TRACKING SCOPE 3 EMISSIONS AND ANALYZING THEIR IMPACT ON CLIMATE TRANSITION GOALS

Lappeenranta–Lahti University of Technology LUT

Degree Programme in Software Engineering, Master's thesis

2024

Mehdi Karmouche

Examiners: Professor Jari Porras (LUT University)

Professor Henry Muccini (University of L'Aquila)

Professor Patricia Lago (Vrije Universiteit Amsterdam)

SE4GD
Software Engineers for Green Deal

With the support of the Erasmus+ Programme of the European Union

This thesis was graded at LUT University and has been accepted by partner institutions of the consortium (619839-EPP-1-2020-1-FI-EPPKA1-JMD-MOB). Successful defence of this thesis is obligatory for graduation with the following national diplomas:

- Master of Computer Science (University of L'Aquila)
- Master of Science in Technology (LUT University)
- Master of Computer Science (Vrije Universiteit Amsterdam)

This Master's thesis was conducted at LUT University in Finland in collaboration with a telecommunication company. This thesis was supervised by Doctor Shola Oyedeji (LUT University) and Professor Jari Porras (LUT University).

Abstract

Lappeenranta–Lahti University of Technology LUT

LUT School of Engineering Science

Degree Programme in Software Engineering

Mehdi Karmouche

Tracking Scope 3 Emissions And Analyzing Their Impact On Climate Transition Goals

Master's thesis
2024
62 pages, 19 figures, 5 tables and 0 appendices
Supervisors: Doctor Shola Oyedeji (LUT University)
Professor Jari Porras (LUT University)
Jonas Kronlund
Sudina Shrestha
Examiners: Professor Jari Porras (LUT University)
Professor Patricia Lago (Vrije Universiteit Amsterdam)
Professor Henry Muccini (University of L'Aquila)

Keywords: Scope 3 emissions, guidance, sustainability, software

Context: Scope 3 emissions often represent the largest part of an organization's carbon footprint. However, organizations face major difficulties when accounting for value chain emissions preventing them from effectively managing Scope 3 emissions and reducing them. **Goal:** The goal of this study is to mitigate some of the challenges faced by organizations when accounting for Scope 3 emissions such as the lack of guidance by providing clear guidelines and a practical implementation example on how to collect, track over time, and analyze value chain emissions. **Method:** The work was conducted in collaboration with a telecommunication company and consisted of using the Design Science Research Methodology (DSRM). The study involved relevance, rigor, and design cycles to design the desired artifacts. **Result:** Two main artifacts were designed in the study. First, a five-step generic framework was established aiming to guide reporting companies on how to effectively track Scope 3 emissions and adjust climate transition goals accordingly. Second, a software tool was developed as a Proof of Concept (PoC) which implements the framework and assesses the impact on the climate transition goals of the industry partner of the study. **Conclusion:** The study emphasizes the importance of supplier engagement in effectively collecting value chain emissions and achieving climate transition goals. Moreover, the study suggests adopting data-driven approaches for collecting and managing Scope 3 data.

Abbreviations

API Application Programming Interface

BI Business Intelligence

CDP Carbon Disclosure Project

CO2 Carbon Dioxide

CSRD Corporate Sustainability Reporting Directive

CSV Comma-Separated Values

DSRM Design Science Research Methodology

EF Emission Factor

ESG Environmental, Social, and Governance

ERP Enterprise Resource Planning

ETL Extract, Transform, Load

GHG Greenhouse Gas

HTTP Hypertext Transfer Protocol

ICT Information and Communication Technology

IT Information Technology

JSON JavaScript Object Notation

JWT JSON Web Token

KPI Key Performance Indicator

NFRD Non-Financial Reporting Directive

POC Proof of Concept

RQ Research Question

SELIS Shared European Logistics Intelligent Information Systems

SER Supplier Engagement Rating

UML Unified Modeling Language

Acknowledgements

I would like to express my gratitude to my thesis supervisors Professor Jari Porras and Doctor Shola Oyedeji for assisting me with my thesis and always providing constructive feedback. I'm also grateful for being part of the Software Engineers for Green Deal Programme and for having the privilege to study at three great universities in Europe such as the University of L'Aquila, Lappeenranta University of Technology, and Vrije University of Amsterdam. Furthermore, I would like to thank Professor Henry Muccini, Professor Patricia Lago, and Professor Jari Porras for providing such an interesting and relevant Master's degree.

To my parents and brothers, thank you very much for your unconditional support throughout the years. It's been a long journey and your help was crucial for my success in life. Thank you for always believing in me and my projects. Moreover, I would like to extend my gratitude towards my closest friends and SE4GD colleagues who have become a chosen family. Navigating this Master's degree was not an easy journey, but your presence made it fun and enjoyable. Finally, I would like to express my gratitude to Susanna Koponen and Letizia Giorgetta for their constant help and assistance to all SE4GD students during the course of this degree.

Declaration of AI Usage

Ilmoitus tekoälyn käytöstä

I hereby declare that AI was used for writing this thesis entitled "TRACKING SCOPE 3 EMISSIONS AND ANALYZING THEIR IMPACT ON CLIMATE TRANSITION GOALS". For this study, AI technology was used to improve the quality of the written content. More specifically, ChatGPT was used to assist in writing tasks by improving writing style, tone, grammar, and structure. Moreover, AI was used to help in understanding general concepts and policies related to the conducted research. The following bullet points further detail how the AI tool was utilized throughout the provided report.

- **Writing style**
  ChatGPT was used during the writing phase of this work to improve the writing style, make the tone of the paragraphs more academic and suitable for a scientific thesis. More specifically, AI was used to rewrite the self-written paragraphs in order to improve their overall quality of style and tone.
- **Grammar**
  Moreover, ChatGPT was also used to correct the grammar of the produced paragraphs in each section. Moreover, the AI tool was used to remove repetitions and redundant sentences and correcting the punctuation.
- **Structure**
  In addition, ChatGPT was used to structure the produced sentences and paragraphs so that the flow of ideas is fluent and not redundant to ensure that the presented information is well structured and easily understandable.
- **Understanding general concepts**
  AI was used to breakdown general concepts and policies related to sustainability such as CSRD for better understanding and comprehension of information related to Scope 3 emissions.

The used AI tools were only utilized for language enhancement, for improving the writing process, and assisting with understanding policies and complex concepts i. AI applications were not used to automatically generate research content. The use of AI in this thesis was carried out with careful consideration with ethical guidelines.

Table of contents

List of Figures

List of Tables

1 Introduction

One of the most threatening phenomena to humans is climate change as it negatively impacts global and local communities around the world. Some organizations, associations, cities, and governments are consequently starting to consider climate change as an emerging priority since the situation requires the mitigation of the impacts of increased temperatures, and changing climate patterns, as the United Nations, 2023 highlighted in their article on the growth of the climate crisis and its effect on global peace. The goal of preventing such consequences of climate change has been discussed by international agreements such as the Paris Agreement by the United Nations Framework Convention on Climate Change, 2015, which set ambitious targets to keep global warming under 2 degrees Celsius and in the best-case scenario under 1.5 degrees Celsius above pre-industrial levels. Following this imperative, other initiatives, regulations, and measures have been established before and after the Paris Agreement to effectively achieve such an objective. These efforts concern different sectors, industries, and governments in the areas of energy production, transportation, industrial manufacturing, telecommunications, and logistics to limit and monitor the carbon emissions coming from human activities. Moreover, the focus extends beyond environmental aspects to also cover social and economic implications.

As part of these initiatives, measures such as the Non-Financial Reporting Directive and the Environmental, Social, and Governance (ESG) reporting frameworks were developed to make companies report on their environmental, social, and governance impacts and activities, and be more accountable and transparent. In recent years, general corporate sustainability reporting has been gaining more importance and attention. This growth in recognition draws attention to the need for companies to clearly report on their environmental impacts as more regulations and measures can potentially be enforced in the future (Bini & Bellucci, 2020.). Moreover, with the introduction of the Corporate Sustainability Reporting Directive (CSRD) in the European Union, companies find themselves under greater pressure to not only report on their sustainability performance but also to navigate the complexities of Greenhouse Gas (GHG) emissions reporting and management. While reporting on Scope 1 (direct emissions) and Scope 2 (indirect emissions from purchased energy) has been relatively well-established, the challenge is now shifting towards reporting value chain emissions, encompassing the entirety of the other indirect emissions along the supply chain with all the different suppliers and stakeholders (Nguyen et al., 2023.). However, researchers have criticized the credibility of such initiatives and disclosure reports as some organizations make use of those reports as a means to improve stakeholders' perceptions and market value without tackling the actual sustainability aspects such as emission reduction strategies for Scope 3 emissions (Bini & Bellucci, 2020.).

Furthermore, value chain emissions are often overlooked in corporate sustainability reporting and sustainability management strategies as discussed by Nguyen et al., 2023 in their work. In fact, Scope 3 emissions constitute a substantial portion of a company's total carbon footprint (Huang et al., 2009.). However, despite their significance, Scope 3 emissions historically receive less attention compared to their Scope 1 and Scope 2 counterparts due to various major challenges. While substantial research has been conducted on managing and reporting Scope 1 and Scope 2 emissions, the unique challenges associated with Scope 3 emissions present an actual obstacle. Despite the issuance of guidelines by the GHG Protocol, corporations struggle with persistent roadblocks in effectively accounting and managing Scope 3 emissions and reporting on them Patchell (2018). A primary challenge in addressing Scope 3 emissions lies in the complex network of suppliers that contribute to a company's value chain. Accessing accurate and comprehensive emission data per product or service from suppliers across diverse industries poses a significant challenge as discussed by different studies in literature such as the one by Lestari & Xiong, 2022. Moreover, each company operates within its unique ecosystem, utilizing various tools, methodologies, and reporting practices, further complicating the standardization of data collection and reporting. Moreover, suppliers may differ in their willingness, engagement level, or capacity to provide emission data, leading to gaps or inconsistencies in reporting which decreases the overall credibility.

Beyond the complexities of data collection, corporations struggle with the deeply rooted dependencies within their value chains. Organizations often operate within global supplier networks, sourcing materials and components from multiple countries, and regions around the world. This geographic aspect introduces additional layers of complexity, as emissions may be influenced by diverse factors such as the usage of different emission factors, local regulations, resource availability, and supply chain disruptions. As a result, corporations face challenges in attributing emissions accurately to specific activities or entities within their value chains as highlighted by Blanco, Caro & Corbett, 2016 in their analysis of the US market in disclosing Scope 3 emissions. As a consequence, corporations could fail to establish realistic and achievable sustainability goals such as achieving a net zero. Furthermore, the dynamic nature of supply chains increases the challenge of Scope 3 emissions management. Supply chain configurations are subject to frequent changes due to factors like market dynamics, technological advancements, and geopolitical shifts, for example, (Llamas-Orozco, Meng & Walker, 2023.).

In addition to the mentioned challenges, there is a pressing need for close collaboration between companies to craft innovative IT solutions to automate the collection, tracking, and management of Scope 3 emissions data in a common and standardized manner (Blanco, Caro & Corbett, 2016.). Communication and collaborative efforts between organizations and their suppliers are essential aspects to successfully develop standardized methodologies, tools, and reporting frameworks that facilitate transparent and comprehensive Scope 3 emissions reporting. This study aims to mitigate these challenges by exploring how to collect, track, and analyze Scope 3 emissions in order to provide clear guidance for companies. Moreover, the study further aims to develop a Proof of Concept (PoC) software system to collect Scope 3 emission data from suppliers, calculate CO2 emissions, visualize the data, and assess the impact of value chain emissions on the climate transition goals of an industrial partner organization in the field of telecommunications. The conducted research in this study is done with that organization, which provides data, industry expertise and knowledge.

1.1 Research Questions

In order to achieve the two main objectives of this study, the following two research questions were defined:

- **RQ1: How to collect, track, and analyze Scope 3 emissions?**
  Rationale: Data and its quality are very much essential to be able to account for Scope 3 emissions especially when dealing with upstream emissions, however, there is a lack of guidelines for companies on how to do so. Moreover, to tackle the lack of guidance concerning value chain emission management, the aim of this research question is to explore and find clear guidelines for collecting data, tracking it over time, and setting or adjusting climate transition goals.
- **RQ2: What are the impacts of Scope 3 emissions on the climate transition goals of a telecommunication company?**
  Rationale: Knowing whether the already set climate transition goals are achievable and comparing current performance with the required one are both important aspects when aiming to reduce value chain emissions. For the scope of this study, the aim is to calculate the impact of a selected number of products and services on the climate goals of a telecommunications company through the usage of a developed software tool.

1.2 Scope and Limitations

The focus of this thesis is on Scope 3 emissions because of the pressing challenges of the value chain emission management and their important contribution to the overall carbon footprint of organizations compared to the Scope 1 and 2 emissions as discussed previously. Moreover, the focus is only on the emissions occurring during the production of goods and services purchased by a company and not on the usage and disposal of those goods and services. In other words, this thesis focuses on upstream emissions and more specifically the first category of Scope 3 emissions which is the purchased goods and services due to their important contribution to the overall emissions of the partner organization of this study. Additionally, the technical contribution of the study uses the data of four direct suppliers from the supply chain. In addition, one limitation of the study lies in the lack of data availability of purchased goods and services as a consequence of privacy and data protection rules put by the partner organization.

1.3 Thesis Structure

The thesis consists of six different sections and is structured as follows:

- Section 1: Introduction
  The Introduction section sheds light on the context of the conducted study by highlighting current sustainability reporting initiatives and discussing the current challenges in value chain emissions management. Additionally, the Introduction specifies the research gap, objectives, main research questions, scope, and limitations of this thesis.

- Section 2: Related Works
  This section reviews existing literature, research, and practices related to sustainability reporting such as the GHG Protocol, and Scope 1, Scope 2, and Scope 3 emissions to provide background information and highlight gaps in the literature. Moreover, this section sheds light on previous literature tackling the pressing challenges concerning value chain emissions management in detail such as the lack of guidance, data-related difficulties, and lack of supplier engagement in the value chain.

- Section 3: Methodology
  This section dives deeper into the adopted research methodology for this study which is the Design Science Research Methodology (DSRM). More detailed information on how this methodology was provided in this section by describing the different relevance, rigor, and design cycles used throughout the study.

- Section 4: Research Execution and Results
  In the fourth section, the previously defined cycles are elaborated in more detail by describing the executed techniques and processes. Each step that led to the final version of the designed generic framework is thoroughly discussed, highlighting the iterative improvements and refinements made along the way before yielding the final designed artifacts of the study. Additionally, this section dives deeper into the development process of the PoC software tool, explaining how it was designed and developed.

- Section 5: Discussion
  In this section, the focus shifts to discussing the results of the conducted research by assessing the designed artifacts. Moreover, a reflection is conducted to investigate

how the goals and research questions were achieved and answered and to discuss the different implications of the study. Threats to validity such as external, construct, and conclusion along with mitigation strategies were included in the Discussion section of the thesis.

- Section 6: Conclusion
  The Conclusion section consists of re-iterating the two main research questions, research objectives, and the main findings of the study. Also, the limitations of the study and potential future work are also discussed.

-

2 Related Works

In this section, relevant information and definitions are provided to give context and foundational knowledge of this study. Additionally, relevant studies are also mentioned to provide more context and shed light on the challenges faced by organizations in Scope 3 management. Namely, this section covers the GHG Protocol, Scope 1, 2, and 3 emissions, CDP, data collection, GHG Protocol calculation methods, and finally the challenges faced by organizations when it comes to accounting and tracking value chain emissions.

2.1 Greenhouse Gas Protocol

In the context of sustainability reporting and CO2 emissions, the Institute & Sustainable Development, 2015 developed the GHG Protocol which is considered one of the foundational frameworks assisting companies with managing and reporting on carbon emissions. The protocol aims to provide international standards, guidelines, and tools for quantifying and reporting GHG emissions. In the same goal, the protocol aims to promote the use of these standards to reduce CO2 emissions on a global scale. Moreover, the GHG Protocol organized the emissions into three different categories called scopes as illustrated in Figure 1. Scope 1 covers direct emissions emitted by the company. Scope 2 is the indirect emissions originating from the purchased energy. While Scope 3 covers the other indirect emissions occurring in the value chain and that are not covered in the first two scopes. By putting these scopes in place, the GHG protocol aims to help corporations to more systematic when reporting on their GHG emissions. Furthermore, the protocol brings additional valuable information on the data collection techniques and calculation methods needed for accurate emission allocation (Institute & Sustainable Development, 2015.). The following subsections provide more information on each scope with a deeper focus on Scope 3 emissions.

2.1.1 Scope 1 Emissions

The GHG Institute & Sustainable Development, 2015 defined Scope 1 emissions as a type of emissions that encompass direct greenhouse gas emissions that result from sources that are owned or controlled by an organization. These emissions typically arise from activities such as the combustion of fossil fuels in stationary sources as well as from industrial processes. Scope 1 emissions are considered a fundamental component of an organization's carbon footprint, as they represent the direct impact of its operations on the environment Institute & Sustainable Development, 2015. Analyzing and quantifying Scope 1 emissions is an essential first step for organizations seeking to understand and mitigate their greenhouse gas emissions, as it provides a baseline for identifying emission reduction opportunities, implementing mitigation strategies, and demonstrating environmental accountability. Moreover,

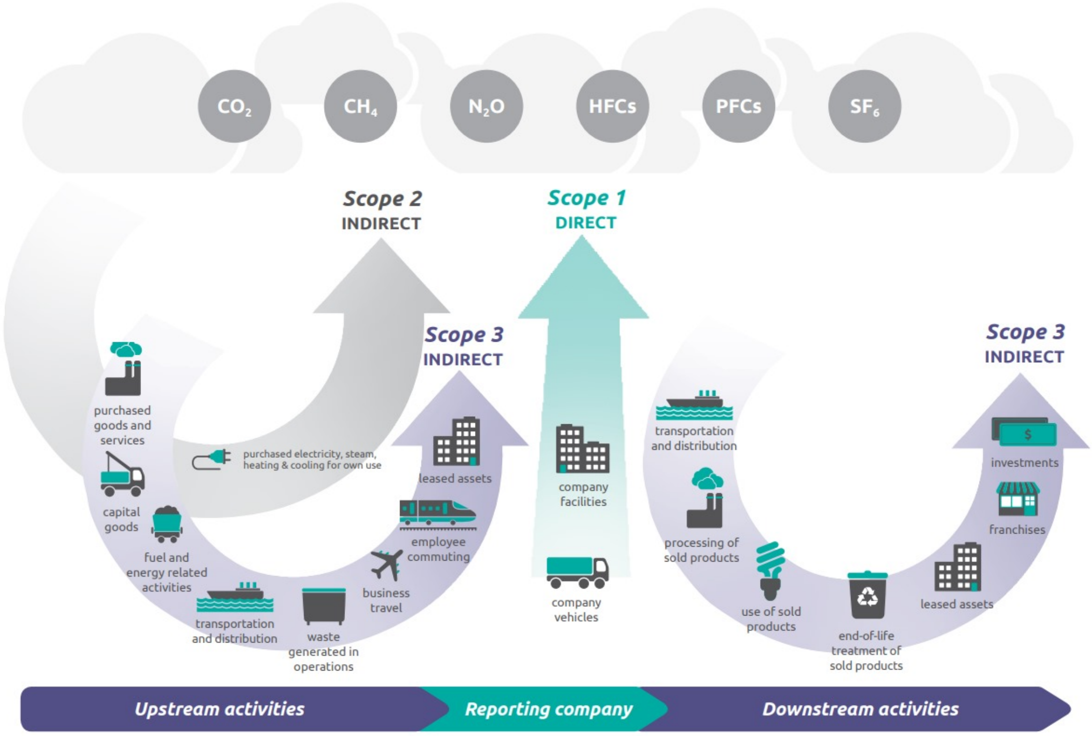

Figure 1: GHG Protocol scopes. Source: (WRI & WBCSD, 2011.)

tracking Scope 1 emissions enables organizations to comply with regulatory requirements, meet sustainability targets, and enhance their overall environmental performance. Additionally, Scope 1 emission data is the most straightforward to collect and calculate as everything is happening internally within the company (Institute & Sustainable Development, 2015.). Although there are clear guidelines that can be utilized to report and manage value chain emissions, the latter is not the largest portion of the overall emissions of organizations as stated by Li, Wiedmann & Hadjikakou, 2019 in their work.

2.1.2 Scope 2 Emissions

Scope 2 emissions, as outlined in the Scope 2 standard by the GHG Institute & Sustainable Development, 2014, refer to indirect greenhouse gas emissions associated with the generation of purchased or acquired electricity, steam, heating, and cooling consumed by an organization. Unlike Scope 1 emissions, which originate from sources directly owned or controlled by the organization, Scope 2 emissions are generated off-site but are a consequence of the organization's activities. These emissions are typically produced by utilities and energy providers that supply electricity or other forms of energy to the organization. Understanding and accounting for Scope 2 emissions is crucial for organizations committed to assessing their environmental impact comprehensively. In fact, Brander, Gillenwater & Ascui, 2018 claim that the total generated electricity can reach 25% of the global GHG emissions. By accurately quantifying Scope 2 emissions, organizations gain insights into the environmental consequences of their energy consumption and can identify opportunities to minimize their carbon footprint through the adoption of energy efficiency technology and strategies such as the usage of renewable energy, and other sustainability initiatives (Brander, Gillenwater & Ascui, 2018.). Moreover, tracking Scope 2 emissions enables organizations to evaluate the environmental performance of their energy providers, advocate for cleaner energy sources, and contribute to the transition towards a low-carbon economy. A robust understanding of Scope 2 emissions is essential for informing energy management strategies, evaluating the effectiveness of climate mitigation efforts, and promoting sustainable business practices that align with broader environmental and climate objectives (Institute & Sustainable Development, 2014.).

2.1.3 Scope 3 Emissions

As mentioned before and according to the Scope 3 GHG WRI & WBCSD, 2011, Scope 3 emissions encompass indirect GHG emissions originating from sources beyond a company's direct control, involving entities along the suppliers in the value chain such as logistics providers, waste managers, travel suppliers, lessees, lessors, franchisees, retailers, and customers. These emissions are established to prevent double counting with Scopes 1 and 2. Scope 3 emissions has 15 different categories of emissions. These types of emissions are further categorized into upstream and downstream emissions. In Table 1, the 8 upstream categories of Scope 3 emissions are described ranging from purchased goods and services to upstream leased assets. As defined in the Scope 3 standard by the WRI & WBCSD, 2011, the upstream emissions refer to the indirect emissions associated with the bought and acquired goods and services.

On the other hand, downstream emissions are the ones associated with the sold and distributed goods and services and consist of seven different categories such as downstream transportation and distribution due to selling products, processing of sold products, investments, and franchises. In Table 2, the downstream emission categories are further described according to the (WRI & WBCSD, 2011.).

Additionally, according to the Scope 3 standard by the WRI & WBCSD, 2011, the emissions are constrained by a time boundary. In other words, some categories of the Scope 3 might have emissions happening in past years, while others in the present reporting year or future years as illustrated in Figure 2. All categories account for the emissions happening during the reporting but some categories can include past years or future emissions. For example category number 1, 2, 3, and 4 all account for past years and current reporting years. While category number 9, 10, 11, and 12 account for current reporting year emissions as well as future year emissions because of the nature of the categories. In Figure 2, it is noticeable that

Table 1: Upstream Scope 3 categories. Source: (WRI & WBCSD, 2011.)

Category	**Description**
Purchased goods and services	Extraction, production, and transportation of goods and services purchased or acquired by the reporting company in the reporting year.
Capital goods	Tangible assets used in the production of goods or services over an extended period of time.
Fuel- and energy-related activities	Emissions associated with upstream activities such as mining, drilling, refining, and transportation of fossil fuels.
Upstream transportation and distribution	Transport and distribution of goods and materials from suppliers to the reporting company's facilities.
Waste generated in operations	All types of waste produced as a byproduct of the reporting company's operations.
Business travel	Travel undertaken by employees or representatives for business purposes.
Employee commuting	Travel by employees to and from their workplace.
Upstream leased assets	Assets leased for use in exploration, extraction, production, and processing of natural resources.

Table 2: Downstream Scope 3 categories. Source: (WRI & WBCSD, 2011.)

Category	**Description**
Downstream transportation and distribution	The emissions originating from transportation and distribution of sold products during the considered reporting year.
Processing of sold products	The handling of intermediary goods sold during the reporting period by downstream entities.
Use of sold products	The utilization of products and services sold by the reporting company within the reporting period.
End-of-life treatment of sold products	The management and disposal of products sold by the reporting company (within the reporting period) at the conclusion of their life-cycle.
Downstream leased assets	The functioning of assets possessed by the reporting company and rented out to other entities during the reporting period, excluding those accounted for in Scope 1 and Scope 2 emissions – disclosed by the lessors
Franchises	The operation of franchised outlets during the reporting period, excluding those covered by Scope 1 and Scope 2 emissions
Investments	The management of investments during the reporting period, not encompassed within Scope 1 or Scope 2 emissions.

most Scope 3 downstream emissions categories account for the current reporting and future years. However, software companies might have different Scope 3 categories compared to traditional organizations and manufacturers as noted by the work of Sipilä, Partanen & Porras, 2023. Through the usage of DSRM, the authors created a new model of emission scopes tailored to software companies. The model specifically acknowledges servers and the cloud as a source of emissions for the Scope 3 category (Sipilä, Partanen & Porras, 2023.).

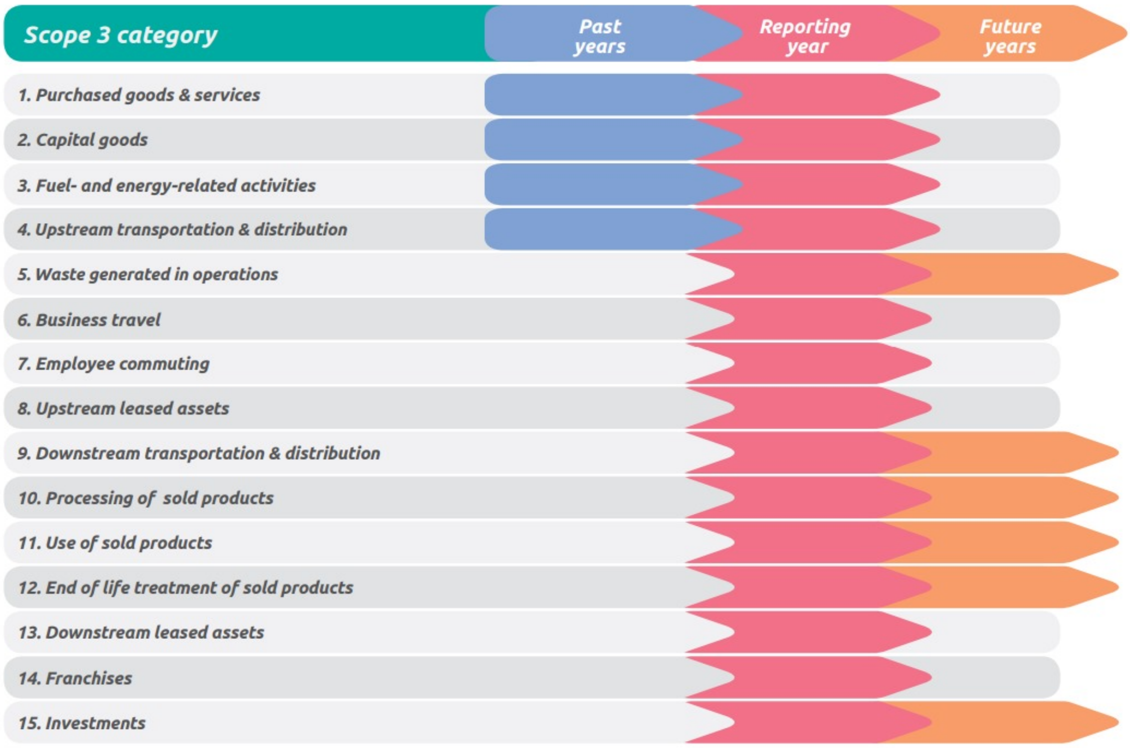

Figure 2: Time boundaries of Scope 3 emissions. Source: (WRI & WBCSD, 2011.)

2.2 Carbon Disclosure Project

The Carbon Disclosure Project, 2024 is defined as a globally recognized initiative that plays an important role in promoting corporate transparency and action on climate change. Founded in 2000, the CDP operates as a non-profit organization with a mission to encourage companies and cities to disclose their environmental impacts such as carbon emissions. Through its annual disclosure platform, the CDP collects and assesses environmental data from various organizations, cities, and governments worldwide, providing investors, policymakers, and the public with valuable insights into corporate environmental performance and climate-related risks. The CDP's disclosure framework enables companies to measure, manage, and report their GHG emissions, aligning with international reporting standards such as the GHG Protocol. By fostering transparency and accountability, the CDP aims to empower stakeholders to make informed decisions, drive climate action, and accelerate the transition to a low-carbon economy. Furthermore, the CDP initiative is a data source that could be used in different projects for further analysis of the state of the carbon accounting and data sharing of such data (Carbon Disclosure Project, 2024.). In the research field, the CDP is widely used as a primary or secondary source of data utilized to carry out different studies concerning value chain emissions and supplier engagement such as the research conducted by Dahlmann & Roehrich, 2019. Moreover, the CDP provides structured and well-labeled data compared to other sources such as the CSR reports Dahlmann & Roehrich, 2019.

In fact, the CDP's scoring methodology evaluates companies' environmental management practices and climate strategies, facilitating benchmarking and comparison across industries as stated by the Carbon Disclosure Project, 2023 in their scoring methodology report. Moreover, the scores are a means to incentivize suppliers to share their impacts, whether positive or negative on the environment. The CDP offers three different questionnaires covering three main areas which are climate change, water, and forests. To generate the overall score, the questions span between general questions and sector-specific questions for high-risk and high-impact sectors. To further bring more granularity to the scoring methodology, the scoring system Carbon Disclosure Project, 2023 is based on unique questions for each questionnaire. As shown in Table 3, the score can range from D- to A, and the levels that a company can go through to reach full grade are Disclosure, Awareness, Management, and Leadership while an F grade signifies that there is a lack of sufficient information and the evaluation can't be carried out (Carbon Disclosure Project, 2023.).

Table 3: Scoring Levels. Source: (Carbon Disclosure Project, 2023.)

Level	Climate Change	Water	Forests	Score band
Disclosure	1-44%	1-44%	1-44%	D-
	45-79%	45-79%	45-79%	D
Awareness	1-44%	1-44%	1-44%	C-
	45-79%	45-79%	45-79%	C
Management	1-44%	1-44%	1-44%	B-
	45-74%	45-74%	45-74%	B
Leadership	1-69%	1-69%	1-69%	A-
	70-100%	70-100%	70-100%	A

Prior CDP scoring methodologies involved assigning an overall score between 0 and 100% based solely on the completeness of a company's disclosure. This approach received criticism for being susceptible to greenwashing, where companies could appear environmentally friendly without taking substantive carbon reduction actions as noted by Guo et al., 2020 in their conducted work to analyze CDP scoring methodologies. To effectively explore the impact of these different scoring methodologies, Guo et al., 2020 conducted an empirical study assessing how the type of scoring technique influences an organization's carbon performance. The study concluded that the new four-level ranking system, as illustrated in Figure 3, positively affects carbon performance, whereas the previous methodology did not demonstrate such an effect or correlation with regard to carbon performance.

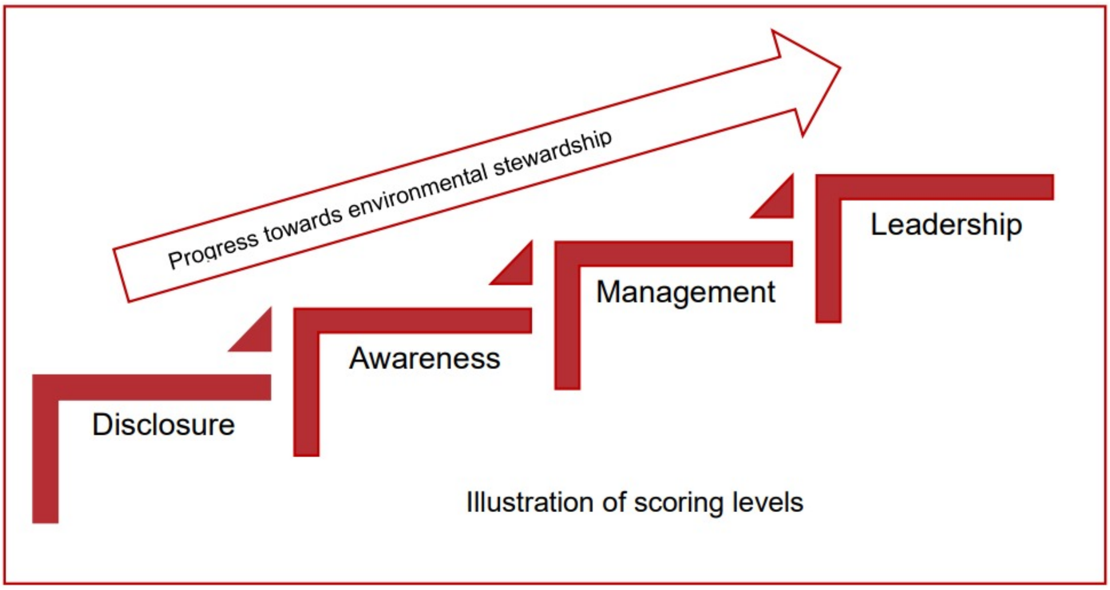

Figure 3: CDP Scoring Levels. Source: (Carbon Disclosure Project, 2023.)

2.3 Data Collection

As described in previous sections, collecting Scope 3 data is a challenge for many corporations as it requires a large engagement of the network of suppliers and having a good understanding and clarity of the activities and their amounts of GHG emissions (Lestari & Xiong, 2022.). Identifying the activities that have the most emissions helps greatly in the data collection. Indeed, the corporate value chain standard by WRI & WBCSD, 2011 defined a four-step iterative process, as illustrated in Figure 4, for collecting and evaluating emission data. The process involves data collection, choosing the appropriate data, gathering the data and addressing any gaps if existent, and ultimately enhancing the data over time. In this process, data, activity or emission factors data, and their quality are very important and essential for having accurate results in the calculation phase. The Scope 3 standard defined the activity data as the quantitative representation of an activity emitting CO2 emissions while emission factors are defined as estimations that convert activity data into CO2 emissions. Furthermore, there are two different types of data for Scope 3 emissions: primary and secondary data (WRI & WBCSD, 2011.).

2.3.1 Primary Data

Primary data consists of information directly related to specific activities within a corporation's value chain. It originates from direct suppliers or other entities primarily involved in the value chain. This type of data is typically acquired through direct monitoring methods such as meter or sensor measurements, utility bills, and purchase invoices (WRI & WBCSD, 2011.). Moreover, primary offers numerous advantages and is strongly recom-

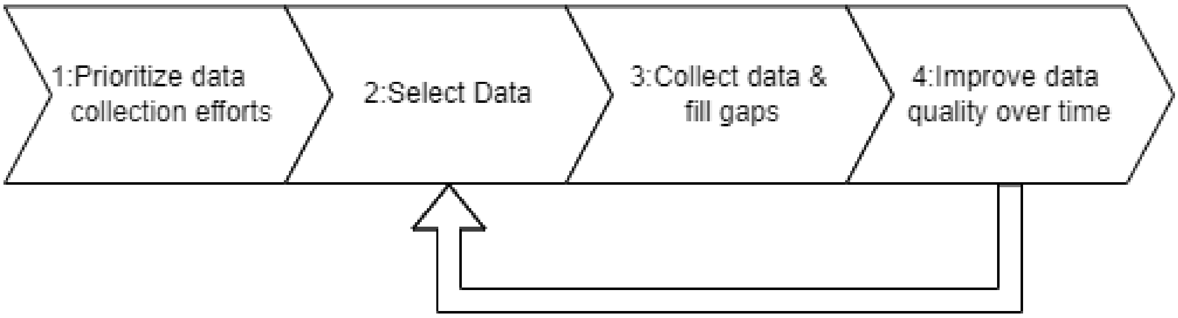

Figure 4: Data Collection Steps. Source (WRI & WBCSD, 2011.)

mended for comprehensive tracking and measurement of GHG emissions within the value chain. Supplier-specific data, in particular, provides valuable and detailed insights into the value chain, facilitating individualized tracking of specific suppliers and enhancing clarity regarding GHG emission reductions (Nguyen et al., 2023.). Furthermore, primary data plays a crucial role in fostering GHG awareness throughout the supply chain network. However, collecting such data may incur significant costs as it necessitates the establishment of various processes, devices, and practices necessary for data collection such as meters, and might generate a significant burden on reporting companies Nguyen et al., 2023. Consequently, in cases where primary data is unavailable or insufficient, secondary data may serve as a viable alternative to fill the data gaps and proceed with the data collection processes (WRI & WBCSD, 2011.).

2.3.2 Secondary Data

The second type of data serves as a valuable resource when primary data is unavailable or its quality cannot be assured. This category of data encompasses information sourced from external sources beyond the reporting organization's value chain. Examples of such data include industry averages and estimates obtained from literature, government publications, or other reputable sources (Protocol, 2013.). It is imperative, however, that companies exercise caution and rely solely on data from trusted databases to mitigate the risk of errors and inaccuracies. In addition and unlike primary data, secondary data offers a cost-effective and straightforward means of data collection for companies, as it does not entail the setup of complex data collection processes (WRI & WBCSD, 2011.). Nonetheless, secondary data comes with some drawbacks and limitations as it may not accurately reflect the activities of the reporting organization, potentially leading to inaccuracies in estimating GHG emissions and overlooking optimizations taken by specific suppliers (Protocol, 2013.).

2.4 Calculation Methods

Accurate calculation formulas and methods are essential for generating the total GHG emissions of a business entity as accurately as possible reflecting the actual reality of the conducted activities of organizations. Selecting the appropriate calculation method is crucial as it must account for various factors such as the Scope 3 category, supplier engagement levels, data availability, data quality, and data types. Different calculation methods are available such as the supplier-specific, hybrid, average, and spend-based methods. One method may be more suitable than another depending on the previously mentioned factors, making it crucial to choose accurately for better results and decision-making (Protocol, 2013.). Figure 5, illustrates each calculation method and the overall needed data.

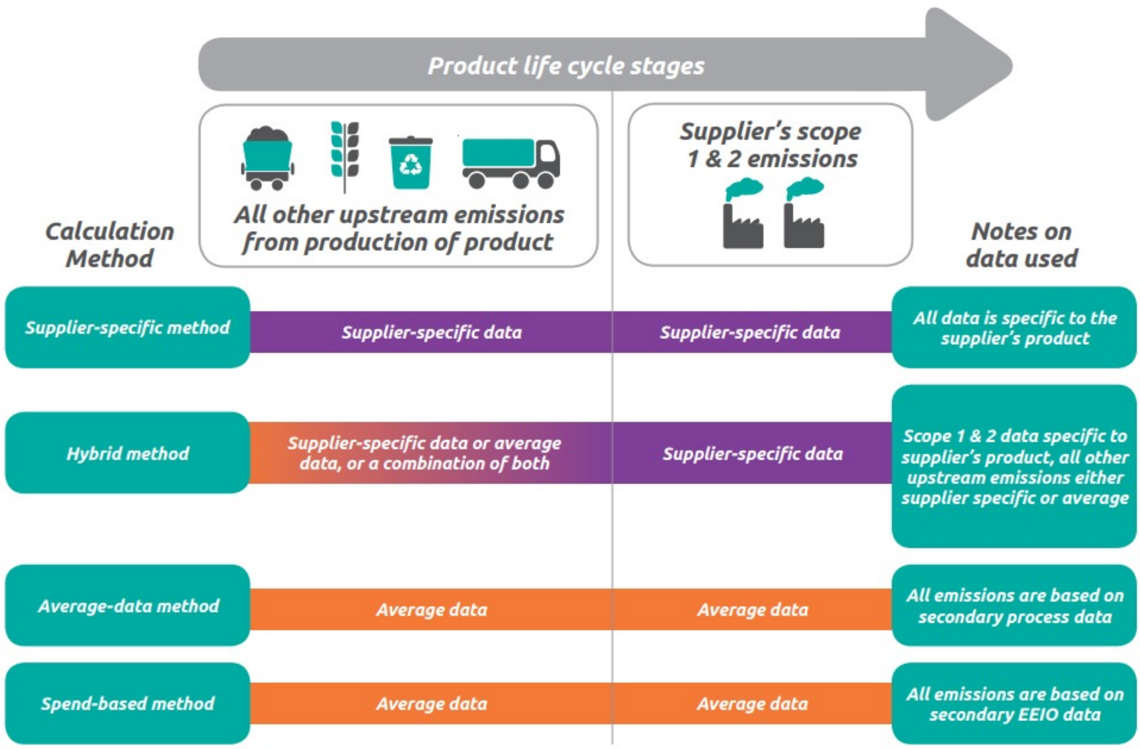

Figure 5: Calculation Methods and Data Types. Source: (WRI & WBCSD, 2011.)

For the case of the purchased goods and services category, choosing the most suitable calculation method is a result of going through a specific decision tree as illustrated in Figure 6. The GHG Protocol, 2013, provided this decision tree to accurately use and determine the most suitable calculation method based on different factors such as impact, business goals, data availability on the physical quantity and product-level data. To ensure accurate and reliable results, it is imperative that the answers to the decision tree questions are provided transparently and objectively, without bias towards any particular calculation method for the company's own benefit. In the following subsections, each calculation method for the first category of the Scope 3 emissions will be detailed by giving its formula and the data required according to the GHG Protocol, 2013.

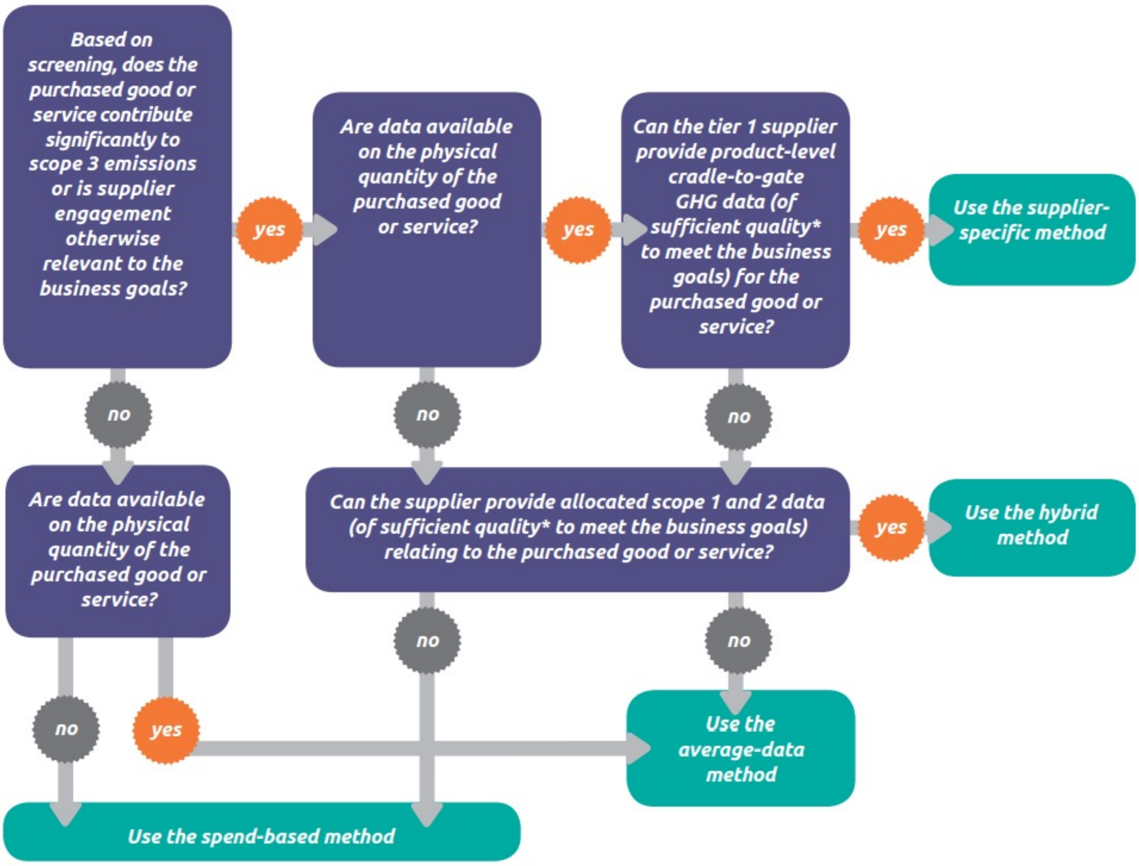

Figure 6: Calculation Methods Decision Tree

2.4.1 Supplier-specific Method

The GHG Protocol, 2013 noted that the supplier-specific method is the most accurate of all the various methods as it avoids any allocation and uses data directly related to the reporting organization. To apply this calculation method, the following formula can be applied:

$$\text{Total Emissions} = \sum_i (Q_i \times EF_i)$$

where:

$$Q_i = \text{quantity of good } i \text{ purchased (e.g., kg)}$$

$$EF_i = \text{emission factor of purchased good or service } i \text{ (e.g., kg CO}_2\text{e/kg)}$$

2.4.2 Spend-Based Method

The spend-based calculation method is the last alternative of the four available methods (Protocol, 2013.). However, it is one of the most common used calculation method as it is easy to apply if costs are known. The spend-based method is utilized when product-level emission data is not available and all the other methods cannot be used. This method consists of multiplying the amount of money spent on a product or a service by an emission factor describing the mean emission amount per spend unit in a specific currency. The following formula can be used to effectively apply the spend-based calculation method:

$$\text{Total Emissions} = \sum_i (V_i \times EF_i)$$

where:

$$V_i = \text{value of purchased good or service } i \text{ (in \$)}$$

$$EF_i = \text{emission factor of purchased good or service } i \text{ per economic value unit (kg CO}_2\text{e/\$)}$$

2.4.3 Average-Data Method

Concerning the average-data calculation method, the reporting organization is required to use data related to the physical mass or other relevant units and multiply them by industry average emission factors. In fact, this method is a mix of primary activity data and secondary emission factors for purchased products and services. The following formula can be utilized to apply the average-data calculation method when the mass of purchased goods and services is available:

$$\text{Total Emissions} = \sum_i (M_i \times EF_i)$$

where:

$$M_i = \text{mass of purchased good or service } i \text{ (in kg)}$$

$$EF_i = \text{emission factor of purchased good or service } i \text{ per unit of mass (kg CO}_2\text{e/kg)}$$

2.4.4 Hybrid Method

The hybrid method is a combination of different methods, by using primary data provided by the suppliers and utilizing secondary data to fill the gaps if needed. For this method, the reporting organization might collect life cycle assessment (LCA) data or other relevant emission factors. According to the Greenhouse Gas Protocol, 2013, the hybrid method requires three main types of activity data which are the allocated scope 1 and scope 2, mass or volume of the material, and the quantities of the waste output (Protocol, 2013.).

2.5 Challenges of Scope 3 Management

Accurately reporting on Scope 3 emissions and reducing them is still a challenge for most companies as stated by Hettler & Graf-Vlachy, 2024. Scope 3 emissions are complex to fully manage as they are related to the value chain as a whole and usually, they constitute a big portion of the total carbon footprint of an organization. As the number of suppliers in the value chain increases, the difficulty of measuring and estimating Scope 3 emissions becomes even greater as mentioned by Royo, 2020 in his work. Moreover, Blanco, Caro & Corbett, 2016, stated that in the US and across the different sectors, the Scope 3 upstream emissions account for around 74% of an organization's carbon footprint. Literature has explored different challenges that explain why value chain emissions are considered difficult to act on and reduce.

The lack of guidance concerning how to handle value chain emissions and manage them over time in order to reduce them is a significant challenge in the industry field. Juurikka, 2023 conducted research to explore the various challenges faced by food production industry organizations, using value chain emissions and reporting. The findings of the study highlighted a major industry challenge regarding knowledge and guidance on Scope 3 emissions. One critical issue is the excessive flexibility in the GHG Protocol, which often leaves room for interpretation and uncertainty as confirmed by the study of Talbot & Boiral, 2013. The flexibility leads to confusion and uncertainty about how to proceed with accounting for Scope 3 emissions in a complex value chain, especially in the food industry sector (Juurikka, 2023.). The lack of guidance often leads to significant discrepancies in how emissions are reported by different organizations, as each company can adopt a unique and specific methodology that suits their available resources and business goals. Additionally, Juurikka, 2023 noted that the inconsistency in Scope 3 accounting not only harms the comparability and consistency of reported data but also affects the credibility of the GHG inventories. For instance, small-scale suppliers, in particular, struggle due to their limited resources and technical knowledge, which decreases their ability to provide accurate emission factors for their customers. Furthermore, even sustainability field experts face challenges in fully understanding and applying the GHG Protocol's instructions, especially when deciding which categories to account for and which ones to neglect from their value chain emissions list (Juurikka, 2023.). Such a lack of clear guidelines was also explored by Downie & Stubbs, 2013 yielding to similar results. One of the critical issues identified is the limited rigor in determining which emission sources are relevant and should be included in Scope 3 assessments. Companies often rely on subjective judgments or limited external advice, resulting in varied and sometimes insufficient inclusion of emission sources. This lack of standardized criteria increases the complexity of the challenges concerning Scope 3 accounting, as organizations may either overlook significant emissions or include sources that do not actually affect their overall

GHG emission footprint (Downie & Stubbs, 2013.)

Another significant challenge faced by organizations in reporting Scope 3 emissions is engaging suppliers across the value chain. The study Stenzel & Waichman, 2023 highlights that engaging suppliers in data sharing is a major obstacle that harms accurate Scope 3 estimation and reduction. This issue is further complicated by the often limited visibility and control organizations have over their extended value chains. Effective supplier engagement, data sharing, and availability are critical and needed for obtaining and measuring reliable Scope 3 emission data, yet it remains a complex and resource-intensive objective Stenzel & Waichman (2023).

Moreover, the work conducted by Dahlmann & Roehrich, 2019 provides valuable insights into sustainable supply chain management, detailing three distinct types of supplier engagement: basic engagement, transactional engagement, and collaborative engagement. Basic engagement typically involves minimal interaction and information exchange, focusing on compliance and basic reporting. Transactional engagement, on the other hand, includes more structured data sharing and performance monitoring but still operates within a limited scope. Collaborative engagement is considered to be the most advanced form of engagement with suppliers, involving a deeper partnership where organizations work closely with both upstream and downstream suppliers to align on strategic sustainability goals. Furthermore, the work of Dahlmann & Roehrich, 2019 emphasizes that collaborative engagement fosters innovative relationships and joint problem-solving, setting common strategic goals and driving collective action toward emission reductions. This approach can greatly improve the accuracy and effectiveness of the value chain emissions reporting by creating a more integrated and transparent supply chain. However, the study also notes that most companies engage only with a limited number of suppliers and often struggle to broaden the engagement scope over time. This limitation is due to various factors, including the complexity of managing extensive supplier networks, the varying levels of supplier maturity in sustainability practices, and the resource constraints faced by companies Dahlmann & Roehrich (2019).

In addition to the lack of guidance, and supplier engagement, another challenge prevents companies from reaching sustainability stewardship when it comes to Scope 3 accounting and reductions which is data availability and quality. The work conducted by Shin & Searcy, 2018 aimed to assess the challenges in reporting GHG accounting in the alcohol sector by conducting a case study and semi-structured interviews in Canada. The researchers have highlighted the unavailability of primary and even secondary data as a major obstacle (Shin & Searcy, 2018.). In fact, emissions from agricultural activities, transportation, and production processes constituted major sources of Scope 3 emissions, yet reliable data on these processes were challenging to acquire.

Furthermore, the work of Royo, 2020 highlighted another challenge that prevents companies from collecting and measuring Scope 3 emissions and setting realistic climate goals in the transportation and logistics sector. The author emphasized the usage of information and communication technologies as a means to share the Scope 3 data between the different entities of the value chain. However, most companies utilize legacy systems with proprietary communication mechanisms. As a consequence, the communication between different systems becomes more difficult. Such a problem requires automation and API integration of the different systems for carbon emission collection, calculation, and climate goal setting. However, these highly interconnected and scaled IT systems often raise security issues such as confidentiality and integrity (Royo, 2020.). To mitigate such a challenge, different initiatives were taken to establish an IT system to ensure data sharing and emissions calculation. For instance, the author sheds light on a solution for emission calculation that ensures software system communication in a cloud computing setting as illustrated in Figure 7. The figure highlights the overall architecture of the system and contains important components such as the services dedicated to benchmarking carbon footprint performance, calculating emissions, and persisting the data in a centralized database while being able to share it with different stakeholders. This solution is part of a project named The Shared European Logistics Intelligent Information Systems (SELIS) aiming to improve the connection between suppliers in the logistics sector leveraging cloud computing and SELIS Community Nodes to integrate systems transport management systems of logistic service providers with ERP systems of shippers and facilitate the collaboration between logistic companies and suppliers (Royo, 2020.). Despite the innovation aspect of the project, this solution also suffers from security issues such as confidentiality, integrity, and trust as highlighted by Royo, 2020.

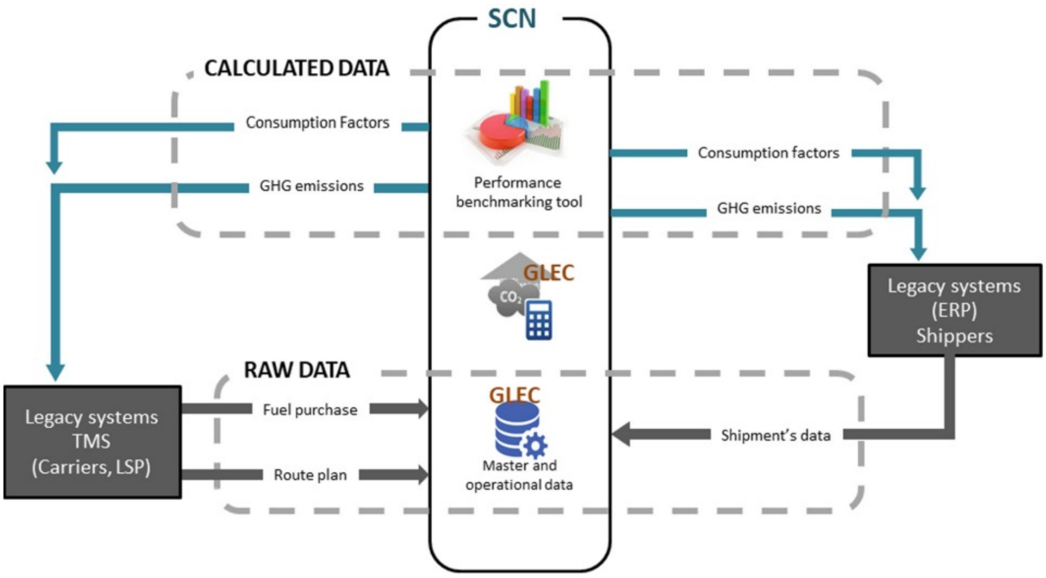

Figure 7: Cloud Computing System for Scope 3 Emission Calculation. Source: (Royo, 2020.)

3 Methodology

This section discusses the adopted research methodology in this study to answer the set research questions. The following subsections shed light on the DSRM and the overall utilized cycles throughout the thesis.

3.1 Design Science Research Methodology

This study is based on the DSRM as defined by Hevner & Chatterjee, 2010 and is using its different cycles iteratively to provide a generic yet comprehensive framework for organizations to track Scope 3 emissions and assess their impact on climate transition goals. Additionally, the DSRM is used to establish a PoC software tool. The DSRM is chosen as the main methodology for this work because it ensures that the artifact built addresses actual problems and requirements. Additionally, DSRM contributes to the incremental improvement of the concerned artifacts leading to a more stable and robust result since different stakeholders and experts can also be included in the feedback loop. The methodology consists of three different cycles which are the relevance cycle, design cycle, and rigor cycle as established by Hevner & Chatterjee, 2010. Figure 8 illustrates in more detail the established cycles for this study.

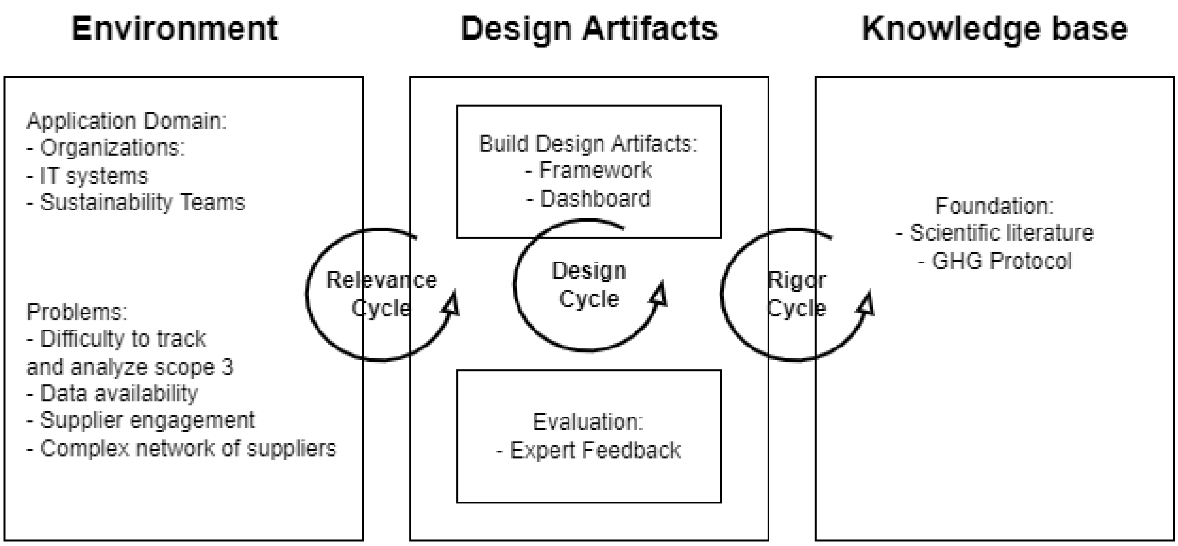

Figure 8: DSRM cycles as defined by Hevner & Chatterjee, 2010

- **Relevance Cycle:** The relevance cycle in design science research is a fundamental phase that mitigates the gap between the conducted research process and the real-world application environment. It begins with identifying a specific opportunity or problem within an actual application domain, which includes the people, organizational systems, and technical systems working towards a common goal. This context provides the necessary requirements and sets the criteria for evaluating the success of the research. The relevance cycle ensures that the designed artifact is not only theoretically sound but also practically useful by returning it to the environment for field testing and evaluation. Feedback from this real-world application informs whether further iterations are needed, either to address deficiencies in the artifact's performance and usability or to refine the initial requirements based on practical insights. Through iterative feedback and adjustments, the relevance cycle aims to ensure that the final artifact effectively improves the environment and meets the defined goals (Hevner & Chatterjee, 2010.).

In this study, the application domain consists of all the organizations that are facing challenges related to activities of tracking, collecting, and analyzing value chain emissions involving different stakeholders such as sustainability analysts. Moreover, the application domain also includes IT systems as they are an important component in collecting, storing, computing, analyzing Scope 3 emissions, and automating such processes. Regarding the problems faced and tackled, the main challenge is the difficulty in collecting and tracking value chain emissions from different suppliers over time. This challenge can be broken down into issues of data availability, a large number of suppliers, and a lack of supplier engagement. Specifically, suppliers are not always engaged and may not share relevant data, such as product life cycle assessment reports.

- **Design Cycle:** The Design Cycle is the core of any design science research project as it links between two main important steps which are designing the artifact and evaluating it. It involves an iterative process where a designed artifact is established, evaluated, and refined based on expert feedback, surveys, or workshops for example. This cycle generates and assesses various design alternatives against set criteria until an optimal solution is achieved. The inputs for these requirements come from the Relevance Cycle, while the design and evaluation methods are derived from the Rigor Cycle. However, the primary function of the methodology happens within the Design Cycle. This cycle requires a balance between the development of the solution and its assessment to adhere to requirements. Both activities must be grounded in relevance and rigor. In fact, simply having a strong rationale for the artifact's construction is not enough if the evaluation process is weak Hevner & Chatterjee, 2010. Therefore, artifacts must be rigorously tested in controlled environments before they are field-tested in real-world scenarios, as part of the Relevance Cycle.

  For the purpose of this study, the design cycle aims to establish two main artifacts. First, a framework aiming to provide a general solution to collect, track, and calculate

Scope 3 emissions while assessing climate transition goals. Second, a PoC dashboard application that implements the framework in an industry context and assesses the Scope 3 emissions and climate transition goals of a telecommunication company. To evaluate these artifacts, the feedback from field experts such as sustainability analysts was used to iteratively and incrementally improve the concerned designed artifacts.

- **Rigor Cycle:** The rigor cycle ensures that the work conducted is grounded on robust scientific and engineering foundations Hevner & Chatterjee, 2010. This cycle draws upon a comprehensive knowledge base, involving a careful selection and study of appropriate concepts, theories, and frameworks. Importantly, the rigor cycle not only incorporates established scientific and engineering principles but also integrates the latest experiences and expertise within the application domain (Hevner & Chatterjee, 2010.).

  In the context of this study, a review of scientific literature was carried out to better understand the challenges related to Scope 3 emissions accounting and management. This review included examining current methodologies and identifying gaps in existing research. Key sources of guidance were the GHG Protocol and its various standards, which provided a solid foundation for understanding emissions tracking and reporting. The rigor cycle also involved exploring existing solutions and best practices to address similar challenges, ensuring that our approach was informed by both historical and the latest guidelines and standards.

3.2 Overall Cycles

Overall, establishing a a new generic framework for tracking Scope 3 emissions and developing a PoC for it took 6 phases as illustrated in Figure 9. Inspired by the study of Betz et al., 2024, the Rigor and Design cycles were merged as illustrated in Figure 9. Initially, it was crucial to identify as precisely as possible the problems and challenges faced when dealing with value chain emissions and aiming to adopt a data-driven approach to collect, track over time, and analyze the impact on the climate transition goals. Next, we developed a first version of the framework addressing those problems and challenges. Alternating between rigor, design, and relevance cycles, the framework was improved to take into account other newly discovered aspects such as supplier engagement. Moreover, the development of a dashboard was carried out in the last 2 phases as a means of a PoC of the previously elaborated framework and to assess the impact of Scope 3 emissions on the climate transition goals of the partner telecommunication company. The field experts have provided their guidance, knowledge, and requirements to successfully develop the software tool.

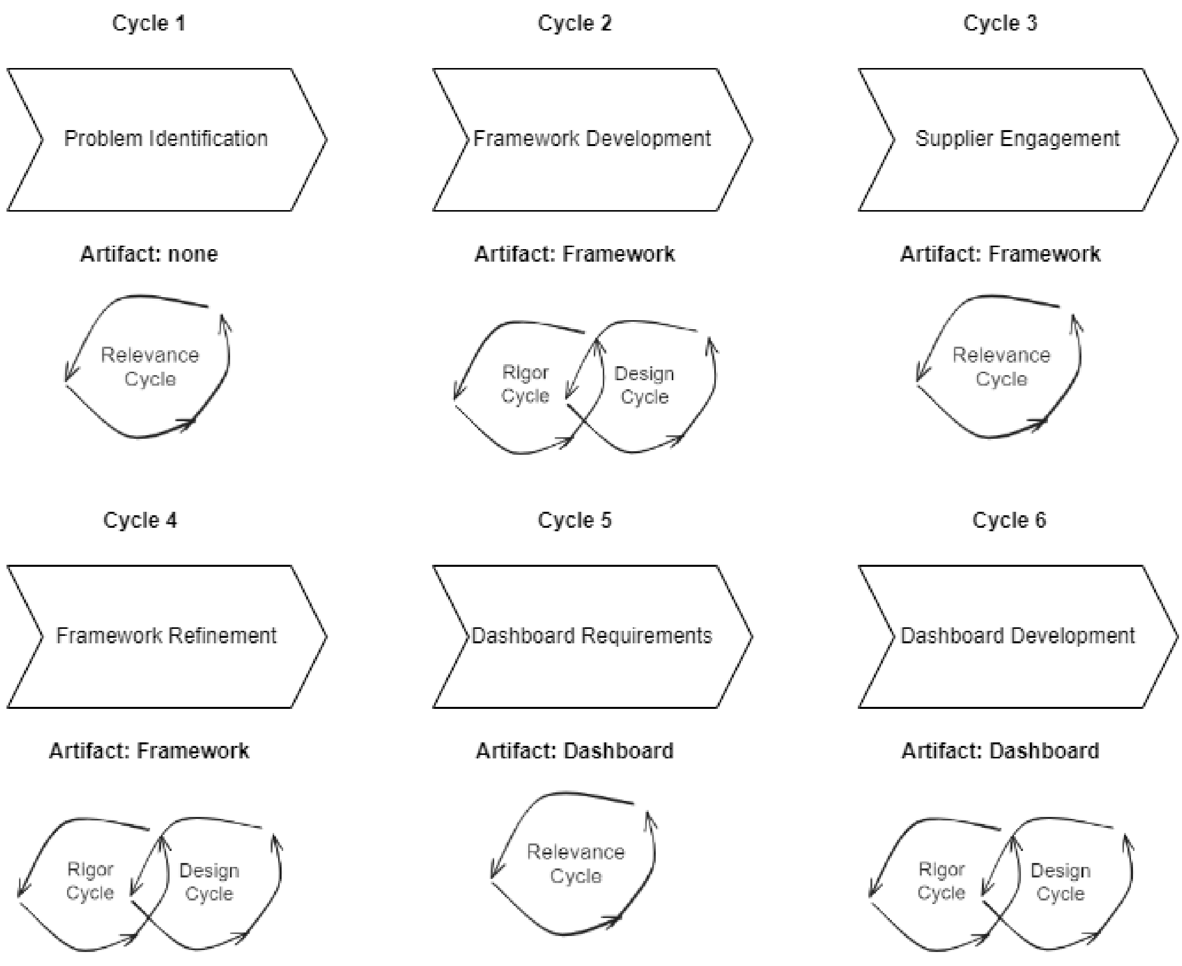

Figure 9: Overall applied cycles

4 Research Execution and Results

In this section, each cycle is explained thoroughly to detail the steps taken to complete it following the overall cycles illustrated in Figure 9. Moreover, additional explanation is also provided to further explain the transition from one cycle to the other while shedding light on the execution steps and the yielded results.

4.1 Relevance Cycle 1: Problem Identification

As discussed in the background and related works sections, companies encounter numerous challenges in accounting for value chain emissions which often represent a significant portion of their total yearly emissions (Blanco, Caro & Corbett, 2016.). One of the primary challenges is the complexity of the supplier network. Large companies often work with a vast network of suppliers, each with its own unique practices and standards for tracking and reporting emissions. This diversity makes it difficult to gather consistent and comprehensive data across the entire value chain. Another significant challenge is the quality and unavailability of emission data (Royo, 2020.). Many suppliers lack the resources or expertise to accurately measure and report their emissions. This results in incomplete or unreliable data, which hinders a company's ability to fully understand and manage its Scope 3 emissions (Juurikka, 2023.). Additionally, the use of different standards and practices in emissions accounting further complicates the issue. Various industries and regions may adhere to different guidelines, making it challenging to harmonize the data into a cohesive and comparable format. This lack of standardization can lead to significant discrepancies and inconsistencies in emissions reporting and data sharing (Royo, 2020.).

To validate these challenges and accurately identify the needs, we conducted meetings with industry experts and got inspiration from the literature readings previously mentioned. In these interviews, different questions were asked such as "What do you think are the challenges faced by organizations in Scope 3 management" and "Do you think it would be useful to have a generic framework to assist companies in Scope 3 emission management". These meetings primarily involved sustainability experts, as shown in Table 4 who have extensive experience in value chain emission accounting and ESG reporting and this cycle 2 meetings were held online. Through these discussions, it became clear that there is a strong need for a comprehensive framework that outlines the steps required to effectively track value chain emissions as a mean to provide a generic and simple framework for companies that are starting their value chain emissions reporting journey. Moreover, the experts affirmed that the framework should also cover the creation of scenarios to assess and adjust climate transition targets based on the collected emissions providing more visibility and insights into the future.

Table 4: Cycle 1: meetings with field experts

Position	Expertise	Organization	Number of meetings	Meeting mode
Corporate responsibility manager	Sustainability and business design	Telecommunication company	2	Online
ESG manager	ESG Reporting, Sustainability Regulations and Compliance	Telecommunication company	2	Online

Additionally, industry experts highlighted the necessity for a practical tool that can implement some of the key steps of this framework while visually presenting insights on climate goals. More specifically, one of the interviewees remarked, "I find a dashboard that tracks our climate transition progress against our science-based targets and drills down into Scope 3 emissions and scenarios really interesting". Such a tool would facilitate more efficient and accurate tracking of emissions through automation, helping companies to better manage value chain emissions and sustainability goals.

4.2 Rigor and Design Cycle 2: Framework Development

State-of-the-art: The published Scope 3 Standard by WRI & WBCSD, 2011 provided general guidelines on how to manage value chain emissions on an industry level. The Scope 3 standard contained an overview of the steps required to adhere to the standard as well as some other requirements. The overview was a foundation and an inspiration for the framework to be developed in this study. Figure 10 illustrates the 9-step overview process of the GHG Protocol. The latter starts initially on a high-level of abstraction by setting general business goals and objectives, then reviewing the accounting and reporting principles of the reporting organizations. Next, different processes follow, such as Scope 3 activities identification, data collection, and emission allocation. The overall procedure then ends with the reporting being done at the last step. Additionally, several researchers have stated that the GHG Protocol contains gaps, offers excessive flexibility, and thus leaves room for different interpretations by the stakeholders (Talbot & Boiral, 2013.). Finally, it is noticeable that the provided overview process by the GHG Protocol is a linear process and not iterative offering fewer chances for returning to previous steps for improvement purposes as shown in Figure 10.

Designed Artifact: Drawing from previous research, an initial version of the framework, illustrated in Figure 11, was established. In order to design such an artifact, the constant participation of the field experts was valuable for evaluation purposes as shown in Figure

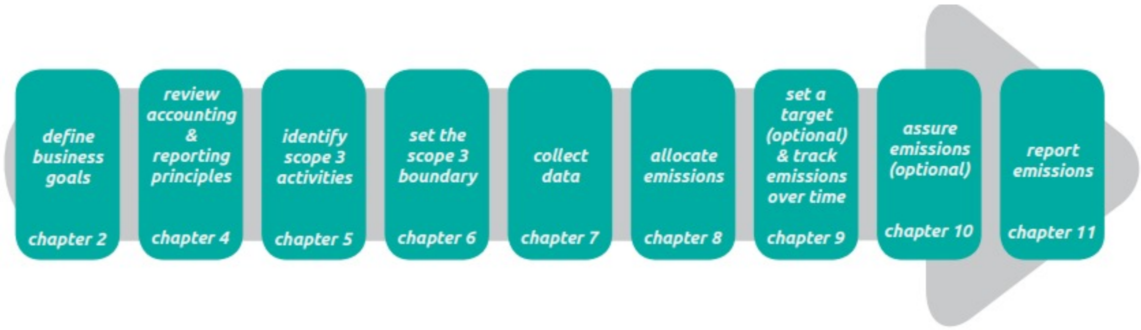

Figure 10: GHG Protocol Overview. Source: (WRI & WBCSD, 2011.)

8. Some steps were removed from the overall guidelines provided by the WRI & WBCSD, 2011, as those steps can be judged to be high-level and create room for interpretation and ambiguity. Moreover, the proposed framework leverages iteration as an important aspect which was lacking in the framework shown in 10. More specifically, the designed framework consists of the following four main steps.

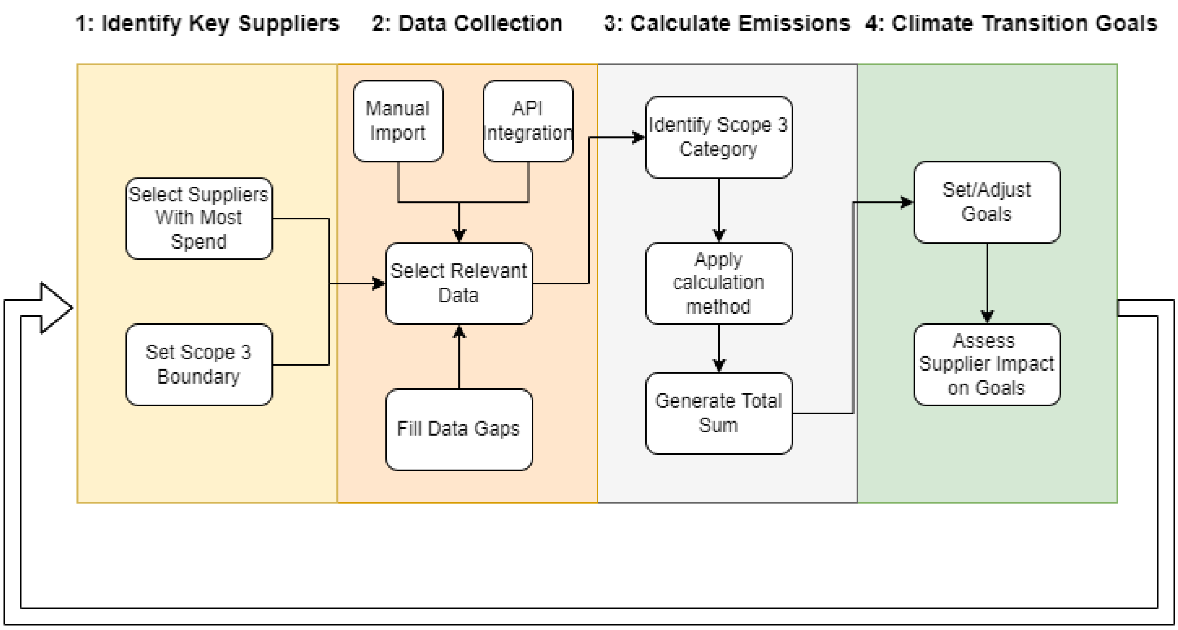

Figure 11: Framework First Version

- **Identify Key Suppliers**: Identifying the key suppliers that contribute the most to the organization's value chain emissions is the most crucial first step in the framework. Not only does this facilitate determining a focused and arrow scope, but also makes the emission tracking and management task more achievable. While the best-case scenario is, ideally, to cover all suppliers, many organizations find this approach to be overwhelming and daunting given the large scale and complexity of their supply chains since the higher the number of suppliers gets, the harder it gets to make informed decisions for carbon reductions (Royo, 2020.). In order to address this, it is practical to set the Scope 3 boundary by focusing on direct suppliers as an initial first step. Tier 1 suppliers are the ones the organization directly does business with, making the next steps of the framework more viable. For instance, a telecommunications company can decide to get started by focusing on critical suppliers that supply critical components, such as network infrastructure and computer and IT equipment.

Additionally, filtering out direct suppliers with minimal spending can significantly enhance the efficiency of the value chain emissions tracking process. By concentrating on suppliers with the highest spending, companies can prioritize the major contributors to their overall emissions. For instance, if a company estimates that a substantial majority of its expenses come from just 20% of its suppliers, it can focus on collaborating with these key suppliers first to implement emissions reduction measures.

Furthermore, the targeted approach allows companies to establish better relations with their critical suppliers, which helps in better collaboration and more effective implementation of the sustainability initiatives agreed upon. In fact, this narrowing of scope not only makes the tracking process feasible but also allows for greater and quicker collaboration in reducing the overall carbon footprint of the organization. By starting with a manageable subset of suppliers, firms can then expand incrementally the coverage as they improve further the systems and processes, with the objective of completely covering the value chain with its different stakeholders and collaborators.

- **Data Collection**: The second main step of the framework is data collection, which is crucial as it serves as the foundation for the subsequent steps. Providing various methods for collecting data increases the likelihood of obtaining comprehensive information from suppliers over the long term. Therefore, it is essential to support the manual import of files containing emission data. For example, suppliers can send or upload spreadsheets or CSV files. However, manual import can be error-prone, slow, and inefficient. To address these issues, API integration presents a more effective alternative. Integrating suppliers with the customer via an API for submitting value chain emissions data reduces human intervention, automates data processing and cleaning, enhances scalability, and provides more detailed insights into the value chain.

  After collecting the available data, the subsequent task is to select the relevant data required for calculating emissions, such as direct emissions and emission factors. This step is crucial to ensure that the data used for emissions calculations is accurate, comprehensive, and up-to-date.

First, it is important to identify and extract data that directly relates to the organization's Scope 3 emissions. This includes data on activities and processes that contribute to indirect emissions throughout the value chain. Next, the selection process should also involve reviewing the emission factors used in the calculations. These factors are essential for converting activity data into estimated emissions. It is also important to ensure that the emission factors are the most recent and accurate, as they can significantly influence positively or negatively the final emissions calculations. Organizations can obtain updated emission factors from reputable sources such as government agencies, industry associations, or scientific literature.

If there are any gaps in the data or if the emission factors used are not accurate, addressing these issues becomes necessary at this phase. Data gaps can occur for various reasons, such as incomplete reporting from suppliers, missing historical data, or new activities that have not yet been measured. In order to fill these gaps, organizations can use several techniques and approaches such as data estimation and extrapolation using industry-specific averages from trusted and certified databases or engage further with the suppliers to collect additional information.

- **Calculate Emissions**: Calculating value chain emissions follows the data collection phase. The primary objective of this step is to estimate Scope 3 emissions as accurately as possible using the GHG Protocol calculation methods. Initially, it is crucial to dynamically identify the relevant Scope 3 categories from the 15 available ones. Next, the appropriate calculation formula is applied depending on the quality and type of the collected data. For example, for the first category of the value chain emissions, which is the purchased goods and services, there are four different calculation methods: supplier-specific method, hybrid, method, average data method, and spend-based method. Additionally, allocation might be needed in cases where suppliers don't provide product-specific data or when emissions need to be distributed among different services or products. By going through the decision tree illustrated in Figure 6, the correct calculation formula can be utilized.

  Furthermore, emissions can be detailed per supplier and, if data permits, per product. This level of granularity is important for understanding the emissions profile of individual suppliers and products, providing deeper insights into the overall performance of the value chain. This detailed breakdown not only facilitates targeted emissions reduction strategies but also enhances the overall comprehension of the value chain's environmental impact, enabling more informed decision-making in subsequent steps.

- **Climate Transition Goals**: The final step in this initial version of the framework is to establish and adjust climate transition goals. Once key suppliers have been identified, data has been collected, and emissions have been calculated, the organization can proceed to set or refine these goals in alignment with its overall business objectives and strategies. For example, a company might aim for a net zero goal by 2040, using 2021 as the base year. With the data gathered from the earlier steps, the organization can explore different scenarios, such as expansion and reduction scenarios, to gain deeper insights into setting and adjusting climate transition goals.

An expansion scenario could occur when the current year's emissions are higher than those in the base year. In this scenario, the growth rate of emissions can be calculated and projected into future years up to the target year for the climate transition goal. This analysis helps the organization determine whether its climate goals are feasible under current trends and, if not, how much deviation could occur. However, this scenario can be complex because it must account for various influencing factors, such as increased demand for certain goods or services, changes in operational scope, or market expansion, which can all affect the overall emissions. Moreover, a reduction scenario could be applied when the current year's emissions are lower than those of previous years since the base year. By calculating the reduction rate and projecting this trend into future years, the organization can evaluate whether they are on the right track to meet their climate transition goal. This scenario is more straightforward but still requires careful consideration of ongoing and future reduction initiatives, potential efficiency improvements, and changes in the operational environment that might impact emissions. Both scenarios should be compared to the yearly required emission reduction needed to achieve the climate transition goal. If the analysis indicates that the goal is not achievable under current conditions, the organization can explore alternative measures. These might include implementing additional reduction initiatives such as adopting bio-fuels, switching to recycled materials, or enhancing energy efficiency.

Another crucial aspect is assessing the impact of individual suppliers on the climate transition goal over time. By evaluating each supplier's contribution to overall Scope 3 emissions, the organization can pinpoint which suppliers have the most significant impact. This detailed analysis enhances clarity and granularity within the value chain, enabling informed decision-making and more effective emission reductions. Understanding individual suppliers' impact offers several key benefits. Firstly, it enables more targeted and effective engagement strategies. Knowing which suppliers contribute most to overall emissions allows the organization to focus its efforts on high-impact suppliers. By working collaboratively, they can develop and implement common targeted emissions reduction initiatives.

4.3 Relevance Cycle 3: Supplier Engagement

After two cycles, a significant need emerged hindering the applicability of the framework, particularly in the data collection phase and the subsequent steps. Both interviewees stated that supplier engagement is key for having more replies to the CDP questionnaires. The conversations between the partner telecommunication company and its suppliers are conducted by vendor managers who hold annual meetings with suppliers to drive conversations about sustainability and data sharing. Not having supplier engagement reflected in the framework hinders the applicability of the framework and highlighted the urgent need to incorporate supplier engagement as an additional major step in the framework since data collection efforts might fail if suppliers are not committed and engaged to share such data. According to the study Dahlmann & Roehrich (2019), organizations must engage with their suppliers to effectively address climate change and reduce carbon emissions. This need was validated through meetings with field experts in sustainability, who unanimously emphasized the importance of enhancing supplier engagement. They highlighted that fostering deeper conversations and more information sharing with suppliers is crucial for addressing sustainability concerns, such as Scope 3 emission reduction, through collaborative efforts and having common climate transition goals. These experts also pointed out that successful supplier engagement could lead to innovative solutions, increased transparency, and stronger partnerships, ultimately driving more significant and collaborative sustainable environmental impacts.

4.4 Rigor and Design Cycle 4: Framework Refinement

State-of-the-art: The work of Stenzel & Waichman, 2023 highlighted that supplier engagement is still a major challenge for Scope 3 reporting organizations. Moreover, the study of Tidy, Wang & Hall, 2016 emphasized the use of supplier engagement programs as a way to achieve common goal setting and assessment of operations against standards and also help in achieving the GHG emissions targets. Additionally, many researchers have used the CDP as a source of data for their study. For Dahlmann & Roehrich, 2019, the usage of the CDP was ideal as it provided a more comprehensive and structured database. In the same context, the sustainability field experts from the industry partner have been using the CDP as one of the main ways to collect relevant sustainability data from suppliers using questionnaires.

Designed Artifact: The aim of this cycle is to design a new version of the framework, incorporating supplier engagement as a foundational pillar, as illustrated in Figure 12. The engagement step, positioned as the second step of the framework immediately after identifying key suppliers, encompasses several processes. Primarily, it involves fostering direct communication between customers and suppliers through meetings, presentations, and questionnaires. This cross-communication is essential for gaining a deeper understanding of mutual goals, challenges, and areas for improvement. Such interactions provide a platform for detailed discussions on emission reduction strategies, thereby enhancing the collaborative efforts towards sustainability. This iterative process of dialogue and feedback not only strengthens relationships but also drives continuous improvement and innovation in sustainability practices. Moreover, to drive more impact from these conversations, benchmarking suppliers based on their engagement in the last few years can offer great value before starting the data collection step. To do so, different KPIs can be used such as the CDP scores and the Supplier Engagement Ratings (SER). The aim is to compare suppliers that are from the same sector in order to create a sense of urgency and competition within the supplier network. The framework is not limited to using CDP KPIs. In fact, companies can also incorporate their own customized processes and metrics for supplier engagement.

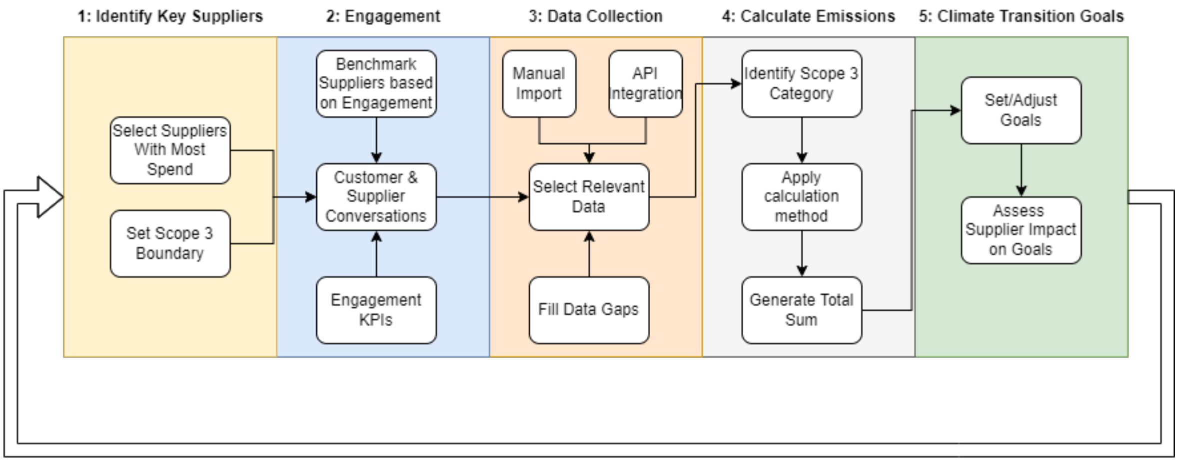

Figure 12: Framework Final Version

4.5 Relevance Cycle 5: Dashboard Requirements

This cycle identified a critical need for a software tool to implement the framework in an industrial context while automating processes such as data collection, supplier engagement benchmarking, and visualizing the journey toward the climate goals. The existing literature, as discussed in the first and second sections of this study, highlights the significant challenges that companies face in terms of improving supplier engagement, collecting and analyzing Scope 3 data, and setting or adjusting climate transition goals. As a consequence, we observe a clear necessity to develop a dashboard tool as a PoC for the framework, leveraging data provided by the industry partner organization.

To validate the observed need, multiple meetings were conducted with field experts from the sustainability sector. These discussions confirmed the pressing and urgent requirement for an internal tool to automate these tasks. Centralizing emission data and automating the generation of supplier engagement KPIs not only facilitates operations but also provides important business value. Experts emphasized that the current process of using engagement KPIs during supplier interactions is tedious, manual, and in some cases error-prone. An automated tool would simplify this process, enhance data accuracy, and foster a more effective and efficient engagement with suppliers while providing insightful visualizations to understand the value chain network even further and assess the journey to achieving the climate transition goals. By incorporating these functionalities, the proposed software tool would significantly advance the organization's sustainability efforts and contribute to more robust climate transition strategies.

Furthermore, the field experts from the industry partner provided additional details by giving the desired functional requirements. The functional requirements for the software tool are the following:

- **FR 1:** The system shall be able to process CDP data and store it in a local database.
- **FR 2:** The system shall be able to visually represent different CDP scores based on a chosen supplier from the value chain.
- **FR 3:**: The system shall be able to generate insights on the engagement of the suppliers by analyzing those who replied to the questionnaires and those who did not.
- **FR 4:** The system shall be able to input emission data related to the purchased goods and services Scope 3 category and process that data.
- **FR 5:** The system shall be able to use the GHG Protocol calculation methods to compute the total emissions and a relative emission goal based on the provided data.
- **FR 6:** The system shall be able to visualize scenarios such as reduction, expansion, and meeting climate transition goals scenarios.
- **FR 7:** The system shall be able to authenticate users and manage their roles by having vendor managers and admin roles.

Additionally, it is important to mention that the inputs to the system are the CDP records, purchased goods and, Scope 3 emission data, and the user credentials such as email and password. Understanding and clearly defining these inputs is crucial as it ensures that the system is designed to handle and process the necessary data efficiently. In fact, by specifying these inputs, the software can be established to answer the functional requirements defined previously. More specifically, the CDP data can look like data spreadsheet files with different answers to the CDP questionnaires. While the purchased goods and services emission data can consist of emission factors, number of units, and quantity in kilograms for example. Furthermore, the available and provided data by the partner telecommunication organization covered the last two years since 2023 using 2021 as the base year.

4.6 Rigor and Design Cycle 6: Dashboard Development

State-of-the-art: Before diving deeper into designing the artifact, research has been to conducted to get inspired from existing sustainability reporting software tools namely the ones that focus on the value chain and the Scope 3 emission reporting. More specifically, Watershed [1], Greenly [2], and ImpactOS [3] are software platforms that were studied to get inspiration for designing and developing the PoC dashboard tool. In fact, these platforms aim to assist companies in measuring, managing, and reducing their carbon footprint while automating different processes for better productivity, accuracy, and granularity. Moreover, the SELIS cloud computing project, as described in the study of Royo, 2020 because it provided a detailed high-level architecture of a Scope 3 emission management system in the sector of logistics and transportation., was a great inspiration for designing such software. Furthermore, Chehrehgosha Kenari, 2024, conducted a study evaluating the importance and significance of the usage of digital tools and their impact on Scope 3 emissions reporting. In fact, the author claimed that using digital tools, automation, and Business Intelligence (BI) processes can provide great potential for achieving sustainability goals and leveraging more granular and detailed insights into the supply chain.

Designed artifact: Based on the studied literature, sustainability reporting tools, feedback of field experts, and the functional requirements, a software tool was designed as a PoC of the framework and to be used internally by the telecommunication industrial partner.

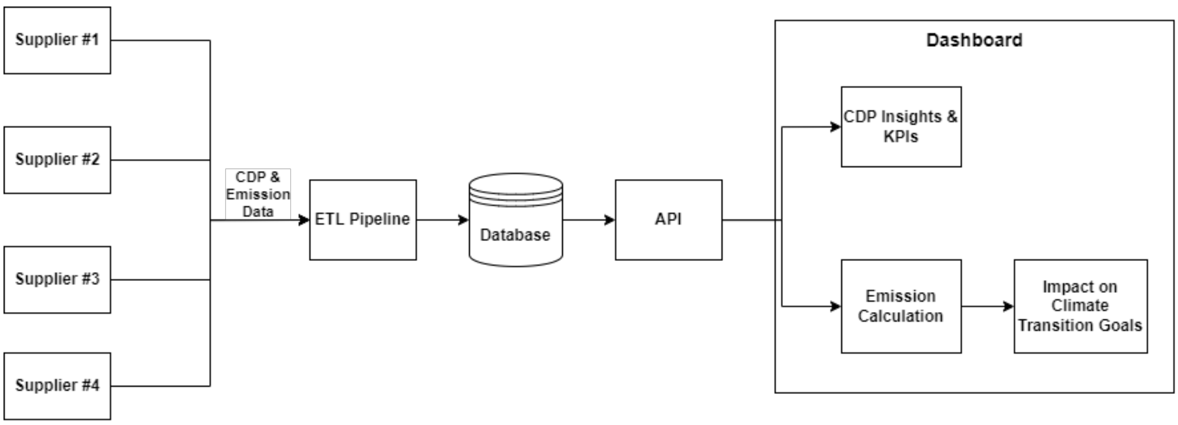

Figure 13: Technical Overview of PoC

4.6.1 PoC: Technical Overview

A general architecture overview of the PoC software tool was designed as illustrated in Figure 13. The input of the system is mostly coming from the suppliers in the value chain

[1] https://watershed.com/
[2] https://greenly.earth/en-gb
[3] https://www.impactos.ai/

and their CDP questionnaires. For the scope of this PoC, only four suppliers were taken into consideration due to the limitation of data availability by the partner telecommunication company. Handling the CDP and Scope 3 emission data is initially executed on the first API layer. The latter implements an Extract, Transform, Load (ETL) pipeline to access the relevant data, process the input data, prepare it for further analysis, and store it in a centralized database. The latter was a NoSQL type of database since the processed data was expected to be sparse as not all the questions of the CDP questionnaires are answered by every supplier. Using a NoSQL database ensures that the system does not store null values thus optimizing storage capabilities. More specifically, the ETL pipeline was designed to execute the following processes:

- **Extract:** The extract part of the ETL pipeline involved reading the uploaded CDP files and extracting relevant data points. For each of the 165 suppliers, approximately 122 data points were extracted. These data points included various important pieces of information such as the supplier name, priority level, revenue, response status, submission date, previous year status, activity group, Scope 3 purchased goods and services, emission direction, current year supplier engagement year, previous year supplier engagement year, and more. Moreover, this part of the pipeline was also responsible for extracting Scope 3 emission data such as the purchased goods and services. This phase was important in gathering all the necessary information to understand each supplier's impact on Scope 3 emissions and their engagement over the last two years.
- **Transform:** Once the data was successfully extracted, the transformation phase prepared the data for persistence involving several key steps. First, it was essential to handle cases where data fields were empty, as some suppliers did not complete the CDP questionnaires. This required filling in missing data where possible, marking it appropriately, or leaving it empty to not store it later on. Second, since most of the data fields were in string format, it was necessary to convert these strings into the correct data types. For example, date fields need to be transformed into proper date formats to ensure accurate and meaningful analysis later on.
- **Load:** After extraction and transformation, the final step consisted of loading the data into the NoSQL database for persistence purposes. Each supplier's information was stored in a centralized database, ensuring that all their relevant CDP data was easily accessible. Moreover, the emission data of the purchased goods and services was linked to their corresponding supplier using unique identifiers. Moreover, the overall process consisted of loading all the transformed and cleaned data points into the NoSQL database, leveraging a comprehensive repository of information ready to be queried for data analysis purposes. In addition, by storing the data in a NoSQL database, we ensured centralizing data, allowing for efficient data retrieval and management as the

number of suppliers and the volume of data could potentially grow over the upcoming years.

Additionally, to serve the dashboard with the needed data, a server hosting an API was established as a layer between the database and the dashboard client application. Using HTTP and JSON, the server and API were designed to serve the dashboard with the required data through the implementation of different API endpoints utilizing various HTTP verbs as illustrated in Figure 14.

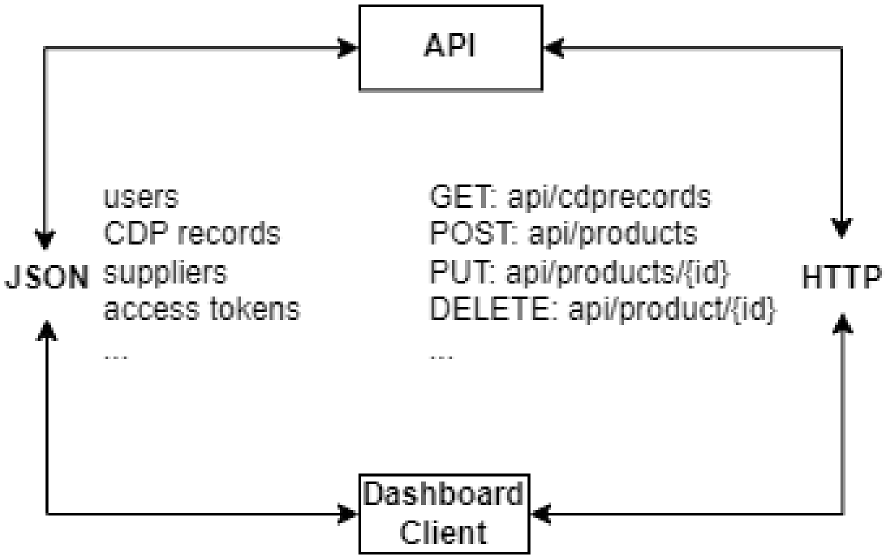

Figure 14: API and Dashboard

Furthermore, registration and authentication are crucial steps in the proof of concept (PoC) as they are necessary for accessing all functionalities in the dashboard while ensuring that some data chunks are accessible only by specific users. For the established PoC, the authentication and registration processes involve only a username and password. Upon receiving the password, the server hashes and salts it to enhance security practices. Once a user account is created, a role can be assigned to that account, either as a vendor manager or an admin role. A vendor manager account has limited access to the implemented functionalities and cannot alter data in the system. On the other hand, an admin has full access to the system features, including detailed CDP supplier information and their KPIs, and can add purchased goods and services along with their emission factors.

4.6.2 PoC: Engagement

Vendor managers play a critical role in engaging with suppliers as they are the ones responsible for having conversations with the suppliers, and the illustrated dashboard in Figure 15 is designed to support them in those interactions. By utilizing various KPIs, vendor managers can benchmark supplier performance and guide conversations toward more comprehensive data sharing and enhanced accuracy in emissions reporting. The aim is to strengthen supplier engagement by using specific scores and metrics tailored to each supplier and their respective sector, as illustrated in Figure 15. This approach aligns with the principles of the GHG Protocol, which emphasizes the importance of accurate and transparent Scope 3 emissions data. By benchmarking suppliers using sector-specific KPIs, vendor managers can identify areas for improvement and foster collaboration to reduce greenhouse gas emissions more effectively. This method not only promotes better data accuracy but also encourages suppliers to adopt more sustainable practices and reduction initiatives, ultimately contributing to the organization's overall sustainability objectives. The following bullet points describe each KPI used in this section of the dashboard in detail and use the Carbon Disclosure Project, 2023 scoring methodology as a reference for the utilized metrics.

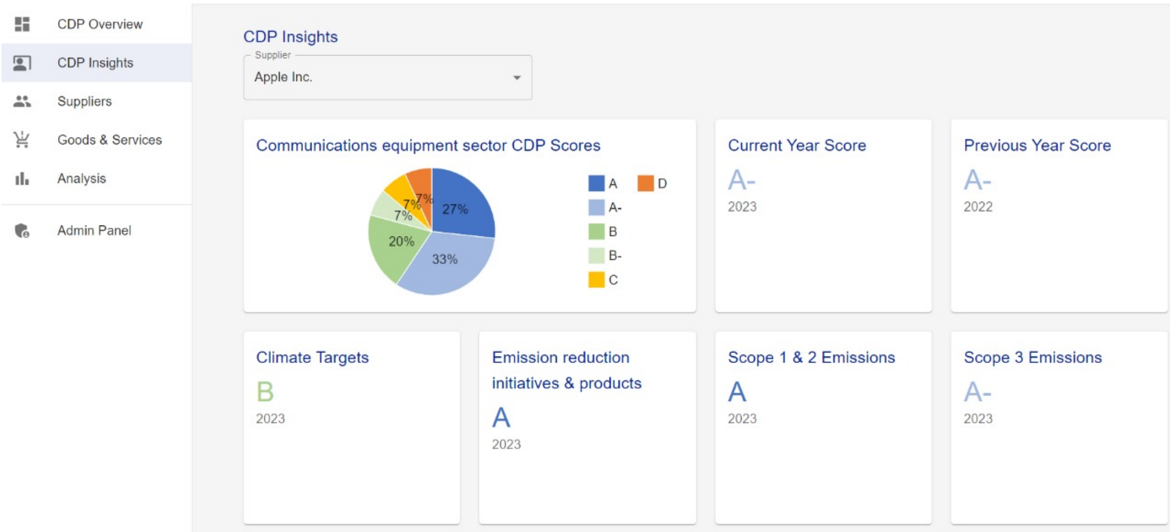

Figure 15: Supplier Specific CDP Scores

- **Supplier Engagement Rating:** The first metric used in this section of the dashboard is the SER of a specific supplier for the current year. This KPI evaluates how effectively an organization is engaging with its customers to address climate-related issues. A higher score is awarded when the questionnaire responses are comprehensive and qualitative, as verified by the responsible CDP teams. For example, as illustrated in Figure 15, the current year SER for Apple Incorporation is A-, maintaining the same rating as last year. This data was effectively gathered from CDP records and answers to the questionnaires of the partner telecommunications organization as explained in the previous technical overview section.
- **Climate Targets:** The climate target KPI refers to how well the supplier is disclosing, aligning with the climate transition targets, and progressing towards those targets using transparent and coherent reporting. For the example of this supplier, the climate target rating is B meaning that they are at the Management level and not yet at the leadership

level according to the Carbon Disclosure Project, 2023 scoring methodology. In other words, this company is doing well in pursuing its climate targets but there is still room for improvement in the upcoming years.

- **Emission reduction & initiatives:** This KPI assesses the organization's initiatives to reduce GHG emissions. To do so, the level of disclosure of these initiatives is assessed as well as their impact and effectiveness. For the supplier in Figure 15, the supplier has a score of A which is the best score achievable.
- **Scope 1 & 2 emissions:** Similarly, the Scope 1 & 2 emissions KPI is generated based on the completeness and transparency of the company's reporting on Scope 1 and 2 carbon footprint. Additional points are awarded for the accuracy and independent verification of the emission data, as well as for demonstrating improvements in emissions reduction over the years.
- **Scope 3 emissions:** The final KPI utilized in this part of the designed dashboard is the Scope 3 emissions rating. Unlike the Scope 1 & 2 KPI, this rating focuses exclusively on value chain emissions, examining the fifteen different groups of value chain emissions, such as the purchased goods and services. For the selected supplier in Figure 15, the supplier has a score of A-, indicating that while they are performing well, there is still potential for potential enhancements to achieve an A grade.

To further incentivize suppliers to engage with reporting organizations, benchmarking their performance against competitors within the same industry can be highly effective. As illustrated in Figure 15, 27% more companies in the same industry have achieved a higher SER of A. Such visualizations are crucial for vendor and supplier managers, as they provide clear, comparative insights that can drive strategic discussions and initiatives aimed at improving scores in the upcoming year. This competitive benchmarking not only highlights areas for improvement but also fosters a sense of urgency and motivation among suppliers to adopt best practices and enhance their sustainability efforts. Additionally, this visualization replaced manual interventions that vendor managers were doing every time they had to conduct conversations with the suppliers. With the established dashboard, the vendor manager is only asked to choose the concerned supplier from the list of suppliers, and the rest of the visualizations and KPIs are automatically generated.

4.6.3 PoC: Data Collection

Following the supplier engagement phase, the next steps are data collection and emission calculation. For the scope of this PoC, the industry telecommunication organization provided data from four different suppliers. Moreover, this PoC specifically targets the first category of the value chain emissions which is the purchased goods and services. In fact, this category accounts for over 54% of the overall Scope 3 emissions for the telecommunication company in 2023, making it a significant focus area for emission reduction efforts. Table 5 shows the different utilized purchased goods and services in this study such as mobile network equipment, routers, phones, and transportation due to network construction along with their emission factors, quantities, and units.

Table 5: Purchased Goods and Services

Supplier	**Product**	**Emission Factor**	**Quantity**	**Units**	**Period**
Supplier #1	Mobile network equipment	23 kgCO2/kg	24000 kg	9000	Yearly
Supplier #2	Router	23 kgCO2/kg	300 kg	100	Yearly
Supplier #3	Phone	65 kgCO2/kg	NA	30000	Yearly
Supplier #4	Network Construction	2.68 kgCO2/l	2000 liters	NA	Monthly

The emission factors were provided by the telecommunication industry partner and were used by the company for the last years since the base year and were verified and validated by sustainability consultants. However, for the scope of this study and for privacy, the number of units and quantities were not the actual figures used by the company but rather estimations that are close to reality as affirmed by the sustainability field experts. The first supplier is a provider of mobile network equipment and the provided data concerns the manufacturing stage only. The second supplier provides specific internet router categories for customer solutions and the emission factor only concerns the manufacturing stage. The third supplier is a large mobile phone vendor providing different types and models of phones. The used emission factor describes a group of different phone models rather than a specific one and the emission factor covers the manufacturing stage solely. Finally, The fourth supplier provides network building services and maintenance. For that supplier, the provided emission factor covers the diesel fuel consumed by trucks and excavators in liters for establishing network poles and related facilities.

The given data was ingested into the system via an API by sending a POST request with the necessary JSON object that includes the product or service information. This approach allows for automated data integration from various sources while handling use cases where important and required data points are missing. Alternatively, users have the option to manually enter data through the dashboard interface, as illustrated in Figure 16. This manual entry method provides flexibility and accessibility for users who may need to input data directly or make adjustments to it. The dual methods of data ingestion enhance the system's versatility, making it suitable for different operational needs and ensuring comprehensive data capture for emissions reporting and analysis.

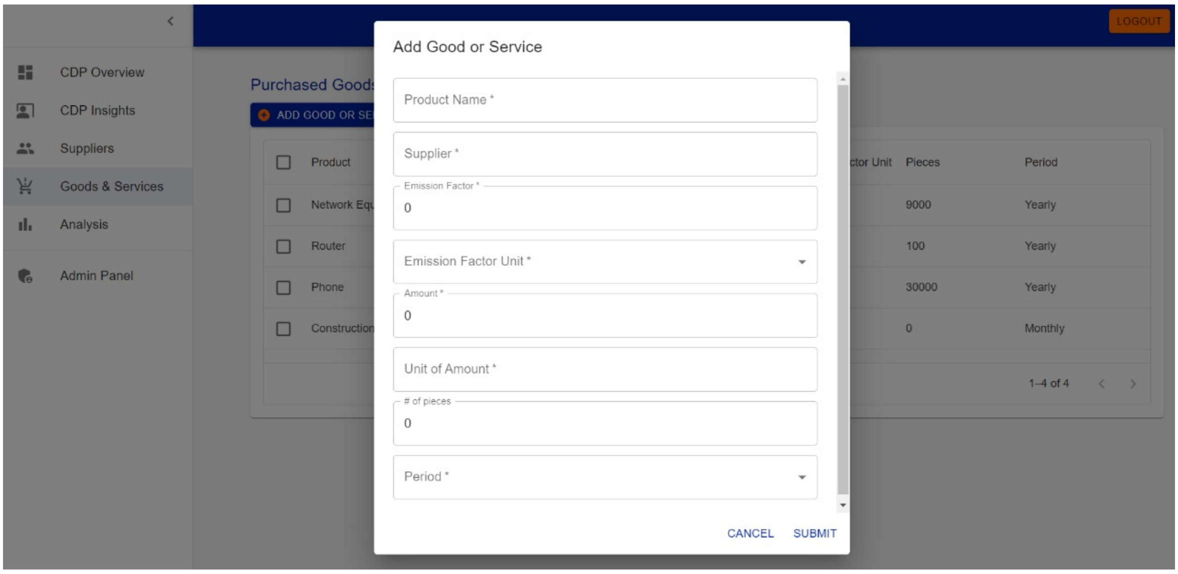

Figure 16: Purchased Goods and Services

4.6.4 PoC: Emission Calculation

Once the emission data is collected, the procedure is then followed by the calculation of the total emissions generated by the given purchased goods and services using the GHG Protocol calculation methods. Drawing from the decision tree illustrated in Figure 6, the average-data method was utilized as it best matches the available data. After converting all the provided data to a yearly basis and applying the average-data method, the total emissions summed up to 2573.22 tCO2 for the year 2023. That number constitutes around 0.96% of the total Scope 3 emissions of the 2023 year of the partner telecommunication organization as the total number amounted to 268,879 tCO2. The overall climate transition goal of the telecommunication company was to reduce the total Scope 3 emission to 138,598 tCO2 by 2030 which translates to a 42% reduction since the base year as noted in the annual sustainability report. However, since the data used for this PoC is limited to four products and services from only four specific suppliers, a relative goal had to be computed. The relative goal is computed by taking 0.96% of the 2030 overall target. In other words, for the chosen products and services, the total emissions in 2023 which was 2573.22 tCO2 needs to be reduced to 1326.41 tCO2 by 2030 to adhere to the already set climate transition goal. More specifically, this transition constitutes a 48.45% reduction between 2023 and 2030 which represents a 6.45% difference compared to the previously established reduction rate. Thanks to the established emission calculation process, the gap was identified and reported to the field sustainability experts.

Furthermore, these calculations are automatically triggered and the metrics are updated whenever a new good or service is processed by the system. The results of the emission calculation phase are illustrated in Figure 17. The automated aspect of the tool allows the different stakeholders and users, to gain granular insights on the available data immediately.

Figure 17: Climate Targets

4.6.5 PoC: Climate Transition Goals

After calculating the total emissions of the available purchased goods and services, analyzing the climate transition goals comes next. This section of the PoC consists of computing different scenarios which are the expansion, reduction, and custom scenarios using a linear change model. As illustrated in Figure 17, the green line represents the needed reduction between the years 2021 and 2030 required to achieve the climate transition goal established by the telecommunication industry partner in their annual sustainability report. In other words, the green line represents the 48.45% reduction until 2030. On the other hand, the expansion scenario is represented by the red line and it describes the growth of the emissions in the next years until 2030. The growth is generated by calculating the increase rate of the overall Scope 3 emissions of the telecommunication industrial partner between the base year and 2023. The expansion scenario sheds light on the possibility that Scope 3 emissions of the selected goods and services might increase if reduction initiatives and strategies are not implemented on time. By establishing the expansion scenario, we can compare the gap between reaching climate transition goals and the expansion scenario. In 2030, the total Scope 3 emissions would reach 3881 tCO2. This means a gap of 2555.55 tCO2 if no reduction initiative is taken and if the growth continues between 2021 and 2023.

The custom scenario is made for users who want to establish different reduction percentages and see their impact by visually assessing if the already set climate transition goals can be achieved or not. For instance, in Figure 17, a custom reduction scenario was set to 25% by 2030 and is represented by the yellow line on the graph. Such a scenario can give immediate insights to field sustainability experts by assessing the relationship between the reduction rate and the climate transition goal. The dynamic visualization of the line of the custom scenario describes in detail the potential yearly Scope 3 emissions of the available products and services in the system.

4.6.6 PoC: Authentication and Resource Access

To ensure the dashboard is accessible and functional for various users, a registration and authentication mechanism was established. For this PoC, the authentication mechanism relied on a combination of a username and password, transmitted securely to the server using HTTP. The registration process required each username to be unique. Passwords were securely hashed and salted before being stored in the database. Moreover, the assignment of roles and user permissions were a critical feature within the system, as they forbid some users without the required permissions to access resources. As such, vendor managers are granted access to specific user interfaces and datasets related to their responsibilities, ensuring they can perform their duties without unnecessary exposure to broader system data. More specifically, the vendor managers can access functionalities related to the CDP records and are not able to edit purchased goods and services. In contrast, administrators possess a holistic view of the system, with full access to all supplier data and various KPIs and the right to edit and manage all the resources including user roles. In fact, a super user account was made for the system and was given the right to create accounts and upgrade users from vendor managers to admins roles or vice versa as a means to make the dashboard usable for the telecommunication company.

In Figure 18, the UML sequence diagram illustrates the process of authenticating a user within the system. This process is initiated when the user inputs their credentials. The client application forwards this data via an HTTP POST request to the server. Upon receiving the request, the server queries the database to fetch a user object associated with the provided email. The server then compares the input credentials with the stored credentials for the located user object with the aim of verifying it. The user is authenticated if the credentials match, in which case the server creates an access token and returns it to the client application. If the credentials do not match, the system responds with an error message, indicating that authentication has failed. This sequence ensures secure verification of user credentials and appropriate handling of authentication outcomes. Moreover, the access token is then stored in the client application of the user for a limited time and is attached to the headers of the upcoming HTTP requests.

Furthermore, the developed software provided different resources for use such as the CDP records, supplier information, and Scope 3 emission data. It was mandatory to design a mechanism to allow users to efficiently access those resources from the database and be able

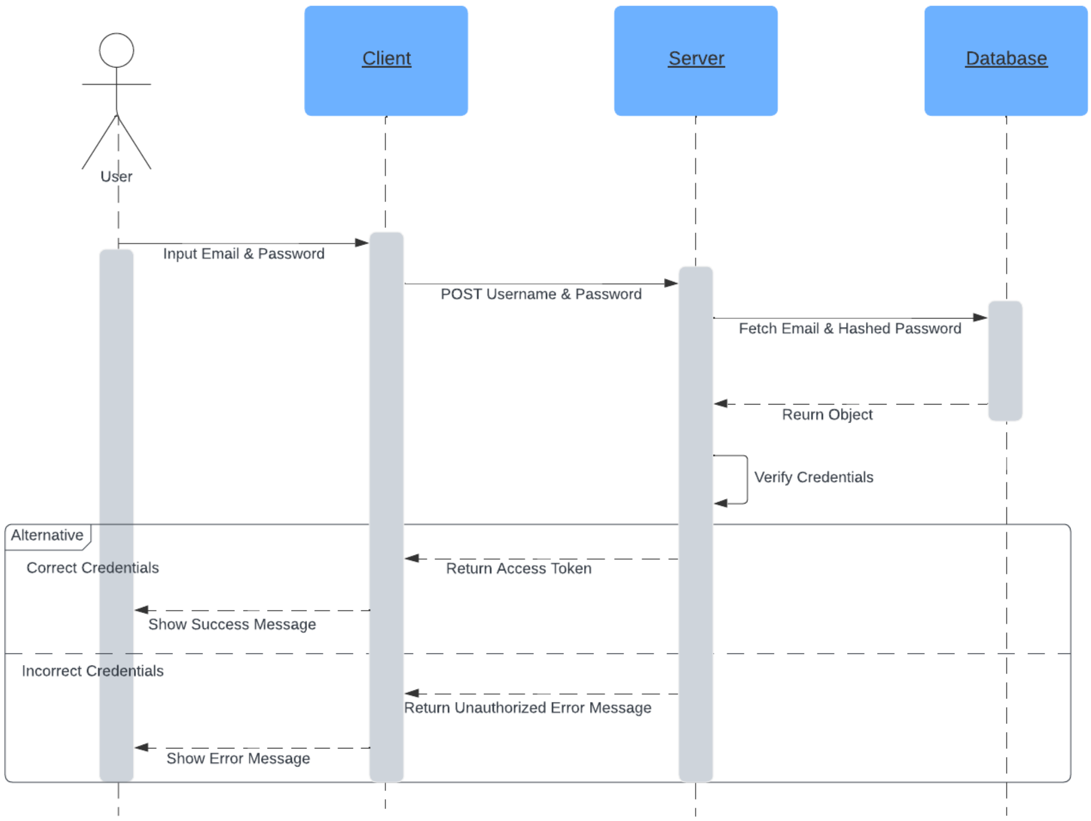

Figure 18: Authentication UML Sequence Diagram

to ensure security. The process is, illustrated on the UML sequence diagram in Figure 19, initiated with the client application requesting access to a specific resource through the use of HTTP requests such as a GET request. The server is then responsible for verifying the access token by decoding the JSON Web Token (JWT) found in the headers of the request and verifying if the role of the user matches with the requested resource. In case of a valid access token, the database is fetched for the requested resource and then forwarded back to the client if the object is found in the database. Otherwise, an error is sent to the client application specifying that the resource could not be found.

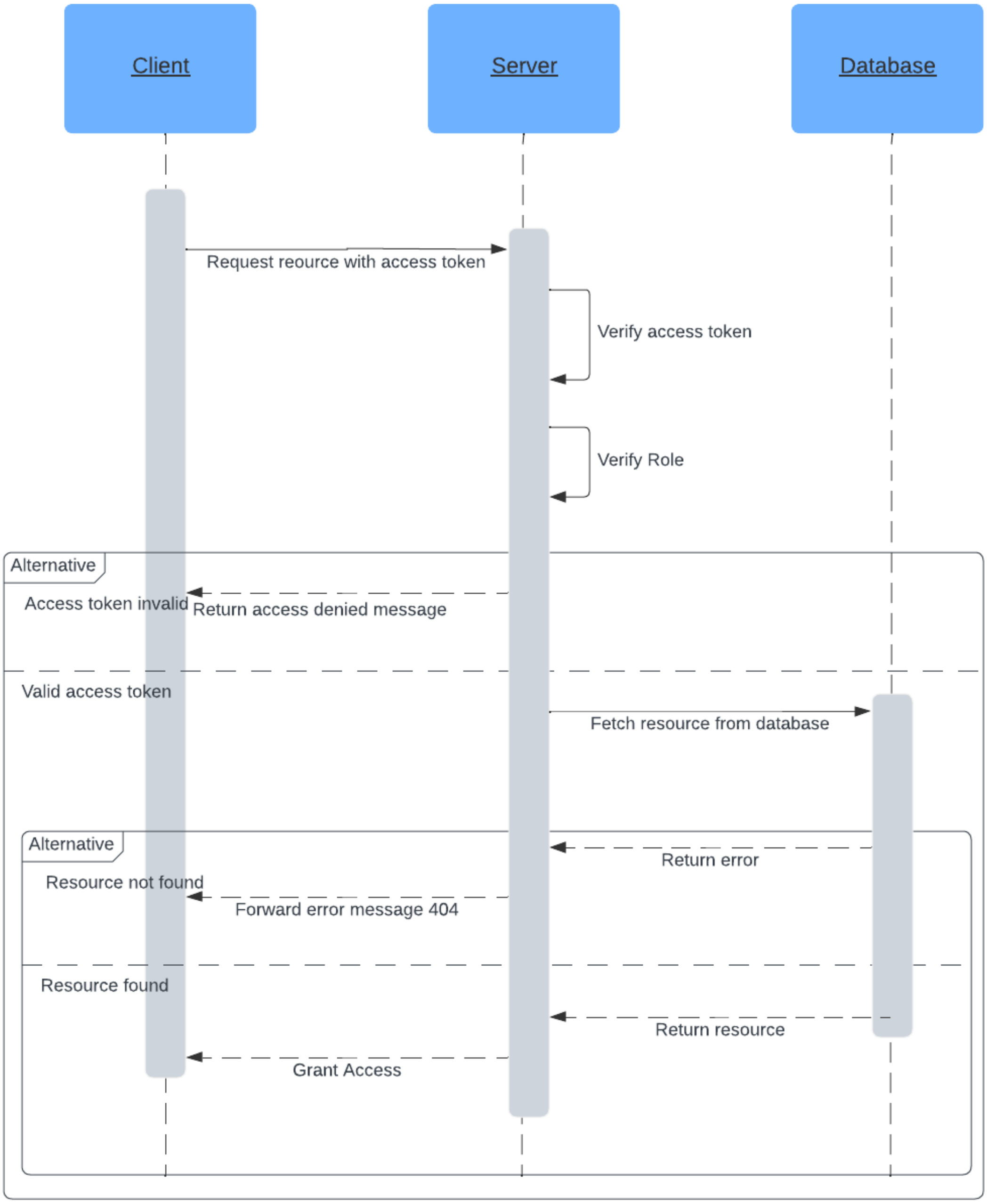

Figure 19: Resource Access UML Sequence Diagram

5 Discussion

This section discusses the results of the conducted study by going through the research questions and how they were answered. Moreover, the key findings of the study are also discussed and evaluated based on the already set study objectives. This section also tackles the different threats to validity and the adopted mitigation strategies. The threats to validity discussed in the section include external, construct, and conclusion validity.

5.1 Findings Interpretation

This study aimed to explore avenues concerning collecting, analyzing, and tracking over time value chain emissions and to improve the Scope 3 emission reporting and accounting in an industrial context. To do so, the study focuses on answering two main research questions which are “How to track and analyze Scope 3 emissions” and “What are the impacts of Scope 3 emissions on the climate transition goals of a telecommunication company?”. The following subsections discuss the research and industry gaps and how the study mitigates them by answering the research questions.

5.1.1 Discussion RQ1: How to collect, track, and analyze Scope 3 emissions

For the first research question, the aim was to explore already available frameworks and models to provide a generic step-by-step process for organizations that are in the journey of reporting and accounting for value chain emissions, especially beginners. The WRI & WBCSD, 2011 was found to be one of the main available standards for companies that are on such a mission. However, that standard failed to tackle important aspects that organizations are struggling with. For instance, supplier engagement was not a focus of such a standard. Moreover, the standard offered excessive flexibility leaving room for interpretation and uncertainty as discussed in the literature by Talbot & Boiral, 2013. Thus, to mitigate this gap and to answer the first research question of the study, a generic framework was established to guide companies on how to collect, track, and analyze Scope 3 emissions. In collaboration with an industrial partner in the field of telecommunication and using the DSRM throughout the span of the study, the framework was established and consisted of five main steps as discussed in Section 4. The five-step generic framework consists of identifying key suppliers, engaging with suppliers, collecting data, calculating the Scope 3 emissions, and finally setting or adjusting the climate transition goals. More specifically, the supplier engagement step consisted of collaborating with the value chain supplier through bi-directional conversations about emissions and climate transition goals but also through using KPIs and data-driven approaches to benchmark suppliers and create a sense of urgency and competition to increase engagement. Furthermore, the iterative nature of the proposed framework provides great value for reporting companies by enforcing the repetition of the different steps to increase the chances of improvement. The need for such a framework is very much existing within reporting organizations as there is a lack of guidance and knowledge concerning Scope 3 emissions (Juurikka, 2023.). The designed framework serves as a bird's-eye view for companies that are discovering how to collect, track, and analyze value chain emissions and reporting on them and for organizations that are struggling to engage their value chain suppliers. Additionally, to answer the first research question, more specifically, on how to collect value chain emissions, the study sheds light on API integration between reporting organizations and suppliers. Such an integration can offer great potential for automating calculation processes and removing the human from the loop while having more granular insights.

5.1.2 Discussion RQ2: What are the impacts of Scope 3 emissions on the climate transition goals of a telecommunication company?

For the second research question, the objective was to examine how Scope 3 emissions impact the climate transition goals of the telecommunications company using real-world data from the industry partner. To achieve this, the study applied the previously designed framework to the available data from the telecommunication organization and their suppliers. The implementation process involved several DSRM cycles, which were guided by the expertise of sustainability field experts from the industrial partner. Throughout these cycles, the need for automation became obvious. Consequently, an ETL pipeline was developed to clean, process, and prepare the data for further analysis. This pipeline ensured that the data was correct and readily available for use in various scenarios. Additionally, a dashboard was created to leverage the processed data effectively. This dashboard allowed for the establishment of expansion, reduction, and custom scenarios to assess their impact on the company's climate transition goals. However, the provided emission factors by the partner telecommunication company were averages and not product-specific emission factors LCA data for the chosen products and services was not available for this study.

The second research question was addressed by establishing these scenarios and determining the necessary reductions to meet the climate goals. For instance, one of the findings indicated that a 48.45% reduction in emissions was required to align with the company's objectives. This analysis provided valuable insights into the specific actions needed to achieve significant emissions reductions. Furthermore, the PoC of the software tool demonstrated the practical application of the designed framework within an industrial context. The designed and developed software enabled the use of data to validate the framework's effectiveness, highlighting its potential to support telecommunications companies in their efforts to meet climate transition goals. This practical implementation not only answered the research question but also showed the utility of the framework and data-driven approaches in achieving meaningful sustainability objectives concerning Scope 3 emissions management.

5.2 Threats to Validity

In this section, different threats to validity concerning this thesis are discussed such as the external, construct, and conclusion threats to validity along with established mitigation strategies for such threats.

5.2.1 External Validity

The findings of the thesis, especially the framework artifact, are intended to be generalizable to other companies even in different sectors beyond telecommunications. In fact, the framework was designed to be generic enough to provide a comprehensive understanding for companies new to Scope 3 emissions reporting. It aims to guide them on how to collect, track, and analyze Scope 3 emissions while effectively collaborating and engaging with suppliers using simple and available data sources such as the CDP and its different metrics.

However, one potential external threat to validity lies in the fact the PoC software tool was developed and tailored for a specific organization. Using the available data and functional requirements from one organization can potentially limit the generalizability of the results of the study. To mitigate this issue, the designed dashboard was developed modularly, enabling minimal modifications for adding new features such as covering other Scope 3 emission categories. Yet, another limitation of the study was the unavailability of product-level data for purchased goods and services, which could impact the generalizability of the results. To address this limitation, the study included data from four different types of suppliers, typical to telecommunications organizations such as network construction companies, mobile phone vendors, and router providers. This approach enhances the likelihood that the results can be generalized to other companies within the same sector as they might also have the same or similar kinds of suppliers in their value chain.

5.2.2 Construct Validity

To ensure construct validity and avoid ambiguous definitions, inconsistent measurement tools, and subjective interpretations, this study clearly defined important concepts such as Scope 3 emissions, supplier engagement, climate transition goals, and the CDP. To mitigate such issues even further, the research questions were clearly defined including a rationale for each one to ensure the alignment with the objective of the study. Furthermore, standardized tools and protocols were used such as the Scope 3 standard byWRI & WBCSD, 2011 which was referenced and used throughout this work. Additionally, the usage of the Carbon Disclosure Project, 2024 further reinforces the construct validity of the study through the usage of reliable frameworks and initiatives.

5.2.3 Conclusion Validity

Concerning the conclusion validity of the study, a threat was identified related to a key finding. While using data-driven KPIs for benchmarking suppliers is effective for driving more conversations and extracting valuable data, the validity of this approach is highly dependent on the quality and relevance of the data used for benchmarking. Poor quality or availability can lead to irrelevant comparisons of suppliers and thus incorrect decision-making.

To mitigate this issue, we utilized the official and published scoring methodology from the Carbon Disclosure Project, 2023, incorporating scores such as the SER of the current year and the previous one, and KPIs related to climate targets and Scope 3 emissions reduction initiatives. Moreover, the same types of scores were consistently used to systematically benchmark all the suppliers in the value chain of the telecommunication company. By adhering to these standardized processes, potential bias was minimized.

6 Conclusions

This study explores avenues to improve the overall Scope 3 accounting and reporting by tackling challenges such as lack of guidance concerning how to collect, and track value chain emissions and how to assess their impact on climate transition goals set by organizations. The results of the thesis were twofold. First, a generic framework was established consisting of five main steps which are identifying key suppliers, engaging with suppliers, collecting data, and adjusting or setting climate transition goals. Second, a PoC software tool was developed to assess the impact of the Scope 3 emissions of a telecommunication company partner. The tool also puts the framework into practice by using data provided by the organization. The first designed artifact, the iterative framework, directly answered the first research question of the study by providing a step-by-step workflow on how to collect, track, and assess Scope 3 emissions. Moreover, the designed software aimed to answer both the first and second research questions by using the purchased goods and service provided data to calculate the overall Scope 3 emissions and compare it to the previous set climate transition goal while establishing different scenarios such as expansion and reduction. Moreover, CDP data of all the tier 1 suppliers was used to benchmark suppliers and provide valuable insights to drive meaningful conversations and help the organization set common goals and get more accurate from its suppliers.

Furthermore, this study has both theoretical and practical contributions aiming to tackle the challenges faced by organizations concerning value chain emissions and future work can tackle the limitations of the study to further improve it and explore other avenues. On the theoretical side, future work can explore other sources of data to use for benchmarking suppliers apart from the CDP and assess which one offers better performance. Such an addition to the framework can be valuable to expand the range of usage and explore other alternatives to the CDP. Additionally, integrating the reduction actions and initiatives and their impact on financial aspects such as cost could offer potential improvement in the applicability of the proposed framework and software system. On the practical side, future work can be focused on improving technical and data-related limitations such as increasing the number of purchased goods and services used in the PoC and also covering other main categories of the value chain emissions such as capital goods and waste generated in operations.

References

Betz, S., Penzenstadler, B., Duboc, L., Chitchyan, R., Kocak, S. A., Brooks, I., Oyedeji, S., Porras, J., Seyff, N. & Venters, C. C. (2024). Lessons Learned from Developing a Sustainability Awareness Framework for Software Engineering using Design Science. *ACM Transactions on Software Engineering and Methodology* 33(5), pp. 1–39.

Bini, L. & Bellucci, M. (2020). *Integrated Sustainability Reporting*. Springer. URL: https://link.springer.com/content/pdf/10.1007/978-3-030-24954-0.pdf.

Blanco, C., Caro, F. & Corbett, C. J. (2016). The state of supply chain carbon footprinting: analysis of CDP disclosures by US firms. *Journal of Cleaner Production* 135, pp. 1189–1197.

Brander, M., Gillenwater, M. & Ascui, F. (2018). Creative accounting: A critical perspective on the market-based method for reporting purchased electricity (scope 2) emissions. *Energy Policy* 112, pp. 29–33.

Carbon Disclosure Project (2023). *CDP Scoring Methodology Overview*. https://cdn.cdp.net/cdp-production/cms/guidance_docs/pdfs/000/000/233/original/Scoring-Introduction.pdf. https://cdn.cdp.net/cdp-production/cms/guidance_docs/pdfs/000/000/233/original/Scoring-Introduction.pdf.

Carbon Disclosure Project (2024). *CDP Climate Change Report 2024*. Carbon Disclosure Project. Available at: https://www.cdp.net/en. URL: https://www.cdp.net/en.

Chehrehgosha Kenari, A. (2024). The use of digital tools in Scope 3 emissions reporting. MA thesis. University of Oulu.

Dahlmann, F. & Roehrich, J. K. (2019). Sustainable supply chain management and partner engagement to manage climate change information. *Business Strategy and the Environment* 28(8), pp. 1632–1647.

Downie, J. & Stubbs, W. (2013). Evaluation of Australian companiesś scope 3 greenhouse gas emissions assessments. *Journal of Cleaner Production* 56, pp. 156–163.

Guo, T., Zha, G., Lee, C. L. & Tang, Q. (2020). Does corporate green ranking reflect carbon-mitigation performance? *Journal of Cleaner Production* 277, p. 123601.

Hettler, M. & Graf-Vlachy, L. (2024). Corporate scope 3 carbon emission reporting as an enabler of supply chain decarbonization: A systematic review and comprehensive research agenda. *Business Strategy and the Environment* 33(2), pp. 263–282.

Hevner, A. & Chatterjee, S. (2010). *Design research in information systems: theory and practice*. Vol. 22. Springer Science & Business Media.

Huang, Y. A., Lenzen, M., Weber, C. L., Murray, J. & Matthews, H. S. (2009). The role of input–output analysis for the screening of corporate carbon footprints. *Economic Systems Research* 21(3), pp. 217–242.

Institute, W. R. & Sustainable Development, W. B. C. for (2014). *GHG Protocol Scope 2 Guidance: An Amendment to the GHG Protocol Corporate Standard*. URL: https://ghgprotocol.org/sites/default/files/GHG%20Protocol%20Scope%202%20Guidance.pdf.

Institute, W. R. & Sustainable Development, W. B. C. for (2015). *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (Revised Edition)*. URL: https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.

Juurikka, V. (2023). Navigating the complexities of carbon accounting in the food value chain–scope 3 emissions accounting challenges in the Finnish food industry sector. MA thesis. Helsingin yliopisto.

Lestari, N. & Xiong, J. (2022). *The Impact of Logistics Provider Data Maturity in Defining Scope 3 Transportation Emissions*. Tech. rep. MIT. URL: https://dspace.mit.edu/bitstream/handle/1721.1/142955/SCM38_Xiong_Lestari_Project.pdf?sequence=1&isAllowed=y.

Li, M., Wiedmann, T. & Hadjikakou, M. (2019). Enabling full supply chain corporate responsibility: scope 3 emissions targets for ambitious climate change mitigation. *Environmental science & technology* 54(1), pp. 400–411.

Llamas-Orozco, J. A., Meng, F. & Walker, G. S. (2023). Estimating the environmental impacts of global lithium-ion battery supply chain: A temporal, geographical, and technological perspective. *PNAS Nexus*. URL: https://academic.oup.com/pnasnexus/article-pdf/doi/10.1093/pnasnexus/pgad361/53812916/pgad361.pdf.

Nguyen, Q., Diaz-Rainey, I., Kitto, A. & Ben I. McNeil Nicholas A. Pittman, R. Z. (2023). Scope 3 Emissions: Data Quality and Machine Learning Prediction Accuracy. *PLOS Climate*. URL: https://journals.plos.org/climate/article?id=10.1371/journal.pclm.0000208.

Patchell, J. (2018). Can the implications of the GHG Protocol's scope 3 standard be realized? *Journal of Cleaner Production* 185, pp. 941–958.

Protocol, G. G. (2013). *Technical Guidance for Calculating Scope 3 Emissions (version 1.0)*. https://ghgprotocol.org/sites/default/files/standards/Scope3_Calculation_Guidance_0.pdf. World Resources Institute and World Business Council for Sustainable Development. Washington, DC.

Royo, B. (2020). Measuring and allocating scope 3 ghg emissions. *Towards User-Centric Transport in Europe 2: Enablers of Inclusive, Seamless and Sustainable Mobility*, pp. 200–211.

Shin, R. & Searcy, C. (2018). Evaluating the greenhouse gas emissions in the craft beer industry: an assessment of challenges and benefits of greenhouse gas accounting. *Sustainability* 10(11), p. 4191.

Sipilä, A., Partanen, L. & Porras, J. (2023). Carbon Footprint Calculations for a Software Company–Adapting GHG Protocol Scopes 1, 2 and 3 to the Software Industry. In: *Inter-*

national Conference on Software Business. Springer Nature Switzerland Cham, pp. 442–455.

Stenzel, A. & Waichman, I. (2023). Supply-chain data sharing for scope 3 emissions. *npj Climate Action* 2(1), p. 7.

Talbot, D. & Boiral, O. (2013). Can we trust corporates GHG inventories? An investigation among Canada's large final emitters. *Energy Policy* 63, pp. 1075–1085.

Tidy, M., Wang, X. & Hall, M. (2016). The role of Supplier Relationship Management in reducing Greenhouse Gas emissions from food supply chains: supplier engagement in the UK supermarket sector. *Journal of Cleaner Production* 112, pp. 3294–3305.

United Nations (2023). *With Climate Crisis Generating Growing Threats to Global Peace*. This article discusses how climate change poses a major threat to both global and local communities worldwide. URL: https://press.un.org/en/2023/sc15318.doc.htm.

United Nations Framework Convention on Climate Change (2015). *Paris Agreement*. The Paris Agreement sets ambitious targets to limit global warming to well below 2 degrees Celsius and ideally to 1.5 degrees Celsius above pre-industrial levels. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

WRI & WBCSD (2011). *GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard*. URL: https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf.