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LUT School of Energy Systems

Energy Technology

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Estimating calculating and reporting methods for multi-sector carbon footprint calculator

Master's Thesis

ABSTRACT

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Estimating calculating and reporting methods for multi-sector carbon footprint calculator

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Keywords: LCA, LCI, carbon footprint, carbon footprint calculator, climate change, carbon accounting, decarbonization, carbon neutrality

Decarbonization has become a global trend. Individuals, businesses, countries, and the whole world are trying to decrease emissions and their own carbon footprint. There are many instructions, standards, guides, and methodologies regarding this subject, but no clear vision which of them are the best and most suitable in a given context. Unity is needed regarding this subject.

This thesis compares methodologies and standards for carbon footprint calculation and reporting concerning building and construction, logistics, and companies. The methodologies are primarily divided into three different life cycle inventory methods. Process-based method is the most exact but time consuming, input-output is not requiring as much resources but is the most inaccurate, and hybrid method which is a combination of the two.

The case presented in this thesis is a calculation process of Vastuu Group Oy's carbon footprint. The calculation is done with hybrid methodology following GHG (greenhouse gas) Protocol's guidance. 18 different carbon footprint calculators are reviewed and compared. After this, the results are calculated again with five chosen tools and the results are compared. Lastly, there is a recommendation for a road to carbon neutrality for Vastuu Group Oy. Information presented in the theory and case parts can be used for developing a more unifying carbon footprint calculator.

TIIVISTELMÄ

LUT University

School of Energy Systems

Energiatekniikan koulutusohjelma

Kim Sundberg

Lasku- ja raportointimetodien arviointi monialaisen hiilijalanjälkilaskurin kehittämistä varten

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Hakusanat: LCA, LCI, hiilijalanjälki, hiilijalanjälkilaskuri, ilmaston muutos, hiililaskenta, dekarbonisaatio, hiilineutraliteetti

Dekarbonisaatiosta on tullut globaali trendi. Yksilöt, yritykset, valtiot ja koko maailma yrittää vähentää hiilidioksidipäästöjä ja omaa hiilijalanjälkeään. Aiheeseen liittyen on monia oppaita, standardeja ja metodologioita, mutta ei tarkkaa visiota mitkä näistä ovat parhaita ja sopivimpia eri tilanteisiin. Yhtenäisyyttä kaivataan ja sitä olisi lisättävä.

Tämä diplomityö vertailee hiilijalanjäljen laskentaan ja raportointiin liittyviä standardeja ja metodologioita rakennusten ja rakentamisen, logistiikan ja yritysten osalta. Laskentamenetelmät ovat yleisellä tasolla jaettu kolmeen eri elinkaari-inventaarioanalyysi metodiin. Prosessipohjaiseen metodiin, joka on aikaa kuluttavin, mutta tarkin, panos-tuotospohjaiseen malliin, joka vaatii vähiten resursseja, mutta on epätarkin, sekä hybridimalliin, jossa käytetään hyväksi kumpaakin edellä mainittua mallia.

Työn tapaustutkimus osuudessa lasketaan Vastuu Group Oy:n hiilijalanjälki. Laskenta suoritetaan käyttäen hybridimallia ja GHG (greenhouse gas) Protocol standardia. Seuiraavaksi 18:aa eri hiilijalanjälkilaskuria esitellään ja vertaillaan. Tämän jälkeen yrityksen hiilijalanjälki lasketaan uudelleen viidellä valitulla laskurilla. Viimeiseksi diplomityö antaa suosituksen yritykselle hiilineutraliuden tiekartasta. Diplomityön teoriaosuutta ja tuloksia voi käyttää hyväksi yhtenäisemmän hiilijalanjälkilaskurin kehittämisessä.

PREFACE AND ACKNOWLEDGEMENTS

I am grateful for this opportunity to conduct my thesis work for Vastuu Group Oy as part of the climate economy team, where I studied calculation and reporting methodologies, standards, calculators, and created a road to carbon neutrality for the company. Today, the climate change topic is important and engaging everywhere in the world and I am fortunate for being able to work with this subject.

First, would like to express my gratitude to Lars Albäck for providing me this position and trusting to my use of judgement on the job. I want to thank my advisors Ahti Jaatinen-Värri and Ilkka Lakaniemi for responsiveness and advice, Sami Koskela for consistent guidance and tips, and the personnel of Vastuu Group for providing me valuable data for the thesis.

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Helsinki, 5.11.2021

Kim Sundberg

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SYMBOLS AND ABBREVIATIONS

Abbreviations

CEN	European Committee for standardization
CF	Carbon footprint
COP	Conference of the Parties
EE	Embodied energy
EF	Ecological footprint
EIO	Economic input-output
EPD	Environmental product deceleration
EV	Electric vehicle
GB	Gigabyte
GHG	Greenhouse gas
IEFA	Integrated ecological footprint assessment
IT	Information technology
LCA	Life cycle assessment
LCCF	Life cycle carbon footprint
LCI	Life cycle inventory
LCE	Life cycle energy
LCIA	Life cycle impact assessment
OE	Operational energy
PCF	Product carbon footprint
PUE	Power usage effectiveness
TDP	Thermal design power
WTW	Well-to-wheel
Hkm	Passenger kilometre

Symbols

°C	Degrees Celsius

Indices

eq	equivalent

1 INTRODUCTION

Effects of the climate change can be seen all over the world, and many of them are irretrievable even over thousands of years. These changes can already be seen in forms such as continuing rise of sea level (IPCC 2021). UNFCCC (United Nations Framework Convention on Climate Change) published NDC (Nationally Determined Contributions) report together with IPCC (Intergovernmental Panel on Climate Change), and the findings state that without immediate action, the temperature can rise up to 2.7°C above pre-industrial levels by the end of this century which would have catastrophic consequences (Saier 2021). However, if the greenhouse gas emission reductions are strong enough, the effects of climate change can be mitigated (IPCC 2021). These mitigations are considered as a global priority in the COP (Conference of the Parties), which is the yearly United Nations Climate Change Conference. United Nations brought almost every country together in Glascow from October to November 2021 to make an agreement on how the battle against climate change can be won (UN Climate Change Conference UK 2021).

Large countries such as Brazil and Mexico have pulled back their promises regarding the subject, and China which is causing the largest climate emissions globally and promises to be fully carbon neutral until 2060 does not have any concrete actions supporting the goal (Kokkonen 2021). For countries to reduce their emissions, all economic sectors are needed to take part in limiting their impacts. This has created a need for environmental management tools, and increased attention to climate data and sustainability reporting approaches of companies (Radonjič 2018, 362). Carbon footprint describes the closest estimation of climate change impact of a company, a country, an item, or anything (Berners-Lee 2010). The concept is used widely but it seems to lack a standard definition (Penz 2018, 1126).

1.1 Objectives and methods of this work

This study is centered around three different sectors: Building and infrastructure, logistics, and companies. The main goals of this work are to clarify how the different carbon footprint (CF) calculation methodologies differ and what are the main standards guiding the process. The work is done for Vastuu Group Oy and the case example is to calculate the company’s carbon footprint using the most suitable methodologies and standards presented, and in addition with five different carbon footprint calculators found on the internet. Vastuu Group Oy is a Finnish company operating in the IT (information technology) sector. The results are compared and intended to prove how the chosen methodology, emission factors, and standards affect the outcome. This information can be used in developing a consistent carbon footprint calculator. The research questions of this work are:

- What are the main standards and methodologies used, when calculating the carbon footprint of building and construction, logistics, and companies?
- What is the carbon footprint of Vastuu Group Oy?
- How much does it cost for Vastuu Group Oy to reach carbon neutrality?
- How much and why the different calculator results differ?

This study includes theoretical and research parts. Theoretical part reviews first the laws and taxonomy encouraging to clarify carbon footprints of different sectors. CF calculation concept Life Cycle Assessment (LCA) and its phases, and differences of standards and methodologies are explained. Government and ministry reports, and studies are working as references. The research part clarifies the main emission sources of Vastuu Group Oy and calculates the company's carbon footprint. The carbon footprint consists of mainly CO_2, but Kyoto Protocol covered five other greenhouse gases methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6) are added in CO_2 equivalents when it is possible (UNFCCC n.d.). The CF sources are solved with an inquiry to the employees and discussing with human resources and management. After that, 5 out of 18 calculators are chosen for further analysis and the company's CF is calculated again. Lastly the carbon footprint of Vastuu Group Oy is clarified, and the cost of reductions and compensation are presented.

2 REGULATION AND EU TAXONOMY REGARDING CLIMATE CHANGE

Carbon footprint (CF) is a term for a method which can evaluate the amount of carbon emissions in tonnes of CO_2 to answer the concerns regarding climate change. There are global goals to reduce these emissions and reach towards low carbon economy. The goals can be achieved through innovations such as low carbon services and goods, and mutually set agreements. (Muthu 2021, 95)

Paris Agreement is international and legally binding contract which was made in 2015. The mutual goal of this is to stop the average global temperature rise to 1.5°C above pre-industrial level. To achieve this goal, global carbon emissions need to be reduced and thereby human made carbon emissions and carbon sinks binding these emissions should be balanced in the second half of this century. All parties are expected to act towards low carbon economy, which means more work in developing technologies and circular economy, increasing transparency and funding for climate operations. All parties prepare, report, maintain, and achieve their national targets on their own. (Ministry of the Environment 2021)

Finland is following the Paris Agreement as part of the European Union and achieved the 2020 goals ahead of its time. From the 1990s level Finland has been able to reduce carbon emissions 21% and the goal is to be fully carbon neutral by 2035. With these goals Finland is aiming to be the first fossil-free welfare society in the world. The largest emission reduction potential in Finland resides in the transport sector. Creating infrastructure for electric vehicle (EV) charging and halving transport related emissions until 2030 by increasing electrification and biofuel use are the main goals for this sector. The whole community structure requires to readjust to climate change by also supporting cycling, walking and public transportation (Finnish Government n.d.).

The agenda 2030 accepted by United Nations is guiding Finland and other countries to the direction of low carbon economy. It is covering three sustainability dimensions: economic, social, and environmental including 17 goals of sustainable development. Important goals regarding this work are:

7. Ensure access to affordable, reliable, sustainable, and modern energy for all
9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
11. Make cities and human settlements inclusive, safe, resilient, and sustainable
12. Ensure sustainable consumption and production patterns
13. Take urgent action to combat climate change and its impacts

A large development to be done for reaching Finnish goals is renewing the land use and building act. Main goals of the renewed act are carbon neutral society, strengthening the diversity of nature and increasing the quality of building. Climate change mitigation is considered in planning, building, and maintenance of the built product (Ministry of the Environment 2019). The government will produce a roadmap for low carbon construction and support municipalities with their energy efficiency projects. Using wood as a material will be highly supported and the share of zero energy buildings are expected to rise from 10% to 90% (Prime Minister's Office 2020, 51, 72, 78). Companies are part of sustainable development as well. For example, a large Finnish bank Nordea is reducing its investment- and corporate loan portfolio carbon footprint for 40-50% until 2030 and many other international banks have done similarly. This means businesses and companies are in a hurry to reduce their own carbon footprint to maintain the financial support from banks and investors. For this to happen, businesses and public authorities should be able to measure progress and GHG emission reductions. (Kukkonen 2021).

Different sector and industry economic actions are intended to be defined in a new EU taxonomy setting. It's most important functions regarding this work are climate change mitigation, the transition to circular economy, and pollution prevention and control. In the future, taxonomy is dividing financial products to categories which represent how environmentally friendly they are (Valtiovarainministeriö 2021). A way to boost the above-mentioned is to promote sustainable finance and help the financial sector to make investment decisions based on more environmental and social considerations (European commission 2021b). For this, EU announced a voluntary Green Bond Standard in 2020 which is going to help investors to identify sustainable investments (European commission 2021).

Now, EU has come to an agreement concerning the proposal for a new climate law in Europe. The law is setting a pathway to climate-neutral Europe 2050 by ensuring that all sectors are contributing to the same goal in a manner which is cost-efficient and fair for everyone with sector specific roadmaps. Under this law, the EU's net greenhouse gas emissions should be reduced 55% by 2050. The policies regarding climate, transporting, energy, and taxation should be suitable for reaching this target. (European Commission 2021d)

3 CARBON FOOTPRINT STANDARDS, CALCULATION PRINCIPLES AND METHODS

In this section the phases, main problems, and applications of life cycle assessment (LCA) concept are explained. This work centralizes on the LCA of buildings, infrastructure, logistics, and companies and brings out practical examples from the life cycle assessment process. Standards are the key when using LCA and therefore the most important and largest standards are shown and explained regarding the above-mentioned sectors. Different standards and methodologies are previewed to see if any of them particularly stands out. The preview and comparison are done because the low carbon economy is being rapidly capitalized by the business sector. Methods, standards, and tools are giving more and more value to consumers and organizations when the accuracy of them are increasing (Robinson 2017, 4436).

3.1 Life cycle assessment

Carbon footprint calculation includes the full amount of greenhouse gases (GHGs) emitted, removed, and embodied during for example the life cycle of a product, service, or activity. The whole life cycle from raw material to disposal must be taken into consideration and in between there are stages such as moving the raw material, manufacturing, packaging, and distributing the product for user consumption. The stages are different with dissimilar products. The whole evaluation process is called life cycle assessment (LCA). (Pandey et al. 2010, 143)

LCA is recognized by The European Commission as a methodology which identifies potential impacts and environmental intervention of a product or service through their entire life cycle (Nikolić Topalović 2018, 4). In 2003, The European Commission also stated that the best framework for Environmental impact assessment is LCA, but unity for life cycle analysis methodologies is needed and the quality of used data should be assured. The data must reflect real-life process chains of industry and used methodology should consider the unity on current mode of operation. (European Commission 2021c)

LCA was standardized by ISO 14000 series in 2000 and it supports sustainable development through ecologic and economic perspective. Since then, life cycle assessment has been used as an environment management tool which helps to improve management of resources, choosing the best available technologies, and improve processes. LCA is a methodology that has evaluated carbon footprint successfully for a large variety of different systems and applications and it consists of 4 steps based on EN 14040 standard:

1. Goal and Scope
2. Life cycle inventory (LCI)
3. Life cycle impact assessment (LCIA)
4. Interpretation and discussion

Goal and scope defines the boundaries for the system and answers to a question what the purpose of the study is. Life cycle inventory collects all the input data such as raw materials and energy, with outputs as the complete product and emissions to air and measures them quantitatively. Life cycle impact assessment provides understanding about what is the process, the scale, and impact to the environment. Interpretation and discussion is the last phase, which is meant to detect new related data that have improvement prospects. When discussing LCA phases, cradle-to-gate and cradle-to-grave are often mentioned. This describes mostly the life cycle phases of a product such as building material. Cradle-to-gate illustrates the phases from raw material phase to factory gate. Cradle-to-grave includes all the phases starting from raw material to factory gates but includes the disposal and possible recycling as well. (Muthu 2021, 7-9, 98)

3.2 LCI Methodologies

Life cycle inventory is an integrated part of LCA where all phases and materials which produce emissions, are presented. In broad perspective, life cycle inventory methods are divided to three types: Economic input-output (EIO), process-based, and hybrid methodology. In Figure 1 can be seen results from a search from Web of Science database. “LCA” and other keywords were used to clarify which of these three methodologies has been the most popular in recent years among studies.

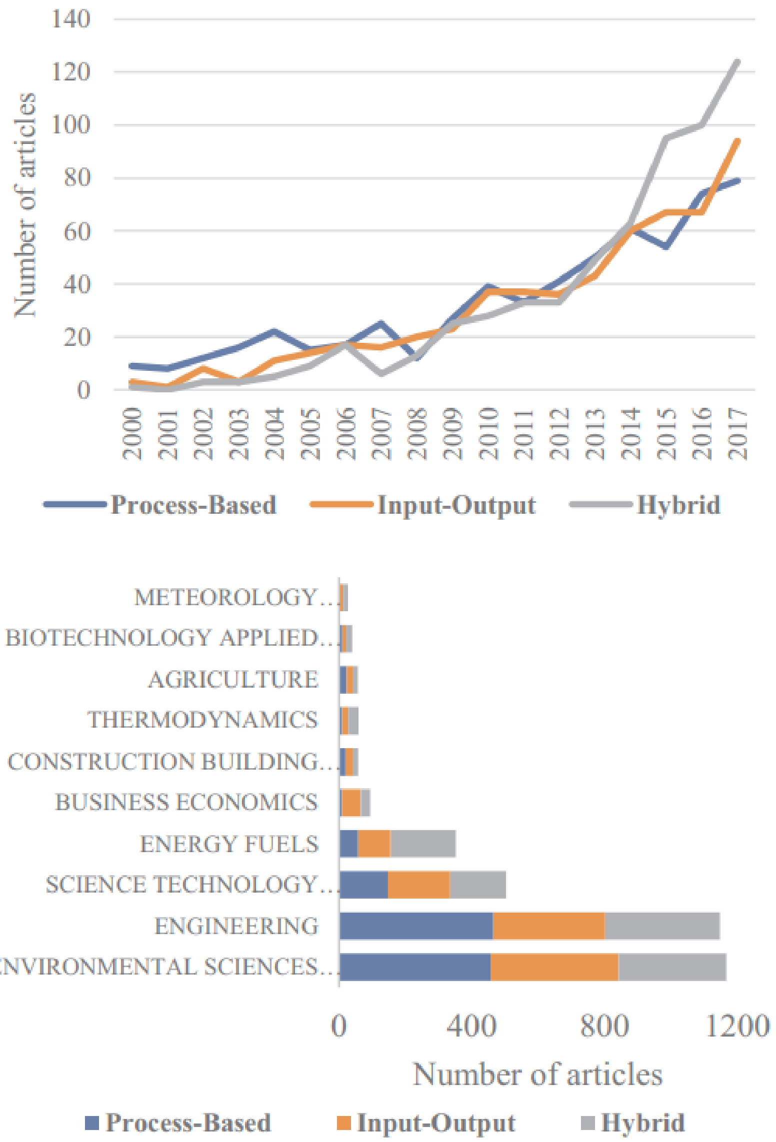

Figure 1. Popularity of LCA methods in 2000-2017 (Fenner, et al. 2018)

The least popular method in 2017 was process-based methodology. It is using material and energy flows as inputs and emissions and wastes as outputs. This is the most detailed process out of the three, which means it requires large amount of data usually from many different sources and significant investments on work and time. This also means it is the most reliable method compared to others, because actual data is used provided by manufacturers. A large problem regarding this methodology is known as “truncation error”, where data is unavailable, and the boundary of the system is incomplete (Venkantraj 2021, 2). Process-based methodology is recommended by ISO standards and is primarily made for smaller scale applications such as products. (Fenner, et al. 2018 1143-1144)

The economic input-output methodology is recommended to use with larger systems as countries and cities. It links the economic sector economic data with final demand emissions of large supply chains. It is using energy tariffs to convert different industry sector monetary flows to physical energy flows. Geographical areas can be used as boundaries which makes single process analyzing more complex. The data is usually built from open sources from industry energy usage, inputs, and emissions and with increasing number of available sources, the method is easier to use (Fenner, et al. 2018 1143-1144). When comparing costs and time, this methodology is better than the process-based LCA and dodges the truncation error by using IO-data from transactions happening between different industry sectors. The problem is that used prices and tariffs can easily under- or overestimate the real values (Venkantraj 2021, 2).

The hybrid methodology is created to combine the advantages from both the above mentioned strategies. It uses the process-based detailed analysis with information about sector level from input-output method. It is shown to gain more popularity because of the flexibility it is providing (Fenner, et al. 2018 1143-1144). There are several different hybrid methodologies, but a tiered hybrid analysis is the most common of them. It combines coefficients from process and input-output to expand the system boundaries analyzed and adds information that typically would not be included in neither of them. This methodology is based on framework from process analysis but is using both input-output and process data. If boundaries between input-output and process are not defined clearly enough, there is a risk of double counting. Usually, the hybrid method descriptions are not clear, which makes it hard to reproduce these methods. Also, the real benefits of hybrid data over input-output or process data are often not understood. (Crawford 2017, 1275-1276)

Figure 2 is showing an illustrative image, which displays how the LCA methodologies are used between functional units. The method chosen is dependent on the functional unit such as product or country through its scale.

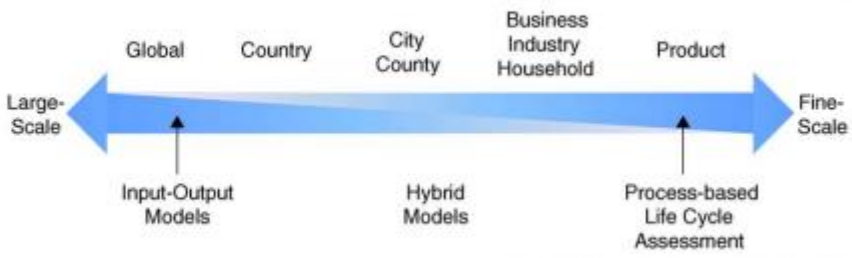

Figure 2. An illustrative image on how the different LCA methods are mainly used (Peters 2010)

3.3 Carbon footprint of buildings

A 2017 study reviewing 251 life cycle carbon footprint calculation cases from 19 different countries showed, that the carbon footprint of buildings is forming from embodied carbon (24%), operational phase carbon, (75%), and demolition (1%). Even if coherent life cycle carbon footprint (LCCF) calculation protocol is used, some variation will appear from embodied carbon and operational CO_2 emission calculations. This is because manufacturers use dissimilar production processes even if the building materials are the same (Schwartz 2017, 231). The operational energy (OE) comes from operation and maintenance of the building and embodied energy (EE) is consumed during the construction process, which includes everything from raw material extraction to manufacturing the product. OE and EE together are forming the concept of life cycle energy (LCE) and when LCE is minimized, the carbon footprint of a building sector reduces significantly. Embodied energy calculations are more difficult to make because the methods are not standardized, and they are very complex and time consuming. These methods are using data from different sources and unequal boundary definitions which makes the whole life cycle energy evaluation difficult (Venkantraj 2021, 1).

More accurate results can be achieved if unified protocols as the Environmental product declaration (EPD) or EN 15804 are used as they are describing closely real-life construction component production processes (Schwartz 2017, 240). Standards EN 15804 and EN 15978 are trying to strengthen the protocols used in Europe. The first one is providing a framework to unify EPDs for construction services and products. The second one provides a structure to calculate and assess new and already existing buildings environmental performance. If data for a current project is not available, the standards are providing default values such as 300 km transportation distance for building products. (Fenner, et al. 2018, 1145)

Technical Committee of the European Committee for Standardization (TC350/CEN) and ISO have both been providing EPDs which are meant to provide information about life cycle assessment on construction materials. EN 15804 is specifically developed for Europe and is currently in popular position to assess construction product environmental performance, which is needed for accurate calculations. There are comparable standards for this as ISO 21930 which has small differences compared to the EN 15804. ISO 21930 has a better comparability for North Americas geographical areas, flexibility of reporting, and structure. The revised version of ISO 21930 is made more similar to EN 15804, which has a reputation of a core for European product category rules for construction products. (Durão 2020, 1-3)

EN 15978 is dividing the life of a building to modules. Modules include product (A1-3), construction (A4-5), use (B), end-of-life (C) and recovery potential (D) stages. When LCA is done, often not every stage is processed. Instead, boundaries such as cradle-to-gate or cradle-to-grave are chosen, which define what parts of the building's life are calculated. The latter is often not used, because of uncertainty what activities are performed in the end of building's life. Recommendation for building lifespan is usually 60 years. (Hawkins 2021, 90-91)

The EN 15978 has its downsides as well. When LCA scope is chosen, it affects differently to materials. For example, module D is benefitting steel over concrete, because it can be easily recycled to other valuable material, and this means varying material structure's carbon footprint could depend on the chosen LCA scope. Storing and sequestration of biobased materials as timber is forming the second problem. This can be included in Module A which is a standard practice or in Module D. The standard practice is usually giving negative values for embodied carbon, which can be discouraging to resource-efficient design of a product. Third, there is no globally accepted way for accounting potential benefits regarding temporary storages or delayed emissions of carbon. To solve this problem, International Reference Life Cycle Data System Handbook and PAS 2050 guides are using a factor of linear reduction for delayed emissions, but this method is sensitive to the chosen time horizon (Hawkins

2021, 91). There is a lack of transparent method for verifying, measuring, and reporting greenhouse gas emissions which was internationally accepted. Popular LCA methodologies are often used, because they simplify the measuring process of a whole building's lifespan emissions (Fenner, A.E., et al. 2018 1142-1145).

Because there is a large need for coherence for standards, the European Commission (EC) revealed a new European framework for sustainable buildings in 2018. Level(s) is using already existing standards to create mutual understanding what is sustainability performance of buildings and helps aligning the project with current European (or other) policy. This basis can be suited for developing commercial environment certificates such as Finnish RTS, English BREEAM and American LEED. There are six main targets in Level(s) methodology:

1. Carbon footprint of the whole life cycle
2. Resource efficient material usage
3. Efficient water usage
4. Healthy facilities and air quality indoors
5. Adaptation to climate change
6. Life cycle costs (Ministry of the Environment 2021b)

Level(s) was tested in Finland on 2018-2019 in over 20 construction projects and the results stated that the testing increased understanding about building's sustainability. There is still space from improvement because of inability to report "handprint", complex instructions, and time-consuming data gathering. There was also a consideration that Level(s) is requiring additional work and not providing clear added value. (Venäläinen 2019, 9)

Finland Ministry of the Environment has used Level(s) and sustainable construction standards EN 15643 series, EN 15804 and EN 15978 as basis when producing the first version of method for the whole life carbon assessment of buildings. This carbon footprint analysis guide is covering entire life cycle of a building. This includes manufacturing, transporting products that the construction project is using, the worksite, the use phase, needed maintenances, and lastly demolition together with recycling. The assessment includes also “handprint”, the positive environmental impacts caused by the project. This considers the possibilities for building’s carbon sinks and storages, spare renewable energy produced throughout the lifecycle of a building, and the positive effects from construction product’s re-use and recycling. The assessment method is supporting the development of Finnish land use- and construction law and the goal is to bring standardized LCA method for Finland with the energy and climate strategy. The method for the whole life carbon assessment of buildings is using construction products and processes database used in Finland. The database is still under development but meanwhile it is providing temporal emission data. The guide is not suited directly for assessing infrastructure projects. (Kuittinen 2019, 5-12)

3.3.1 Green building certification systems and conceptual ecological footprint methodology

Comparing buildings sustainability performance is hard because there are over 600 certifications made for that purpose and their baseline differ from each other. Even large certificates as BREEAM, LEED, CASBEE, DNGB, and Green Star are not perfect and are showing technical and methodological issues. Technical problems include inconsistency between these systems when used in different countries and even at sub-national level. The systems are based on different parameters and could be using different weighting on the same parameter. Methodological problems refer to different perspectives where building’s life cycle is assessed. For example, LEED is assessing the environmental impacts at the design stage, and it is found that sometimes the building’s operational performance level is much lower than predicted.

Different countries have produced different certification systems as already mentioned U.S made LEED, U.K made BREEAM, CASBEE from Japan, DNGB from Germany, and Green Star used in Australia and New Zealand. For example, China, where roughly 2 billion square meters is built each year in terms of new buildings, produced a certification system 3-Star. The 3-Star rating system goes from 1 star to three stars, which is the best level. Globally recognized LEED has similarities and dissimilarities compared to 3-stars. As many large certifications, both are credit based, and credits are earned with categories. LEED has also mandatory credits as energy usage, which need to be reduced 10% comparing to conventional buildings. After the mandatory categories, rest of the credits are selected freely by developers. Final score is built from the earned credits and a result is given with a certification level of Certified, Silver, Gold, or Platinum. LEED has six certification tracks for new construction, existing building operations, commercial interiors project, core and shell project homes and neighborhood, when 3-Stars has only 2 for residential buildings and public buildings. (Zou 2018, 880-882)

Other differences between these certificates exist as only LEED is assessing innovation and 3-Stars considers operations and maintenance, and land efficiency. With LEED, the building can have low credits in some areas, but still perform great which allows developers to choose only areas where they perform better. 3-Star is disallowing this by giving stars by each category's minimum number and not the total credits. LEED certification is given by applying a submission of the designed project to the Green Building Certification Institute which rates the construction based on design. 3-Star certification process can also give certification from the design but has a second stage, where the building's operation phase is assessed. Because of the additional operational phase and National Government organized assessment, the process is more complicated than with LEED. (Zou 2018, 882, 887)

Certificates are important because for example, large Finnish banks Nordea and OP are informing to provide loans for projects with "Green Buildings" certification. LEED "gold", BREEAM "very good", the Nordic Swan Ecolabel, Miljöbyggnad "silver", the RTS "2 stars", or other standard, which is Green Bond Committee approved (Nordea 2020, 4), (OP 2018, 7). Rating systems as certificates are still lacking the ability to define the Earth's resource use and overuse. An alternative solution for rating system could be calculating the ecological footprint (EF), which is focusing to "biocapacity", the ecosystem's capacity to renew what the demand consumed. (Pomè 2021. 1-2)

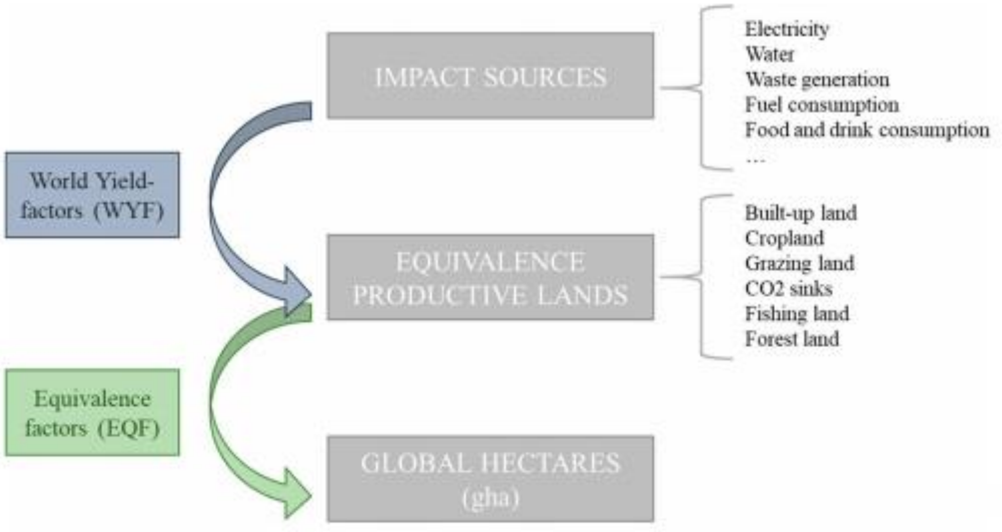

Figure 3. EF calculation methodology (Pomè 2021)

The ecological footprint gives global hectares of land as output. The comprehensive method is first of the two primary methods, using overall consumption macroscopic statistics with LCA data. The component method is calculating the footprint using six types of land, which are impacted during the process. These lands are comparable and productive i.e. Forest land, fishing land, cropland and CO_2 sinks. This is an input-output analysis and seems to be better with building impact evaluation. EF is using impact sources (i.e. Electricity, water, fuel consumption, water) and converts them to above-mentioned lands needed, to even out the impacts. In Figure 3 the calculation methodology is presented in two steps. First "WYF" stands for world yield-factors which converts the produced emissions and consumptions into equivalence productive lands. After that equivalence factors are used to convert the lands into normal hectares called global hectares. The global footprint network is providing worldwide EF accounts and biocapacity annually and keeping world yield-factors and equivalent factors up to date every year. (Pomè 2021, 3)

A large advantage for this new conceptual EF methodology is the ability to look at the occupancy of people in the building and take it to account when assessing the efficiency of the building. The integrated ecological footprint assessment (IEFA) integrates the two above-mentioned component and comprehensive approaches to allow product and material's embodied energy impact source evaluation and use WYF and EQF in addition. The model has still certain limitations relating to inventory quality, absence of benchmarks, and standards needed for the calculations. (Pomè 2021, 15)

3.4 Carbon footprint of different infrastructure projects

LCA methods are making general assumptions in terms of effects and location, which often do not fit for all construction projects. Assessment of specific construction settings require adaptation (Krantz 2015, 1157). When constructing infrastructure such as tunnel, LCA can only provide a frame and not give a precise definition for calculating energy and materials. A Spanish study is defining a simplified model using LCA frame, tested with constructed real tunnel data. The study calculates only the CO_2 emissions from the construction of the tunnel, not from operations and maintenance, to provide CO_2 emission ratio per tunnel meter. In the introduced tunnel case CO_2 emissions are formed from five sources: Consumed diesel and electrical energy, explosive usage, used materials and methane emissions caused by possible carboniferous strata and the phases include excavation, removing rock waste, installing support and lining, and auxiliary services. System boundary overview can be seen in Figure 4.

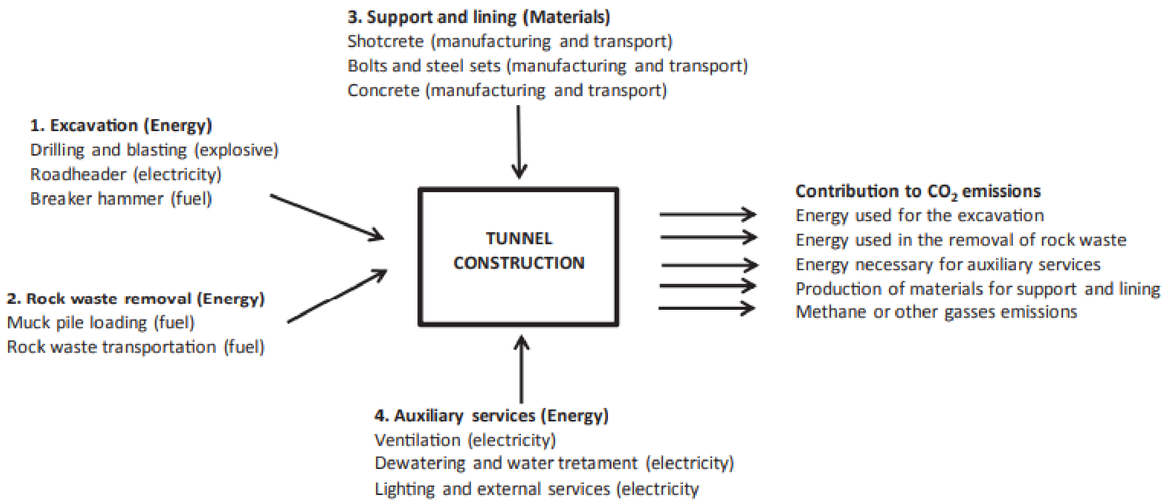

Figure 4. System boundary overview from Spanish tunnel project (Rodríguez 2020)

Each four phase's consumptions are calculated, and country or region-specific conditions are taken into consideration. In this case, conversion factors and rock mass strength are examples from region specific variables. There are just a few calculation steps in the presented simplified model because anyone should be able to calculate the emissions emitted from a tunnel project. Rodríguez's study results conclude, that 80% of the emissions come from steel and concrete, which means that tunnel's carbon footprint could be easily estimated when the total amount of materials is known. (Rodríguez 2020, 1-11)

There is a large variety of infrastructure projects and LCA should be able to adapt to all of them. A significant number of tools are only built for performing LCA of road pavement. The problem is that different tools provide different results because parameter values and models used are not the same. Largest dissimilarities are coming from calculating the impacts of uncommon materials used, when common materials are not as sensitive to the LCA tool chosen. One reason for this could be that every material is not linked to the databases the tools have. Even if the construction stages, equipment, and materials used are the same, the results can be very different. To reduce these differences, uniform product category rules and framework for pavements are needed, which would give an opportunity to build a standardized framework for these projects. Development of consistent databases should be built and updated often to comply with standards and these databases should be available for everyone to increase reliability. (Dos Santos 2017, 37)

3.5 Carbon footprint of logistics

Kellner is summarizing that logistic activities account for close to 5,5% of worlds greenhouse gas emissions. Freight transport holds 90% of these emissions with two-third produced by vans and trucks. The need for standardization of accurate, comparable, and transparent GHG assessment is also applying to logistics. (Kellner 2016, 565)

European Committee for Standardization (CEN) published a methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers) EN 16258 in 2012. This is the only official and international supply chain transportation standard for calculating emissions. The standard is not accepted globally but is usually considered as a starting point because of the potential it has. The shipment-level emission calculations are solved with two steps, first the transport operation total volume greenhouse gases are computed and secondly, that quantity is allocated to single shipments. The first step calculates the total transport operation GHG emissions, which include every operation related to moving the shipment, for example the empty trips back. After this, the fuel consumption is translated into GHG emissions with provided conversion factors. Consumption patterns are specific to the vehicle and are considering every factor effecting fuel consumption except how the weight capacity is utilized. This includes the design of vehicle, driver behavior, average gradients of the road, congestions etc. Second part allocates the calculated GHG volume to the shipments. EN 16258 allows different emission allocation units, such as volume, mass, or distance, which can cause ambiguities and are leaving room for interpretation. A 2016 study recommends the usage of only one allocation scheme which is distance because it promotes the trade-off between causality, fairness, and accuracy better than others, and is simpler and more pragmatic based on numerical experiments and discussion of road freight transport GHG emission drivers. (Kellner 2016, 565-574)

EN 16258 follows the well-to-wheel (WTW) approach, which includes all indirect fuel supply emissions from raw material to distribution and the direct emissions when the vehicle is operated (Grönman 2018, 1067). Well-to-wheel is the prevalent LCA method at a regulatory level and is used in the Fuel Quality Directive and Renewable Energy Directive by European Union. Also, China, and the Environmental Protection Agency (EPA) from USA are using this LCA methodology in policy options assessment. Because vehicle life cycle impacts are not included, WTW is seen as simpler LCA (Moro 2015, 5).

Daniel Hülemeyer and Dustin Schoeder compared the four different defined ways of calculating the transport emissions provided by the EN 16258. The first is measuring the carbon footprint emissions of every individual transport which should be the preferred source of data. The allocation schemes from previous segment were assessed using the first defined option. This method is facing challenges when subcontractors are used, because the data for calculation is not available or the quality of data is arguable. In addition, the method is using a large amount of financial and personal resources due to needed vehicle data interfaces and transport management system. The second way is evaluating the average consumption of fuel for specific vehicles or routes, but it contains the same subcontractor problem as the first one. If the earlier methods are not possible to conduct, the recommendation is to use the fleet's average value. The standard comprises that the own fleet, the partner's, and the subcontractor's fleet fuel consumption data are heterogeneous, which lowers the quality of it. The fourth and the most common alternative is using default values based on tonne kilometres of the unit, provided by different reporting tools and guidelines. This option is practical, but at the same time the most inaccurate because investments in modern vehicles and driver's efficiency are not affecting to the results. (Hülemeyer 2019, 140-142)

GLEC framework is a guideline provided by Global Emission Council (GLEC) to calculate transport emissions with a global scope. It can be used together with GHG protocol and has earned a mark called "Built on GHG Protocol", which means it follows the requirements given by GHG Protocol (Akopian 2016). The general steps of the approach are:

1. Plan where the transport chains and methodology are defined
2. Data collection, where data guidelines are reviewed and gaps identified
3. Emissions calculation, where emission factor is chosen and calculations are done for transport chain
4. Definition of assumptions and reporting

The aim of this framework is to be precise when measuring distance and provide a valid approach when exact covered distances by subcontractor's are not known. There is a large number of emission factors and consumptions considering different regions, vehicle types, and fuels in the annex of GLEC framework. These are allowing the user to utilize many different combinations and give the customer information, which helps to choose green and sustainable logistic services. (Hülemeyer 2019, 142-143)

In Hülemeyer's study, GLEC framework is compared to the EN 16258 with example calculations using an example case. In the comparison, standard EN 16258 is used together with Deutscher Speditions- und Logistikverband (DSLV) guideline. It helps identifying the EN 16258 requirements and describes how to use it practically, such as clarifying the possibilities when analyzing single shipment emissions allocation. The results of calculations are different between the two standards due to varying calculation methods, emission factors, conversion factors and deviation factors. The results are proving the deviation between different approaches, but it is not known which result is correct or more valid. Hülemeyer recommends combining elements from both standards. Transport chain segmentation as introduced in the GLEC framework is a feasible option. Using fuel consumption average values with the vehicle class and calculating emissions of transshipments with already existing method from GLEC framework, valid methodology could be built. Small logistic businesses do not have knowledge nor the manpower to do decisions about what practice, approach, and standard is the most suitable for their service. Therefore, only a standard being as practical as possible and with the right amount of detail, can have the potential to become a global standard. (Hülemeyer 2019, 142-152)

When following different standard's instructions, fuels are usually one of the main parts of logistics CF and their GHG emissions must be known or solved. This data can be acquired with the information of volumes used, fuel densities, lower heating values, percentage of fossil and renewable carbon contents and the emissions from fuel production process. The problem is that this kind of data is not publicly available anywhere. A second option is to use public databases such as LIPASTO in Finland, where estimations of annual traffic-based emissions can be found. (Grönman 2018, 1067) When assessing electrical vehicles, GHG intensity must be calculated for 1 kWh of electric energy. For example, European Commission's Joint Research Centre (JRC), EUCAR and Concawe provided database is summarizing average kilowatt hours GHG intensity in EU countries 2009, which was 540 gCO_2eq/kWh. This considers low voltage electricity consumed and because the production emissions are highly dependent on location, this value is only giving a direction. For comparison, this value is 30 gCO_2eq/kWh when considering Sweden and 1200 gCO_2eq/kWh in Poland. (Moro 2015, 8)

3.6 Company's carbon footprint and standards

After the 2015 Paris Agreement, there has been a rising interest to determine carbon footprints in a corporate level. Large number of initiatives, calculation methods and guidelines are being launched to help greenhouse gas emission quantification. According to Harangozo 2017, the Greenhouse Gas Protocol is the most widely used tool for accounting these emissions in organizational level. The GHG Protocol is working as a standard to measure and report both direct and indirect GHG emissions of a company. It divides emissions between three scopes as seen in the Figure 5.

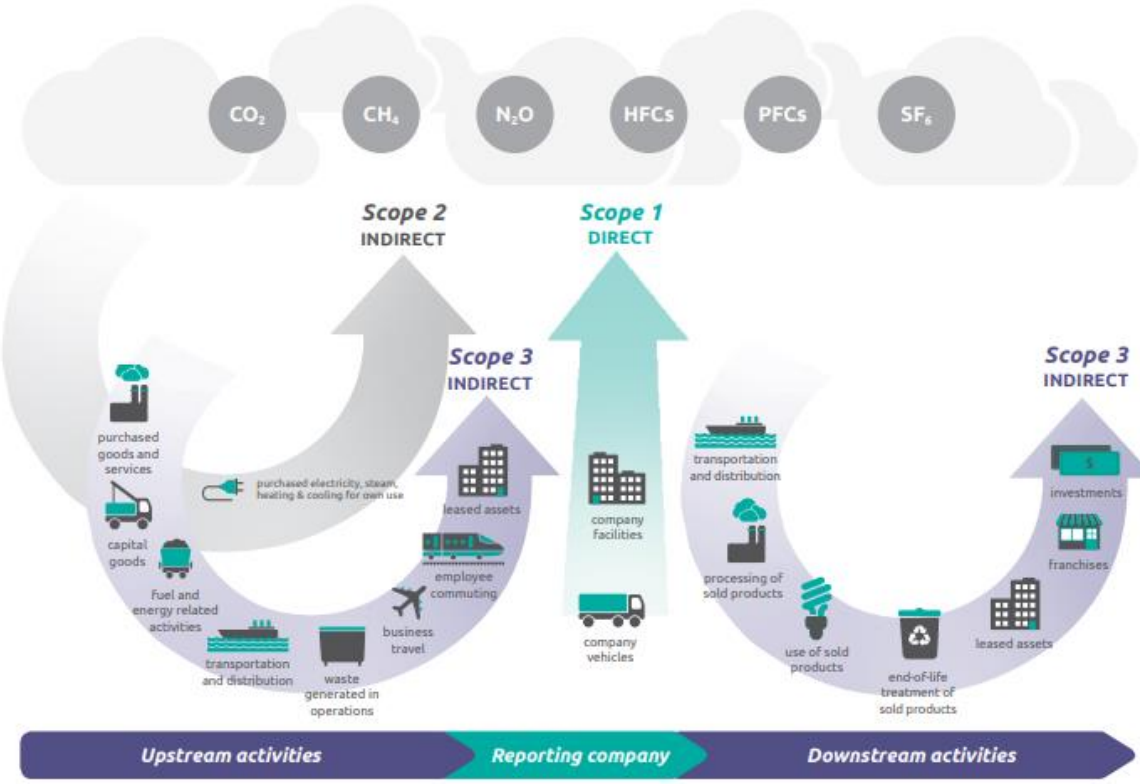

Figure 5. GHG Protocol scopes (GHG Protocol 2011)

Scope 1 includes direct emissions from the reporting company as owned vehicles etc. Scope 2 includes indirect upstream emissions caused by energy usage. This means the electricity, heating, or cooling energy bought and produced elsewhere. Scope 3 is divided to upstream and downstream activities. Upstream in this case is covering all generated indirect emissions resulting from acquired or purchased services and goods, and downstream emissions include indirect emissions resulting from sold services and goods (GHG Protocol 2011, 29). Scope 3 comprises for example the raw material extraction and transportation with distribution actions, product usage and end-of-life phases. It is a voluntary category, which means companies do not need to report the emissions from that scope. A study focusing among the US companies found out that 74% of all emissions are caused from scope 3 activities. Oil and gas industry's use phase for example could achieve 90% of the entire carbon footprint. (Harangozo 2017, 1177-1179)

European Commission's Institute for Environment and Sustainability has assembled short descriptions from large corporate level carbon footprint analysis methods. ISO 14064 is a large international standard, which is divided to three different parts. The first portion ISO 14064-1:2006 is specifying organization level requirements and principles for determining and reporting greenhouse gas emissions. Requirements are given also for GHG inventory of a corporation. ISO 14064-2:2006 is providing steps for determining, monitoring, and reporting project level reductions or removal improvements of GHG emissions. This includes guidance how to identify and select sources and sinks of emissions and process the data to the documenting and reporting phase. The last part of the standard ISO 14064-3:2006 is providing requirements for conduction or management how to certificate and validate greenhouse gas assertions. This part is used together with ISO 14064-1 or -2. (Pelletier 2011, 16)

The Global Reporting Initiative (GRI) provides standards and framework to help organizations measure, understand, and report their environmental impact. The goal of the framework is to find consensus to the reporting of sustainability impacts and seeks to make it comparable and verifiable. This is a well-known framework for businesses to report their social and environmental performances voluntarily.

The World Resources institute developed the GHG Protocol Corporate Standard with the World Business Council on Sustainable Development. This multi-stakeholder association is providing guidance and standards for different types of companies and organizations with preparing an inventory of GHG emissions. It covers the accounting and reporting process of GHG emissions defined in the Kyoto Protocol, which are carbon dioxide, methane, hydrofluorocarbons, nitrous oxide, perfluorocarbons, and sulphur hexafluoride. The Corporate Value Chain (Scope 3) Accounting and Reporting Standard supplements the Corporate Standard with guidelines and requirements on how to calculate and report corporate indirect scope 3 emissions. (Pelletier 2011, 17)

The United Kingdom have produced corporate GHG emission accounting guide called Defra, which is suitable for all organizations. It has been developed under businesses consultation and is mostly GHG Protocol based. Defra provides instructions for scope 1 and 2 emission reporting and substantial scope 3 emissions reporting is encouraged but not mandatory.

Defra is also providing a calculation tool and continuously updated factors for conversion with information to help companies reducing their environmental impact.

The International Reference Life Cycle Data System (ILCD) is providing reproducible LCA data and assessments. The system has two parts: the ILCD Data Network and Handbook. The Handbook follows the ISO 14040 and ISO 14044 outlines and together with the data network they are providing more specific and quality-assured guidance than the framework provided by ISO.

French ADEME has produced GHG accounting guide and tool Bilan Carbone for organizations. This methodology considers all greenhouse gases, when most accounting methods are covering only the six from Kyoto Protocol. Therefore, Bilan Carbone's method with the included emission factors is compatible with many different schemes and the guidance is called more comprehensive than large part of the available GHG accounting methods for organizations. (Pelletier 2011, 18)

Generally, product or corporate carbon footprint calculation is carried out with process-LCA methodology, where the supply chain is built and data is gathered from all process units. As with other sectors, the hybrid methodology can be used when assessing corporate carbon footprint as well. The advantage here is to use already obtainable financial data such as company financial accounts and invoices from suppliers from wanted year such as inputs with more specific process-based information. Uncertainties occur if the data is old or not available. Sector aggregation problems occur if the environmental input-output data does not match with the sector and category of spent money. (Navarro 2017, 723)

Comparing carbon footprints of different corporations should be executed with caution, because the above-mentioned standards are defining system boundaries and accounting principles or framework for carbon footprint calculations differently. Comparisons are not considered relevant if the methodologies and boundaries are not similar. This is why the CF analysis requires common methodological validity.

4 CARBON FOOTPRINT OF VASTUU GROUP OY

Vastuu Group Oy is a Finnish information technology company previously known as Suomen Tilaajavastuu Oy, which was already then providing services for real estate and construction industry and preventing the grey economy. Most of the company's services are provided online and the core of operations is to provide reliable data for digital services. Vastuu Group is an under 100 people company where the ownership base is mostly in the construction and real estate industry associations. The company is working towards a better future for everyone through utilizing reliable data, intelligent services, and sustainable solutions for the built environment. The carbon footprint of Vastuu Group Oy is calculated within the Greenhouse Gas Protocol Corporate Standard (2004) boundaries. The standard allocates emissions to three scopes specified under section 3.6. An amendment to the above-mentioned standard, GHG Protocol Scope 2 Guidance, and Corporate Value Chain (Scope 3) Accounting and Reporting Standard are used for more specific instructions. The main steps followed are:

1. Emission source identification
2. Selection of calculation methods
3. Data collection and choosing emission factors
4. Calculations

The preferred calculation method is the process-based methodology, where specific data is used, but averages and estimations based on studies are also used when needed. Data is gathered primarily from 5 years where 2016 is the starting point. Emission factors can be found on databases as VTT provided LIPASTO. Calculations are done with the Excel-tool and the results are compared with other ready-made free and paid carbon footprint calculation services.

The goal of this case is to calculate the carbon footprint of Vastuu Group Oy as closely as possible and discover how the results differ from other calculation service's results. The process is done under the five main principles of GHG accounting and reporting, which are relevance, completeness, consistency, transparency, and accuracy according to GHG Protocol (GHG Protocol 2011, 23).

4.1 Inventory analysis and scopes

First the emission sources are identified and allocated to different scopes. In this section all the material and energy flows are described. The identification process is done by studying the company, discussing with human resources, and creating an inquiry with Google Forms for employees to answer questions about commuting and business travel.

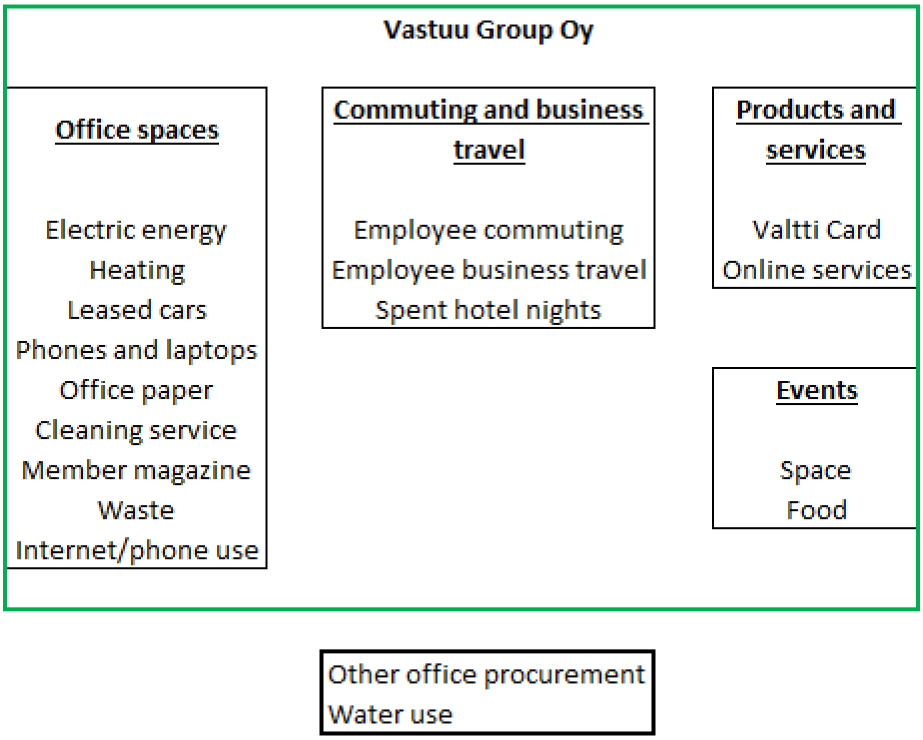

Figure 6. System boundary

System boundary includes all the activities producing CO_2 emissions excluding other office procurement than phones and laptops, IT development, and water usage. Vastuu Group does not have noticeable amount of procurement. Investments are made in the form of IT development, which can be excluded because it has a very small impact. Water usage is the last one outside the boundary line because there is no factory or production facility or anything else that would use noticeable amounts of water. When considering employee commuting, business travel, electricity, and heat, the consumptions and also the energy production are considered. Leased cars are in operational control, which means other than petrol and diesel related emissions can be excluded. Events are considering the space and served food. Online services include servers, where the products are running, and the Valtti Card is the only physical product produced elsewhere. Vastuu Group Oy has a subsidiary, Platform of Trust Oy, which has an office space in Tampere and it is included. Emission sources are divided to scopes in Table 1.

Table 1. Scope allocation

Scope 1 direct emissions	**Scope 2 indirect emissions**	**Scope 3 indirect emissions**
-	Office space heating	Valtti Card production, shipping, and recycling
	Office space electricity	Server use
		Employee commuting and business travel
		Heating and electricity life cycle emissions
		fuel life cycle emissions
		Internet and phone calls
		Office procurement
		Events and catering
		Member products
		Cleaning service
		Waste

Scope 1 includes the direct emissions as mobile or stationary combustion, process emissions, or fugitive emissions. Vastuu Group does not have any of the previously mentioned emissions, such as company owned vehicles, which is why the column is empty.

Scope 2 comprises the bought electric and heating energy. This energy is consumed by the office spaces of the company and its subsidiary.

Scope 3 has the most emission sources compared to scopes 1 and 2. The upstream emissions of Vastuu Group Oy includes the servers where the company provided services are working, Valtti Card, which is the only physical product from the company, office cleaning, shipping, internet and phone use, waste, emissions regarding the production of used fuel in employee commuting and travel, office procurement, events and food for employees, and offered products such as member magazines. Downstream emissions include the use and end-phases of products and services, and downstream transportation. Also, used electricity scope 3 emissions are considered.

4.2 Heat and electricity consumption

Vastuu Group Oy bought electricity emission factor is 198g/kWh. The sources consist of 41% peat and fossil fuels, 25% renewable and 34% nuclear power. Because renewable and nuclear source emission factor is 0g/kWh, the scope 3 upstream emissions are added to the calculations. Nuclear power CO_2 emission median value is estimated to be 12g CO_{2eq}/kWh by World Nuclear Association (World Nuclear Association 2021). In Finland electricity produced with renewables in 2019 was 40% with hydropower, 19% wind power, and almost all the rest (41%) with biomass. For comparison, the share of photovoltaics is only 0,2% and is not considered for this reason (Statistics Finland 2020). For hydropower 18,5g CO_{2eq}/kWh is used, which is lesser than IPCC provided data 24g CO_{2eq}/kWh from 2014. The value is from a study where close to 500 hydropower plants were evaluated (IHA 2018). In Finland the wind power life cycle emissions are evaluated between 10-11g/kWh and 10,5g CO_{2eq}/kWh is used (Finnish Wind Power Association 2014). Biomass electricity production LCA values have large amount of variation. Electricity generation from only biomass-based systems produce GHG emissions depending on the fuel burned. With different agriculture feedstocks used, the amount of CO_2 equivalent emissions varies from 43g CO_{2eq}/kWh to 1731g CO_{2eq}/kWh (Kadiyala 2016, 7). Wood based fuels are the main source of bioenergy in Finland, which means value from the lower end 50g CO_{2eq}/kWh is used (Ministry of Agriculture and Forestry of Finland 2020). Second office space in Tampere is evaluated starting from 2019 and because there is no electricity consumption data, it is calculated in relation to Espoo office square meters and consumption. Espoo office is 578m^2 and Tampere office is 48m^2.

Because there is no heat consumption data available, the calculations are performed with the Confederation of Finnish Construction Industries RT values from 2019. Espoo office is heated with geothermal heating and Tampere office with district heating. The emission factor for geothermal heat is 8.43kg CO_{2eq}/m^2/a for a residential building (Vuorinen 2019) and reduced to 5.05kg CO_{2eq}/m^2/a because according to European Commission, non-residential buildings consume 40% less energy on average than residential buildings (European Commission 2013). Tampere office space consumption is added from 2019 and Ministry of the Environment given value 130g CO_2/kWh is used for district heating (Kuittinen 2019, 46). As electricity consumption, Tampere office heat consumption is calculated in relation to Espoo office square meters and with specific heat consumption value 40.5 kWh/m^2 from 2009 Finnish non-residential building (Kosonen 2010, 33).

Table 2. Office heating and electricity consumption emissions

Year considered	**2016**	**2017**	**2018**	**2019**	**2020**
Electric power consumption [kWh]	28710	28980	28092	30042	16012
Electricity scope 2 [kg CO_{2eq}]	5685	5738	5562	5948	3170
Electricity scope 3 [kg CO_{2eq}]	332	335	325	347	185
heating [kg CO_{2eq}]	2924	2924	2924	3176	3176
Emissions [t $CO2_{eq}$]	**8.94**	**9.00**	**8.81**	**9.47**	**6.53**

In Table 2 electricity consumption is divided to scopes. Scope 2 and scope 3 heating emissions are reported together because of lack of data. Because the Ministry of The Environment considers geothermal heating emissions as 0, Confederation of Finnish Construction Industries RT provided LCA value is used considering scope 2 and scope 3 emissions.

4.3 Employee commuting and business travel

Employee commuting habits are clarified with an inquiry including subjects as commuting to workplace, work related flights, spent hotel nights and other work-related travelling. The goal in this section is to clarify what mode of transport are the employees using when commuting to work and how long is the route, how many flights are taken in a year and where, and how many work-related nights are spent in a hotel in a year. The questions are asked separately between a normal year and year 2020, which eliminates the effect of the pandemic influencing the results. Table 3 is showing the inquiry results, where car “P” designates petrol as fuel and car “D” indicates diesel cars. The answers shown are real data results from 23 respondents.

Table 3. Inquiry results of commuting to work

Mode of transport	**Car "P"**	**Car "D"**	**Bus**	**Bicycle**
Number	9	6	5	3
Number 2020	4	3	2	1
Distance [km]	64000	30100	20200	
Distance 2020 [km]	33120	7278	2788	
CO_{2eq} [t]	**8.32**	**3.61**	**0.73**	
CO_{2eq} 2020 [t]	**4.31**	**0.87**	**0.10**	

From Table 3 can be seen, that commuting to work halved after 2019 because people moved to working from home. The distance commuted was only 38% of normal level and CO_{2eq} emissions 42%.

Table 4. Other work-related travelling

Mode of transport	**Car**	**Train**	**Ship**
Distance [km]	9530	10700	800
Distance 2020 [km]	3621	4066	304
CO_{2eq} [t]	**1.24**	**0.00**	**0.12**
CO_{2eq} 2020 [t]	**0.47**	**0.00**	**0.04**

Other travelling is done by car, train, or a ship and these results are shown in Table 4. Travelling on sea was done from Helsinki to Tallinn and the emissions are calculated with factors regarding car ferries. The 2020 distances are estimated to 38% of normal year results noted in Table 2. VR is used when travelling by Train in Finland. The CO_2 emission factor for passenger trains is 1,4g/hkm (passenger kilometre), but all the emissions are compensated by VR through Nordic Offset and presented as zero in Table 4. (VR 2021)

Table 5. Inquiry results regarding flights

Flights	Europe short	Europe long	Long-haul flight
Number	6	40	4
Number 2020	8	2	0
Distance [km]	2400	53040	26400
Distance 2020 [km]	3200	2800	0
CO_{2eq} [t]	**0.62**	**7.90**	**3.01**
CO_{2eq} 2020 [t]	**0.83**	**0.42**	**0.00**

Flight results are shown in Table 5 and the types are divided to three different groups, because the emission factors differ between short, long, and long-haul flights. Short flights inside Europe are under 463km, where long flights are over 463km. Long-haul flights are made outside of Europe. Some of the results are not designating the distance of flight inside Europe, and are assumed to be 1500km, which is close to the distance between Helsinki and Frankfurt airports. There were no flights inside Finland marked in the inquiry. The results show that the number of flights taken reduced 80% in 2020 and the emissions were only 11% from the normal year levels.

Table 6. Emission factors used. (Speth, et al. 2016), (VTT 2016), Edwards, et al. 2016)

Mode of transport	Emission factor
Petrol car [g CO_{2eq}/km]	130
Diesel car [g CO_{2eq}/km]	120
Bus [g CO_{2eq}/hkm]	36
Train [g CO_{2eq}/hkm]	0
Ship [g CO_{2eq}/hkm]	144
Flight short, Europe [g CO_{2eq}/hkm]	260
Flight long, Europe [g CO_{2eq}/hkm]	149
Long-haul flight [g CO_{2eq}/hkm]	114
Petrol production [g CO_{2eq}/MJ]	13,8
Diesel production [g CO_{2eq}/MJ]	15,4
Jet fuel production [g CO_{2eq}/MJ]	15,7

Table 7. Fuel production upstream emissions

Fuel production	Emissions
Petrol production CO_{2eq} [t]	1.83
Petrol production 2020 CO_{2eq} [t]	0.93
Diesel production CO_{2eq} [t]	0.94
Diesel production 2020 CO_{2eq} [t]	0.24
Jet fuel production CO_{2eq} [t]	2.46
Jet fuel production 2020 CO_{2eq} [t]	0.26

The GHG Protocol is guiding to include upstream emissions of used fuel to perform full life cycle assessment. Table 6 is showing the emission factors used in the production of the fuel as well as the factors used in the emission calculations. Production factors represent grams of CO_2 equivalent per megajoule of final fuel. VTT provided database LIPASTO is used, and the data is from 2016. The emission factors regarding fuel production are from European Commission and Massachusetts Institute of Technology and vary from 2012 to 2014. Table 7 is showing the emissions regarding fuel production, which are accountable for 17-21% of the whole life cycle emissions from presented fuels.

Table 8. Inquiry results regarding spent hotel nights

Work related hotel nights	
Number	75
Number 2020	10
CO_2 [kg]	184.5
CO_2 2020 [kg]	24.6

Staying in hotels are closely related to travelling, which is why emissions produced by hotel nights are included in this section in Table 8. As seen in Tables 2-4, the results are far lower in 2020 than in earlier years. Only 13% of emissions are produced by nights in hotel compared to normal situation. The emitted amount of CO_2 is calculated using Citypark hotels carbon footprint calculations (Citypark 2017).

Table 9. Commuting and travelling total consumption

Year considered	2016	2017	2018	2019	2020
Number of employees	26	35	46	56	62
Commuting to work [kg CO_{2eq}]	14310	19264	25318	30822	14231
Work related travelling [kg CO_{2eq}]	1531	2061	2708	3297	1387
Flights [kg CO2eq]	13041	17556	23073	28089	3367
Fuel production [kg CO_{2eq}]	5911	7956	10457	12730	3858
Work related hotel nights [kg CO_{2eq}]	209	281	369	449	66
Sum [t CO_{2eq}]	**35.0**	**47.1**	**61.9**	**75.4**	**22.9**

The total CO_2 consumption from commuting and business travel is calculated for years 2016-2020. Because the number of employees has changed during the period considered, the results are extrapolated taking that into account. Table 9 shows the results in tonnes from commuting and travelling. The sum is highly relative to the number of employees. The largest difference can be seen in 2020 where the number of employees has risen, and the consumption is still only 30% from the 2019 level.

4.4 Office procurement

This section comprises two major parts, which are mobile phones and laptops, and a smaller part for an IT company, which is office paper. Other issues are left outside the boundaries, because they are not replaced or acquired often, and there is very small amount of them, such as PC's. A new employee is given a smartphone and a laptop, and both are replaced every 4 years. The amount of procurement is calculated considering the number of new employees and the average of replaced tools in a year. Office paper use is 3 boxes a year, which makes up to 6000 sheets of paper per year.

The laptop product carbon footprint (PCF) can be acquired from Lenovo, smartphone PCF from Apple, and office paper PCF from a study. Lenovo ThinkPad T480s has an emission factor of 357kg CO_{2eq}/pcs (Lenovo 2017). IPhone 12 life cycle emissions are 70kg CO_{2eq}/pcs (Apple 2020) A 2012 study represents three different values for office paper depending on the calculation methodology used. The PAS 2050, ISO 14040/14044 standards, and CEPI framework provided values of 950kg CO_{2eq}, 930kg CO_{2eq}, and 860kg CO_{2eq} per tonne and their mean value 913g CO_{2eq}/kg is used (Dias 2011, 34).

Table 10. Emissions from office procurement

Year considered	2016	2017	2018	2019	2020
Number of laptops	11	15	17	21	23
Laptop consumption [kg CO_{2eq}]	3927	5355	6069	7497	8211
Number of smartphones	11	15	17	21	23
Smartphone consumption [kg CO_{2eq}]	770	1050	1190	1470	1610
Office paper consumption [kg CO_{2eq}]	27	27	27	27	27
Sum [t CO_{2eq}]	**4.7**	**6.5**	**7.3**	**9.0**	**9.9**

From Table 10 can be seen that most of the emissions are coming from laptops because of the high emission factor per piece, when the smallest amount is coming from office paper consumption because only close to 30kg of paper is used every year.

4.5 Events and catering

Events CF is formed using estimations, because there is no data available from rental space sizes or locations. Events are organized two times a year and estimated time and size of the used space is 500m^2 and 8 hours. Usually, 4/5 of employees are present. Only event catering is added to calculations.

Table 11. Emission from corporate events

Year considered	2016	2017	2018	2019	2020
Events [kg CO_{2eq}]	28	28	28	28	0
Meals including meat [kg CO_{2eq}]	106	142	187	228	252
Vegetarian meals [kg CO_{2eq}]	19	25	33	40	44
Sum [t CO_{2eq}]	**0.14**	**0.18**	**0.23**	**0.28**	**0.30**

From Table 11 emissions from events are shown. Using Finnish event agency TAPAUS calculator for energy consumption from use of space in Finland, area of 500m^2 is emitting 14kg of CO_{2eq} in 8 hours (TAPAUS 2021). Meal examples are provided by Ministry of the environment, where emission factor for one meat including meal is 3.81kg CO_{2eq} and 1.34kg CO_{2eq} for vegetarian meal (Saarinen et al. 2011). 2020 events consumption is zero because they were held remotely. According to Vastuu Group, 1/3 of the people is estimated to order vegetarian meals in the company events.

4.6 Products and services

Services and products used and provided by the company includes Valtti Card production, cloud server use, internet use and phone calls, office cleaning, and member magazine subscription for employees.

4.6.1 Valtti Card

The Valtti Card is an identity card produced in China, where a minimum of 50 000 cards are ordered at a time. 1-2 orders are assumed to take place in a year depending on yearly production rate. If over 100 000 cards are ordered in a year, the amount is divided for two transports. The shipments are assumed to be sent from Hong Kong to Helsinki. Transporting by train, aircraft and ship is used during the calculations, because different transporting methods have been tested. Transporting emissions are calculated with CarbonCare CO_2 calculator, which is using the European EN 16258 standard and well-to-wheel method taking all fuel life cycle steps and cargo handling into consideration (CarbonCare 2021). After that, an average of 10 cards are delivered at a time to a customer in a letter. One letter delivery emits 21g CO_{2eq}/pcs (Kaustia 2010). One plastic ID card weighs 5g (WWF 2019, 7) and ICMA Card Manufacturing is assuming 50g CO_{2eq} is emitted during the production phase (Trüggelmann 2012, 23).

In Finland, plastic cards are instructed to be placed in mixed waste bin. This waste is then burned for heat and electricity (HSY 2021). Statistics Finland provided fuel classification table gives values for plastic. Plastic waste default net calorific value 25.0GJ/t and CO_2 default emission factor 74.1t/TJ are giving an emission factor of 1.85kg CO_{2eq}/kg for plastic waste (Statistics Finland 2021). In Table 12 the life cycle emission results from Valtti Card can be seen.

Table 12. Valtti card emissions

Year considered	2016	2017	2018	2019	2020
Valtti Cards	77268	95279	111808	146139	123592
Weight [kg]	386	476	559	731	618
Production emissions [kg CO_{2eq}]	3863	4764	5590	7307	6180
Transporting methods	Air-craft	Ship	Train, aircraft	Ship, aircraft	Ship, train
Transporting emissions [kg CO_{2eq}]	1697	35	1247	1616	51
Letter to clients [kg CO_{2eq}]	162	200	235	307	260
Disposal [kg CO_{2eq}]	716	883	1036	1354	1145
Sum [t CO_{2eq}]	**6.44**	**5.88**	**8.11**	**10.58**	**7.64**

4.6.2 Server use

To clarify the emissions from server use, the processor models running the servers, their energy consumption, power usage effectiveness (PUE), the time servers are online and electricity production emission factors need to be known. Because there are approximately hundred different services used, it is hard to specify every single of them and find values for them, which means the first already mentioned truncation error has occurred. Therefore, only the main processes are calculated with Amazon AWS provided values. The servers are using instances, which have different baseline performances, used electricity consumptions, and processors. With the known instances used, the power needed can be clarified. There is no data to specify how many real processors are used to handle Vastuu Group Oy data, but the production and end-of-life stage emissions can be evaluated with DELL provided data.

Table 13. Used instances, time and power consumption in a month

Instance	Number	Time [h]	Baseline performance (%)	TDP [W]
T2.nano	8	2708	5	90
T2.micro	22	5416	10	90
T2.small	5	1692	20	90
T2.medium	7	1014	40	90
T2.large	2	339	60	90
T3.nano	19	5745	5	145
T3.micro	9	2031	10	145
T3.small	11	3722	20	145
T3.medium	53	8917	20	145
T3.large	49	7316	30	145
T3.xlarge	4	1014	40	145
C5.xlarge	3	678	50	240
C5.2xlarge	1	339	50	240
M5.large	11	2034	50	240
Sum	**204**	**42964.4**		

Table 13 is showing the number of instances and used time in a month by Vastuu Group. T2 instances are using Intel Xeon Broadwell/Haswell Processors, with a base frequency of 2.5GHz, which can be found from Intel product page. The thermal design power (TDP) representing the average power is ranging from 27W to 165W averaging close to 90W, which is used. T3 instances are using Intel Xeon E5-2686 processor with a TDP of 145W. C5 instances are using the Intel Xeon Platinum 8124M Processors, with Skylake process technology, using 240W. Lastly there is M5 instances, which are using Intel Xeon Platinum 8175M Processors with a TDP of 240W (AWS 2021). The baseline performances are provided by AWS itself for every instance except C5 and M5. Because T2/T3.large instances have 40-60% baseline performance, C5 and M5 can be assumed to be average of 50% (AWS 2021b).

Amazon states in an IEA report, that half of the power used by Amazon data centers is green (IEA 2020), but because of the large criticism expressed by Greenpeace (Greenpeace 2019), Finnish power production values are used instead. Statistics Finland benefit sharing method provides the emission factors for electricity production by year 2016-2019 and year 2020 is assumed with three year moving average. The factors are from 116g CO_2/kWh to 146g CO_2/kWh (Statistics Finland 2019). All the available real data used in this section is from years 2020-2021. Because the instance time data and gigabytes transferred are changing widely and are hard to predict, same results are used for past years. Dell is evaluating that use stage represents 83% of the life cycle emissions of a server (Dell 2019). The remaining 17% is added to the calculations and consists of 16.6% of manufacturing, 0.3% of transportation, and 0.1% of end-of-life emissions.

Table 14. Server emissions from hour-based data and average TDP

Year considered	**2016**	**2017**	**2018**	**2019**	**2020**
Server electricity consumption [kWh]	26593	26593	26593	26593	26593
Electricity production emission factor [g CO_{2eq}/kWh]	146	131	144	116	131
Emissions [t CO_{2eq}]	**4.68**	**4.20**	**4.61**	**3.72**	**4.20**

Because the manufacturer provides only the TDP value, which is an average and not the peak power, the server power use is calculated with three different ways to ensure the viability of the results. The first way is to multiply different instance times, TDP and PUE to get kilowatt hours. PUE used in this work is 1.67 and is an average from 1600 datacenters. PUE is a factor, where total datacenter energy usage including servers, cooling, lights etc. is divided by only server used energy (Frazelle 2020, 2). Table 14 is showing the results from the first analysis.

Table 15. Server emissions from hour-based data and estimated peak power

Year considered	**2016**	**2017**	**2018**	**2019**	**2020**
Server electricity consumption [kWh]	24210	24210	24210	24210	24210
Electricity production emission factor [g CO_{2eq}/kWh]	146	131	144	116	131
Emissions [t CO_{2eq}]	**4.26**	**3.82**	**4.20**	**3.38**	**3.82**

Second way of calculation is to use average maximum server wattage instead of TDP for every instance, which is 330W (Shehabi 2018, 5). The wattage is divided by 4, representing each server in the Xeon processor: disk, fans, core, and network interface (Mazzucco 2011, 5). PUE and time consumed are the same. The results are shown in Table 15.

Table 16. Server emissions from transferred gigabytes

Year considered	2016	2017	2018	2019	2020
Transferred data [GB]	211667	211667	211667	211667	211667
Power consumption [kWh]	9525	6350	4763	3175	2381
Emissions [t $CO2_{eq}$]	**1.68**	**1.00**	**0.83**	**0.44**	**0.38**

Third and last way of calculation is to estimate the consumption from gigabytes (GB) of transferred data. The power consumption estimates for 1 gigabyte is ranging from 0.004kWh/GB to 136kWh/GB, but according to Aslan et al. 0.06kWh/GB is used. This value is from 2015 and is estimated to decrease by 50% every 2 years, which is considered in the calculations (Aslan 2017, 794). Because the range of power consumption estimates is so wide, the data has been compared to other studies. According to Andrae and Edler, the estimation for 2020 would be between 0.027-0.085kWh/GB (Andrae 2015). The IEA and The Shift Project deliver estimations from 0.002kWh/GB to 0.072kWh/GB (IEA 2019). Table 16 is showing the results from transferred data.

4.6.3 Member products and additional services

In Table 17 the emission results from member magazines, office cleaning, internet use, and phone calls can be seen. The data is gathered from company invoices and used with emission factors provided by Finnish environment institute and Finnish Research Center VTT. Member magazines are provided for employees four times in a year and one magazine is emitting 154g CO_2/pcs (Pihkola 2010, 105). Emission factors for office cleaning 0.1kg CO_2/eur, and phone calls and internet use 0.28kg CO_2/eur are provided by Finnish Environment Institute (Salo 2019, 15). Cleaning service intensity is reduced for year 2020, which almost halves the emissions. Internet and phone calls are calculated with default values for one year and the pandemic is estimated not to affect the results greatly.

Table 17. Additional service and member product emissions

Year considered	2016	2017	2018	2019	2020
Member magazines [kg CO_{2eq}]	16	22	28	34	38
Office cleaning [kg CO_{2eq}]	1079	1079	1079	1079	640
Internet and calls [kg CO_{2eq}]	7933	7933	7933	7933	7933
Sum [t CO_{2eq}]	**9.03**	**9.03**	**9.04**	**9.05**	**8.61**

4.7 Waste

Because the Valtti Card end-phase emissions were calculated in section 4.6.1, this section indicates only the waste generated from the office spaces. The data regarding waste is available only from year 2020, which is used for every year. The waste data is from the whole building, which means it is divided by the percentage of square meters that Vastuu Group is using. Because the building includes cafeteria which is assumed to produce more waste than office spaces, 2020 values are more valid to use for every year. There is no recycling data, which means the results are calculated with municipal waste factors.

Table 18. Waste from office space

Year considered	2016	2017	2018	2019	2020
Waste [kg]	538	538	538	583	583
Emissions [t CO_{2eq}]	**0.22**	**0.22**	**0.22**	**0.23**	**0.23**

Table 18 is showing the emissions from office waste. Statistics Finland provided fuel classification table gives values for municipal waste. Municipal waste default net calorific value 10.0GJ/t and CO_2 default emission factor 40.0t/TJ are giving an emission factor of 0.4kg CO_{2eq}/kg for municipal waste (Statistics Finland 2021). The amount of waste for one working day is 2.15kg from real data. National Solid Waste Management Association gives approximations by building type and for same size office the amount of waste is 2.62kg for one day, which is close to calculated results (NWRA 2021).

5 CARBON FOOTPRINT CALCULATORS

In addition to calculations shown in section 4, the emissions are calculated with the ready made tools found from the internet. This work considers 18 tools in total, which are evaluated according to their price, databases, followed standards, and parameters used for the calculation. The above-mentioned information is found from product websites, e-mail conversations, and demos where the product is presented through a videocall. Figure 7 is showing a scorecard on which the points are based. There are 4 categories and maximum points for each is five.

First there is the parameters section and the 16 parameters describe the areas considered in section 4. For example, when the assessed tool has an option for 6 different areas (employee commuting, waste, events, etc.), it gets 2 points for being 6/16. Databases and standards are working the same way, but because this work is done using GHG Protocol, 4 points is given if the tool uses the same standard. This way it can be seen if there are differences in the results even when the same accounting and reporting standard is used. Because there are many different prices for these tools, it is categorized as well. Yearly payments are given lower points, because the company must commit to the tool for a long time.

Parameters	1/16	5/16	8/16	12/16	15/16
Databases	Smaller (Such as studies)	Smaller (Such as studies), by country	International databases, by country	International databases, large amount of options, by country	Follow international standards, large amount of options, by country, + many databases for different sectors
Standards	Non-international standards	One International standard	Large international standards as EN14040/EN14064	GHG Protocol	GHG Protocol + other international standards
Price	Over 2000e, yearly payments	Under 2000e, yearly payments	Under 500e, yearly payments	Under 250e, monthly payments	Under 100e, monthly payments
Points	**1**	**2**	**3**	**4**	**5**

Figure 7. Scorecard

5.1 Pay to use calculators

Figure 8 shows the first 11 calculators assessed. The tools are provided by Pathzero, Greenfeet, OneclickLCA, Compensate plus, Climatepartner, Ecovadis, Bearingpoint, HelloCarbo, CO2nnector, Carbonzero, and Chooose. Each of them has differences such as some has downloadable platforms and others can be used inside the website. In this work the aim is to find a tool which can be used and results can be seen without external consultation.

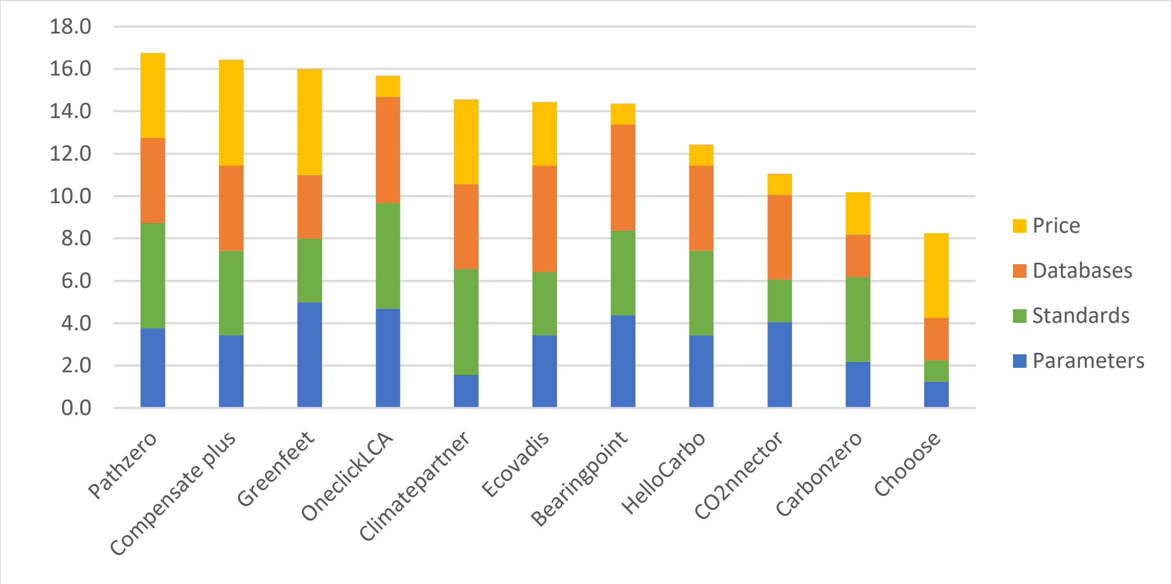

Figure 8. Evaluation of pay-to-use calculators

Pathzero provided tool has the highest points, but some of the other calculators have more options for parameters. Most of these tools do not have an option to calculate product carbon footprint, which applies also to Pathzero. This means Valtti Card emissions cannot be evaluated with Pathzero but provided services can, which means server use in practice. Events is another parameter that is not included. Pathzero is Australian and founded in 2020. It includes GHG Protocol use in the standards and is using large databases as DEFRA. This service costs 250e per month and has an option to compensate emissions through the platform.

Greenfeet is American also 2020 launched tool. This has more points regarding parameters and has a trial time to be tried with. Databases mentioned are from government bodies and the tool is GHG Protocol based. Pricing is only 100e per month. This tool was not selected, because it does not calculate the emissions itself with emission factors and the emissions must be calculated by yourself. The tool then provides tables and figures from the emissions, but the results would be the same that section 4 already showed, and they cannot be compared.

OneclickLCA tool for calculating corporate emissions is Finnish, uses a large number of databases including Ecoinvent and Finnish SYKE etc. Standards used are GHG Protocol, ISO14064, and others for different projects. The price is starting from 2000e per year, which is high for one time use.

Compensate plus is a Finnish service and it is using mostly databases open for everyone such as VTT, which is also used in section 4. The calculations are based on GHG Protocol framework. Parameter options are smaller compared to other options, but very competitive. Compensate plus and other tools as Chooose are focusing on helping companies to compensate emissions through their platform. Because of the built-in emission compensation system and large Finnish partner companies such as Supercell, the decision is to use Compensate plus as a pay-to-use tool. This tool costs 39e per month. There is also a free 2-week trial available. Compensate plus tool is selected for this work because of great customer support, feedback from co-workers of Vastuu Group Oy, and the desire to support domestic service.

Climatepartner, Ecovadis and Bearingpoint are offering consulting-based service, where the emissions or consumptions from invoices are provided by the client company and the results are given back when the calculations are done. These services have emphases as Bearingpoint is centralizing more to the product consumption and Ecovadis includes results touching ethics, labor and human rights, and sustainable procurement in addition to influence the environment. For this work it is essential, that the emissions can be calculated immediately, and therefore these services are left unselected.

Another 2020 launched tool is provided by HelloCarbo from France. When the price is left out, the other aspects are comprehensive with databases as Ecoinvent, Exiobase, and studies regarding different areas, and GHG Protocol guided calculations. The tool is new and only provided with French language, which can cause problems.

CO2nnector and Carbonzero are both based on ISO14064 standard and Carbonzero uses GHG Protocol in addition to that. CO2nnector could have higher points in Figure 8, but because the scorecard gives more points for GHG Protocol it stays at 11 points. This is not making the tool worse, but less suitable for this work. CO2nnector is using large databases as IPCC Emission Factor Database, DEFRA and Ecoinvent, where Carbonzero is using also large UNFCCC and EPA databases. CO2nnector has the highest price comparing to other assessed tools.

Chooose has only 1 point in parameters, and includes only the number of employees, events, employee commuting and business travel. The database is based on a 2019 study and calculated following the IPPC 4th assessment report. The price is connected to the amount of compensation needed.

5.2 Free to use calculators

This work considers 7 different free-to-use calculators of which 4 are chosen. In Figure 9 options can be seen, and they are assessed with three different categories. The categories which are databases, standards, and parameters are assessed the same way as in pay-to-use section. Only price is left out.

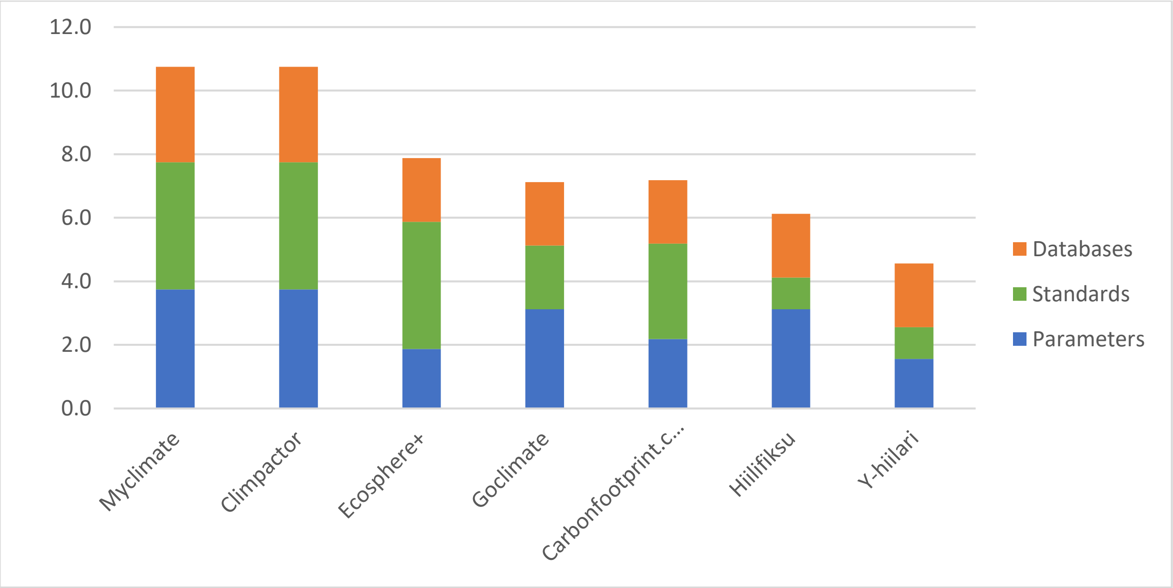

Figure 9. Evaluation of free-to-use calculators

The first of the chosen calculators is Myclimate found in 2002. This calculator established by Swiss Federal institute of Technology Zurich is using mostly GHG Protocol, ISO14040 and ISO14067 as basis methodologies. Large databases such as IPCC and Ecoinvent are giving the emission factors for calculations. Myclimate is the most suitable, when looking only parameters.

Climpactor is a Finnish carbon footprint calculator produced by Technology Industries of Finland. Climpactor is also focusing on handprint effects as wellbeing and equality, but they are out of this work boundaries and not considered. This calculation tool is using international standards such as GHG Protocol as well but cannot be labeled under only one standard. The databases used are public and Finnish such as Statistics Finland and electricity provider Helen. Climpactor shares the number 1 position with Myclimate, in every field and for this reason it is chosen.

Third chosen calculator is Goclimate, which was created in 2017 in Sweden. The tool is designed for Swedish businesses but can be used because of the similarity of the neighbor country, and the ability to assess cloud and server emissions. The calculator uses GHG Protocol as basis and is close to being GHG Protocol compliant. Mostly Swedish databases and own studies are used to provide emission factors.

Fourth tool chosen is Finnish Hiilifiksu. Helsinki University and Sitra provided tool is created for organizations, but when looking the contents and parameter options it can be used for this work. It is updated in 2019 and using Finnish databases such as VTT and Ministry of Environment provided information.

Other tools seen in Figure 9 are not used in this work. Although Ecosphere+ from UK and Carbonfootprint.com provided tools have more points altogether than Hiilifiksu, the parameter options are too small to be operated with. Y-hiilari is a Finnish Environment Institute provided calculator but does not have the required parameters for this work.

6 RESULTS AND COMPARISON

In this section the results from section 4 are evaluated and compared with results from other calculators. Together there are five tools used to calculate the emissions with the same data provided.

6.1 Calculation results and evaluation

The results are shown in tables as in section 4. If the shown tool does not have the option to assess the parameter or the parameter cannot be evaluated with the data provided, it is marked with "-". If the parameter is evaluated but the result is included in another parameter, it is marked with "*". These situations are specified more with the results. Tables are not showing the sum of emissions if they are not comparable. Figures in this section are made comparable with including only the same input parameters.

6.1.1 Electricity and heating results

First the results from electricity and heating are presented. From Table 19 can be seen that the emissions in most cases are not far out from each other and every tool uses kWh in a year to calculate electricity emissions as input. This work calculations represent the lowest emissions and the Swedish Goclimate gives the highest results when electricity is considered. Compensate plus and Hiilifiksu have the ability to add the emission factor from real data but are still giving higher results compared to this work. Electricity upstream emissions are calculated 347kg CO_{2eq} in this work, when Compensate plus estimation is 1000kg CO_{2eq}. The results regarding electricity can be seen visually in Figure 10.

Emissions from heating are harder to evaluate because of lack of data. Because Compensate plus, Climpactor, Goclimate, and Hiilifiksu have options to assess only district heating, the item is left unfilled. Myclimate does not specify the energy-based emissions and provides heating and electricity values together.

Table 19. Electricity and heating emission comparison

Calculator used	This work	Compen-sate plus	Myclimate	Climpactor	Goclimate	Hiilifiksu
Electricity emis-sions [kg CO_{2eq}]	6295	6900	9000	6650	10100	7138
heating [kg CO_{2eq}]	3176	-	*	-	-	-
Emissions [t $CO2_{eq}$]	**9.47**	**-**	**9.00**	**-**	**-**	**-**

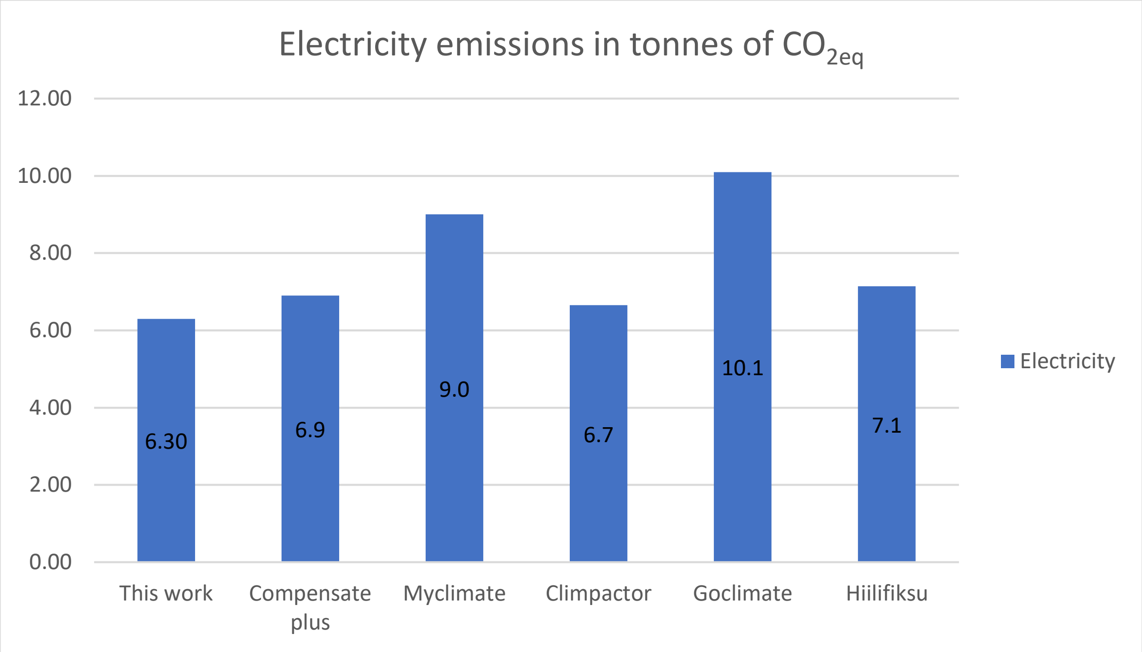

Figure 10. Electricity results comparison

6.1.2 Employee commuting and business travel results

In Table 20 the emissions from employee commuting and business travel are shown. In this table, work related travelling includes only travelling by car to increase comparability. Travelling by train and by ship is not included but it is informed if the tool has an option for these. Compensate plus does not have an option for employee commuting but the consumption can be measured in litres of fuel. The amount of fuel is calculated with VTT LIPASTO database where 2016 average values for car fuel consumption are given (VTT 2016). Average car consumption factor used here is 5.6L/100km and average biofuel blend is used in both petrol and diesel cars. Upstream emissions from commuting is 7.6 tonnes of CO_2 when this work shows 12.7 tonnes of CO_2. In compensate plus, work related travelling does not have the option to include ship or train travel. The tool recognizes airports around the world, which means accurate flight routes can be measured. The John F. Kennedy International Airport is used for long-haul flights, Frankfurt Am Main airport for long flights, and Stockholm Arlanda Airport for short flights. Nights at the hotel are assumed to be one night per visit and one visit evaluated to be 80e. The price is chosen from Scandic hotel in Stockholm when booked one moth early.

Table 20. Employee commuting and business travel emission comparison

Calculator used	**This work**	**Compen-sate plus**	**Myclimate**	**Climpactor**	**Gocli-mate**	**Hiilifiksu**
Commuting to work [kg CO_{2eq}]	42307	34900	90200	37380	42600	45662
Work related travelling [kg CO_{2eq}]	4262	3400	8600	3530	4300	4457
Flights [kg CO2eq]	28089	49100	67600	38440	98600	64759
Work related hotel nights [kg CO_{2eq}]	449	4000	6300	3730	*	9150
Sum [t CO_{2eq}]	**75.11**	**91.40**	**172.70**	**83.08**	**145.50**	**123.99**

Myclimate has the largest results for commuting by car and the input is kilometres. Flight emissions are closer to other tool results, even when the input used is number of flights divided in 3 groups: up to 3h flights, 3-6h flights and more than 6h flights. In Myclimate there is an option to include travelling by ship emissions. Climpactor total emissions are the closest compared to this work's results. All the Climpactor inputs are given in kilometres. When employee commuting is calculated, the tool gives over 100 times larger emission results compared to other tools. Therefore, work commuting kilometres are put into business travel section and calculated there. The Finnish Technology Industry providing the Climpactor tool could not provide answers regarding this problem, which means it is most likely a bug. There is an option to include both travelling by ship and by train.

Goclimate has the largest emissions when flights are reviewed, and part of the reason is that hotel nights are included in flights. The flight emissions are calculated with input data given in hours, which differs from other tools and presumably affects the results. Lastly Hiilifiksu results can be seen as average to other tool results. Only hotel night emissions are over two times higher compared to others. Number of hotel nights is an input for all tools except for Compensate plus.

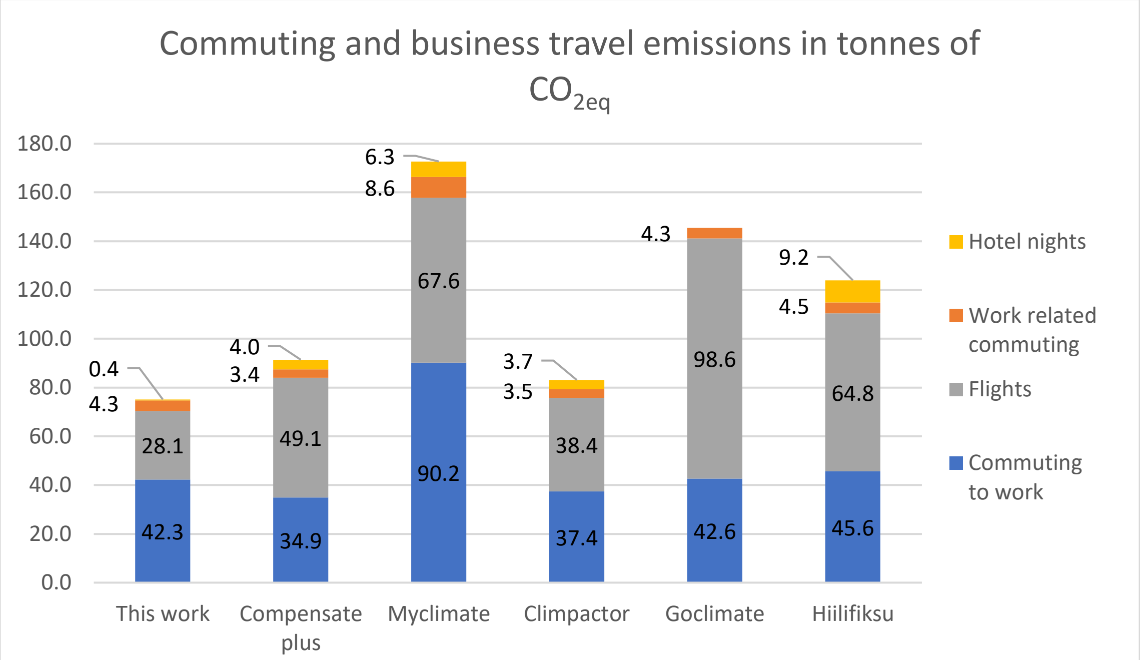

Figure 11. Commuting and business travel results comparison

In Figure 10 emission comparison from this section is shown visually. The largest differences occur with this work and Myclimate results, where Myclimate calculations are two times higher.

6.1.3 Office procurement results

Results from office procurement comparison can be seen in Table 21. Climpactor results are the highest. It is the only tool, which is requiring the input in euros when other tools calculate with the number of electronic devices. Climpactor input is put into material and supplies under electronics and electrical industry which is a large category. Other results are closer from each other.

Table 21. Office procurement emission comparison

Calculator used	This work	Compensate plus	Myclimate	Climpactor	Goclimate	Hiilifiksu
Laptop consumption [kg CO_{2eq}]	7497	6300	13800	28810	7300	3268
Smartphone consumption [kg CO_{2eq}]	1470	2700	*	*	1400	1229
Office paper consumption [kg CO_{2eq}]	27	30	36	-	-	27
Sum [t CO_{2eq}]	**8.99**	**9.03**	**13.84**	**-**	**-**	**4.52**

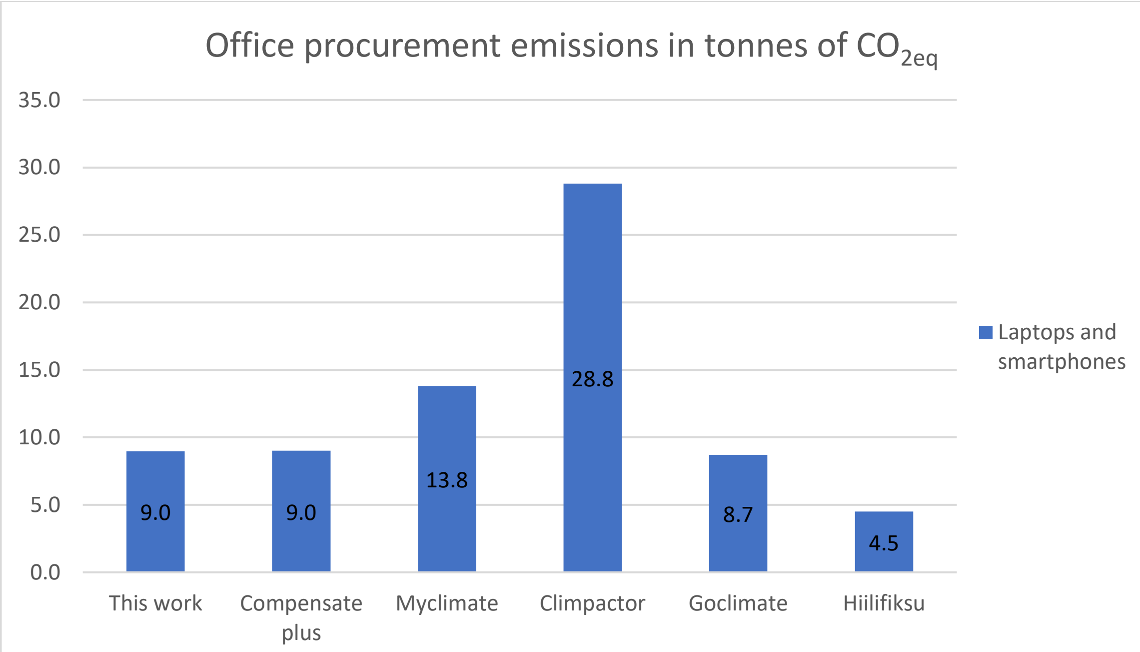

Figure 12. Office procurement results comparison

In Figure 12 office procurement emission comparison can be seen. To make the results comparable, office paper emissions are not included here. Results from this work and Compensate plus are almost identical, and Goclimate emissions do not differ a lot. Hiilifiksu provided results are the smallest.

6.1.4 Events

Results from events and meals comparison can be seen in Table 22. These results show similarities between this work and Myclimate, and Compensate plus and Hiilifiksu. This work and Myclimate uses participants, space size, and used time as inputs, when Compensate plus and Hiilifiksu use the amount of money spent. Hiilifiksu has an option to use both, but monetary option is used here. Climpactor and Goclimate do not have the option to calculate event emissions. Every calculator including this work is using the number of meals as input, when Compensate plus is using price. Compensate plus does not calculate meat and vegetarian meals differently. All the other calculators use different emission factors for vegetarian meals including Goclimate, which does not specify the emissions from meals.

Table 22. events and meals emissions comparison

Calculator used	This work	Compensate plus	Myclimate	Climpactor	Goclimate	Hiilifiksu
Events [kg CO_{2eq}]	28	400	63	-	-	454
Meals including meat [kg CO_{2eq}]	228	1400	80	-	100	104
Vegetarian meals [kg CO_{2eq}]	40	*	27	-	*	12
Sum [t CO_{2eq}]	**0.30**	**1.80**	**0.17**	**-**	**-**	**0.57**

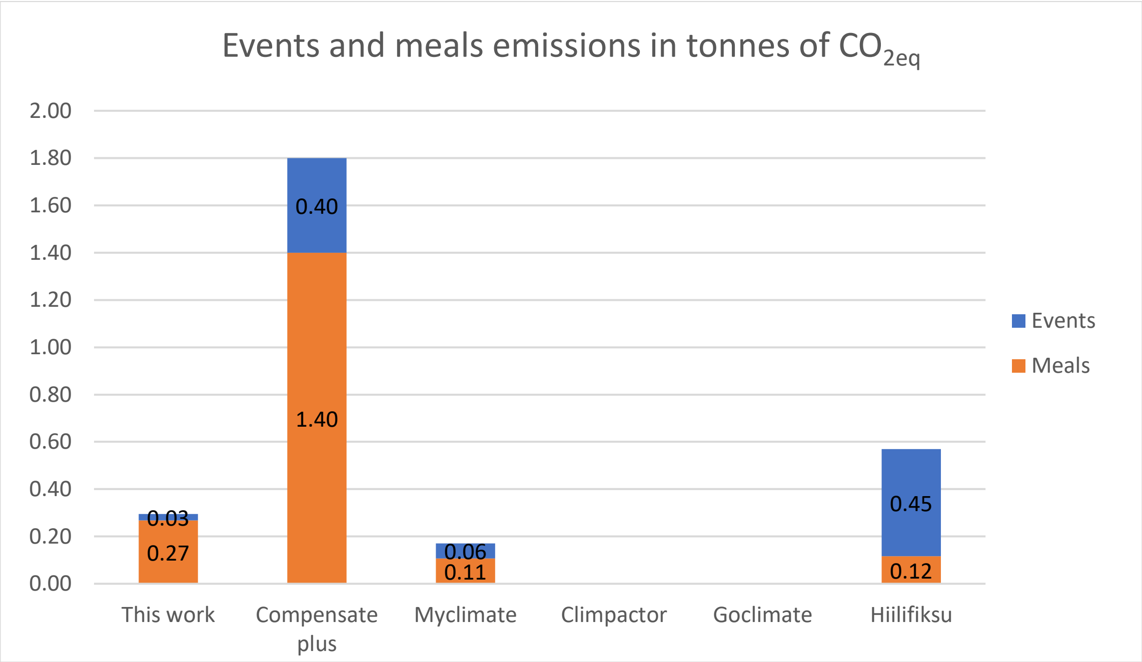

Figure 13. Events and meals result comparison

Figure 13 is showing the result comparison between used calculators visually. Here the differences from different inputs show more clearly. Compensate plus have ten times more produced emissions from meals compared to other calculators. Myclimate event time does not have an option for use in hours, which means 1 day is used. Other calculators are using 8-hour duration but this does not seem to affect the results a lot.

6.1.5 Valtti Card results

In Table 23 results from Valtti Card emissions are shown. Because the compared emission calculators are mainly designed for corporate carbon footprint calculations, they do not include product carbon footprint. Climpactor is the only tool to assess this section. Myclimate and hiilifiksu have the ability to evaluate the emissions of waste from Valtti Card, and Hiilifiksu can focus only on plastic waste. Climpactor emissions are 33% higher compared to results of this study. Production emissions are close to double with Climpactor, but transporting emissions are almost negligible. Production of cards are assessed with Finnish electricity emission factor and emissions from one plastic card. The transporting methods and distance are the same 19900km with container ship and 7800km with freight plane. Climpactor does not take weight into consideration. Letters are included with Climpactor and one letter is rounded to 100m of driving. Disposal is also showing much smaller results with Climpactor, which makes the sum of emissions to be formed almost only from production. Figure 14 shows the results visually.

Table 23. Valtti Card emission comparison

Calculator used	**This work**	**Compensate plus**	**Myclimate**	**Climpactor**	**Goclimate**	**Hiilifiksu**
Production emissions [kg CO_{2eq}]	7307	-	-	15750	-	-
Transporting emissions [kg CO_{2eq}]	1616	-	-	10	-	-
Letter to clients [kg CO_{2eq}]	307	-	-	*	-	-
Disposal [kg CO_{2eq}]	1354	-	573	20	-	51
Sum [t CO_{2eq}]	**10.58**	**-**	**-**	**15.78**	**-**	**-**

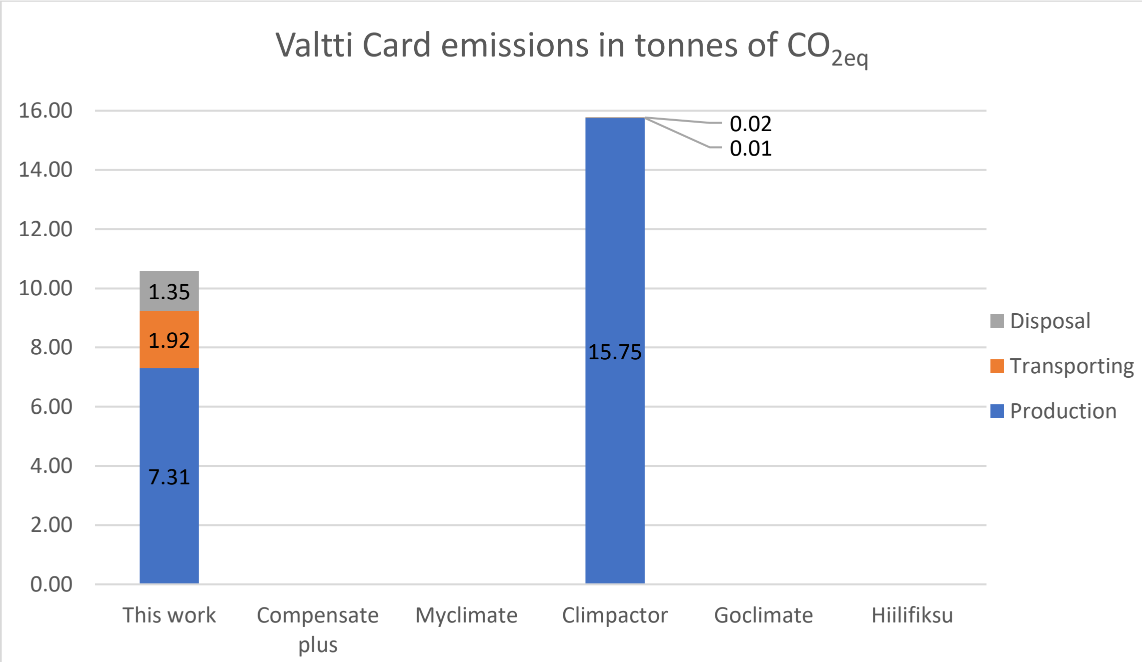

Figure 14. Valtti Card results comparison

6.1.6 Server use results

In Table 24 the results from server use can be seen. This work's results represent the smallest amount of emissions. Compensate plus and Climpactor both evaluated the emissions with the cost of server use, which could explain the similarity of the results. Myclimate does not have an option to calculate server use emissions. Goclimate uses quite similar method as this work to produce input data. The number of used active cloud servers is the input. The number can be clarified with data of used instances and the percentage of how much is one instance using capacity from a dedicated server. The input to Goclimate is 12 servers with 100% of capacity. Hiilifiksu is using the electricity usage as input. Figure 15 is showing a visual representation from the emissions from server use.

Table 24. Server use emission comparison

Calculator used	This work	Compensate plus	Myclimate	Climpactor	Goclimate	Hiilifiksu
Emissions [t CO_{2eq}]	**3.72**	**13.50**	**-**	**13.00**	**5.40**	**7.50**

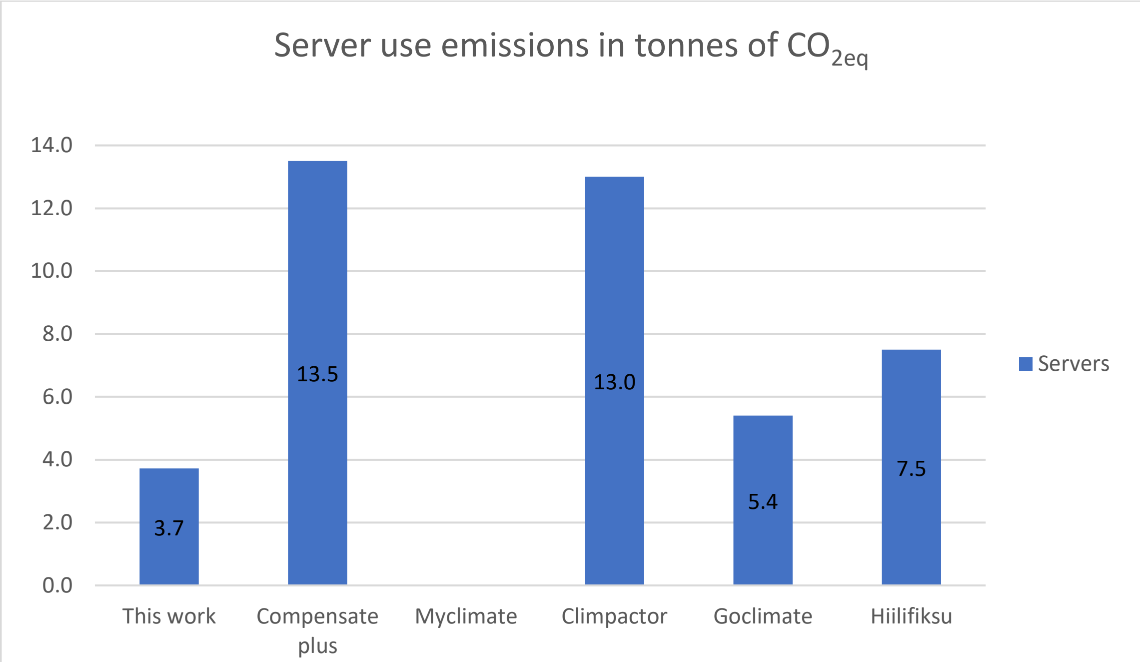

Figure 15. Server use results comparison

6.1.7 Member products and additional services results

The results from member products and additional services can be seen in Table 25. Member magazine emissions are calculated with the number of magazines in this work, and with Hiilifiksu and Compensate plus with money spent. The amount of money is used as input in every calculator where the category is available for both office cleaning, and internet and calls. The emission factors appear to be from the same source in this work and in Hiilifiksu, which is why the amount of GHG's are the same. Myclimate needs an input in kilograms of paper. Climpactor, and Goclimate do not have the option to include these categories. Climpactor has an option for internet and calls, and the input is money spent under telecommunications. In Figure 16 the results can be seen visually. Climpactor is not included for increased result comparability. In this work's and Hiilifiksu's results most of the emissions consists of internet and calls. Emissions from member magazines are minimal but with Compensate plus they are more significant.

Table 25. Member products and additional services emission comparison

Calculator used	This work	Compensate plus	Myclimate	Climpactor	Goclimate	Hiilifiksu
Member magazines [kg CO_{2eq}]	34	400	-	-	28	34
Office cleaning [kg CO_{2eq}]	1079	1500	-	-	-	1079
Internet and calls [kg CO_{2eq}]	7933	4000	-	7080	-	7933
Sum [t CO_{2eq}]	**9.05**	**5.90**	**-**	**-**	**-**	**9.05**

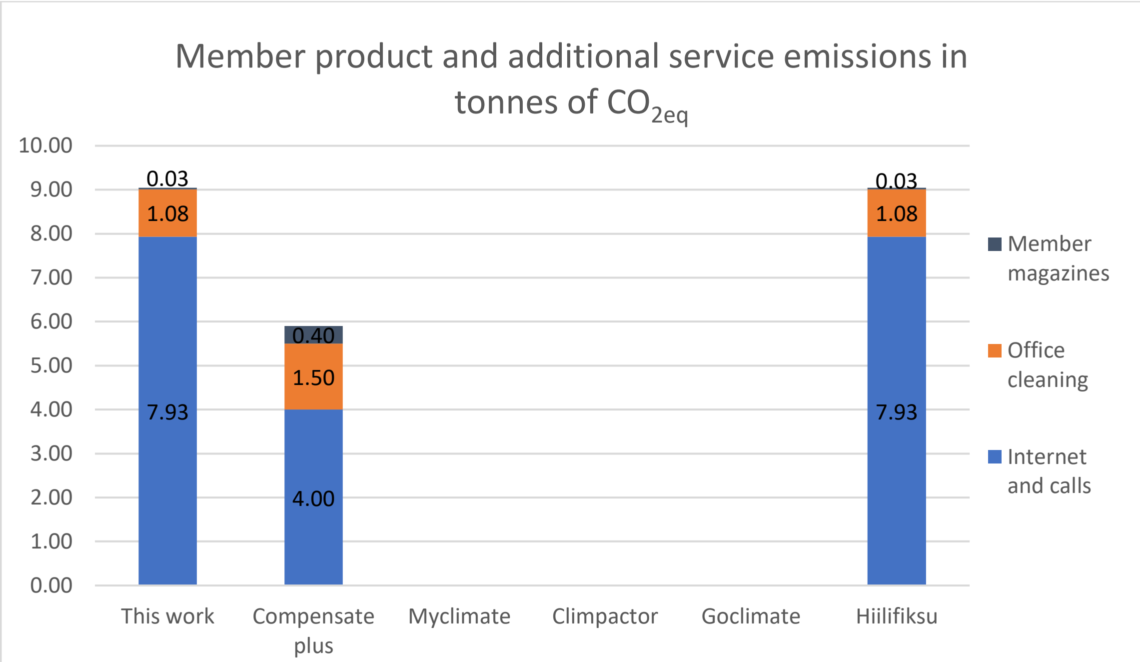

Figure 16. Member products and additional services results comparison

6.1.8 Waste

The results from wastes are shown in Table 26. In waste section, kilograms are used as input in most cases. Climpactor uses kilograms of waste as well but does not accept under 1000kg of waste. The result from Climpactor is 0,01t/CO_{2eq} if 1 tonne of waste is used as input. Goclimate is evaluating the amount of emissions using the number of employees. It considers consumed coffee and fruits, and residual waste as inputs. In Figure 17 the results can be seen visually. Goclimate's results are considerably higher compared to any other calculator. Sorted waste does not affect the results, because waste input is mixed waste in all cases.

Table 26. Waste emission comparison

Calculator used	This work	Compensate plus	Myclimate	Climpactor	Goclimate	Hiilifiksu
Waste [kg]	583	-	583	583	-	583
Emissions [t CO_{2eq}]	**0.23**	**-**	**0.46**	*****	**4.60**	**0.24**

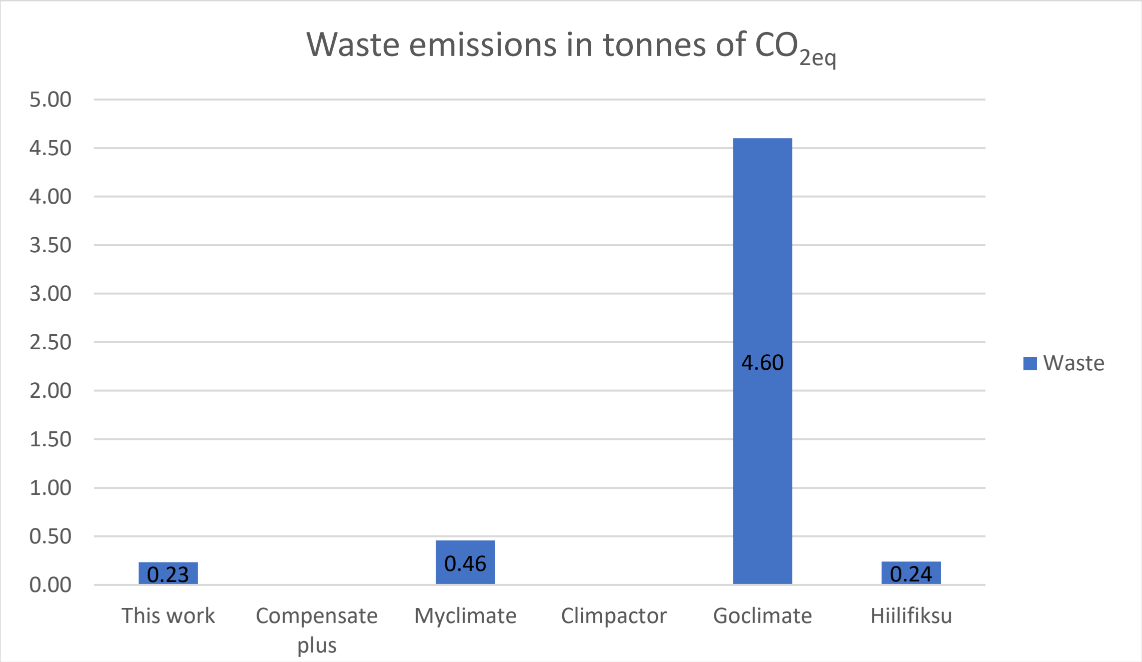

Figure 17. Waste results comparison

6.2 Comparison and sensitivity analysis between used calculators

In this section, the results are analyzed, and the decision of used result is made. Because all the emission factors used by the tools are not known, some assumptions need to be done. In every category, the results from this study are used and can be adjusted based on other tool results if there is a need. The results are adjusted using the matrix in APPENDIX 1. The evaluation matrix shows what parameters are used to adjust the results in color. The adjustment is done with used calculator result’s averages.

Green: The parameter is used to adjust the results.

Yellow: There is an argument if the parameter can be used or not. Decision specified in this section.

Red: The parameter cannot be used. Reason specified in this section.

In almost every category of results comparison, at least one tool gives a value which is significantly higher than others. Large differences can be seen when results from process analysis-based method and input-output-based method are compared. An example from this can be shown with Hiilifiksu calculator, which can assess the carbon emissions from events with both space size and hours used, and with the cost of rented space. Using the cost from invoice produces 454kg CO_{2eq}, which is equal to the use of 260 hours of 500m^2 hotel space.

Because only Compensate plus, Climpactor and Hiilifiksu have the option for adding real emission factor, they are used with this work to adjust electricity emissions. The average of the 4 results is 6.75t CO_{2eq}. This is 7% higher than the original 6.30t CO_{2eq}. Emissions from heating are not compared, because the used tools do not have the option for geothermal heat. For this reason, the original result 3.1t CO_{2eq} is used. Used energy emissions are approximately 9.9t CO_{2eq}.

Commuting to work and work-related travelling are assessed with Compensate plus, Hiilifiksu, Goclimate, and Climpactor. Climpactor and marked red in the matrix because commuting to work section presumably does not work. The results are calculated with work related travelling part of the tool, which has the same options needed. Myclimate's results are two times higher compared to other tools. Flights and hotel nights are assessed with all other tools except Goclimate because it is not specifying the results. The original emission is calculated to be 75.4t CO_{2eq}. Commuting to work and work-related travelling emissions decreased but because flight and hotel night emissions increased a lot, the carbon emissions are 32% higher and final result is 99.7t CO_{2eq}.

For office procurement, laptop, smartphone, and office paper consumptions are evaluated. This section can be assessed with every tool except for Myclimate and Climpactor. In Climpactor the input is under electronics and electronic industry. This area is wide and considered more inaccurate compared to others, and Myclimate because it does not specify the results. Office paper is assessed with Compensate, Myclimate, and Hiilifiksu because other tools have no option for this. Laptop consumption would decrease 19% with the adjustment of other tools but because this work is using manufacturer provided emission data and larger emission factor, only this work emissions are used for laptops. Smartphone and office paper consumption increased 16% and 10%. Because laptops have the largest role in this group, the emissions increased 3% from 8.9t CO_{2eq} to 9.2t CO_{2eq}.

Events are adjusted with Compensate, Myclimate and Hiilifiksu results. This is because the event space is not the same every time and there is no absolute emission factor for it. Climpactor and Goclimate are left out because they have no option for events. Meat including meals and vegetarian meals are assessed together to include more tools to the evaluation. Compensate plus and Climpactor are left out regarding meals. Compensate plus is the only one evaluating this section by cost which is more inaccurate than evaluating by quantity. There is no option for meals in Climpactor. The emissions increased 30% from the original 0.3t CO_{2eq} to 0.4t CO_{2eq}.

Valtti card emissions can be assessed with only Climpactor because other tools do not have the option to calculate product emissions. Because Climpactor provided transporting emissions are very small, they are considered unreliable and for this reason left out from evaluation. Disposal can be assessed with Myclimate, Climpactor and Hiilifiksu. Production emissions increased 58% and disposal emissions decreased 63%. The final emissions increased 14% from 10.6t CO_{2eq} to 12.0t CO_{2eq}.

Server use emissions are assessed with two first methods from this work. The third method considering transferred data is unreliable because the emission range for 1 gigabyte is wide and the results are very small compared to other results. In addition, server use is evaluated with every tool except for Myclimate, which has no option for this section. The emissions increased 108% from 3.7t CO_{2eq} to 7.8t CO_{2eq}. This is a large but expected increase because of the used assumptions in the calculation process. If the EU's average electricity production emission factor was used instead of Finland's, this work's results from server emissions would have been 8.0t CO_{2eq}. This is very close to the average from CF tool results and strengthens the assumption, that the real value is somewhere between 3.7-8.0t CO_{2eq}, specially if Amazon AWS datacenters are using even close to 50% green energy.

Member magazines are evaluated with Compensate plus, Goclimate, and Hiilifiksu. Office cleaning is evaluated with Compensate plus, and Hiilifiksu. Internet and calls are evaluated with Compensate plus, Climpactor, and Hiilifiksu. Other tools do not have options for these sections. The emissions decreased 11% from 9.0t CO_{2eq} to 8.1t CO_{2eq}.

Waste emissions are assessed with Myclimate and Hiilifiksu. Because there is no financial data from waste, Compensate plus is left out. Climactor cannot evaluate small amounts of waste and Goclimate uses number of employees as input data, which gives values that differ greatly. The emissions increased 33% from 0.2t CO_{2eq} to 0.3t CO_{2eq}.

Figure 18 shows the emissions calculated in section 4 compared to the adjusted results. All component emissions are increasing when adjusted except additional services, where internet and calls form the greatest portion. Climpactor evaluated the emissions to a bit lower, when Compensate plus halved the emissions. Originally calculated emissions from Vastuu Group are 117.7t CO_{2eq} and adjusted emissions 147.4t CO_{2eq}. When compared, the results increased 25%.

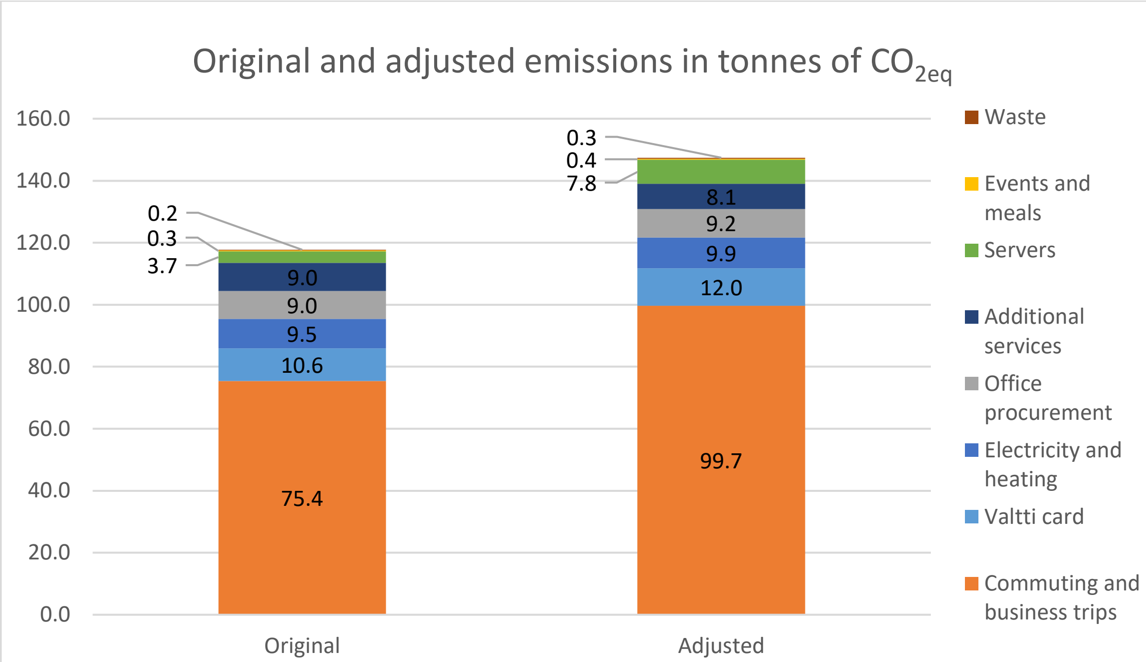

Figure 18. Vastuu group total emissions comparison with 2019 values

7 ROADMAP TO CARBON NEUTRALITY

This section provides a base for Vastuu Group Oy to achieve carbon neutrality. A Corporate Accounting and Reporting Standard revised edition from GHG Protocol is guiding companies to account and report emissions at minimum from scopes 1 and 2 (GHG Protocol 2015, 25). The minimum effort is marked as a milestone but because the scope 3 emissions form 93% of whole value chain emissions, this section calculates emission reduction opportunities and their cost for all scopes. The goal is to estimate possible reductions from the emission sources and compensate the rest. Scope 3 compensation costs are calculated with Compensate plus price which is 28e/t CO_{2eq}.

Vastuu Group does not have any scope 1 emissions and scope 2 considers upstream electricity and heating emissions. If the company would change electricity contracts to 100% green, the cost is 440e more in a year. Because the Espoo office is already heated with green geothermal energy, only the $48m^2$ district heating is left. The additional cost of using green district heating is estimated 44e per year. The cost of electricity and district heating are estimated with Fortum’s prices. Together, it costs 480e per year to make Vastuu Group Oy fully carbon neutral with minimum requirements, which is scopes 1-2. This amount is extremely small for an IT company of this size.

Scope 3 emission reduction opportunities can be started from commuting and business travel. This is by far the largest emission source of Vastuu Group Oy. Year 2020 emissions regarding commuting and business travel were only 30% compared to 2019 emissions, even with 8 new employees. With relation to year 2021 number of employees, the emissions are estimated to be 131.7t CO_{2eq} and 30% of that is 40 tonnes of CO_{2eq}. Because 70% reduction is a large step, more realistic result at first could be 50%, which means 65.9t CO_{2eq} to be compensated every year. The cost is 1844e/a with 50% reduction and 1121e/a with 70% reduction.

Electricity scope 3 emissions decreased 47% from year 2019 to 2020. The amount of used electricity can be assessed in proportion to employees being at work, which means this part can be evaluated with results from commuting to work. The upstream emissions from electricity use are 0.19t CO_{2eq} in year 2020 and evaluated to be 0.22t CO_{2eq} in 2021. District heating upstream emissions are evaluated 34.8% and geothermal heat 47.8% (Vuorinen 2019). This is makes up to 1.5t CO_{2eq} of upstream heating emissions to be compensated in a year. The cost for both electricity and heating together is 48e/a.

Vegetarian meals in events form approximately 33% from all meals. Two scenarios are calculated for this section. First is 50% of all meals are vegetarian and second is 100%. Because there are more employees compared to year 2020, the emissions increase from 296kg CO_{2eq} to 305kg CO_{2eq}. If 100% of the meals would be vegetarian, the emissions decrease to 159kg CO_{2eq}. These reductions are very small on the company scale, because the yearly cost decreases from 9e to 4e.

From additional services, member magazines are ordered for only 2 times a year from year 2021, which means the emissions can be split from 38kg CO_{2eq} to 19kg CO_{2eq}. The reduction and cost are both under 1e. This is not added to the calculations because the results cannot be measured with an accuracy of 1 euro.

Last significant reduction can be done with Valtti Card if the service is transferred to cloud. There is no data how much the service would use electricity or cloud space. Because there are 9 services provided by Vastuu Group Oy, all server emissions are divided to those services. The Valtti Card service is evaluated to use 1/9 part of server emissions calculated in section 6, which is 0.86t CO_{2eq}. Because Valtti Card now have several stages emitting GHG, the emissions would decrease 93%. The cost before reduction is 337e/a and after reduction 24e/a.

There are no other significant reductions to be made by Vastuu Group Oy. If scope 3 companies such as Amazon AWS providing the servers or phone and internet services decrease their emissions in the future, the yearly cost for Vastuu Group Oy will decrease as well.

In Figure 19 and Figure 20 the original emissions calculated in section 4 and adjusted emissions from section 6 are shown with reduction possibilities. Electricity consumption is decreasing more in adjusted model because Compensate plus evaluated the upstream emissions to be lower than in original calculation results. In both figures commuting and business travel, and office procurement results have increased because the numbers shown are 2021 estimations with today's number of employees. Commuting and business travel reductions are calculated with 50% reduction from the 2019 values. Best case values are extrapolated results from year 2020 pandemic values. The emissions decreased 70% in 1 year.

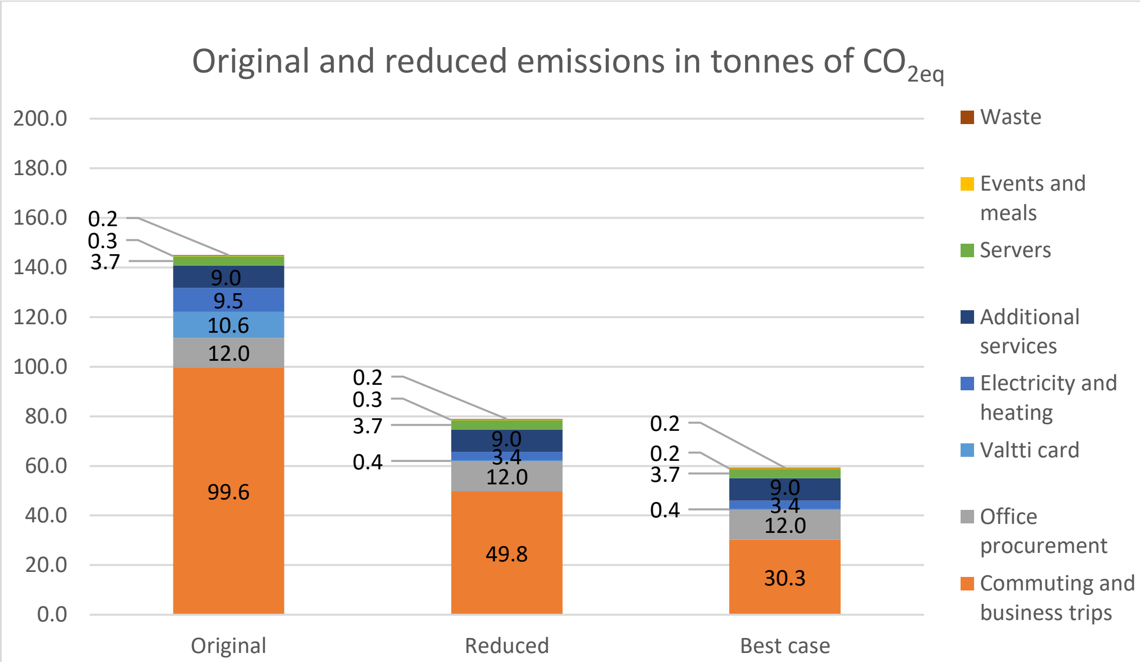

Figure 19. Original emissions compared to reduced emissions

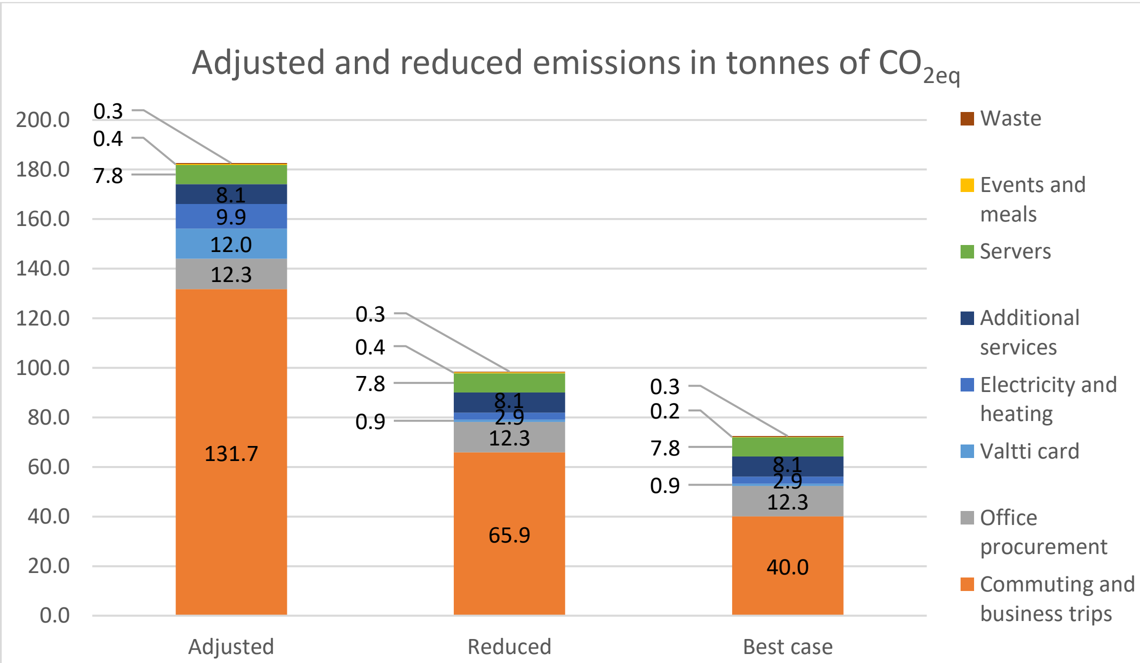

Figure 20. Adjusted emissions compared to reduced emissions

In Figure 21 and Figure 22 the costs of emissions are shown from original and adjusted emission results. Electricity and heating costs are increasing from original to reduced results because compensating the produced emissions are cheaper than buying green electricity and compensating the rest. Reducing commuting and travelling are affecting greatly to costs and the largest potential is found there. Because the compensations are done using Compensate plus, the additional cost of use of the service are added. Final cost with no reductions is between 5692e/a and 4640e/a. Reduced option between 3644e/a and 3095e/a and best case scenario between 2888e/a and 2518e/a.

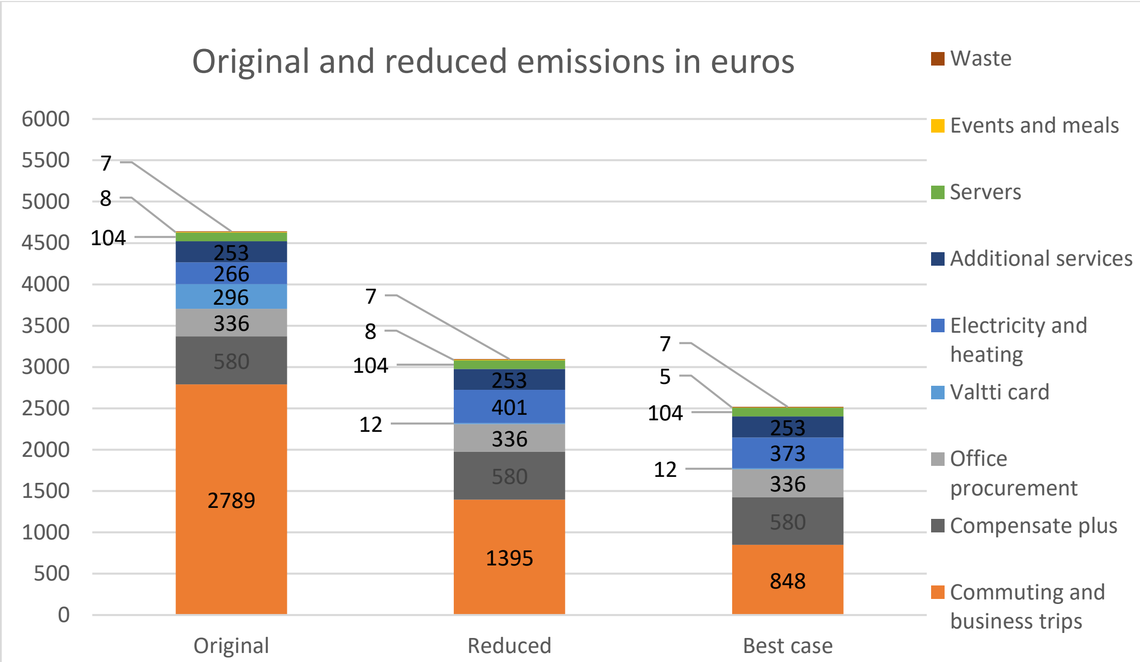

Figure 21. Original emission costs compared to reduced emission costs

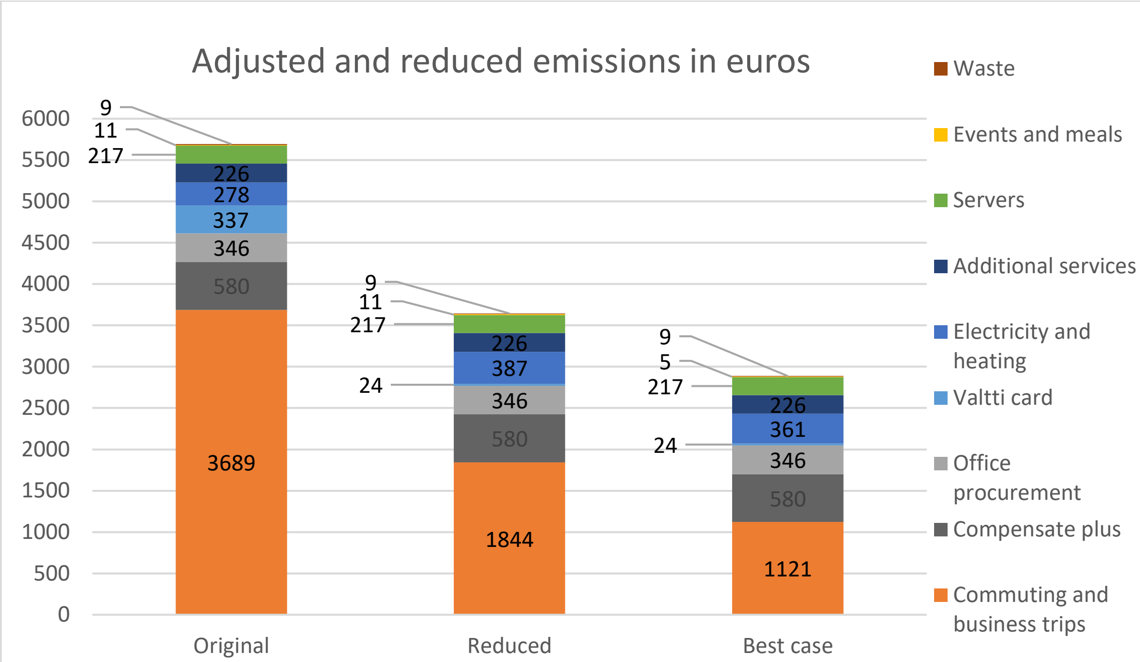

Figure 22. Adjusted emission costs compared to reduced emission costs

Because the emissions of an IT-company are already small and hard to reduce, the recommendation of this work is to change the electricity and Tampere office district heating contracts to 100% green. The recommendation is to follow the adjusted model, where the five carbon footprint calculator results are taken into consideration with this work's calculations. Total emissions are then 176.6 tonnes of carbon equivalents per year. New green contracts and emission compensations cost 6010e/a. The recommendation is shown in Figure 23 and Figure 24.

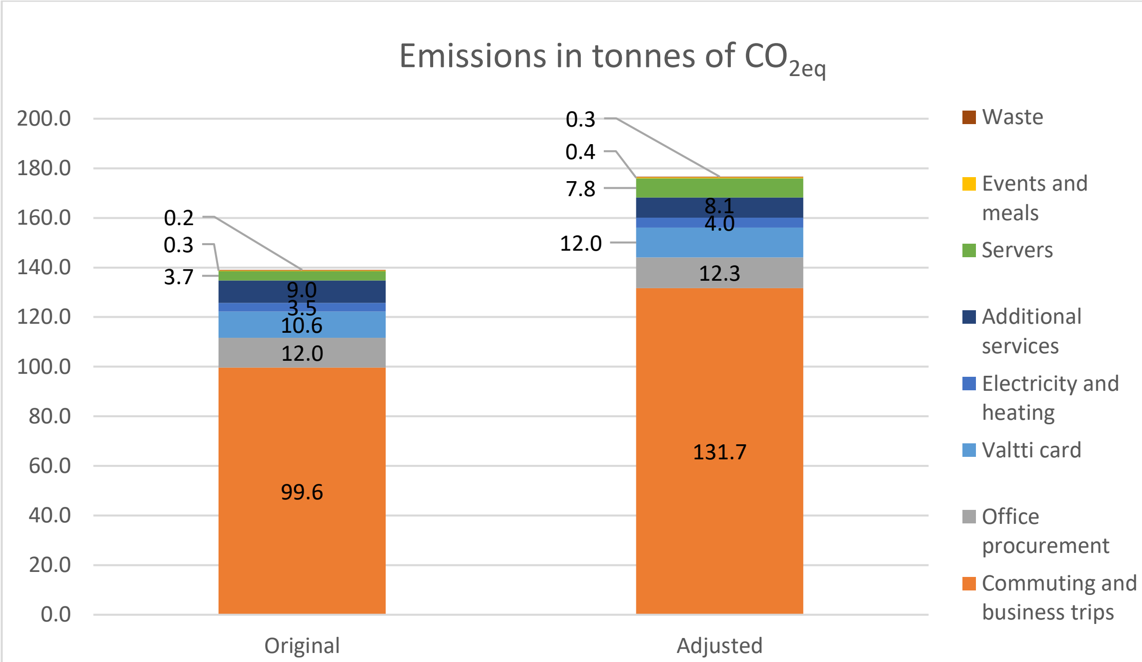

Figure 23. This work's recommendation for Vastuu Group Oy

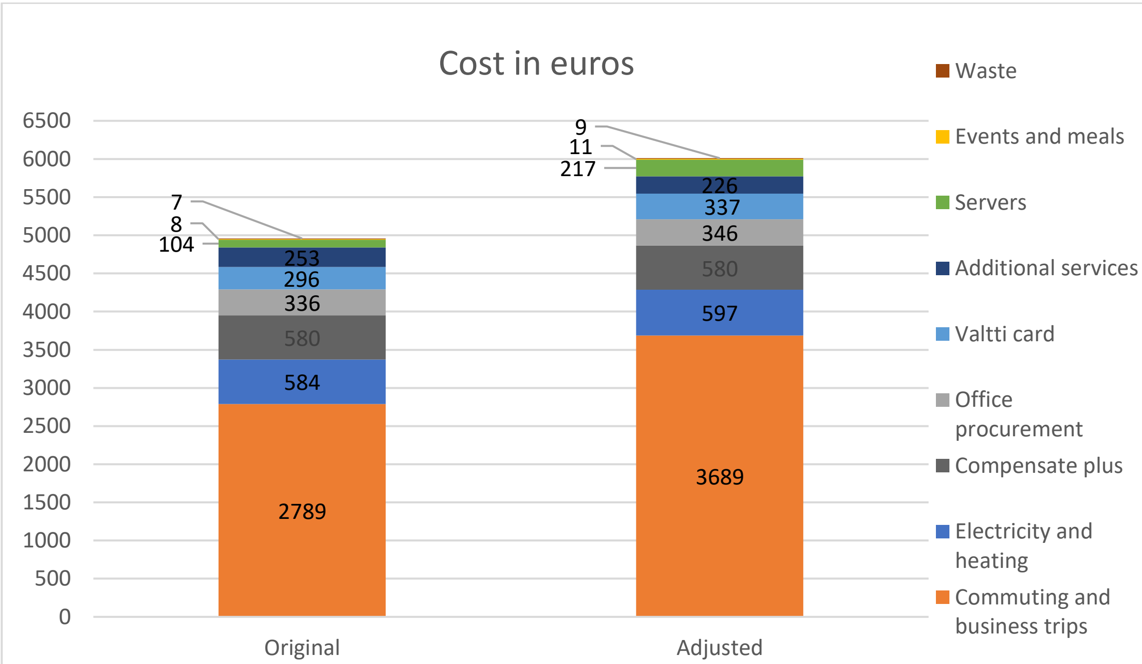

Figure 24. This work's recommendation costs for Vastuu Group Oy

8 CONCLUSIONS FOR CARBON FOOTPRINT CALCULATOR DEVELOPMENT

The hybrid methodology is working well with this work. The truncation errors caused by process-based method can be easily fixed with attaching input-output based factors when they are needed. There are variations of instructions and standards guiding the life cycle assessment process and this work confirms the fact that unity is needed for standardization, but any specific guidance or standard is not yet being chosen for global guide. The differences from the emission results are mostly coming from used data, and only a small part of it is caused by the chosen guidance. In the near future there will most likely be large and reliable data banks to be used for different projects. The recommendation here is to use the largest and most popular options, which provide country-specific information.

The emission results in Figure 23 are showing that the adjusted recommendation for Vastuu Group Oy is evaluated to be 26% higher than the original emissions. The difference is formed from varied emission factors used by the 5 calculators. Some of the calculator’s factors are using cost as input when original work is primarily using process-based data. The adjusted version results are higher mostly because input-output methodology can easily under/overestimate emissions. Other variations are coming from pure assumptions and emissions from server use is an example for this. Firstly, it is assumed, that all the servers used are provided by Amazon AWS, when there are others as well. Secondly, the electricity that servers are using is assumed to be produced with Finnish electricity production emission factors. There is not enough data or time to go through all server providers and the physical servers they are using. There is also a lack of data of electricity production emission factors that Amazon AWS is using. Because Finland has been ahead of EU’s emission reduction goals, safe assumption would be that also electricity and electricity related emissions are lower. The difference in emissions makes the adjusted model to be 21% more costly. As a whole the costs are still small compared to different sectors and a price close to 6000e/a is very reasonable to make this size company fully carbon neutral. The constant price of Compensate plus service is 580e/a which is little under 10% from the total costs. The reason for recommending the adjusted model over the original, is that overcompensating is not as significant problem as undercompensating. Overcompensation would mean that the company is then carbon negative, and if the emissions and compensation is wanted to be in balance, it costs less. Also, assumptions such as server consumption calculations are adjusted towards the assumed real values.

This work shows that the results provided by different emission calculators, are not comparable as such. Any of the used tools do not have all the options needed to calculate case Vastuu Group Oy emissions on their own. For example, every calculator lacked the ability to use geothermal energy as a heating option, which is surprising when considering the increased demand of it. Most of the tools have the option to report green heating but green district heating is a different subject compared to geothermal heating. These options will hopefully expand with the data banks. The case LCA process in practice is mostly searching for consumption data from inside the company. Because mostly this data is provided by invoices, the process could be updated automatically in a monthly basis if the data were gathered straight from the source.

9 SUMMARY

This thesis was studying carbon footprint calculation and reporting methodologies, and standards guiding the process. The work was centered around three sectors: Building and construction, logistics, and companies. Overall, the well-known life cycle assessment (LCA) was seen to be the most suitable because it considers all the life cycle phases of a product, service, building, etc. LCA has three major life cycle inventory (LCI) methods to be chosen from. LCI presents all the emissions sources of the assessment. Process-based method is the most precise option because it is using real material and energy flows as inputs and outputs. This option requires the most resources and is mostly used with smaller processes as products. Economical input-output method uses economic data with final demand emissions and converts the monetary flows to energy flows. This is mostly used with large processes as cities and countries, and is more inaccurate than the process-based method. Hybrid method is combining advantages from the two above mentioned methods and is gaining more popularity because it can be weighted towards process-based, or input-output based methods. The methodology should be chosen based on the size of the process and the resources available. All the sectors have different options for standards but there is no unity or global recognition for the best and most suitable option. This work recommendation is to use the most popular standards used in the country and follow the current laws regarding the subject and prefer hybrid methodology because of its flexibility.

The case in this study was using the hybrid methodology and GHG Protocol standards to calculate the carbon footprint of Vastuu Group Oy. The methodology was mostly process-based but EIO-method were used when needed. All the major emission sources were included except water use, and other office procurement than laptops, mobile phones, and office paper. Water is used only by employees in office and there are no constant large procurement sources. The inputs were gathered from an inquiry to the employees, discussions with human resources and management, and invoices. Scopes 1-3 were considered, and the result was 117.7t CO_{2eq} emissions in a year with 2019 values. Scope 3 represents 93% of all the emissions produced.

The next step was to evaluate 18 carbon footprint calculators and choose 5 of them to work with. 11 of the tools were pay-to-use and 7 free-to-use. Compensate plus was the only paid calculator chosen and Myclimate, Climpactor, Goclimate, and Hiilifiksu were the four free-to-use tools used in this work. The tools were selected based on how suitable they were for calculating Vastuu Group Oy's emissions. The assessment categories were parameters, standards, databases, and price. They were evaluated with a scorecard presented in section 5. After this, the Vastuu Group Oy emissions were calculated again with the additional tools. Because none of the tools could include all the emission sources and had very different parameter options, the results were incomparable as such. The originally calculated results were adjusted with the results provided by the five tools and the results increased 25% to 147.4t CO_{2eq}. The adjustment was done with tool average values and the evaluation matrix presented in appendix 1. The increase in emissions was due mostly because of monetary based inputs required by the tools.

Lastly this study provided a roadmap to carbon neutrality for Vastuu Group Oy. The largest emission reduction potential is in commuting and business travel, which forms 64% of the company's emissions. As a result of the pandemic and working from home, results from commuting and business travel in 2020 were only 30% of 2019 numbers. Because Vastuu Group Oy is an IT-company already producing relatively small amount of emissions the recommendation of this work is to change the electricity contracts and Tampere office district heating contract to 100% green. Other scope 3 reductions such as from server use are hard to reduce from the company's end. The recommendation for compensation is to follow the adjusted model where the five used tool results, presented in section 7 are taken into consideration as well. The reason for this is, that overcompensating is not as significant problem as undercompensating. Total emissions with the recommendation and adjusted model are 182.6 tonnes of carbon equivalents in a year. If Compensate plus service is used for compensating these emissions and new fully green electricity and heating contracts were used, the cost would be 6010e in a year.

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APPENDIX 1: Evaluation matrix for adjusting the calculation results

	This work	Compensate plus	Myclimate	Climpactor	Goclimate	Hiilifiksu
Electricity	By consumption and provider emission factor. Includes renewables and average values.	By consumption and provider emission factor. Option for renewables and average values.	By consumption. Does not specify heating and electricity results. Option for renewables.	By consumption and provider emission factor. Option for renewables.	By consumption. Option for renewables and average values.	By consumption and provider emission factor. Option for renewables.
Heating	By office space area. Geothermal heat.	By consumption and provider emission factor. Only district heating, fuel and gas. Option for average value.	By consumption. Option for oil, gas wood, district heating. Does not specify heating and electricity results.	By consumption and provider emission factor. Only district heating and gas.	By consumption. Only district heating. Option for average value.	By consumption and provider emission factor. Option for renewables.
Commuting to work	By distance and fuel consumption. Car and bus. Petrol and diesel.	By fuel use. Gas, and many options for different fuels.	By distance. Public transport and car.	By distance. Car, bus and emission free options. Results impossible, maybe a bug.	By distance. Car.	By distance. Car, train, bus. Diesel, petrol, gas and electric options for car. Green electricity option.
Work related traveling	By distance and fuel consumption. Car, bus, train, ship.	By fuel use. Gas, and many options for different fuels.	By distance or fuel use. Public transport and car.	By distance. Car, bus, train or ship.	By distance. No option for fuels.	By distance. Car, train, bus, ship. Diesel, petrol, gas and electric options for car. Green electricity option.
Flights	By quantity. Short-haul, medium-haul and long-haul flights.	By distance from airport to airport. 4 different class options.	By quantity. Short-haul, medium-haul and long-haul flights. Business class option.	By distance. Inside Finland, abroad and long-haul flights.	By total flight hours.	By distance. Short flights, long flights and long-haul flights.
Hotel nights	By quantity.	By cost.	By quantity.	By quantity.	No input. Included with flights.	By quantity. Option to choose cost.
Laptops	By quantity.	By quantity or by cost.	By quantity. Does not specify the results	By cost. Input under electronics and electrical industry.	By quantity.	By quantity.
Mobile phones	By quantity.	By quantity or by cost.	By quantity. Does not specify the results	By cost. Input under electronics and electrical industry.	By quantity.	By quantity.
Office paper	By weight.	By cost.	By weight. Option for recycled paper.	No option.	No option.	By weight. Option for recycled paper.

Event	By area and time.	By cost.	By area, time, and participants.	No option.	No option.	By cost or used area and time
Meals (meat)	By quantity.	By cost. Meat or vegetarian not specified.	By quantity.	No option.	By quantity.	By quantity.
Meals (vegetarian)	By quantity.	By cost. Meat or vegetarian not specified.	By quantity.	No option.	By quantity.	By quantity.
Server use	By quantity of used servers and capacity.	By cost.	No option.	By cost. Input under telecommunications.	By quantity of used servers. Difficult to solve. Option for cloud and dedicated server. Option for green electricity.	By electricity consumption. Option for green electricity.
Valtti card	Product production, logistics and disposal.	No option.	No option.	Input under product procurement. Option for logistics and disposal.	No option.	No option.
Member magazines	By quantity.	By cost.	By weight.	No option.	No option.	By quantity.
Office cleaning	By cost.	By cost.	No option.	No option.	No option.	By cost.
Internet and calls	By cost.	By cost.	No option.	By cost.	No option.	By cost.
waste	By weight.	By cost of waste services.	By weight.	By weight. Minimum of 1 tonne.	By the number of employees.	By weight. Option fo recycling.