# CLIMATE IMPACTS OF SMALL EXPERT COMPANIES : CASE STUDY

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**ABSTRACT**

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Abstract

Being among the greatest threats and challenges of our time, climate change is not a battle of individual industries and countries but is an issue of global nature and requires collective action. The notable rise and increase of knowledge work in recent decades require us to better recognise the effect the field poses on climate.

This study strives to strengthen the understanding of emissions caused by small expert companies and approaches the research problem through a case company, which is a consultancy of few employees. The study accounts for emissions from year 2020 from the company office's heat and electricity consumption, commuting, procurement of laptops as well as transmission of data. The calculation is carried out in accordance with the Greenhouse Gas Protocol's Corporate Standard.

Results point out that even though the office the company is using is very small, the emissions from district heat consumption are still of great significance, although emissions from sourced laptops caused the most emissions. Year 2020 was greatly affected by the COVID-19 pandemic and very little commuting took place, but emissions were also assessed for a normal year 2020 scenario, which showed that in a normal year the emissions from commuting would outweigh everything else. Emissions from data transmission pointed out to be negligible.

Emissions of an expert company can be mitigated by sourcing laptops used or at least prolonging their lifetime as long as possible. This can be advanced by purchasing models that are possible to repair and upgrade to maintain the necessary functionality. Furthermore, a company can strive for efficiencies in space utilization and try to get by with an office as small as possible and when needed, rely on shared or flexible spaces. If possible, a company can also take efforts to utilize renewable electricity and incentivise employees use of public or light transportation and increase the share of remote work.

Key words
Climate change, knowledge work, office, computer, commuting

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Tiivistelmä

Ilmastonmuutoksen ollessa yksi aikamme suurimpia uhkia ja haasteita, se ei ole ainoastaan yksittäisten teollisuudenalojen tai maiden vastuulla, vaan on luonteeltaan globaali ongelma ja vaatii kollektiivista toimintaa. Tietotyön määrän huomattava kasvu viime vuosikymmeninä vaatii, että sen ilmastovaikutukset pyritään tunnistamaan.

Tämä tutkielma pyrkii vahvistamaan pienten asiantuntijayritysten aiheuttamia ilmastovaikutuksia ja lähestyy tutkimusongelmaa tapausyrityksen kautta, joka on muutaman työntekijän konsulttiyritys. Päästöt lasketaan vuodelle 2020 ottaen huomioon yrityksen toimiston sähkö- ja lämpöenergiankulutuksen, työmatkailun, hankitut tietokoneet sekä datan siirron. Laskenta on toteutettu noudattaen GHG Protocol Corporate Standardia.

Tulokset osoittavat, että huolimatta yrityksen käytössä olevan toimiston pienestä koosta, kaukolämmönkulutuksesta aiheutuneet päästöt olivat huomattavat, vaikka suurin osa päästöistä syntyikin kannettavien tietokoneiden hankinnasta. Vuotta 2020 muutti kuitenkin merkittävästi COVID-19-pandemia, ja työmatkoista aiheutuneiden päästöjen rooli oli vähäinen. Päästöt arvioitiin kuitenkin myös normaaleille olosuhteille, eli tilanteelle, jossa koronapandemian vaikutukset pyrittiin jättämään huomiotta, jolloin työmatkailun päästöt nousivat merkittävimmäksi päästölähteeksi. Datan siirrosta aiheutuneet päästöt osoittautuivat tehtyjen olettamuksien valossa vähäpätöisiksi.

Tapausyrityksen sekä muiden asiantuntijayritysten päästöjä pystyttäisiin laskemaan hankkimalla tietokoneet käytettyinä ja käyttämään niitä mahdollisimman pitkään. Käyttöiän pidentämistä voidaan edistää hankkimalla malleja, joita on mahdollista korjata ja päivittää tarpeellisen toiminnallisuuden ylläpitämiseksi. Yritys voi myös pyrkiä hyödyntämään toimistotilansa mahdollisimman tehokkaasti ja hyödyntää tarvittaessa esimerkiksi jaettuja tai joustavia tiloja. Mahdollisuuksien mukaan yritys voi myös pyrkiä käyttämään uusiutuvaa sähköä ja kannustaa työntekijöitään käyttämään julkista tai kevyttä liikennettä sekä tekemään enemmän etätöitä.

Asiasanat
Ilmastonmuutos, tietotyö, toimisto, tietokone, liikkuminen

Säilytyspaikka
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# 1 INTRODUCTION

## 1.1 Research background

Anthropogenic emissions in recent years have been the highest in history, and they have posed widespread impacts on natural systems. The last 30 years have likely been the warmest 30-year period of the last 1400 years, and since 1880 to 2012 the average global temperature on Earth has increased 0.85 °C. The upmost 75 meters of oceans globally have increased by 0.11 °C in temperature by decade over the period from 1971 to 2010. Since the beginning of industrialization, the acidity of the oceans has increased 26% and the global mean sea level rose by 0.19 meters over the period 1901-2010. (IPCC, 2015.)

Climate change has already brought about observable effects, such as shrinking glaciers, shifting plant and animal ranges, intense heat waves, droughts, stronger and more intense hurricanes and other events that take place regionally and globally. Global climate change is projected to take place over centuries. (NASA, 2021.) Global warming is a result of atmosphere trapping more heat and therefore blocking it from escaping the Earth. Gases such as carbon dioxide ($CO_2$), methane ($CH_4$), water vapor ($H_2O$) and nitrous oxide ($N_2O$) are examples of greenhouse gases that cause global warming when their concentration in the atmosphere increases. (NASA, 2021b.) Human activities, such as burning of fossil fuels, production of goods and changes in land use have had an effect on climate change. Approximately half of all anthropogenic $CO_2$ emissions over the period of 1750 and 2011 occurred during just the last four decades. Of all the anthropogenic emissions after 1750, approximately 40% have remained in the atmosphere. (IPCC, 2015.)

Although the collective recognition of climate change has clearly increased in the 2010's, on a decision-making level it has been discussed and advanced for decades. The first major conference was the *Earth Summit* (the so-called Rio Conference) in 1992, which opened the *United Nations Framework Convention on Climate Change* for signatures and was ratified two years later, in 1994. (UNFCCC, 2019a.) Other treaties were subsequently linked as extensions to that treaty: the *Kyoto Protocol* in 1997, which set internationally binding emission reduction targets, as well as the *Paris Agreement*, which aimed to strengthen the co-operation to combat climate change and to limit the temperature rise to 1.5 °C. (UNFCCC, 2019b; UNFCCC, 2019c.)

IPCC (2015) has stated that climate change cannot be mitigated effectively if individual agents advance their own interests independently, because climate change is a problem of collective action and global in scale, because most greenhouse gases accumulate over time and emissions from separate agents, be those individuals, organizations or countries, effect other agents. Although some industries contribute to climate change more significantly than others, it is important to gain knowledge and strive for improvements even in areas that do not at first glance seem as important in the combat against climate change. Comparing to energy production and industrial companies, for example, knowledge work in general does not seem as crucial, but knowledge workers still contribute to industries such as transportation when they commute to the office, construction and energy production when they build, renovate and exploit office buildings and manufacturing of goods when they procure work equipment, such as computers, monitors, printers, phones and other appliances. In the U.S., transportation sector caused 29% of total emissions, electricity 25%, and commercial & residential buildings 13% and industry 23% of total emissions in 2019 (EPA, 2021). Knowledge workers contribute to all of these sectors either directly or indirectly. Forrester, a US-based consultancy, assessed the number of information workers globally in 2012 based on a definition of "*—workers who use a PC, smartphone, or tablet for work purposes an hour or more per day*" to be 478 million and to increase to 865 million by 2016. In 2018 they assessed the number of knowledge workers to be 1.25 billion. (Forrester, 2020.) Albeit many job profiles that are usually not considered knowledge work, such as food delivery personnel, the aforementioned assessment stresses the necessity of recognizing the emissions from knowledge work in many similar areas they participate in, such as production and use of ICT devices and computers.

Knowledge economy is a term used to illustrate the transition from an economy that relies heavily on physical capital and pursues organizational performance through competitive advantage, such as cheap labor, to that where the advantage is increasingly garnered from intangible goods, such as knowledge, research and development, software, brand equity and human capital (Morris, 2010). According to Morris (2010), all OECD economies have experienced three structural changes in the past forty years: knowledge-based services have become major sources of added value, exports and jobs; a shift in investment priorities of businesses from physical assets to intangible assets as well as the growth of well-educated workforce. Behind these changes, Morris continues, are three drivers. Firstly, there is a market demand from shifting towards higher value-adding goods and services that are associated with knowledge economy. Secondly, there are new "general purpose" technologies which have essentially enabled the formation of a knowledge economy and the expansion and diversification of global markets while also enhancing the flow of new ideas and good practices. This has strongly to do with the third driver, globalization, which has increased the pace of change through trade and change of information, knowledge, capital as well as humans. (Morris, 2010.) A reminiscent phenomenon is discussed by Lehmann & Hietanen (2009), which they refer to as "informationalisation" to describe the increasing share of information workers, which in Finland had risen from 12% of all workers in 1998 to 39% in 2000. They also recognized the trends concerning the increase of distance work as well a creative work and that these trends together have and probably will continue to increase the role of office work and its ecological importance globally (Lehmann & Hietanen, 2009).

## 1.2 Aim of the research

The evident rise and growth of knowledge work, the remarkable number of small companies and their seemingly forgotten position in the combat against climate change ferments the need for stronger knowledge of their environmental impacts. The aim of this thesis is to look into the climate impacts of small expert companies through a case company (hereafter Company) and recognise its carbon footprint for year 2020. Since the year 2020 was an exceptional year because of the still ongoing COVID-19 pandemic, the results are also modelled to represent the year 2020 if the year had been normal and had not affected the day-to-day activities.

Furthermore, the results of the carbon footprint calculation are examined in relation to existing, comparable works that have focused on knowledge work. This enables the consideration of mitigation pathways as well as recognition of best practices to control emissions of a small expert company, although there is no reason why the discussed mitigation pathways would not also apply to larger companies as well. In general, the results aim to strengthen the understanding of emissions caused by small expert companies and which factors carry the most significance and what measures can be taken to reduce their climate impacts.

The research question of this thesis are as follows:

1. What was the carbon footprint of Company in 2020 and what were the most significant emission sources?
2. What measures can Company and other small expert companies take to reduce their emissions most efficiently?

The carbon footprint is calculated in accordance with the GHG Protocol's Corporate Standard.

## 1.3 Structure of the thesis

This thesis consists of 6 sections. The first section introduces the background, motivations and objectives of the study. The second section addresses relevant literature and theories on assessing organizations' climate impact through concepts of life cycle assessment, carbon footprint and GHG Protocol as well as literature on previous studies on knowledge work's climate impact. Third section presents the applied standard, GHG Protocol together with the used data. Fourth section presents the findings of the study and fifth will discuss the results as well as possible mitigation pathways and the shortcomings of this thesis in some detail. Finally, the sixth chapter concludes the study.

# 2 THEORETICAL FRAMEWORK

The theoretical framework of this thesis builds first and foremost on the concept of carbon footprint and how it is computed. Therefore, the concept and significant related matters, such as different methodologies, standards and conventions will be introduced first. It is followed by literature on carbon footprint of areas in connection to knowledge work in general, mainly properties' energy consumption, commuting, work equipment and use of digital services.

## 2.1 Carbon footprint

This section addresses the theory, key definitions and conventions behind the concept of carbon footprint and how it can be calculated.

### 2.1.1 Theoretical background of carbon footprint

Carbon footprint is defined by Wiedmann & Minx (2007) as "*—a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product.*" This definition reaches companies, industries, other organizations, governments, processes as well as individuals. It is to be held distinct from other indicators, such as ecological footprint or carbon handprint (Galli et al., 2012). The aforementioned definition by Wiedmann & Minx (2007) includes only carbon dioxide ($CO_2$) emissions. However, especially so in recent years, other substances with global warming potential have been included in carbon footprint calculations as carbon dioxide equivalents ($CO_2$e.). Other substances, such as methane ($CH_4$) are converted into carbon dioxide equivalents using global warming potential factors. (Galli et al., 2012). There is immense variation in the cumulative radiative forcing caused by different greenhouse gases. Being the most common, other substances are compared to carbon dioxide, but the radiative forcing caused by carbon dioxide is relatively low in comparison to other greenhouse gases. To name examples, for methane (CH4) the 100-year GWP is 28, for nitrous oxide ($N_2O$) 265 and for carbon tetrafluoride ($CF_4$) 4880. (IPCC, 2015.)

Global warming potential (GWP) is a metric that was introduced in the First Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) as an effort to unify the measure of impact that different gaseous substances pose to the climate. It is an "*—index measuring the radiative forcing following an emission of a unit mass of a given substance, accumulated over a chosen time horizon, relative to that of the reference substance, carbon dioxide* ($CO_2$)*.*" Widely used default metric nowadays is the 100-year GWP ($GWP_{100}$). (IPCC, 2015.) Next, the theoretical background whence the concept of carbon footprint was eventually derived is addressed.

European Commission has stated that out of different life cycle methods, life cycle assessment (LCA) is the most scientific and best enables the consideration of different environmental impacts. It takes note of a product's environmental impacts throughout its life cycle: procurement of raw materials, production, use as well as end-of-life treatment. This perspective is called *gradle-to-grave*. (Antikainen et al., 2012.) LCA is divided into four phases: goal and scope definition, inventory analysis, impact assessment and interpretation. However, it is not a uniform method and there is variation in how it is carried out even though it is a standardized method. Standards that dictate the framework for LCA are ISO 14040, ISO 14044, ISO/TR 14047, ISO/TS 14048 and ISO/TR 14049. To enable a greater degree of uniformity, however, guidelines have been developed. The most up-to-date and complete is the so-called ILCD Handbook (International Reference Life Cycle Data System) produced by European Commission. Next, the four phases of LCA are addressed.

Any LCA begins with goal and scope definition. Clear definition of goals is essential to ensure the right use and interpretation of the results that are to come. Goal definition guides the setting of scope, which again is definitive for the LCA to be carried out. Also, from the set goal derives the view in which the quality control is performed. (Antikainen et al., 2012). According to ISO 14040:2006 the goal definition of an LCA states the intended application for the LCA, the reasons for carrying it out, the intended audience as well as whether the results are intended to be used comparatively and disclosed publicly. The scope of the study should include information about the product system under inspection, its functions, functional unit, boundaries of the system, allocation procedures, selected impact categories and impact assessment methodology, data requirements, used assumptions, limitations, type of potential critical review as well as type and format of the report required for the study. An inspected system can have various functions, which requires the definition of those that shall be studied, as they depend on the set goals and scope. A functional unit is required primarily to provide a reference flow to which the system's inputs and outputs are related. This makes the results comparable between separate LCA's, especially when the inspected systems are different. System boundary defines the processes to be included in the system. The boundary depends on the goals and scope. (ISO 14040, 2006). The system boundary shall be consistent with the original goal of the study, and the criteria used to set the boundary shall be identified and explained. (ISO 14044, 2006.)

Goal and scope definition is followed by life cycle inventory analysis (LCIA). What is done during the LCIA is initially planned in the goal and scope definition. It involves data collection and calculations to quantify the material and energy flows of a product system, such as inputs of energy, raw materials and formation of waste and co-products. When calculating energy flows, different fuels and sources of energy are taken into consideration as well as the efficiency of converting and distributing those energy flows. The allocation of flows and releases between processes is also done in the inventory analysis phase, as most often industrial processes do not yield a singular product. (ISO 14040, 2006).

All calculation procedures and assumptions made need to be clearly documented and used consistently throughout the study. (ISO 14044, 2006).

LCIA is followed by an impact assessment. Impact assessment uses the results of the LCIA to evaluate the significance of the potential environmental impacts that the system pose in the chosen impact categories (ISO 14040, 2006). The mandatory elements of impact assessment according to ISO 14044:2006 are the selection of impact categories, category indicators and characterization models, assignment of inventory analysis results to the selected impact categories as well as calculation of category indicator results. (ISO 14040, 2006.)

In interpretation phase of an LCA the results are consistently and accurately put together and considered as a whole and should provide an understandable, complete and consistent image of the results. Findings can be represented ultimately as recommendations and conclusions to whoever was defined as the audience of the study. (ISO 14040, 2006.) Being an iterative method, each phase of the LCA allows for returning to and revising the previous phase. In the LCIA realities may appear which lead to researchers revising the scope set in the previous phase. (Antikainen et al., 2012.) ILCD Handbook guides to collect data in an iterative manner especially in fully new technologies or complex product systems, so that the first iteration uses very generic data that is expanded in the following iterations and therefore producing more precise results. (European Commission, 2010).

However, criticism exists towards both LCA being not broad enough and on the other hand being too broad. According to Heijungs (2010), oversimplification can lead to distortions in cases of land use changes, for example. Thus, broadening of LCA has emerged at least in forms of life cycle costing (LCC), social life cycle assessment (S-LCA) and life cycle sustainability assessment (LCSA). On the other hand, LCA has also been seen as being in fact too broad in terms of resources, such as money, time and data and even the results. Thus, a need for simplifying the LCA methodology is also present. Diversity in the nature of data as well as the needs of the organization has led to the deployment of simplified life cycle methods that are still able to provide adequately reliable results. Streamlined life cycle assessment, carbon footprint and water footprint are examples of these simplified methods. There is great variation in how these methods are applied to different uses. (Antikainen et al., 2012.)

Complete LCA produces data to assess the environmental impact through many impact categories, such as eutrophication and acidification, but carbon footprint is an LCA in which the inspection is limited to only the impact category of climate change. Carbon footprint can be seen as a sub-set of the data that is produced by carrying out a complete LCA. (European Commission, 2009.) The reason that the choice of impact categories is limited to climate change exactly derives from different reasons. Oftentimes climate change is defined as the primary target or it may be known beforehand that climate change is the most significant impact category of the inspected system and therefore considering other impact categories would only make the process more complex and adding little to no value (Heijungs, 2010). These restrictions made beforehand usually require extensive knowledge of the system to be able to reliably and rationally set such limitations to the calculation, because there is a risk that some other impact category is more significant than climate change (European Commission, 2009).

### 2.1.2 GHG Protocol

The concept of carbon footprint has seen a lot of fluctuation in execution and has therefore produced incomparable results during the history of the term, which is stressed by Matthews et al. (2008), who describe the definition of carbon footprint as surprisingly vague regarding how much the term was used already in the 2000's, and stress the importance of boundaries and call for consistent and comprehensive rules for inclusion of emissions from the supply chain. This has led to the development of standards aiming to unify carbon footprint calculations and enable their comparability. Ruževičius & Dapkus (2018) point out that while over 30 different methodologies exist for calculating carbon footprint, guidelines for small organizations particularly are absent and others are easily considered too complex, expensive and time consuming.

The first carbon footprint protocol that was created was the LCA-based Corporate Standard by the Greenhouse Gas Protocol (GHG Protocol), published in 2001 and revised in 2004. Its origins reach back a few years to 1997, when the need for an international standard for greenhouse gas accounting and reporting was picked up by World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD). Corporate Standard introduced the concept of dividing emissions into three scopes. (GHG Protocol, 2021a.) By now, GHG Protocol has reached a position of a global standard in terms of assessing entities' carbon footprints (Patchell, 2018).

The first standard for calculating the carbon footprint of an individual product was the PAS 2050 published in 2008 (Wiedmann, 2009). Like GHG Protocol standards, it is based on life cycle assessment methodology, although the method review recommends using a hybrid life cycle assessment (HLCA) (Minx et al., 2007). GHG Protocol published its own standard in 2011 for quantifying and reporting carbon footprint of a product, the Product Standard. PAS 2050 was revised in 2011 and was influenced by the lessons learned during the development of the Product Standard. These two standards have sought for consistency in terms of quantifying the emissions, but Product Standard also sets guidelines for reporting, too. (WRI/WBCSD, n.d.)

GHG Protocol has published a variety of separate and complementary standards to respond to the needs of different stakeholders and organizations. For organization level, the most relevant standards are the aforementioned *Corporate Standard* supplemented by the Corporate Value Chain (Scope 3) Accounting and Reporting Standard, also referred to as the *Scope 3 Standard*. Together they dictate the framework for accounting the emissions of an organization. An organization can choose whether to report in conformance only with the Corporate Standard or also with the Scope 3 Standard. The former requires the reporting of scopes 1 and 2 and allows for optional inclusion of some or all scope 3 emissions, as the latter requires the reporting of also scope 3 emissions in accordance with the Scope 3 Standard. Scope 3 Standard is intended to enable comparing company's own emissions over time, but it is not designed for comparing scope 3 emissions between companies. (WRI/WBCSD, 2011.)

GHG Protocol's Corporate Standard builds on five accounting and reporting principles: relevance, completeness, consistency, transparency and accuracy. Relevance requires the GHG inventory to appropriately reflect the company's emissions. Completeness requires the accounting and reporting of all emissions within the chosen boundaries of the inventory, and any exclusions shall be disclosed and justified. Consistency requires using consistent methodology to enable meaningful comparisons over time, and any changes concerning the data, boundaries, methods or other relevant circumstance shall be reported. Transparency requires disclosing and addressing any relevant assumptions and proper referencing to data sources. Accuracy requires ensuring that the emissions are quantified as accurately as possible and is not systematically over- or underestimated as far can be judged. (WRI/WBCSD, 2004.)

Corporate Standard first requires setting boundaries on both organizational and operational level. On organizational boundary setting, two approaches exist and affect the outcome: equity share approach and control approach. Equity share refers to the company accounting for emissions from operations in accordance with its equity share in the operation. Therefore, the approach reflects economic interest. The control approach, however, dictates that the organization shall account for emissions from operations over which it possesses control. If the company decides to use the control approach, it also has to decide whether to use financial or operational control approach. After the organizational boundaries are set, the organization decides on the operational boundaries, which means identifying operational emissions and categorizing them as either direct or indirect and choosing the scope of accounting and reporting. Direct emissions (scope 1) are emissions that emerge from sources owned or controlled by the accounting organization. Indirect emissions (scopes 2 & 3), again, are emissions from sources owned or controlled by another organization but occur because of the activity of the accounting organization. Therefore, the division between direct and indirect emissions is also dependent on the chosen approach when organizational boundaries were set. (WRI/WBCSD, 2004.)

For greater transparency and clarity, the GHG Protocol introduced the concept of categorizing emissions into the aforementioned scopes 1, 2 and 3. Initially this was to ensure that emissions are not double counted between functions or companies. To elaborate on the former, scope 1 emissions compose of those that come "*—from sources that are owned or controlled by the company –* ". This means, for example, the emissions from combustion of fuels in vehicles, boilers or furnaces owned or controlled by the company. Scope 2 includes emissions "*—from the generation of purchased electricity consumed by the company.*" This is defined as electricity purchased or otherwise brought into the company. Scope 3, again, includes all other indirect emissions, which are divided to upstream and downstream emissions. (WRI/WBCSD, 2004.) When reporting in accordance with the Corporate Standard, scope 3 emissions are optional, but when reporting in accordance with the Value Chain (Scope 3) Protocol, scope 3 emissions are required.

Examples of scope 3 emissions are extraction and production of purchased materials and transportation of purchased fuels. (WRI/WBCSD, 2011.)

After the system (organizational and operational) boundaries are set, the organization shall identify and calculate its emissions, which takes place in five steps:

1. Identifying GHG emission sources
2. Selecting a calculation approach
3. Collecting activity data and choosing emission factors
4. Applying calculation tools
5. Rolling-up of GHG emissions to corporate level

Emissions can usually be identified from four sources: stationary combustion, mobile combustion, process emissions and fugitive emissions. The ratio of these can vary and depends on the nature of the organization's activity. (WRI/WBCSD, 2004.)

After identifying GHG emission sources, a calculation approach is chosen. Most commonly the emissions are calculated by applying emission factors to related proxy measures of activity, such as electricity consumption or fuel combustion. It is uncommon that emissions are directly measured using concentrations and flow rates at a production site. After choosing the calculation approach, the required data is collected, such as the amount of consumed electricity or fuel as well as the emission factors to relate to those amounts. After collecting data and choosing emission factors, a specific calculation tool can be applied, but is not necessary although encouraged, as they are peer reviewed and regularly updated. (WRI/WBCSD, 2004.)

This chapter aimed to describe the theoretical background on which the concept of carbon footprint derives from as well as the most common standard family, GHG Protocol. Carbon footprint is essentially an LCA that only focuses on one impact category, climate change, and GHG Protocol is the main standard instructing the process that should be followed when calculating an organization's carbon footprint. Next, existing literature on the carbon footprint of office and knowledge work are addressed.

## 2.2 Carbon footprint of office work

This section introduces and discusses some of the literature and earlier research that has been carried out on different areas related to knowledge and office work, although the research may not be directly attached to it, but are, nevertheless, its prerequisites. Office work generally requires an office space, work equipment and that employees commute to the office, although COVID-19 pandemic forced many to working remotely. It remains to be seen how the learned practices of remote work learned during the pandemic remain when the situation alleviates. In addition, modern knowledge or office work usually involves a remarkable amount of using digital services, such as teleworking, cloud services and use of internet in general.

A fairly modest body of research seems to exist on the environmental impact of office workers albeit the environmental impact of its components, such as commercial buildings has been studied considerably. If limited to small companies, the existing literature seems to be very limited.

Some earlier research on offices' and knowledge workers carbon footprint in general has been carried out and the subject has been addressed already in 2004, when WWF Finland commissioned Ahonen (2004) to study methods for reducing carbon dioxide emissions in offices and public events in Finland, as it was recognised that unlike industry, offices and public events had no requirements in terms of greenhouse gas emissions and required attention. The work of Ahonen (2004) had a practical approach and suggested ways to save energy and materials as well as alternative ways of commuting, although the approach was not too systematic and suggestions were left superficial. It must be noted that at the time, the availability of data was quite scarce and has developed greatly since then. Nevertheless, it stresses the fact that offices, too, were of concern in terms of environmental harm already in the 2000's.

Tjandra et al. (2016) studied the carbon footprint of an office environment in Singapore and grouped emissions sources into core devices (use of computers and printers), shared resources (air-conditioning and lighting), pantry (refrigerators and microwave ovens) and transportation (employees traveling from home to office and back home). Their results showed that 65% of the emissions within scope came from air conditioning, 20% from employee commuting, 9% from lighting, 2% from pantry, 2% from printer and printing paper and 1% from computer electricity consumption. It is notable that the office is in Singapore, which may be seen as an increase in electricity consumption from air conditioning in comparison to other, cooler countries. (Tjandra et al., 2016.) Although in Finland, again, properties' energy management is possibly higher since the climate is significantly cooler. Therefore, in this sense the comparability of offices' carbon footprint from different geographical may vary greatly. Office worker's environmental impacts have also been studied by Gaidajis & Angelakoglou (2011), who looked into the environmental impacts of an office workstation at a University in Greece. In contrast to Tjandra et al. (2016), they concluded that the electricity consumption of devices carried the most significance, followed by the manufacturing of appliances.

Other universities have also calculated and disclosed their climate impacts. University of Turku has calculated its carbon footprint from year 2018. It was 21 680 $tCO_2e$, of which properties caused 31.5% (mostly from district heat), travel 33.3% (mostly from air travel) and research equipment 30.3%. Other categories such as other procurements, logistics and waste management carried only minor significance. (University of Turku, 2021.) University of Jyväskylä also looked into their climate impacts in year 2019 and found out that 43% of their emissions came from investments, 26% from procurements, 14% from energy & properties, 6% from commuting, 5% from traveling, 5% from food, 1% from student exchanges and less than 1% from University's own vehicles. Per person the carbon footprint was 2.4 $tCO_2e$. Emissions from energy & properties per person were 340 $kgCO_2e$ and 144 $kgCO_2e$ from commuting. (Geneidy et al., 2021.)

Although universities rely heavily on knowledge and producing more of it, the infrastructure that is required for a university is wildly different in comparison to a small expert company, as they have a tremendous amount of space, research equipment, vehicles and other material that requires maintenance, too.

Castrén & Snellman, a Finnish law firm, calculated their carbon footprint in accordance with the GHG Protocol in 2019 to have been 750 $tCO_2e$ (Castrén & Snellman, 2020). According to Finder database (2021), the company had 199 employees in 2019, thus the carbon footprint per employee was approximately 3780 $kgCO_2e$. Half of their total emissions originated from business travel. Emissions from heat consumption per employee were 1174 $kgCO_2e$. The nature of work that Castrén & Snellman does can require larger premises as, for example, they most likely meet a lot of customers face-to-face at the office. Their emissions from IT-equipment were 259 $kgCO_2e$ per employee. Commuting emissions per employee were 117 $kgCO_2e$. (Castrén & Snellman, 2020.)

This chapter aimed to briefly describe some of the existing literature on the emissions of knowledge work particularly, although only studies on larger organizations were found and none for small companies particularly. Knowledge work's emissions are next addressed through its components: transmission of data, work equipment, commuting and office spaces.

### 2.2.1 Transmission of data

A plentiful body of research exists for the growing electricity demand of the ICT industry, and many of those studies have drawn their motives from the viewpoint that growing energy demand also brings about a greater environmental impact. This section will go through some of the studies carried out in recent years to grasp the development of the industry and what is its role in business side. Belkhir & Elmeligi (2018) note that the information and communication (ICT) industry, for example, has gained fairly little attention as a greenhouse gas contributor, but on the contrary, it has been spoken of in a positive tone as it has enabled efficiencies in other industries and therefore has a positive impact. For example, video conferences and smart property management systems have greatly induced the decrease in emissions in those areas. (Belkhir & Elmeligi, 2018.)

Digital transformation is predicted to grow rapidly and the need for a more thorough recognition of the environmental impact of the ICT industry is deemed necessary. Its role is twofold, as at the same time the industry uses an increasing amount of electricity, it also enables significant efficiencies and improvements in other areas of society. (Belkhir & Elmeligi, 2018;Hiekkanen et al., 2020.) Obringer et al. (2021) also state that the environmental impact of increasing internet use has been overlooked although the benefits have been praised. The twofold role of ICT is generally classified as having direct and higher-order impacts. The direct impact, being the manufacture, operation and disposal of ICT and related devices, is more straightforward than higher-order impacts, being the optimizing effect on other areas of business and society. For example, transport of goods can be done more efficiently in the era of e-commerce as logistics develop to be more and more optimized but creating and running the system naturally requires more electricity. Properties' energy management has also seen notable improvements due to digitalization. Commuting and business travel can be replaced with methods of teleworking, such as conference calls and video meetings. However, the increasing efficiency is being offset by a rapidly increasing number of different services and devices, and therefore the contribution of information and communication technologies to a low carbon economy is ambiguous. Estimates and calculations have been carried out on the total electricity consumption, for example, but the nature of rapid change and variety of impact mechanisms make it very challenging to quantify the total electricity consumption accurately. (Court & Sorrell, 2020.)

Average electricity intensity, being the amount of electricity per unit of transmitted data, of transmission networks plays an important role and is widely used in life cycle assessments that take the use of Internet services into account. There are two approaches to compute such results. Top-down approach, often criticized of overestimating the intensity, divides network/subsystem level total consumption of electricity by the total data transferred through the network/subsystem. Bottom-up approach, often criticized of underestimating the intensity, sums electricity consumptions of individual devices and divides that by the data transferred through that equipment. (Aslan et al., 2018.)

Aslan et al. (2018) looked into earlier studies from 2005-2015 that aimed to evaluate the electricity intensity metric of transmission networks and noted that depending on the time, assumptions, system boundaries the electricity intensity varied substantially from 136 kWh/GB in 2000 to 0.004 kWh/GB in 2008. Results vary because of the time period and differences in system boundaries. Being a complex and large system, internet has been divided into subsystems: data centres, undersea cable, IP core network, access network, home/on-site networking equipment and user devices, and the choice of systems examined has varied greatly between studies. (Aslan et al., 2018.)

There are numerous assessments on the global electricity consumption of the ICT industry. Van Heddeghem et al. (2014) estimated that ICT products and services used a total share of 3.9% of global electricity consumption in 2007 and 4.6% in 2012, suggesting an annual growth of nearly 7%. Malmodin & Lundén (2018), on the other hand, looked into the presumption of electricity consumption following the increasing data traffic and therefore creating a substantial growth in electricity demand. According to them, this has not happened. Although the data traffic has indeed increased 30-fold from 2005 to 2015, it has simultaneously become significantly more efficient. The computing capacity per energy unit for a typical rack server has in the same period increased 100-fold, and in the US the electricity consumption of data centers has remained at 70 TWh since 2010 and was expected to remain at that level in 2020, too. (Malmodin & Lundén, 2018.)

Obringer et al. (2021) gathered data use figures (GB/hour) for different applications, electricity consumption of data centers and data transmission as well as electricity production emission data for different countries and formed estimates for emissions from using these applications. For data centers the electricity usage was assumed at 0.01 kWh/GB (reference year 2018) and for transmission 0.06 kWh/GB (reference year 2020). For Google Hangout (nowadays Google Meet) the carbon footprint was assessed at 7.5 $gCO_2e$/hour at minimum and 204 $gCO_2e$/hour at maximum, depending on video quality and the electricity profile. For Zoom the carbon footprint varied between 15 and 157 $gCO_2e$/hour. (Obringer et al., 2021.) Although including a great deal of uncertainty, these figures might be feasible for drawing estimates. Results could potentially be adjusted with local electricity profiles, but it is unclear how and which data centers are actually used if a video call, for example, takes place between two people in central Finland. Obringer et al. (2021) state that if a person were to have 15 video conferences of 1 hour, their monthly footprint would be 9.4 $kgCO_2e$. By turning off the video, it would shrink to just 377 $gCO_2e$. Again, if a million users would turn off their video and had the same number of meetings, the combined monthly footprint would be reduced by 9023 $tCO_2e$. This exemplary calculation was computed assuming with emissions of 157 $gCO_2e$/hour. (Obringer et al., 2021.)

Itten et al. (2020) conclude that the order of relevance in terms of environmental impact is different for end users and big operators, such as cloud service providers. Servers of big operators run at almost full capacity day and night and hence the electricity consumption is of greater importance than manufacturing, but for end users the device and hardware manufacture is more relevant, because the devices' computational power greatly exceeds the users' requirements. Belkhir & Elmeligi (2018) assessed that the field of ICT contributed 1.06-1.7% in 2007 and 3.06-3.6% in 2020 of global greenhouse gas emissions. Itten et al. (2020) note that there is a consensus on lack of sufficient high-quality data concerning the life cycle of networks and data centers as well as electronic devices in general, and that many life cycle assessment projects in the ICT field have to rely on outdated, greatly uncertain data if it even exists, and that there is a dire need for transparent and up-to-date inventory data on manufacturing, operating as well as disposing of ICT-related products and services.

The electricity consumption has been studied abundantly although the scopes have varied tremendously between different studies. Most of them recognize and press the fact that ICT has indeed brought about gains in efficiency in many areas of society but remind that the number of devices and networks has not ceased to increase, although data transmission has also become more efficient itself. Means to accurately measure the electricity consumption of ICT is still missing, which is pointed out by the variation of chosen methodologies and the results they have produced. What also should be kept in mind is the variation in electricity profiles and that electricity production has different impacts in different areas and affects the surroundings differently.

### 2.2.2 Work equipment

This section focuses on the existing literature and research on the climate change impact of laptop computers, which are the usual work equipment of knowledge workers. A few of the most notable studies from 2010 onwards on laptops' carbon footprints are brought forth. Some studies on computers have surfaced before 2010, but they are not given an in-depth recognition here because there is not a dire need to lean on them as there is more recent research available.

O'Connell & Stutz (2010) from Dell carried out an LCA-based carbon footprint calculation on a Dell E6400 laptop on three different markets to respond to the wishes of customers and retailers. This model was chosen because it is a typical business laptop sold in high volumes. They accounted for raw materials and product manufacturing (in Asia), transport to final assembly location (Europe or Asia), the assembly, transport to customers (those in USA, Germany and China), use of product (four years in USA, Europe and China), transport to recycling location as well as end-of-life disposal and recycling. Transportation to customers in Europe was not taken into account, but it is safe to assume that the transportation is at least not presumed too low, as the transportation to further locations usually causes higher emissions, if the product was assembled in Europe. The total carbon footprint of the E6400 laptop was between 320 kg$CO_2$e in Europe and 370 kg$CO_2$e in China, although these figures include the assumption made by the researchers that with a recycling rate of 75% the carbon footprint is lowered by 30 kg$CO_2$e. Nevertheless, the emissions during the whole life cycle are concentrated on the manufacturing phase, which represents 42% of total emissions in China and 50% in Europe. The emissions in the manufacturing phase are concentrated on the part production, where (in order of relevance) the mainboard, display, chassis and battery together make up about 95% of the total emissions of the part production. The use phase has the biggest role in China, 65%. This is because of the different energy production profile in China. (O'Connell & Stutz, 2010.)

Apple released a product environmental report for a 13-inch MacBook Pro in 2020 carried out in accordance with ISO 14040 and 14044 standards. The carbon footprint is 217 kg$CO_2$e for the model with 1.4 GHz quad-core processor and 256 gigabyte (GB) storage. 76% of the emissions come from production, 6% from transport, 17% from use and less than 1% from end-of-life processing. Production includes the extraction, production and transportation of raw materials and manufacturing, transporting and assembling all parts as well as product packaging. Transport includes air and sea transportation of the finished product and packaging from the location of manufacturing to regional distribution hubs and from there to end customers. Use phase, as was in the case of a Dell laptop, is also assumed to be four years. End-of-life processing includes transportation from collection hubs to recycling centers and the use of energy in the mechanical separation and part shredding. In the same report, Apple also disclosed the estimated carbon footprints of 13-inch MacBook Pro's with different configurations. At largest the carbon footprint is when a 2.4 GHz quad-core processor and 512 GB storage is chosen, when the carbon footprint is 300 kg$CO_2$e. (Apple, 2020.)

Liu et al. (2016) studied the carbon footprint of laptop production in China, as it plays a significant role in its total export value. The researchers assess that computer exports account for approximately 15 to 30% of emissions from China's exports and that China produced over 90% of all personal computer products in the world in 2012. Laptops contributed to approximately 51.5% of the computer sector. The study carried out by Liu et al. (2016) is limited to cradle-to-freight emissions. Therefore, comparing to the previous two studies presented, this study has narrowed out the shipment to end users, use phase and end-of-life treatment. For the functional unit they chose a 14-inch HP laptop, as it is among the most exported 14-inch produced in China and is sold in high volumes and is described as a typical business laptop. The total carbon footprint for the selected laptop was 179 kg$CO_2$e, of which the biggest shares come, in order of relevance, from manufacturing the display (31.3 kg$CO_2$e), outer case (26.3 kg$CO_2$e) and motherboard (25 kg$CO_2$e). (Liu et al., 2016.) The total carbon footprint is approximately equal to that of the production of a MacBook Pro, although in the case of a MacBook carbon footprint assessment, the scope was more thorough and included also the share of production-phase transportations. It is also approximately the same as was in the case of a Dell laptop, which produced approximately emissions of 160 kg$CO_2$e in the manufacturing phase.

Use phase plays a different role in the previously mentioned studies, as with the Dell laptop studied by O'Connell & Stutz (2010), the use phase played a role between 47 and 65%, as with a 13-inch MacBook Pro with 1.4 GHz quad-core processor and 256 GB storage, the use-phase only caused 17% of the total estimated emissions (Apple, 2020). It seems that the use phase of a laptop computer is taken root on an assumption of four years, which is positive in terms of comparability across separate studies. However, the studies that were given an in-depth look in this thesis provided varying details about the assumptions that were done concerning the use phase itself. In the case of the Dell laptop, for example, it was assumed that the laptop is connected to an external power supply for the whole use phase: 24 hours a day 365 days a year for four years, and 60% of the time it is turned off, 10% in sleep mode and 30% in idle mode, which is assimilated to active use. This calculates to approximately 50 hours of active use per week, 52 weeks a year for four years (O'Connell & Stutz, 2010). It is reasonable to express doubt on this assumption being slightly superfluous, meaning that the use phase is likely estimated too high. In case of the MacBook Pro, however, the use was described as "power use" and in the product environmental report it was stated that the use scenarios were based on historical customer use data for similar products (Apple, 2020). Despite being 10 years apart, the use phase of the MacBook Pro is likely much more accurate, and this is reflected also on the phase-specific emissions: use phase emissions play a significantly smaller role in life cycle emissions of a MacBook.

The main circuit board and the display seem to be components that usually demand a relatively large share of the emissions that emerge during the production of a laptop. Andrae & Andersen (2010) studied the consistency of life cycle assessments of laptop computers from a few studies carried out between 1997 and 2008. They also noted that manufacturing the main circuit board has played a significant role in almost all of these assessments, ranging from 55 to 85 kg$CO_2$e. The assessed electricity consumption varied dramatically in all phases they studied. For example, two studies on laptops from 2007 and 2008 had assessed the electricity consumption during four years of use at 190 kWh and the other during five years at 580 kWh. The total carbon footprints of laptops varied from a dubious 55 to 660 $kgCO_2e$. (Andrae & Andersen, 2010.) Therefore the three studies that were given an in-depth look here show pleasingly little fluctuation in terms of the total carbon footprint as well as between respective life cycle phases. The key figures of those three studies are summarized in Table 1.

Table 1. Studies on different laptop models' carbon footprints.

| Model, reference year, source | Total carbon footprint [$kgCO_2e$] | Production share [$kgCO_2e$] | Use, transportation, end-of-life share [$kgCO_2e$] |
|---|---|---|---|
| Dell E4600, 2010. (Court & Sorrell, 2020) | 320-370 | 134-185 | 160-240 |
| MacBook Pro, 2020. (Apple, 2020) | 217-300 | 163 (in lowest case) | 52 (in lowest case) |
| HP, 14-inch, 2016. (Liu et al., 2016) | 179 | 179 | - |

Opportunities lie also on refurbishing used laptops, when the most emission-intense parts would not need to be replaced. Refurbishment has become especially popular regarding smartphones. Zumegen (2020) studied the carbon footprint of a company refurbishing smartphones and found that refurbishing can have a significantly lower carbon footprint in comparison to manufacturing a new one, as the emissions from refurbishment varied from approximately 7-30% of those of a new one. The subject has gained wide recognition and a concept of “reverse logistics” has been formulated, meaning that the supply chain starts at the end user and travels back to suppliers through different operators, such as recycling centers. This has been implemented in forms of highly functional return programs. (Curvelo Santana et al., 2021.) Dasaklis et al. (2020) have even proposed a framework that utilizes blockchain technology to aid reverse logistics supply chains.

When it comes to the consideration of utilizing used laptops, a question of functionality is also present in the use-phase of a computer. This, together with energy efficiency, is discussed by André et al. (2019) in the context of technological development, as the device needs to be able to fulfill its main function as well as other obligatory features. This has to do with the lifetime of a computer, which are commonly reported to be 3-5 for the first use and 2-3 years for second use. At large, the carbon footprint of annual use of a second-hand laptop is 58 % of that of a new laptop. (André et al., 2019.) Prakash et al. (2012), however, note that 10 %

gains in energy efficiency between models would only justify the upgrade in 33-89 years.

Depending on the laptop's energy consumption, it is either the manufacturing or the use phase of a laptop that causes most emissions. Assumptions on laptop's lifetime, use time as well as the mode of use vary between studies. Furthermore, it is clear that laptops have recycling potential but there is also a dire need for manufacturers to enable this by making them more repairable and upgradable.

### 2.2.3 Commuting

According to Cao & Yang (2017), transportation is the fastest growing sector in terms of energy consumption and $CO_2$ emissions. They also note that China is experiencing a rapid suburbanization, meaning that new towns and blocks are, instead of walking and public transportation, characterized by wide roads and large blocks that enables and demands inhabitants to use cars. They see this phenomenon to be occurring increasingly in developing countries.

Liu et al. (2016) note that in addition to direct emissions, studies have shown the significance of energy consumption and emissions occurring from indirect sources: manufacturing of vehicles, infrastructure construction, production and distribution of fuels as well as maintenance processes. There is immense variation between transportation modes regarding these processes, which is why the importance of life cycle assessment is stressed when informing policymakers in transportation. When accounting for energy consumption and direct emissions, an intercity bus produces the least emissions per passenger-kilometer of travel on all inspected trip ranges, ranging from 200 to 1600 km. Between the two most popular transportation modes, cars and airplanes, cars with high occupancy rates are generally more efficient in terms of emissions and energy consumption on trips less than 800 km in distance. On longer trips, airplanes tend to be more efficient as the energy-demanding take-off and climb phases are not as dominant. Cars with low occupancy rates are generally the least efficient in terms of fuel consumption and per-passenger trip basis. (Liu et al., 2016.)

There is usually great difference between emissions from ordinary day-to-day commuting and business travel, because the former usually takes place by public transportation, private car or by foot or bicycle. Baumeister (2019) notes that business travel is usually directed towards further destinations, and in those cases, flying is oftentimes the only feasible option. In short-haul flights (where distance is less than 1000 kilometers) the emissions per passenger kilometer are the highest, because the energy-intensive take-off and climb phases are in a greater role than they are on long-haul flights (distances of 1000 kilometers or more) as well as the tendence of having lower load factors, since the amount of cargo is usually lower on short-haul flights. (Baumeister, 2019.)

In 2020, the daily lives of many changed when the COVID-19 pandemic came to the fore and brought about a spectrum of socio-economic countermeasures in numerous countries. In addition to schools, shops, museums, restaurants getting partially closed, office spaces were also closed by many companies as governments recommended employees to stay and work from home if possible. (Shibayama et al., 2021.) An annual Working Life Barometer shows that in Finland approximately half of all employees worked remotely at least to some degree in 2020. Over a million workers transferred to working fully remotely in 2020.

In most European countries, 60-80% of those with home office possibility chose to work at home. This had a significant impact on daily commuting behavior because of two reasons: recommendation of avoiding contacts had an immense impact on the daily amount of commuting itself, but also because public transportation has been stigmatized as an environment of high risk in terms of infectious respiratory disease. (Shibayama et al., 2021.)

The wide study carried out by Shibayama et al. (2021) showed that the change in commuting behavior presented itself differently between countries, occupations and area types, for example, and the degree of people working from home office varied between countries. In many countries regarding the transportation mode of choice, a shift from public transportation to private cars was observed. Public transportation was rationalized by avoiding risk of infection, exercise, general feeling of unsafety as well as order of employer, to name a few. Those that did not change their commuting behavior and sticked to public transportation argued, for example, that there is no infection risk, there are no alternative transportation modes or that alternatives are time-consuming and costly. (Shibayama et al., 2021.)

Of interest regarding the COVID-19 pandemic is the effect on commuting behavior that sticks even after the pandemic is over. Shibayama et al. (2021) did not present assessments on how long the trend of change in commuting behavior will persevere, but Awad-Núñez et al. (2021) note that after the pandemic, measures such as the increase of supply and vehicle disinfection could result in greater willingness to use public transportation in Spain. They also noted that provision of supplies such as steering wheel and handlebar cover could increase the popularity of shared mobility services. However, in Bangladesh, a distrust towards public transportation was observed during the pandemic by Anwari et al. (2021), although the researchers do not see the results as likely transferable to other countries.

McKinsey carried out an analysis on how remote work will persist after the corona pandemic is over and found that around 20-25% of workforces in advanced economies could work remotely from home three to five days a week, although they stress that some work, such as negotiations, brainstorming sessions and onboarding of new employees is best done in person. (Lund et al., 2021.) Such change could pose significant decreases in mobility emissions.

There are wild differences between emissions caused by different modes of transportation. Even small differences can grow to be very significant when daily commuting to work is in question.

### 2.2.4 Office spaces

Companies, especially those specializing in information-centric work, usually have office spaces, which use energy and materials in different ways. This chapter addresses how buildings and their usage brings about greenhouse gas emissions.

Greenhouse gas emissions of buildings are divided into two categories: embodied greenhouse gases, that occur from the used materials when they are built or renovated and to operational greenhouse gases, that occur from use-phase energy consumption. The significance of energy consumption is great, although the significance of embodied greenhouse gases grows when buildings' energy efficiency enhances. This is not caused purely be relative change, because solar technology and energy storages used in buildings may increase the emissions arising from used materials. However, at the same time, emissions from electricity and heat production tend to decline. (Häkkinen & Vares, 2018.) According to Confederation of Finnish Industries (2018), the use-phase energy consumption can constitute up to three quarters of the building's life cycle emissions.

Life cycle emissions of a building are to large extent determined in the design phase and the possibilities to influence the emissions after the building is finished, are limited. Location of the building determines the possible energy sources and circumstances for groundwork. Other factors greatly affecting the building phase emissions are the choice of structural material, space planning and energy efficiency goals. (Puuinfo, 2020.) Location of the building plays a role in its life cycle emissions not only because of the varying emissions from construction-related groundwork and available energy sources, but also because it effects how people commute to the building. Fenner et al. (2020) looked into life cycle emissions of buildings and noted that in many residential building cases, the daily commuting of tenants may play a significant role in the total greenhouse gas emissions. Therefore, they note, the location of the building is of great importance when trying to reduce the total emissions. However, the emissions from the buildings' occupants are rarely measured and their role is still fairly unknown. (Fenner et al., 2020.)

According to Statistics Finland (2020), the total emissions of Finland were 52.8 million $tCO_2e$, of which 74% originated from the energy sector. According to Gynther, (2020), 26% of the end use of energy in 2019 originated from the heating of buildings. In 2016, the share of emissions from heating buildings was assessed to be as high as 30% of the total emission in Finland, most of them deriving from small houses (Mattinen et al., 2016). Buildings are heated in different ways and choosing the heating system depends heavily on the purpose, location and size of the building. Large buildings in urban areas are almost always heated with district heat, even though geothermal heating has gained popularity. Heating systems show more fluctuation between small houses, where geothermal heating has become more and more popular whereas direct electricity heating has become rare. The energy consumption of service buildings (buildings used for business, offices, gatherings, teaching as well as traffic and healthcare) is experiencing a declining trend, because the buildings have become more energy efficient. (Mattinen et al., 2016.)

Relative energy efficiency of a company or a building can be examined through utilization rate, which is defined by Deutsche Asset Management (2016) as "*the usable square feet (USF) divided by the number of persons assigned within the USF*". USF includes not only the desk area the employee is using, but also all the shared spaces such as kitchen area and toilets (Deutsche Asset Management, 2016). If the office space is too large in comparison to the number of employees and the nature of the work that is done, the use of space is inefficient. According to Harris (2016), in traditional office space the utilization rate can be as low as 30-40% during a workweek, indicating a tremendous waste of capacity. However, simultaneously in the UK, the average office densities have risen by a third from approximately 16-17 square meters per workstation to 10.9 square meters, pointing out more efficient use of space. In Sweden the average density is noticeably lower and therefore more inefficient, as Holmin et al. (2015) report of average spaces of great as 25-35 square meters per employee in older office properties and 17-22 in newer ones. Simultaneously it has become common to provide fewer workstations than there are workers to avoid low utilization rates and waste of space and energy. This has been together with exercising desk sharing policies and a so-called 8:10, meaning that there are 8 desks per 10 workers. Policies like these speak of pursuing "spaceless growth", which means that growth in headcount as well as output is targeted but without acquiring or leasing real estate. (Harris, 2016.)

In their report concerning the future of work after the COVID-19 pandemic, Lund et al. (2021) from McKinsey found that some companies have started the transition towards flexible workspaces after gaining positive experiences of remote work during the pandemic and that on average, the 278 questioned executives planned to reduce their office space areas by 30 percent. G. Miller (2014) also states that the area or space per worker is continuing to decline over time, and collaborative work environments are becoming more common.

As a summary it can be stated that buildings bring about tremendous amounts of emissions, and it is of the highest necessity to use them as efficiently as possible in terms of space as well as energy.

# 3 METHODOLOGY AND DATA

This section will address the methodology and data used to calculate the carbon footprint of Company. Firstly, a description of the used methodology is presented and followed by the data points, their sources, necessary assumptions, justifications as well as used emission factors.

The carbon footprint is calculated for year 2020. However, as 2020 was predominantly affected by the COVID-19 pandemic, much of the commuting and business travel that would normally happen, did not take place. Thus, those results cannot be used as such to draw useful metrics, such as emissions per employee per year, as the results most likely are quite a bit different in normal circumstances. For this reason, the carbon footprint is also calculated for another scenario, the *normal scenario,* where normal commuting and business travel takes place based on enlightened assumptions. This is done to have a representative scenario for a normal day-to-day activity.

## 3.1 Company outline

Company is a consultancy of less than five full-time employees. The number of employees whose main job was for Company varied between 3 and 4 and therefore had an average of 3.5 employees in 2020. The average headcount was calculated by adding the headcounts in the beginning and end of 2020 and dividing the number by two. In 2020 Company employed 2.57 person-years and in the normal scenario would have employed 2.86 person-years. Person-years were calculated by dividing the days of employment (reduced by days on parental leave) by 365 days and multiplying by the part-time factor, which is weekly work hours divided by 37.5 hours.

Company has a small office space at a co-working facility in Finland, where spaces such as toilets, kitchens and some areas for co-working are shared. In its daily activity Company is a traditional consultancy and the work happens mainly at its own office space or at customers' premises. The only work equipment the employees need is essentially a laptop.

From March 2020 when the COVID-19 pandemic spread to Finland as well, all employees started working remotely from home. The pandemic had a negative economic effect and short-term layoffs had to be effectuated in 2020 as the demand for offered services weakened.

## 3.2 Methodology

This sub-chapter describes the chosen carbon footprint calculation methodology in greater detail. This calculation is carried out in accordance with the GHG Protocol's Corporate Standard.

A calculation that complies with GHG Protocol's Corporate Standard starts by setting organizational boundaries and choosing the approach for consolidating greenhouse gas emissions, which is applied consistently throughout the process. The emissions can be consolidated by equity share or control approach, and if the company owns all of its operations, the organizational boundary is the same whichever of the two approaches is chosen. In this calculation the complexity of the system under inspection is not of high complexity as the company is an expert company and wholly owns all of its operations. (WRI/WBSCD, 2004.)

After determining organizational boundaries, the organization needs to set the operational boundaries by identifying and categorizing emissions from its operations and choosing the scope of accounting and reporting. This calculation complies with the Corporate Standard and therefore takes into account emissions from scopes 1 and 2 and from chosen scope 3 categories as well. (WRI/WBSCD, 2004.) The operational boundaries are presented in Figure 1.

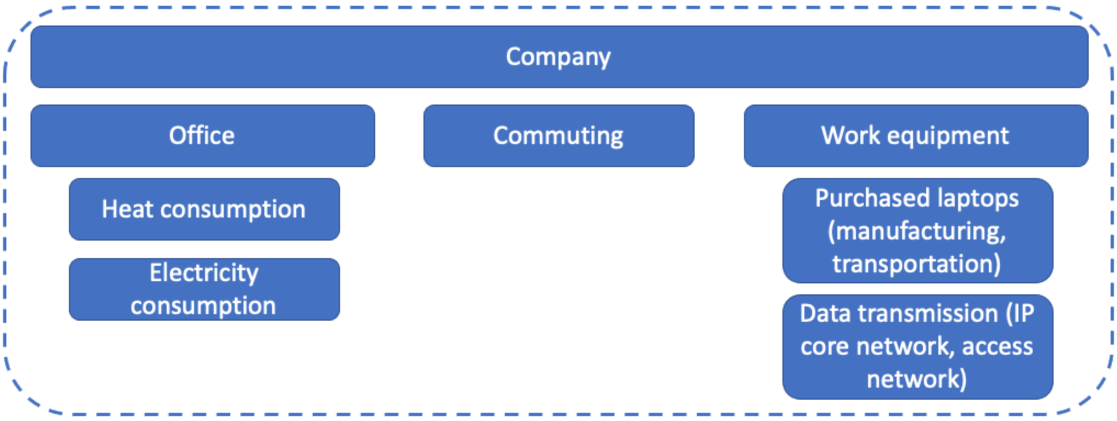


Figure 1. Operational boundaries of the system.

The company does not own or control sources combusting any fuels, such as oil furnaces or vehicles and therefore produces no scope 1 emissions. The office that is in the company's disposal is heated with district heat and uses electricity. Both heat and electricity energy are purchased energies and are therefore scope 2 emissions. Complying with Corporate Standard, scope 3 emissions are voluntary but depending on the nature of the organization's operations, can be the major source of emissions. In this calculation the categories are chosen based on their evaluated significance, such as commuting, or their yet unexamined ponderability, such as the use of the internet. The chosen scop 3 categories are the following:

- **1. Purchased goods and services**

- o Acquired laptops: Manufacturing
  - o Use of the internet: Data transmission
- **3. Fuel- and energy-related activities**
  - o Indirect emissions from commuting and (emissions from refining and distributing fuels)
- **4. Upstream transportation and distribution**
  - o Acquired laptops: Upstream transportation
- **7. Employee commuting**
  - o Emissions from employee commuting to the office and back home

Next, the data, emission factors and assumptions used in the carbon footprint calculation are presented.

## 3.3 Data

This chapter will go through the used data, emission factors and assumptions to assess the carbon footprint of Company. The data was gathered in April 2021 using inquiries. In the beginning of each of the next sections it is described how the data was acquired in more detail and which emission factors and assumptions were used.

### 3.3.1 Office energy use

The company has a dedicated office space at a co-working facility. The exact area of the office space dedicated to the case company was not available during the gathering of data for this thesis, but by visual estimate it was assessed to be approximately 7 square meters in area. The emissions from the consumption of electricity and district heat are assessed by allocating a share of the facility's total energy consumptions to Company. The share of energy consumption to be allocated to Company is formed by dividing the area that is in the control of Company, that being the dedicated office space, by the total area of the facility. The facility's total consumption of both electricity and district heat are multiplied by this ratio. The total consumption figures of the facility from year 2019 were reported by Company, as the data for year 2020 was not available. The data is evaluated to be technically fairly compatible in terms of as the facilities are assumed to not have changed in terms of total area or property technology, although the data may be more optimal for the *normal* scenario, because the use of electricity regards that of a normal year, where companies work mainly in the facility and consume more electricity. The consumption of heat energy is standardized on a year-level using heating degree days provided by Finnish Meteorological Institute (2021). For Helsinki the heating degree days was 2906 in 2020 and 3419 in 2019, the ratio being 0.85 (Finnish Meteorological Institute, 2021). The consumption of heat energy in 2019 is therefore multiplied by this standardized ratio to produce a somewhat realistically corresponding heat energy figure for 2020.

Both the electricity and district heat are supplied to the facility by Helen. Helen discloses the specific emissions of different energies they produce. For district heat the specific emissions were 182 $gCO_2/kWh$ in 2020 and for electricity 139 $gCO_2/kWh$ in 2019 (figure for 2020 not yet available) (Helen, 2021). These emission factors are used in this calculation.

What is notable about the co-working facility is that some spaces, such as kitchens, toilets and open working areas are shared among all companies that operate in the facility. Therefore, in reality, the energy that is allocated based on the area of Company's dedicated office space does not portray precisely the energy that is consumed by Company. Those areas are not in control of Company, which is why they are not initially taken into account. They are, however, considered through a sensitivity analysis.

### 3.3.2 Commuting and business travel

The commute and business travel data were gathered from the company employees in April 2021 using an inquiry form. The data was inquired on how the commuting actually took place in 2020 but the employees were also asked to assess how it would have taken place if the year 2020 was normal and the COVID-19 pandemic had not occurred. The exact data that was acquired included the following information for both scenarios:

- Number of workdays
- Share of remote workdays
- Distance from home to the workplace
- Percentage share of each form of commuting taking place on a journey from home to the workplace

In 2020 commuting took place by car, train, tram, subway and electric scooter. In a normal year the commuting would take place by car, train bus and electric scooter. Walking and cycling are assumed to not cause any emissions. Table 3 presents the total distance travelled with each form of commuting in 2020 both actual and normal scenarios.

Table 2. Distances commuted in 2020.

| Form of commuting | Distance travelled in 2020, actual [km] | Distance travelled in 2020, normal [km] |
|---|---|---|
| Car, diesel | 7 | |
| Train | 12999 | 59859 |
| Bus, city | - | 288 |

| | | |
|---|---|---|
| Tram | 180 | 759 |
| Subway | 108 | - |
| Electric scooter (Xiaomi M365 Pro) | 36 | 759 |

Emissions for public commuting are calculated using emission factors from LIPASTO database, a traffic emission database developed by VTT Technical Research Centre of Finland Ltd. These emission factors are specific to Finland and prevalent circumstances and are therefore of high reliability. The used emissions factors for commuting are reported next.

According to VR (2021), commuter train models are Flirt or Sm5 trains in the HSL area and Sm4 or Sm2 trains in VR's commuter traffic area. These trains are electric and therefore do not cause direct emissions when in use, but the indirect emissions from producing the electricity are taken into account. Lipasto has electricity consumption figures for Sm4 and Sm5 trains only. For Sm4 commuter train the electricity consumption is 0.09 kWh/pkm and for Sm5 0.07 kWh/pkm. An average of these two figures is used for calculating the electricity consumption of all trains in this thesis. VR or HSL have not disclosed the exact share of renewable energy in their electricity consumption, which is why the indirect emissions are calculated using the average emissions from electricity production in Finland by the benefit allocation method in latest reported year, 2018, which is 144 $gCO_2e$ / kWh (Tilastokeskus, 2021).

According to Lipasto, a city bus with 43 seats produces direct emissions of 55 $gCO_2e$/pkm with a utilization rate of 18 passengers and has an energy consumption of 0.82 MJ / pkm. The share of electrical and gas buses is assumed insignificant and that most buses run on diesel. Indirect emissions from buses are calculated by using the energy consumption per passenger kilometre and multiplying it by the emissions from refining and distributing the fuel, diesel. European Commission (2015) has reported emission factors for refining and distributing different fuels, and for diesel the factor is 18.17 $gCO_2e$ / MJ.

For private cars the emission factors are also retrieved from Lipasto, where there are figures available for road, urban and mixed driving. The drive is assumed to be mixed, where 27% of the driving happens on urban area and 73% on road. Emissions from an average diesel car in 2016 is used. Indirect emissions for diesel cars are calculated by using the energy consumption (MJ / km) of an average diesel car in 2016 together with emission factors for refining and distributing diesel published by European Commission (2015). For diesel the factor is 18.17 $gCO_2e$/MJ.

For the Xiaomi M365 Pro electric scooter the energy consumption is 1.1 kWh per 100 km or 0.011 kWh / km (Electric Travel, 2021). However, the scooter is charged at the employee's home, and because all employees reported having renewable energy contracts, charging the scooter does not cause emissions. Emission factors for different forms of commuting are summarised in Table 4.

Table 3. Used emission factors for commuting.

| Form of commuting | Direct emissions | Energy consumption | Indirect emissions |
|---|---|---|---|
| Car, diesel | 141 $gCO_2e$/km | 2.1 MJ/km | 38.2 $gCO_2e$/km |
| Train, Sm4/Sm5 | 0 $gCO_2e$/pkm | 0.078 kWh/pkm | 11.2 $gCO_2e$/pkm |
| Bus, city | 55 $gCO_2e$/pkm | 0.82 MJ/pkm | 14.9 $gCO_2e$/pkm |
| Tram | 0 $gCO_2e$/pkm | 0.24 kWh/pkm | 34.6 $gCO_2e$/pkm |
| Subway | 0 $gCO_2e$/pkm | 0.18 kWh/pkm | 25.9 $gCO_2e$/pkm |
| Electric scooter | 0 $gCO_2e$/pkm | 0.011 kWh/km | 0 $gCO_2e$ / km |

### 3.3.3 Work equipment

In the case of Company, work equipment refers to only the laptops that the employees are equipped with. Each employee is provided with a personal laptop when they begin working at the company. Used data and emission factors to calculate the emissions from manufacturing and transportation the laptops acquired in 2020 are presented in this chapter. Furthermore, the emissions from all use of laptops are assessed.

In 2020 two 13-inch MacBook Pro 2020 models with 2.4 GHz quad-core processors and 512 GB storages were acquired. Apple has disclosed a product environmental report on a 13-inch MacBook Pro life cycle in accordance with ISO 14040 and 14044 standards, and according to that report, the carbon footprint of a corresponding 2019 model is 300 $kgCO_2e$ when production, transport, use and end-of-life treatment are taken into account. Apple has disclosed the phase-specific emission percentages for a cheaper MacBook model, which has a total carbon footprint of 217 $kgCO_2e$. For that model, the share of emissions for different phases were 76% for production, 6% for transport, 17% for use and less than 1% for end-of-life treatment. (Apple, 2020.) It is assumed that the shares for different phases stay the same when the components are upgraded. Thus, the emissions of different phases for the models acquired by Company are as follows: 228 $kgCO_2e$ for production, 18 $kgCO_2e$ for transport, 51 $kgCO_2e$ for use and 3 $kgCO_2e$ for end-of-life treatment. Out of these figures, production and transportation are taken into account for the two acquired MacBooks.

Electricity consumption of all laptops is assessed based on the 2020 MacBook Pro's power adapter wattage, which is 61 watts. There are no relevant measurements of the actual power consumption of the MacBook when in normal use and therefore the wattage of the power adapter is used, although it is a some degree of overestimation. It is assumed that the laptops use 61 W of electricity per hour, and they are used roughly 7.5 hours per workday. Thus, the electricity consumption of one laptop per workday is 457.5 Wh. Multiplying that by the total number of workdays in 2020, the total electricity consumption from use of laptops is 263 kWh.

All the laptops used by the company employees were used at the office for the first three months of 2020 and the remaining of 2020 everyone worked remotely and charged their laptops at home. The electricity consumption figure is from 2019 and reflects a situation where two full-time employees worked at the office and charged their laptops. It is assumed that a full-time worker works on 253 days a year. Thus, the electricity consumption figure includes the charging of laptops on 506 workdays in total. In 2020, based on the commuting data, a total of 100 workdays were worked at the office. Therefore, the data includes more laptop charging than was actually done, but because the calculation on electricity consumption of laptops contains uncertainty, the electricity consumption data is left unmanipulated. A total of 396 days were worked remotely from home. Using the daily electricity consumption of a MacBook, the total electricity consumption from charging the laptops at home totals to 181.17 kWh. However, as all of the employees reported having renewable energy contracts at home, the charging of laptops did not cause notable emissions.

End-of-life treatment of laptops is a changing field, and it cannot be presumed that laptops are disposed of and recycled as raw materials after the assumed use time of four years. There are numerous actors who do the necessary refurbishment for laptops and then resell them to consumers or organizations. As it is of high uncertainty what happens to the computers after four years and also assessed minor in significance (according to Apple, less than 1% of total life cycle emissions), end-of-life treatment emissions of work laptops are ignored in this thesis.

### 3.3.4 Transmission of data

On a daily basis the employees use the internet, email, video calls and various other internet-based services. Being an intrinsic part of the work, the use of these services is assessed as a part of the company's carbon footprint. Being an area of relatively dubious data for now, the emissions from using the internet was not divided into sub-categories, such as video conferences and use of cloud services, but was all treated as one.

The employees of the company were instructed to measure their total internet traffic during two or three normal workdays. Operating systems such as Windows and macOS collect these data automatically and the employees were not required to download external software but were instructed to document the figures produced by the operating system. Both downloaded and uploaded data were taken into account. Out of all traffic figures, one average was calculated and used as a general internet use factor per employee per workday. The amount of data traffic may differ between roles, and therefore for representativeness it is beneficial that various roles are taken into account and averaged.

One of the employees measured their internet use on two days and two employees on three days. The average internet use per employee per workday was 3.88 GB including downloaded and uploaded data. Table 5 presents the gathered data.

Table 4. Daily use of the Internet in gigabytes by the company employees.

| Employee | Workdays in 2020: actual, normal | Total assessed amount of data transmitted in 2020, actual [GB] | Total assessed amount of data transmitted in 2020, normal [GB] |
|---|---|---|---|
| Employee 1 | 126, 126 | 489 | 489 |
| Employee 2 | 200, 250 | 776 | 982 |
| Employee 3 | 200, 250 | 776 | 982 |
| Employee 4 | 50, 50 | 206 | 206 |

The emissions from using the internet (transmitting data) are assessed by using electricity consumption figures per transmitted data unit (kWh / GB) from the literature and then applying the electricity profile mix of Finland.

Being a large, complex system and consisting of multiple subsystems and therefore stressing the importance of setting boundaries, this thesis relies on a study carried out by Aslan et al. (2018). They reviewed 14 studies estimating the electricity intensity of data transmissions and then recalculated an estimate representing the most common system boundaries including Internet Protocol core network and access network, which they refer to as the "transmission network" and they note that this system boundary represents " *– the network of equipment used for data transmission and access at a national level.*" The estimate they computed was 0.06 kWh/GB for year 2015. However, they recognised that the electricity intensity of transmission networks seems to approximately halve every two years. (Aslan et al., 2018.) Therefore, it is likely that the electricity intensity for transmission networks is noticeably lower in 2020. However, this assessment is to be considered with great criticism, as the system boundary is still limited and represents only the commonality that has been present in the studies reviewed by the aforementioned authors. The realities may appear somewhat different if the boundaries are widened to touch the entirety of infrastructure affected in greater detail. However, if taking note of the development in efficiency of electricity use throughout the infrastructure, the figure used might as well be exaggerative.

# 4 RESULTS

This chapter presents the results of the carbon footprint calculation for Company for actual year 2020 as well as an assessment of what the emissions would have been if 2020 had been a normal year and circumstances presented by the COVID-19 pandemic had not affected the day-to-day activity. This means that remote work would not have been the principal form of work and lay-offs had not been necessary. The results are presented separately in the following chapters for both the actual and normal scenarios and are then compared.

## 4.1 Actual 2020

With the set operational boundaries, the carbon footprint of Company for year 2020 was 1127 kg$CO_2$e. It is approximately 11% of an average Finn's annual carbon footprint (Sitra, 2018). The average carbon footprint per employee was 322 kg$CO_2$e. Per person-year the carbon footprint was 438 kg$CO_2$e. Table 6 presents the data by category.

Table 5. Distribution of Company's actual emissions in 2020.

| Category | Sub-category | Sub-category | Scope | Emissions [kg$CO_2$e] | %-share of total |
|---|---|---|---|---|---|
| Office energy use | Electricity | | 2 | 104 | 9.2% |
| | District heat | | 2 | 351 | 31.2% |
| Work equipment | Acquired laptops | Manufacture | 3 | 456 | 40.5% |
| | | Transportation | 3 | 36 | 3.2% |
| | | Use | 3 | 0 | 0% |
| Commuting | Car | Direct | 3 | 1 | 0.1% |
| | | Indirect | 3 | <1 | <0.1% |
| | Train | Indirect | 3 | 150 | 13.3% |
| | Subway | Indirect | 3 | 3 | 0.2% |
| | Tram | Indirect | 3 | 6 | 0.6% |
| Transmission of data | Electricity consumption | | 3 | 19 | 1.7% |
| Total | | | | 1127 | 100% |

It can be seen majority of the emissions in 2020 originated from the sourcing of laptops, totaling to over 40% of total emissions and 30% more than the emissions from heat consumption and approximately the same as the total energy use of the office. This is perhaps against what was expected, as usually the energy consumption of properties is easily considered to be the main source of emissions. In relation to the number of employees the office space is quite small, which leaves the emissions rather low. Commuting, which was lesser in 2020 because of the pandemic, totaled to share of 14%. Transmission of data contributed only a share of 2%.

## 4.2 Normal 2020 scenario

The normal scenario represents a situation where the COVID-19 pandemic had not taken place and the circumstances presented by the pandemic had not affected the day-to-day activity. This means that the employees would commute to the office instead of working remotely and that other forced circumstances, such as temporary layoffs would not have been necessary.

The assessed carbon footprint for the normal scenario is 1705 kg$CO_2$e, being 49% higher than it actually was in 2020. Average carbon footprint per employee was 487 kg$CO_2$e and 596 kg$CO_2$e per person-year. The change stems mainly from the increase in emissions from commuting, as employees started working remotely in March and did not travel from home to the workplace and back. In the case of Company, train is the main form of commuting and brought about 40% of the total emissions, changing the distribution of total emissions remarkably. Table 7 presents the data by category.

Table 6. Distribution of Company's emissions in the normal 2020 scenario.

| **Category** | **Sub-category** | **Sub-category** | **Scope** | **Emissions [kg$CO_2$e]** | **%-share of total** |
|---|---|---|---|---|---|
| Office energy use | Electricity | | 2 | 104 | 6.1% |
| | District heat | | 2 | 351 | 20.6% |
| Work equipment | Acquired laptops | Manufacture | 3 | 456 | 26.7% |
| | | Transportation | 3 | 36 | 2.1% |
| | | Use | 3 | 0 | 0% |
| Commuting | Bus | Direct | 3 | 15 | 0.9% |
| | | Indirect | 3 | 4 | 0.2% |
| | Train | Indirect | 3 | 690 | 40.4% |
| | Tram | Indirect | 3 | 26 | 1.5% |
| Transmission of data | Electricity consumption | | 3 | 23 | 1.3% |
| Total | | | | 1705 | 100% |

## 4.3 Effect of COVID-19 pandemic to emissions

The carbon footprint was assessed to be 49% higher in the normal scenario in comparison to the actual year 2020. The change stems mainly from commuting, because normally the employees would commute to the office. Most of the emissions from commuting originate from electricity production for trains, as that is the primary form of commuting within the company in terms of distance traveled. Figures 2 and 3 show the distribution of emissions by area in actual and normal 2020 scenarios.

Figure 2. Distribution of Company's actual emissions in 2020.

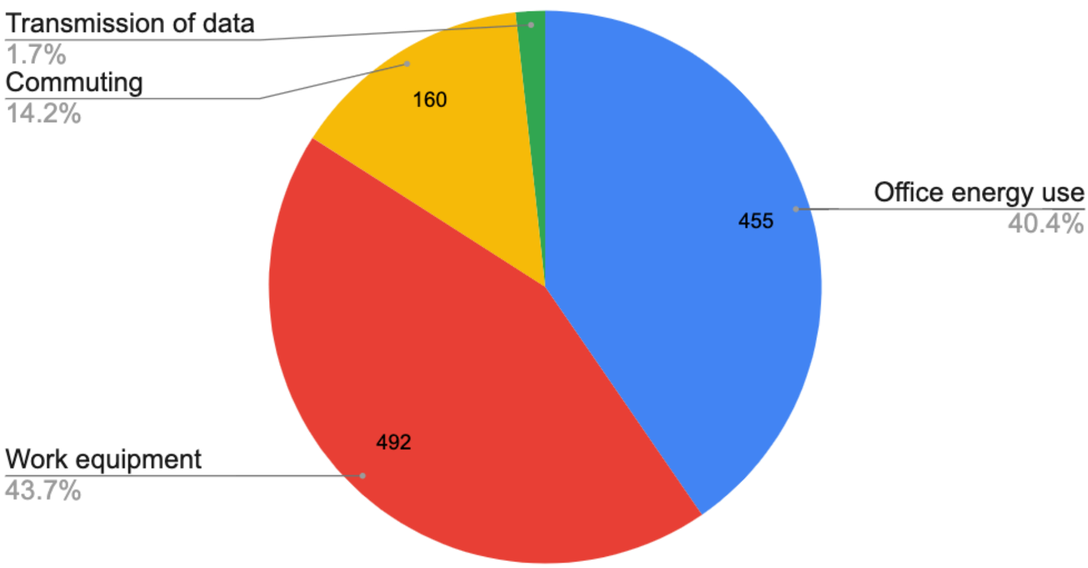

Figure 3. Distribution of Company's emissions in normal 2020 scenario.

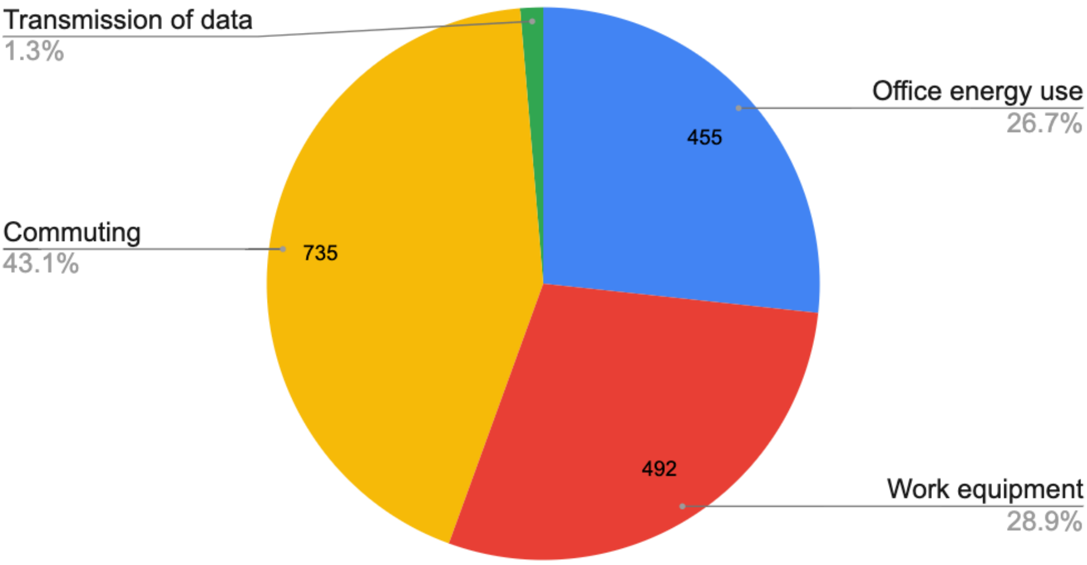


Table 8 presents the emissions per employee by category in actual and normal 2020 scenarios.

Table 7. Employee-specific emissions per category.

| Category | $kgCO_2e$ per employee, 2020 actual | $kgCO_2e$ per employee, 2020 normal |
|---|---|---|
| Office energy use | 130 | 130 |
| Commuting | 46 | 210 |
| Purchased laptops | 141 | 141 |
| Transmission of data | 5 | 7 |
| Total | 322 | 487 |

## 4.4 Sensitivity analysis

As a part of the carbon footprint assessment some of the most pressing assumptions and factors are assessed to evaluate their significance regarding the total carbon footprint. The office energy use has a significant role in the total emission, and the data it relies on are the energy consumption figures, unit emissions as well as the area-based allocation. Energy consumption is measured by the energy company and the unit emissions are also disclosed by them, and these are considered to be highly reliable. What is of some uncertainty is the area that should be allocated to the case company. The campus has shared spaces which are used by everyone and if everyone at the campus would calculate their own carbon footprint by allocating only the area of their dedicated office, a significant share of the total energy consumption emissions would be left unallocated. Thus, it is justifiable to do sensitivity analysis on the allocated area. However, the area of the shared spaces is not known, and therefore the sensitivity analysis is done on the assumption that the dedicated office space area is counted as doubled and tripled in size. The assessment of emissions with doubled and tripled office area is presented in Table 9.

Table 8. Sensitivity analysis on office space area.

| Total carbon footprint, 7 m2 area | Total carbon footprint, area doubled | Total carbon footprint, change-% | Total carbon footprint, area tripled | Total carbon footprint, change-% |
|---|---|---|---|---|
| 1127 $kgCO_2e$ | 1713 $kgCO_2e$ | 43% | 2230 $kgCO_2e$ | 86% |

The office space the company is using is perhaps exceptionally small and doubling or tripling its size is probably closer to the industry average when measuring the area per employee.

Commuting also has a major role in terms of the total carbon footprint, but the data used from both use as well as the mode of transport -specific emissions are considered reliable and therefore need not be examined through sensitivity analysis. Similar is the case with laptop manufacturing, as the emission information was produced by the manufacturer itself and was less than three years old.

# 5 DISCUSSION

This section will at first discuss the results of the calculation in relation to existing literature, and then proceeds to addressing the ways to reduce the carbon footprint of Company as well as other small expert companies based on the most significant emission sources recognised. From the results it can be seen that emissions come mostly from commuting, office energy consumption and sourcing of laptops. In the following chapters these areas and corresponding mitigation pathways are conversed on separately.

## 5.1 Results and challenges

This study, through its research questions, has strived to strengthen the understanding of emissions occurring from small expert companies and office work in general. Knowledge work is becoming more and more common, which shows especially in the demand of different ICT devices needed to process, use and store data. However, emissions from transmitting data pointed out to be close to negligible, although it was clearly the area of most uncertainty. Emissions from manufacturing of devices, however, were significant. The great significance of properties' energy consumption as well as commuting was expected, and even though the office space at Company's control is noticeably small, the emissions are still significant and further stress the importance of efficient space utilization.

Comparison of the actual and normal year 2020 scenarios points out the significance of commuting, even though almost none of the commuting was done by car. It evinces the benefits of successful adjusting to remote work and enables the employees to live further away. This, however, may retract the benefits of remote work, as the employee needs to commute from a further distance and therefore may cause more emissions than another employee who lives closer and does no remote work at all, for instance.

Publicly available carbon footprint calculations for small expert companies are notably scarce and none were found, which is a challenge for meaningfully comparing the results of this thesis to existing works. The scarcity of such calculations may result from the fact that small companies, especially expert companies, may not have faced pressing demands from their stakeholders and that small companies rarely prioritize matters that are not as pressing in nature or that the calculations are kept private. Furthermore, calculating one's carbon footprint takes time and effort and oftentimes requires purchasing services from a consultancy, which may be a barrier for many micro-sized companies. This issue is recognised and discussed by Ruževičius & Dapkus (2018), for example.

Comparing the emissions of a small business to those of an even medium-sized one proves out to be difficult. Small size of an expert company allows for a very small office, even a shared one as well as the lack of heavy IT-equipment such as servers and necessary personnel to operate them. However, comparison of separate areas is possible, such as energy consumption of the office as well as commuting, if they are put into proportion by headcount, for example. This could be done in the cases of University of Jyväskylä, University of Turku and the law firm Castrén & Snellman, for example. In comparison to these, Company's emissions from commuting per employee were significantly higher. This is because two of the Company's employees live relatively far from the office (>50 kilometres) and even though they commute by train, the annual distance travelled is notable and increases the commuting emissions per employee significantly. This is only significant when the employees actually commute to the office, but COVID-19 showed the possibilities of remote work, and that daily commuting is not always necessary and also enables the possibilities to consider a smaller office space. Regarding the emissions from energy & properties, they are notably higher with the three mentioned institutions, which is mainly explained by the large area that needs to be heated. (University of Turku, 2021; Geneidy et al., 2021; Castrén & Snellman, 2020.)

Another challenge is the availability of data, which pointed out a challenge and can also be an issue for other companies in some areas of operation. The data regarding the property is not optimal, as the consumption of both heat and electricity had to be allocated based on area of the office space, which was also based on a visual assessment. Although the total consumption of the building is accurate, the allocation is not. Furthermore, the specific energy emissions were reported directly by Helen and are considered reliable. However, for all energy providers it might not be the case, which would force the party carrying out the calculation to rely on other, more uncertain emission factors. The received data on commuting was quite accurate, as the day-to-day commuting usually takes place in same manner most of the time. Business travel, meaning the travel that needs to be done in order to meet customers face-to-face, however, pointed out a challenge. Year 2020 was an exceptional year and very little business travel had to be taken and would probably have been little or close to insignificant, but if more business travel had taken place, it would have pointed out a great challenge. Flights would most likely be the most significant form of business travel and they would be easy to remember and list by Company employees, but for other business travel that might take place by car, train or other public transportation, the calculation would have to include a lot of uncertainty, as exact data was not available from a bookkeeping system, for example. Also, some areas, such as waste management was not taken into account as there was no data available and its significance was assessed low, as the amount of waste was extremely low in 2020. The importance of paper has been stressed in many contexts, although it is evident that paper's purposefulness has seen a decline due to the generalization of digital products and platforms. It is likely that the production of paper is more significant in terms of emissions than recycling it.

The number of employees is low, which depletes the credibility of computed averages and narrows the extensibility of the total results. Carbon footprint per employee can be seen as an efficiency metric in terms of emissions of people employed but carries significant superficialities. Headcount does not take into attention part-time workers and part-time absences, such as sabbaticals, and depending on the field and organization itself, can pose a noticeable difference if the carbon footprint per employee is used as an efficiency metric to assess the relationship of emissions and economic input. Thereby a new metric, carbon footprint per person-year is suggested for experimenting and criticising to enable better comparability. It overruns the carbon footprint per employee -metric at least in terms of taking into attention part-time employments and absences, such as unpaid holidays, that take place during employment but may not be reflected in headcount. Thus, carbon footprint per person-year enhances especially the comparability of small companies, where small changes can remarkably alter the results. Computation of new metrics for accurately and fairly comparing the environmental impact of small companies and other operators is encouraged.

Next, possible ways to mitigate emissions of small and other expert companies, too, are discussed.

## 5.2 Mitigation pathways

### 5.2.1 Sourcing of laptops

Most evidently when a new employee is hired, they are equipped with a work laptop. A new MacBook Pro 13" has a carbon footprint of 246 $kgCO_2e$ when production and transportation are taken into account. It even exceeds the average annual emissions from commuting per employee (210 $kgCO_2e$). However, it is likely that as more employees enter Company, some will quit. This enables the rotation of laptops and thus not all employees are equipped with a brand new one. According to Confederation of Finnish Industries (2018) the average employee turnover rate for industry officials was 13% in 2018, which is a safe assumption to use for a consulting company, too. Therefore, 13% of the new employees are equipped with a used work laptop and cause no emissions and thus the average emissions for equipping a new employee with a laptop are those from producing and transporting a new laptop decreased by 13%. In the case of Apple MacBook Pro 2020 model, the average emissions would be 214 $kgCO_2e$. This is what would presumably happen nonetheless, and not all employees receive a brand-new laptop. If company were to increase its headcount by 20 and presuming that this includes the employee turnover rate of 13 %, the emissions from sourcing the laptops would sum to 4280 $kgCO_2e$.

According to Prakash et al. (2016), there is evidence that the key strategy to reduce the environmental impact of ICT products is to extend their service time, particularly so in the case of laptops. The lifetime of a computer varies greatly, but in many cases it is assumed to be four years (i.e. Hart, 2016; Apple, 2020). Oftentimes the lifetime is even less than three years, and it is not necessarily caused by physical fault, but rather a loss of functionality because the performance is difficult or impossible to expand. This leads to users purchasing a new device sooner although the old device could be upgraded. (Prakash et al., 2012.) Prakash et al. (2012) press that policymaking on sustainable product policies should focus on things such as modular construction, recyclability and standardisation of components rather than the products' energy consumption, as the manufacturing plays the most significant role in a laptops' life cycle. This reflects to singular companies so that they can choose to favour laptop models that are possible to maintain by upgrading and repairing, so that the use time can be prolonged as long as possible.

An evident opportunity to lower the emissions of equipping the new employee with a laptop is to source them used or refurbished. André et al. (2019) assessed that the emissions of a refurbished second-hand laptop are 58 % of those of a new one, presuming that the use time is the same. Numerous operators offer such service and could potentially be interested in partnerships. Carried out successfully, increasing the headcount to 20, the emissions from laptop procurements would cause approximate emissions of 2482 $kgCO_2e$. Another opportunity worth considering is to ponder whether the employee actually needs an additional work computer in addition to their own at all. If their own computer meets the functionality and other requirements of the job, the use of their own computer could be subsidized, as sometimes it may very well be the the case that the employee utilizes the work laptop as their own, anyway.

### 5.2.2 Office space

Energy use of the office was the second greatest source of emissions in 2020. More importantly, the consumption of district heat causes majority of those emissions, and they can be influenced through two components: the area that is heated (dictates the amount of necessary heat) and the source of the heat. The office is small and because areas such as kitchens, hallways and toilets are shared, the emissions that come from heating the office are relatively small per employee. However, the district heat is supplied by Helen and causes notable emissions still. Because the office space is in the co-working facility, Company cannot decide from which supplier to buy the electricity from and cannot therefore decide to switch to a renewable contract, although it possible to plead to the property owner to consider options. Situation is the same with electricity consumption: only the consumption is to some degree controllable.

Eventually if and when Company needs a larger office space, the space could be primarily looked for from buildings utilizing geothermal heat instead of district heat. However, the current model of using shared spaces is strikingly efficient in terms of space utilization, as the area per employee is very low. When spaces such as kitchens, toilets and hallways are shared, their utilization rate should be significantly higher, particularly so when an organization has only few employees. In terms of the efficiency of space utilization, it is strongly justifiable to strive for such efficiency also when the headcount increases. Furthermore, the dedicated space should be kept as small as possible and utilize shared or otherwise flexible spaces. With the current office and a headcount of 3.5 in average, the area per employee is only 2 $m^2$. According to a study carried out by Gensler (2012), in U.S. the average area per employee in the private sector was 189 square foot or approximately 17,5 $m^2$, almost 8-fold to that of Company. If Company were to reserve a space that has 17.5 $m^2$ for each employee in the current building, the emissions from district heat would rise to almost 3100 $kgCO_2e$ and the total emissions to 3900 $kgCO_2e$, which is 3.3-fold in comparison to the actual emissions of year 2020.

It is evident that the current office space utilization is extremely efficient, which may be only seen to be followed by not having a dedicated office space at all, but to rely on concepts such as office hotels and flex-spaces, where a workstation can be reserved by anyone. However, when Company's headcount eventually increases, keeping the area per employee as low as 2 $m^2$ may require more effort, although it can be done by regulating remote work and practising concepts such as rotating hot desks, although issues in workplace dynamics have reported to have arisen at least by Hirst (2011.)

The energy consumption of Company's office also cannot be regarded as generic as the office is very small even for a company of few employees, although it may be more and more generic for companies to have even extremely small, dedicated office spaces and rely more on shared spaces. This was pointed out also by Lund et al. (2021) from McKinsey, as they noted that more and more companies are seeking to reduce the size of their offices and increase the use of flexible workspaces after learning to cope with remote work during COVID-19 pandemic. In this sense Company serves as a prime example of how the emissions can be controlled, as at the same time the energy consumption at home stays roughly the same, less commuting takes place and less office space is required. Furthermore, smaller office spaces are not purely a question of emissions, but costs, too, and decreasing emissions can decrease costs as well.

### 5.2.3 Commuting and working remotely

Emissions from commuting can be controlled by either changing or otherwise altering the mode of commuting or decreasing the amount of commuting that is done. The COVID-19 pandemic forced many to adapt to working remotely and has left many considering how the nature of work will be post-pandemic. Lund et al. (2021) from McKinsey report that over 20 % of workforce could work remotely three to five days a week as effectively as they would at the workplace, which could result to 3-4 times more people working remotely in comparison to pre-pandemic times, having a significant impact on transportation, among other things. If remote work is executed in "shifts" or otherwise in a systematical manner, it would simultaneously allow for a smaller office space, as it would not be necessary to be able to station 100 % of the staff.

Chosen mode of commuting is always a choice of the employees themselves, but employer can try to encourage or subsidize the use of public or light transport. Di Dio et al. (2020) saw promise in involving citizens in a scheme that rewards the citizen with prizes if they gather scores by commuting by low-carbon means. The same principle could be applied at a workplace to motivate people to avoid using cars or other transport modes of high emissions, so that instead of only subsidizing the use of low-carbon options, it is turned into a competition that rewards the best performers. This could be executed together with a subsidizing program, which could, in the best scenario, allow for the employee to monitor and easily reward the best performers. Also, Cole-Hunter et al. (2015) reported that greenness surrounding a work or study address pointed out to be a positively significant determinant of bicycle commuting. Organizations within an area or building could plead to the landlord or otherwise orchestrate the execution of such measures, such as planting of bushes or acquiring green walls.

Furthermore, Lakhera & Sharma (2020) looked into the possibilities of green human resource management (Green HRM) as a way to reduce employees' carbon footprint and named six general initiatives: encourage digitalization, provide shared transportation, create green areas within the organization, ban plastics within the organization, declare smoke free areas and encourage green concepts. For human resource management they named seven approaches: fully online recruitment process (in terms of materials), employee procurement (make candidates aware of organization's green goals initiatives), induction (make new employees aware of organization's green goals and initiatives), performance management systems (regarding green goals), employee learning and training (helping employees be more green), rewarding green achievements and creating environmentally friendly offices. (Lakhera & Sharma, 2020.) The initiatives touch on many relevant areas, such as transportation and material efficiency, but digitalization is seen purely as an opportunity. Training of employees and spreading of awareness as well as incentivising green actions is stressed heavily. Similarities appear on the list made by WWF (2021), on which they name seven sins of an office as part of their Green Office tool. The first and most important subject on their list is management and second is communications and engagement (WWF, 2021). Both reflect the importance of educating and making more people aware of these efforts.

This chapter aimed to bring forth and discuss feasible ways to reduce the climate impact of organizations that require an office space to which the employees commute and use computers. Regarding the office space it is showed that it is beneficial to try and use the space as efficiently as possible and favouring remote work, so that the office does not need to be able to accommodate the full headcount of the organization. This also decreases the emissions from commuting, as all employees are not required to commute to the office daily. Regarding the computers, it is recommended to prolong the lifetime of work laptops as long as possible by sourcing models that are repairable and upgradable. Also, the laptops may be possible to source as second-hand.

# 6 CONCLUSIONS

In this master's thesis the focus was on the climate impacts of knowledge work through a case company, which was a consultancy of few employees. It was found that in 2020 the consumption of district heat and sourcing of laptops caused the most emissions. What was surprising is that even though Company's office space is very small, the consumption of district heat was still of high significance. In a normal situation without the COVID-19 pandemic, commuting would have been the highest source of emissions even though no commuting was done by car. Even though commuting is mostly done by train, long distance from home to work accumulates and grows the emissions remarkably. Emissions from data transmission pointed out to be negligible, at least with the made assumptions.

It is possible for a knowledge organization to significantly decrease its emissions by paying attention to purchases, space utilization and commuting patterns. Sourcing laptops used and prolonging their lifetime as long as possible can have a significant effect on total emissions. The office space can be utilized as efficiently as possible by minimizing the area per employee and utilizing office hotels or other flexible workstations, although this is most likely easier for a small organization of few employees. However, this can be done simultaneously with increased share of remote work, which also decreases the necessary commuting. Employees commuting patterns can also be affected with incentives and competitions.

Inevitably, comparing the carbon footprint of a small company to larger institutions, such as universities and other institutions of significantly higher headcount, is difficult. Small consultancy is a very flexible organization and can get by with a very small office space and shared spaces, does not require broad IT-infrastructure and does little business traveling. Furthermore, a small and young organization may not have systems that would enable better gathering of data, which also was the case in the case of Company's business travel.

The main limitation of this thesis was the lack of sufficient of reliable and accurate data, especially in the case of the office space, which stresses the development of measures and practices so that when it becomes more and more common for small companies to calculate their carbon footprint, it is possible in the first place. In many cases it may be that the need for such is only noticed when the first calculation is attempted to carry out and only then the motivation to develop the data arises. This should only become more and more common in the future years and likely the needs will breed solutions.

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