluding them would lead to an underestimation of emitted greenhouse gases.

In terms of the restaurant services, it was considered that it is an offer provided by the university and the individual choices are influenced by what exactly is offered. This means that the university has an impact on the emissions caused by the individuals. For that reason, food-related emissions are recommended to be included as well. It can be argued that restaurants on campus are often operated by individual companies and therefore not under the direct influence of the institution (Helmers et al., 2021). However, just like the HEI could influence local district heat providers or choose the electricity provider, new restaurant policies could also create positive impacts on the offered restaurant services and push for more sustainable practices. However, it is certainly one of the mitigation measures that require close collaboration between a university and these service providers.

In addition, it should be encouraged to also consider categories that are not defined as the most relevant ones and, if possible, to conduct at least an internal calculation for those emissions. Considering the overall goal of reaching carbon neutrality with the help of the calculated carbon footprint, it is beneficial to be aware of as much detail as possible when it comes to the impacts caused on campus. While they might not be part of an officially published greenhouse gas emissions inventory, following up on additional emission categories can further deepen the assessment.

In that context, allocating the emissions to each of the university’s departments or faculties separately might allow a further localisation of released emissions and could therefore help when defining appropriate mitigation measures or new guidelines for common procedures at the university, supporting the shift to a carbon-neutral campus. Examples of this approach can be found at the NTNU, Norway (Larsen et al., 2013) and the University of Leeds, UK (Townsend and Barrett, 2015).

5.2. Excluded emissions

The University of Oulu is purchasing renewable electricity, which was assigned the emission factor of 0 t CO$_2$e in consensus with data from the transmission network operator and the national statistics service (Fingrid Oyj, 2021; Statistics Finland, 2022). The assumption is, that there are no operational emissions caused by hydropower, wind and solar power. Full life-cycle emissions are not taken into consideration, because that would go beyond the boundary set for the University’s carbon footprint. EFs reported by the official Finnish sources concerning electricity consumption also focus on operational emissions.

However, although those purchase agreements exist, the University is being supplied via the national grid and therefore receives the national mixture. In that regard, the average emission factor for the consumed electricity in 2019 corresponds to 101 g CO$_2$e/kWh due to the

Fig. 6. The carbon footprint of the University of Oulu in 2019.
usage of fossil fuels for national energy production, as well as the impact of imported electricity.

In this work, we follow the approach of an EF of 0 t CO₂e for the consumed renewable electricity to reach a consensus with other Finnish universities for calculating the institutional CF. The University of Eastern Finland (Eskelinen, 2021), the University of Jyväskylä (El Geneidy et al., 2021) and the Tampere Universities (Tolvanen, 2021) all applied this method.

Additionally, the purchase of 100% renewable electricity by major customers like university properties also sends a strong signal to the network operators and electricity providers to increase the share of renewable energies, especially if it comes from a major customer and therefore justifies the usage of the EF based on the purchased type of electricity.

5.3. Standardisation of the calculation approach

The assessment process for the University of Oulu’s CF provided first-hand experience on the various scopes and categories of emissions that can be included or omitted from the calculation. When matching the results of this work to the ones from other Finnish Universities, massive differences can be found, making a comparison in the current situation difficult.

The University of Jyväskylä reported a CF of 40,873 t CO₂e in 2019 (El Geneidy et al., 2021), which is effectively twice as much as the result for the University of Oulu. The main reason seems to be that there is no calculation of the impact of investments was included, which was not done in this work. On the other hand, there is the Lappeenranta–Lahti University of Technology (LUT) with a reported CF of 2054 t CO₂e in 2019 (Nurkka et al., 2020). While there are also differences in size and number of students, LUT University decided to exclude emissions allocated to district heating because the property owner has control over the purchase and is already offsetting the emissions.

These examples show that different institutions have come up with different, individual methods. If there would be a common approach and a standardised guideline, the CFs would be more comparable. Common guidelines would reduce the necessary preparation before the calculation and potentially enable the comparison between the results of different universities. To support the idea of a standardised approach amongst HEIs, the following methods and scopes are being suggested, based on the study’s experience:

Scope 1 and 2 emissions should be calculated following the available standardised methods, for example, the GHG Protocol Corporate Standard (WRI and WBCSD, 2004). Activity or consumption data is multiplied with the appropriate EF. Categories that should be assessed as part of scope 3 are business travel, emissions related to property and waste management, restaurant services, procurements of research equipment and office supplies, IT equipment, as well as commuting.

For the latter, it was found that more accurate results might be obtained when combining a survey conducted amongst the university’s community with data retrieved from the campus services as described in the results section. Regarding restaurant services, an assessment based on raw order data divided into different food categories is seen to shield more reliable results and should be the preferred method. Using a monetised approach as, for example, EEIOA when calculating the emissions of procurements could be used if more specific data is not obtainable. Otherwise, it seems advisable to refer to the actual consumption of a certain product and an appropriate EF, as was done in this study for printing paper and IT equipment.

5.4. Limitations

On a general level, the availability of data is the most prominent limitation experienced during the calculation process. This includes for example missing or incomplete information or faulty and outdated EFs (see for example Kulkarni (2019), Sangwan et al. (2018) and Gómez et al. (2016). Travelling and commuting are the emission categories that are often named as being subject to complications during the acquisition of reliable data sources (see for example Ozawa-Meida et al. (2013)). Similar limitations were observed while calculating the carbon footprint of the University of Oulu.

The presented calculation is the first time an emissions inventory has been created for the University of Oulu, meaning that every assessment process had to be done from the scratch and was developed along the way. This is true in particular for the collection of relevant data. Missing structures for the gathering of information considerably slowed down the process and should be eliminated for future assessments. Especially the detail in which information is collected by campus services or other service providers needs to be developed further. An example of that can be found in the approach for categories such as the procurements of research and laboratory equipment. More specialised EFs could lead to more accurate results, which at the same time would require the acquisition of further specialised financial data revealing also specific categories of procured items.

The experience acquired during the assessment of this case study suggests, that the development and improvement of strategies for collecting data should be considered a special point of focus. This also includes the selection of appropriate accompanying factors and variables used in the calculations. With more consistent procedures, it could be possible to achieve the reduction of potential errors and decrease the amount of unavailable or incomplete data, leading to a more accurate carbon footprint. In addition, developing reliable structures for the collection of data might prove beneficial, especially for institutions with future commitments towards carbon neutrality or mitigation measures, as following up on those goals requires a regular update of the emissions inventory. Future calculations could be considerably sped up when existing structures from previous calculation rounds can be utilised.

5.5. Mitigation Measures

The calculation of the carbon footprint provides an appropriate starting point for an HEI to start considering the reduction of environmental impacts and increase the sustainability of its operations. A declaration of emission reduction was seen to closely correlate with the plan to conduct annual carbon footprint calculations after the initial process. This is for example the case with many Finnish institutions, where the calculation effort is often coordinated by an official working group and embedded in the universities’ sustainability policies (see for example University of Eastern Finland (Eskelinen, 2021) and University of Jyväskylä (El Geneidy et al., 2021). Based on that, it would be appropriate for the University of Oulu as well, to clearly state its intentions toward carbon neutrality and what kind of mitigation measures will be implemented.

Commonly applied measures include for example energy-saving policies (Eskelinen, 2021; Larsen et al., 2013) and refurbishment of older buildings (Opel et al., 2017) to reduce the amounts of energy-related emissions. Other actions concentrate on improving travelling guidelines (El Geneidy et al., 2021; Ozawa-Meida et al., 2013), promoting for instance alternatives for short distances compared to airplanes or the increased use of virtual meetings (Sangwan et al., 2018). In addition, the carbon footprint calculation is utilised to pinpoint the most CO₂-intensive processes on campus to provide a guide for potential reduction measures (Alvarez et al., 2014; Townsend and Barrett, 2015).

As stated before, the largest source of emissions in this case study is the district heating required for the buildings on the two main campus areas. Energy-related emissions have therefore a considerable impact on the institution’s carbon footprint. While all electricity contracts of the university guarantee the usage of 100% renewable energy sources, this is not the case for heating. In general, the high consumption of district heat on the campuses in Oulu is mainly owned to the fact that the geographical location of the university results in a heating season of over
half a year. In terms of heating degree days, studies show that the northern part of Europe usually has about twice as many as regions of Western and Southern Europe (Spinoni et al., 2018), explaining the different impact compared to case studies of other countries. Unfortunately, it is not possible to switch to another district heating network in the same area, as there is only one network in the city. The high EF of DH in turn is due to heat currently still being used as fuel. The local provider is currently starting a decarbonisation process for its operations, but the process will take several years. In addition, the university is only renting the premises and cannot easily influence the decision of the property provider if a willingness to buy less polluting district heat is signalled. Similar observations were made by Clabeaux et al. (2020) considering the choice of an electricity provider and should also be possible for a different source of energy. If only district heat produced by renewable energy sources could be purchased, the institution’s carbon footprint could be reduced by over 7700 t CO₂e, lowering the share of Scope 2 emissions to near insignificance.

Other mitigation measures that could be introduced at the University of Oulu are, for example, incentives for more environmentally friendly commuting practices or updated travelling guidelines to reduce the impact of flights or rental cars. The feasibility of remote working or online conferences has been thoroughly tested during the ongoing pandemic and can be seen as one option for reducing greenhouse gas emissions of transportation.

Furthermore, new procurement policies should be introduced at the university, favouring more energy-efficient or sustainable products within the bounds of economic feasibility. And although electricity derived from renewable energy sources is defined as carbon neutral, energy efficiency and savings should not be neglected in the future, as the carbon footprint is not the only sustainability indicator a higher education institution should be aware of. In terms of renewable electricity, the University of Oulu might also continue the roll-out of solar PV systems on the rooftops of the main campus areas to support the overall energy transition.

5.7. Carbon-neutral universities

While the importance of HEIs reaching for carbon neutrality is nowadays widely recognised, it is also necessary to assess more closely by what means a university should reach this target. Offsetting, compensation measures or simply purchasing renewable energy are easy and fast to apply measures but would not lead to sustainable carbon neutrality in the long term. Future work should address more what kind of reduction methods are used and how the HEI is presenting sustainability goals. What exactly is the role a university must play besides educating the next generation and acting as role models for society? How far does the responsibility of universities go in terms of environmentally friendly practices, for example, along the supply chain of goods used or services offered on campus and how the research is conducted?

The latter question will also become increasingly important regarding a current shift to multi-place working arrangements opening possibilities to work from home. This means that, while students and employees are part of the university’s community, they would not necessarily visit the campus area. So far, this would exclude any emissions caused by them from the calculation process of the HEI’s carbon footprint. This could lead to a mere shifting of emissions instead of a real reduction and increase the amount of greenhouse gases not covered by potential mitigation targets.

In addition, it could be considered how the positive impact of a university’s research can be accounted for when analysing environmental and sustainability goals. Would it be legitimate to use approaches such as the carbon handprint to quantify potential emission reductions supported by research and education? In the same vein, it could be argued that an HEI should focus on developing methods for decreasing the carbon footprint of other entities, such as industrial companies, even under the risk that such research activities prevent the institution from reaching carbon neutrality themselves. Additional sustainability indicators apart from the carbon footprint could help to answer these questions.

6. Conclusions

The carbon footprint of the University of Oulu was calculated using a hybrid approach combining aspects of LCA and EEIOA. The results for 2019 amount to 19,072 t CO₂e. The highest share of this is purchased district heat, which accounts for around 40% of the total carbon footprint – a result that is not common in other published case studies. This outcome highlights the importance of considering the local characteristics of the HEI when recommending mitigation measures. Furthermore, discovered uncertainties or unavailability of data supports the necessity to not only develop a calculation method and discuss the scopes of emissions but also to focus on the acquisition of appropriate data and introduce strategies for a better, easily repeated collection of information.

More collaboration and transparency are desirable for future calculation processes conducted by educational organisations, as it will open possibilities for comparison between institutions or even collaborations for reducing greenhouse gases and reaching carbon neutrality. Comparability is especially useful considering all the scopes of emissions that may or may not be included in an emissions inventory. Depending on the chosen categories, the results of educational organisations can vary greatly. It is important that the high impact of indirect, non-energy-related emissions on the carbon footprint is recognised and mandatory inclusion of the main categories of this scope needs to be supported. In contrast to other types of organisations, such as industrial companies, the students and researchers of a university are not employees in a traditional sense. They are contributing members of the university’s community and the cornerstone of the institution’s work. Hence, emissions caused by individual decisions related to the university’s activities should be considered as part of the organisation’s carbon footprint. Even if that is not the common practice of other emission inventories on an
organisational level. However, while a common guideline is useful, the main motivation of CF calculation is to set and monitor one’s own carbon neutrality goals rather than a comparison with other institutions.

Furthermore, deeper analyses, for example, examining the carbon footprint by considering the impact of individual units on campus, might be one aspect to be considered for future work. This will also help to identify the most appropriate mitigation measures. In addition to that, even scopes of emissions previously identified as not having priority might yield helpful information when calculated and should not be neglected. Moreover, the positive impact of research and education, for example, in form of a carbon handprint, is another aspect that could add depth to the research on the emissions associated with a university. Finally, it is necessary to note that the calculation of a carbon footprint will always remain a process. For one, even if a category of emissions is added to the results, a deeper analysis of those emissions will certainly be possible and other categories might be added later as well. On the other hand, the final carbon footprint is only the start of the next step by providing the basis for the mitigation of emissions and the raising of awareness among the university’s community.

One purpose of this case study was to support the discussion of the necessity of adapting current official guidelines and potentially creating a common framework for educational organisations that reflect the special needs of those institutions. This work also provides a case study from a Northern European country to widen the availability of applied carbon footprint methodologies. Finally, this work contributes to the ongoing discussion about universities seeking to achieve carbon neutrality. Further research will focus on concrete suggestions for reducing emissions in individual categories and draw a pathway to carbon neutrality based on the results of the carbon footprint calculation.

Credit author statement

Julia Kiehle: Conceptualisation, Data curation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review & editing. Maria Kopsakangas-Savolainen: Conceptualisation, Methodology, Supervision, Writing – review & editing. Meeri Hilli: Conceptualisation, Data curation, Formal analysis, Investigation, Writing – review. Eva Pongrácz: Conceptualisation, Methodology, Project administration, Supervision, Writing – review & editing

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.

Data availability

No data was used for the research described in the article.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2022.117056.

Appendix

Emission factors used in the calculation of the University of Oulu’s carbon footprint.

<table>
<thead>
<tr>
<th>Table A</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission factors used in the carbon footprint calculation of the University of Oulu.</td>
<td></td>
</tr>
<tr>
<td><strong>Emission scope/category</strong></td>
<td><strong>Unit</strong></td>
</tr>
<tr>
<td>Scope 1</td>
<td></td>
</tr>
<tr>
<td>Transporter van&lt;sup&gt;a&lt;/sup&gt;</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/km</td>
</tr>
<tr>
<td>Diesel car&lt;sup&gt;b&lt;/sup&gt;</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/km</td>
</tr>
<tr>
<td>Plug-in hybrid vehicle&lt;sup&gt;c&lt;/sup&gt;</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/km</td>
</tr>
<tr>
<td>Light fuel oil&lt;sup&gt;d&lt;/sup&gt;</td>
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</tr>
<tr>
<td>Scope 2</td>
<td></td>
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<td>District heating&lt;sup&gt;e&lt;/sup&gt;</td>
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<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/MWh</td>
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<td>Scope 3</td>
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</tr>
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<td>Waste&lt;sup&gt;c&lt;/sup&gt;</td>
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</tr>
<tr>
<td>Biowaste</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/t waste</td>
</tr>
<tr>
<td>paperboard</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/t waste</td>
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<tr>
<td>Scrap metal</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/t waste</td>
</tr>
<tr>
<td>Glass</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/t waste</td>
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<tr>
<td>Paper</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/t waste</td>
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<tr>
<td>Mixed waste</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/t waste</td>
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<tr>
<td>Wood waste</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/t waste</td>
</tr>
<tr>
<td>E-waste</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/t waste</td>
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<tr>
<td>Batteries</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/t waste</td>
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<tr>
<td>Hazardous waste</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/t waste</td>
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<tr>
<td>Transportation 1</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/tonne-km</td>
</tr>
<tr>
<td>Transportation 2</td>
<td>kg CO&lt;sub&gt;2&lt;/sub&gt;e/t waste</td>
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<td>Business travel</td>
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(continued on next page)
Table A (continued)

<table>
<thead>
<tr>
<th>Emission scope/category</th>
<th>Unit</th>
<th>Emission factor</th>
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<tbody>
<tr>
<td>Train</td>
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<td>Rental Car</td>
<td>kg CO₂/km</td>
<td>0.152</td>
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<td>Domestic flight</td>
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<td>Medium-haul flight</td>
<td>kg CO₂/km</td>
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<td>Hotel overnight stay</td>
<td>kg CO₂/spend € per day</td>
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<td>IT-Equipment</td>
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<tr>
<td>Laptop</td>
<td>kg CO₂/item</td>
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<td>Mobile phone</td>
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<td>General procurement b</td>
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<tr>
<td>Cleaning supplies</td>
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<td>Printing paper</td>
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<td>Printed books</td>
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<tr>
<td>Restaurant services</td>
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<tr>
<td>Meal including meat a</td>
<td>kg CO₂/meal</td>
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</tr>
<tr>
<td>Meal without meat</td>
<td>kg CO₂/meal</td>
<td>0.903</td>
</tr>
<tr>
<td>Coffee</td>
<td>kg CO₂/cup</td>
<td>0.019</td>
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<tr>
<td>Fruits &amp; Vegetables b</td>
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<td>1.22</td>
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<tr>
<td>Dairy products</td>
<td>kg CO₂/kg product</td>
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<tr>
<td>Eggs &amp; Egg products</td>
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<tr>
<td>Fish</td>
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</tr>
<tr>
<td>Meat</td>
<td>kg CO₂/kg product</td>
<td>15.32</td>
</tr>
</tbody>
</table>

a (VTT Technical Research Centre of Finland Ltd., 2017).
b (SYKE, 2021; Tilastokeskus, 2021).
c (SYK, 2019).
d Helsingin seudun ympäristöpalvelut (HSY).
e (SYKE, 2021).
f (Alvarez Franco, 2021).
g (Seppälä et al., 2009).
h (Eskelinen, 2021; Larsen et al., 2013; Tolvanen, 2021).
i (University of Helsinki, 2019).
j (Pihkola et al., 2010).
k (Eskelinen, 2021).
l (University of Helsinki, 2019).
m (Suominen, 2020).
n (Latva-Hakuni, 2020).

References
J. Kiehle et al.