CORPORATE CARBON FOOTPRINT ASSESSMENT AND DEVELOPMENT FOR A DISTRIBUTION SYSTEM OPERATOR

Lappeenranta–Lahti University of Technology LUT

Master’s Thesis in Industrial Engineering and Management

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ABSTRACT

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Global surface temperatures have been rising due to greenhouse gas emissions from human activities and global warming has become a defining challenge of our time. In the effort to mitigate human made climate change, corporate carbon footprinting has emerged as a widely spread tool used by companies worldwide to assess the environmental impact of their operations. Assessing a corporate carbon footprint however requires companies to extensively collect and manage data inventories throughout their business activities and supply chain. Furthermore, companies often lack the capabilities to produce holistic assessments of their corporate carbon footprint. Addressing these challenges, this thesis provides a practical example of applying the Greenhouse Gas Protocol’s standards for assessing the corporate carbon footprint of an urban electricity distribution system operator. Additionally, observations to further develop the assessment process are discussed.

Overall, the case company’s corporate carbon footprint for the assessment year of 2022 amounted to 13416 tons of carbon dioxide equivalent of which 95% are indirect emissions occurring from activities in the supply chain. Due to the high significance of supply chain related emissions, assessment development efforts should focus on information systems for improved data management and on stakeholder engagement to nurture accuracy and reliability of the assessment. Furthermore, distribution system operators are pivotal in enabling the transition towards low-carbon energy systems. Developing standardized approaches within the industry may lower the burdens of electricity distribution and transmission stakeholders when assessing and managing their corporate carbon footprints.

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Above all, I want to thank my family and friends for the received support throughout my time as a student. The most valuable possessions we have are the connections we make with other people - for we are not here on this planet for ourselves, but for others. I dearly hope that in the future I can return the received support and be of help when help is needed.

Topias Viiala

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ABBREVIATIONS

CCF	Corporate carbon footprint
CH_4	Methane
CHP	Combined heat and power
CO_2e	Carbon dioxide equivalent
CSR	Corporate Social Responsibility
DSO	Distribution system operator
EEIO	Environmentally-extended input output
EPA	Environmental Protection Agency
ESG	Environmental, Social & Governance
GHG	Greenhouse gas
GWP	Global warming potential
HV	High-voltage
LCA	Life-cycle assessment
LV	Low-voltage
MV	Medium-voltage
NO_2	Nitrogen dioxide
SF_6	Sulfur hexafluoride
TSO	Transmission system operator
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute

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1 Introduction

Global surface temperatures have been rising due to greenhouse gas (GHG) emissions from human activities and global warming has become a defining challenge of our time (IPCC, 2023). The effects of global warming promise unforeseen floods, droughts, storms and a rising sea-level that threaten lives and economies worldwide (Raworth, 2017). Growing public and political awareness of global warming and its risks has resulted in wide-spread adaptations of climate policies and mitigation processes (IPCC, 2023). Consequently, organizations and corporations are increasingly adopting climate impact reduction targets and implementing strategies (Zvezdov & Hack, 2016), that align with the Paris Agreement of limiting global warming of average global temperatures to not exceed 1,5 °C from pre-industrial times (United Nations, 2023).

A requirement in implementing strategies and successfully achieving GHG emission reduction of corporate operations is the holistic assessment of a corporate carbon footprint (CCF). Organizations can not effectively manage what they do not measure. Consequently, a growing number of organizations is advancing global warming mitigation by assessing and reporting their CCF (Marlowe & Clarke, 2022). Furthermore, the rationale for assessing a CCF goes beyond combating global warming. For instance, organizations perform carbon footprinting also in hopes of identifying cost saving potential, gaining competitive differentiation, improving their brand image, pursuing financial incentives, following trends in corporate social responsibility (CSR) and meeting stakeholder reporting requirements (Tang & Demeritt, 2017). Attaining these goals through carbon footprinting requires decision-makers to have timely and accurate information across their value chain, business processes and activities (Zvezdov & Hack, 2016). Adversely, organizations are often limited in producing thorough corporate carbon footprints as information systems for coherent data collection, GHG emission quantification and impact management are either not existing or often lacking (Rydén & Sandegård, 2020).

This master thesis is a case study and focuses on corporate carbon footprinting of a distribution system operator (DSO), Helen Electricity Network Ltd. (Helen DSO), which is responsible for distributing electricity and managing the electrical network in the capital of Finland. The thesis contributes by advancing the understanding of how existing frameworks can be utilized to assess and quantify a corporate carbon footprint. In order to credibly quantify the corporate carbon footprint and underlying GHG emissions of Helen DSO, the thesis follows widely adopted guidelines and standards provided by the GHG Protocol. Ultimately this master thesis report shows *what* a corporate carbon footprint is, *how* it can be assessed and *what* Helen DSOs carbon footprint is. Adherently, this master thesis includes recommendations on *how* the process of quantifying a CCF can be developed based on observations during the research and assessment of the case company.

1.1 Background and purpose

Corporate carbon footprinting is increasing and is setting in to become a typical reporting practice in the field of environmental, social and governance (ESG) activities (Rydén & Sandegård, 2020). Several Finnish DSOs as well as the national transmission system operator Fingrid in Finland include GHG emissions inventory results in annual sustainability reports (Caruna, 2023; Elenia, 2023; Fingrid, 2023). Furthermore, foreseeable changes in legislation and financial markets put pressure on companies to consider their impact on the environment. Also, stakeholder and customer engagement demand reporting of environmental impact measures. The case company is not excluded from the aforementioned drivers as well as the resulting business environment, hence, measuring and assessing a corporate carbon footprint is essential in managing GHG emissions and addressing stakeholder needs.

According to the World Meteorological Organization (WMO, 2022) "the energy sector is the source of around three-quarters of global greenhouse gas emissions and the supply of electricity from clean energy sources must double within the next eight years to limit global temperature increase." This puts DSOs into the center of an energy transition and portraits the significance of sustainable power grids enabling environmentally friendly societies and industries. Supporting this, Helen DSOs own estimates foresee an increase in electricity usage due to urbanization trends, changes in heat production methods and an increasing number of electric vehicles (Helen DSO, 2023b). The changing business environment and a strategic goal to enable a sustainable energy system steered the case company to further assess their own corporate carbon footprint.

Prior to this master thesis the case company has performed carbon footprint estimations and emission activity data has partially been reported to selected stakeholders. Whereas direct emissions from owned equipment and purchased energy could be assessed without dedicated resources, the case company has identified that assessing GHG emissions over the whole supply chain, including activities of direct business partners and their suppliers further down the supply chain, can be considered demanding. For this reason, supply chain GHG emission were estimated based on spending data rather than primary data or process life-cycle assessment (LCA) data. Thorough research of business activities, operations and the supply chain from a carbon footprinting perspective was needed for an accurate GHG emission inventory assessment. Hence, the goal of this master thesis is to increase knowledge on how a corporate carbon footprint can be assessed for DSOs.

1.2 Research questions

In accordance with aforementioned background and goals, following research questions have been established:

- What is Helen DSO's corporate carbon footprint?
- How can the process of corporate carbon footprinting be developed?

The first research question addresses the direct need to know what the carbon footprint of the case company is and how it can be assessed. This will support future decision-making in targeting risk mitigation and carbon reduction efforts. The second research question focuses on observed challenges and opportunities while assessing the corporate carbon footprint in order to discuss options for corporate carbon footprinting with less effort or resource dependency and more accuracy in the context of the case company.

1.3 Research methodology

Research methodologies describe how a given research is conducted whereas the ultimate goal of any research is to create new knowledge. For research in itself to be of any value, it needs to be conducted in a systematic way that is "planned, organized and has a specific goal" (Goddard & Melville, 2001). This section describes the selected research methodology and study design for achieving the objective of this thesis.

According to Zainal (2007), the "case study method enables a researcher to closely examine the data within a specific context". Case studies therefore investigate phenomena within a limited range of activities with inclusion of the relationship between these activities. In order to achieve robustness, it is important for case study methods to build a strong case study design. Researcher may choose between a single case design, if no other cases are available for replication, or a multiple-case design in order to examine similarities and make comparisons between the cases to provide general conclusions with applicability to a broader field. Furthermore, case studies are categorized into exploratory, descriptive and explanatory case studies. Explanatory case studies intend to explore interesting phenomena through general questions which aim to reveal potential examination opportunities of the observed phenomena. Descriptive case studies intend to describe phenomena in perspective of a given theoretical framework. The goal with descriptive case studies is to examine a certain scope of the case subject. Explanatory case studies examine data in order to reveal certain phenomena within the context of given data. Ultimately, explanatory case studies aim to derive a theory that explains observed phenomena and their occurrence. (Zainal, 2007)

Given that this master thesis is limited to a single company and its operations, no comparison or valid generalization can be made from the results. This means that the single-case study design is the most applicable for this master thesis and the research is conducted as such. Furthermore, the research questions aim to increase knowledge about the naturally occurring carbon footprint of the case company which leads to conclude that a descriptive case study is best suited for explain the scope of the case companies impact on global warming. Hence, this thesis is considered a descriptive single-case study with empirical rather than theoretical emphasis. A literature review provides the necessary theoretical framework and forms the perspective under which the case company's operations and environmental performance are examined. Furthermore, a discussion based on key observations and empirical findings will provide decision-making support and recommendations for further research.

The GHG emissions quantification requires establishing an inventory of activity data (AD) as well as sourcing of emission factors (EF) for specific activities (Larpkern & Suvarnapunya, 2017). Consequently, the sum of GHG emissions for a specific activity can be calculated by multiplying the activity with the emissions factor as shown in Equation 1.

Equation 1. GHG emission quantification

$$AD \times EF = GHG\ emission \qquad (1)$$

where AD is the activity data, EF the appropriate emission factor and GHG emission the reflecting mass of accounted emissions for a given activity.

1.4 Scope and limitations

The corporate carbon footprint has been assessed in accordance with the guidance of the GHG Protocol accounting and reporting standards by World Business Council for Sustainable Development (WBCSD) and World Resource Institute (WRI). This thesis is limited to assessing only the corporate carbon footprint of the case company and is specific to its operations. Furthermore, the carbon footprint evaluation period is limited to 2022 and GHG emissions will be quantified based on business activities only from that year. It is worth noting that the carbon footprint and related GHG emissions of Helen DSO may vary significantly from year to year due to changing operations or investments that did not occur during 2022.

The focal method of quantifying GHG emissions is to gather business activity data and to apply a corresponding emission factor. Business activity data includes purchased goods and services during the evaluation period as well as activities that fall under operational control of the case company. Pure financial transactions such as taxes or salaries are omitted from business activities for this research. Business activity data is collected from reports and communication with relevant staff and stakeholders. Activity data may be kept confidential so as to not disclose confidential information or violate data protection rights. The same confidentiality applies in part to collected emission factor data as the data may not be publicly available. Hence, business activity data as well as emission factors are presented when possible. Nevertheless, calculation methods are disclosed and data sources, with the exception of internal reports and confidential data, are referenced and presented.

As described in chapter 1.1 Background and Purpose, one goal of the thesis is to add knowledge and accuracy of Helen DSO's CCF. Consequently, primary data for business activities and emission factors is prioritized if available. Secondary data, averaged data, environmentally-extended input-output (EEIO) emission factors and literature are used to fill in data gaps or substitute unavailable primary data.

1.5 Structure

The research structure for assessing Helen DSO's carbon footprint is adapted from the GHG Protocols scope 3 accounting and reporting steps whereas only steps regarding GHG emission quantification were considered. Quantifying the corporate carbon footprint started by reviewing accounting and reporting principles, which after inventory activities were identified and the organizational boundary was set. Thereafter thorough data collection was conducted to gather activity data and emission factor data. Finally, emissions were allocated using the collected data and the resulting GHG emissions inventory was reviewed. (GHG Protocol, 2011a)

The thesis structure was selected to guide and support readers which might not have prior experience in corporate carbon footprinting or are unfamiliar with DSO operations. Table 1 provides a brief overview of each chapter giving a short description of its content.

Table 1. Thesis structure

Input	**Chapter**	**Output**
Background information	1. Introduction	Introduction of the thesis, background, objectives, research questions, methodology, structure, scope and limitations
Theory and literature review	2. Theoretical framework	Introduction of concepts and theories applied in this research, including assessment standards and calculation methods
Data of the case company and its activities	3. Case company introduction	Introduction of the case company, its business environment and collected inventory data

Data collection and emission quantification	4. Helen DSO's carbon footprint	Detailed presentation of GHG quantification results for each assessment scope
Observations	5. Discussion	Discussion of observations gathered during the research regarding information systems, stakeholder engagement and data.
Main findings	6. Conclusions	Overview of results, contributions and further development potential

After the introduction of the thesis, the theoretical framework for the research and the case company is presented. Hereafter, the research results are outlined and key observations of the assessment process are discussed. The conclusions provide an overview of results and provide the reader with a broader understanding of practical contributions as well as implications of the research.

2 Theoretical framework

This chapter outlines the theoretical framework and methodologies applied during this case study. A definition for the term carbon footprint is provided after which GHG emissions are defined and methods for assessing a corporate carbon footprint and GHG emission quantification are described. The corporate carbon footprint has been assessed in accordance with the guidance of the GHG Protocol accounting and reporting standards. Hence, the corporate standard and corporate value chain (scope3) standard from the GHG protocol are summarized as these standards constitute the principles and methods of assessing GHG emissions on an organizational level in this research. (GHG Protocol, 2004; GHG Protocol, 2011a)

Corporate carbon footprinting serves as a useful tool for the assessment of a company's greenhouse gas emissions. This is necessary for coherent management and mitigation of emissions. The basis of the carbon footprint calculation is life cycle assessment (LCA) which provides information on several environmental impacts caused during the life cycle of products, of which the carbon footprint describes only the effect on global warming. A method in which the review of environmental effects is extended to only one indicator has also attracted criticism. The applicability needs to be evaluated always on a case-by-case basis. On the other hand, a simple indicator enables communication in a way that is understandable to the general public. This has partly been the reason for the development of carbon footprint accounting to the widespread adoption of its use in the private sector. Despite the apparent simplicity of the indicator, successful calculation often requires extending the work beyond the company's own operations as well and external operations within the supply chain are often of great importance to the company's total emissions. These external operations need to be covered, too, which complicates the calculation considerably. However, the implementation of the assessment already in itself leads to a systematic review of the supply chain and can reveal hidden development needs at both the strategic and operational level of activities. (GHG Protocol, 2011a; Pohjalainen, 2018)

2.1 Defining carbon footprint

Carbon footprints are widely used to assess, evaluate and report the total amount of greenhouse gases generated from the activities of an organization or during the life cycle of products. This section provides the background for conducting and managing carbon footprints of organizations based on scientific literature. General methods for conducting a carbon footprint analysis are presented and the rationale for choosing the selected corporate carbon footprinting method for this thesis is derived.

Though the methodologies for carbon footprinting are still evolving, carbon footprinting has emerged as one of the most significant ways to indicate environmental impact and contribution to global warming (Pandey et al., 2010). Despite this significance and extensive use publicly, the term “carbon footprint” lacks adequate definition in scientific literature (East, 2008). Furthermore, (Wiedmann, 2009) argues that scientific literature does not provide a definite origin for the term carbon footprint though it is assumed that the term is a derivation of the term Ecological Footprint which was formulated in the 1990s. Upon further investigation, other terms such as greenhouse gas accounting or carbon accounting have been identified to describe the environmental impact assessment of organizations. Publicly, the use of the term carbon footprint has spread widely and is nowadays understood synonymously with the impact of an entity on the environment. (Wiedmann, 2009)

According to Cordero (2013), a carbon footprint can be considered a simplification of a life-cycle assessment which includes all environmental impact categories, whereas carbon footprints only account for the impact on global warming. The ambiguity of the term itself implies that the methodologies for carbon footprinting are broadly debated and that selecting a suitable method for environmental impact assessments may depend on the motivation and opportunities for conducting such assessments. One commonality between Wiedmann’s and Cordero’s definitions (Cordero, 2013; Wiedmann, 2009) is the simplification of the scope of assessed impact categories: carbon footprints account not for all environmental impacts but only global warming potential is assessed via quantification of GHG emissions. The methods for GHG quantification however are abundant and assessment scopes as well as the subject of assessment vary as well (Cordero, 2013). Further classification is needed in order to identify a suitable carbon footprinting methodology and to establish a rationale for selecting it for this thesis. Examining the literature on carbon footprinting methodologies provides an overview of options of methods than can be considered while exploring the reasons for carbon footprinting will assist narrowing down a suitable approach.

According to Cordero (2013), methodologies for assessing carbon footprints can be classified into three types:

- Methodologies which use environmentally extended input-output (EEIO) analysis for calculating a carbon footprint of whole industries, sectors and countries.
- Corporate carbon footprinting methodologies, which assess direct and indirect emissions over all activities of an organization, including operations and supply chains.
- Product carbon footprints, using a life cycle assessment (LCA) based approach to assess emissions that occur over the life cycle of products and services from cradle-to-grave.

Regarding methodological issues, Wiedmann & Minx (2008) make a distinction of two different approaches for calculating carbon footprints: the bottom-up approach which they call process analysis and top-down approach, also called environmentally extended input-output analysis. The process analysis method aims to provide results on environmental impacts from cradle-to-grave for products and services based on life cycle assessment methodology. This approach prioritizes primary data though secondary data is used to fill in gaps. Generally, this approach yields higher levels of accuracy for defined products and services. Process analysis, however, is considered cost and labor-intensive due to extensive data collection efforts and data quality requirements. Furthermore, the achieved level of detail with primary data is usually only accurate for an individual product or service. Using secondary data to extrapolate emissions inventories for whole product groups adds uncertainty to the assessment results. Contrarily, environmentally extended input-output analysis, the top-down approach, is applicable for estimating emissions inventories of larger entities such as governments and organizations. However, its applicability for assessing individual products and services is limited. Environmentally extended input-output analysis uses input-output tables to convert economic values comprehensively into GHG emission data. This method allows for a complete assessment of entire industries or sectors but at the same time a lack of detail and accuracy limits the suitability of for assessing the success of emission mitigation activities at the operational level. The biggest benefit of the environmentally extended input-output analysis is its feasibility as it requires much less time and effort than process-based analysis. Conclusively, integrating top-down and bottom-up approaches into a hybrid-EEIO-LCA method would provide a complete and comprehensive carbon footprint assessment yet more relevant emissions sources can still be assessed in detail. The challenge herein is that few have acquired the necessary skills to perform hybrid assessments as the method requires careful separation of activities as to avoid overlapping or double assessments. Furthermore, hybrid methods require the assessor to have in-depth knowledge about the constitution of economic accounts in order to detract costs of emission sources that are already subjected to process-based analysis. Hybrid methods therefore can be considered to have advantages of LCA and EEIO based approaches, however challenge of each approach may not be eliminated fully as the hybrid method adds complexity to the overall assessment process. (Wiedmann, 2009)

Choosing a method for organizations to assess their corporate carbon footprint depends on the motivation and capabilities of organizations to conduct a GHG inventory. Therefore, organizations should be familiar with the needs and wants for conducting the assessment while balancing the planned scope of results with performance capabilities. Furthermore, by examining the benefits associated with carbon footprint analysis, organizations gain insights into how such assessments can positively impact their overall operations and supply chains. Next to the convergent reason of raising environmental impact consciousness, scientific literature also discusses supply chain management benefits for conducting carbon footprints. For example, Cordero (2013) emphasizes that traditional supply chain management activities aim to derive economic benefits and increase feasibility while sustainability aspects are often neglected. Integration of environmental and social aspects into supply chain management activities would enable organizations to secure long-term economic performance and robustness of their supply chains. (Cordero, 2013)

The objectives of this thesis are to assess the carbon footprint of the case company and provide implications to further develop the assessment process as stated in chapter 1.3 Furthermore, the case company has external requirements to conduct a GHG emissions inventory that includes their supply chain activities. Additionally, reporting requirements to stakeholders and customers require a level of robustness to the assessment which a carbon footprint assessment purely based on EEIO analysis can not provide. Hence, a bottom-up or process-based analysis is required at least for the most relevant emissions sources. Product carbon footprints for services sold of the case company can be considered interesting though this approach would limit out emissions allocated to activities of the company that are not related to a given product but otherwise significant to the operation and supply chain of the case company. Therefore, the hybrid-EEIO-LCA based approach seems most suited. GHG emissions of high-priority activities can be quantified with a bottom-up approach and less significant emissions sources can be estimated with a top-down approach.

2.2 Global warming potential indicator

This chapter describes the concept of carbon dioxide equivalent (CO_2e) and its relation to global warming. Global warming is a phenomenon caused by human activities and results from emissions of greenhouse gases into the atmosphere. These gases trap heat in the atmosphere, which leads to an increase in temperature and other adverse effects on the environment. The concept of global warming potential (GWP) and its associated indicator CO2e have been developed to quantify the impact of GHGs on the environment. (IPCC, 2023)

CO_2e is the unit of measurement that allows for the comparison of GWP values of different greenhouse gases. The GWP value of a particular gas is a measure of its potential to cause global warming relative to carbon dioxide. Hence, CO_2e is used to express the GWP of GHGs in terms of the amount of carbon dioxide over a specified period. The GWP of carbon dioxide is set to one, and the GWP of other gases is expressed in terms of multiples of carbon dioxide as can be seen in Table 2. For example, one kg of emitted sulfur hexafluoride gas equals the global warming effect of 23,5 tons of CO_2 over the span of 100 years. Hence the GWP100 value of SF_6 is 23500 and 1 kg of SF_6 gas equals 23500 kgCO_2e. (GHG Ptrotocol, 2011b)

Table 2. GWP values of accounted GHGs (GHG Ptrotocol, 2011b)

GHG	**Chemical formula**	**GWP100 value**	**Common emission sources**
Carbon dioxide	CO_2	1	Fossil fuel combustion
Methane	CH_4	28	Agriculture
Nitrous oxide	NO_2	265	Fertilizers
Sulfur hexafluoride	SF_6	23500	Insulation gas in electrical equipment

In this research four of the seven greenhouse gases described in the Kyoto Protocol (UNFCCC, 1997) are used to calculate activity related CO_2e emissions factor when pre-calculated CO_2e emission factors were not available. These are carbon dioxide (CO_2), methane (CH_4), nitrous dioxide (NO_2) and sulfur hexafluoride (SF_6). While emissions from fuel combustion contain a complex mixture of gaseous and particulate substances, the majority by mass are greenhouse gases, particularly CO_2, CH_4 and NO_2 (Healt and Safety Executive, 2013). SF_6 gases are important in this CCF assessment as SF_6 gases have unique properties enabling compact and space saving network equipment which is preferred at urban DSOs such as the case company since space for network equipment is usually limited. Since in this assessment only fuels and GHG gas leakages require extrapolation of CO_2e based emissions factors, only the aforementioned gases and their GWP values are presented.

2.3 GHG protocol

The corporate carbon footprint has been assessed in accordance with the guidance of the GHG Protocol accounting and reporting standards by the World Business Council for Sustainable Development (WBCSD) and World Resource Institute (WRI). This section outlines principles of the GHG Protocol, the organizational boundaries for the research and GHG quantification methods in accordance with the GHG Protocol guidance.

"The Greenhouse Gas Protocol is a multi-stakeholder partnership of businesses, non-governmental organizations, governments, and others convened by the WRI and the WBCSD. Launched in 1998, the mission of the GHG Protocol is to develop internationally accepted greenhouse gas accounting and reporting standards and tools, and to promote their adoption in order to achieve a low emissions economy worldwide. " (GHG Protocol, 2004)

The GHG Protocol has produced separate but complementary standards which provide requirements and guidance for companies to prepare and report a GHG emissions inventory. For this thesis, two of the developed standards are applied in particular. These are the GHG Protocol Corporate Accounting and Reporting standard (corporate standard) (2004) as well as the corporate value chain (scope 3) accounting and Reporting Standard (scope 3 standard) (2011). The scope 3 standard builds on the corporate standard and the two standards are used in conjunction to assess the corporate carbon footprint of the case company. The corporate standard provides guidance on the assessment of direct GHG emissions (Scope 1) and indirect GHG emissions from purchased energy (scope 2). Emissions under scope 1 are directly emitted during operations controlled by the reporting company or from fuel-combustion of stationery or mobile assets that are owned or controlled by the reporting company. Scope 2 emissions are indirect emissions that occur from the generation or purchased energy. Scope 2 emissions may be assessed based on a location-based assessment or a market-based assessment. Location-based scope 2 emissions reveal average GHG emissions based on the geographical location of the reporting company whereas market-based scope 2 emissions are based on contractual agreements and present actual GHG emissions of purchased energy. The scope 3 standard supplements the corporate standard and provides requirements and guidance for companies to report on indirect GHG emissions from value chain activities not included in scope 2. An overview of the scopes is presented in Figure 1. (GHG Protocol, 2004; GHG Protocol, 2011a)

Emissions type	*Scope*	*Definition*	*Examples*
Direct emissions	Scope 1	Emissions from operations that are owned or controlled by the reporting company	Emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment
Indirect emissions	Scope 2	Emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting company	Use of purchased electricity, steam, heating, or cooling
	Scope 3	All indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions	Production of purchased products, transportation of purchased products, or use of sold products

Figure 1. Overview of scopes (GHG Protocol, 2011a)

Companies shall account and report their GHG emissions inventory based on 5 principles which are relevance, completeness, consistency, transparency and accuracy. The principle of relevance implies that a GHG report includes all relevant information needed by internal and external stakeholders. The principle of relevance should be used when determining which activities shall be included and excluded from the GHG inventory. The principle of completeness implies that a company's GHG inventory appropriately reflects all relevant emissions of scope 1, scope 2 and scope 3. The principle of consistency requires companies to use a consistent approach and application of the GHG quantification methods to ensure comparability over time. The principle of transparency relates to the degree to which information of the GHG inventory is disclosed. Furthermore, transparency of information requires clear documentation that allows an audit trail and internal reviews respectively. Accuracy is the principle that steers companies to choose data with sufficient accuracy which allows a reasonable level of confidence to make decisions based on the results of GHG quantification. (GHG Protocol, 2011a)

Further requirements include that companies should set organizational boundaries and choose one consolidation approach under which the GHG emission inventory is built. Companies shall choose to set organizational boundaries between three different consolidation approaches that shall be applied consistently. These are the equity share approach, the financial control approach or the operational control approach. Under the equity share approach, a company accounts for GHG emissions from operations according to the share of equity or ownership in the operation. The financial control approach determines an organizational boundary under which a company accounts and reports on GHG emissions under which it has financial control. The operational control approach requires companies to account and report for 100 percent of the GHG emissions over which it has operational control. For the purpose of this thesis the operational control approach is chosen as the organization boundary. Additionally, the standard provides requirements for setting a GHG target, tracking emissions over time and on the reporting of GHG inventory. As this thesis focuses on providing a status quo of GHG quantification and determining the corporate carbon footprint of the case company, setting GHG targets and tracking emissions over time are excluded from the case study. (GHG Protocol, 2011a)

A major focus of the thesis is to extensively analyze the case companies supply chain and increase accuracy of scope 3 emissions. Scope 3 is divided into upstream and downstream activities with a total of 15 different categories. Categories 1 to 8 cover upstream activities and categories 9 to 15 describe downstream categories. The categories are presented in Figure 2. (GHG Protocol, 2011a)

Upstream or downstream	Scope 3 category
Upstream scope 3 emissions	1. Purchased goods and services 2. Capital goods 3. Fuel- and energy-related activities (not included in scope 1 or scope 2) 4. Upstream transportation and distribution 5. Waste generated in operations 6. Business travel 7. Employee commuting 8. Upstream leased assets
Downstream scope 3 emissions	9. Downstream transportation and distribution 10. Processing of sold products 11. Use of sold products 12. End-of-life treatment of sold products 13. Downstream leased assets 14. Franchises 15. Investments

Figure 2. Scope 3 categories (GHG Protocol, 2011a)

This study applies calculation methods provided by the GHG Protocol to quantify GHG emissions of scope 1, scope 2 and scope 3. The abstract method to quantify emissions of a specific activities is described with Equation 1. In the following sections, the framework for emissions factors, activity data and applied calculation methods is described.

Following the Technical guidance for Calculating Scope 3 Emissions (GHG Protocol, 2011c), emissions are allocated to selected scope 3 categories. The guidance offers multiple calculation methods for scope 3 categories whereas each calculation method requires the collection of activity data and emission factors. The guidance also provides data collection guidance and calculation formulas. As multiple calculation methods are available the guidance also provides a ranking of calculation methods in order of specificity. More specific methods yield higher accuracy, reliability and quality of emissions data. However, more specific methods may also require more time and are labor intensive. For this reason, companies should prioritize calculation methods based on the relative size of emissions within scope 3 activities. Business goals, data availability and data quality are also factors that companies may use to select applicable calculation methods. Furthermore, initial screening of scope 3 activities may help companies to prioritize which calculation methods to apply. (GHG Protocol, 2011a; GHG Protocol, 2011c)

As mentioned in the previous section, calculation methods are ranked according to specificity. More specific methods may be applied to activities of higher significance to the reporting company. Specific methods also require data collection of primary activity and emission data as well as specific emissions factors. Primary data can be e.g., supplier-specific data which has the advantage of providing better representation of the specific activity. Secondary data can be used when primary data is not available to supplement data gaps. Secondary data may be collected from applicable databases or literature respectively. (GHG Protocol, 2011a)

Activity data is a measurable quantity that produces GHG emissions. Activity data can be for example liters of fuel, kilograms of purchased material or euros spent on a specific product. Emissions factors are factors that are used to convert activity data into GHG emissions as presented in Equation 1. Emission factors provide the necessary information of how much $kgCO_2e$ for example the production of a certain product emits (for example $kgCO_2e/kg$, $kgCO_2e$/€, …). Material and product specific emission factors cover emissions that occur over the life cycle of a product or activity, also called life cycle emissions factors. Emissions factors that cover emissions occurring in the life cycle of a product up to the point of purchase by the reporting company are called cradle-to-gate emissions factors. Cradle-to-gate emission factors are used in this study to calculate emissions of goods and services within scope 3. Energy related emission factors may also be life cycle emissions factors, including all emissions that occur from extraction of raw materials, transportation, processing and combustion. Combustion emission factors however cover only emissions that occur during the combustion of fuels. Combustion emission factors are used to calculate scope 1 and scope 2 emissions whereas emissions for scope 3 category 3 consider only upstream related life-cycle emission of purchased energy, excluding emission from combustion. Emission factors that exclude combustion emissions are also called upstream emission factors. Figure 3 provides an overview of different emissions factors that are applied in quantifying GHG emissions during the assessment of case company's corporate carbon footprint (GHG Protocol, 2011c)

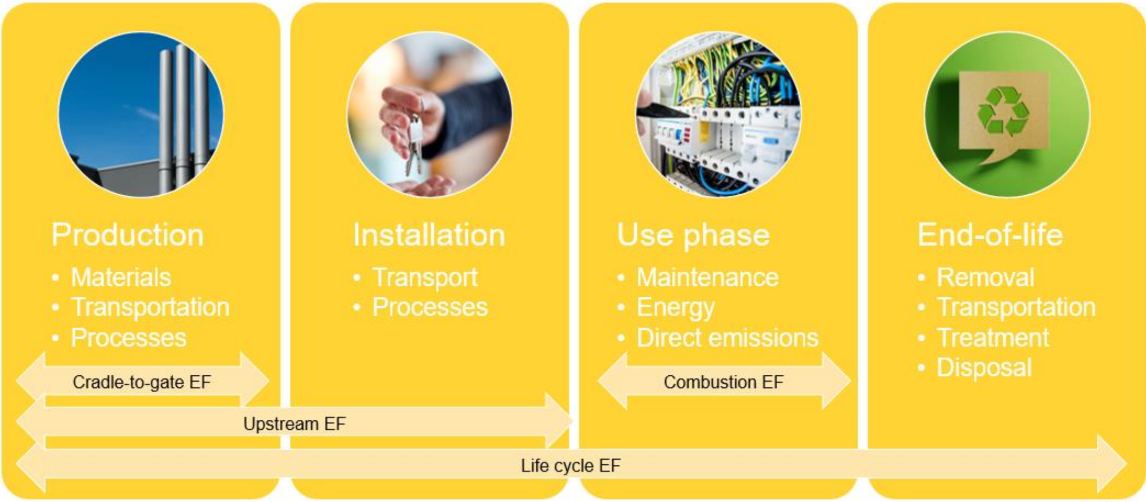

Figure 3. Emission factors, applied from scope 3 standard (GHG Protocol, 2011a)

Another source of data used for quantifying GHG emissions is environmentally-extended input output (EEIO) data. EEIO models estimate GHG emissions for different sectors and products in an economy. The resulting emissions factors can be used to estimate cradle-to-gate emissions for a product category or industry. The input required for applying EEIO data is cost data and the output is a quantity of GHG emitted per unit of cost. Advantages of using EEIO data include the comprehensive coverage of the entirety of an GHG inventory. Furthermore, EEIO data provides simplicity in the application which saves time and cost. Disadvantages include a lack of accuracy as the same products may be purchased for different prices. EEIO databases are also usually limited to a specific geographic region, which means that EEIO emission factors may be limited in applicability in other regions. (GHG Protocol, 2011c)

Scope 1 emissions are calculated based on average combustion emission data for specific fuel types and primary data of SF6 gas leakage. Scope 2 emissions are quantified based on primary data as well as location-based average data. Calculation methods to quantify GHG emissions are chosen depending on the data types available for either activity data or emission factor data. Calculation methods may also be combined for allocating GHG emissions to a specific scope 3 category. The following calculation methods are applied in this thesis to calculate scope 3 GHG emissions: supplier-specific method, hybrid method, average-data method, spend-based method, waste-type-specific method and distance-based method. Table 3 presents which calculation method was used in assessing GHG emissions of selected scope

3 categories in this study. Categories not shown in Table 3 were excluded from the GHG inventory as the case company does not have activities that would contribute to downstream category emissions. (GHG Protocol, 2011a; GHG Protocol, 2011c)

Table 3. Used calculation methods

	Calculation methods					
Category	Sup-plier-spe-cific	Hybrid	Aver-age-data	Spend-based	Waste-type-spe-cific	Dis-tance-based
1&2: Goods and services, Capital goods	x	x	x	x		
3: Energy-related upstream	x		x			
4: Logistics				x		
5: Waste management					x	
6: Business travel				x		x
7: Employee commuting			x			
8: Leased assets				x		

The supplier-specific method uses primary data for activities as well as supplier specific emission factors. Activity data for the supplier specific method is constituted of physical measurements such numbers (unit), masses (kg) and meters (m). The emission factors used in the supplier-specific method are LCA-based primary data sets that present cradle-to-gate emissions of the activity data, e.g., CO_2e/unit, CO_2e/kg or CO_2e/m. The hybrid method uses supplier-specific data in conjunction with secondary data to fill in data gaps. Secondary data in the hybrid method can be EEIO data-based emission factors or average emission factors that are found from databases or that are extrapolated. The average data method uses average emission factors in the quantification of GHG emissions based on primary or secondary activity data. The spend-based method uses EEIO data to estimate GHG emissions. The activity data used in the spend-based method is inflation adjusted cost data, which is used to quantify GHG emissions based on EEIO emissions factors. The waste-type specific method is used for assessing GHG emissions for category 5. For applying the waste-type specific method, activity data on masses and types of waste is necessary. Furthermore, emissions factors for waste-type specific treatment methods are required. These are, for example,

CO_2e/kg of plastic incineration. The distance-based method is used in conjunction with the spend-based method to quantify GHG emissions of business travels. For quantifying GHG emissions with the distance-based method, data on distances travelled per transport mode need to be collected and emission factors for each transport mode need to be sourced. Emission factors for transport modes are, e.g., CO_2e/km of travel by car or CO_2e/pkm of travel with public transport. (GHG Protocol, 2011a; GHG Protocol, 2011c)

2.4 Summary of theoretical framework

As the research design sets out to describe the scope of the case company's carbon footprint, the provided theoretical framework and its chapters outline why and how the impact scope can be assessed.

First, the development of carbon footprinting and the rationale for selecting the GHG quantification standards and guidance is provided. The term carbon footprint is described and set in context of measuring an organisation's impact of global warming. Common reasons for conducting the assessment are presented based on scientific literature to highlight the potential practical uses and motivation behind the assessment process. Furthermore, the motivational background provides the direction for further research and development of the assessment process for the case company.

Secondly, the measurement unit, mass of CO_2e, for global warming impact is described. This measurement unit and the quantified total of it within the assessment boundary describe the scope of the case company's carbon footprint. Furthermore, the method of extrapolating the measurement unit is presented and relevant greenhouse gases for extrapolating the CO_2e emissions factor in this thesis are listed with their relevant GWP value. These are CO_2, CH_4, NO_2 and SF_6.

Thirdly, the GHG Protocol's corporate standard and scope 3 standard are presented, introducing the guidance and accounting principles under which the corporate carbon footprint is assessed and the GHG inventory conducted. Furthermore, the applied calculation methods are described in order to enable re-enactment of the assessment and provide grounds for comparability between this and future corporate carbon footprint assessments of the case company.

3 Case company introduction

Helen Electricity Network Ltd. (Helen DSO) is a limited liability company with offices in Helsinki and is licensed by the Finnish Energy Authority to operate the electricity distribution system in Helsinki. The company's main task is electricity distribution and to offer network services to customers in Helsinki. This task includes operation, maintenance and construction of the local electricity grid as well as ensuring that the electricity grid works at all times and under all conditions. Helen DSO is a subsidiary of the Helen Oy which is solely owned by the City of Helsinki. In 2022, Helen DSO supplied its more than 415.000 customer with roughly 4,5 TWh of electricity which makes it the third largest electricity DSO company when measured by number of customers or electricity distribution in Finland.

3.1 Business environment

The operating environment is characterized by its urban character as the case company operates in the capital of Finland, Helsinki, which is compact both in terms of population and building stock. The special features of the city include the high cost of land, expensive construction costs and a limited space reserved for grid components. In addition, the electricity grid must be taken good care of as customers in cities are more sensitive to the effects of power cuts. The capital is home to many functions and services that are important for the functioning of society, such as the national government and the center of Finland's economic hub. This requires a reliable electricity network. (Helen DSO, 2023a)

Helen DSO's electricity network is comprised of high, medium and low voltage networks. The high voltage (HV) network transfers electricity at 110 kV to 25 primary substations. Additionally, the local big power plants and a couple of the biggest customers are connected to this voltage level. The national grid is also connected to the high voltage network. The medium voltage (MV) network operates at 20 or 10 kV and distributes electricity from primary substations to secondary substations. The low voltage (LV) network operates at 0,4 kV and connects secondary substations with distribution cabinets and end-customers. Figure 4. Helen DSOs networkdepicts a schematic overview of this network wherein dark blue elements in the figure constitute Helen DSO's network. Low-voltage customers are depicted as light blue and the national grid and power generation are pink. Overall, the electricity network has more than 6000 km of cables and no less than 97% of the network in Helsinki runs underground. (Helen DSO, 2023a)

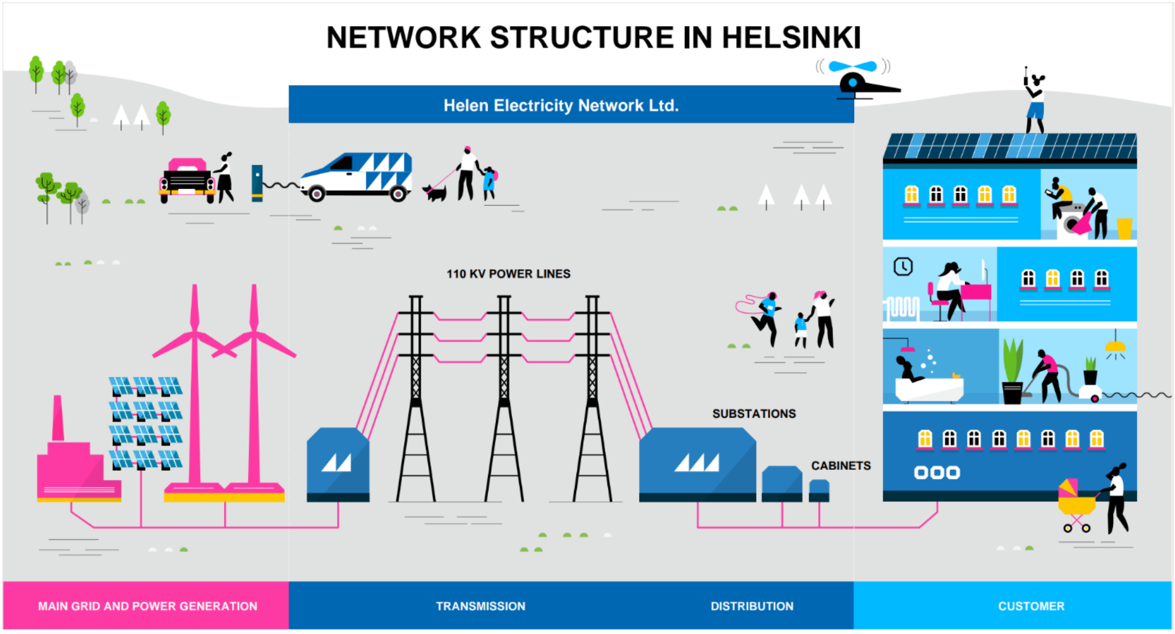

Figure 4. Helen DSOs network (Helen DSO, 2023a)

The business environment is expected to have significant changes in the short and long term. In the near future, there will be a major change in electricity usage in Helsinki. The local Combined Heat and Power (CHP) plants burning coal will be shut down. Additionally, operations of the CHP plant using natural gas as input has been minor due to high prices of natural gas and geopolitical tension. As a development trend, large-scale electricity production will be relocating elsewhere, such as wind-power production far away from Helsinki. Simultaneously, there will be a major decrease of district heat production capacity with the discontinuance of CHP plants. When this district heat production will have to be produced locally other major solutions for local district heat production are needed. Expectedly, heat for district heating will be produced by large-scale electric boilers and industrial-sized heat pumps which will remarkably increase electricity consumption. This change will challenge the capacity of the local 110 kV network as large-scale power generation will be relocated outside of Helsinki and large amounts of electricity will have to be transferred from the national transmission grid to the HV network. Additionally, electricity use will increase due to increased urbanization, electric transport becoming more common and changes in heating methods of buildings. The aforementioned electrification requires investments to support higher loads on the network. Large customers are also expected to increase their electricity consumption though electricity use is also expected to decrease in services and industry thanks to energy efficiency measures and remote work. (Helen DSO, 2023b)

Further into the future, there are significant factors that may increase or decrease electricity use, depending on how they are used. These include hydrogen production and refining modular nuclear reactors for heat production. The role of the distribution network, along with the changes brought about by the energy transition, will be oriented towards supporting a new, two-way consumption profile of electricity distribution and managing experimental consumption spikes. Other factors that will affect the operating environment and set new network requirements are small-scale local production of electricity with photo-voltaic panels, increasing charging points for electric vehicles and requirements for flexibility of consumption in the electricity grid due to weather related irregular power generation from renewable power sources. (Helen DSO, 2023b)

3.2 Case company inventory data

This chapter discusses the inventory data for assessing Helen DSO’s corporate carbon footprint. Activity data that was collected for each scope is described and activities that are unique or significant for Helen DSO’s operation are briefly elaborated on.

3.2.1 Scope 1 inventory data

Scope 1 inventory data includes activity data of direct emissions from fuel combustion in vehicles owned or operated by Helen DSO as well as fugitive emissions of GHGs during operations. In order to assess emissions from fuel combustion, liters of purchased fuel and fuel type were collected from fueling bills. An internal report was readily available and a precise number of liters of diesel and gasoline were able to be determined. Fugitive emissions arise from SF_6 gas leakage during operation of distribution equipment. Some SF6 gas leakage also occurs during the assembly and disassembly of related distribution equipment.

SF_6 gas is popularly used in substation switchgear and ring main units (RMU). RMUs are fully enclosed, compact, factory assembled cabinets used for medium-voltage power distribution. SF_6 gas is popularly used for insulation within RMUs and substation switchgear due to the gas' electronegativity and high dielectric strength (Schneider Electric, 2003). These properties allow RMUS's to be built compactly which is ideal for secondary substations that are located in tight spaces which is common in an urban environment. SF_6 gas, however, has other properties which makes it a far more potent greenhouse gas than CO_2. The future use of SF_6 gas insulated switchgear is somewhat uncertain as the European Union is working on a directive which would effectively ban any further use of the gas (Eurpoean Parliament, 2023). However, during 2022 SF_6 insulated switchgear is still operated by Helen DSO and SF_6 gas leakage is assessed annually for reporting purposes.

3.2.2 Scope 2 inventory data

Scope 2 inventory data includes purchased energy amounts during 2022. Energy may be purchased in the form of electricity, heating, cooling and steam. Helen DSO does not require nor purchase steam for its operations, hence the data on purchased electricity for own use and district cooling as well as district heating in owned facilities was collected. District cooling and heating data was available from internal reports for substation facilities. District heating data was collected from facility managers of the office building in Käpylä, Helsinki. Electricity consumption at the office building was available from internal reports as well. Further electricity purchases occurred during 2022 due to distribution losses in the distribution network. Distribution losses occur as no electrical circuitry runs at 100% efficiency. DSOs are to purchase distribution losses by competitive tender procedures (Sähkömarkkinalaki 2013/588, 2013). The carbon footprint of distribution losses is determined according to the production method of this electricity. Distribution losses may be technical or non-technical. Technical losses occur for example in distribution cables due to electrical resistance of the cables. Other sources for distribution losses are power losses within transformers and the electrical heating of substations. Non-technical distribution losses occur from intervention in the distribution system such as electricity theft. The amount of purchased electricity and origin was collected from internal reports. In 2022, Helen DSO purchased roughly 92,6 GWh of electricity to cover distribution losses, which is a 2% loss of overall electricity that was distributed to customers during 2022.

3.2.3 Scope 3 inventory data

Scope 3 inventory data includes data on all purchases except purchased energy, which is assessed in scope 2. Emissions from purchases occur during the supply chain of purchased goods and services which requires an extensive overview of supply chain activities. In the case of Helen DSO, the main priority was to collect data on network equipment which is pivotal to ensure flawless operations of the distribution system now and in the future. Materials and products are considered network equipment if they are acquired solely for the purpose of integration into the distribution network. Material and component data was collected from internal reports, focus meetings and stakeholder contacts and data collection for these was the most extensive and effortful task in data collection for this research. A list of network components for which activity data was collected during this study is presented in Table 4.

Table 4. List of assessed network components

Network components
Electrical meters
LV cables
MV cables
HV cables
Cable protection pipes
RMUs
Transformers
Secondary substation cabins
Automation equipment
LV switchgear

Emissions related to network components occur during their whole life-cycle which is why activity data for the construction phase, or installation of network components, as well as maintenance is collected. This data includes fuel consumption data of strategic partners that are involved in construction and maintenance services. Furthermore, masses of construction materials used for the installation of network components were collected from partners and internal reports. Further construction related activity data regards joint construction projects and substation related projects. In 2022, a building renovation project of one primary substation occurred for which financial data was collected. Another substation related project was the refurbishment of protection and control equipment for which the supplier was able to report project-specific emissions and no further activity data was required for GHG emissions quantification. For joint-projects only financial data was able to be acquired. Hence, costs of projects constitute the activity data for joint projects and the substation building renovation project. Use phase activity data for network components is considered under maintenance services and energy use whereas energy use is considered under scope 2 and not included in scope 3 activities. Maintenance service activity data includes fuel consumption during services and data was provided by suppliers respectively.

Another significant activity regarding Helen DSO's carbon footprint is the supply of electricity through the main grid. Helen DSO is supplied with electricity from the main grid and pays for the transmission services. Hence, transmission losses that occur in the main grid due to the intake of electricity to the distribution network are considered energy-related upstream activities in category 3 of scope 3.

Further activity data for scope 3 includes business travel data such as distance traveled in kilometers and mode of travel as well as travel ticket costs. Activity data on employee commuting includes the average number of people employed during 2022 and the average commuting distance per average commuting mode based on reliable statistical data. Waste management activity data includes masses of specific waste types which were sourced from annual waste reports. The remaining scope 3 inventory is constituted of financial cost data and includes the costs of all goods and services purchased during 2022 which have not been discussed earlier in this chapter. These costs also include costs of information technology and data processing which is pivotal in the operating and controlling the distribution network.

4 Carbon footprint assessment of the case company

This chapter presents an overview of Helen DSO's electricity distribution system and its GHG emission inventory results. It is outlined how GHG emissions were assessed and how calculation methods were applied to reach the calculation results that encompass Helen DSO's carbon footprint. The identified emissions are categorised in coherence with Scope 1, 2 and 3 of the GHG protocol.

Helen DSO's total GHG emissions during 2022 are presented in Table 5. Overall, Helen DSO's corporate carbon footprint and as such the total of GHG emissions during 2022 were 13416 tCO2e. Scope 1 activities contributed 457 tCO2e to the total carbon footprint, 194 tCO2e came from scope 2 activities and 12765 tCO2e from scope 3 activities.

Table 5. Helen DSO's corporate carbon footprint

	Helen DSO (2022)	
Distributed power	4477	GWh
Scope 1	**t CO_2e**	**g CO_2e/kWh**
SF_6 leakage, fuel consumption	457	0,10
Scope 2	**t CO_2e**	**g CO_2e/kWh**
Distribution losses, energy		
- market-based	194	0,04
- location-based	13 198	2,95
Scope 3	**t CO_2e**	**g CO_2e/kWh**
Scope 3 total	12 765	2,85
- network components	5 203	
- TSO power supply	3 399	
- Construction and maintenance	1 723	
- other scope 3 emissions	2 440	
Total Scope 1 + 2 (market)	651	0,15
Total Scope 1 + 2 + 3	13 416	3,00

The distribution of applied calculation methods for quantifying Helen DSO's carbon footprint are presented in Figure 5.

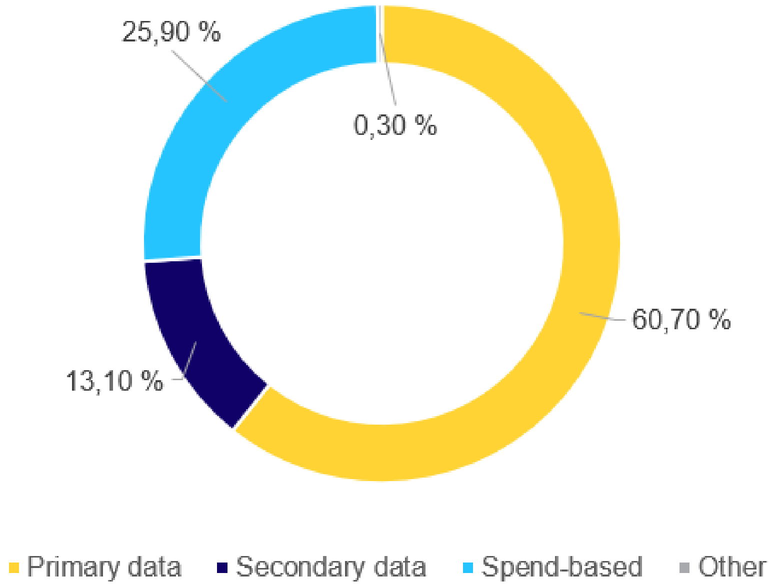

Figure 5. Calculation method distribution

Overall, more than 60% of Helen DSO's GHG inventory was assessed based on supplier-specific primary data and emission factors. A share of 13,1% of GHG emissions were quantified based on average data sources from emissions factor databases or literature. 25,9% of identified GHG emissions are estimations based on the spend-based methods using EEIO data. 0,3 % of GHG emissions are assessed either with the hybrid method, distance-based method or waste-type-specific method.

4.1 Scope 1 direct emissions

Scope 1 emissions, or direct GHG emissions, occur from sources that are owned or controlled by the reporting organization, for example combustion in operated vehicles or emissions from process equipment (GHG Protocol, 2004). In the case of Helen DSO, Scope 1 emissions occur from combustion in owned or controlled vehicles, stationary stand-by generators and SF_6 leakage from owned electricity distribution equipment. If construction activities would not have been outsourced, the fuel combustion of construction machinery would be accounted in scope 1, too. Activity data, such as litres of fuel and kg of leaked SF_6 gas was gathered from internal reports.

For assessing Helen DSO's Scope 1 emissions, fuel-specific emissions factors were calculated based on three greenhouse gases. Finland's national statistical institute (Tilastokeskus, 2022) provides year-specific data on CO_2 emissions per combusted liter of fuel type. This data was supplemented with NO_2 and CH_4 combustion emissions data from Ecoinvent database. Using the GWP100 values from chapter 2.2 , the CO_2e factor per liter of fuel can be calculated as shown in Table 6.

Table 6. Fuel type emission factors

Diesel combustion	Emissions (g/l)	GWP100-factor	EF, gCO_2e/l	Source
CO_2 emissions	1872,13	1	1872,13	Tilastokeskus, 2022
CH_4 emissions	0,13	28	3,74	Ecoinvent, 2023
NO_2 emissions	0,13	265	35,44	Ecoinvent, 2023
CO_2e emission			**1911,31**	

Gasoline combustion	Emissions (g/l)	GWP100-factor	EF, gCO_2e/l	Source
CO_2 emissions	2029,98	1	2029,98	Tilastokeskus, 2022
CH_4 emissions	0,12	28	3,30	Ecoinvent, 2023
NO_2 emissions	0,18	265	46,81	Ecoinvent, 2023
CO_2e emissions			**2080,09**	

The emission factors from Table 6 can be used in conjunction with the GWP100 factor for SF_6 gas to calculate the Scope 1 emissions for Helen DSO as presented in Table 7. The most significant activity in this scope is the SF6 leakage from distribution equipment with 456,61 tons of CO_2e, making up 99,82% of total Scope 1 emissions in 2022.

Table 7. Scope 1 emissions

Aktivity	Activity		Emission factor		Emissions	
Diesel, vehicles	361,82	l	1911,31	gCO_2e/l	0,69	tCO_2e
Diesel, generator	54	l	1911,31	gCO_2e/l	0,10	tCO_2e
Gasoline, vehicles	12,9	l	2080,09	gCO_2e/l	0,03	tCO_2e
SF_6 leakage	19,43	kg	23500	$kgCO_2e/kg$	456,61	tCO_2e
				Scope 1 Total	**457,43**	**tCO_2e**

4.2 Scope 2 indirect emissions, purchased energy

Under scope 2 the emissions from purchased energy are quantified. These include emissions from purchased energy for power consumption at facilities under Helen DSO's operational control, including emissions from district cooling and heating as well as distribution losses in the network. Distribution losses in Finland occur mainly due to technical features of the distribution network (Caruna, 2021). For example, electrical resistance in the network converts electrical power to heat which requires DSOs to surmount a power deficit by purchasing additional electricity to what is distributed to and consumed by customers (Caruna, 2021). Overall, Helen DSO purchased 92,6 GWh of electricity to cover distribution losses during the evaluation period. Further energy purchases from electricity consumption at the office building and for charging of electrical vehicles at the office accumulated to 194 MWh during 2022. District heating consumption at facilities, including substations, amounted to 815 MWh and the district cooling consumption total was 296 MWh. The activity data for scope 2 was assessed based on internal reports.

Emission factors for assessing location-based scope 2 emissions were sourced from a database provided by CO2data.fi. This database is an open, free-of-charge emission factor database for the construction industry which presents average emissions data on construction products used in Finland and on construction processes and services (CO2data, 2022). The average emission factor for electricity in the year 2022 was 140,2 gCO_2e/kWh. The average district heating emissions factor was 210,8 gCO_2e/kWh and for district cooling the emission factor was 37,2 gCO_2e/kWh. These emission factors are based on the benefit allocation method and are adjusted for the year 2022. Emissions factors for the market-based scope 2 assessment were sourced directly from suppliers and are considered primary data. Noteworthy is that emission factors for district cooling and distribution losses are 0 gCO_2e/kWh as the power generation for both is certified to be CO_2-free.

Scope 2 emissions are indirect, as reporting companies do not produce scope 2 emissions themselves. Scope 2 emissions arise from consumed energy that is produced at power plants and similar facilities that are not controlled or owned by the reporting company. Nevertheless, companies can reduce scope 2 emissions by optimizing energy consumption or sourcing energy from low-carbon production methods if possible. Optimizing energy consumption lowers both market-based and location-based assessment variants of scope 2 emissions as overall consumption decreases. Market-based scope 2 emissions depend on specific power generation methods which vary in their emissions intensity. Changing energy supply to low-carbon methods can have significant implication on allocatable GHG emissions. Opting for low-carbon power had the most significant impact on Helen DSO's total corporate carbon footprint. This becomes clear when comparing market-based to location-based scope 2 emissions regarding distribution losses. Applying the location-based method, the emissions from distribution losses themselves would make up roughly half of Helen DSO's total corporate carbon footprint. Location-based scope 2 emissions can be seen in Table 8.

Table 8. Location-based scope 2 emissions

Location-Based Scope 2	**t CO_2e**
Electricity	27
District heating	171
District cooling	11
Distribution losses	12988
Total	**13198**

Looking at market-based scope 2 emissions though, the emissions from covering distribution losses are null as Helen DSO was able to procure and cover all distribution losses with CO_2-free certified nuclear power. In other words, this single activity of procuring CO_2-free power to cover distribution losses halved the corporate carbon footprint of Helen DSO. Market-based scope 2 emissions can be seen in Table 9.

Table 9. Market-based Scope 2 emissions

Market-Based	**t CO_2e**
Electricity	46
District heating	148
District cooling	0
Distribution losses	0
Total	**194**

Companies may choose to report either location-based or market-based scope 2 emissions (GHG Protocol, 2004). In hopes of homogeneous reporting and ability to compare emissions of companies within the same industry, reporting both location-based and market-based scenarios would be ideal. Nevertheless, it may be challenging for companies to acquire coherent emissions factors for energy consumption which may result in preference of generic or average emission factor usage. Also, during this research multiple sources for generic emission factors of electricity consumption were identified and the results of the location-based scope 2 emissions may vary significantly depending on which emissions factor was selected. For this reason, the market-based scenario, which is based on primary data, was selected as the main scenario of this study.

4.3 Scope 3 indirect emissions, supply chain emissions

GHG emissions for scope 3 cover all other indirect emissions from a company's value chain which have not been accounted for in scope 2. Overall, Helen DSO's scope 3 emissions amount to 12765 tCO_2e during 2022. The most emissions therein occurred from purchased goods and services under category 1 and 2 with 9217 tCO_2e. Another significant category is category 3 which includes 3422t CO_2e emissions from fuel and energy related upstream activities. Emissions under category 4, logistics, and category 8, upstream leased assets, are based on a spend-based estimations not significant and included in the GHG emissions of other goods and services in chapter 0. A categorized breakdown of scope 3 emissions is presented in Table 10.

Table 10. Scope 3 emissions

Category	Description	t CO_2e
C1-C2	Network components	5203
C1-C2	Construction and maintenance	1723
C1-C2	Other goods and services	2376
C3	TSO power supply	3399
C3	Other fuel and energy related activities	23
C5	Waste treatment	9
C6	Business travel	14
C7	Employee commuting	18
	Scope 3 total	**12765**

The GHG Protocol's scope 3 standard divides scope 3 emissions into 15 categories which are either upstream categories or downstream categories as can be seen in Figure 2. Downstream scope 3 categories are not relevant for Helen DSO as the company offers only distribution services that do not incur downstream activities such as transportation, processing, use or treatment of sold products. Furthermore, Helen DSO does not have franchising operations nor investments or holdings in other companies, which would have been assessed under scope 3 categories 14 and 15. However, Helen DSO does own a few apartments in substation buildings. These are leased out at times and can be considered leased assets under category 13 of scope 3. Emissions in this category are estimated to be insignificant and they are irrelevant to Helen DSOs main industry of electricity distribution. Nevertheless, heating of these apartments is considered in scope 2 emissions as part of substation district heating consumption, hence category 13 has not been assessed separately in this study.

As not all scope 3 categories are calculated and other companies in the same industry have chosen their own categorization for the breakdown of scope 3 emissions, it was decided to conform with a similar breakdown to enable industry wide comparability. Scope 3 emissions quantification and applied calculation methods as well as underlying activity and emission data is described in detail in the following subchapters.

4.3.1 Network components

Network components are materials and equipment that make up the distribution network. Network component purchases during 2022 add up to have the highest impact in Helen DSO’s carbon footprint and scope 3 emissions with 41 % of total scope 3 emissions as can be seen in Figure 6.

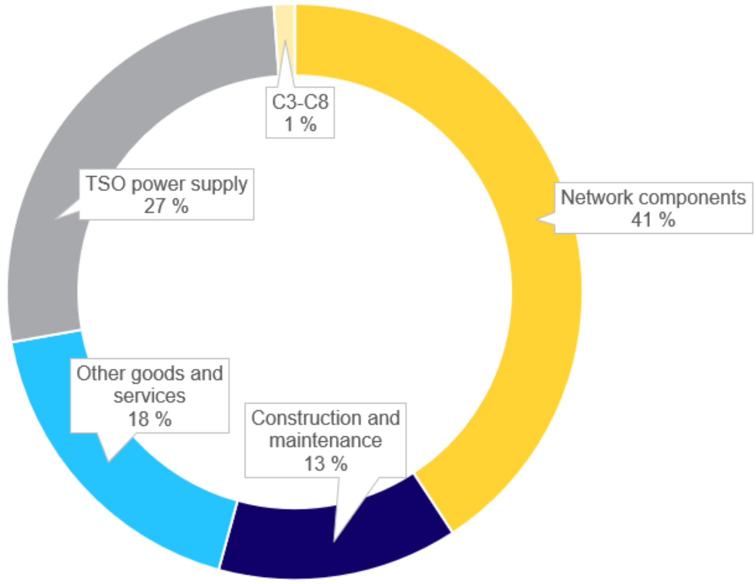

Figure 6. Scope 3 emissions breakdown

Network components include electrical cables, cable protection pipes, electrical meters and equipment used in substations such as ring main units (RMU), transformers, secondary substation cabins, automation systems and low-voltage switchgear that is directly needed for electricity distribution in the distribution network.

Activity data for network equipment was gathered from internal reports, supplier contacts and financial data such as bills. The priority of data collection was to identify the purchased number of units of each network component. Also, masses of equipment and masses of their materials were collected from product data sheets and suppliers. The cost data of purchased equipment was collected, too, in case the spend-based calculation method needed to be used for a lack of more accurate data. Although all suppliers were contacted and asked for emission factor data for purchased equipment, suppliers' capabilities to produce data on their products environmental impact and GHG emissions varied significantly. Hence, various calculation methods were needed to assess GHG emissions of network components. As use-phase emissions are accounted for in Helen DSO's scope 1 and scope 2 assessment as well as under maintenance services, only cradle-to-gate emissions for network components were assessed. The GHG emissions results and applied calculation methods are presented in Table 11.

Table 11. Network component GHG emissions

Calculation method	Network component	Activity data	Unit	tCO_2e
Supplier-specific method	Electrical meters	17949	unit	690
	LV cables	93,4	km	1762
	MV cables	34,8	km	1104
	110 kV cables	3,7	km	105
Hybrid method	Secondary substation cabins	6	unit	36
Average method	Electrical meters	4884	unit	196
	RMUs	46	unit	66
	Transformers	55	unit	911
	Cable protection pipes	120,5	km	256
Spend-based method	Automation equipment Low-voltage switchboards	confidential	€	78
			Total	**5203**

Product-specific data with cradle-to-gate GHG emission factors were provided by suppliers for all individual electrical cable products and 79 % of electrical meters. Coherently, with the supplier-specific calculation method 3661 tCO_2e emissions could be identified. Secondary substations may be located within buildings or outdoors in transformer cabins as shown in Figure 7. These cabins may vary in size and used materials. The GHG emissions for purchased substation cabins in 2022 were calculated based on the hybrid method provided by the GHG Protocol calculation guidance. The suppliers were able to provide allocated scope 1 and scope 2 emission data for manufacturing of the cabins as well as an estimation of used materials during manufacturing. Based on average emission factors for materials from CO2data.fi and allocated scope 1 and scope 2 emissions, the calculation using the hybrid method added up to 35,8 t CO_2e for 6 cabins.

Figure 7. Transformer cabin example (Alfa Elkamo, 2023)

The average calculation method was applied for electrical meters for which no product-specific emission factors could be sourced. The applied emission factor of 40,14 $kgCO_2e$/unit is an average based on cradle-to-gate emission factors of four similar electrical meters that were reported by suppliers. A similar approach was applied for calculating GHG emissions of purchased RMUs. Suppliers were contacted and asked if product-specific emission data was available. Although environmental assessments were done for some products, the provided emission factor were for similar though different products as purchased by Helen DSO in 2022. GHG emissions factors for the RMUs were therefore calculated based on provided emissions data and results are regarded as an average. The average method was also applied for calculating GHG emissions of procured transformers. Two separate cradle-to-gate emission factors could be sourced from suppliers for a 630 kVA transformer. The average emissions factor was calculated to be 13,5 tCO_2e per 630 kVA transformer unit or 7,23 $kgCO_2e$/kg. During 2022 Helen procured 630 kVA, 800kVA and 1000kVA transformers each with a different mass. Using the average emissions factor, mass for each transformer size and the quantity of transformers, the GHG emissions for this network component group could be calculated as presented in Table 12.

Table 12. Transformer GHG emissions

Transformer size	quantity	mass per unit, kg	tCO2e
630 kVA	18	1870	243
800 kVA	16	2230	258
1000 kVA	21	2700	410
			911

For the rest of the purchased network components no emissions data nor bills of materials could be collected so the spend-based calculation method was applied. This regarded automation equipment and distribution boards in secondary substations. The GHG emissions for these added up to 77,7 tCO_2e based on EEIO data from the U.S. Environmental Protection Agency (2023).

4.3.2 Construction projects and maintenance services

This section discusses GHG emissions from construction projects and maintenance services that were purchased during 2022. This section covers emission of the construction phase and installation of distribution network equipment as well as maintenance services of the distribution network under partnership agreements. The cradle-to-gate emissions of network components are not included under construction and maintenance emissions as network components have been assessed separately. However, other construction materials, e.g. asphalt and gravel, are considered. Helen DSO has effectively outsourced and contracted most construction and maintenance related activities, which means most operational field work is done under partnership agreements or projects by suppliers and partners. Hence, activities such as infrastructure construction, replacement projects of network components, expansion projects of the distribution network, substation projects and maintenance of the distribution network are purchased as ad-hoc turnkey services or under partnership agreements. This also means that logistical and transport activities such as transport of construction materials and commute to and from project sites is not managed by nor operated by vehicles owned by Helen DSO.

As 97% of the distribution network and its cables run underground, replacing components and expanding the network falls under infrastructure construction projects which require machinery, earthworks and construction materials. Underground cables are placed into cable protection pipes which are laid in trenches as can be seen in Figure 8. These trenches are first dug up, then cables and protection pipes are placed after which the trenches are re-filled and if necessary repaved.

Figure 8. Cable laying construction site (Helen DSO, 2023c)

The construction process requires machines and construction equipment which consume fuel and energy. As infrastructure construction in urban environments is expensive, at times these projects are combined with other infrastructure projects under joint construction projects with the City of Helsinki and other stakeholders. Furthermore, joint projects have the benefit of dividing costs and limiting traffic obstruction during construction works as electrical cables, freshwater pipes and sewage pipes are placed at the same time. Substation projects in 2022 include two projects of which one was a renovation of a primary substation building and the other was a protection and control system refurbishment. Although substations and included equipment can be considered network components, the GHG emissions of these projects are included in construction project and maintenance services as these projects were procured as projects separately from partnership agreements.

The activity data is collected either directly from partners or from internal reports. Activity data includes fuel consumption during construction and maintenance services, amount of used construction materials in kilograms and project cost data. Emission factors include fuel-type specific emissions factors and average emission factors for specific construction materials. The protection and control system refurbishment project emissions were accounted based on supplier-specific emissions provided by the supplier and emissions were able to be accounted for as CO_2e per project. Other projects such as joint-projects and the primary substation's building renovation projects emissions were estimated with the spend-based calculation method as bills of materials were not available for the assessment.

The results of the construction project and maintenance service GHG emission quantification are presented in Table 13.

Table 13. Construction and maintenance service emissions

Construction and maintenance	**tCO_2e**
Fuels and energy	412
Construction materials	270
Substation and joint projects	1041
Total	**1723**

Overall GHG emissions in 2022 from purchased construction projects and maintenance services were 1723 tCO_2e of which fuels and energy consumption accounted for 412 t CO_2e, construction materials accounted for 270 tCO_2e and other projects such as substation and joint projects accounted for 1041 tCO_2e.

4.3.3 Other purchased goods and services

This section covers GHG emissions from all services and goods purchased during 2022 except of network components, construction projects or maintenance services. Emissions of services and goods under this section are estimated based on the spend-based calculation method using EEIO data from the U.S. Environmental Protection Agency (EPA) (EPA, 2018). The method requires a thorough categorization of all expenditure of Helen DSO during 2022. Services and good expenditures were categorized according to categories within the EEIO dataset. Furthermore, spend-data was adjusted for inflation and the currency was converted to enable the use of particular EEIO data as it is from 2018.

The category with the most GHG emissions was miscellaneous professional, scientific, and technical services category with 1743 tCO_2e, followed by the data processing, internet publishing, and other information services category with 408 tCO_2e. These categories cover various consultation services, metering services, administrative services and services related to information technology and data processing. The remaining miscellaneous goods and services for which GHG emissions were accounted are all other purchases made by Helen DSO during 2022. The remaining categories add up to 226 tCO_2e. In total, other goods and services are estimated to incur 2376 tCO_2e or 17,7 % of Helen DSOs total corporate carbon footprint.

4.3.4 Energy-related upstream emissions

This section includes upstream emissions of purchased fuels and electricity as well as transmission losses from electricity supplied into the distribution network from the TSO Fingrid. Helen DSO does not sell electricity but rather distribution services similar to a logistics operator, hence emissions from the generation of electricity that is distributed are not included in this section. Emissions from combustion of used fuels and energy is accounted for in scope 1 and 2 of Helen DSOs GHG inventory.

In case of Helen DSO, this section covers the emissions of upstream emissions of purchased electricity, district heating and cooling as well as cradle-to-gate emissions of purchased fuels. Furthermore, transmission losses in the main grid proportionally to the amount of electricity supplied via the main grid are considered upstream energy-related emissions as well.

A major contributor to Helen DSO’s corporate carbon footprint within scope 3 are transmission losses in the main grid. Not all electricity is generated locally within the distribution network but supplied via the main grid to the distribution network in order to meet demand. This means that emissions which are directly linked and change mutually to the supply of electricity from external sources are considered upstream emissions. As large-scale electricity generation from CHP plants will be discontinued in the future, the electricity supply via the main grid is likely to increase as will the significance of transmission losses in the main grid for Helen DSO's scope 3.

Electricity and heating related upstream emissions depend on the generation method which is why electricity and heating suppliers were contacted and asked to report production specific emission factors. Upstream emissions factors were able to be sourced from suppliers in the form of $kgCO_2e/kWh$ for purchased electricity, district heating and cooling. Cradle-to-gate emissions for combusted fuels in owned or operated vehicles of Helen DSO were collected from the Ecoinvent database. Table 14 presents the assessment results for category 3 of Helen DSO's scope 3 GHG emissions.

Table 14. Scope 3 Category 3 GHG emissions

Activity	**tCO_2e**
Purchased energy related upstream emissions	23,1
Purchased fuel related upstream emission	0,2
TSO supplied power related transmission losses	3398,6
TOTAL category 3 GHG emissions	**3422**

Fingrid's annual report (Fingrid, 2023) provided the necessary data to assess emissions of transmission losses proportionate to the supplied electricity. The allocated transmission losses and related GHG emissions can be calculated based on the total amount of GHG emissions for transmission losses in the main grid during the reporting period, the proportion of transmission losses per transmitted unit of electricity and the amount of supplied power to the reporting company in the reporting year. Table 15 presents the GHG emission calculation for power taken from the main grid.

Table 15. TSO supplied power related GHG emissions

Description		
GHG emissions per transmission losses (Fingrid, 2023)	60,0	$t\ CO_2e/GWh$
Transmission losses per transmitted electricity (Fingrid, 2023)	2,3	%
TSO supplied power in 2022	2481,7	GWh
Transmission losses for supplied power	56,6	GWh
TSO supplied power related GHG emissions in 2022	**3398,6**	**$t\ CO_2e$**

4.3.5 Waste management

This section presents GHG emissions that occurred during 2022 from third-party disposal and treatment of waste that was generated due to operations of Helen DSO. Waste generated during the services of main partners are considered under this section as well since they are linked directly to operations of Helen DSO.

Helen DSO collects annually reports on generated waste as part of its ESG reporting requirements. The reports reveal activity data about masses of specific waste types which enables the application of a waste-type-specific method to quantify GHG emissions. Waste treatment methods were then estimated according to each waste type. Emission factors were collected from Defra (Defra, 2019) and the Ecoinvent database which provide waste treatment method specific emissions factors. Overall, waste treatment and disposal are estimated to generate 9,12 tCO_2e for waste generated during 2022.

4.3.6 Business travel

GHG emissions from business travel occur from employee transportation for business related activities in vehicles and travel methods which are not owned or operated by the reporting company. Therefore, business travel related GHG emissions may occur with vehicles owned by staff, taxis or various modes of public transportation. GHG emissions that arise from stays in hotels have not been assessed in this study.

In the case of Helen DSO, business travel activities can be separated into kilometer allowance-based travel and paid travel. Kilometer allowance-based travel occurs when employees travel with their own vehicles, for which they are compensated based on the travel mode and distance travelled. Paid travel occurs when employees travel for business-related trips using third-party owned and operated travel modes such as air travel, taxis or railway for which fees are paid or compensated by Helen DSO.

Activity data for kilometer allowance-based travel includes distance in kilometers and travel mode, which allows for a distance-based calculation method. GHG emission can be calculated then by applying the appropriate emission factor for the used travel mode. For paid travel only ticket and fare prices could be collected as activity data which means that a spend-based method was applied to determine GHG emissions for different travel modes.

Emission factors for kilometer allowance-based travel were collected from VTT's Lipasto material which includes average emissions per vehicle type (VTT, 2020). For paid travel the Quantis-suite.com scope 3 evaluator was used which automatically calculated GHG emissions based on adjusted cost data of travel modes using EEIO emission factors.

Overall, GHG emissions from business travel generated 14,1 tCO_2e during 2022 of which 2,2 tCO_2e occurred from travel of employee-owned vehicles and 11,9 tCO_2e from other travel modes.

4.3.7 Employee commuting

Employee commuting-related emissions arise from travelling between office and home of employees. Emissions for this category are assessed based on average-data calculation method using statistical data of the travel distance and transportation modes in the capital area of Finland. Most recent data could be found for 2021 and it is assumed to correspond with 2022 activities as travel modes have not changed significantly from one year to the other. The calculation is done by first identifying the average daily commuting distance per person. This distance is then multiplied by the number of employees in 2022 to reach the average total amount of distance travelled for commute in that year. The total commute distance is then divided by different transport modes based on a statistical breakdown of typical transportation modes for travel activities in the metropolitan area of Helsinki. This allows to identify the typical commute travel distance by transport mode which can be used to calculate the total commuting emission using different emission factors for given transport modes.

A person living in the Helsinki metropolitan area travels on average 30,3 kilometers per day of which 26% is spent on commuting to and from work. Hence, each employee commutes on average 7,88 km every working day. This value includes the average impact of remote work. The year 2022 had on average 228 working days and Helen Electricity Network employed 92 people in 2022 which sums up to 165249 km of total commuting distance or 1796 passenger-kilometers. Table 16 shows the average distribution of travel methods and total emissions by travel method. (Traficom, 2023).

Table 16. Employee commuting GHG emissions

Travel method	Distribution	Distance, km	Passenger-km	t CO_2e
Personal vehicle	78 %	128894	1401	16,99
Public transport	14 %	23135	251	0,01
Other	8 %	13220	144	
Total	**100 %**	**165249**	**1796**	**17,00**

A share of 8% of commuting is done by walking, personal bicycles or other travel methods (Traficom, 2023). These are considered either carbon neutral or not significant and hence do not add to Scope 3 emissions. Overall, employee commuting is estimated to have generated 17 tCO_2e during 2022.

5 Discussion

This chapter discusses the challenges and opportunities associated with assessing a corporate carbon footprint using the GHG Protocol's accounting and reporting standards in context of the case company. The discussion explores the roles of information systems, stakeholder engagement, and the challenges of data collection in achieving accurate and reliable carbon footprint assessments. By understanding these aspects, environmental sustainability goals and the contribution to the global effort of mitigating global warming can be addressed thoroughly. Though the discussion is based on observations of assessing a corporate carbon footprint for Helen DSO, the empirical findings may also support other organizations in implementing the GHG protocol's accounting and reporting guidance to their operations.

The process of developing a corporate carbon footprint has many steps and each step needs to be planned and executed with due diligence and care. Companies that newly start the endeavor of assessing their corporate carbon footprint should take their time. Firstly, they need to identify the business goals that they plan to achieve. In order for corporate carbon footprinting to be of any benefit rather than a burden, aligning business goals and strategies are as important as the communication of the goals to the staff. Management plays a crucial role during the first steps and managerial support and coherent communication of corporate carbon footprinting project may ease burdens throughout the assessment process.

Fortunately, in the case of Helen DSO management was supportive. Helen DSO has set a strategic goal for participating and contributing towards a sustainable energy system. The communication of this strategic goal in general staff meetings prepared employees for the data collection activity and the meaning of data collection and assessment process became clear before the project had even started.

Having set business goals, the next step is to prepare and get familiar with the accounting and reporting guidance. Though the GHG protocol can be considered to be written in an easily understandable way, having to get familiar with several standards, understanding principles, setting organizational boundaries, developing the activity data inventory, collecting data and further reporting on results can be considered quite extensive even with experience on environmental impact assessment. Each company is individual in their operations and business model which means that what works for one company, e.g., in terms of leveraging existing information systems, engaging stakeholders or data collection, might not work for other companies.

5.1 Information systems

Information systems play a crucial role in collecting, managing, and analyzing activity data and emission factor data for assessing corporate carbon footprints. This chapter explores the significance of information systems in the context of carbon footprint assessment, including their role in data collection, integration with existing systems, and the benefits and challenges associated with their use.

The accurate measurement and management of GHG emissions require a comprehensive data collection process. Information systems can provide the necessary infrastructure to capture and store GHG inventories efficiently. Furthermore, these systems can be used to facilitate the collection of data from various sources, such as energy consumption records and purchase data, which would enable organizations to measure their carbon footprint accurately. A pre-requisite for a successful facilitation of information systems however is the integration of systems, ensuring interoperability and coherent data streams. Organizations often already have established information systems in place for managing various aspects of their operations, such as enterprise resource planning (ERP) systems. Though the case company also has ERP and information systems, other sources were needed for data collection. Integrating carbon accounting tools into these existing systems could allow for seamless data flow, improved data accuracy, and streamlining reporting processes. To see if ERP and carbon accounting systems can be integrated, however, needs to be determined via a feasibility assessment. Furthermore, the requirement planning process for successful integration itself demands extensive technological expertise of existing information systems as well as experience of corporate carbon footprinting. This leads to suggest that integrating existing information systems with carbon accounting tools should follow initial GHG inventory assessments.

Potential benefits of information systems in corporate carbon accounting can be found at an increase of data accuracy and reliability. If carbon accounting and management systems are operated manually, human error can not be avoided. For the assessment of Helen DSO’s corporate carbon footprint, a tabular calculation file was developed manually to store emission data and quantify GHG emissions. This required an iterative process of entering data, multiple sprints of recalculation and extensive formatting of the calculation file. Furthermore, emissions factors represent emissions for a certain point in time. Manufacturing processes and energy mixes change over time which renders a static list of emission factors obsolete for future carbon footprinting. Information systems however are likely to reduce calculation errors and inconsistencies. Automating data collection and calculation processes can further minimize tedious data entries and associated risks of human error. Further benefits include extended monitoring and real-time reporting capabilities. If information systems setups allow it, companies could have the chance to track their emissions inventory throughout their reporting year and undertake corrective actions in a timely manner. Having carbon footprint related data in a centralized system also allows for reporting and comparing the development of a company's carbon footprint on consecutive reporting periods. This would also have implications of enhancing data analysis and decision-making. Generating detailed reports and performing scenario analysis can help to identify trends and emerging patterns before intervention windows close. Furthermore, monitoring and tracking capabilities within carbon management systems allows for data-driven decision-making which would support to reach sustainability goals effectively and controlled.

Next to potential benefits, information systems also bear challenges. Information systems rely on data availability and data quality. Collecting accurate and comprehensive data from various sources within operations and supply chains may be challenging enough. Inputting incomplete or unreliable data can scrutinise the accuracy of automatically generated corporate carbon footprints. Furthermore, data may underlie confidentiality or be of sensitive nature. Also, in this master thesis some data underlies confidentiality. If data security and privacy concerns are not addressed and prepared for coherently, data security risks can grow. Additionally, compatibility issues between systems and data formats may pose a challenge and requires technical expertise and coordination between different departments within an organization.

5.2 Stakeholder engagement in data collection

Data collection turned out to be a critical and most tedious component of corporate carbon footprinting. This chapter discusses observed challenges in the data collection process and outlines how engaging stakeholders and integrating data collection with procurements operations could provide valuable opportunities in developing future corporate carbon footprint assessments.

Assessing a corporate carbon footprint requires data from various sources across an organization's operations and supply chain. These sources include reports on energy consumption, operational activities, waste management and procurement activities. Data sources may be internal from within the organisation or external from stakeholders such as suppliers and partners. The complexity and diversity of these data sources present challenges in planning and implementation of the data collection. Furthermore, data quality and availability are crucial for accurate carbon footprinting. Organizations may encounter issues that include data gaps, inconsistencies and varying data collection methods throughout the assessment process. Collecting data from various sources with different data collection methods calls for a systematic approach that includes defining collection methods, specifying necessary data scopes and data formats. These need to also be communicated to stakeholders participating in the data collection process may they be internal or external.

One option to address challenges is to actively involve procurement stakeholders and develop procurement operations as to collect relevant data on environmental impact in the early stages of procurement. This can include working with suppliers to obtain information on their emissions as well as the emissions of supplied products early on in tendering and procurement processes. Further options to engage suppliers and procurement stakeholders is to prepare sustainability programs and advocate that supplier also assess their carbon footprint. During the assessment work it was observed that suppliers that have prior engagement in corporate carbon footprinting, have environmental impact mitigation strategies established or entered commitments like the Science Based Targets initiative were better prepared in providing data on their emissions as well as emissions of their products. Fostering these kinds of supplier relationships and engaging other stakeholders to share data and promote sustainable practices throughout their supply chain bears the potential of commonly decreasing boundaries and challenges associated with corporate carbon footprinting. Furthermore, verification and auditing practices by third parties can aid in validating the accuracy of reported data by suppliers and help to identify inconsistencies. Overall, data collection from stakeholders and suppliers required extensive contacting and engagement within the case companies supply chain. Data was collected from suppliers on a case-by-case approach retrospectively. Implementing dedicated data collection systems or integrating these systems in existing procurement or ERP systems could streamline the collection and management of activity and supplier-specific emission data.

Another observation during the process of corporate carbon footprint was made during meetings with stakeholders such as the main grid Fingrid and other DSOs. Assessing supply chain emissions still holds a noticeable level of uncertainty. Transmission and distribution industry specific reporting guidelines could improve carbon accounting efforts and provide consistency in GHG reporting that would also improve comparability. Furthermore, some suppliers mentioned that different customers collect data in different formats and scope which provides challenges and requires additional effort in preparing required data. These discussions resulted in the need to develop a common approach on collecting, assessing and reporting GHG inventories within the DSO industry.

5.3 Data review

This section provides a review of data used for assessing Helen DSO’s corporate carbon footprint. Discussed are sources of emissions factors and relevant databases which provided them. Additionally, data accuracy and related implications on results and future development are discussed. Furthermore, data gaps such as missing data or data that is difficult to attain are overviewed.

General sources for emissions factor data were either suppliers, which could provide primary data, or databases and literature for secondary data and average emissions factors. Supplier-specific data allowed for rather effortless GHG quantification and results can be considered more accurate when compared to average data. However, supplier-specific data which is not third-party verified does not guarantee reliability and data verification is something that should be considered in further assessments of Helen DSO’s corporate carbon footprint. Another challenge with collecting supplier-specific data is that both gathering and producing the data may require a substantial amount of time and effort. Additionally, if data needs to be collected from suppliers further up the supply chain the probability of receiving data may decrease. This was the case with distribution cabinets. Though the amount of installed distribution cabinets was identified, neither specific cost data, as costs were included in turnkey services of strategic partnership agreements, nor supplier-specific emission factors could be pinpointed. In these situations, it may be necessary to resort to average emissions factors though these could not be identified either for distribution cabinets. Other cases for activity data that was not accounted for in the assessment were spare parts, accessories and fitting materials used in construction and maintenance services. The list of these materials can turn out to be extensive and efforts to assess supplier-specific emissions are estimated to be disproportionate to the extent that these material's emissions have significance on DSO's overall corporate carbon footprint. Further research may be needed, however, to support this claim.

Emission factors other than suppler-specific emissions factors were gathered either from publicly available or commercial databases. Average emission factor data was gathered in this research from databases such as Ecoinvent, CO2data.fi and DEFRA. Other sources for secondary data include publications from government owned institutions such as the Finnish Transport and Communications Agency Traficom, the Finnish government owned research institution VTT and in case of EEIO data the U.S. Environmental Protection Agency. Benefits of public data sources such as aforementioned databases and publications are that they are free to be used and data is readily available in online sources. On the downside, the emissions factors may not be updated frequently and quantified emissions may poorly represent actual emissions. Commercial databases such as Ecoinvent again do provide more accurate data though acquiring these sources accrue additional costs for the assessment.

In the long term, it is advisable to pursue strong stakeholder relationships with suppliers and encourage the production of supplier-specific contemporary emissions factors that are verified by third parties to ensure reliability and accuracy. Though little observations could be made to support that product-specific and contemporary emissions data will be broadly available in the foreseeable future, efforts in pursuing such data could provide the necessary development to improve data accuracy and decrease dependency on less accurate data such as EEIO data.

6 Conclusions

In this thesis, GHG emissions of the local electricity distribution company in Helsinki, Helen DSO, were investigated and quantified for the year 2022. Several calculation methods were applied and an extensive data collection process of activity data as well as emission factors enabled the quantification of Helen DSO's carbon footprint in accordance with scope 1, scope 2 and scope 3 of the GHG Protocols accounting and reporting guidance. Overall, 60,6% of GHG emissions could be quantified based on primary data and supplier-specific emissions factors which is a significant increase in the accuracy and specificity of Helen DSO's carbon footprint compared to previous CCF estimations. Therefore, the research goal of increasing accuracy was achieved successfully. At the same time the first research question can be answered as follows: Helen DSO's total corporate carbon footprint of 2022, and the sum of its scope 1, scope 2 and scope 3 emissions, was 13416 tCO_2e or 3 gCO_2e per distributed kWh.

Scope 1 emissions added up to be 457 tCO_2e of which the majority occurred due to SF_6 gas leakages from network components. In time, SF_6 gas leakages are likely to stop due to a planned ban of SF6 gases and the resulting replacement of SF_6 gas in network equipment with alternatives. Scope 2 emissions accounted for 194 tCO_2e according to the market-based approach. The biggest GHG mitigation activity was identified when comparing location-based with market-based scope 2 results as procuring emission-free electricity to cover distribution losses roughly halved Helen DSO's potential carbon footprint. Scope 3 activities were the biggest contributor to Helen DSO's corporate carbon footprint with 12764 tCO2e overall. During 2022, the biggest sources of scope 3 GHG emissions were cradle-to-gate emissions from network components with 5203 tCO_2e of which distribution cables, transformers and electrical meters contributed the most. Although a single electrical meter's cradle-to-gate emission is only 40,1 $kgCO_2e$/unit on average, the sheer mass of units that were replaced in 2022 added up to occur 886 tCO_2e of emissions. Though electrical meters are replaced continuously as they reach the end of their life cycle, the DSO industry is preparing for a change in metering requirements which results in the need to update and replace large numbers of electrical meters before the changed requirements become active. The result is a peak in electrical meter related GHG emissions for the reported and upcoming years. This is just one example of annual fluctuations of GHG emissions related to purchases of Helen DSO. Future investments into the distribution system do not necessarily occur evenly each year, hence some years may account for significantly higher emissions than others. This means that the corporate carbon footprint will strongly correlate with the execution of planned investments. Changes in the business environment are also expected to affect Helen DSO's corporate carbon footprint. The electrification of heating methods, discontinuance of large local CHP power plants, charging of the increasing number of electric vehicles and small-scale local production of electricity will increase temporary electricity spikes and affect capacity requirements of Helen DSO's distribution network. Furthermore, major electricity generation will be relocated in the future and the role of the main grid of Fingrid will become more important than ever in supplying Helsinki with electricity. Conclusively, mutual emissions, like emissions allocated from main grid transmission losses, are likely to increase if electricity supply from the main grid is increasing.

The second research question of how Helen DSO's corporate carbon footprint assessment process can further be developed was answered by discussing observations made during the assessment process. Future development should consider interoperable information systems as a source to support business analytics and decision-making. Integration of information systems with ERP systems may streamline data collection, automate GHG quantification and enable advanced GHG inventory monitoring and reporting capabilities. An additional contribution of this research was to increase the knowledge of existing sources for emissions data and an advanced capability to evaluate data sources for GHG emission quantification. Furthermore, data gaps and challenges in data collection were identified which supports the preparation of future corporate carbon footprinting efforts. Further development potential relates to fostering strong stakeholder relationships that encourage capabilities in providing supplier-specific emission data on purchased products. Another stakeholder related contribution of this research is the identified need to engage with stakeholders to commonly develop GHG data collection and reporting principles. This is important since DSOs are in a central position of decarbonizing society and industry and will play a significant role in enabling the decarbonizing of the energy system. Electricity consumption is expected to increase while electricity generation is expected to become less carbon intensive as fossil fuel-based energy generation is replaced by low-carbon energy production methods. DSOs therefore enable sustainable and low-carbon solutions of their customers and stakeholders on a broader scale.

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