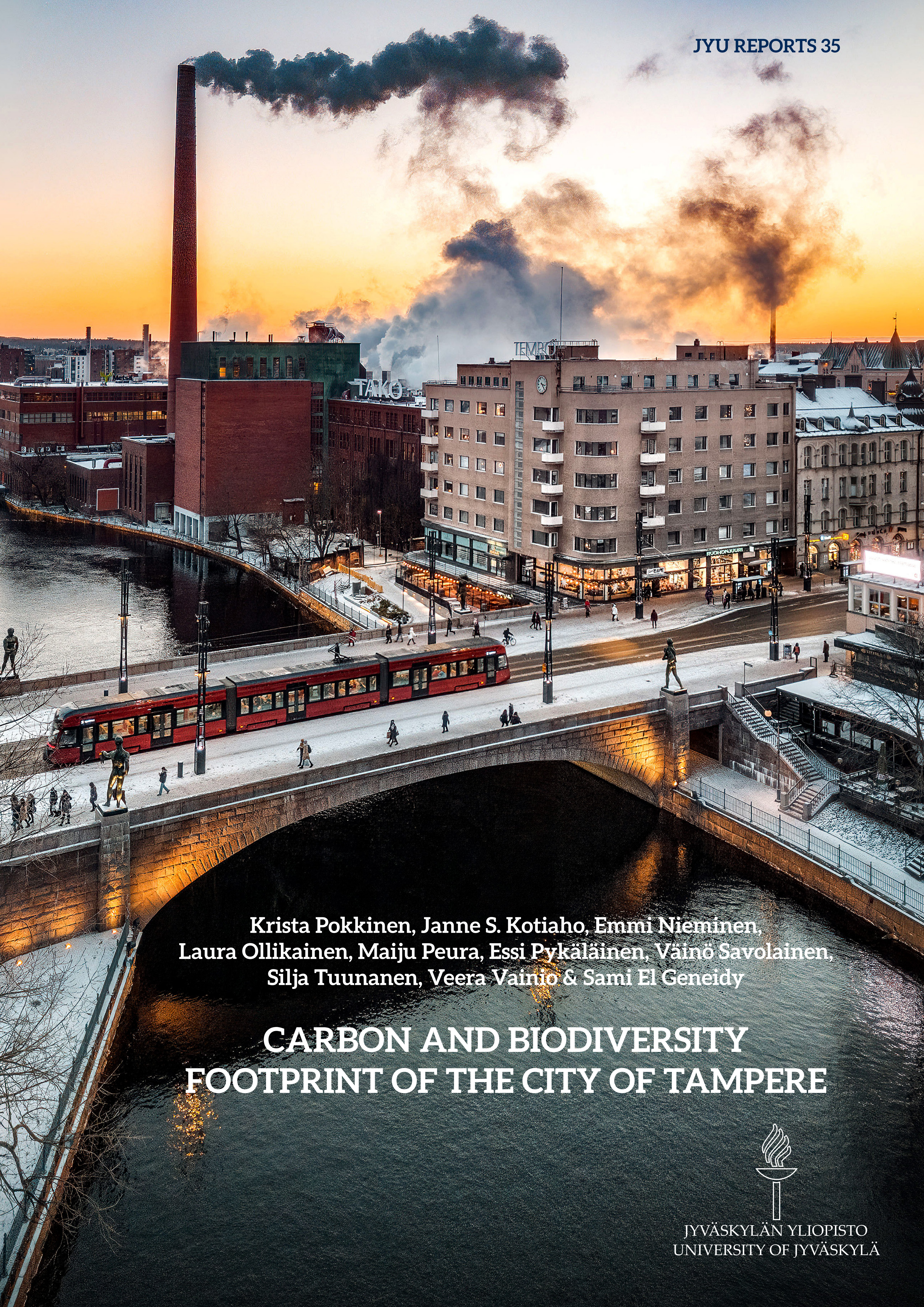

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Abstract

The four most serious existential risks for humanity are the failure to mitigate and adapt to climate change and biodiversity loss, and the natural disasters and extreme weather conditions that are becoming more common all over the world as a result of climate change. The assessment of the carbon and biodiversity footprints of the City of Tampere described in this report for the year 2021 are the first steps towards comprehensive work against climate change and nature loss, which every organization must undertake sooner or later. Results are reported for procurement of goods and services and in more detail for food, energy and water, investments, waste management and work-related travel. The biodiversity footprint of the City of Tampere in 2021 was 557 nPDF (potentially disappeared fraction of species globally) and the carbon footprint 207 763 t CO_2e. Food products caused 22 % of the biodiversity footprint. Red meat, dairy products and poultry caused the largest biodiversity footprints within food products. Other major causes for the biodiversity footprint were heat consumption (13 %) and construction (12 %). In terms of the carbon footprint, heat consumption was the largest contributor and caused 22 % of the carbon footprint. Especially the use of peat in heat production increased the carbon footprint. The second largest carbon footprint came from the consumption of food products (14 %) and construction (13 %).

The biodiversity footprint of the material consumption of street renovation was calculated as well. The carbon and biodiversity footprints of street renovation were compared between traditional street renovation and renovation that followed the principles of circular economy. Street renovation that followed the principles of circular economy caused 40 % smaller biodiversity footprints and 35 % smaller carbon footprints than traditional renovation. Scenarios on how the City of Tampere could reduce its carbon and biodiversity footprints were also calculated. Scenarios included for example implementing the principles of circular economy in construction, reducing energy consumption and replacing meat and dairy products with plant-based products.

The method used in the report assesses the global extinction risk caused to different species under one unit of measurement, similar to a carbon footprint. This makes it possible to compare the biodiversity footprints of different organizations and international supply chains. In the future, cities and regions around the world can utilize the presented assessment to develop and implement measurable strategies towards net zero emissions and nature positive impacts.

Tiivistelmä

Ihmiskuntaa eniten uhkaavat riskit ovat luontokadon ja ilmastonmuutoksen torjunnan ja niihin sopeutumisen epäonnistuminen sekä ilmastonmuutoksen seurauksena kaikkialla maailmassa yleistyvät vaaralliset sääilmiöt ja luonnonkatastrofit. Tässä työssä kuvattu Tampereen kaupungin vuoden 2021 hiili- ja luontojalanjälkien arviointi on ensimmäinen askel kohti kokonaisvaltaista ilmastonmuutoksen ja luontokadon vastaista työtä, johon jokaisen organisaation on ennemmin tai myöhemmin ryhdyttävä. Tulokset on raportoitu käyttötalouden hankintojen lisäksi erikseen tarkemmin elintarvikkeille, energialle ja vedelle, sijoituksille, jätehuollolle sekä työmatkoille. Tampereen kaupungin vuoden 2021 luontojalanjälki oli 557 nPDF (osuus maailman lajeista, jotka ovat riskissä kuolla sukupuuttoon globaalisti) ja hiilijalanjälki 207 763 t CO2e. Elintarvikkeet aiheuttivat 22 % luontojalanjäljestä. Elintarvikkeista punainen liha, maitotuotteet ja siipikarja aiheuttivat suurimmat luontojalanjäljet. Muita suuria luontojalanjäljen aiheuttajia olivat lämmön kulutus (13 %) ja rakentaminen (12 %). Hiilijalanjäljestä lämmön kulutus aiheutti 22 %. Etenkin jyrsinturpeen käyttö lämmön tuotannossa nosti lämmön aiheuttamaa hiilijalanjälkeä. Seuraavaksi eniten hiilijalanjälkeä aiheuttivat elintarvikkeet (14 %) ja rakentaminen (13 %).

Hankkeessa laskettiin käyttötalouden lisäksi vaikutukset myös yhdelle investointitapaukselle: kadun saneeraukselle. Saneerauksen hiili- ja luontojalanjälkiä vertailtiin sekä perinteisin keinoin että kiertotalousperiaatteita noudattavan saneerauksen välillä. Kiertotalousperiaatteita noudattava kadun saneeraus aiheutti 40 % pienemmän luontojalanjäljen ja 35 % pienemmän hiilijalanjäljen kuin perinteinen saneeraus. Rakentamisen kiertotalousperiaatteiden lisäksi hankkeessa laskettiin skenaariot Tampereen kaupungin hiili- ja luontojalanjälkien pienentämiseksi energian kulutusta vähentämällä sekä liha- ja maitotuotteiden korvaamisella kasvipohjaisilla tuotteilla.

Luontojalanjäljen laskentamenetelmä kokoaa erilaisille lajeille aiheutetun sukupuuttoriskin yhden mittayksikön alle hiilijalanjäljen tavoin. Tämä mahdollistaa organisaatioiden ja kansainvälisten tuotantoketjujen luontojalanjäljen vertailun. Tulevaisuudessa kaupungit ja alueet ympäri maailman voivat hyödyntää tässä raportissa esitettyä menetelmää kehittääkseen ja toteuttaakseen mitattavia strategioita nettonollapäästöjen ja luontopositiivisuuden saavuttamiseksi.

Glossary

Driver | Direct cause of biodiversity loss, such as land and water use, direct exploitation of natural resources, climate change, pollution or invasive alien species.

Procurement | Procurement describes the purchases of goods and services by an organisation.

Carbon dioxide equivalent (CO_2e) | A unit used to measure carbon footprint. It describes the combined global warming potential of greenhouse gases (such as carbon dioxide, methane and nitrous oxide).

Carbon footprint | Describes the adverse effects on the climate caused by a specific entity (such as an organisation or an individual). A synonym for climate impact.

Climate impact | A synonym for carbon footprint.

Mitigation hierarchy | Adverse impacts on nature caused by human activities should primarily be avoided, secondarily minimised and, as a last resort, offset ecologically and by restoring degraded nature on site.

Biodiversity impact | A synonym for biodiversity footprint. Adverse effects on nature caused by such human activities as land use.

Biodiversity footprint | Describes the adverse effects on nature and biodiversity caused by a specific entity (such as an organisation or an individual). A synonym for biodiversity impact.

PDF (potentially disappeared fraction of species) | A unit of biodiversity footprint describing the fraction of the species of the world that are likely to disappear globally (become extinct) as a result of direct drivers causing biodiversity loss (such as land use).

nPDF | Nano PDF. Expanded PDF value (nPDF = PDF x 10^9).

Emission | A synonym for carbon footprint and climate damage.

1 INTRODUCTION

In early 2023, the World Economic Forum published a report in which it listed the most significant risks threatening humanity over the next decade (WEF, 2023). The report is based on the views of 1,200 international risk experts from academia, companies, governments, international communities and civil society. Failure to mitigate and adapt to biodiversity loss and climate change, and the natural disasters and extreme weather events, which are becoming more common globally as a result of the climate change, are the most serious risks threatening humanity. The risks arising from climate change and biodiversity loss are a more serious threat to humanity than such phenomena as geopolitical conflicts, waves of refugees and cyber threats (WEF, 2023). In fact, the international scientific community has for some time highlighted the fact that mitigating climate change and stopping biodiversity loss are mutually supporting goals and they must be resolved simultaneously (Pörtner et al., 2021). The regulatory pressures to report on carbon and biodiversity footprints are also increasing. Over the past few years, the European Union has introduced or has been preparing such instruments as the Corporate Sustainability Reporting Directive (CSRD), Corporate Sustainability Due Diligence Directive (CSDDD), sustainable finance taxonomy and the Carbon Border Adjustment Mechanism (CBAM), which all have impacts on the way in which organisations report on their carbon and biodiversity footprints (European Commission, 2023a; 2023b; 2023c; 2023d). The assessment of the carbon and biodiversity footprints generated by the City of Tampere is the first step on a path towards a comprehensive effort to combat climate change and biodiversity loss that every organisation must ultimately take. The work to manage these risks, which constitute the most serious threat humanity is facing at the moment, is of exceptional importance and makes the City of Tampere a global trailblazer.

All life on earth relies on biodiversity and functional ecosystems. Biodiversity means life in all its different forms, while biodiversity loss or degradation of nature means the gradual disappearance of wild animals and plants from the earth as a result of human activity – degradation of ecosystems, disappearance of species, and the reduction in the size of populations, which means fewer individual animalsimpact and species (Ketola et al., 2022; Kotiaho et al., 2023). Biodiversity loss and the degradation of natural habitats are now progressing more rapidly than ever before in the history of humanity (IPBES, 2018). At the moment, as many as one million of the eight million species living on earth are in the danger of becoming extinct (IPBES, 2019). Land use is now the most serious threat to animal and plant species occurring on land and in freshwater and marine habitats (Jaureguiberry et al., 2022). However, climate change is becoming an increasingly important driver of biodiversity loss. If global warming cannot be limited to 1.5 degrees, climate change will probably become one of the major causes of biodiversity loss (Román-Palacios & Wiens, 2020; Trisos et al., 2020; Urban, 2015; WWF, 2022). At the moment, the earth's climate is warming more rapidly than at any time over the past 2,000 years and the average temperature is now about 1.1°C higher than in the pre-industrial era (IPCC, 2021).

The five most important reasons for global biodiversity loss are as follows: humanity has taken over the living environments of other species and is extensively changing them; we are using wild species as food or as commodities in excess of their reproductive capacity; the climate change that we have caused is too rapid from the perspective of evolutive adaptation; we are polluting the environment making it uninhabitable for animal and plant species; and we have introduced animal and plant species to areas outside their natural habitats where they cause damage to indigenous species (IPBES, 2019; Ketola et al., 2022; Kotiaho et al., 2023). It should be noted that biodiversity loss does not only affect the environment. It is a matter of sustainable development, economy, human wellbeing and health, international security, ethics and moral issues. Nature supplies us with food, fibres, energy and medicines and plays a critical role as a regulator of climate, air and water quality, flood management and storms. Nature keeps us alive and supports all dimensions of our wellbeing. As the World Economic Forum states in the report referred to at the start of this document, biodiversity loss threatens the existence and wellbeing of humanity. It has been estimated that about USD 44 billion of the global GDP is strongly or moderately dependent on nature (WEF, 2020). Researchers have also estimated that USD 7.2 billion of the value of the world's largest listed companies is exposed to a biodiversity risk, which has not been taken into account in corporate responsibility strategies (Carvalho et al., 2023).

All sectors of society must take action to stop climate change and biodiversity loss. Even though carbon footprint is already widely used by organisations to assess climate damage, there are few similar tools for assessing biodiversity footprints or biodiversity impacts (Bull et al., 2022; El Geneidy et al., 2021, 2023; Peura et al., 2023). Organisations can only develop effective strategies and instruments to reduce carbon and biodiversity footprints if they know which of their actions generate the most significant footprints. Tampere is the first city in Finland that has calculated its own biodiversity footprint. The calculation method tailored for its organisation was jointly developed by the City of Tampere and the University of Jyväskylä, and it can also be used by other cities in the future.

The calculation is based on the carbon and biodiversity footprint assessment method developed by the University of Jyväskylä (El Geneidy et al., 2021, 2023; Peura et al., 2023; Pokkinen et al., 2023). The carbon and biodiversity footprints generated by the procurement made by the City of Tampere organisation in 2021 and entered in its profit and loss account were calculated in a joint research project by the City of Tampere and the University of Jyväskylä. This report describes the basis for the method to calculate the carbon and biodiversity footprints and it presents the detailed results for operating economy procurement, food products, energy, water, waste management, work-related travel and for the investments entered in the balance sheet. For the first time, the biodiversity footprint generated by street construction was also calculated using a project as an example.

2 METHOD

2.1 Starting point for the City of Tampere

City of Tampere has ambitious environmental and climate targets. For example, it plans to achieve carbon neutrality by the year 2030 (Tampereen kaupunki, 2022a). The City of Tampere also gives a high priority to the protection of biodiversity and in 2022, it prepared the biodiversity programme to promote this goal (Tampereen kaupunki, 2022b). The emphasis in the biodiversity programme is on local nature but in the joint research project by the City of Tampere and the University of Jyväskylä discussed in this report, the focus is on global environmental impacts arising from supply chains.

The City of Tampere is determined to identify the most significant environmental impacts arising from its activities and it recognises its responsibility for mitigating impacts on nature as a whole. Through supply chains, the impacts are felt across the globe and they can only be minimised if the most important causes of the impacts are identified. The City of Tampere makes a substantial number of purchases each year. In 2021, it spent a total of about EUR 1.1 billion on external purchases, and in 2022, the figure was about EUR 1.2 billion. The health and social services reform led a fall in the volume of purchases from the start of 2023.

In this joint research project, the City of Tampere is examining both the biodiversity and climate impacts of its activities for the first time. The study will provide the City of Tampere with important information allowing it to plan its activities so that climate and biodiversity impacts can be mitigated. In the future, the calculations should also be expanded to cover investments that are likely to contribute substantially to the adverse effects. Using such instruments as procurement criteria, the City of Tampere should also actively seek ways to reduce its climate and biodiversity footprints.

As part of the project, carbon and biodiversity footprints were also calculated retroactively since 2019 for a Power BI report, which can be used as a basis for monitoring and comparing the impacts. The report results can be examined at annual level and by filtering at the level of product categories or between city departments. The calculations for the Power BI report are based on the income statement, which means that it does not take into account the refined calculation developed in this joint research project for certain categories. The aim is to develop the Power BI reporting so that the data entered in financial accounting is transferred to it automatically and on an up-to-date basis, which allows real-time monitoring.

2.2 Initial data and scope

In addition to the carbon and biodiversity footprints generated by the operational economy procurements made by City of Tampere, the biodiversity footprint generated by food products, energy, water, waste management, work-related travel and investments were also calculated in the project. The biodiversity footprint generated by the purchases for the renovation of the Yliopistonkatu street was also calculated in the project for two different scenarios, in which traditional street construction was compared with construction based on circular economy principles.

The calculation of the footprints is primarily based on the figures taken from the City of Tampere income statement for 2021. However, only the companies specified in the City of Tampere SAP accounting software that were still part of the City of Tampere organisation in 2023 were considered in the final calculations (Figure 1). This was done to ensure that the results would better reflect the current situation. As the health and social services service area and the Pirkanmaa Rescue Services were transferred under the wellbeing services counties in 2023, the purchases they had made in 2021 were not included in the calculations. Subsidiaries of the City Tampere were also left out of the calculations but including them in the figures should be considered in the future.

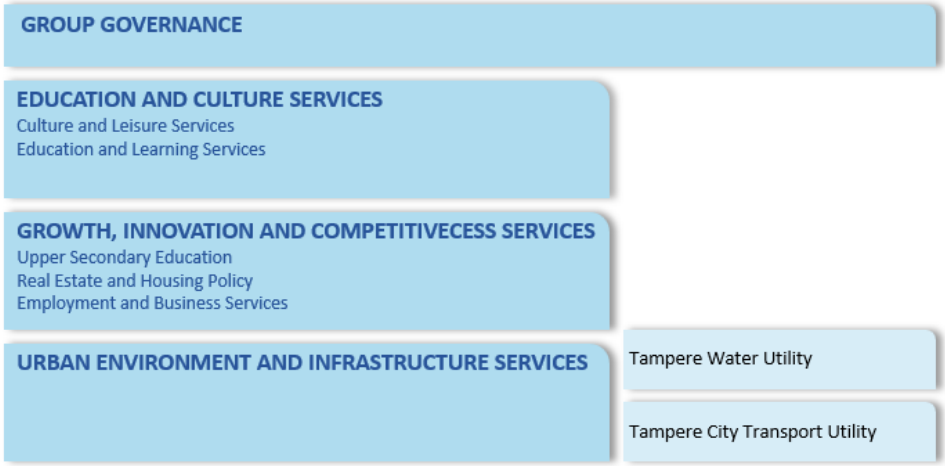


Figure 1. City of Tampere units included in the calculations (by SAP company).

The income statement of the City of Tampere financial accounting for 2021, and the data on energy consumption, investments, work-related travel and the amount of waste collected were used as initial data. The data on food purchases received from Pirkanmaan Voimia Oy, a City of Tampere subsidiary, was also included in the calculations. Pirkanmaan Voimia provides catering services for such places as daycare centres, schools and hospitals (Pirkanmaan Voimia Oy, 2023). The figures for food products are from the year 2022. Not all accounts in financial accounting were considered in the footprint calculations. Such items as wages and salaries, taxes, interest payments and balance sheet accounts (excluding investments) are outside the scope of the report. To avoid double calculations, euro-denominated expenses generated by food products, energy, water, waste management and work-related travel have been eliminated from the accounts of the income statement. Figure 2 shows the items included in the calculations, basis for calculating the damage they cause, and the items excluded from the calculations.

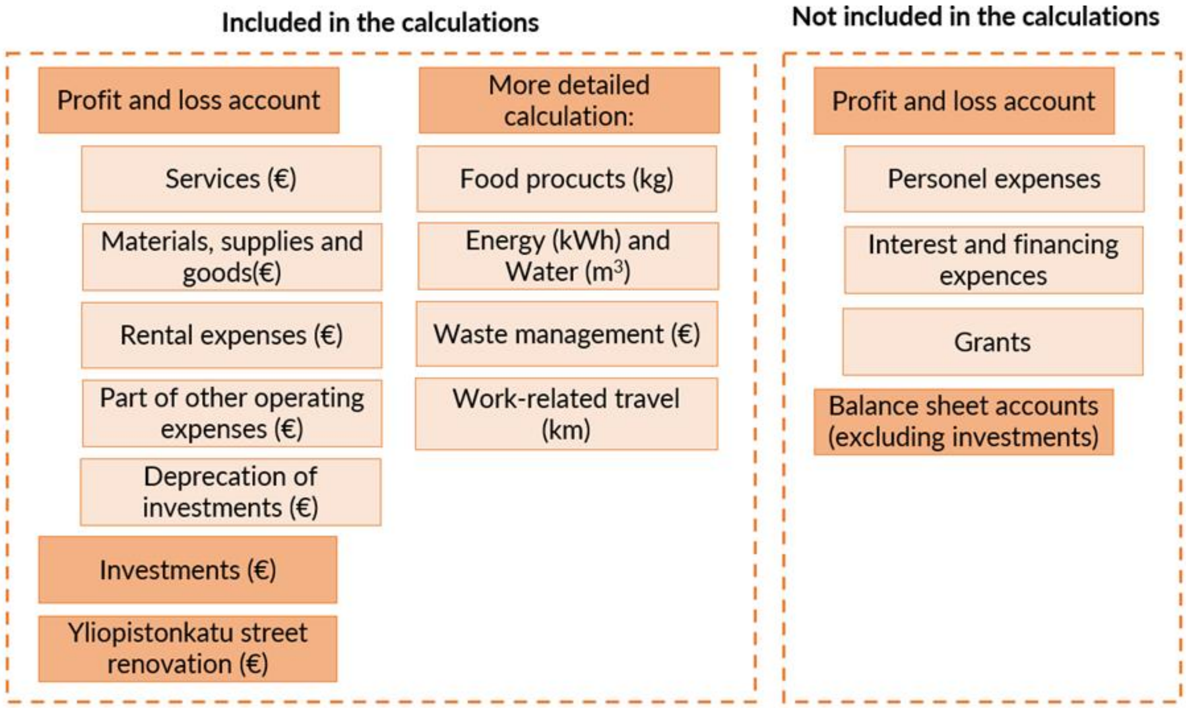


Figure 2. Items included in and excluded from the calculations. The unit used as a basis for calculating the impacts is shown in brackets.

2.3 Method used to calculate the carbon and biodiversity footprints

The method to calculate the carbon and biodiversity footprints developed by the University of Jyväskylä was used in the project (El Geneidy et al., 2023; Peura et al., 2023; Pokkinen et al., 2023). Four things are needed to calculate the biodiversity footprint (biodiversity impacts) generated by the activities of an organisation: type and amount of consumption, type and volume of the cause of the biodiversity loss resulting from the consumption (driver of biodiversity loss), location of the driver of biodiversity loss, and biodiversity loss caused by the driver (Figure 3). The biodiversity footprint generated by the City of Tampere is examined from the perspective of land and water use, climate change and pollution.

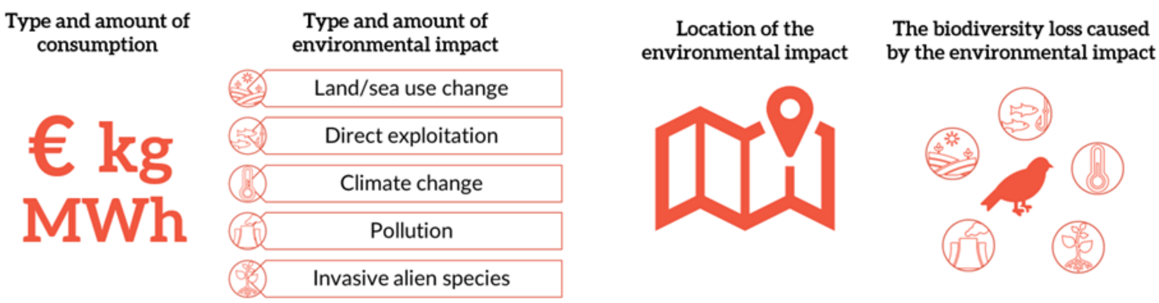


Figure 3. The components needed to calculate biodiversity footprint. The five drivers of biodiversity loss as defined by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019).

The assessment of carbon and biodiversity footprints based on an organisation's financial accounting can be divided into five different stages (Figure 4; El Geneidy et al., 2023). Calculation of the carbon and biodiversity footprints starts with the selection of suitable accounting data and its level of accuracy. After this, the calculation method is selected. This project uses a method that combines data kept in the EXIOBASE (Stadler et al., 2018) and LC-IMPACT (Verones et al., 2020) databases (El Geneidy et al., 2023). In the next stage, the organisation's accounting categories and prices are harmonised with the data used in the calculation method. After these stages, the calculations can be made and the results interpreted. The stages of Figure 4 are examined in more detail in the sections below.

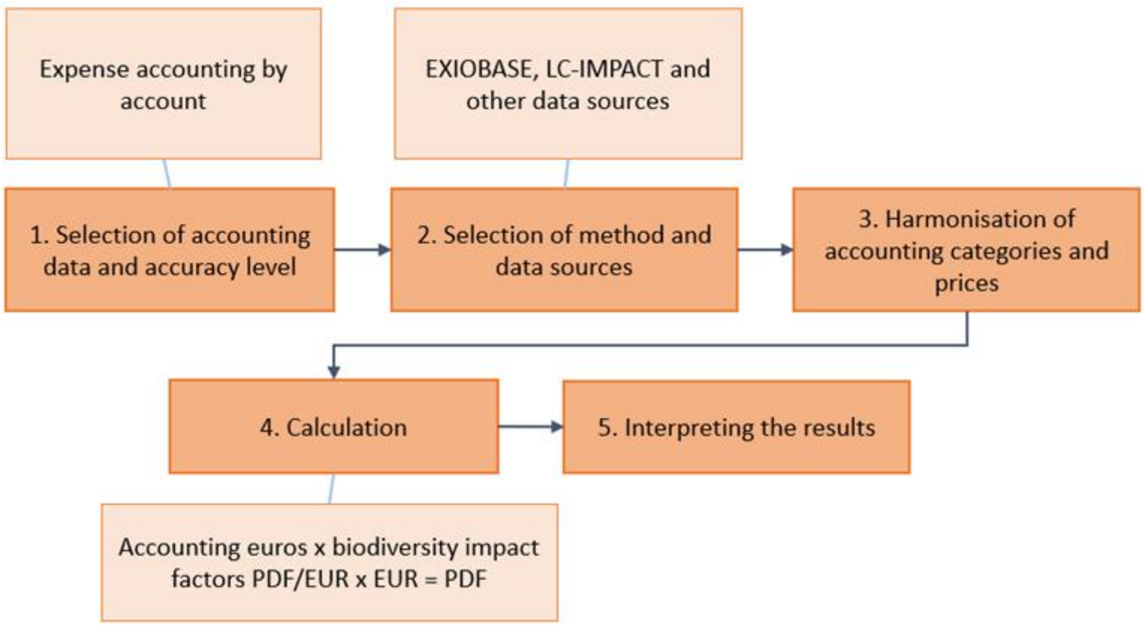


Figure 4. Stages of calculating carbon and biodiversity footprints. The figure is based on El Geneidy et al, 2023.

2.3.1 Selecting the accounting data and the level of accuracy

In this project, only the carbon and biodiversity footprints of the City of Tampere organisation (consumption of the City of Tampere administrative departments) were calculated. The footprints generated by individuals and communities residing in Tampere were not considered. The calculations were carried out based on the City of Tampere financial accounting, which contained data on purchases of materials, goods and services. Purchases made by City of Tampere units could also be itemised on the basis of the financial accounting. Value added taxes have been entered in the financial accounting in accordance with the VAT instructions for municipalities and wellbeing services counties (Vero, 2023).

2.3.2 Selecting the method and data sources

The calculation method used combines a number of different open, global databases and datasets (El Geneidy et al., 2023). The causes of climate damage, direct causes of biodiversity loss (drivers) and their location are modelled using the EXIOBASE database. The biodiversity loss caused by drivers is modelled using the LC-IMPACT database. The method used allows comprehensive calculation of the carbon and biodiversity footprints generated by a variety of different organisations. More detailed information on the methods is given in the sections below.

Drivers of biodiversity loss

EXIOBASE is an environmentally extended multi-regional input-output database (EEMRIO), which contains data on export and import flows between countries and regions and their environmental impacts by sector (Stadler et al., 2018). The database combines monetary flows with the drivers of biodiversity loss generated by consumption. The EXIOBASE database takes into account average impacts for the whole duration of the life cycle of products and services. For example, for products it covers the impact arising from primary production, manufacture, packaging and transport. The EXIOBASE version 3.8.2 used in the project contains the data on 200 product categories in 44 countries, and in five major regions comprising the remaining countries (Stadler et al., 2018, 2021). The first year of the EXIOBASE factors depends on the examined driver of biodiversity loss. All factors are from the year 2019 but for the land use, for example, the original factors are from the year 2011 and the size of the factors in 2019 is based on the modelling of changes in factor size over time (Stadler et al., 2021).

EXIOBASE can be used to calculate the size of the driver of biodiversity loss (such as land use of specific type) generated by the euro-denominated consumption of a specific product in Finland. The emission factors (kg CO_2e/EUR) used to calculate the carbon footprint are taken from EXIOBASE. In addition to land use (15 land use categories, such as forestry and beef cattle grazing), pollution (five categories, such as nitrogen and phosphorus emissions), climate change (carbon dioxide, nitrogen oxide and methane emissions) and water use are also among the drivers of biodiversity loss examined (Figure 5).

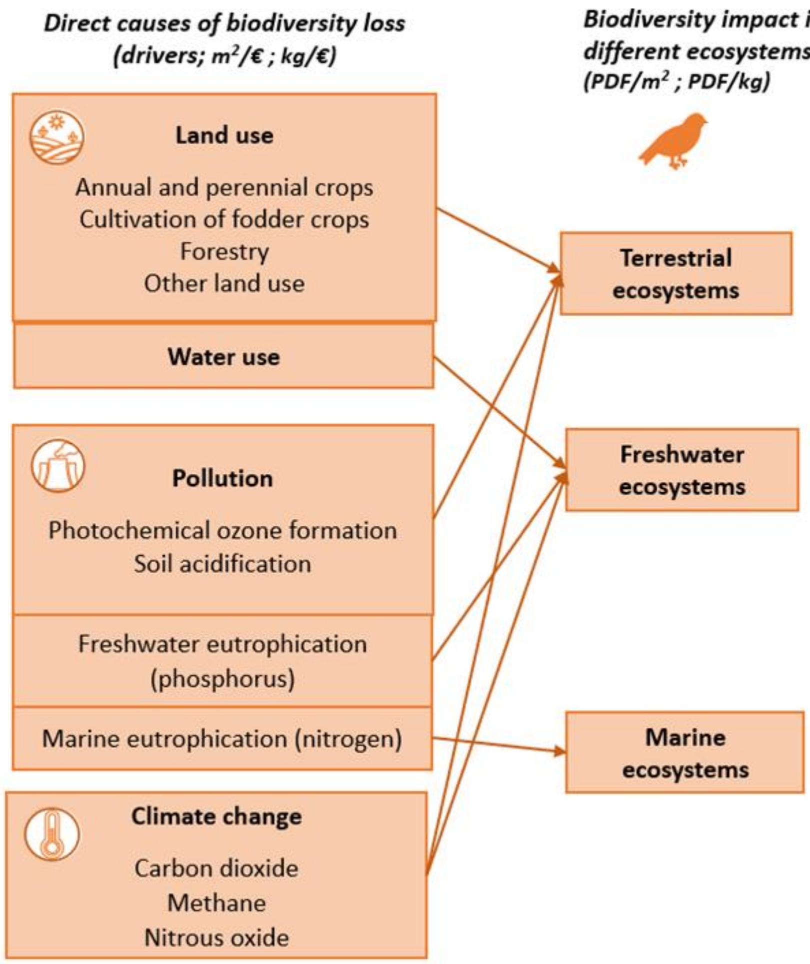


Figure 5. Direct causes of the impact to different ecosystems (drivers) are considered when the biodiversity loss is calculated. For example, in biodiversity loss affecting terrestrial ecosystems, consideration is given to the impacts of land use, pollution and climate change.

The data on the manner in which the impacts of the product category consumed in Finland are distributed across the globe by region are also taken from EXIOBASE. A total of 44 different countries, including Finland and many other European countries, are separately listed in EXIOBASE. The following five major regions are also available: Africa (South Africa is listed as a separate country), Central and South America (Brazil and Mexico as separate countries), Asia and the Pacific region (China, Japan, Indonesia, South Korea and India as separate countries), Middle East and Europe (including small countries and island states, such as Iceland and the Vatican City).

EXIOBASE contains 200 product categories for which country-specific drivers of biodiversity loss can be calculated. The product categories include construction, health and social services, electrical equipment, wind-generated electricity and ICT services. The method cannot be used to make comparisons between products in the same product category.

Biodiversity loss

The LC-IMPACT database is needed in the calculation of the biodiversity loss. It can be used to calculate the biodiversity loss caused by a specific driver of biodiversity loss (Verones et al., 2020). The fraction of all species of the world that are likely to become globally extinct if the harmful activity continues is used as the indicator of biodiversity loss (PDF = potentially disappeared fraction of species globally). The indicator is based on data and studies on the distribution and vulnerability of species and the sensitivity of species groups to different drivers of biodiversity loss (Verones et al., 2020). The PDF indicator has been claimed to act as a biodiversity equivalent (BDe) (El Geneidy et al., 2023). When the species of the world are examined globally as a single entity, comparisons can be made between biodiversity impacts generated in different geographical locations (El Geneidy et al., 2023). Thus, the indicator can be seen to function in the same manner as carbon dioxide equivalent works with the carbon footprint. However, in this report, we refer to the indicator with its original name: PDF. Biodiversity loss is estimated separately for the species of terrestrial ecosystems, freshwater ecosystems and marine ecosystems. Figure 5 shows which drivers of biodiversity loss are considered in the biodiversity loss impacting different ecosystems. For example, water use is only included in the biodiversity loss affecting freshwater ecosystems.

LC-IMPACT provides country-specific biodiversity impact factors for different drivers of biodiversity loss (244 countries). The biodiversity impact factors are shown, for example, as PDF/m^2 or PDF/kg and they are country-specific because a specific amount of a driver of biodiversity loss causes different amounts of global biodiversity loss in different countries. Using the Pymrio tool (Stadler et al., 2021), we can determine the distribution of the biodiversity loss caused by a specific product category between different countries. Pymrio is an open source tool that can be used to calculate biodiversity impacts. Biodiversity impact factors (global PDF/unit of the driver of biodiversity loss) are typically higher in areas of rich biodiversity on the equator.

The LC-IMPACT database contains a more detailed country-specific breakdown than the EXIOBASE database. For example, the environmental impact on Africa described in EXIOBASE is divided between the countries of the African region in the LC-IMPACT database. This results in country-specific PDF/EUR factors, the sum of which is ultimately the global biodiversity impact factor PDF/EUR of the product category for a specific driver (Figure 6). After this has been done to all drivers of biodiversity loss, the biodiversity impact factors of the same ecosystem are summed up, resulting in global PDF/EUR biodiversity impact factors for terrestrial ecosystems, freshwater ecosystems and marine ecosystems.

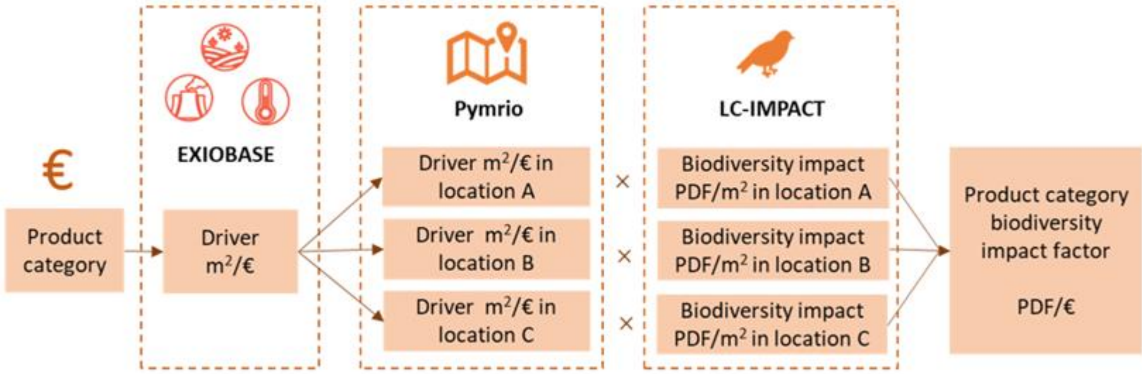


Figure 6. Graph showing how EXIOBASE and LC-IMPACT are combined to calculate the biodiversity impact factors. In the example, the product category (200 product categories) generates a certain amount of a driver of biodiversity loss (15 drivers). In the example shown in the Figure, this is given as m^2/EUR. Using Pymrio, the driver is applied to 49 countries or a larger region. Country-specific drivers (m^2/EUR) are multiplied by country-specific biodiversity impact factors (PDF/m^2) and the sum of the products is the biodiversity impact factor of the driver for a product category in the form PDF/EUR.

Knowledge of the biodiversity loss affecting terrestrial ecosystems is based on research data on such matters as how different types of land use are changing living environments, how climate change is changing the distribution of species' habitats and how soil acidification impacts the number of plant species. Knowledge of the biodiversity loss affecting freshwater ecosystems is based on research data on such matters as how water consumption is reducing the size of wetland areas, how climate change is changing the flow of rivers and how phosphorus is causing eutrophication of water bodies. Knowledge of the biodiversity loss affecting marine ecosystems is based on research data on the eutrophication impacts of nitrogen in marine areas.

The unit of biodiversity footprint (PDF) often generates very small values (between 0 and 1) because it is the contribution of a single organisation to global biodiversity loss. As a result, it may be difficult to understand the significance of biodiversity loss. To make it easier to present the results, biodiversity footprint can be expressed using prefix nano (10^{-9}), in which case the abbreviation nPDF is used (nPDF= PDF x 10^9).

2.3.3 Harmonising accounting categories and prices

A suitable product category was selected for each account of the City of Tampere accounting system from the 200 alternatives available in EXIOBASE. The City of Tampere data used in the project is from 2021. The financial data contained in EXIOBASE is from 2019, which means that the euro-denominated figures in the accounting data had to be converted into 2019 prices. The change was made by deducting the impact of consumer price index (CPI) inflation from the 2021 prices using a product category-specific inflation factor (Tilastokeskus, 2023a). The euro-denominated prices used by City of Tampere in its accounting are also purchaser's prices (definition: Tilastokeskus, 2023b) whereas the euro-denominated prices in EXIOBASE are basic prices (definition: Tilastokeskus, 2023c). The prices used by the City of Tampere in its accounting were converted into basic prices by taking into account taxes on products, product subsidies, trade and transport margins, and the value added tax. The change was carried out by means of a product category-specific price adjustment factor (El Geneidy et al., 2023). In practice, these changes reduce the euro amounts used in the calculation in relation to the prices used in accounting (Formula 1).

$$
\begin{aligned}
Basic\ price = {} & Purchaser's\ price\ - (Purchaser'\ s\ price \times Inflation\ factor) \\
& - (Purchaser'\ s\ price \times\ price\ adjustment\ factor)
\end{aligned}
$$

Formula 1. Calculating the harmonised prices.

2.3.4 Calculating the carbon and biodiversity footprint

After the City of Tampere accounting data had been harmonised with the EXIOBASE product prices, the organisation's carbon footprint was calculated by multiplying the euro amounts contained in the accounting data by emission factors (kg CO_2e/EUR), while the biodiversity footprint was calculated by multiplying the euro amounts contained in the accounting data by biodiversity impact factors (PDF/EUR, separately for different ecosystems). This produced the organisation's carbon and biodiversity footprints for each individual ecosystem.

2.3.5 Combining ecosystems

The biodiversity impact affecting terrestrial and freshwater ecosystems contains the following groups of species: mammals, birds, amphibians, reptiles and vascular plants. The biodiversity impact affecting marine ecosystems contains lobsters, bony fishes, cartilaginous fishes and sea cucumbers. The biodiversity impacts affecting different ecosystems should not be directly combined (Verones, et al., 2020). Biodiversity impacts affecting ecosystems can, however, be combined by assigning a weighting for each ecosystem (El Geneidy et al., 2023). The estimated percentage of the species within each ecosystem of all plant and animal species occurring on earth is used as the weighting (Román-Palacios et al., 2022). The biodiversity footprint values of each ecosystem are multiplied by the weight and the weighted values of the ecosystems are summed up (Formula 2).

$$PDF_{combined} = PDF_{terrestrial} \times 0.801 + PDF_{freshwater} \times 0.096 + PDF_{marine} \times 0.102$$

Formula 2. Combining ecosystem-specific biodiversity footprints into a single biodiversity footprint using weights (Román-Palacios et al., 2022; El Geneidy et al., 2023).

2.4 Calculating the impact caused by food products

The impact caused by food products was calculated more accurately on the basis of quantitative consumption (kg). As EXIOBASE only has ten food-related categories, calculating the impact caused by food products on its basis could produce rather vague results. Using kilogramme-based calculations allows the calculation of the biodiversity footprint for 44 different food product categories, in which case the calculation of the damage caused by food products produces more accurate results than the euro-based EXIOBASE calculations. The calculations were based on the study produced by Poore and Nemecek (2018) in which they analysed the amount of the driver of biodiversity loss per kilogramme of food product. The data was used for land use (m^2/kg) and for CO_2 emissions (CO_2e/kg). At the moment, land use and climate change are the only drivers of biodiversity loss taken into account in kilogramme-based calculations but the number of drivers can be increased in the future, at least for pollution and water use. In addition to the existing food product categories, this project has produced new categories based on estimates of the raw materials and their distribution in the products. For example, in this work we estimated that pork-beef minced meat contains 50% pork and 50% beef.

Food products have been divided into animal-based and plant-based products. Plant-based food products are further divided into annual and perennial plants. In the case of plant-based food products, it was assumed that all land use would take place in the product's country of origin. In the case of animal-based food products, grazing takes place in the country of origin but such matters as cultivation of fodder plants are assigned to more than one country, using the EXIOBASE database and Pymrio tool (Stadler et al., 2021). This is because such products as feeds are often imported to Finland. Kilogramme-based factors of the drivers of biodiversity loss (m^2/kg or CO_2e/kg) have been combined with the biodiversity impact factors of the LC-IMPACT database (PDF/m^2 or PDF/CO_2e) so that biodiversity impact factors for a variety of different products (PDF/kg) can be calculated (Figure 7). Each food product and each of its country of origin, production or import has its own biodiversity impact factor.

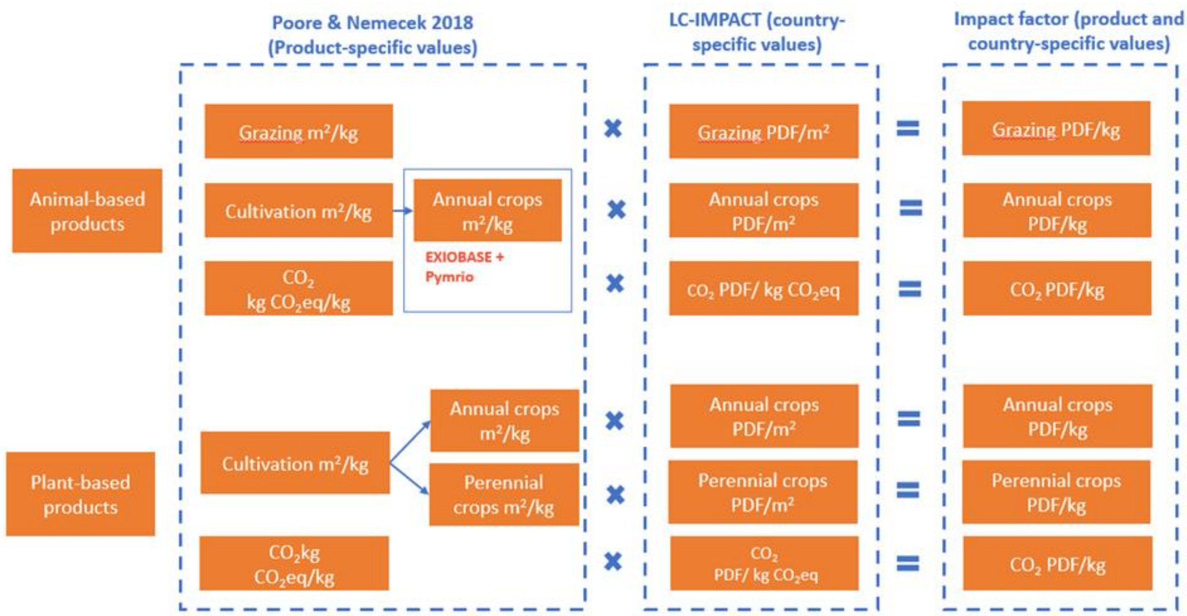


Figure 7. A graph illustrating the combination of product-specific factors based on the study by Poore & Nemecek (2018) and the LC-IMPACT database so that biodiversity impact factors can be calculated. Food products are divided into animal-based and plant-based products. In cultivation, there is also a division into annual and perennial plants. Product-specific values (m^2/kg) are multiplied by country-specific biodiversity impact factors (PDF/m^2), resulting in the impact factor for product category PDF/kg.

2.5 Calculating energy, water and work-related travel

The impact caused by energy, water and work-related travel was also calculated on the basis of physical consumption. Life-cycle assessment was used in the calculation of energy, water and work-related travel. Using life-cycle assessment, the environmental impacts of individual products and services can be assessed from manufacturing to final disposal (Huijbregts et al., 2017). The damage was calculated using the Ecoinvent database, which produced the structure of the supply chains, the production inputs they require (such as the natural resources used) and the adverse effects arising from the production (such as air pollution).

The calculations were made using openLCA software, in which the life-cycle pf supply chains were constructed on basis of the Ecoinvent database (Wernet et al., 2016). Because of limited computer calculation capacity, some of the supply chains had to be made less detailed using the cutoff function of openLCA (value used: 1e-9 or none). The life-cycle impacts were assessed using ReCiPe, which is one of the life-cycle assessment methods (Huijbregts et al., 2017). Drivers of biodiversity loss were per one unit of consumption (for example, land use: m^2/kWh). The drivers of biodiversity loss calculated in the method were as follows: for terrestrial ecosystems, land use (agricultural land), soil acidification, formation of photochemical oxidants, and climate change; for freshwater ecosystems, freshwater eutrophication, climate change and water use; and for marine ecosystems, marine eutrophication (Figure 8).

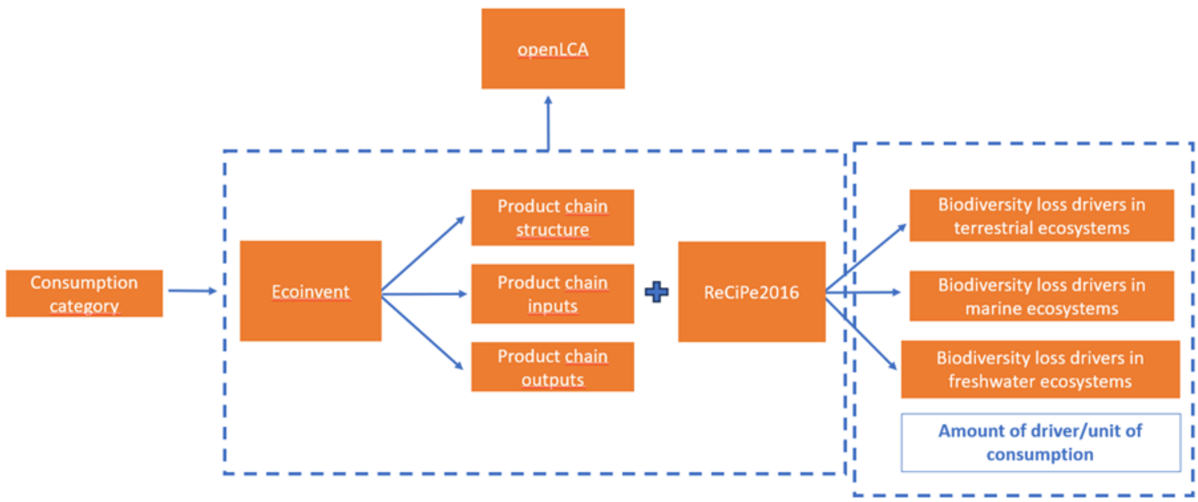


Figure 8. Modelling of energy and water consumption and work-related travel using Ecoinvent and ReCiPe 2016 databases.

3 RESULTS

3.1 Carbon and biodiversity footprints of the City of Tampere organisation in 2021

The biodiversity footprint generated by the City of Tampere totalled 5.57E-07 PDF or 557 nPDF. This means that the biodiversity footprint generated by the City of Tampere organisation is likely to cause the disappearance of 0.0000557 per cent of all species on earth if the biodiversity loss caused by the activities continues at its current rate. The carbon footprint generated by the City of Tampere totalled 207,773 t CO_2e. Other operating economy caused 50% (281 nPDF) of the biodiversity footprint and 54% (111,290 t CO_2e) of the carbon footprint (Table 1). Other operating economy procurement, which included construction and IT services and equipment, accounted for 91% of the financial accounting expenditure. The results are presented in more detail in the sections below.

Table 1. Absolute (nPDF and t CO_2e) and relative (%) biodiversity and carbon footprints of the City of Tampere and the expenses (EUR) by category.

	nPDF	Biodiversity footprint (%)	t CO_2e	Carbon footprint (%)	Expenses (€)	Expenses (%)
Other operating economy	281	50	111 293	54	501 451 156	91
Food products	125	22	28 665	14	13 912 000	3
Heat	75	13	46 573	22	571 071	0
Electricity	44	8	8 694	4	4 485 461	1
Investments	28	5	10 948	5	29 504 785	5
Water	4	1	1 164	1	3 242 438	1
Waste management	1	0	300	0	374 282	0
Work-related travel	0	0	136	0	512 215	0

By category, food products were responsible for the highest proportion (22%) of the biodiversity footprint (Figure 9a). It was followed by heat consumption (13%) and construction (12%). Construction includes construction materials, and the maintenance and repairs of buildings. Food products caused the largest footprint but the euros spent on them only accounted for about 3% of all euros spent on purchases (Figure 9b). At the same time, heating only accounted for 0.1% of the euros spent on all purchases. Biodiversity and carbon footprints and the expenses generated by the categories are shown in Appendix 1. Of the drivers of biodiversity loss, climate change was the biggest cause (51%) of the biodiversity footprint (Figure 10). Land use accounted for 35% and pollution for 8% of the biodiversity footprint.

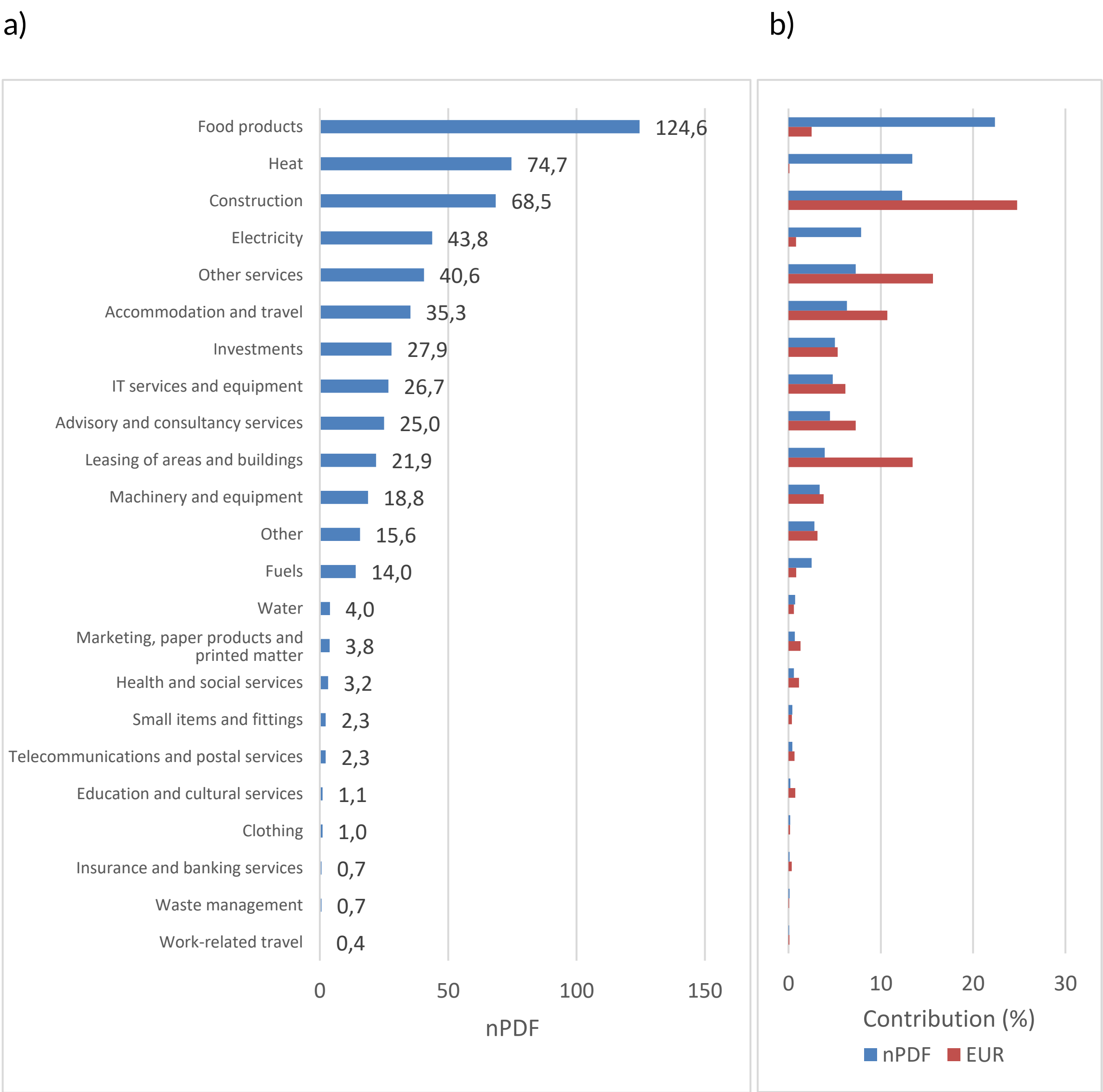


Figure 9. a) Biodiversity footprint (nPDF) of the City of Tampere by consumption category and b) contributions (%) of the categories to total biodiversity footprint and expenses.

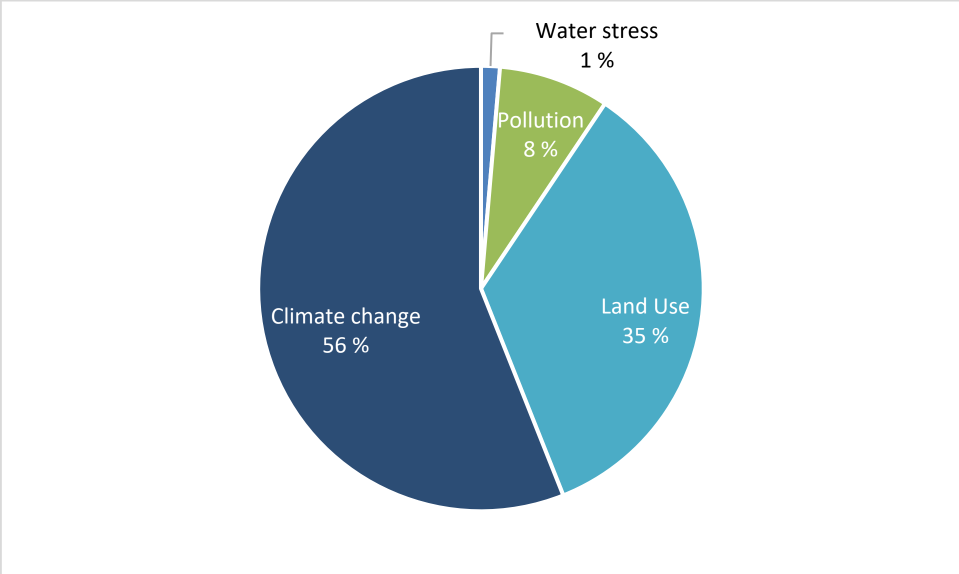


Figure 10. Breakdown of the City of Tampere biodiversity footprint by the drivers of biodiversity loss. Food products, work-related travel and energy are not considered in the breakdown because for them, the number of the drivers of biodiversity loss varied.

A total of 22% of the City of Tampere carbon footprint (46,570 t CO_2e) was generated by heat consumption (Figure 11a). Food products accounted for 14% (28,700 t CO_2e) and construction for 13% (24,200 t CO_2e) of the carbon footprint. The large carbon footprint generated by construction was partially explained by the large number of construction-related purchases. In monetary terms, construction-related purchases accounted for 25% of the purchases entered in financial accounting (Figure 11b). Other services accounted for 16% of the procurement expenditure. Other services include purchases of customer services. Leasing of areas and buildings was the third largest purchasing category (14% of all procurement expenditure).

The footprints of food products, consumption of heat, electricity and water as well as work-related travel have been calculated based on their quantitative consumption, which means that the results for them may not be in direct proportion to the euros spent on them.

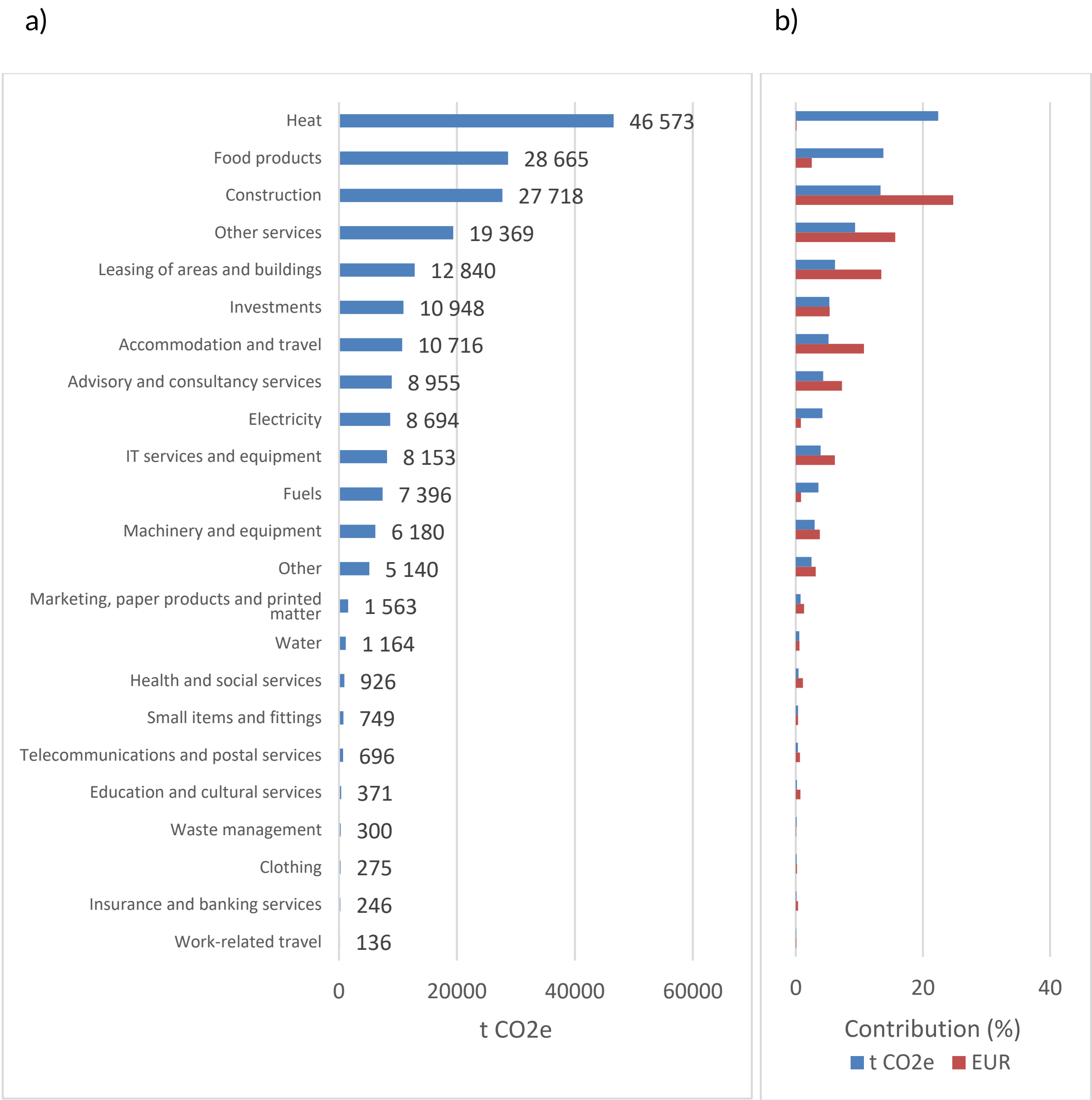


Figure 11. a) Carbon footprint (t CO_2e) of the City of Tampere by consumption category and b) contributions (%) of the categories to total carbon footprint and expenses.

3.1.1 Results by unit and utility

When the results are examined by unit, the Urban Environment and Infrastructure Services generated the largest biodiversity footprint in 2021 (26%) (Figure 12). It was followed by Tampere Water (17%) and Real Estate and Housing Policy (16%). The figures for individual units do not include the impacts caused by food products, investments, work-related travel and waste management because the purchases made by units and utilities could not be extracted from the figures. Of the biodiversity loss generated by Urban Environment and Infrastructure Services, 27% resulted from construction, 21% from heat consumption and 15% from electricity consumption (Figure 13).

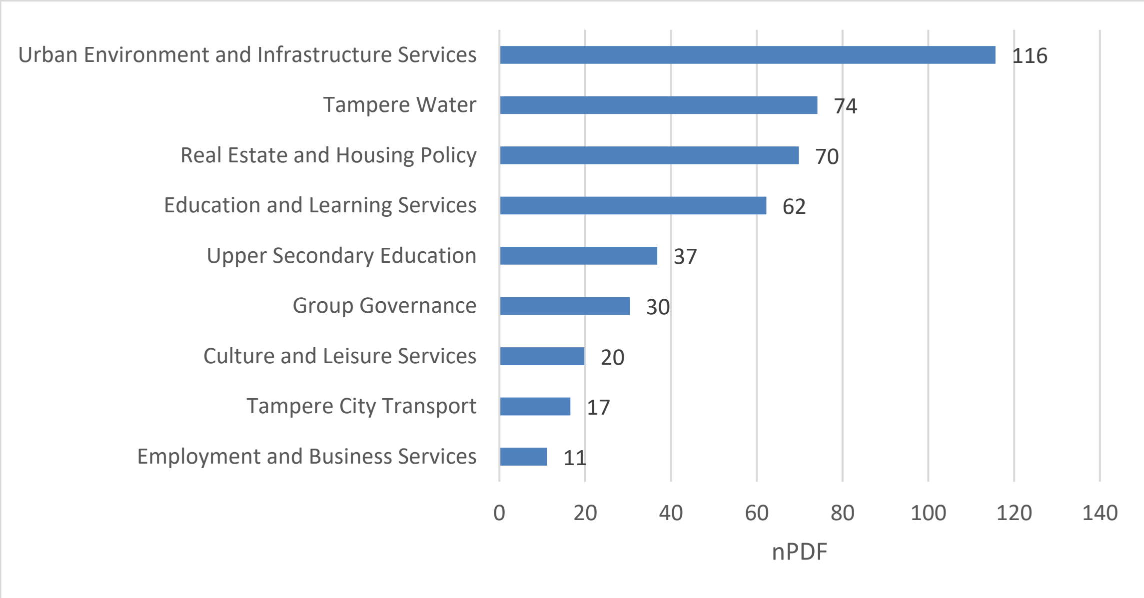


Figure 12. Breakdown of absolute biodiversity footprint (nPDF) between the units and utilities of the City of Tampere organisation.

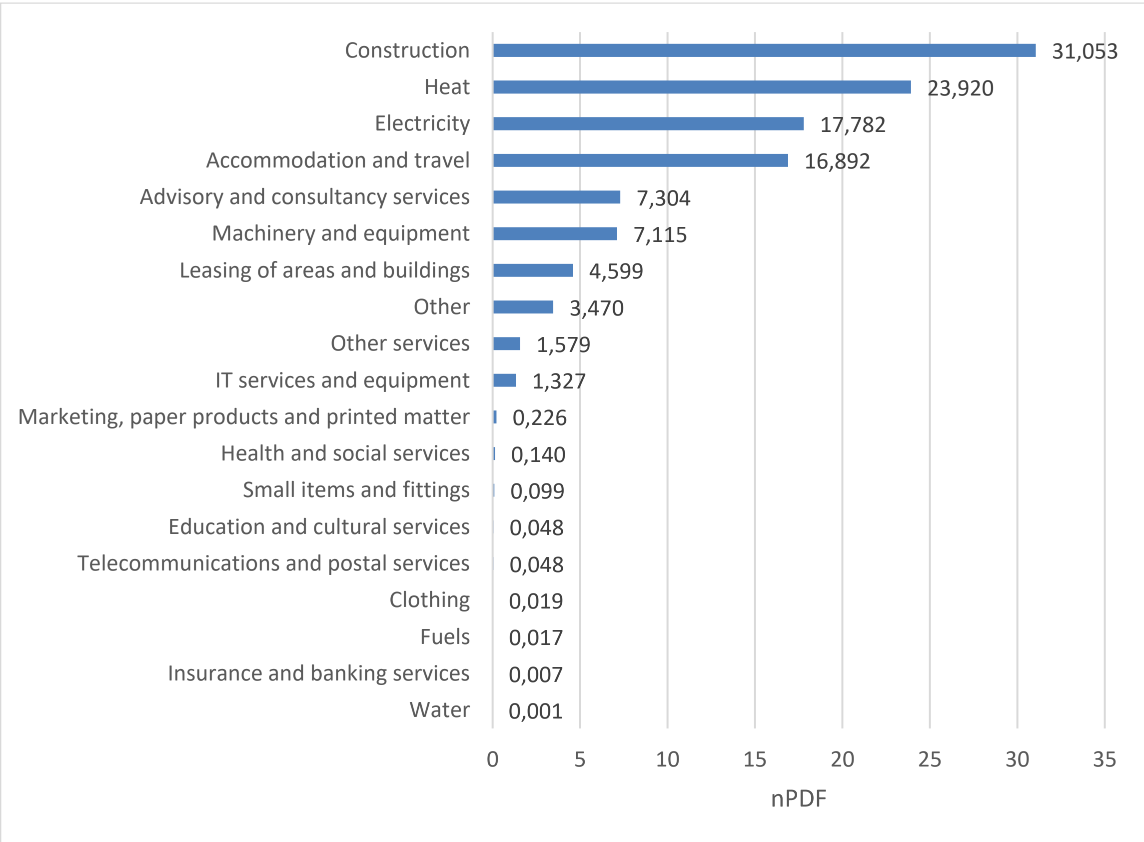


Figure 13. Breakdown of the absolute biodiversity footprint (nPDF) generated by Urban Environment and Infrastructure Services between categories.

Urban Environment and Infrastructure Services were also responsible for the largest (27%) carbon footprint (Figure 14). It was followed by Tampere Water (19%) and Real Estate and Housing Policy (16%). The biodiversity and carbon footprints of all units and their percentages of each category are shown in Appendix 2.

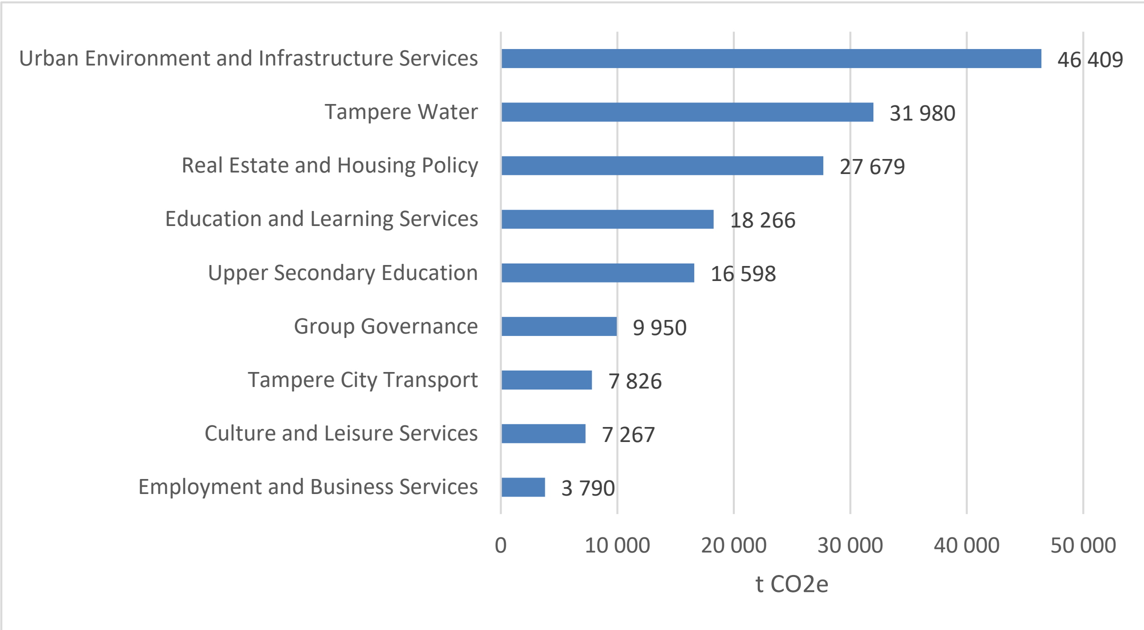


Figure 14. Breakdown of carbon footprint (t CO_2e) in the internal units and utilities of the City of Tampere organisation.

Heat consumption accounted for 32% of the carbon footprint generated by the Urban Environment and Infrastructure Services (Figure 15). It was followed by construction (26%) and accommodation and travel (14%).

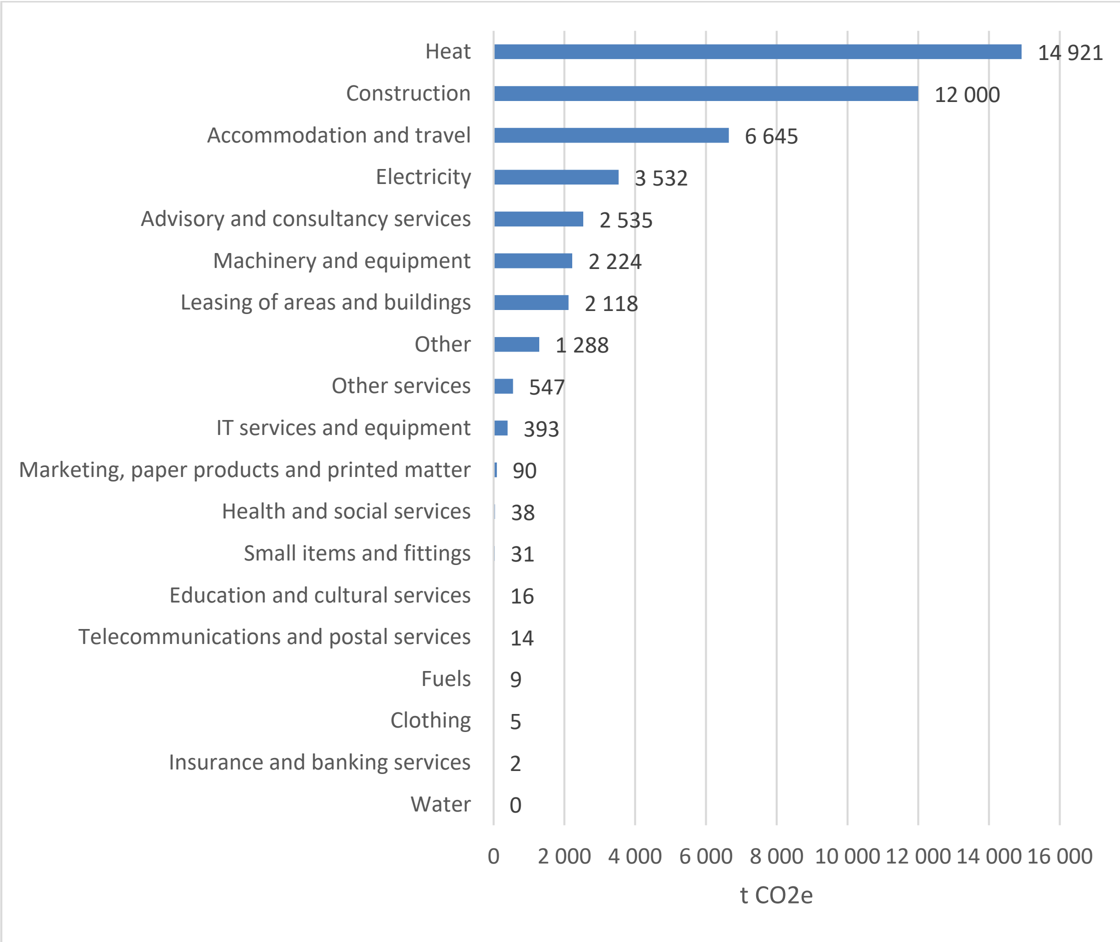


Figure 15. Breakdown of the carbon footprint generated by Urban Environment and Infrastructure Services between categories.

3.1.2 Food products

The data on the food products purchased by the City of Tampere were received from Pirkanmaan Voimia Oy as kilogrammes consumed by product. The food product procurement made in 2022 were used in the calculations because the figures for 2021 were not available. The countries of origin for all products were not directly available. In such cases, we used Finland's national statistics on the countries of origin of such products as bananas. In such cases, one product may have more than one country of origin. To avoid double calculations, the 2021 food product expenses entered in financial accounting have been removed from euro-denominated calculations of carbon and biodiversity footprints.

Food consumption accounted for 22% of the biodiversity footprint and 16% of the carbon footprint of the City of Tampere. The biodiversity footprint generated by the City of Tampere food purchases totalled 124 nPDF. Red meat generated the largest biodiversity footprint (34%, Figure 16a). Red meat contains products made from beef, pork and mutton. It was followed by dairy products (22%) and poultry

(10%). Even though red meat is responsible for the largest biodiversity footprint, it only accounts for 3% of the kilogrammes of food purchases (Figure 16b). All meat products generated 52% of the biodiversity footprint caused by food products. Even in kilogramme terms, the amount of poultry products purchased was about 5% lower than the purchases of red meat and the biodiversity footprint generated by red meat was about 70% larger than that of poultry. At the same time, vegetables account for the largest share of the kilogrammes purchased (27%) but only for 6% of the biodiversity footprint. Biodiversity and carbon footprints of the food product categories are shown in Appendix 3.

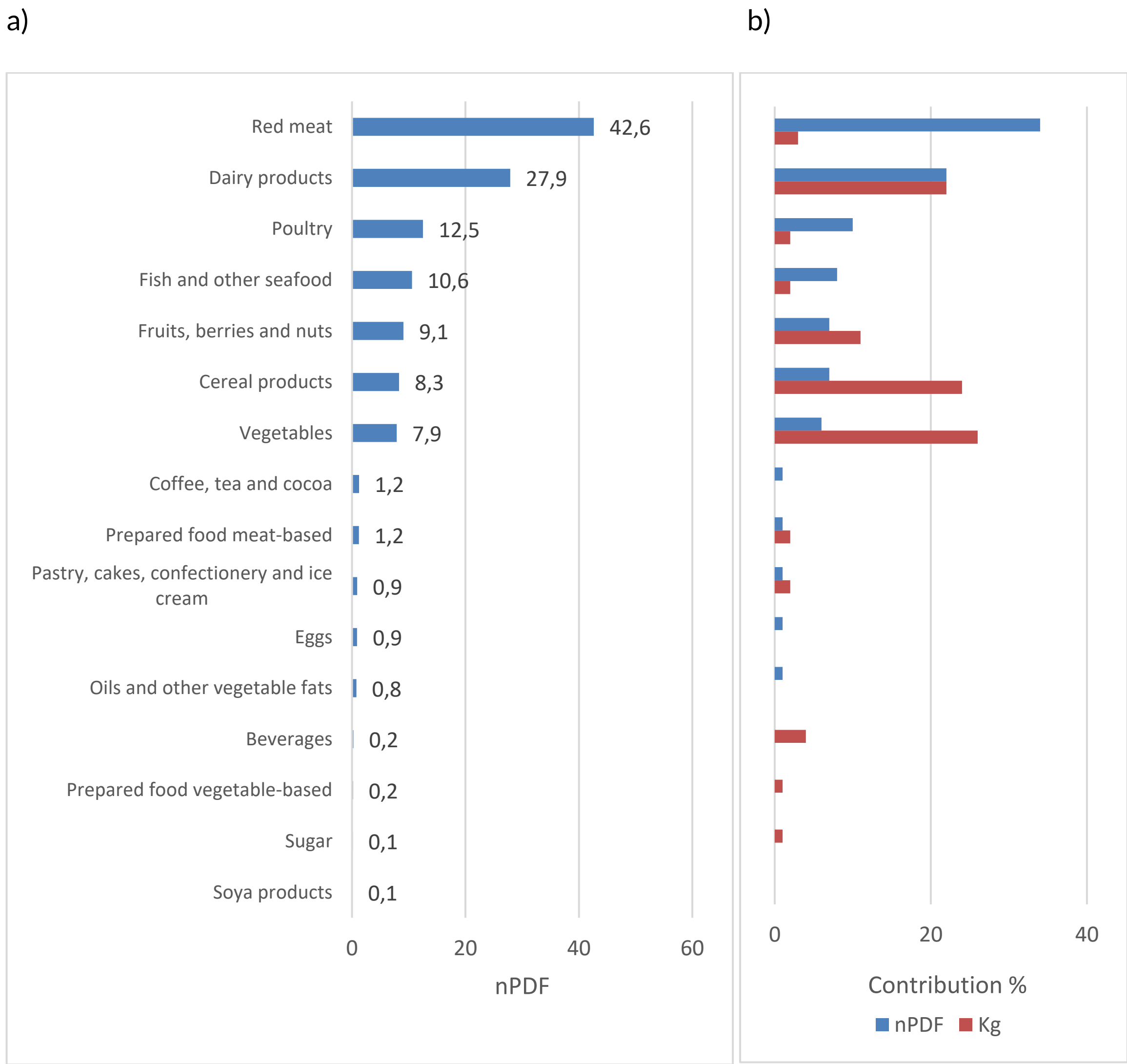


Figure 16. a) Breakdown of the biodiversity footprint (nPDF) generated by food products in different consumption categories and b) breakdown (%) of biodiversity footprint and kilogrammes in different categories.

The easiest way to reduce the biodiversity footprint of food products is to do it where the impacts and the volumes purchased are the largest. This can be illustrated with a fourfold table showing that the product categories with a high biodiversity impact intensity and that are purchased in large volumes may have the best potential for reducing biodiversity impacts (Figure 17). The horizontal axis of the fourfold table shows the volumes purchased in kilogrammes (10,000 kg) and the vertical axis shows the biodiversity impact intensity (PDF/kg). The values of both axes have been scaled to a two-base logarithm scale. The gaps between the values shown on the logarithm scale widen in accordance with the logarithm base, which means that the values of the fourfold table axes do not describe the absolute value of the biodiversity impact intensity or the volumes purchased. However, with a logarithm scale, comparisons between values can be made on the same graph. Red meat, poultry, dairy products, fruits, berries and nuts are located in the top right-hand corner of the graph. These product categories may have the best potential for reducing impacts because they are purchased in large volumes and they have a high biodiversity impact intensity (PDF/kg) (Figure 17). However, the fourfold table should be examined in overall terms because the potential for reducing biodiversity impact also exists in product categories with a high biodiversity impact intensity (top left-hand corner) or that are purchased in large volumes (bottom right-hand corner).

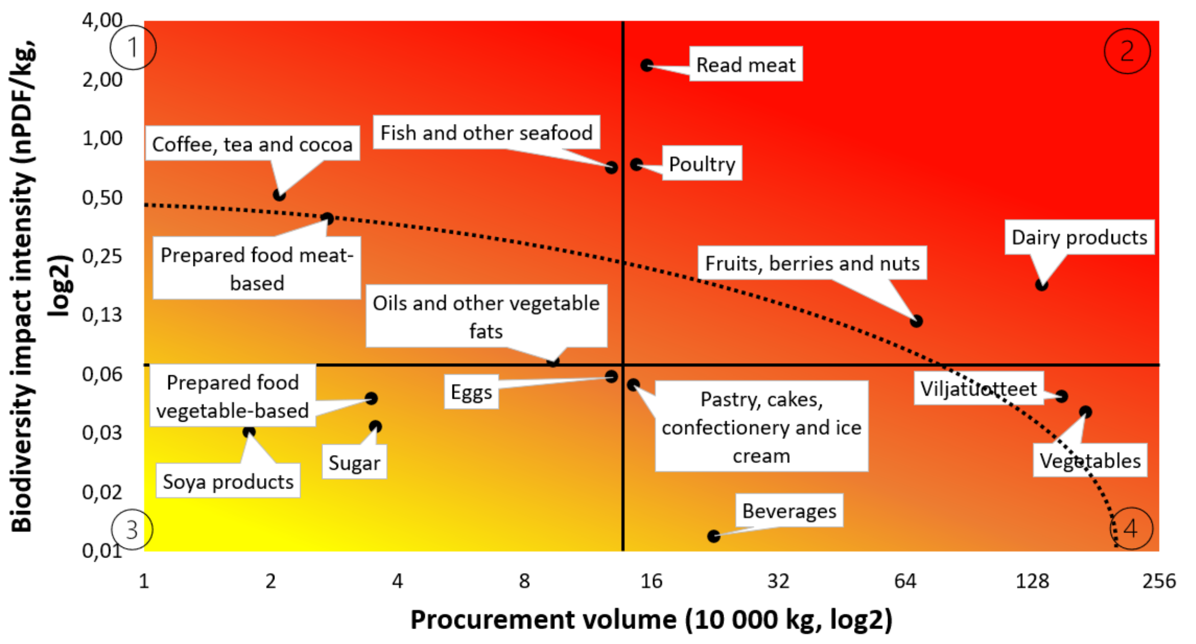


Figure 17. Biodiversity impact intensity (PDF/kg) and purchasing volumes (10,000 kg) of food product categories in a fourfold table. The values have been scaled to the figure using a two-base logarithm scale. Biodiversity impact intensity median on the vertical axis is 0.07 (nPDF/kg) and the median of purchasing volumes on the horizontal axis is 13.7 (10,000 kg). The food product categories that may have the best potential for reducing biodiversity impact remain above the arc of the graph.

The carbon footprint generated by food products totalled 28,650 t CO_2e. Red meat accounted for the highest proportion (37%) of the carbon footprint (Figure 18a). It was followed by dairy products (21%) and cereal products (14%). Cereal products accounted for more than 20% of the kilogrammes of food products purchased, as a result of which their carbon footprint is large when compared with other categories (Figure 18b).

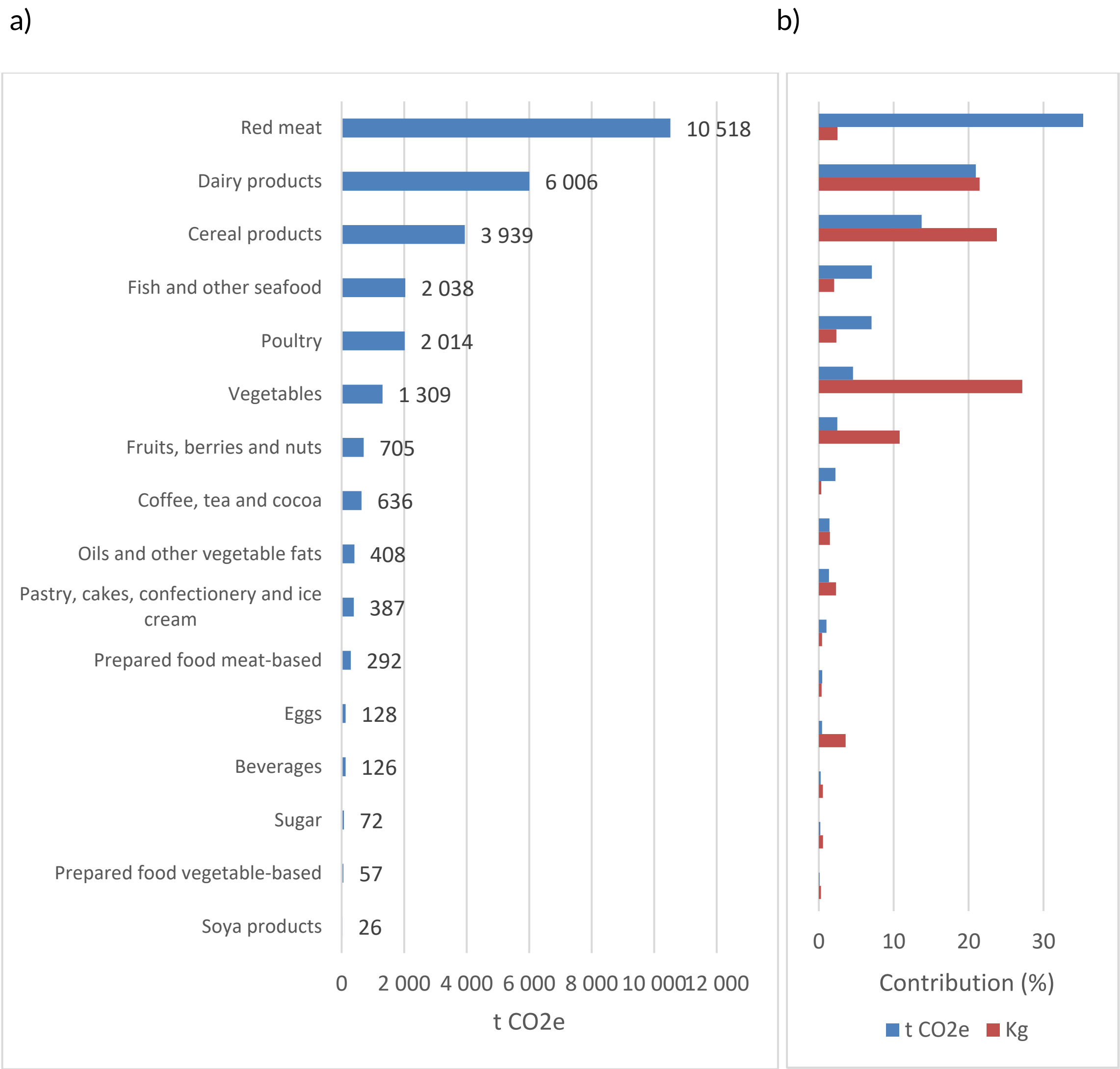


Figure 18. a) Breakdown of the carbon footprint generated by food products in different consumption categories and b) breakdown (%) of carbon footprint and kilogrammes in different categories.

3.1.3 Energy and water

Calculations of energy and water were carried out based on the 2021 consumption figures. In 2021, heat consumption totalled 175,767 MWh, electricity consumption 108,293 MWh and water consumption 4,823,754 m^3.

Most of the district heat is generated locally in the Naistenlahti and Lielahti power plants and in a cogeneration process in the Tammervoima power plant (Tampereen Energia, 2022). About 30% of district heat is generated with wood fuel (Figure 19a) and whole-tree wood accounts for about one third of this amount. District heat is also generated with natural gas, mixed waste, milled peat and light fuel oil. Residual heat is also used in heat generation. Hydropower accounts for 66% of the electricity generation (19b). Electricity is also generated with wood (17%), wind power (17%), mixed waste (6%) and solar energy (1%).

a) b)

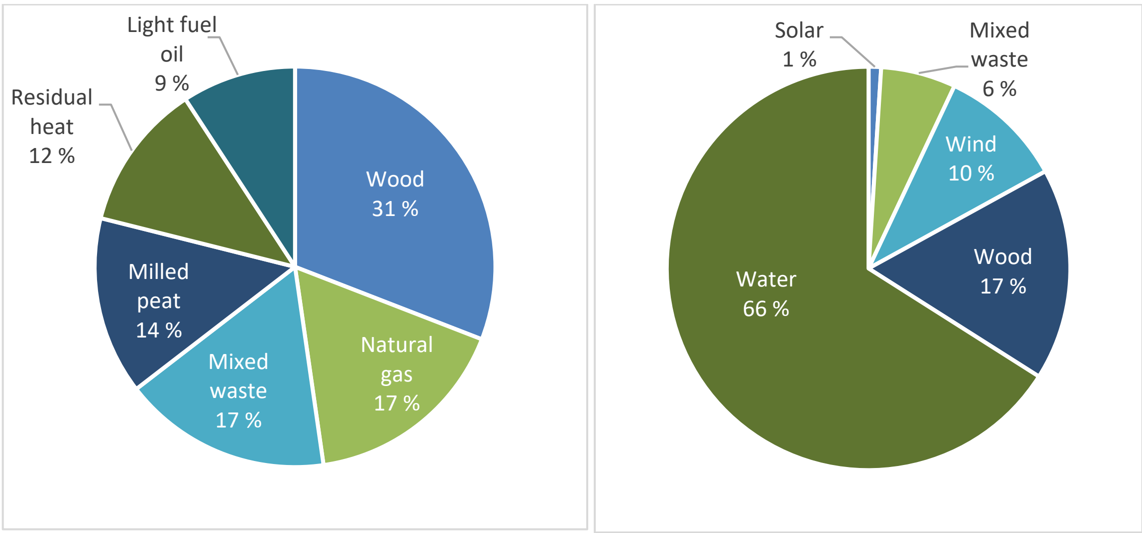


Figure 19. a) Breakdown of the heat used by energy source (City of Tampere, email, 2022c) and b) breakdown of the electricity used by energy source (Tampereen sähkölaitos, 2023).

The biodiversity footprint of heat consumption totalled 74.7 nPDF, of which 52% was generated by the use of milled peat (Figure 20a). It was followed by mixed waste (15%) and natural gas (14%). The impact caused by residual heat has not been calculated as it is considered a by-product of other processes, which are the real causes of the loss arising from heat generation. The carbon footprint generated by heat consumption totalled 46,573 t CO_2e. Milled peat accounted for most of the carbon footprint (57%) (Figure 20b). It was followed by natural gas (15%). Milled peat has by far the highest biodiversity impact and emission factors and as a result, it accounts for a high proportion of the biodiversity and carbon footprints generated by heat.

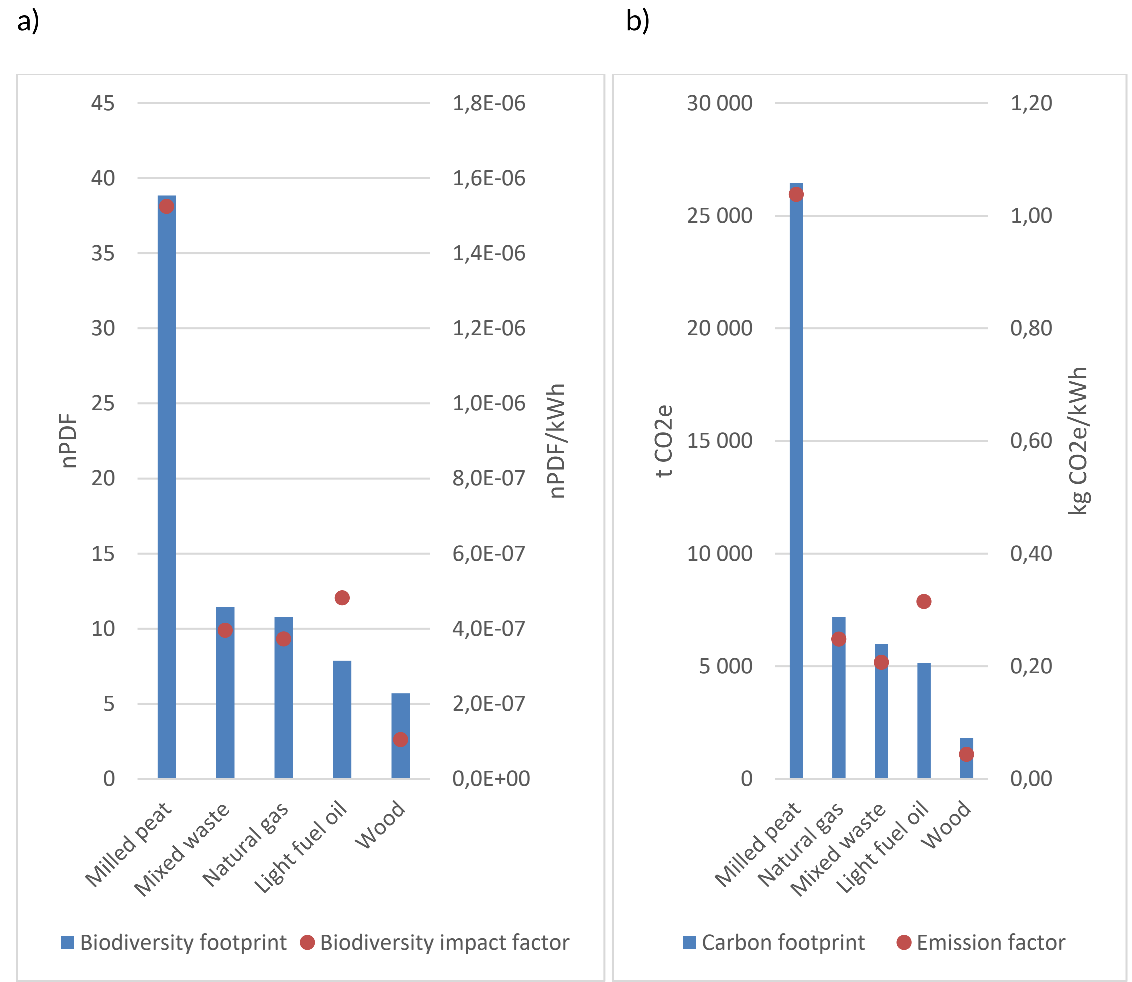


Figure 20. a) Biodiversity footprint generated by heat by energy source and the average biodiversity impact factors of the energy sources (nPDF/kWh) and b) carbon footprint of heat by energy source and the emission factor of the energy sources (kg CO_2e/kWh).

The biodiversity footprint generated by electricity consumption totalled 43.8 nPDF. Wood use accounted for most (80%) of the biodiversity footprint generated by electricity (Figure 21a). Hydropower accounted for only 0.01% of the biodiversity footprint generated by electricity even though it accounted for most of electricity generation. Hydropower electricity has one of the smallest biodiversity impact factors and as a result, it only accounted for a small proportion of the biodiversity footprint. The carbon footprint generated by electricity consumption totalled 8,694 t CO_2e. Burning of mixed waste accounted for the largest proportion (44%) of the carbon footprint (Figure 21b). It was followed by the burning of wood (39%). The biodiversity footprint generated by water consumption was significantly smaller than that of heat and electricity consumption (3.9 nPDF). The carbon footprint generated by water consumption totalled 1,164 t CO_2e. Biodiversity and carbon footprints generated by energy consumption and their amounts in kilowatt hours (kWh) are shown in Appendix 4.

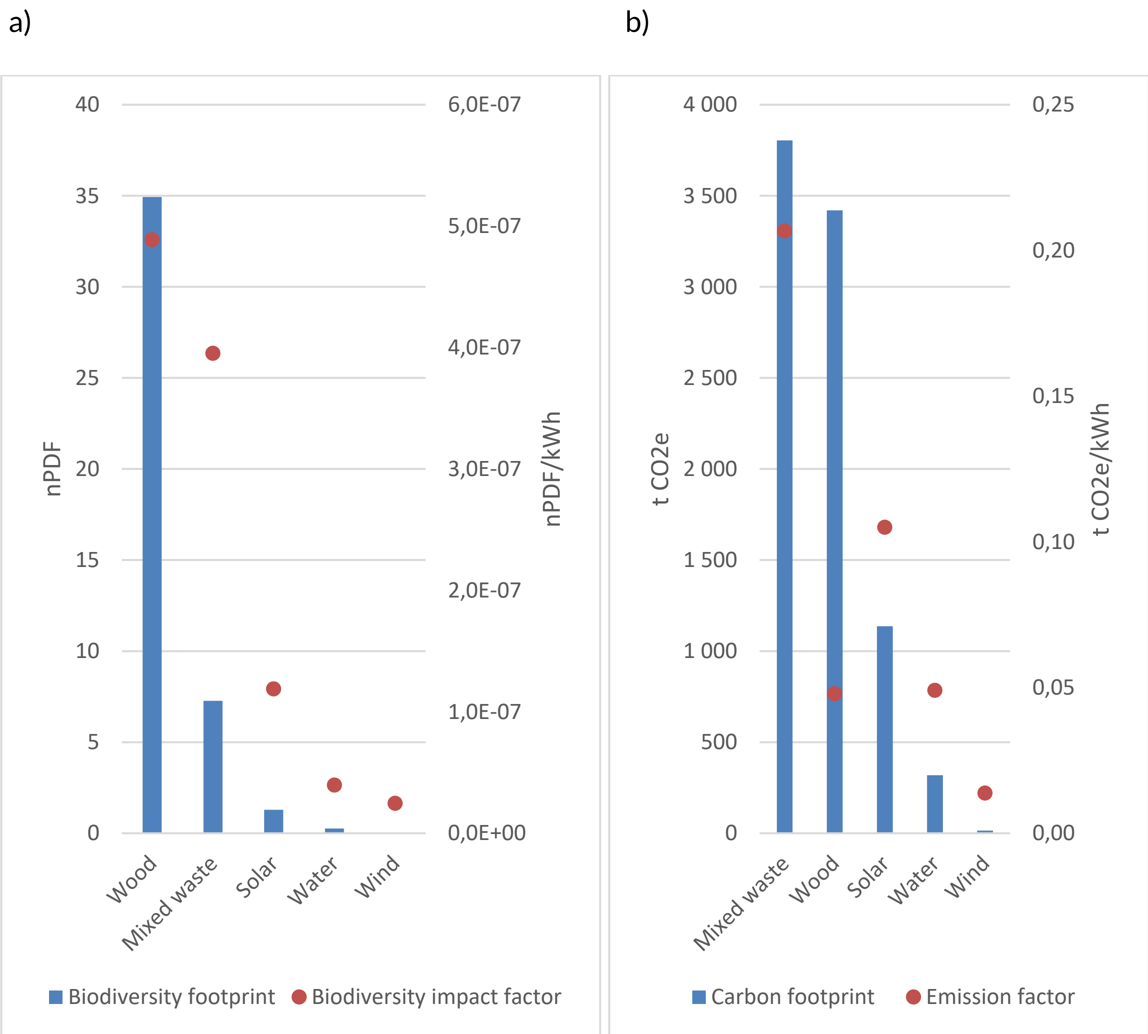


Figure 21. a) Biodiversity footprint generated by electricity consumption by energy source and the average biodiversity impact factor of the energy sources (nPDF/kWh) and b) carbon footprint generated by electricity consumption by energy source and the emission factor of the energy sources (kg CO_2e/kWh).

3.1.4 Waste management

The impacts generated by waste management have been calculated based on the amount of waste collected in Tampere. The impacts arising from the transport of waste could not be taken into account in the calculations. Pirkanmaan Jätehuolto provided data on the expenses generated by different waste fractions in 2021. No data on tonnes of waste was available. To avoid double calculations, the expenses arising from waste have been deleted from the waste collection and laundry services account contained in financial accounting.

The biodiversity footprint generated by waste management amounted to 0.7 nPDF. Special waste accounted for about 60% of the biodiversity footprint generated by waste management (Figure 22a). Special waste comprises the waste accumulating in sand and grease separators and the other waste fractions requiring special treatment. Special waste also accounted for more than 50% of the waste management expenses (Figure 22b). It should be noted that the waste charges vary by waste fraction and thus, the expenses arising from waste fractions do not necessarily directly correlate with the waste volumes.

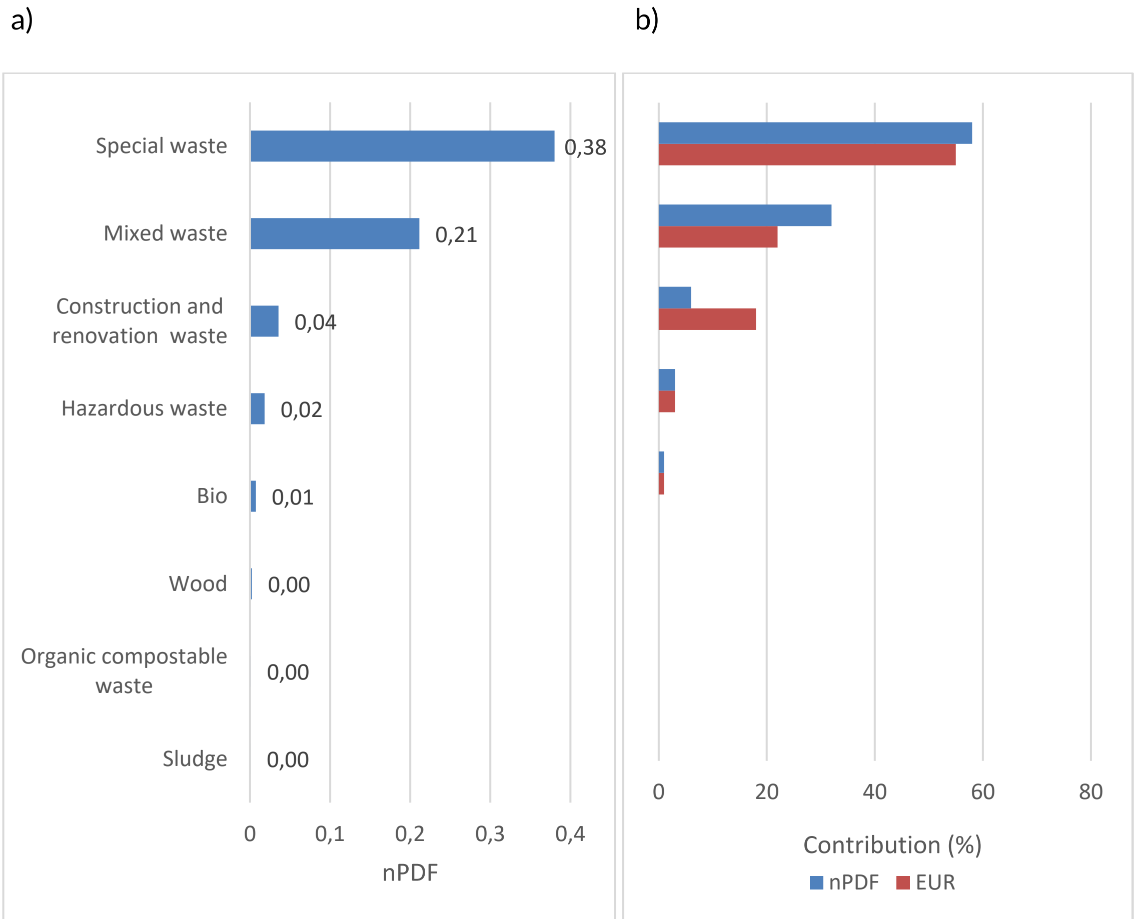


Figure 22. a) Breakdown of biodiversity footprint (nPDF) generated by waste management in different waste fractions and b) breakdown of biodiversity footprint and costs in different waste fractions (%).

Mixed waste generated 32% of the biodiversity footprint of waste management. There is no separate category for mixed waste in EXIOBASE and thus the impacts caused by it were calculated using the impact factor averages of the biowaste, plastic waste and paper waste destined for incineration. EXIOBASE does not contain any impact factors for recyclable waste fractions for Finland. However, recyclable waste fractions, too, generate carbon and biodiversity footprints at other stages of their life cycles, for example, when materials are transported and processed into new products. These could not be taken into account in the calculations. Construction and renovation waste also contains recyclable soil and other materials, for which no impact factors were available either.

The carbon footprint generated by waste management amounted to 300 t CO_2e. Special waste also accounted for most (57%) of the carbon footprint (Figure 23a). Mixed waste was responsible for 34% and construction and renovation waste for 5% of the carbon footprint. Mixed waste has the largest carbon footprint in relation to the money spent on it (Figure 23b). Biowaste only accounted for one per cent of the carbon and biodiversity footprints. The figures do not include the biowaste generated by such parties as Pirkanmaan Voimia Oy. The waste expenses generated by health and social services and rescue services could not be extracted from the waste management data either. The carbon and biodiversity footprints and expenses generated by waste management are shown in Appendix 5.

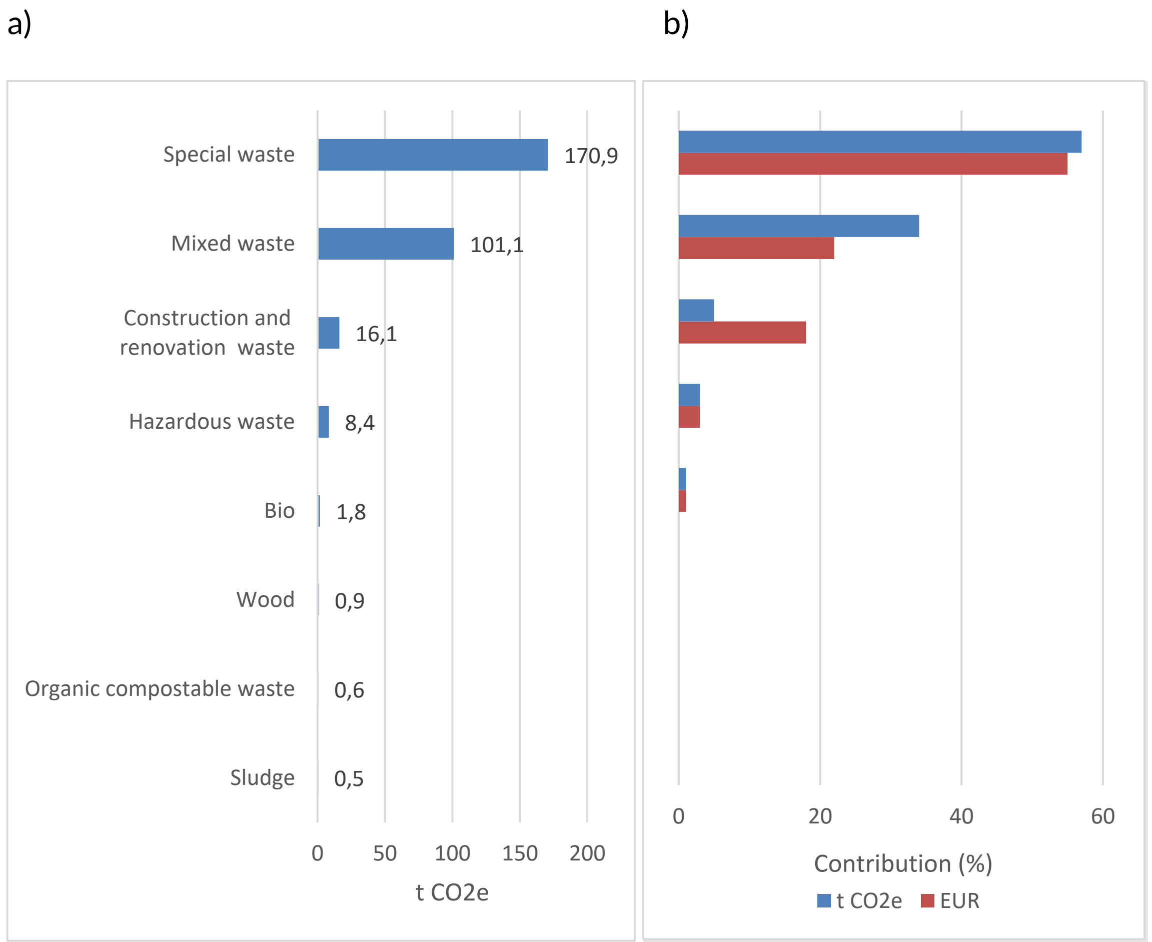


Figure 23. a) Breakdown of carbon footprint (t CO_2e) generated by waste management in different waste fractions and b) breakdown of carbon footprint and expenses in different waste fractions (%).

3.1.5 Work-related travel

The impacts caused by work-related travel were calculated based on kilometres travelled on different modes of transport. Air travel, train travel and car use were examined. The year 2019 was included in the calculations because in 2021, travel was still affected by COVID-19 restrictions. It was not possible to extract the flights and train journeys made by rescue services and health and social services personnel from the rest of the air and train travel data. However, the car use of the personnel of the City of Tampere units and utilities could be extracted from the other work-related car use. To avoid double calculations, the travel account for the personnel contained in financial accounting has been removed from the calculations.

In 2021, about 330,000 km were travelled by air, about 1,075,000 km by car and about 370,000 km by train (Table 2). Number of flights decreased by 90% between 2019 and 2021. Kilometres travelled by train decreased by 85% and car kilometrage by 35%. In kilometre terms, air travel was the most popular mode of transport in 2019 whereas in 2021, most of the journeys were made by car.

Table 2. Kilometres travelled by different modes of transport in 2019 and 2021.

	2019	**2021**
Air travel	3 096 000	331 000
Train travel	2 108 000	374 000
Car use	1 643 000	1 075 000

In 2021, work-related travel generated a biodiversity footprint of 0,5 nPDF and a carbon footprint of 136 t CO_2e. In 2021, car use accounted for 70% of the biodiversity footprint (Figure 24) and 60% of the carbon footprint (Figure 25) generated by work-related travel. Air travel generated 20% of the biodiversity footprint and 40% of the carbon footprint. Carbon and biodiversity footprints generated by work-related travel and the kilometres travelled by mode of transport are shown in Appendix 6.

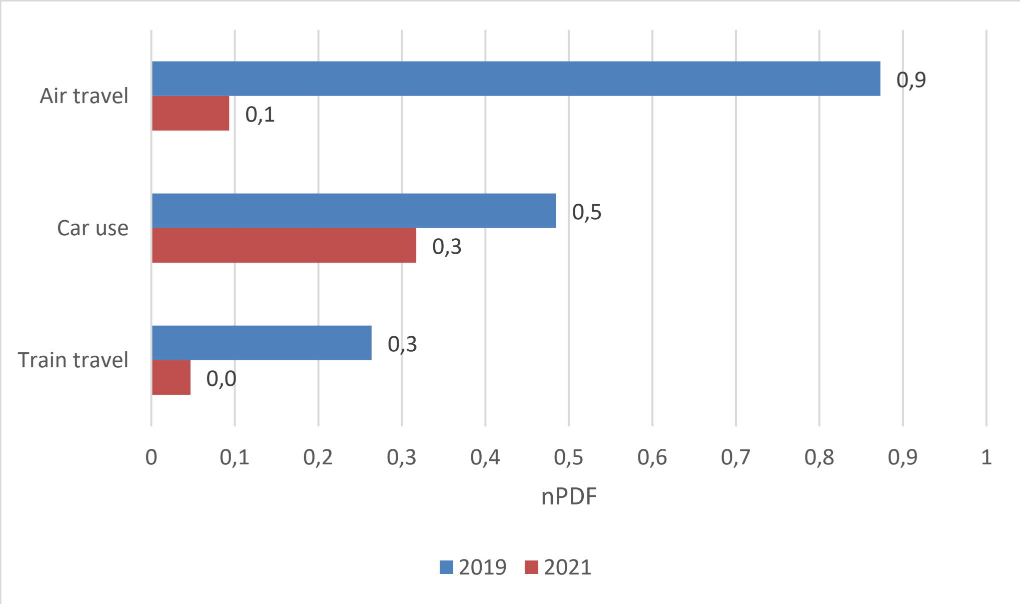


Figure 24. Biodiversity footprint (nPDF) generated by travel by mode of transport in 2019 and 2021.

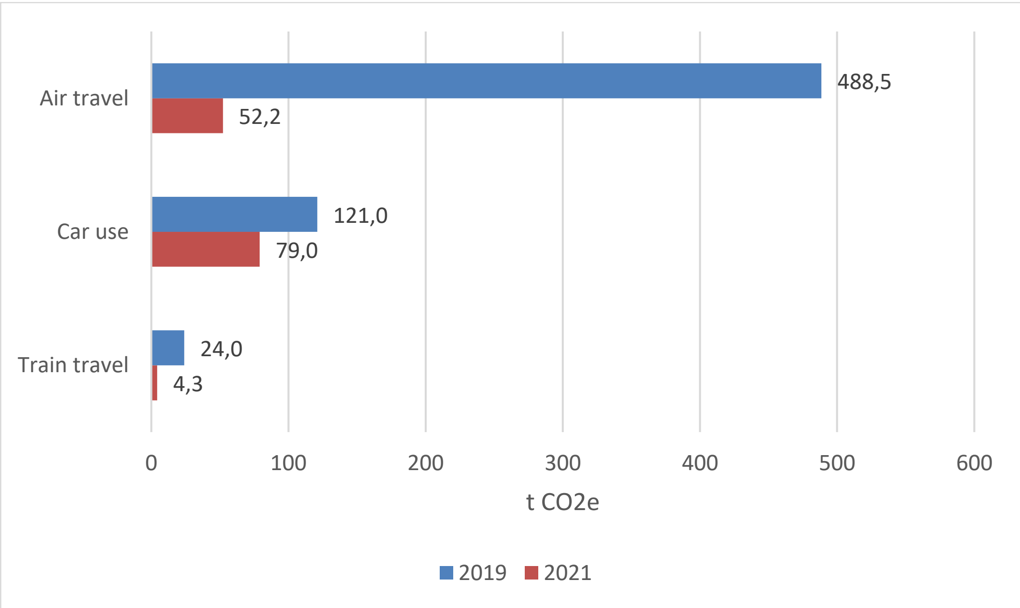


Figure 25. Carbon footprint (t CO_2e) generated by travel by mode of transport in 2019 and 2021.

The City of Tampere unit with the highest amount of car commuting could be determined on the basis of the car use. The Upper Secondary Education unit was the unit with the highest amount of car use in 2019 and 2021 (Figure 26). In all other units (except Tampere Water), kilometres travelled decreased between 2019 and 2021. In Tampere Water, car use increased by 30% between 2019 and 2021. About 33% of all work-related trips in the Upper Secondary Education unit were made by car in 2021. It was followed by Tampere Water (26%) and Culture and Leisure Services (17%).

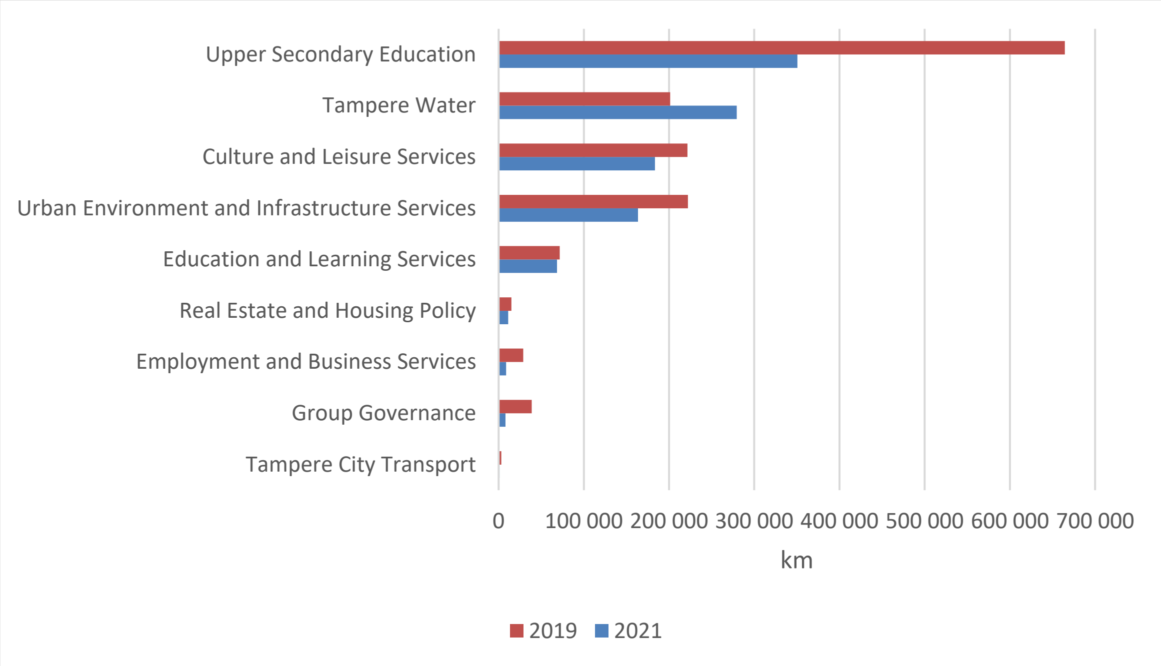


Figure 26. Kilometres travelled by car by unit in 2019 and 2021.

3.1.6 Investments

The financial investments made by the City of Tampere in 2021 were also examined in the project. The impacts were calculated by examining each of the funds in which the City of Tampere had made investments and by determining in which of the companies listed in the funds, investments had been made and in what scale. For many of the funds, only the details of the ten companies attracting the most investments were available. In such cases, the total fund value was proportioned so that the sectors of these top ten companies would correspond to the company breakdown of the fund. The 2021 company breakdown was not available for all funds and for this reason, more recent figures (for 2023) were also used in the calculations. The companies listed in the funds in which the City of Tampere had invested assets were reviewed and combined with the EXIOBASE categories in accordance with the company's sector.

The assets invested by the City of Tampere totalled EUR 153 million in 2021. EUR 29.5 million of this total has been considered in the calculations. Of this sum, EUR 19 million has been invested in funds, EUR 7 million in ETF and index funds and EUR 4 million in real estate funds. Investments in short-term fixed-income funds (EUR 119 million) were not considered in the calculations because they had already been realised (sold). Investments in bonds (EUR 2 million) and capital funds (EUR 179,000) were also left out of the calculations. In addition to companies, many of the funds also invested in currencies and loans issued by governments and these investments accounted for EUR 2.5 million of the funds. These were not considered in the calculations. A total of 27 funds and 2,537 companies were included in the calculations.

The biodiversity footprint generated by the investments amounted to 27.9 nPDF. Investments in electricity companies generated the largest biodiversity footprint (19%) (Figure 27a). Investments in other services (12%), IT services and software (11%) and electronic machinery and equipment (11%) also generated a large biodiversity footprint. The 'other services' category contains companies that could not be placed in any particular EXIOBASE category. In monetary terms, the City of Tampere made the largest investments in other services (17%). They were followed by companies providing real estate agency services (15%) and IT services and software (14%) (Figure 27b). The carbon and biodiversity footprints and expenses generated by investment activities by category are shown in Appendix 7.

a) b)

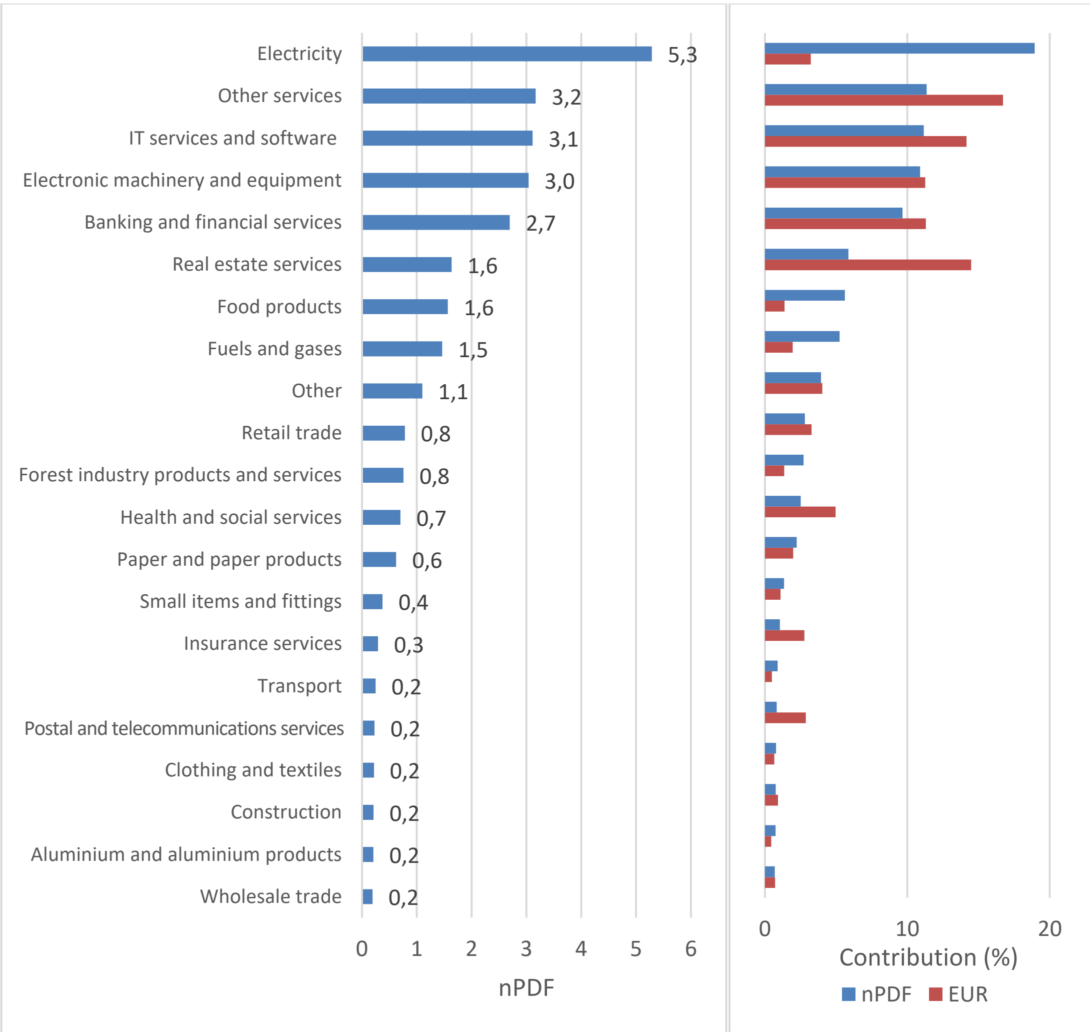


Figure 27. a) Biodiversity footprint (nPDF) generated by investment activities by category and b) breakdown (%) of biodiversity footprint and expenses in different categories.

The carbon footprint of the investments included in the calculations amounted to 10,947 t CO_2e in 2021. Investments in electricity companies generated the largest carbon footprint (32%) (Figure 28a). It was followed by other services (10%) and electronic machinery and equipment (10%). In relation to invested capital, investments in fuels and gases also generated a large carbon footprint (Figure 28b).

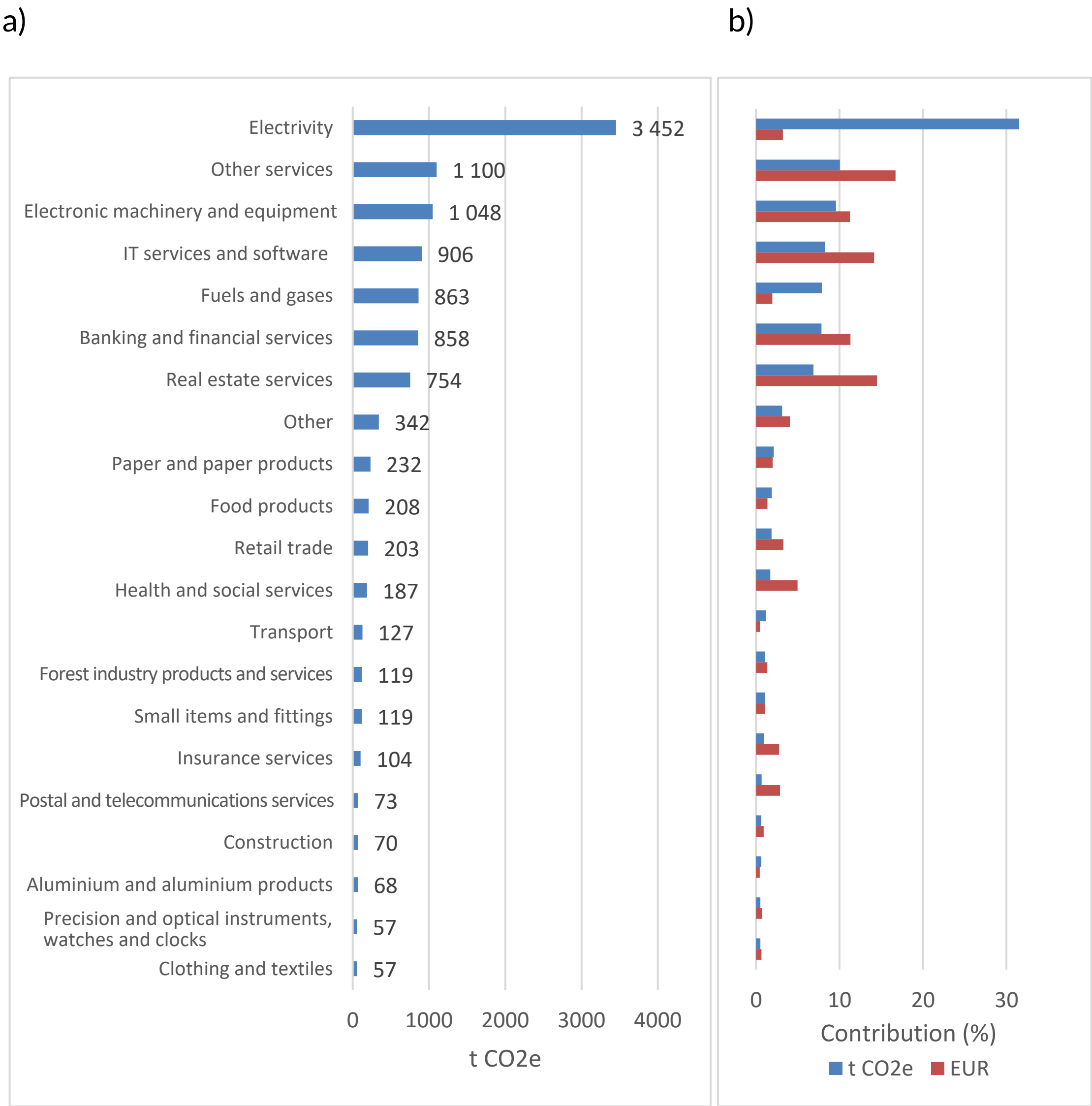


Figure 28. a) Carbon footprint (t CO_2e) generated by investment activities by category and b) breakdown of carbon footprint and expenses in different categories (%).

Investments in electricity companies accounted for 19% of the biodiversity footprint and 32% of the carbon footprint generated by the investments activities. Biomass and waste accounted for 94% of the biodiversity footprint (Figure 29a) and 97% of the carbon footprint (Figure 30a) of the investments in electricity companies. Biomass and waste accounted for 43% and wind power for 40% of the euros invested in electricity companies (Figure 29b). However, wind power only accounted for 3% of the biodiversity footprint and 2% of the carbon footprint. Two companies were responsible for 87% of the biodiversity footprint and 88% of the carbon footprint of the electricity category. These two companies accounted for 39% of the capital invested in the category. The carbon and biodiversity footprints generated by electricity investments and capital invested in euros by category are shown in Appendix 7.

a) b)

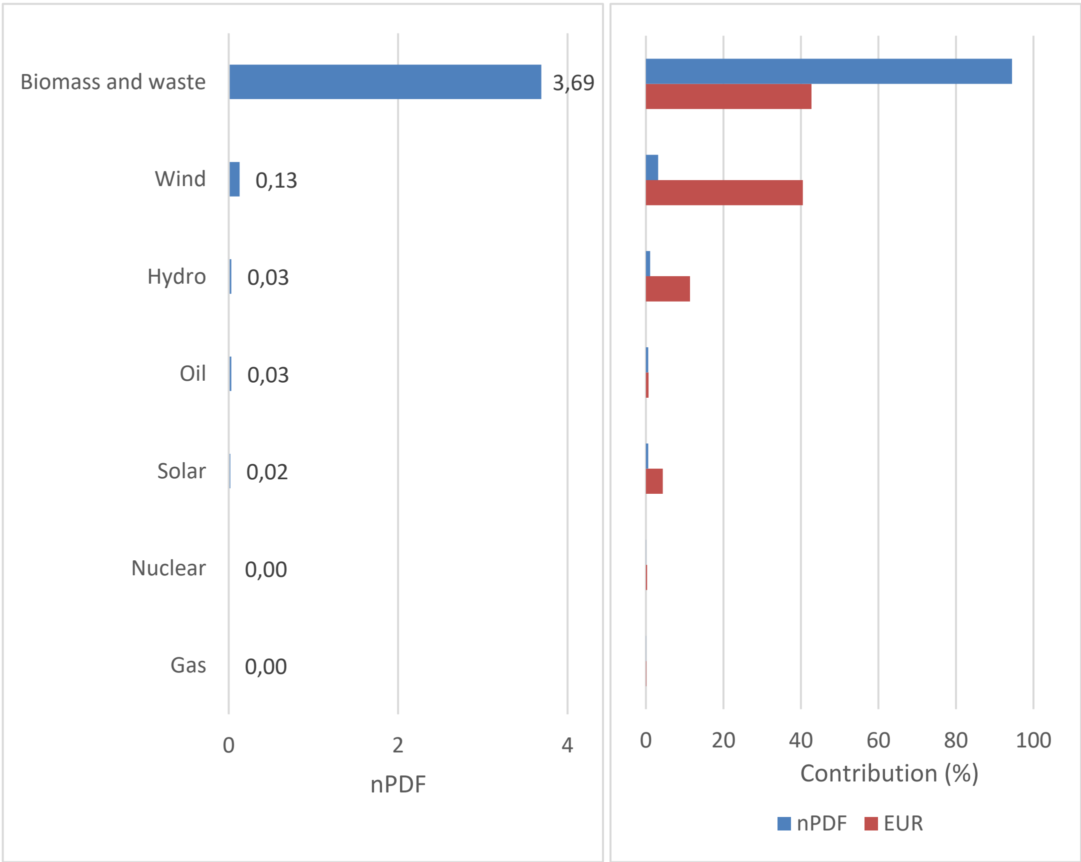


Figure 29. a) Breakdown of the biodiversity footprint (nPDF) generated by investments in electricity companies and b) breakdown (%) of the biodiversity footprint generated by the investments and capital invested in electricity companies in euros in different categories.

a) b)

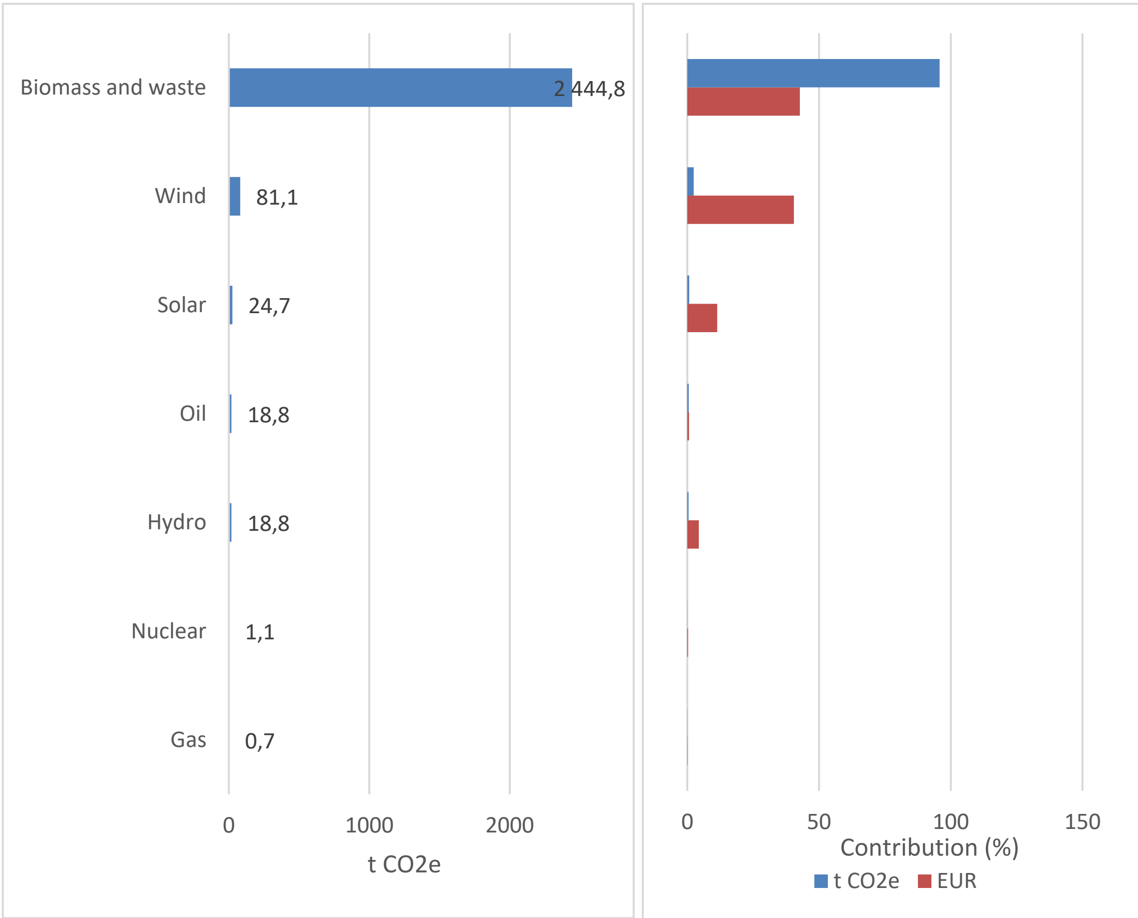


Figure 30. a) Breakdown of the carbon footprint (t CO_2e) generated by investments in electricity companies and b) breakdown (%) of the carbon footprint generated by the investments and capital invested in electricity companies in euros in different categories.

3.2 Carbon and biodiversity footprints of construction projects: renovation of Yliopistonkatu street as an example

The carbon and biodiversity footprints generated by the renovation of the Yliopistonkatu street in Tampere were calculated in the project and used as an example. The impacts generated by the renovation were calculated on euro basis for two different scenarios. The first scenario described 'traditional' street construction and the second scenario resource-wise construction based on the principles of circular economy. The renovation of the Yliopistonkatu street was carried out in a resource-wise manner in accordance with the principles of circular economy. Recycled materials were used and the amount of soil replaced was smaller than in traditional street renovation projects. The costs arising from planning or traffic diversions were not taken into account in the calculations. The data was supplied by the Ihku calculation service, a cost calculation service for the infrastructure sector.

A street renovated in the traditional manner would have generated a biodiversity footprint of 1.0 nPDF and a carbon footprint of 365 t CO_2e. In comparison, a resource-wise street renovation project generated a biodiversity footprint of 0.6 nPDF and a carbon footprint of 240 t CO_2e. In the resource-wise scenario, the biodiversity footprint was 40% and the carbon footprint 35% smaller than in the traditional scenario (Figures 31a and b). The most significant differences between the two scenarios were caused by materials, transport and the use of mobile machinery and other vehicles. The cost difference between traditional and resource-wise construction was 27% in favour of the resource-wise method. Transport was the main source of cost differences between the two scenarios. In the resource-wise scenario, transport costs were 65% lower than in the traditional scenario. For example, soil removed during the work was taken to a nearby construction site instead of a disposal site, which affected the transport costs. In the resource-wise scenario, recycled materials were also extensively used, which reduced the costs of using new materials. Material costs were 37% lower in the resource-wise scenario. Materials accounted for 45% of the biodiversity footprint and 50% of the carbon footprint in both scenarios. There were few fittings-related differences between the two scenarios. The fittings include lighting, traffic signs and benches. The carbon and biodiversity footprints of the Yliopistonkatu street renovation project and the project costs for both scenarios are shown in Appendix 8.

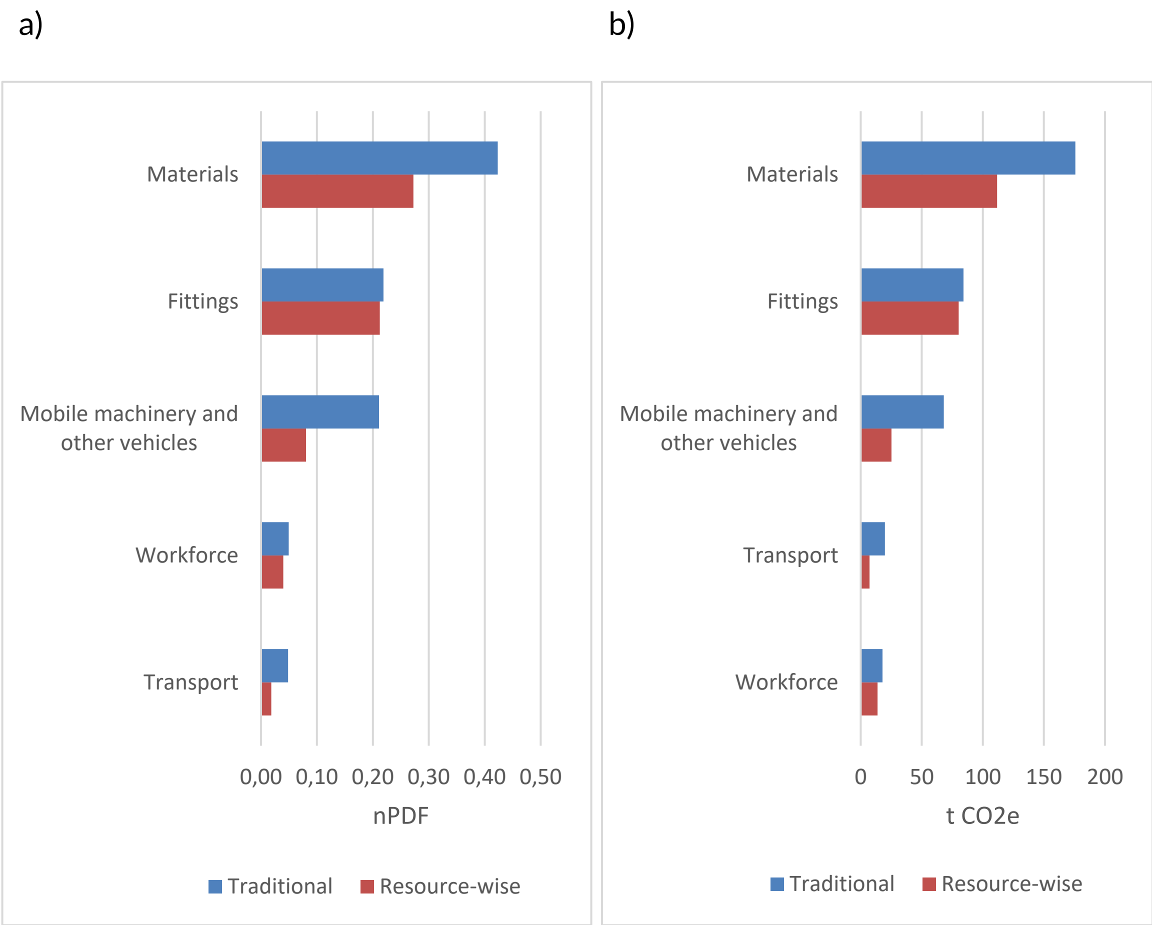


Figure 31. a) Biodiversity footprint (nPDF) generated by traditional and resource-wise street renovation and b) carbon footprint (t CO_2e) generated by traditional and resource-wise street renovation.

Slabs and stones accounted for 40% of the carbon and biodiversity footprints generated by materials in both scenarios (Figures 32a and b). Asphalt was the material with the second largest carbon and biodiversity footprints. The amount of asphalt and soil used was the same in both scenarios. The use of concrete was the most significant difference between the two scenarios. In the traditional scenario, concrete generated 17% of the material biodiversity footprint as against only 4% in the resource-wise scenario. In the resource-wise scenario, the impacts caused by concrete were about 80% smaller than in the traditional scenario. The carbon and biodiversity footprints of materials and expenses generated by the materials in both scenarios are shown in Appendix 8.

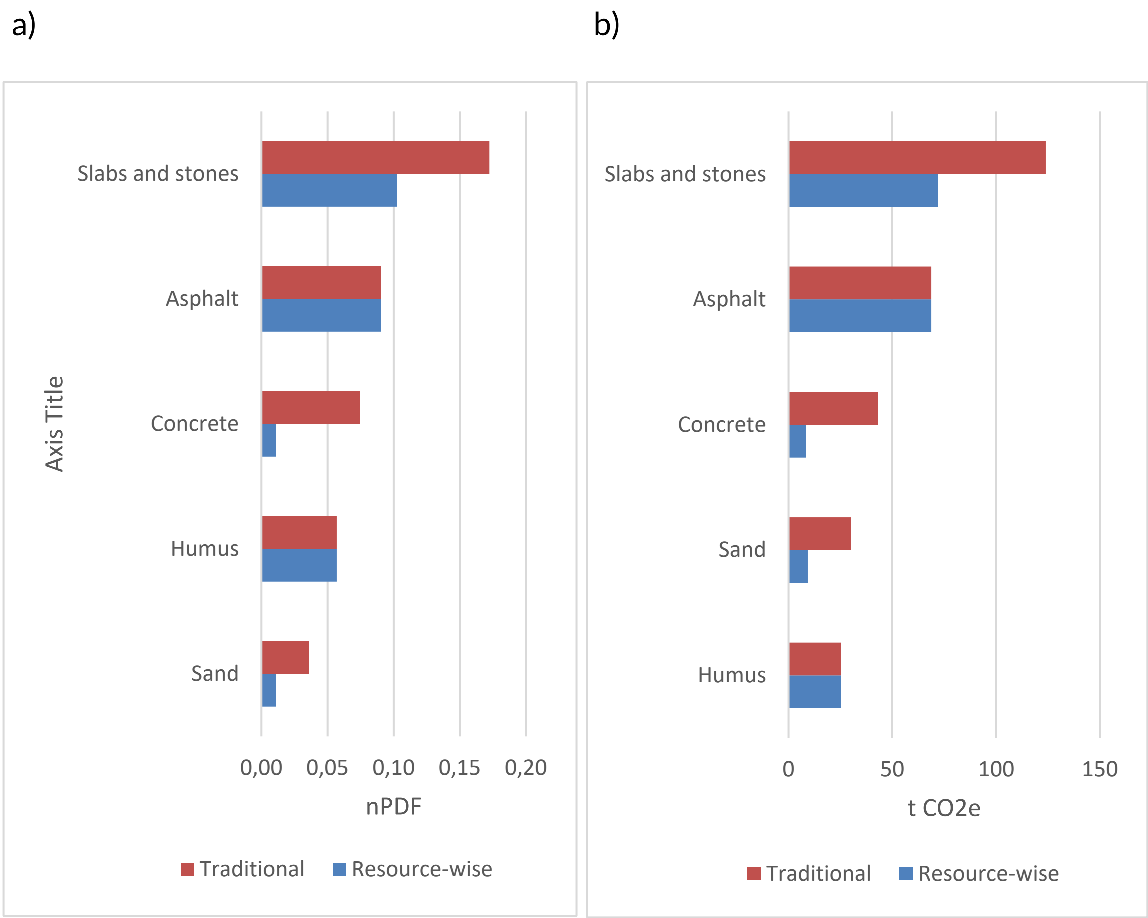
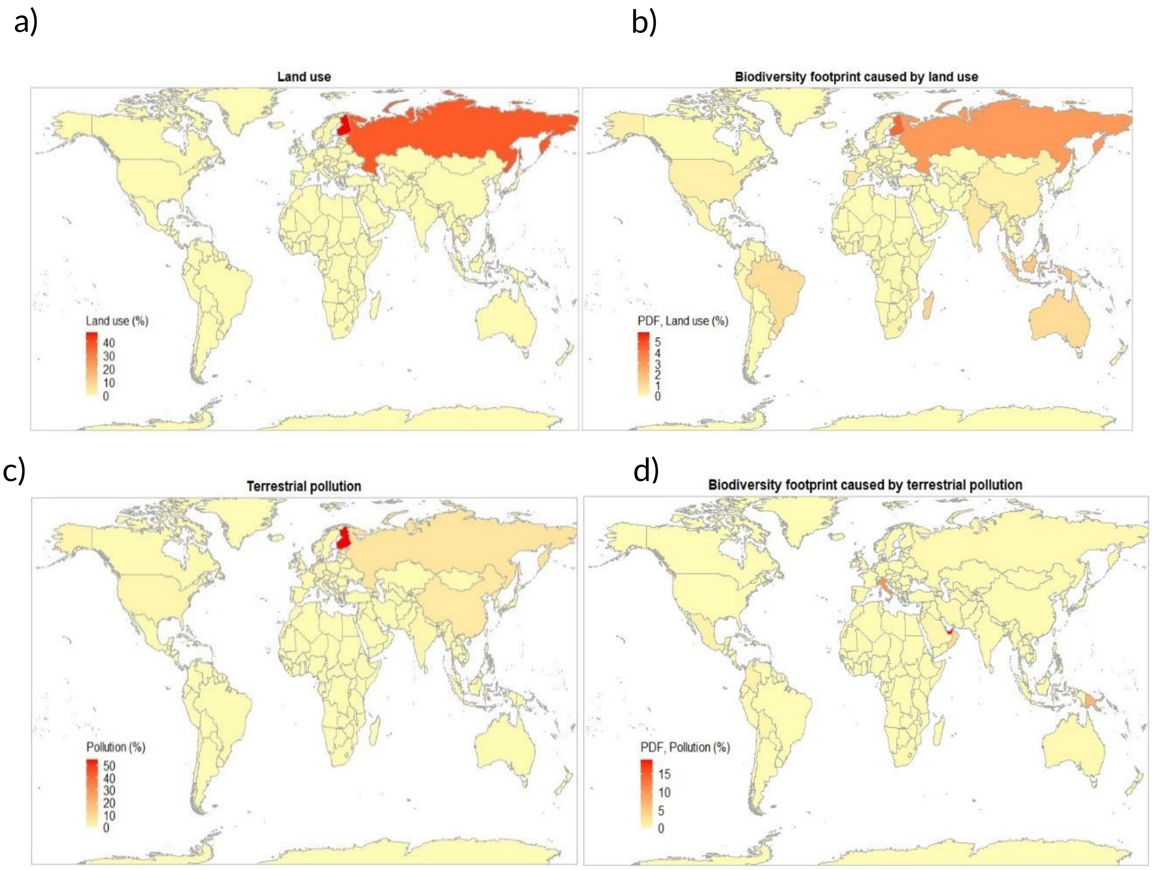


Figure 32. a) Biodiversity footprint (nPDF) generated by materials used in traditional and resource-wise street renovation and b) carbon footprint (t CO_2e) generated by materials used in traditional and resource-wise street renovation.

3.3 Global breakdown of biodiversity footprint

The global breakdown of the biodiversity footprint generated by land and water use and pollution resulting from the procurement could be determined in the project. The calculations are based on the average data on the countries where the inputs of the product categories available in Finland were generated. This means that we do not know in which countries the products purchased by the City of Tampere have been made. It should also be noted that the data used to determine the origin of the biodiversity footprint is based on the global economic structure that existed in 2011. In the future estimates, background data can be updated so that it is at least in accordance with the data for 2019. The distribution of the biodiversity footprint shown in current maps does not take into account the breakdown of the impacts arising from work-related travel and the consumption of energy, water and food products.

Finland accounts for 48% of the land use resulting from the purchases (Figure 33a). Russia comes second (38%) and Estonia third (2%). Even though Finland accounts for almost half of the land use, only 4% of the impacts (biodiversity footprint) caused by land use is generated in Finland. This means that 96% of the biodiversity footprint is generated outside Finland (Figure 32b). Typically, the largest footprints are generated in species-rich countries where land and water use and pollution impact a large number of animal and plant species per unit of area. The largest biodiversity footprints resulting from land use are generated in small island states, such as Guam or São Tomé and Príncipe, which, due to their small size, are difficult to find on the map. Countries generating the largest biodiversity footprints caused by land and water use and pollution are shown in Table 3. A more detailed breakdown of the countries is shown in Appendix 9.



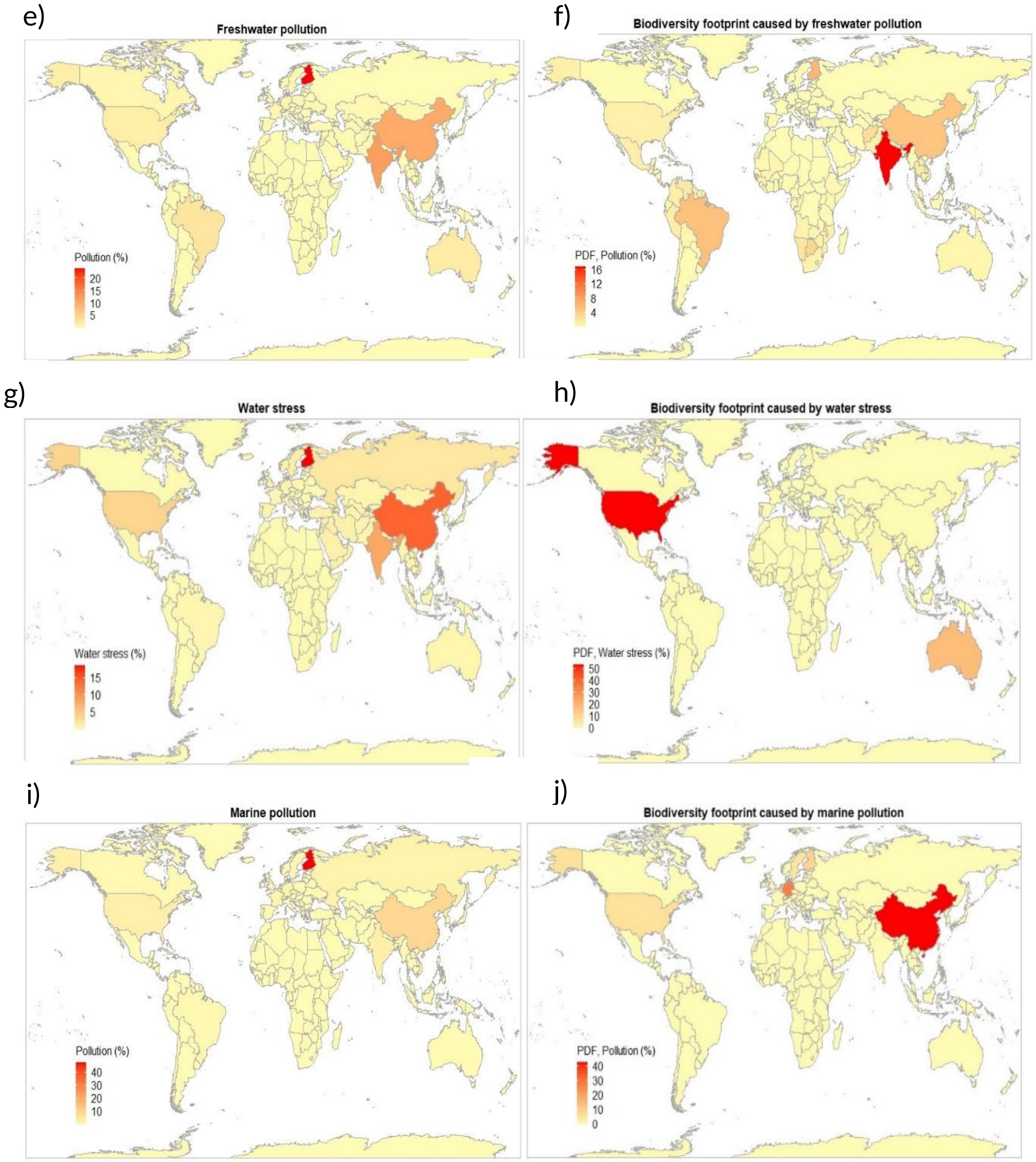


Figure 33. a) Breakdown of land use; b) breakdown of the biodiversity footprint generated by land use; c) breakdown of pollution in terrestrial ecosystems; d) breakdown of the biodiversity footprint generated by pollution in terrestrial ecosystems; e) breakdown of pollution in freshwater ecosystems; f) breakdown of the biodiversity footprint generated by pollution in freshwater ecosystems; g) breakdown of water use; h) breakdown of the biodiversity footprint generated by water use; i) breakdown of pollution in marine ecosystems; and j) breakdown of the biodiversity footprint generated by pollution in marine ecosystems.

Table 3. Percentage of land and water use and pollution generated in the three countries causing the biggest impact and the percentage of the biodiversity footprints that they have generated in the three most highly affected countries.

Land use (m^2)	**%**	**Biodiversity footprint (PDF)**	**%**
Finland	48	Guam	6
Russia	38	São Tomé and Príncipe	5
Estonia	2	Northern Mariana Islands	5
Pollution terrestrial ecosystems (kg)		**Biodiversity footprint (PDF)**	
Finland	55	United Arab Emirates	19
Russia	7	Palestine	13
China	5	Cyprus	11
Pollution freshwater ecosystems (kg)		**Biodiversity footprint (PDF)**	
Finland	24	India	17
India	12	Finland	6
China	10	Brazil	5
Water use (kg)		**Biodiversity footprint (PDF)**	
Finland	19	USA	54
China	14	Australia	18
India	8	Bahamas	5
Pollution marine ecosystems (kg)		**Biodiversity footprint (PDF)**	
Finland	48	China	43
China	9	Germany	28
India	3	Finland	9

The difference between the direct drivers of biodiversity loss affecting Finland and the global biodiversity footprint is caused by the fact that in Finland, the abundance of species or the number of endemic species per unit of area is lower than in such countries as Brazil. Species and numbers of species are not equally distributed around the globe. Unequal distribution means that the same amount of such activities as land use does not cause the same amount of global biodiversity impact in different parts of the world. In regions with a high abundance of species per unit of area, the biodiversity footprint generated by the same amount of land use is larger. However, local biodiversity footprint may be large in regions that are not affected by a large global biodiversity footprint but that are nevertheless affected by harmful environmental impacts. Regions that are not important to global fauna and flora may nevertheless be important to local species, ecosystems and ecosystem services (Verones et al., 2021; Marques et al., 2017).

3.4 Monitoring biodiversity and carbon footprints

The City of Tampere also entered the project results in a Power BI report so that the impacts can be monitored and compared (Figures 34 and 35). Power BI is a Microsoft tool for interactive data analysis and visualisation. In the Power BI report, the carbon and biodiversity footprints generated by the City of Tampere can be examined at annual level and (by filtering the results) at the level of product categories or between units and utilities. The report shows the results from 2019 to the present and it covers the same city organisation units for which the calculations were made in this report on carbon and biodiversity footprints. The Power BI report gives a good overview of the biodiversity footprints of the City of Tampere. It can be used as a tool for continuous monitoring and content filtering allows highly detailed monitoring.

When comparisons are made between the results, it should be noted that the Power BI report is directly based on the accounting data taken from the income statement. Thus, the data on such activities as the procurement of food products is not as accurate as the figures in this report. Likewise, the financial investments made by the City of Tampere are not described in the Power BI report. The Power BI report can only be viewed by internal City of Tampere actors.

However, to ensure up-to-date results in the future, it must be ensured that the income statement data is automatically updated for the report and that the carbon and biodiversity footprint factors are regularly updated so that they can be used as background information for the report. A good basis for such activities already exists because a University of Jyväskylä research group is planning to publish and update the impacts factors on an open basis.

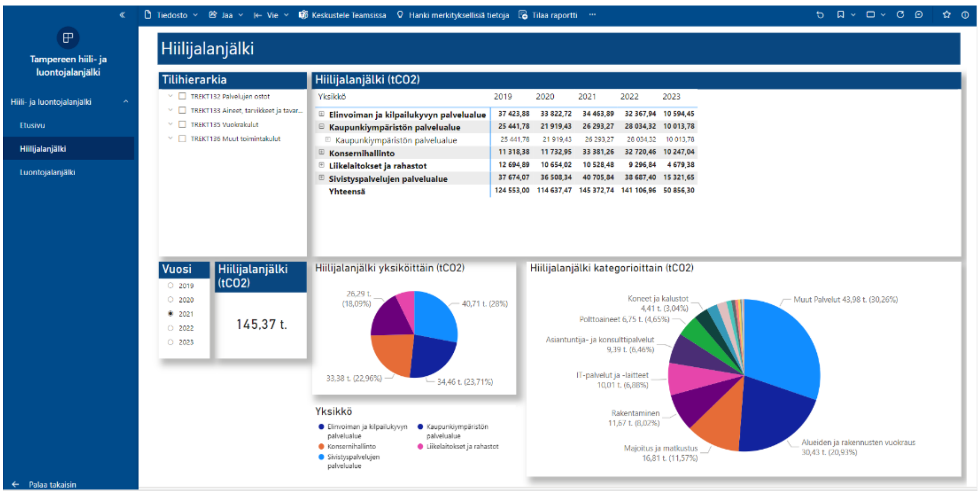


Figure 34. City of Tampere carbon footprint data in the Power BI report (in Finnish).

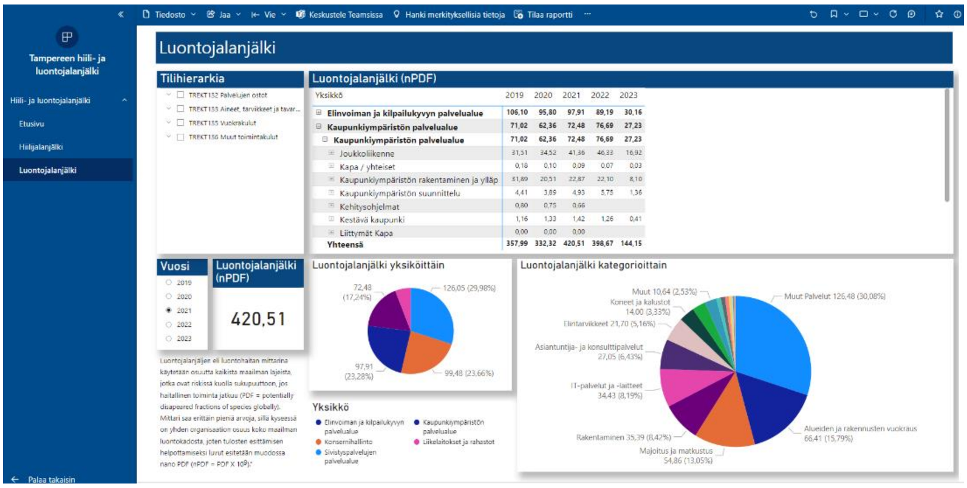


Figure 35. City of Tampere biodiversity footprint data in the Power BI report (in Finnish).

4 REDUCING THE FOOTPRINTS

The best way to reduce the carbon and biodiversity footprints is to avoid causing harmful impacts. However, this is not always possible and in such cases, the impacts should be minimised or offset or the degraded nature should be restored. In the mitigation hierarchy, a principle developed to safeguard biodiversity, the adverse impacts on nature caused by human activity should primarily be avoided, secondarily minimised and, as a last resort, offset ecologically and by restoring degraded nature on site (Figure 36) (Moilanen and Kotiaho, 2021; Sitra, 2022). The first three steps of the mitigation hierarchy are also suited for reducing the carbon footprint.

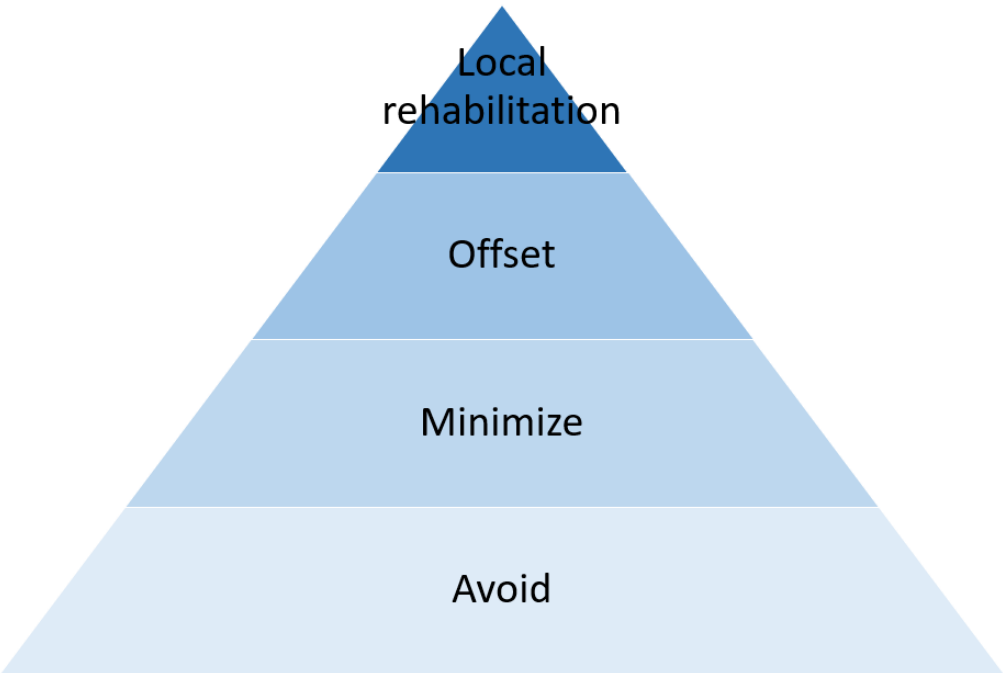


Figure 36. Levels of mitigation hierarchy (Moilanen and Kotiaho, 2021).

The mitigation hierarchy can be applied by taking measures to avoid and minimise the impacts. This can be made, for example, by avoiding unnecessary consumption and by using products and commodities generating minimum biodiversity impact. For example, instead of constructing new buildings, we should renovate old buildings. The carbon and biodiversity footprints generated by renovation are probably smaller than the footprints arising from new construction, as is shown by the comparisons between the carbon and biodiversity footprints generated by traditional and resource-wise renovation of the Yliopistonkatu street. Global biodiversity impacts can also be reduced by avoiding purchasing products from countries that are characterised by exceptionally rich biodiversity. Other alternatives include leasing or borrowing items instead of buying new ones. Organisations should integrate the measures and principles described above into their procurement principles and operating cultures.

The carbon and biodiversity footprints generated by construction can be reduced by observing the principle of circular economy. In the renovation of the Yliopistonkatu street, applying circular economy principles reduced the impacts caused by the work by 35%. If the circular economy principles were used in all construction, City of Tampere could reduce its total carbon footprint by 5% and its total biodiversity footprint by 4% (Table 4).

Table 4. Proposals for reducing carbon and biodiversity footprints and the estimated impact reduction potential of the proposed measures. The impact reduction potential is the percentage of the carbon and biodiversity footprints that can reduced by applying each of the measures when examined at the level of the category or the City of Tampere as a whole.

		Impact reduction potential			
Category	**Reduction measure**	**Biodiversity footprint of the category (%)**	**City of Tampere biodiversity foot-print (%)**	**Carbon footprint of the category (%)**	**City of Tampere carbon footprint (%)**
Other operating economy	Construction based on circular economy principles	9	4	9	5
Food products	Reducing the use of red meat by 50% and replacing it with soya products	17	3	18	2
	Reducing the use of dairy products by 50% and replacing them with oat-based products	11	2	4	0.4
Energy and water	Reducing heat consumption by 20%	13	3	16	4
	Reducing electricity consumption by 20%	7	2	3	0.8
	Reducing water consumption by 20%	1	0.1	0.4	0.1
	Replacing peat, natural gas and fuel oil in heat generation with wood	41	9	61	17
	Replacing peat, natural gas and fuel oil in heat generation with geothermal heat, heat pumps and wind energy	36	8	57	15
Waste management	Reducing the amount of mixed waste by 50%	15	0.02	17	0.02
Work-related travel	Reducing car use by 50% and replacing these trips with train travel	18	0.02	24	0.02
	Reducing air travel by 50% and replacing these trips with train travel	4	0.004	17	0.01
Total			**14–18 %**		**12–24 %**

The carbon and biodiversity footprints of the food products can be reduced by purchasing less red meat and fewer dairy products and by replacing them with plant-based products. If the purchases of red meat were reduced by 50% and replaced with the same kilogramme amount of soya products (such as tofu), the carbon footprint of the food products could be reduced by 18% and their biodiversity footprint by 17%. If the purchases of dairy products were reduced by 50% and replaced with oat-based products, the carbon footprint of the food products could be reduced by 4% and their biodiversity footprint by 11%. These measures could reduce the total carbon footprint of the City of Tampere by 2.5% and its total biodiversity footprint by 5%.

The impacts arising from energy and water consumption can be reduced by consuming less heat, electricity and water. If the consumption of energy and water was reduced by 20%, the total carbon footprint of the City of Tampere would be reduced by 4% and its total biodiversity footprint by 5%. Peat and fossil fuels (such as natural gas) account for a large proportion of the biodiversity footprint arising from heat consumption. Replacing the existing district heat generating methods with district heat produced with less damaging energy sources could significantly impact the footprints generated by heat. If peat, natural gas and light fuel oil used in the generation of district heat were replaced with geothermal heat, heat pumps and wind energy, as proposed by Rinne et al. (2019), the carbon footprint of energy and water consumption would decrease by 57% and their biodiversity footprint by 36%. The total carbon and biodiversity footprints generated by the City of Tampere would be reduced by 15% and 8%, respectively. On the other hand, if the peat, natural gas and light fuel oil used in district heat generation were replaced with the burning of wood, the carbon footprint caused by the consumption of energy and water could be reduced by 61% and the biodiversity footprint by 41%. In overall terms, this would reduce the carbon and biodiversity footprints of the City of Tampere by 17% and 9%, respectively. However, changing over to wood burning should be seen as an interim measure or a partial solution because according to other studies, using wood as an energy source is problematic from the perspective of climate change and biodiversity loss (Norton et al., 2019; Rehbein et al., 2020; Santangeli et al., 2016a, 2016b; Vainio et al., preprint).

The carbon and biodiversity footprints generated by waste management can be decreased by reducing the amount of mixed waste. The amount of mixed waste can be reduced by improving recycling because mixed waste mostly consists of recyclable waste such as plastic and glass packaging (Suomen Kiertovoima, 2023). Reducing mixed waste by 50% could decrease the carbon footprint caused by waste management by 17% and its biodiversity footprint by 15%. However, reducing the amount of mixed waste would decrease the total carbon and biodiversity footprints of the City of Tampere by less than one per cent.

The footprints of work-related travel can be decreased by reducing car use and by using more public transport. If car use was reduced by 50% and these trips were replaced with train travel, the carbon footprint of work-related travel could decrease by 24% and its biodiversity footprint by 18%. Air travel decreased considerably between 2019 and 2021 but it may already have returned to 2019 levels (Varanka et al., 2022). However, on a case-by-case basis, air travel could also be replaced with road travel. If 50% of the air trips made in 2021 were replaced with train travel, the carbon footprint arising from work-related travel could be reduced by 17% and its biodiversity footprint by 4%. They would, however, only have a minor impact on the total carbon and biodiversity footprints generated by the City of Tampere. However, as air travel is increasing they might have a more significant impact in the future.

5 EXAMINING THE RESULTS AND FURTHER ACTION

The project results show that a biodiversity footprint can also be calculated for a city organisation. In Finland, biodiversity footprint has already been calculated for such organisations as S Group and the University of Jyväskylä. In relation to the number of its employees, the biodiversity footprint of S Group amounted to 0.9 nPDF/employee (Peura et al., 2023). The figure for the City of Tampere organisation was 0.07 nPDF (after the exclusion of the Health and Social Services and Rescue Services personnel) and for the University of Jyväskylä, 0.01 nPDF (El Geneidy et al., 2023). However, there are major differences between these organisations. The biodiversity footprints of S Group and the City of Tampere organisation were mostly generated by food products. However, in S Group, food products accounted for a significantly larger proportion of the biodiversity footprint than in the City of Tampere. At the same time, most of the biodiversity footprint generated by the University of Jyväskylä resulted from IT equipment.

Food products were the biggest source of biodiversity footprint and the second-biggest source of carbon footprint in the City of Tampere organisation (Figure 37). Red meat was the food product causing the largest carbon and biodiversity footprints. Dairy products, poultry products and cereal products were other major sources of footprints. When the footprints for food products are calculated, the countries where the raw materials originate are not always considered when the country-specific impact factor is determined. For example, Finland is given as the country of origin for coffee, which means that the countries where the coffee beans come from cannot be taken into account in the calculations. Moreover, the calculation method does not allow detailed comparisons between products within a product category and it is not yet possible to use the method to determine differences between organic products and conventional products. However, the global biodiversity impact caused by domestic products and the land use in Finland resulting from them are in a smaller scale than in many other countries. At the moment, the biodiversity impact generated by water use and phosphorus emissions is not taken into account in the calculation of food products. Including them would also allow the consideration of the impacts affecting freshwater ecosystems in the calculations.

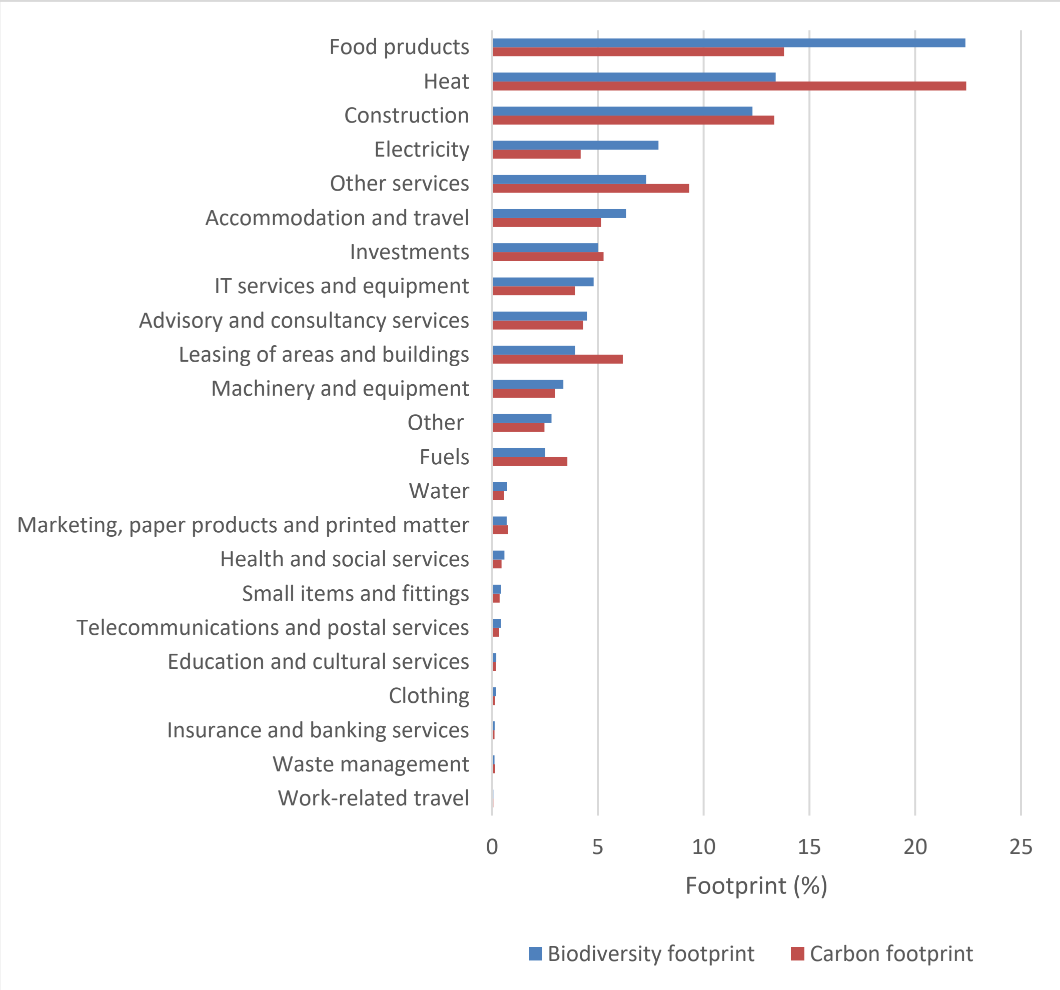


Figure 37. Contributions of categories to carbon and biodiversity footprints.

Heat consumption caused by far the largest carbon footprint. In the district heat used by the City of Tampere, milled peat accounted for most of the carbon and biodiversity footprints generated by heat. However, one third of the district heat was generated with wood. Most of the wood burned in the process consists of forest industry by-products but whole-tree wood is also used. Wood is also used in electricity generation, which increases the biodiversity footprint produced by electricity. On average, wood has a substantially higher biodiversity impact factor than the other renewable energy sources. Even though wood and forests are a renewable natural resource, they may not necessarily be the most sustainable way of generating heat. Forests produce a wide range of different ecosystem services, which means that they are also important to the climate and the welfare of animals and plants (European Environment Agency, 2016).

The calculation method also proved suitable for calculating the biodiversity impacts generated by investments. Most of the biodiversity impacts caused by investments are generated by companies producing renewable energy, which is partly because they have attracted substantial investments. In funds, investments were also made in companies generating energy with oil and natural gas. There are still uncertainties regarding the emission and biodiversity impact factors of electricity, and changes concerning them will be made to the EXIOBASE database in the future. At the moment, the energy generated from such sources as biomass and waste has a higher emission factor than the energy generated with oil.

Special waste accounted for 60% of the carbon and biodiversity footprints of waste management. Special waste contained substantial amounts of such substances as waste accumulating in sand and grease separators. At the moment, the calculation of the impacts caused by waste management is based on the money spent on different waste fractions. Calculating the impacts arising from waste management on the basis of the waste (tonnes) collected would provide a more accurate picture of which waste fractions cause the most substantial impacts. At the moment, the results partially depend on the prices charged for processing waste fractions. Food biowaste produced by Pirkanmaan Voimia Oy and generated in such places as schools is not considered in the calculations either but it should be taken into account in the calculations in the future.

The results of the Yliopistonkatu street renovation show that a street renovation project based on the principles of circular economy will generate significantly smaller carbon and biodiversity footprints than the use of traditional renovation methods. The use of recycled materials and waste soil means less consumption of materials and less transport kilometrage. Using the principles of circular economy would also substantially reduce the impacts arising from construction in other areas.

The titles of the accounts contained in financial accounting do not necessarily give any indication of the purchases included in the accounts. The contents of the accounts should be examined in more detail so that a more detailed breakdown between EXIOBASE categories could be made. For example, food products are also contained in other accounts than the food products account. Moreover, it was impossible to specify the services contained in service accounts. Calculations based on purchase invoices might produce more accurate results.

As the environmental impacts of adverse climate emissions are also taken into account in the calculation of the biodiversity footprint, the carbon footprint must, in practice, always be determined when the biodiversity footprint is calculated. Climate change was responsible for about half of the biodiversity footprint generated by the City of Tampere organisation. This means that, according to current estimates, if measures are taken to reduce the biodiversity footprint, the carbon footprint will probably also decrease. However, all measures to reduce carbon footprint do not necessarily reduce the biodiversity footprint; in fact, the impacts may even be negative (Pörtner et al., 2021). Such risks arise from the use of bioenergy, for example. For example, in electricity generation, wood use has a lower emission factor than solar energy or the burning of mixed waste. If mixed waste or solar energy were replaced with wood in electricity generation, the carbon footprint generated by electricity would be reduced but the biodiversity footprint would increase because wood has a higher average biodiversity impact factor than any of the other currently used sources of electrical energy.

In food products, too, the adverse impacts of a product may vary, depending on whether the focus is on the carbon footprint or the biodiversity footprint. Red meat is the food product category with by far the highest average biodiversity impact and emission factors per kilogramme. Dairy products is the food product category with the second largest biodiversity footprint, while fish and other seafood are the food products with the second largest carbon footprint. From the perspective of the carbon footprint, poultry would be the best meat product but from the perspective of the biodiversity footprint, use of fish and other seafood would be best option. The average biodiversity impact factor of poultry is about 1.5 times higher per kilo than that of fish and other seafood while the emission factor of fish and other seafood per kilo is more than twice as high than that of poultry.

With the calculation method used in this project, the impact of different types of land use, water use, pollution and climate change can be taken into account when the biodiversity footprint is determined (Verones et al., 2020). Generally speaking, the biodiversity footprints affecting terrestrial ecosystems would seem to be most reliable of the biodiversity footprints produced by the method combining the EXIOBASE and LC-IMPACT databases (Verones et al., 2020). In particular, the method contained in the LC-IMPACT database and used to calculate the biodiversity footprint affecting marine ecosystems still needs improvement. In the calculation of the biodiversity footprint of the marine ecosystems, work is under way to develop a method that would take into account the impacts of plastic waste ending up in seas (Hoiberg et al., 2022). The method does not yet take into account such drivers of biodiversity loss as the impact of invasive alien species on the biodiversity footprint. The method used would seem to be as comprehensive as the other comprehensive calculation models already in use (Crenna et al., 2020; Damiani et al., 2023; Lammerant et al., 2022).

Biodiversity footprint indicators are typically based on the state and extent of the ecosystems or the vitality of the species (Marques et al., 2017; UNEP-WCMC et al., 2022). The global PDF currently in use may be difficult to perceive as the figures are often very small. However, with this indicator, the biodiversity footprint can be calculated for many different environmental impacts on a global scale and in a comparable manner. The global PDF could develop into a general biodiversity footprint indicator and become a biodiversity equivalent comparable with the carbon dioxide equivalent (El Geneidy et al., 2023).

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Appendices

Appendix 1

Categories	nPDF	t CO_2e	EUR
Food products	124.6	28 665	13 912 000
Heat	74.7	46 573	571 071
Construction	68.5	27 718	137 103 809
Electricity	43.8	8 694	4 485 461
Other services	40.6	19 369	86 582 491
Accommodation and travel	35.3	10 716	59 291 676
Investments	27.9	10 948	29 504 785
IT services and equipment	26.7	8 153	34 105 567
Advisory and consultancy services	25.0	8 955	40 289 183
Leasing of areas and buildings	21.9	12 840	74 434 911
Machinery and equipment	18.8	6 180	21 034 155
Other	15.6	5 140	17 357 431
Fuels	14.0	7 396	4 578 155
Water	4.0	1 164	3 242 438
Marketing, paper products and printed matter	3.8	1 563	7 191 935
Health and social services	3.2	926	6 251 005
Small items and fittings	2.3	749	2 035 390
Telecommunications and postal services	2.3	696	3 634 409
Education and cultural services	1.1	371	4 106 301
Clothing	1.0	275	963 433
Insurance and banking services	0.7	246	1 935 454
Waste management	0.7	300	374 282
Work-related travel	0.4	136	512 215

Appendix 1. Carbon and biodiversity footprints and expenses of consumption categories (EUR).

Appendix 2

	Education and learning services	Culture and leisure services	Upper secondary education	Real estate and housing policy	Employment and business services	Urban environment and infrastructure services	Central administration	Tampere City Transport	Tampere Water
IT services and equipment	13	2	8	0	1	5	67	0	2
Telecommunications and postal services	7	3	5	0	1	2	77	1	3
Accommodation and travel	49	1	9	0	0	39	0	0	1
Construction	0	12	0	36	0	40	0	0	12
Health and social services	63	2	19	1	2	5	4	4	2
Small items and fittings	68	1	16	0	3	5	5	1	1
Marketing, paper products and printed matter	53	1	25	1	3	8	8	0	1
Leasing of areas and buildings	0	0	21	62	0	17	0	0	0
Education and cultural services	10	1	72	2	3	5	6	0	1
Insurance and banking services	9	0	13	2	10	1	36	28	0
Other services	48	3	2	33	7	3	1	0	3
Other	10	12	16	3	1	23	17	5	12
Advisory and consultancy services	5	4	3	22	21	28	12	0	4
Heat	0	3	18	0	0	32	3	0	44
Clothing	23	7	54	1	0	2	3	3	7
Electricity	0	5	4	1	0	41	0	1	48
Water	0	0	0	0	0	0	0	0	100
Fuels	1	2	0	0	0	0	0	95	2
Machinery and equipment	15	6	14	2	2	40	1	15	6

Appendix 2a. Contributions (%) of the City of Tampere units to the biodiversity footprint generated by consumption categories. The largest contributions are marked in red.

	Education and learning services	Culture and leisure services	Upper secondary education	Real estate and housing policy	Employment and business services	Urban environment and infrastructure services	Central administration	Tampere City Transport	Tampere Water
IT services and equipment	3.7	0.6	2.3	0.1	0.4	1.3	**18.9**	0.1	0.6
Telecommunications and postal services	0.2	0.1	0.1	0.0	0.0	0.0	**1.9**	0.0	0.1
Accommodation and travel	**21.2**	0.5	3.7	0.0	0,1	1.,9	0.2	0.0	0,5
Construction	0.1	9.0	0.3	2.,4	0.2	**31.1**	0.0	0.0	9.0
Health and social services	**1.9**	0.1	0.6	0.0	0.1	0.1	0.1	0.1	0.1
Small items and fittings	**1.4**	0.0	0.3	0.0	0.1	0.1	0.1	0.0	0.0
Marketing, paper products and printed matter	**1.5**	0.0	0.7	0.0	0.1	0.2	0.2	0.0	0.0
Leasing of areas and buildings	0.0	0.0	5.6	**16.4**	0.0	4.6	0.0	0.0	0.0
Education and cultural services	0.1	0.0	**0.7**	0.0	0.0	0.0	0.1	0.0	0.0
Insurance and banking services	0.1	0.0	0.1	0.0	0.1	0.0	**0.2**	0.2	0.0
Other services	**26.2**	1.7	1.2	17.7	3.9	1.6	0.4	0.0	1.7
Other	1.5	1.7	2.4	0.5	0.2	**3.5**	2.5	0.8	1.7
Advisory and consultancy services	1.4	1.0	0.8	5.8	5.5	**7.3**	3.1	0.1	1.0
Heat	0.1	2.2	13.4	0.0	0.0	23.9	2.2	0.0	**32.9**
Clothing	0.2	0.1	**0.5**	0.0	0.0	0.0	0.0	0.0	0.1
Electricity	0.0	2.1	1.7	0.4	0.0	17.8	0.2	0.3	**21.1**
Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**3.9**
Fuels	0.1	0.3	0.0	0.0	0.0	0.0	0.0	**12.2**	0.3
Machinery and equipment	2.6	1.0	2.5	0.4	0.4	**7.1**	0.2	2.7	1.0

Appendix 2b. Biodiversity footprint (nPDF) of the City of Tampere units in different consumption categories. The largest biodiversity footprints are marked in red.

	Education and learning services	Culture and leisure services	Upper secondary education	Real estate and housing policy	Employment and business services	Urban environment and infrastructure services	Central administration	Tampere City Transport	Tampere Water
IT services and equipment	14	2	9	0	1	5	67	0	2
Telecommunications and postal services	7	3	5	0	1	2	77	1	3
Accommodation and travel	36	1	6	0	0	55	0	0	2
Construction	0	2	0	41	0	43	0	0	13
Health and social services	59	9	18	0	2	4	3	3	1
Small items and fittings	61	11	14	0	3	4	4	1	1
Marketing, paper products and printed matter	38	29	18	0	2	6	6	0	1
Leasing of areas and buildings	0	5	20	59	0	16	0	0	0
Education and cultural services	9	12	64	1	2	4	6	0	1
Insurance and banking services	9	3	13	2	10	1	35	27	0
Other services	47	6	2	32	7	3	1	0	3
Other	9	14	15	4	1	25	17	5	11
Advisory and consultancy services	5	3	3	22	21	28	12	0	4
Heat	0	3	18	0	0	32	3	0	44
Clothing	20	19	47	1	0	2	2	3	6
Electricity	0	5	4	1	0	41	0	1	48
Water	0	0	0	0	0	0	0	0	100
Fuels	0	2	8	0	0	0	0	87	2
Machinery and equipment	14	13	13	2	2	36	1	14	5

Appendix 2c. Contributions (%) of the City of Tampere units to the carbon footprint footprint generated by consumption categories. The largest contributions are marked in red.

	Education and learning services	Culture and leisure services	Upper secondary education	Real estate and housing policy	Employment and business services	Urban environment and infrastructure services	Central administration	Tampere City Transport	Tampere Water
IT services and equipment	1 130 372	186 594	704 069	21 885	115 685	392 741	5 513 345	17 938	187 547
Telecommunications and postal services	52 765	21 451	34 663	1 996	9 882	14 420	547 251	4 145	23 348
Accommodation and travel	4 344 701	167 064	723 374	2 008	23 415	6 645 328	39 387	5 258	198 172
Construction	49 113	593 522	89 731	11 484 345	54 559	12 000 083	10 492	1 056	3 670 666
Health and social services	545 819	83 342	162 447	4 129	18 254	37 802	31 410	30 858	13 787
Small items and fittings	459 600	81 514	107 259	1 757	20 166	31 480	32 377	4 618	9 483
Marketing, paper products and printed matter	602 222	458 965	277 729	7 763	38 410	89 887	93 973	323	7 892
Leasing of areas and buildings	9 877	580 653	2 562 165	7 578 316	17 753	2 117 712	10 341	0	2 611
Education and cultural services	33 267	44 247	238 349	5 009	8 975	16 027	21 442	0	4 254
Insurance and banking services	22 163	8 064	31 923	5 544	24 748	2 403	86 841	67 210	1 096
Other services	9 080 263	1 220 122	401 762	6 155 222	1 345 748	547 434	153 547	9 258	594 146
Other	462 863	701 920	772 958	190 491	66 579	1 287 893	869 959	251 636	544 291
Advisory and consultancy services	484 491	311 865	277 604	2 000 593	1 912 803	2 534 974	1 085 292	24 037	350 020
Heat	51 231	1 375 630	8 347 409	0	0	14 921 336	1 349 957	0	20 527 253
Clothing	54 093	53 099	129 723	1 737	119	4 816	6 104	7 775	17 625
Electricity	27 267	411 682	329 525	88 959	5 038	3 531 788	40 065	67 168	4 192 543
Water	137	1 283	1 411	1 076	0	203	0	0	1 159 968
Fuels	214	158 672	604 779	0	0	9 114	4 282	6 463 222	156 092
Machinery and equipment	855 853	807 690	801 135	127 811	128 130	2 223 575	53 573	871 002	319 242

Appendix 2d. Carbon footprint (t CO_2e) of the City of Tampere units in different consumption categories. The largest biodiversity footprints are marked in red.

Appendix 3

	nPDF	t CO_2e
Red meat	42.6	10 518
Dairy products	27.9	6 006
Poultry	12.5	2 014
Fish and other seafood	10.5	2 038
Fruits, berries and nuts	9.1	705
Cereal products	8.3	3 934
Vegetables	7.9	1 309
Prepared food meat-based	1.2	57
Coffee, tea and cocoa	1.2	636
Pastry, cakes, confectionery and ice cream	1.0	387
Eggs	0.9	128
Oils and other vegetable fats	0.8	408
Beverages	0.2	126
Prepared food vegetable-based	0.2	292
Sugar	0.1	72
Soya products	0.1	26

Appendix 3. Carbon and biodiversity footprints generated by food product categories.

Appendix 4

Heat	nPDF	t CO_2e	kWh
Milled peat	38.8	26 443	25 486 018
Mixed waste	11.5	7 182	29 001 331
Natural gas	10.8	5 993	29 001 331
Light fuel oil	7.9	5 140	16 346 205
Wood	5.7	1 814	54 838 880

Appendix 4a. Carbon and biodiversity footprints and consumption of heat energy sources (kWh).

Electricity	nPDF	t CO_2e	kWh
Wood	34.9	3421	18 409 798
Mixed waste	7.3	3804	71 473 333
Solar	1.3	1136	10 829 293
Water	0.3	318	6 497 576
Wind	0.0	15	1 082 929

Appendix 4b. Carbon and biodiversity footprints and consumption of electricity energy sources (kWh).

Appendix 5

Category	nPDF	t CO_2e	EUR
Special waste	0.38	171	207 059
Mixed waste	0.21	101	82 871
Construction and renovation waste	0.04	16	65 930
Hazardous waste	0.02	8	9 836
Bio	0.01	2	2 556
Wood	0.00	1	1 268
Organic compostable waste	0.00	1	558
Sludge	0.00	0	596
Paperboard	0.00	0	2 896
Paper	0.00	0	0
Metal	0.00	0	0
Glass	0.00	0	0
Plastic	0.00	0	711

Appendix **5.** Carbon and biodiversity footprints and expenses generated by waste management (EUR).

Appendix 6

	2021 nPDF	2021 t CO_2e	2021 km	2019 nPDF	2019 t CO_2e	2019 km
Train travel	0.05	4	374 175	0.26	24	2 107 812
Car use	0.32	79	1 075 041	0.48	121	1 642 663
Air travel	0.09	52	331 007	0.87	489	3 096 434

Appendix 6. Carbon and biodiversity footprints and kilometres generated by work-related travel in 2019 and 2021.

Appendix 7

	nPDF	t CO_2e	EUR
Electricity biomass and waste	4.99	3 307	405 229
Other services	3.17	1 100	4 932 136
IT services and software	3.11	906	4 175 069
Electronic machinery and equipment	3.04	1 048	3 321 783
Banking and financial services	2.70	858	3 335 623
Real estate agency services	1.63	754	4 271 327
Food products	1.57	208	405 277
Fuels and gases	1.46	863	574 975
Retail trade	0.78	203	965 467
Forest industry products and services	0.76	119	398 094
Health and social services	0.70	187	1 465 302
Paper and paper products	0.62	232	586 004
Small items and fitting	0.37	119	323 428
Insurance services	0.29	104	815 934
Transport	0.25	127	143 339
Postal and telecommunications services	0.23	73	846 444
Clothing and textiles	0.22	57	193 821
Construction	0.21	70	269 963
Aluminium and aluminium products	0.21	68	131 437
Wholesale trade	0.19	36	211 530
Chemicals	0.18	53	87 490
Precision and optical instruments, watches and clocks	0.17	57	202 653
Electricity wind	0.17	83	383 940

Rubber and plastic products	0.13	34	104 360
Machinery and equipment	0.13	43	166 645
Motor vehicles	0.11	38	102 676
Radio, TV and communications equipment	0.10	32	66 251
Water	0.08	37	150 863
Electricity solar	0.06	24	107 748
Other	0.06	18	61 517
Electricity hydropower	0.03	17	41 126
Electricity oil	0.03	19	6 452
Education and learning services	0.03	9	95 013
Computers	0.02	7	21 064
Printer matter and media	0.02	9	40 987
Hotel and restaurant services	0.02	3	17 080
Leasing of machinery and equipment	0.01	4	11 666
Distribution and sales of electricity	0.01	5	17 320
Iron and steel products	0.01	5	8 744
Electricity transmission services	0.01	4	3 982
Travel agency services	0.01	2	8 467
Mining	0.00	2	3 555
Recreational, cultural and sports services	0.00	1	9 999
Sales and repairs of motor vehicles	0.00	1	9 199
Electricity nuclear	0.00	1	2 965
Electricity gas	0.00	1	841

Appendix 7. Biodiversity (nPDF) and carbon footprints (t CO_2e) generated by investments and the investments in euros (EUR).

Appendix 8

	nPDF	t CO_2e	EUR
Materials	0.27	112	183 829
Fittings	0.21	80	187 923
Mobile machinery and other vehicles	0.08	25	77 068
Workforce	0.04	14	62 337
Transport	0.02	7	40 842

Appendix 8a. Carbon and biodiversity footprints of the resource-wise renovation of Yliopistonkatu street and expenses by category.

	nPDF	t CO_2e	EUR
Materials	0.42	176	582 384
Fittings	0.22	84	396 747
Mobile machinery and other vehicles	0.21	68	388 845
Workforce	0.05	18	160 001
Transport	0.05	20	225 358

Appendix 8b. Carbon and biodiversity footprints of the traditional renovation of Yliopistonkatu street and expenses by category.

	nPDF	t CO_2e	EUR
Slabs and stones	0.10	72	72 069
Asphalt	0.09	69	68 780
Humus	0.06	25	25 275
Concrete	0.01	8	8 474
Sand	0.01	9	9 231

Appendix 8c. Carbon and biodiversity footprints of the materials used in the resource-wise renovation of Yliopistonkatu street and material expenses by category.

	nPDF	t CO_2e	EUR
Slabs and stones	0.17	124	110 230
Asphalt	0.09	69	68 780
Humus	0.07	43	56 729
Concrete	0.06	25	25 275
Sand	0.04	30	30 178

Appendix 8d. Carbon and biodiversity footprints of the materials used in the traditional renovation of Yliopistonkatu street and material expenses by category.

Appendix 9

Biodiversity footprint generated by land use	%	Biodiversity footprint generated by pollution in terrestrial ecosystems	%	Biodiversity footprint generated by pollution in freshwater ecosystems	%	Biodiversity footprint generated by water use	%	Biodiversity footprint generated by pollution in marine ecosystems	%
Guam	6	United Arab Emirates	19	India	17	USA	54	China	43
São Tomé ja Príncipe	5	Palestine	13	Finland	6	Australia	18	Germany	28
Northern Mariana Islands	5	Cyprus	11	Brazil	5	Bahamas	5	Finland	9
Seychelles	5	Italy	10	China	5	Jordan	4	Netherlands	6
Finland	4	Lebanon	10	Sri Lanka	4	Taiwan	2	USA	6
New Caledonia	4	Papua New Guinea	7	Botswana	3	Malaysia	2	Sweden	5
Comoros	3	Qatar	4	Taiwan	3	Puerto Rico	1	Türkiye	4
Mayotte	3	Oman	3	Afghanistan	3	India	1	Latvia	3
Russia	3	Montenegro	3	Panama	2	Armenia	1	Lithuania	3
Samoa	3	North Macedonia	2	Namibia	2	Yemen	1	France	1

Appendix 9. Impacts of the biodiversity footprints arising from land and water use and pollution on the ten largest and the most severely affected regions.