Performance Measurement in Supply Chain Greenhouse Gas Accounting: Assessing the State of the Practice

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ABSTRACT

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Kian Rahimidehban

Supply chain (upstream scope 3) greenhouse gas emissions often account for the majority of a company's total greenhouse gas emissions; however, they are often more challenging to measure and manage than emissions from direct sources (scope 1) or purchased energy (scope 2). Companies use various calculation methodologies and data sources to estimate supply chain emissions. This study evaluated manufacturing and services industry companies' supply chain emissions disclosures to CDP through the lens of GHG Protocol accounting and Supply Chain Performance Measurement (SCPM) principles. A set of indicators for assessing accounting practices according to three GHG Protocol accounting principles –measurement should be complete, accurate, and transparent– and two SCPM metric elements –metrics should show what is happening in a supply chain and be verifiable– were proposed. The results showed that, at most, 32% of disclosures follow both SCPM elements and GHG Protocol principles, and at most, emissions for 6% of supply chain categories are calculated using the emission data collected from suppliers. The results also showed that at least 39% and 32% of supply chain categories have transparency and completeness issues, respectively. This study also found that supply chain disclosures that are more transparent are more likely to be verified by a third party than those that are less transparent. However, a significant number of disclosures that lack transparency is still verified. Overall, the current completeness, accuracy, and transparency issues likely impede companies from reaching scope 3 emissions calculating goals.

Keywords: corporate carbon accounting, scope 3, supply chain emissions, Greenhouse Gas Protocol, Supply Chain Performance Measurement, emission estimation

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> *"The real value of a real education ... has almost nothing to do with knowledge, and everything to do with simple awareness; awareness of what is so real and essential, so hidden in plain sight all around us, all the time...It is unimaginably hard to do this, to stay conscious and alive in the adult world day in and day out".* David Foster Wallace.

International student life is replete with stories and experiences –happy and sad, exciting and dull. I was no exception. I had the privilege of reading papers, working with data, and exploring productive and unproductive research paths for weeks and months. I had the privilege of studying and teaching, developing my skills and knowledge, and helping other students. I had the privilege of meeting kind and smart people along this journey. And, of course, there was sorrow as well – the sorrow of the family and culture left behind, the sorrow of losing loved ones, and the worry for all people in my home country, Iran, fighting for their freedom and rights.

Words cannot describe my heartfelt appreciation for my advisor Dr Shannon Lloyd. I would not have been able to experience this journey without her genuine help, support, and encouragement. I simply cannot return her favour. I will, however, do my best to pay it forward. I am thankful to her in perpetuity.

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To my dad, mom, and brother, your unconditional love and support are precious assets that I would not exchange for anything. I am grateful that I have you by my side.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

1. INTRODUCTION

1.1. Background and Motivation

1.1.1. Significance of Scope 3 Emissions

Greenhouse gas (GHG) emissions from an organization are categorized into direct and indirect emissions. The GHG Protocol, a partnership between World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), has established and published the most used GHG account standards since 2001 (WRI/WBCSD, 2004)). GHG Protocol standards refer to direct emissions from sources controlled or owned by an organization as scope 1 emissions. Indirect emissions from purchased energy consumed by an organization are referred to as scope 2 emissions. All other indirect emissions, including those upstream and downstream of an organization, are referred to as scope 3 emissions. (WRI/WBCSD, 2011).

Scope 3 emissions tend to be a significant portion of companies' GHG emissions. According to (CDP, 2022a), scope 3 emissions on average include 75% of a company's emissions. **Figure *1*** shows the breakdown of three emission scopes by industry sectors (CDP, 2022b; Lloyd et al., 2022). For example, the figure shows that almost 100% of emissions for companies in the financial services sectors are related to their scope 3 emissions. Out of 16 industry sectors assessed, scope 3 emissions account for more than 50% of total emissions for 12 industry sectors; the four industry sectors are cement, steel, transport services, and electric utilities. Findings of the literature also support that scope 3 emissions can be more significant than scope 1 and scope 2. For example, Dragomir, (2012) showed that scope 3 emission of an oil and gas company is 15 times bigger than companies' direct emissions, and Ozawa-Meida et al., (2013) estimated GHG emissions of a university, and scope 3 accounted for 79% of the total emissions.

GHG Protocol corporate accounting standard requires companies to report all scope 1 and 2 emissions but considers scope 3 reporting as optional. However, there is growing pressure from diverse stakeholders, such as governments and investors, for companies to disclose scope 3 emissions. The IFRS a not-for-profit foundation that develops global accounting standards through its International Accounting Standards Board, established the International Sustainability Standards Board in 2021 to establish sustainability disclosure standards to provide investors with the sustainability-related information needed for informed decision-making. In October 2022, the International Sustainability Standards Board voted unanimously to require companies to disclose GHG emissions for all three scopes, including scope 3(IFRS, 2022). In March 2022, the U.S. Securities and Exchange Commission released a proposal to standardize climate-related disclosure for investors for public comment. The proposal would require companies (except small companies) to report their scope 3 emissions when they are material to investors or the reporting company has scope 3 emission targets (SEC, 2022). In June 2022, European Union leaders reached an agreement to revise non-financial disclosure, including requiring companies to disclose scope 3 emissions where relevant (e.g., scope 3 categories with significant emissions) (European Council, 2022). FSB (Financial Stability Board) is an international body that monitors and recommends a global financial system (FSB, n.d.). They developed Task Force on Climate-Related Financial

Disclosures (TCFD) to provide recommendations on the types of information that companies should disclose to support stakeholders, such as investors (TCFD, n.d.). In 2021, TCFD surveyed 100 climate-disclosure users, 106- climate disclosure preparers, and 46 other respondents and close to 95% of the respondents mentioned that scope 3 emissions disclosure is useful for decision-making(TCFD, 2021).

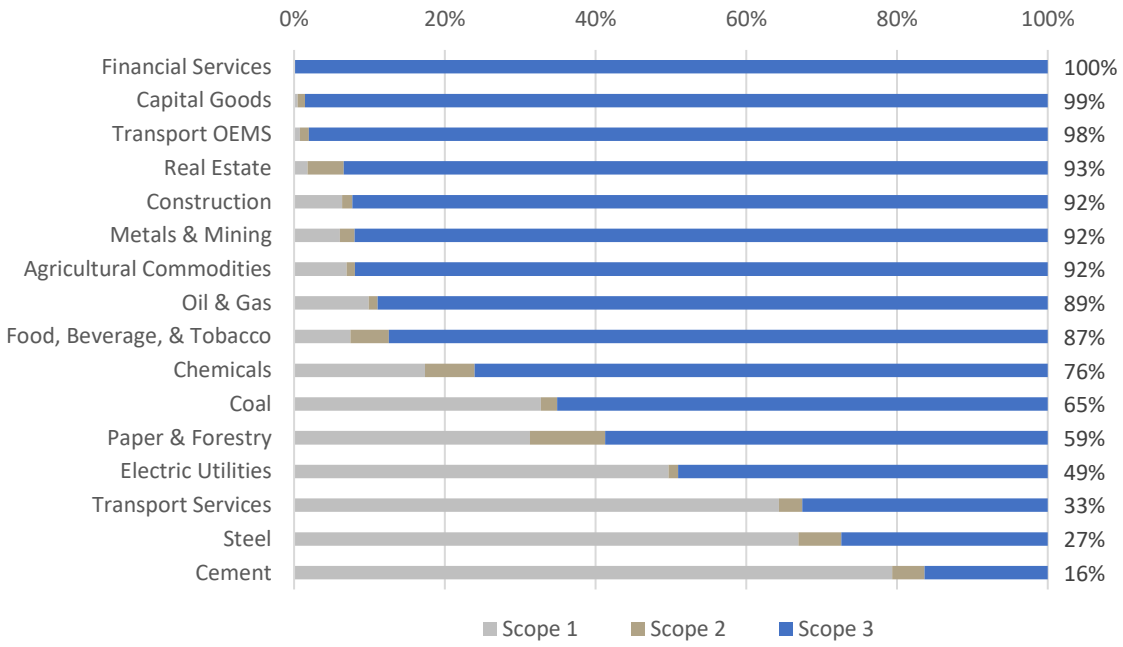

Figure 1. Break down of emission scopes by industry sectors (CDP, 2022b)

1.1.2. Significance of Supply Chain Emissions

Supply chain emissions are the upstream portion of scope 3 emissions. For many industries, supply chain emissions account for most of a company's total emissions (Hertwich and Wood, 2018). CDP (2020a), which administers a global environmental disclosure system, reported that the supply chain emissions of more than 8,000 disclosing companies were 11.4 times higher, on average, than their direct operating emissions. Another study based on CDP disclosure data considered emissions from raw material extraction through end-product manufacturing, determining that the supply chains of eight industries (i.e., food, construction, fashion, fast-moving consumer goods, electronics, automotive, professional services and freight) account for more than 50% of global emissions (WEF/BCG, 2021). In another study, Matthews et al. (2008) estimated that, on average, across all US sectors, upstream scope 3 emissions account for 74% of their total GHG emissions. In addition, global supply chain emissions are increasing faster than collective scope 1 and 2 emissions (Hertwich and Wood, 2018).

1.1.3. Measuring Scope 3 Emissions

The GHG Protocol Corporate Value Chain (scope 3) Accounting and Reporting Standard provides the general approaches and guidelines to measure supply chain emissions for companies (WRI/WBCSD, 2011). The Protocol provides two approaches to measure scope 3 emissions – direct measurements and calculations. Direct measurement is the quantification of emissions by direct monitoring, mass balance and stoichiometry. The calculation is accomplished by multiplying activity data with the corresponding emission factor. Activity data is the level of an activity that results in GHG emissions, and an emission factor is the average amount of emissions generated per unit activity. As emissions are not measured, this approach results in estimates of GHG emissions. According to the GHG Protocol, the calculation is generally used to estimate GHG emissions (Hoepner and Rogelj, 2021; WRI/WBCSD, 2011).

Equation (1) is used to estimate emissions from activity and normalize each GHG emission according to its global warming potential (GWP).

$$GHG = \sum_{i=1}^{n} amount\ of\ activity\ \times\ EF_i \times GWP_i \tag{1}$$

GHG emissions differ in their ability to absorb energy and how long they stay in the atmosphere (IPCC, 2007). Global Warming Potential (GWP) is a metric for comparing the global warming impact of each GHG (e.g., N_2O). For a given GHG, the GWP is a measure of the how much energy will be absorbed by a unit of emissions over a given period of time (usually 100 years) relative the amount of energy that would be absorbed by a unit of carbon dioxide (CO_2) emissions (WRI/WBCSD, 2004). These metrics can be extracted from Intergovernmental Panel on Climate Change reports (IPCC) (IPCC, 2007).

The GHG Protocol defines fifteen categories for scope 3 emissions. **Table 1** shows these categories. These emissions are divided into upstream and downstream for any organization. The GHG Protocol's scope 3 Technical Guidance (WRI/WBCSD, 2013) provides detailed guidelines for calculating emissions for each scope 3 category.

Table 1. Scope 3 categories

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

This study focuses on upstream scope 3 emissions. Here the verbatim definition for each emission category is provided according to the GHG Protocol (WRI/WBCSD, 2011).

1. **Purchased goods and services:** "Extraction, production, and transportation of goods and services purchased or acquired by the reporting company in the reporting year".

2. **Capital goods:** "Extraction, production, and transportation of capital goods purchased or acquired by the reporting company in the reporting year".

3. **Fuel- and energy- related activities (not included in scope 1 or scope 2):** "Extraction, production, and transportation of fuels and energy purchased or acquired by the reporting company in the reporting year, not already accounted for in scope 1 or scope 2, including".

4. **Upstream transportation and distribution:** "Transportation and distribution of products purchased by the reporting company in the reporting year between a company's tier 1 suppliers and its own operations (in vehicles and facilities not owned or controlled by the reporting company)". Also, **"**Transportation and distribution services purchased by the reporting company in the reporting year, including inbound logistics, outbound logistics (e.g., of sold products), and transportation and distribution between a company's own facilities (in vehicles and facilities not owned or controlled by the reporting company)"

5. **Waste generated in operations:** " Disposal and treatment of waste generated in the reporting company's operations in the reporting year (in facilities not owned or controlled by the reporting company)".

6. **Business travel**: " Transportation of employees for business-related activities during the reporting year (in vehicles not owned or operated by the reporting company)"

7. **Employee commuting:** "Transportation of employees between their homes and their worksites during the reporting year (in vehicles not owned or operated by the reporting company)".

8. **Upstream leased assets:** "Operation of assets leased by the reporting company (lessee) in the reporting year and not included in scope 1 and scope 2 – reported by lessee".

Two types of emission factor are used to calculate emissions - combustion emission factors and life cycle emission factors (WRI/WBCSD, 2011). Combustion emission factors include the emission from the combustion of a fuel (e.g., diesel fuel). Life cycle emission factors include all emissions associated with the life cycle of a product or service. For example, for fuel, this would include emissions from fuel extraction, production, transportation, storage, and combustion. In general, upstream life cycle emission factors should be used to estimate supply chain emissions. Table 5.4 (p.34) of Scope 3 Standard (WRI/WBCSD, 2011) specifies the minimum boundaries for

each scope 3 category that should be included in companies' emission inventories. For example, for the purchased goods and services category, companies should include all upstream (also known as cradle-to-gate) emissions of acquired goods and services.

The GHG Protocol also divides the type of data to measure scope 3 emissions into primary and secondary. Primary data are specific to the activities in a company's values chain. In other words, primary supply chain data refers to emission estimates obtained directly from suppliers or others that reflect the emissions estimated for the specific activities occurring in the company's supply chain. Secondary data are not based on specific activities in a company's value chain (Downie and Stubbs, 2012). Rather, it tends to represent industry-averages or proxy estimates from similar activities. Companies may also choose to use a combination of primary and secondary data to estimate their scope 3 emissions. In this case, the company may collect primary data as available for some emission sources and use secondary data for the remaining emission sources (Erhard et al., 2017; Johannes et al., 2019; SBTi, 2018; WRI/WBCSD, 2011).

1.1.4. Challenges of Calculating Supply Chain Emissions

Collection of primary data from suppliers is often challenging. Modern supply chains can have five to six tiers of suppliers spanning the globe with the ability to rapidly re-configure, e.g., in response to price fluctuations (Hassini et al., 2012). Moreover, supply chains have not been designed to be transparent (Bateman and Bonanni, 2019). According to a study, 49 per cent of global manufacturing executives are unable to trace their supply chain beyond tier 1 suppliers (Hans, 2013). Even when companies can identify suppliers, they face multiple challenges in obtaining GHG emission data, with companies and suppliers seeking to protect their competitive advantage and avoid exposure to criticism (Bateman and Bonanni, 2019), lacking tools and resources to collect and share relevant and accurate information (Johannes et al., 2019; WEF/BCG, 2021; Zhang et al., 2022), and unable to make the business case for investing in GHG emission transparency (WEF/BCG, 2021; Zhang et al., 2022).

Given the lack of access to emission data from suppliers, companies tend to use proprietary or publicly available emission factors derived from secondary data (Busch et al., 2020; Downie and Stubbs, 2012; Patchell, 2018). This includes industry-average, environmentally extended input-output (EEIO) (Minx et al., 2009; Suh, 2009), and proxy data. Emission factors tend to be activity-based or spend-based. Activity-based emission factors are estimates of emissions per unit activity, such as mass of material produced, hours of time operated or kilograms of waste generated. Spend-based emission factors are derived from (EEIO) models, which estimate emissions associated with a purchased good or service based on the amount of emission generated by each industry and the economic transactions throughout an economy and take the form of, for example, kg CO_2 per dollar purchase value (Erhard et al., 2017; WRI/WBCSD, 2011).

Life cycle assessment (LCA) is a more detailed and comprehensive method of estimating supply chain emissions and it is a baseline of carbon footprinting (Finkbeiner and Bach, 2021). Companies conduct LCAs to measure the life cycle environmental impacts of their products and services (Alvarez et al., 2019; Kennelly et al., 2019). In addition to GHG emissions, these assessments often cover a diverse set of environmental impacts (e.g., water use, land use, and

chemical releases). Both primary and secondary data can be used in an LCA study. Also, there are different methodologies for conducting and LCA study. Crawford et al. (2018) categorize these methods into process-based LCA, input-output LCA, and hybrid LCA. Process-based LCA is a bottom-up approach in which the environmental impacts associated with all processes in a product life cycle are assessed. Input-output LCA refers to the use of EEIO models for estimating emissions. And lastly, hybrid LCA refers to combinations of process-based and input-output LCA. Each method has its own advantages and limitations; companies and practitioners may choose different methods according to the intended goal of an LCA study (Crawford et al., 2018; Huang et al., 2009; Kennelly et al., 2019). For example, input-output LCA tends to be a less time-consuming approach for identifying emission hotspots but provides emissions measures that tend to be less accurate (Acquaye et al., 2011; Huang et al., 2009; Minx et al., 2009). Moreover, LCA

Overall, emission estimates can considerably vary depending on the used calculation methodology. For example, Harangozo and Szigeti (2017) investigated the freely available online corporate level carbon footprint calculator considering inputs such as procurements and business travel which showed considerable variations in result emission values. Steubing et al., (2022) compared carbon footprint results of products and services using ecoinvent (a process-based LCA database) and hybrid version of EXIOBASE (a hybrid LCA database) and showed that the carbon footprint of more than half of the analysed products using the two approaches differ by more than a factor 2. They also showed that estimated carbon emissions based on input-output LCA are not necessarily overestimating GHG emissions compared with LCA-based LCA. In another study, Roman-White et al., (2021) conducted a supplier-specific LCA for liquefied natural gas (LNG). Their investigation results showed a great improvement between a specific supply chain and average databases. They found that 30-43% GHG lower emission intensity in a specific supply chain compared to the studies using secondary and average databases. Akan et al., (2017) also investigated GHGs in concrete supply chains of construction industry, and concluded that a small change in supplier, transportation mode, routes, and material may change the emission values considerably.

1.1.5. Implications of Calculating Supply Chain Emissions

Companies likely choose different calculations methods depending on their business goals. According to Scope 3 Standard, these goals include "identifying GHG reduction opportunities, setting reduction targets, and tracking performance", " engaging value chain partners in GHG management", "enhancing stakeholder information and corporate reputation through public reporting", "identifying and understanding risks and opportunities associated with value chain emissions" (WRI/WBCSD, 2011).

The specificity of calculation methods and the use of primary emissions tend to affect most of these goals. Regarding the goal of "identifying GHG reduction opportunities, setting reduction targets, and tracking performance", based on equation (1), to reduce supply chain emissions, a company can reduce activity data (e.g., reduce the consumption of a purchased good, such as a raw material) and/or the emission factor associated with the activity (e.g., the cradle-to-gate emissions of the raw material). Reducing activity data might be achievable by, for example, business model innovation or improvement in product and service design. However, other

effective reduction levers, such as engagement with suppliers and procurement policy and choices (CDP, 2020a; EcoVadis, 2020; Johannes et al., 2019; Mahapatra et al., 2021; Penz and Polsa, 2018; WEF/BCG, 2021) tend to be achievable when companies engage with suppliers and rely on their emissions (this is also related to the goal of "engaging value chain partners in GHG management"). Moreover, the other issue is that proxy and secondary emission factor (extracted from databases) could potentially change (i.e., go up and down) over time and make tracking progress towards emission reduction burdensome (Shrimali, 2022). In its recent annual progress report, the Science-Based Target initiative (SBTi) reported that 96% of SBTi companies with approved science-based targets have targets covering scope 3 emissions (SBTi, 2022). However, a recent study of 25 major multinational companies found that only 8 companies (32%) disclosed a moderate level of detail on the plans for scope 3 emissions management (Zhongming and Wei, 2022). They argue that companies could further explain their strategies on scope 3 emissions management, reduction, engagement with suppliers and so forth. Scope 3 emission categories, on average, constitute 87% of these companies' emissions, and their target setting exclusion could potentially lead to misleading climate pledges (Zhongming and Wei, 2022). Moreover, even for those companies with scope 3 targets, another study shows that companies are making less progress toward achieving scope 3 emission reduction targets as opposed to other emission scopes (Giesekam et al., 2021; Qian et al., 2022; SBTi, 2021). Overall, companies use the disclosed GHG emissions to commit to carbon reduction targets. These emissions should be robust (Hoepner and Rogelj, 2021). If companies' commitments do not match their performance, they deliberately or selectively miscommunicate their performance which can lead to carbonwashing (Delmas and Burbano, 2011). In and Schumacher (2021) defined carbonwashing as greenwashing in GHG reporting defined carbon washing as greenwashing in GHG reporting that can lead to negatively affects the business goal of "enhancing stakeholder information and corporate reputation through public reporting"

1.1.6. Performance Measurement Essentials

Identifying GHG reduction opportunities, setting reduction targets, and tracking performance across supply chains can be studied through the lens of supply chain performance measurement (SCPM). In the general context, the goal of SCPM is to measure the performance of large set of tasks (e.g., logistics, inventory management, and sustainability indicators (such as GHG emissions) and to manage them for a company and its supply chain (Maestrini et al., 2017).

Within the context of performance measurement and management (PMM), according to Neely et al. (1995) a performance measure as a "metric used to quantify the efficiency and/or effectiveness of an action" and performance measurement as the "process of quantifying the efficiency and effectiveness of action" (Melnyk et al., 2014; Neely et al., 1995). Efficiency is the level of resources used to achieve the desired result and effectiveness is the extent to which the desired result is achieved (Ahi and Searcy, 2015; Neely et al., 1995). Effectiveness is more pertinent for this study since the study focuses on companies' use of GHG accounting to quantify supply chain emissions, with the intent of identifying reduction opportunities and taking action to reduce emissions.

According to Melnyk et al. (2014), a performance measure is quantifiable and verifiable. They suggest that a metric has three distinct elements: it quantifies what is happening, it is assessed according to a performance standard or target, and it is associated with consequences for being above or below target (Melnyk et al., 2014; Maestrini et al., 2017). Here, the focus is on the first element as it relates to measuring supply chain emissions –the measure should quantify what is happening and be verifiable. The last two elements are more related to target setting and achievement are outside of the scope of this study. Similarly, the Scope 3 Standard specifics five GHG accounting principles for ensuring that a "reported inventory represents a faithful, true, and fair account of a company's GHG emissions," including relevance, completeness, consistency, transparency, and accuracy. The principles of relevance, completeness, accuracy and consistency can be aligned with the element of quantifying what is happening, and the principles of consistency and transparency can be aligned with the element of being verifiable. The first two columns of **Table *2*** provides a brief description of these accounting principles and shows the proposed alignment with the performance measurement elements.

Table 2. Performance measurement and Scope 3 accounting principles

Performance Measurement Elements	**GHG Protocol Accounting Principles**
Quantify what is happening	**Relevance:** reflect company's emissions and supports the needs of decision-makers
	Completeness: account for all scope 3 emissions and discloses and justifies exclusions
	Accuracy: avoid overestimating or underestimating emissions, reduce uncertainty, enable users to make decisions with reasonable confidence
	Consistency: use consistent methodologies over time, describe and justify methodological changes
Verifiable	**Transparency**: disclose assumptions, methodologies, data sources, exclusions, and other relevant information clearly, factually, and in a manner that enables review and assurance

1.2. This Study

1.2.1 Research Objective and Aim

Given the significance of supply chain GHG emissions, the growing demands for their disclosure, the complexities of emissions calculation, and the effects of calculations on supply chain emission accounting goals, this study evaluates the recent practices of supply chain emission accounting and disclosure. This study adds to the body of literature on scope 3 and supply chain GHG emissions accounting by evaluating supply chain emissions disclosures through the lens of supply chain performance measurement and GHG Protocol accounting principles. The study investigates to what extent SCPM metric elements –quantify what is happening and verifiability– and GHG Protocol accounting principles –completeness, accuracy, and transparency– are fulfilled in the companies' emission disclosures. The two principles of relevance and transparency are outside the scope of this study and will be further explained in section 2.3

The results provide a structured understanding of current supply chain GHG emissions accounting practices through a set of indicators. Based on these results, shortcomings of current practices are identified and potential improvements in supply chain GHG accounting and disclosure are suggested.

1.2.2 Thesis Contribution

This thesis sheds light on companies' supply chain emission disclosure to CDP by:

- Investigating the alignment of corporate supply chain carbon accounting principles and supply chain performance measure (SCPM) elements and proposing seven indicators to evaluate whether companies' supply chain carbon disclosure to CDP are complete, accurate, and transparent.
- Categorizing companies' explanations for excluding supply chain emissions through inductive coding.
- Categorizing the data sources and calculation methods used by companies to estimate supply chain emissions and analyzing the extent to which supplier specific emission data is used.
- Evaluating whether more complete and transparent disclosures are more likely to be verified by a third-party.

1.2.3 Thesis Layout

This study is structured as follows. CHAPTER 2 describes the methodology, dataset, and indicators developed and used in this study. CHAPTER 3 presents the results from using the developed indicators to assess companies' 2020 supply chain disclosures to CDP. CHAPTER 4 summarizes the findings and provides recommendations for different stakeholders. Lastly, the APPENDIX provides supplementary tables that summarize the information coded in this study.

CHAPTER 2

2. METHODOLOGY

2.1. Overview of Companies Analyzed

Corporate scope 3 disclosure information were obtained from the 2020 CDP investor and supply chain datasets (CDP, 2020b), which includes corporate responses to the CDP Climate Change 2020 Questionnaire (CDP, 2020b). CDP requires that companies provide data for a one-year reporting period that has already passed (e.g., the previous calendar or fiscal year). The study considered data for companies in two of the 13 primary industries as defined by CDP's Activity Classification System (CDP, 2022a) –manufacturing and services. These companies are of interest because they account for a large share of companies in the CDP dataset (58% of disclosures in 2020 of the total of 4,524 companies (**Figure *3***) and supply chain emissions account for a large portion of their total GHG emissions. Hertwich and Wood (2018) estimated that a supply chain CO_2 emissions account for roughly 80% total CO_2 emissions in manufacturing and 70% in services. The data were merged from the investor and supply chain CDP datasets for these two industries, removing duplicate data for companies included in both datasets.

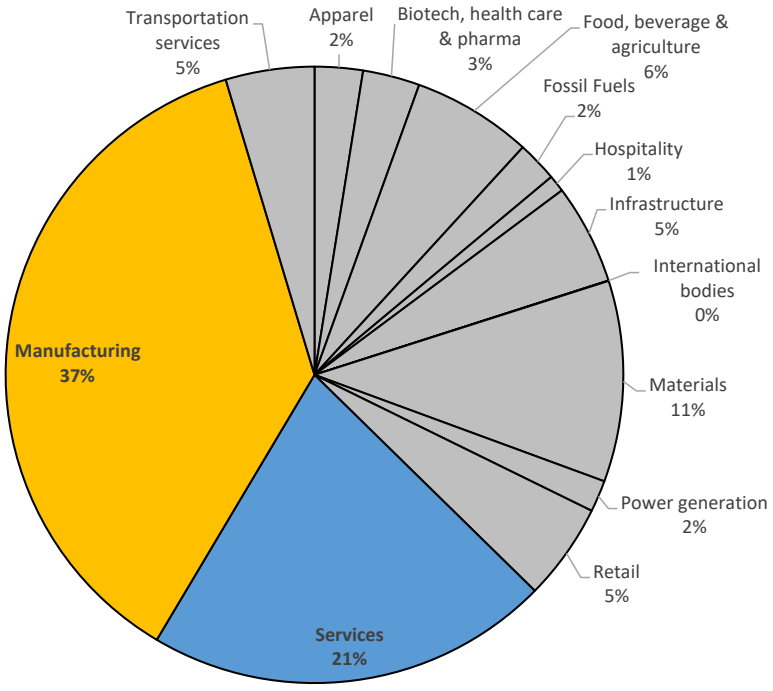

Figure 2. Companies disclosed to CDP-2020 by their primary industry –companies in manufacturing and services industries were selected for this study

Table 3 summarizes the number of observations extracted from the CDP datasets. In 2020, 1666 manufacturing companies and 958 services industry companies disclosed climate data to CDP and agreed to make their data public. Of the disclosing companies, 1028 manufacturing companies and 763 services industry companies provided evaluation status for at least one of the seven supply chain emission categories. Of these, 723 manufacturing companies and 700 of services industry companies completed text fields in English. Information disclosed for each of the seven supply chain categories were considered for these companies, giving a total of 9961 company-supply chain category observations.

Table 3. Overview of observations

Sample	Manufacturing	Services	Total
Companies disclosing climate data	1666	958	2624
Companies considering at least one supply chain category	1028 (62%)	763 (80%)	1791 (68%)
Companies with supply chain information in English	723 (43%)	700 (73%)	1423 (54%)
Company-supply chain categories considered	5061	4900	9961

Figure *3* shows the distribution of companies considered in this study (i.e., with supply chain information disclosed and in English) by their countries of origin. Considering both industries, the top three countries with the highest number of disclosures in the dataset are the United states (23%), United Kingdom (10%), and China (9%).

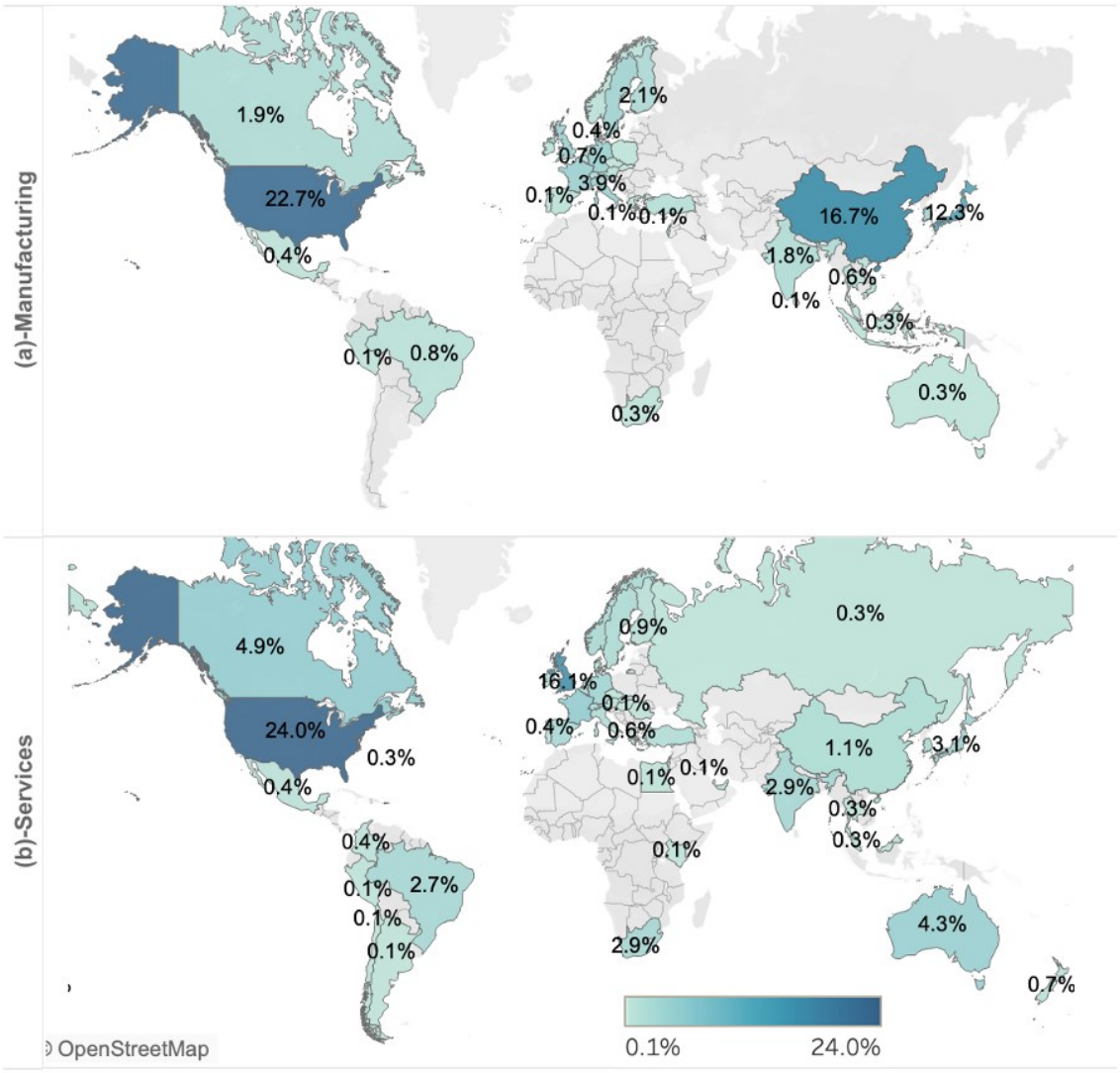

Figure 3. Distribution of companies' origin of countries considered in this study

2.2. Overview of Supply Chain Categories Analyzed

Eight of the fifteen categories of scope 3 categories included in the 2020 CDP questionnaire are related to upstream activities. Information disclosed for seven categories were considered, i.e., purchased goods and services, capital goods, fuel- and energy-related activities not included in scope 1 and scope 2, upstream transportation and distribution, waste generated in operations, business travel, and upstream leased assets. Since the seventh category, employee commuting, is not associated with supply chain emissions, it is excluded from this study. For companies in the manufacturing and services industries, scope 3 emissions data were retrieved for the mentioned seven scope 3 categories from the fields corresponding to sections C6.5 and C10.1c of the 2020 CDP questionnaire. Question C6.5.C1 of the 2020 CDP questionnaire included a set of five

predefined options that companies select to specify the "evaluation status" of each scope 3 category. All companies that assigned one of the following evaluation statuses to at least one of the seven supply chain categories: relevant, calculated; relevant, not yet calculated; rot relevant, calculated; or not relevant, explanation provided were included. This was chosen to represent companies that considered supply chain emissions in their GHG disclosure. Finally, companies that completed the questionnaire in a language other than English were excluded.

2.3. Indicators Developed to Assess Accounting and Supply Chain Performance Elements

Companies' CDP disclosures are insufficient for rigorously assessing the relevance, completeness, accuracy, consistency, and transparency of disclosed emissions. Instead, indicators within the data that reflect these accounting principles were identified. Table 4 lists these indicators, showing their alignment with the performance measure elements and accounting principles.

Regarding completeness, the Scope 3 Standard requires that companies report on all GHG emissions sources and activities within their inventory boundary and disclose and justify all exclusions. The Standard scope 3 requires companies to establish an inventory boundary according to their organizational boundaries, including operations that a company controls (operationally or financially) or including operations according to its share of equity (economic interest or percentage ownership) in the operations. While the Corporate Standard requires scope 1 and 2 accounting and reporting, scope 3 reporting is optional. When companies do include scope 3, Table 5.4 of the Scope 3 Standard describes the minimum boundary for each scope 3 category and requires that companies not exclude activities that would compromise the relevance of the company's reported inventory. According to Table 6.1 of the Scope 3 Standard, scope 3 emissions are relevant if they contribute significantly to scope 3 emissions, contribute to a company's risk exposure, can be influenced by the company, are deemed critical by stakeholders, are from activities outsourced by the company, have been identified as significant by sector-specific guidance, or meet other relevance criteria established by the company or industry sector. For a complete scope 3 inventory, the assumption is that companies should report each scope 3 category unless the category is outside of the company's inventory boundary or the emissions are not relevant. The following as indicators were used for completeness:

- **Percentage of companies that reported emissions as calculated**. Question C6.5.C1 of the 2020 CDP questionnaire included a set of five predefined options that companies could select to specify the "evaluation status" of each scope 3 category. This included two options to indicate that emissions had been calculated (relevant, calculated; and not relevant, calculated) and three options to indicate that emissions had not been calculated (relevant, not yet calculated; not relevant, explanation provided; and not evaluated). In addition, companies sometimes left the evaluation status blank. In these cases, the assumption is that emissions had not been calculated. For each supply chain category, this study evaluates the percentage of companies that reported emissions as calculated.

- **Percentage of companies that provided an explanation for excluded emissions**. Question C6.5.C5 of the 2020 CDP questionnaire provided a text field for companies to disclose and explain any exclusions. The explanation was coded reported for the supply chain categories reported as: relevant, not yet calculated; not relevant, explanation provided; not evaluated; or left blank (status not specified). An inductive coding approach was conducted to extract, code, and categorize the primary explanations provided for excluding the category from their emissions inventory. Based on the varying level of detail in companies' explanations and the nonprescriptive nature of the GHG Protocol, it is not possible to adjudicate whether an exclusion is justified. Here, the percentage of times an explanation was provided for excluded emissions was evaluated. Also, the categories of explanations that resulted from the inductive coding process were described and discussed.

- **Percentage of companies that fulfilled basic reporting requirements for scope 3 emissions.** The above indicators were combined to generate an overall indicator of completeness based on reporting requirements. This is an oversimplification as it assumes that calculated categories are fully calculated, and all explanations adequately justify exclusion of a supply chain category.

The Scope 3 Standard describes accuracy as avoiding systematically overestimating or underestimating emissions, reducing uncertainty, and enabling users to make decisions with reasonable confidence. Two general approaches are identified for quantifying scope 3 emissions – direct measurement and calculation and calculation is most often used in practice. Calculation is based on activity data, which specify the level of activity resulting in emissions, and emissions factors, which specify the amount of emissions per unit activity. Companies can use primary data, obtained from suppliers for specific supply chain activities, and secondary data, which includes industry-average data, financial data, proxy data, or other generic data. The Scope 3 Standard specifies that companies should use primary data collected from suppliers to track performance and achieve GHG reductions most effectively. It was not applicable to identify indicators related to uncertainty or systematic overestimation or underestimation in the CDP dataset. As performance measurement is the focus of this study, the study assumes that the ability to track performance and reduce GHG emissions is improved by supplier-specific. However, data specificity may not necessarily be indicative of data accuracy

- **Percentage of companies that reported use of calculation methods that use emission data from suppliers.** Additional GHG Protocol guidance for calculating scope 3 emissions (WRI/WBCSD, 2013) identifies calculation methods that can be used to quantify emissions for each scope 3 category, listed in order of how specific the calculation is to the individual supplier. Question C6.5.C3 of the 2020 CDP questionnaire provides a text field for describing the emissions calculation methodology for each scope. For supply chain emission categories in which companies specified an evaluation status of relevant and calculated or not relevant but calculated (question C6.5.C1), the text provided about the calculation methodology (question C6.5.C5)) was reviewed, all data sources and calculation methods were identified, and according to the type of method and how specific the data is to suppliers were coded. For each supply chain category, the indicator shows the percentage of companies that reported the use of methods requiring (or potentially

requiring) supplier specific data. This indicator excludes emission categories with a zero-emission value as well as those with no or insufficient calculation methodology description.

- **Percentage of companies that reported using data from suppliers to calculate emissions.** For question C6.5.C4 of the 2020 CDP questionnaire, companies enter the percentage of emissions calculated using data obtained from suppliers or value chain partners. For supply chain categories, it is safe to assume this refers to data from suppliers, not other value chain partners. For each supply chain category, companies that reported emissions as calculated were considered, excluding those that reported emissions to be zero since data from suppliers were likely to be unnecessary for these estimates. Also, some companies did not provide any value for this field (i.e., they left the question blank) and hence, were excluded from this indicator. For these companies, the percentage of companies that reported using data obtained from suppliers was determined. Initially, the average percentage of data obtained from suppliers as an indicator was considered. However, most companies reported that 0% or 100% of data came from suppliers, making the average a poor (i.e., not representative of the dataset) statistic for this question.

The Scope 3 Standard describes transparency as the disclosure of assumptions, methodologies, data sources, exclusions, and other relevant information in a clear, factual, neutral and understandable manner that enables third-party review and assurance. However, third-party verification or assurance is not required by the Corporate Standard. The following as indicators of transparency were used:

- **Percentage of companies that identified data sources for calculated emissions and provided specific explanations for excluded emissions.** Evaluating whether disclosed information is sufficient for assurance is outside of the scope of this project. According to the Scope 3 Standard, evidence for verification includes information about data sources for calculated emissions and justifications for excluding emissions. A more stringent set of requirements was used to distinguish between companies that fulfilled reporting requirements (i.e., calculated emissions or explained exclusions) and those that were more transparent. For each supply chain category, the percentage of companies that identified at least one specific data source (e.g., DEFRA database) for calculated emissions and justified excluded emissions with a specific explanation was determined. This indicator excludes those calculated emission with a zero-emission value.

- **Percentage of companies with assurance complete or in progress.** For questions Q.C10.1c., companies provide information about third- party verification/ assurance – referred to *assurance* in this study– undertaken for their scope 3 disclosure. Companies can specify whether the assurance status is for all scope 3 categories, upstream scope 3 categories, downstream scope 3 categories, or for each scope 3 category (question C10.1c.C1). They then select the assurance status for the current reporting year from a from a predefined set of four options, including "no verification or assurance of current reporting year," underway but not complete for current reporting year – first year it has taken place," "underway but not complete for reporting year – previous statement of process attached," and "complete" (question C10.1c.C3), and they select the type of assurance (undertaken from a predefined set of six options, including "not applicable," "limited assurance,"

"moderate assurance," "reasonable assurance," "high assurance," and "third party verification/assurance underway" (question C10.1c.C4). These options reflect CDP's recognition of different assurance standards that use different terminology. In the questionnaire, CDP notes that different levels of assurance might now always be comparable but notes that "reasonable and high assurance will always provide a higher level of assurance than limited and moderate assurance" (Simnett et al., 2009). For supply chain categories with an assurance status of "complete", those with a reasonable or high assurance type to indicate a higher level of assurance and those with a limited or moderate assurance type as a more limited level of assurance were grouped together. For emission categories with an assurance status of "underway but not complete," this study categorized them assurance underway regardless of the assurance type specified. All other possible combinations of questions C10.1c.C3 and C4 are identified as "No assurance".

Two accounting principles, relevance and consistency, were not evaluated in this study. According to the Corporate Standard, a relevant GHG report "appropriately" reflects the GHG emissions of the company and includes information needed by internal and external decision-makers. Relevance depends on the intended use of the inventory and influences decisions related to setting an inventory boundary, excluding activities (including scope 3 categories), and selecting data sources. Evaluation of relevance would require consideration of decision-maker needs, which is outside of the scope of this study. Consistency reflects the use of consistent methodologies and transparent documentation of methodological changes. Consistency is important to performance measurement as it produces comparable GHG emissions data over time. However, evaluation of consistency would require a longitudinal study, which is outside of the scope of this study but an important opportunity for future research.

Table *4* summarizes the indicators proposed for each three GHG Protocol accounting principles and two supply chain performance measure elements.

Table 4. Proposed Alignment of Performance Measurement Elements with Accounting Principles from the GHG Protocol and Indicators Evaluated Using CDP Disclosure Data

Performance Measurement Elements	GHG Protocol Accounting Principles	Indicators Assessed Based on 2020 CDP Data
Quantify what is happening	**Relevance:** reflect company's emissions and supports the needs of decision-makers	Not evaluated
	Completeness: account for all scope 3 emissions and discloses and justifies exclusions	• Percentage of companies that reported emissions as calculated • Percentage of companies that provided an explanation for excluded emissions • Percentage of companies that fulfilled basic reporting requirements about scope 3 emissions
	Accuracy: avoid overestimating or underestimating emissions, reduce uncertainty, enable users to make decisions with reasonable confidence	• Percentage of companies that reported use of calculation methods that use emission data from suppliers • Percentage of companies that reported using data from suppliers to estimate emissions
	Consistency: use consistent methodologies over time, describe and justify methodological changes	Not evaluated
Verifiable	**Transparency**: disclose assumptions, methodologies, data sources, exclusions, and other relevant information clearly, factually, and in a manner that enables review and assurance	• Percentage of companies that identified data sources for calculated emissions and provided specific explanations for excluded emissions • Percentage of companies with assurance complete or in progress

2.4. Data Analysis Tools Used

Data wrangling, analysis, and visualization in this study were conducted using Microsoft Excel spreadsheet, Tableau software, and Python (pandas' package).

CHAPTER 3

3. RESULTS

3.1 Indicators

3.1.1. Percentage of Companies that Reported Emissions as Calculated

Figure 4 shows the breakdown of reported evaluation status aggregated for all supply chain categories (left column) and for each supply chain category (right columns). Overall, companies in the manufacturing and services reported emissions as calculated for 40% and 45% of all supply chain categories, respectively. Services industry companies were more likely to calculate emissions in all but two categories (i.e., capital goods and upstream transportation and distribution). In both industries, companies were most likely to calculate emissions associated with business travel and least likely to calculate emissions associated with upstream leased assets. Categories that were less often reported as calculated were more often reported as "not relevant, explanation provided." The explanations associated with the four evaluation statuses in which emissions are not reported or calculated are investigated in the next section.

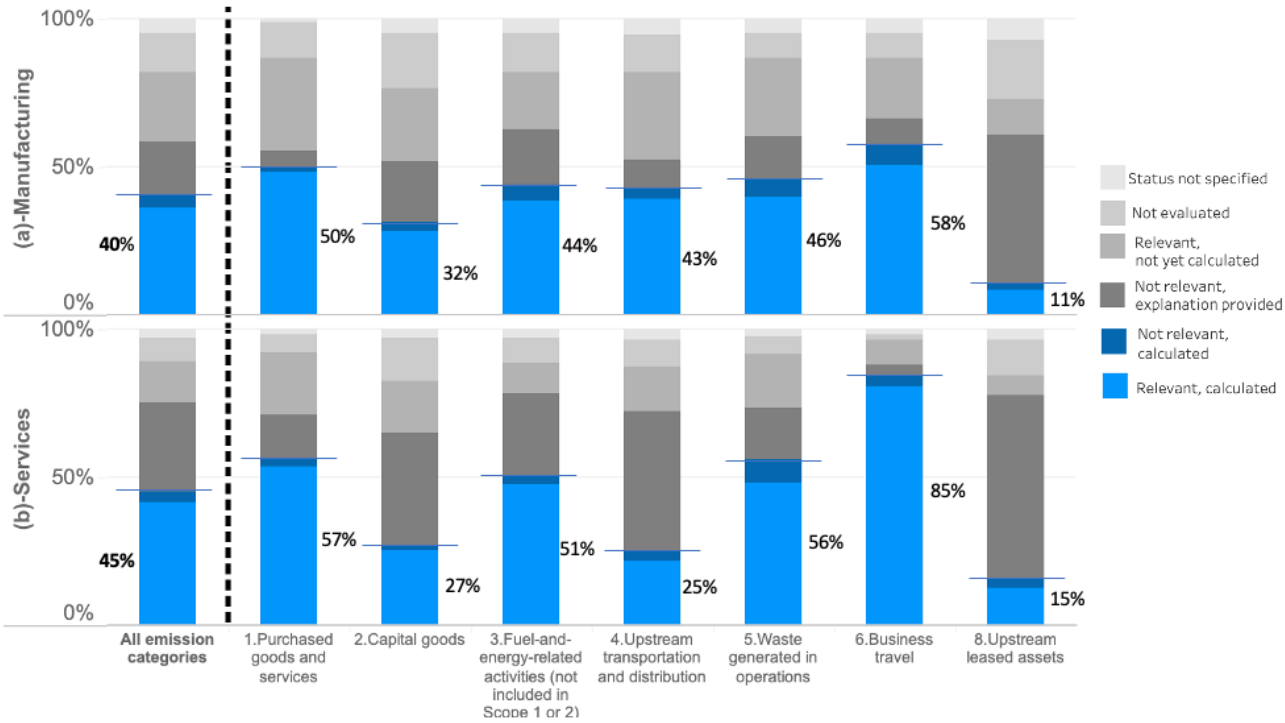

Figure 4. Percentage of companies that reported emissions as calculated for each supply chain category (blue), with the breakdown of all reported evaluation statuses shown

3.1.2. Percentage of Companies that Provided an Explanation for Excluded Emissions.

The percentage of companies that provided an explanation for excluding emissions varied by evaluation status specified –42% for "not relevant, explanation provided," 33% for "relevant, not yet calculated," 19% for "not evaluated," and 6% for instances in which the status was not specified. The level of detail provided varied, from limited information (e.g., "NA") to a detailed explanation for the exclusion. Occasionally companies provided multiple reasons for excluding emissions. In these cases, the coding was based on our interpretation of the primary reason for excluding emissions. The coding process resulted in eight explanation categories, summarized below, with thirty-seven subcategories, detailed in the supplementary material in Appendix 5.1 information.

- **Included elsewhere:** indicated that emissions were included in the estimate for scope 1, scope 2, or another scope 3 category. For example, "*This category includes emissions from the operation of assets that are leased by Proximus in the reporting year but these emissions are already included in the scope 1 or scope 2 inventories*".

- **No emissions:** indicated no activity or no emissions. This is related to the size criterion in the Scope 3 Standard, which specifies that companies should include sources that significantly contribute to total scope 3 emissions. For example, "*Hankook Tire & Technology defines only the GHG emissions associated with the life cycle of tire products as Scope 3 according to internal priorities, and other emissions are not applicable to Scope 3*".

- **Low contribution:** indicated little activity, low emissions, or no significant source of emissions. This is also related to the size criterion of the Scope 3 Standard. For example, " *Capital expenditure is a relatively minor part of our expenditure, typically heat treatment furnaces have a lifespan of 20-30 years. Maintenance capital expenditure is an even smaller part of our overall expenditure on the basis the emissions will be de minimis*".

- **Not relevant for other reasons:** indicated that emissions were not relevant according to other Scope 3 Standard relevance criteria (e.g., not influenced by the company, do not contribute to company's risk exposure), for other accounting-related reasons (e.g., not within the selected boundary), or without further explanation. For example, "*The Group believes there are no relevant emissions to be evaluated as part of waste generated. The Group continue to closely monitor emissions reporting guidelines to ensure relevant emission data is captured*".

- **Estimate in progress:** indicated that emission accounting is in progress or the company is undertaking efforts to enable them to estimate. For example, "*We have started examining on this aspect this year wherein we are developing a framework to calculate this aspect of Scope 3 emissions in a robust and detailed way utilising spend-base and material-based data as per the methodology suggested in Greenhouse Gas Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard (Greenhouse Gas Protocol, 2013)*."

- **Data/accounting issues:** indicated that data or accounting issues prevented the company from estimating emissions. For example, "*Collecting Scope 3 emissions of the source is extremely difficult. In addition, in life insurance business, the source is less significant*."

- **Not yet calculated for other reasons**: indicated that emissions were not yet calculated for other reasons (e.g., focus on other scopes or categories, don't report every year). For example, "*At this time we are not looking at Scope 3. Our focus will be on Scope 1 and 2"*.

- **Specific explanation not provided**: provided an explanation that was not clear, did not address the exclusion of the category, or did not provide a specific reason for excluding the category. For example, "*Not currently collecting or planning to do so at this time - This may change in the future*".

- **Blank (no explanation):** no explanation was provided.

Explanations were quantified here, not justifications. The Scope 3 Standard gives companies considerable flexibility in determining the relevance of scope 3 categories, making it difficult to adjudicate whether exclusions are justified. Even so, some explanations would not pass a basic justification test, particularly those that are incomplete (e.g., stating that a category is not relevant with no additional explanation), unsupported (e.g., assuming emissions are low with limited justification), unclear (e.g. described efforts to reduce emissions instead of explaining why emissions were not calculated), or suggest a misunderstanding of reporting requirements (e.g., referring to emissions already included in another scope or category). In addition, this study does not investigate exclusions when emission estimates are reported. In the CDP reporting framework, the categories are simply reported as "calculated," however, companies sometimes indicate that they did not calculate emissions from all sources related to the supply chain category.

Figure *5* shows emission exclusion reasons breakdown by categories and evaluation status. For excluded emission categories, except for not relevant-explanation provided evaluation status, most companies did not provide any explanation. Overall, considering both industries, for the three evaluation statuses –not specified, not evaluated, relevant-not yet calculated– 59% of emissions are excluded with no explanations. For the not relevant-explanation provided evaluation status, no emission, low contribution, and included elsewhere are the top three reasons of emissions exclusions. For emissions with relevant-not yet calculated evaluation status, 18% of companies mentioned data/accounting issues, and 14% specified that the emission estimation is in progress.

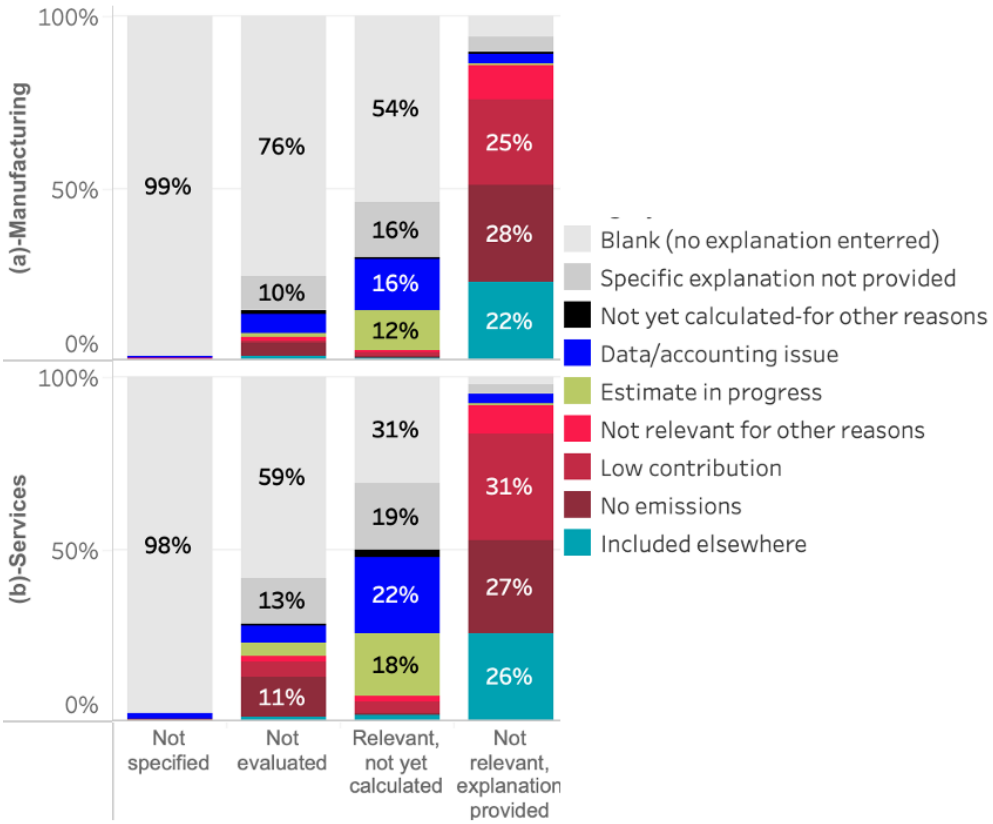

Figure 5. companies that provided an explanation for excluded emissions, with the breakdown of explanations given per evaluation status of emissions

Figure 6 shows the breakdown of explanations for not calculating emissions by supply chain category. Overall, there is no dominant explanation. The three explanations related to relevance of emissions (i.e., no emissions, low contribution, and not relevant for other reasons) were provided for 21% of supply chain categories excluded by manufacturing companies and 41% of supply chain categories excluded by services industry companies, with size (i.e., no emissions and low contribution) being the dominant relevance criterion. The breakdown of explanations varies across the supply chain categories. Lack of relevance due to size was the most common explanation for most categories. Upstream leased assets and fuel-and-energy-related activities (not included in scope 1 or scope 2) were often reported as included in other inventory scopes. Data and accounting issues were more often reported for excluded purchased goods and services. Manufacturing companies were twice as likely than services industry companies to leave the explanation blank for all supply chain categories except business travel. Specific explanation not provided: account for 4% to 15% of explanations. Overall, manufacturing companies provided explanations for 52% of excluded categories, and services industry companies provided explanations for 77% of excluded categories.

The supplementary information in the appendix 5.1 shows the breakdown of explanation reasons into subcategories. Each category of explanation reason is associated with different subcategories. For example, when a company mentions that the emission category has a low contribution to their total scope 3 emissions, the reason for this decision is based on companies interpretation of low contribution. For example, the company may conduct an initial analysis (i.e., screening) and determine that the emission category is not relevant to its business. Alternatively, the company may specify that the emission category is not relevant due to the nature of their business activities (i.e., without any calculations or screening)

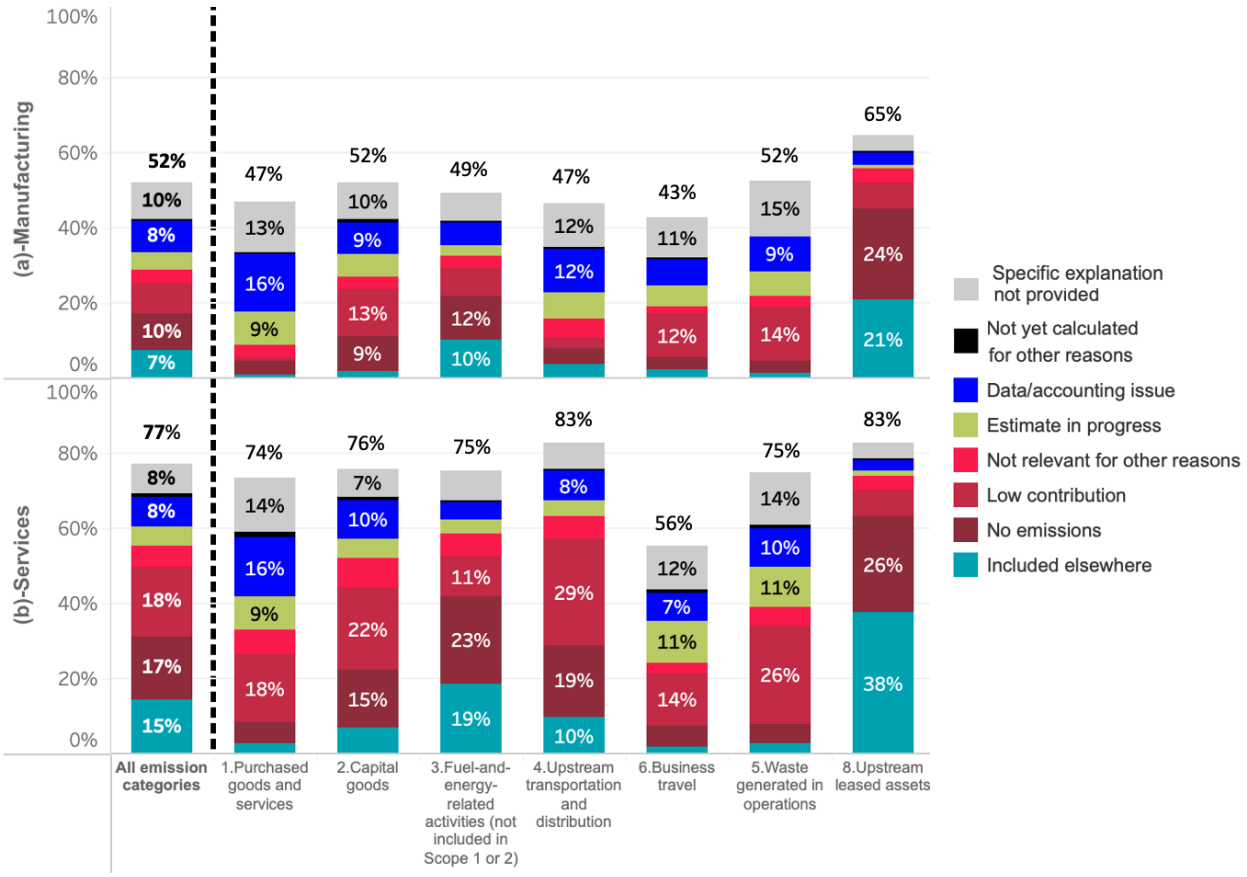

Figure 6. Percentage of companies that provided an explanation for excluded emissions, with the breakdown of explanations given

3.1.3. Percentage of Companies that Fulfilled the Basic Reporting Requirements for scope 3 Emissions

Figure *7* combines the two indicators evaluated above to show the percentage of companies that reported emissions estimates or provided an explanation for excluding emissions for each supply chain category. Within each industry, the percent of companies that fulfilled the reporting requirement is comparable across all supply chain categories. Overall, the reporting requirement was fulfilled 71% of the time by manufacturing companies and 88% of the time by service industry companies. However, the portion of companies that calculated emissions versus those that explained their exclusions varied considerably by supply chain category.

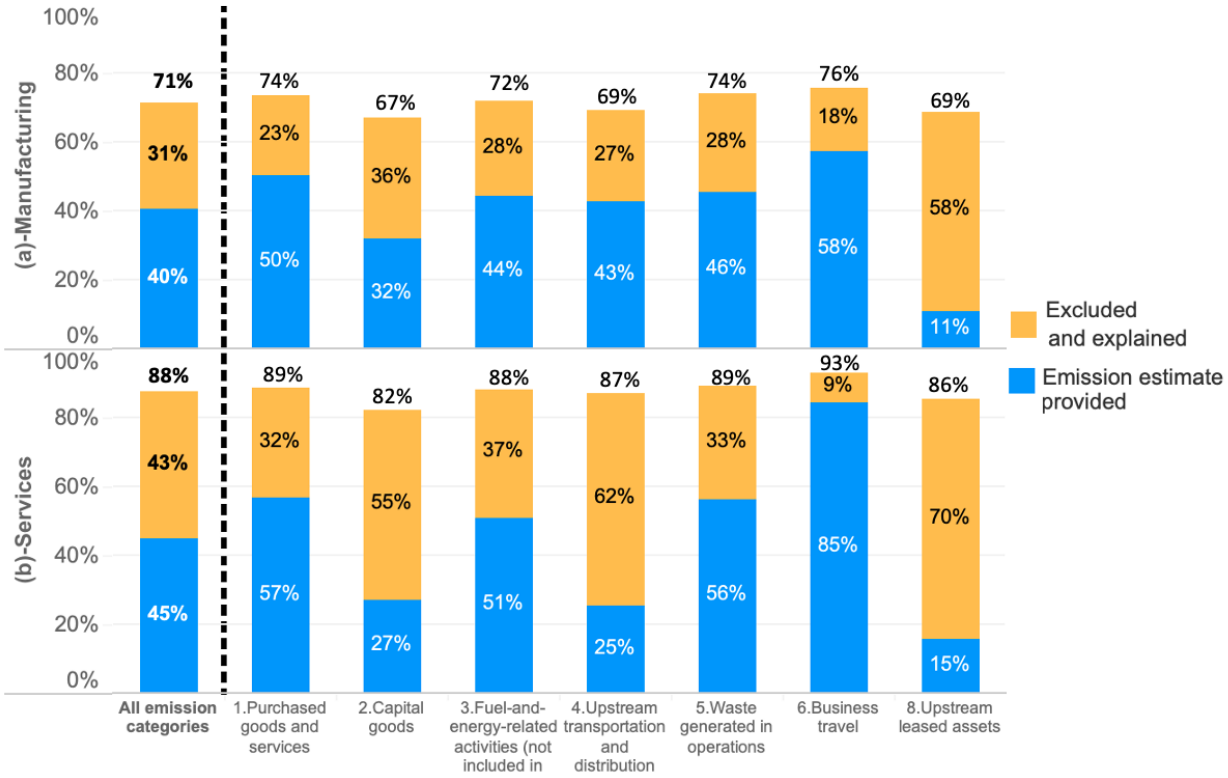

Figure 7. Percentage of companies that fulfilled the basic reporting requirements for scope 3 emissions by estimating emissions or explaining why the category was excluded

3.1.4. Percentage of Companies that Reported Use of Calculation Methods that Use Emission Data from Suppliers

The coding process resulted in the identification of 228 unique data source-calculation method combinations appendix5.2. Each is listed in the supplementary information. As shown in **Figure 8**, data sources were classified based on whether emission data (including emission estimates or emissions factors) were obtained from suppliers or secondary sources and identified the different types of calculation methods associated with each type of data source. Finally, the study showed how the methods identified in the Scope 3 Standard would align with our framing.

Three calculation methods that rely on emission data from suppliers were identified:

- **Supplier-direct**: Supplier-specific emission was obtained directly from a supplier (e.g., via data requests or invoices).

- **Publicly available resources**: Supplier-specific emission data was obtained from information published by the supplier (e.g., environmental declarations, sustainability reports, and company's websites).

- **Disclosure systems**: Supplier-specific emission data was obtained from a disclosure system that collects and disseminates corporate GHG emission data (e.g., CDP.)

Three calculation methods that use data from suppliers, secondary sources, or a combination of the two were identified:

- **Industry collaborations**: Emission data is obtained from an industry initiative that collects and disseminates emission data from suppliers or from secondary sources.

- **Life cycle assessment (LCA)**: Emission data was obtained from a LCA performed by the company or obtained from a public or proprietary LCA database. Depending on how the LCA was performed, GHG emission data may have been obtained from suppliers secondary LCA databases, or from a combination of primary and secondary data sources

- **Energy-based EFs**: Energy-based emission factor (EFs) are used to estimate emissions based on the amount of energy (e.g., fuel or electricity) used. This approach resembles that of scope 1 and scope 2 accounting (Bouchery et al., 2016). While scope 1 and 2 accounting use combustion emission factor, scope 3 accounting uses life cycle (cradle-to-gate) emission factor (WRI/WBCSD, 2013). Energy-based EFs tend to be more accurate than activity-based EFs because fuel and electricity consumption are more directly related to emissions. Companies can obtain relevant EFs from suppliers (e.g., when the company has ooperationalcontrol over a leased asset), thereby enabling supplier-relevant emission estimates. Companies may also select an EF from a secondary source for a supply chain activity (e.g., when a company selects an EF to estimate emissions from business travel rather than obtaining the EF directly from the supplier).

Finally, two calculation methods that use only secondary emission data were identified.

- **Activity-based EFs**: Activity-based EFs are used to estimate emissions from some amount of activity, such as ton-kilometres of freight transport or kilograms of material procured. They come from public and proprietary databases and tend to be based on industry average data. In scope 3 accounting, activity-based EFs can include life cycle or cradle-to-gate (upstream) emissions and are generally derived from LCAs.

- **Spend-based methods**: Spend-based emission factors are obtained from EEIO models, which estimate industry average cradle-to-gate emissions based on industry-level economic output and emissions and the economic transactions between industries. (Huang et al., 2009; Minx et al., 2009). They are used to estimate emissions based on the economic value of on company procurements.

The Scope 3 Standard refers to LCA as a tool for deriving cradle-to-gate and life cycle EFs, not a calculation method. However, some companies specify the use of LCA to calculate emissions. Also, The GHG Protocol's scope 3 Technical Guidance defines a hybrid method in which companies use a combination of supplier-specific and secondary data to estimate emissions, particularly for the purchased goods and services and capital goods categories (WRI/WBCSD, 2013). This study does not evaluate use of the hybrid method; instead, it classifies each data source or method identified by companies.

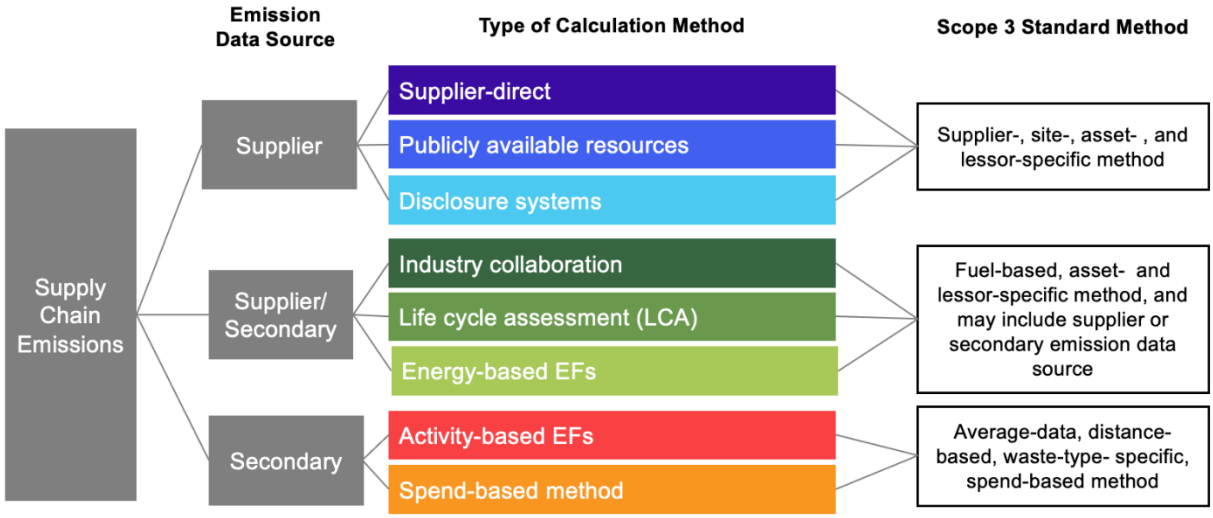

Figure 8. Framework for classifying reported emission data sources and calculation methods

One or more calculation methods for 77% (3320) of 4257 company-supply chain categories were identified for which companies reported emissions as calculated. For the remaining categories, there were three reasons a calculation method could not be identified:

- **No information**: For 4% of calculated categories, the company did not respond to the questions related to calculation methods.

- **Insufficient information**: For 15% of calculated categories, the company did not clearly describe a data source or calculation method.
- **Zero emissions**: For 4% of calculated categories, the company reported zero emissions for the supply chain category.

Figure 9 provides a breakdown of all calculation methods reported by companies for each supply chain category. Overall, the results show a substantial reliance on activity-based EFs and spend-based methods derived from secondary sources. Activity-based EFs were the most frequently reported method for most supply chain categories, with a few exceptions. Spend-based methods were more frequently reported for capital goods, and energy-based EFs were more frequently reported for upstream leased assets.

Methods that use supplier emission data (i.e., supplier-direct, publicly available resources, or disclosure systems) accounted for 1% to 23% of reported methods. They were most frequently used to estimate emissions for business travel by manufacturing companies and for capital goods by services industry companies. Considering both industries, they were less frequently used to estimate emissions waste generations in operations and fuel- and energy-related activities not included in scope 1 or scope 2. For all supply chain categories, supplier emission data was primarily obtained via the supplier-direct method. While supplier indirect methods – i.e., publicly available resources and disclosure systems – were less frequently used, they were an important source of supplier data for estimating emissions associated with capital goods) and purchased goods and services.

Methods that can use supplier/secondary emission data (i.e., industry collaboration, LCA, or energy-based EFs) accounted for between less than 1% and 49% of reported methods. Considering both industries, they were most frequently used to estimate emissions for upstream leased assets. As was also the case with the methods that only use supplier emission data, the methods that use supplier/secondary emission data were less often used for estimating emissions from waste generations in operations and fuel- and energy-related activities not included in scope 1 or scope 2. For most supply chain categories, energy EFs were the most common supplier/secondary method. The one exception was purchased goods and services, for which manufacturing companies reported use of LCA more often than energy EFs. Taken together, the supplier and supplier/secondary methods accounted for between 3% and 58% of reported methods.

Note that calculation approaches are not always in line with the Scope 3 Standard and Technical Guidance. For example, companies reported us of spend-based method for all supply chain emission categories. However, the scope 3 Technical Guidance identifies the spend-based method as appropriate for four of the seven supply chain categories, i.e., purchased goods and services, capital goods, upstream transportation and distribution, and business travel.

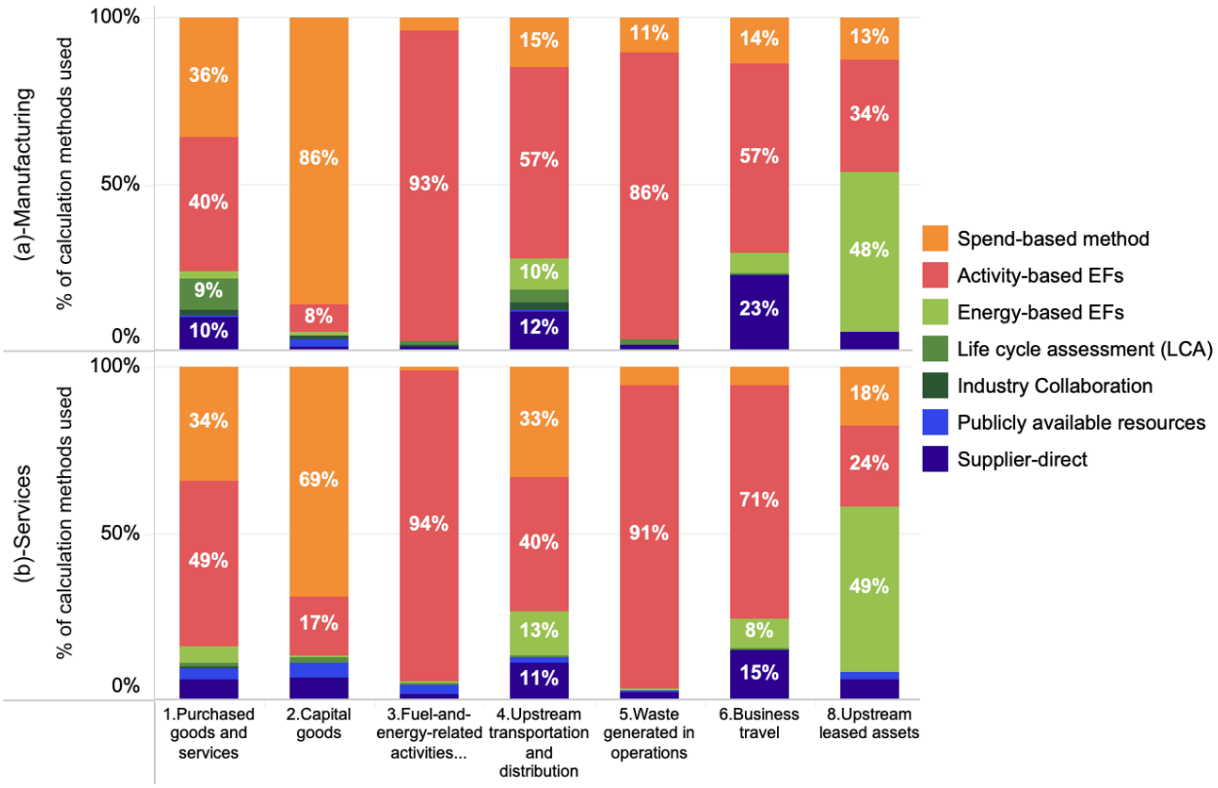

Figure 9. Distribution of calculation methods reported for each supply chain category

Figure *10* shows the use of calculation methods for all supply chain emission categories (aggregated for seven supply chain categories that were shown in (**Figure 9**). Overall, considering both industries, 82% of emissions are calculated using secondary, 10% using supplier, and 8% using supplier/secondary emission data sources. Activity-based EFs (62%) has the highest, and industry collaboration (less than 1%) has the lowest use among all calculation methods.

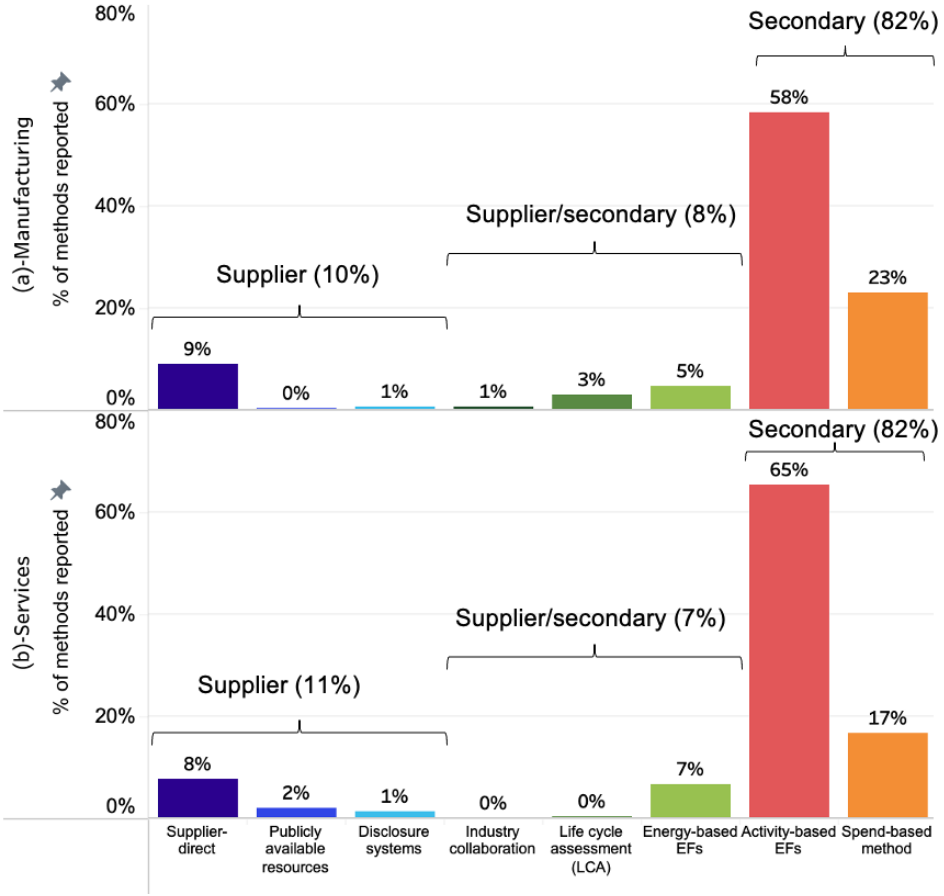

Figure 10. Distribution of calculation methods reported for all emission categories

For companies that reported emissions as calculated, **Figure *11*** shows the percentage of companies that reported use of report emissions as calculated and reported use of at least one calculation method that uses supplier or supplier/secondary emission data. This includes only those emissions that their calculation methodologies could be identified, and hence, it excludes calculate emissions with a zero value, no information, and insufficient calculation methodology explanation. For the seven supply chain categories, between 4% and 62% of companies reported use of methods that use supplier or supplier/secondary data. Overall, these methods were used to estimate emissions for 21% of calculated categories in the manufacturing and services companies. This does not represent the extent to which each category is calculated with supplier-specific emission information. Rather, it more likely represents the extent to which companies use supplier-specific emission information when possible and fill gaps with industry average emission factor. There are two important limitations with our approach. Some companies that report use of supplier/secondary methods will not use supplier emission data, be overestimating the use of supplier data. These estimates may be overestimated since they include calculation methods (i.e., industry collaborations, LCA, and energy-based EFs) that may use emission information from both suppliers and secondary sources.

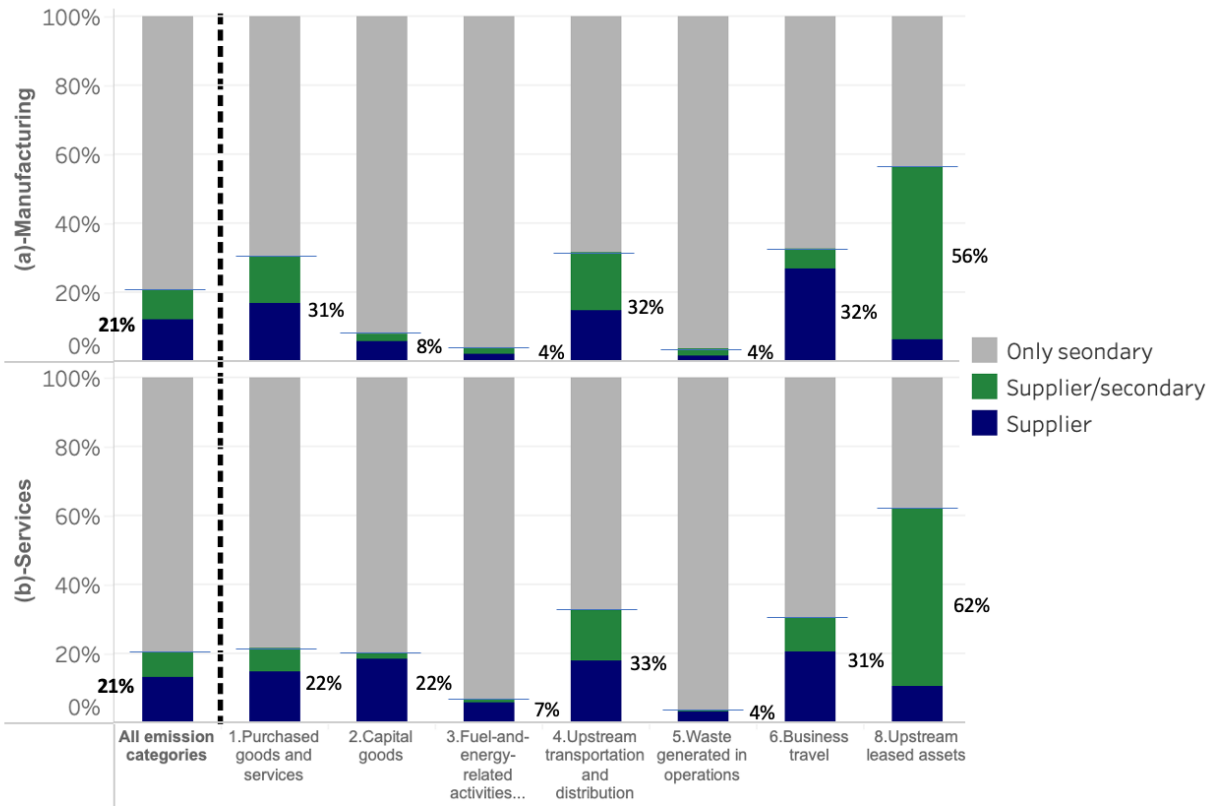

Figure 11. Percentage of companies that reported using calculation methods that use supplier emission data (supplier data in green, supplier/secondary data in blue), excluding companies that reported zero emissions, insufficient and no information

3.1.5. Percentage of Companies that Reported Using Data from Suppliers to Calculate Emissions

Companies tended to report that 0% or 100% of emissions were estimated using data obtained from suppliers. For the calculated emissions, 10% of categories were not provided with any percentage value (i.e., companies left the question blank) and are excluded from this indicator. Also, those emission estimates with a reported emission value of zero were also excluded from this indicator. **Figure *12*** shows the percentage of companies that reported using data from suppliers. Companies are split into two groups, those that reported 100% of estimated emissions to be based on data from suppliers and those that reported between 0% and 100% of estimated emissions to be based on data from suppliers. Companies reported that they used data from suppliers to estimate emissions for between 37% and 85% of emission estimates. Considering both industries, companies were more likely to use data from suppliers to estimate emissions from business travel and less likely to use data from suppliers to estimate emissions associated with capital goods. For all supply chain categories, more companies reported that 100% of emissions were estimated based on data from suppliers.

Reported values should be used cautiously. **Figure *13*** shows the histogram shows the percentage of emissions calculated using the data obtained from suppliers. This excludes emission categories with zero emission values and those that were left blank. Overall, 41% of companies specified 0% to 9% of data obtained from suppliers and 43% specified 100% coming from suppliers. The questionnaire does not specify the type of data included or the extent to which the estimates reflect the supplier's actual emissions. For example, information provided about calculation methods indicated that companies made the determination of an estimate being based on supplier data based on their use of direct emission estimates, activity data, emission factor, or spend data from suppliers. As a result, 100% could reflect very different levels of specificity. For example, a response of 100% could mean that a company obtained direct emission estimates from suppliers. It could also mean that the company received spend data from invoices provided by suppliers but used emission factor from EEIO models (i.e., spend-based methods) to estimate emissions on an industry average basis. While all companies would probably consider the first example to be related to data from suppliers, all are unlikely to consider the second example to be based on data from suppliers.

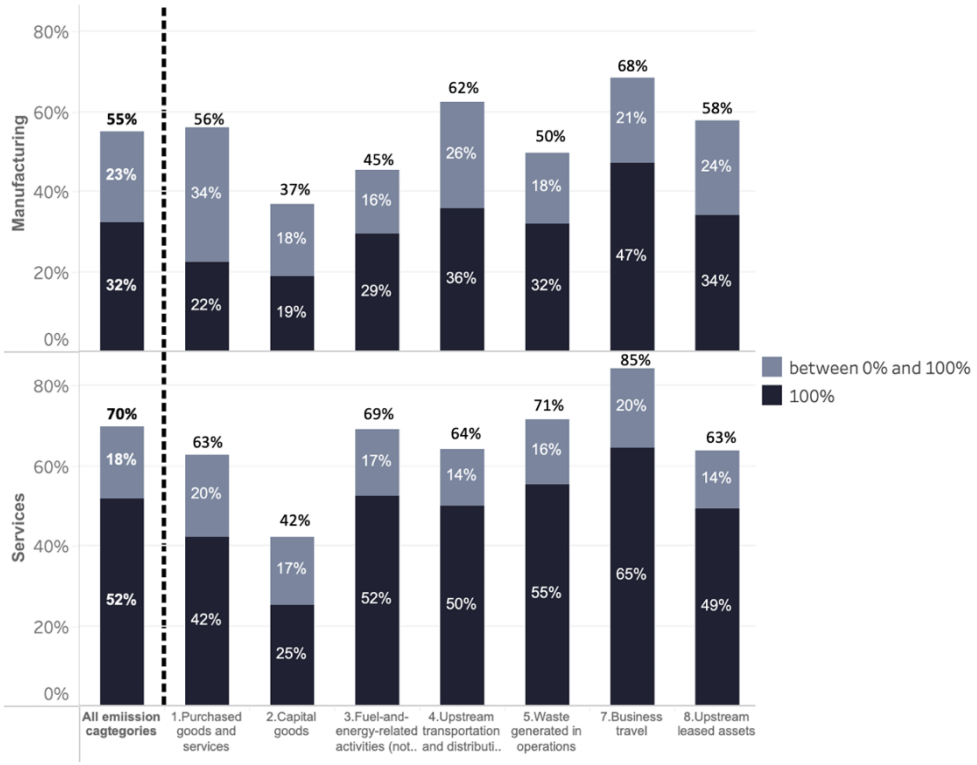

Figure 12. Percentage of companies that reporting using data from suppliers to estimate emissions, excluding emissions that were estimated to be zero

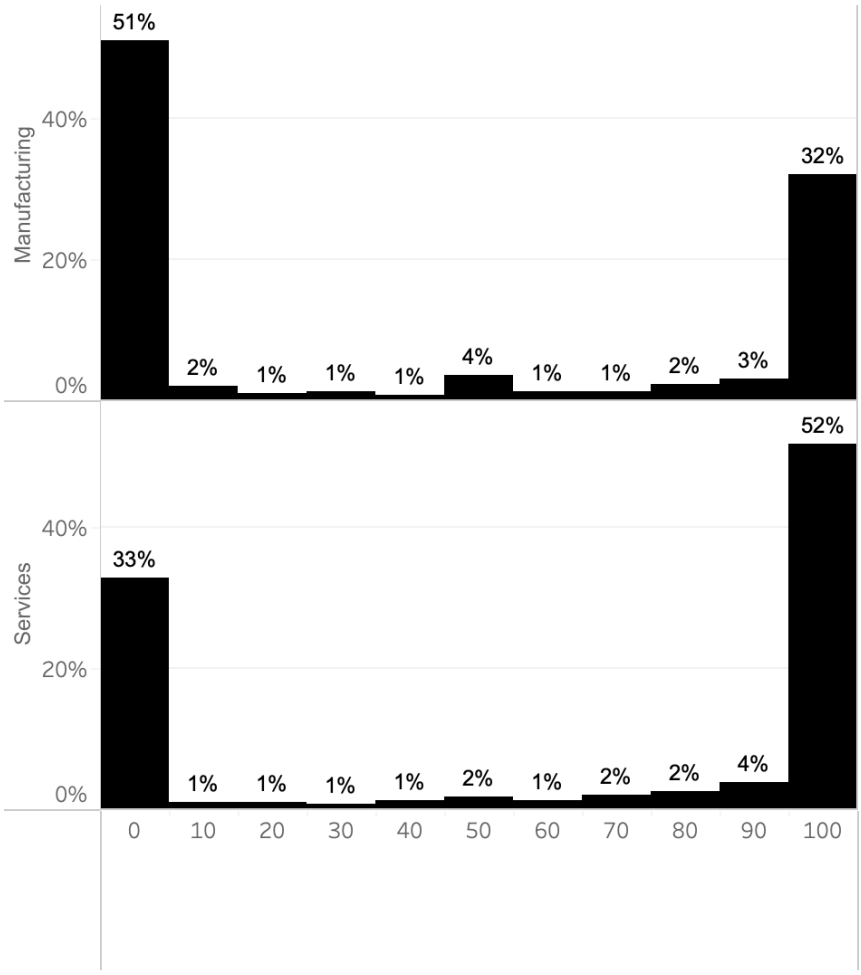

Figure 13. Histogram of the percentage of emissions calculated using the data obtained from supplier

3.1.6. Percentage of Companies that Identified Data Sources for Calculated Emissions and Provided Specific Explanations for Excluded Emissions

Figure *7* showed the portion of emissions that are calculated or excluded and explained. For this indicator, **Figure** ***14*** shows if companies identified data sources for calculated emissions (excluding categories with a zero-emission value) and provided specific explanations for excluded emissions. In other words, for calculated emission categories, calculation methodology, and emission data source (e.g., DEFRA emission factor database) should be provided. And, for excluded emission categories, a specific explanation should be provided. Specific exclusions explanations refer to all explanations provided in **Figure 6** except the category of "specific explanation not provided". Overall, 50% of emissions for companies in manufacturing and 68% for companies in services calculated or excluded emission categories with a certain degree of transparency. Among the supply chain categories, upstream transportation and distribution (45%) for manufacturing companies and business travel for services companies (63%) fulfilled this indicator less than other supply chain categories.

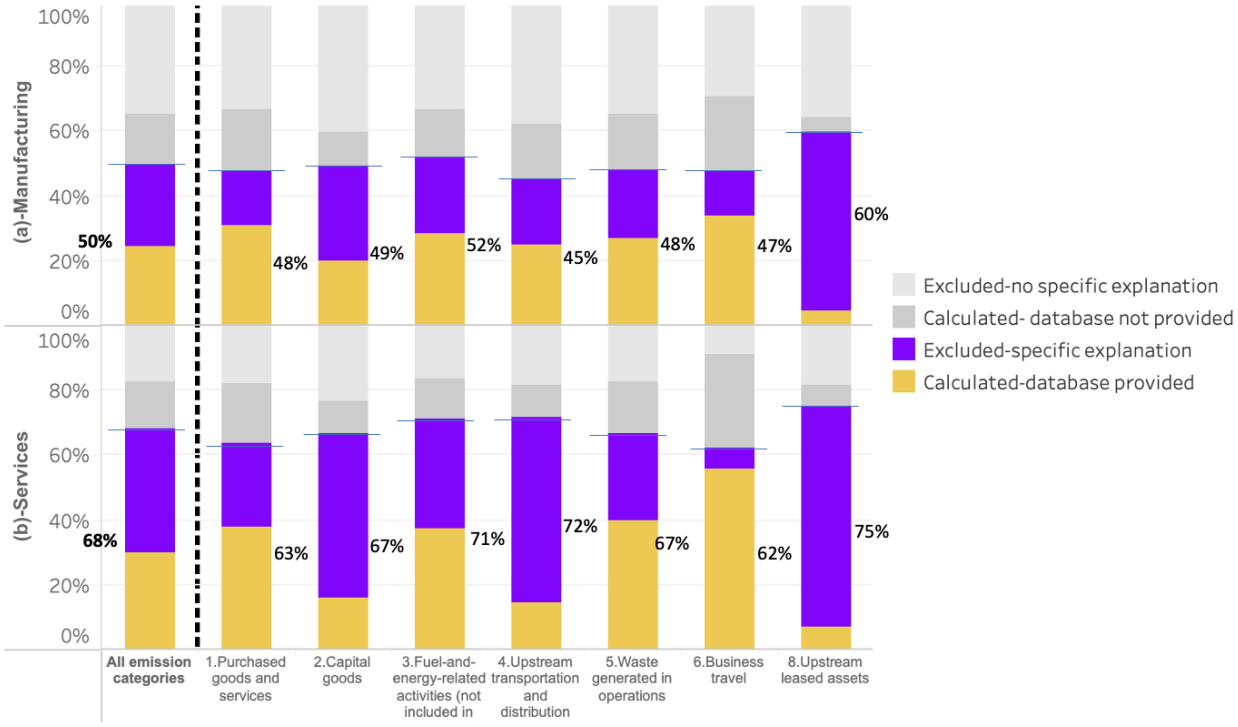

Figure 14. Percentage of companies identified data sources for calculated emissions and provided specific explanations for excluded emissions

3.1.7. Percentage of Companies with Assurance Complete or in Progress

Figure *15* shows the percentage of companies for which assurance is complete or in progress by reported evaluation status. The figure shows that calculated emission categories have more assurance in place than not relevant categories. Overall, assurance was complete or in progress for 15% of supply chain categories in the manufacturing industry and 24% of supply chain category in the services industry. Companies tend to provide more assurance for calculated emissions compared with excluded emissions. Companies in manufacturing verify 32% of calculated and 4% of excluded emissions, and companies in services verify 46% of calculated and 6% of excluded emissions. Also, companies tend to provide limited/ moderate assurance. Considering both industries, 13% of emissions have high/ reasonable assurance, 76% have limited/ moderate assurance, and 11% have assurance in process.

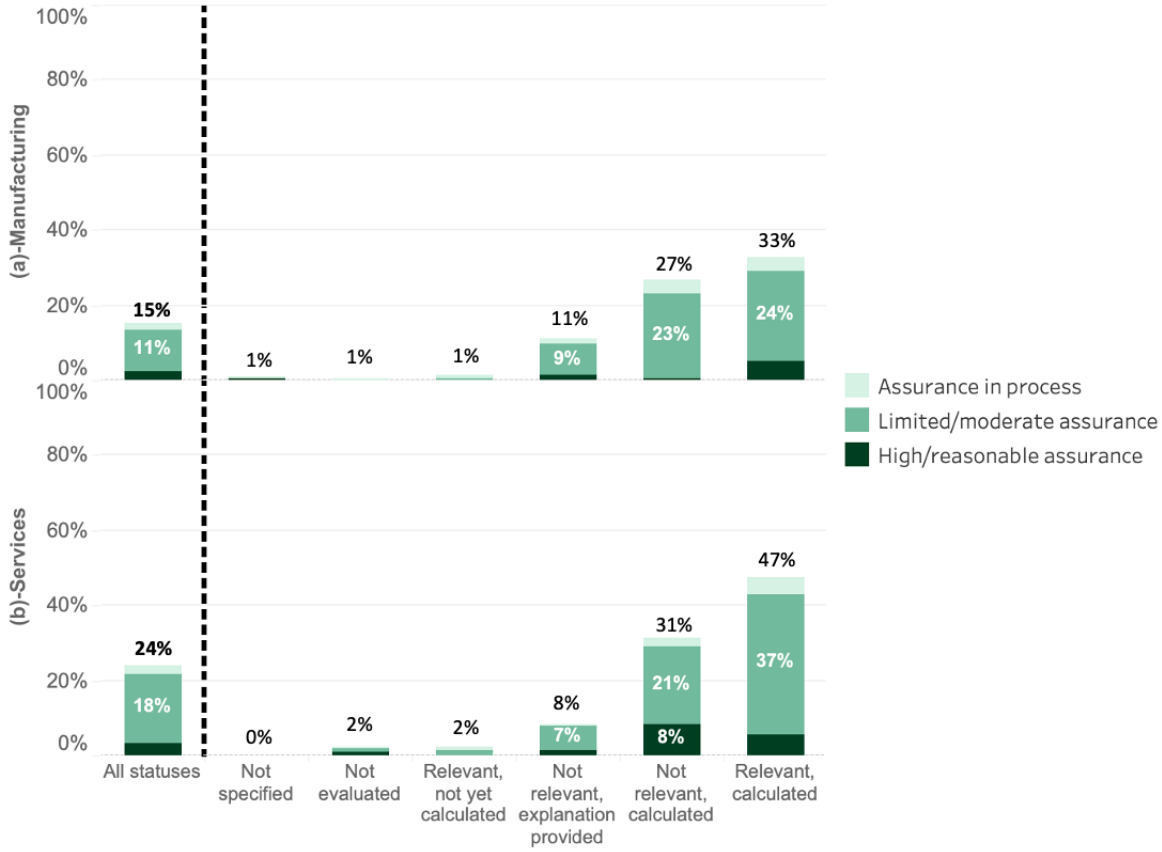

Figure 15. Assurance status per emission evaluation status

Figure 16 shows the assurance status of supply chain categories calculated or excluded. Considering both industries, Business travel (35%) has the highest and upstream leased assets (11%) has the lowest assurance level. As mentioned, limited/moderate assurance type is mostly reported by companies that have assurance in place. The most high/reasonable assurance type was reported for the business category (4%) and the lowest for capital goods (2%).

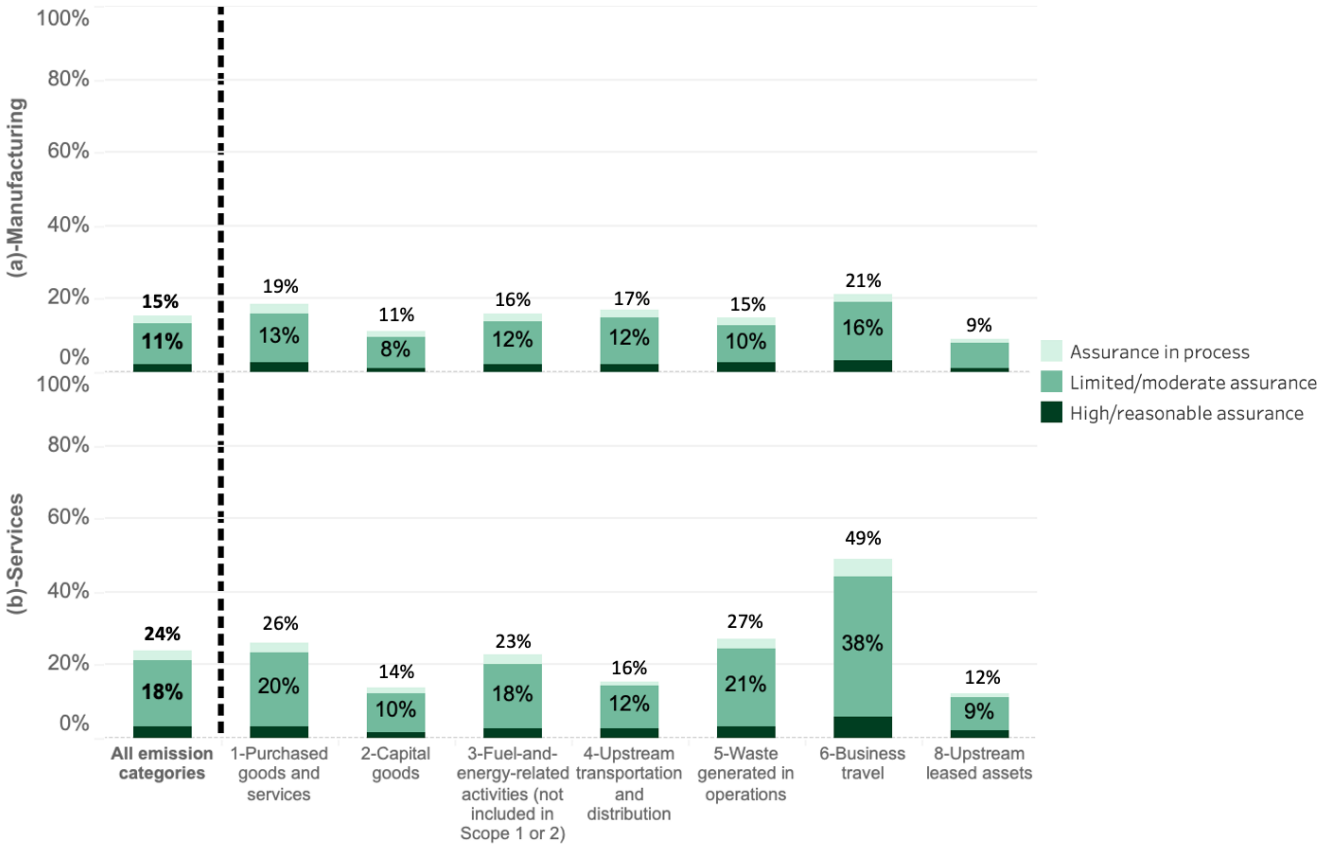

Figure 16. Assurance status per supply chain

We further analyse this indicator by investigating whether more transparent emission reporting is correlated with assurance.

Figure *17* shows that the transparency of calculated categories has a direct connection with assurance. From left to right, transparency of calculation and assurance decreases with one exception; for calculated emissions in the manufacturing companies, the no database provided category is slightly (1%) more verified than the database provided category. The zero-emission category is least verified in the calculated categories that is not surprising considering the fact that excluded emissions are verified less than calculated emissions. Overall, for calculated emission, companies in the services verify emissions (46%) more than manufacturing companies (32%).

Figure ***17*** also shows the assurance status for excluded emissions. Considering both industries, the included elsewhere explanation reason has the highest assurance and the not relevant for other reasons has the second highest assurance. Some companies that specify emissions as not relevant for other reasons consider more than one criterion in assessing the relevance of an emission category (e.g., lack of influence, control, ownership), and these emissions are more verified. Also, between the three explanations related to the relevance of emissions (i.e., no emissions, low contribution, and not relevant for other reasons), the no emission category has the lowest assurance. Also, emission exclusions with no specific explanations, estimate in progress, and no explanation have the lowest (between 0% to 3%) assurance frequency. Data/accounting issue for companies in services has a 9% of assurance (the second highest assurance rate in the services), likely showing that although some emission categories were not calculated, the company verifies that these emissions are relevant and because of data/ accounting issues they were not able to calculate the emissions. Overall, for excluded emissions, services companies verify emissions (4%) similar to manufacturing companies (6%).

Therefore, the results show that assurance tends to positively affect the transparency of calculated and excluded emissions exclusion. In other words, those emission estimations with more transparency in their explanation and those emission exclusions with more specificity in their explanation tend to be more verified. However, a significant number of disclosures that lack transparency are still verified.

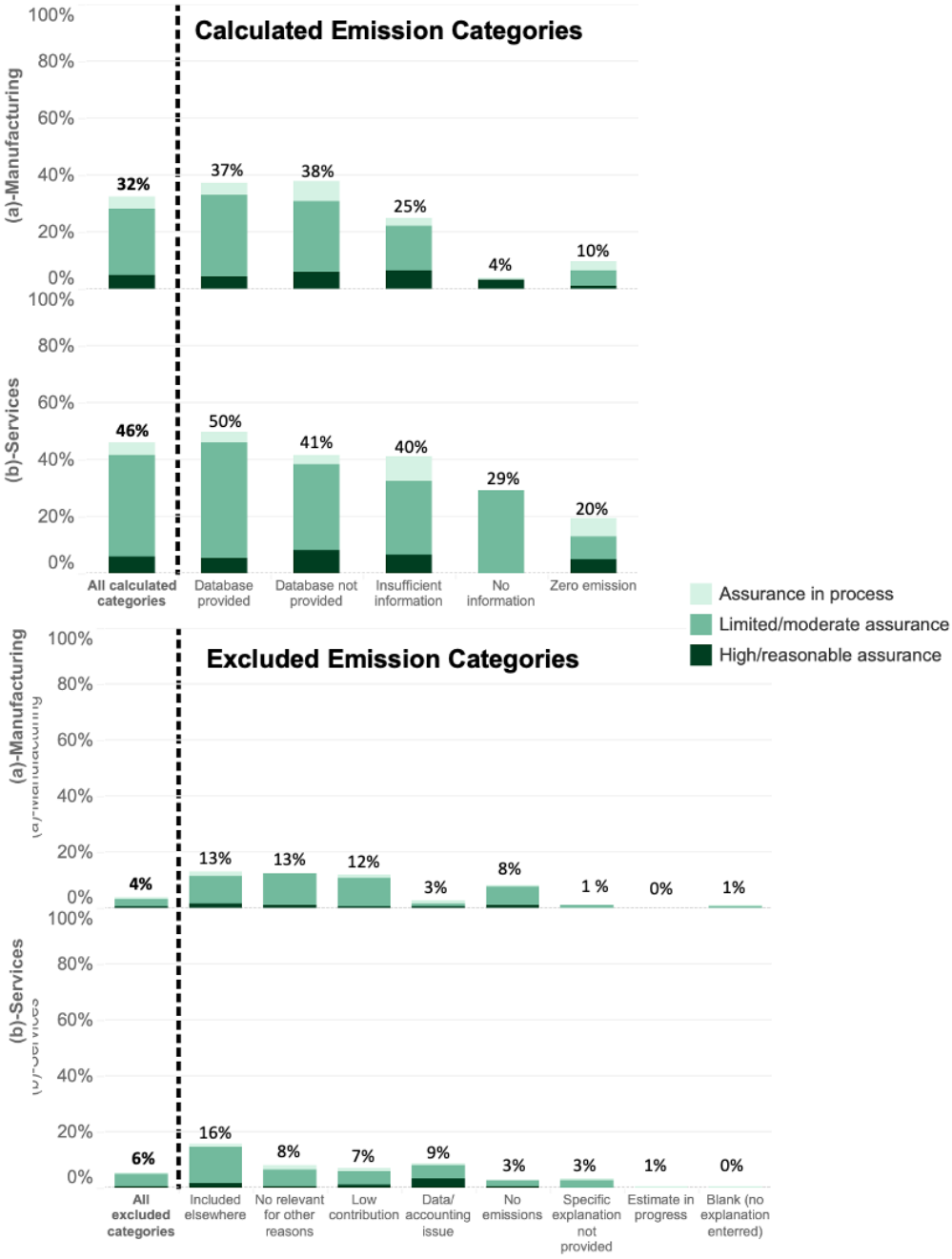

Figure 17. Assurance status vs. transparency for calculated and excluded categories

3.2 Combination of Indicators Assessed

Table *5* provides the results for each indicator. The results are shown for companies in the manufacturing and services industries and aggregated across the two industries.

Overall, emissions were calculated for 43% of supply chain categories. For the categories that were excluded, companies provided an explanation 64% of the time. Based on this basic reporting requirements (i.e., reporting an emission estimate or explaining exclusions) were met 80% of the time. Companies reported use of data from suppliers for 63% of calculated categories. In contrast, they reported use of calculation methods that rely on supplier emission data 21% of time. The former value likely considers diverse types of data, including activity, spend, and emission data, whereas the latter only considers emission data. However, the latter is a generous estimate as it includes calculation methods that rely on supplier data as well as those that may use supplier or secondary emission data. Finally, this represents a relatively complete but less accurate account of supply chain emissions. One important limitation is that these values represent the percentage of emission categories, not the percentage of emissions.

Also, the proposed indicator of transparency showed that 59% of companies provided a sufficient description of emission calculation methodology and mentioned calculation database or provided a specific explanation for the emission exclusions. However, only 20% of emissions are third-party verified. Although the Scope 3 Standard does not require companies to verify supply chain emission inventories, they are recommended for better compliance with accounting principles.

Table 5. Summary of results for each indicator

Performance Measure Element	Accounting Principle	Indicator	Scope of indicator	Manufacturing	Services	Both Industries
Quantify what is happening	Completeness	Percentage of companies that reported emissions as calculated	All emission categories	40%	45%	43%
		Percentage of companies that provided an explanation for excluded emissions.	Not calculated emission categories	52%	77%	64%
		Percentage of companies that fulfilled the basic reporting requirements for scope 3 emissions	All emission categories	71%	88%	80%
	Accuracy	Percentage of companies that reported use of calculation methods that use emission data from suppliers	Calculated emission categories excluding no information, insufficient information, and zero emissions	21%	21%	21%
	-	Percentage of companies that reported using data from suppliers to calculate emissions	Calculated emission categories excluding zero emissions and no percentage	55%	70%	63%
Verifiable	Transparency	Percentage of companies that identified data sources for calculated emissions and provided specific explanations for excluded emissions	All emission categories excluding zero emissions	50%	68%	59%
		Percentage of supply chain categories with assurance complete or in progress	All emission categories	15%	24%	20%

To provide a big picture overview of the results, the indicators are presented together for each supply chain category. This excludes the indicator that assessed the Percentage of companies that reported using data from suppliers to calculate emissions. As it was discussed in section 3.1.5, this indicator considers diverse types of data which makes the indicator difficult to interpret.

Accordingly, each supply chain emission category fits in one of the categories below.

1. **Transparently calculated with supplier emission data**. Including emissions that are
    - Calculated with supplier or supplier/secondary calculation methods and in case of using other calculation methods (e.g., secondary emission data source), they are transparently calculated

2. **Transparently calculated with only secondary data**. Including emissions that are
    - Calculated with only secondary data

3. **Calculated-zero emissions**. Including emissions that have
    - Zero emission value

4. **Excluded as not relevant or included elsewhere.** Including emissions that are
    - Excluded-included elsewhere,
    - Excluded-no emission,
    - Excluded-low contribution,
    - or excluded-not relevant for other reasons.

5. **Calculated-not transparent**. Including calculated emissions that provided
    - No calculation methodology description,
    - Insufficient calculation methodology description,
    - or No emission database

6. **Excluded-others.** Including emissions that are
    - Excluded- estimate in progress
    - Excluded- data/accounting issues
    - Excluded-not yet calculated for other reasons

7. **Excluded-no specific explanation**. Including emissions that provided
    - No specific explanation for the exclusion

8. **Excluded-without explanation**. Including emissions that provided
    - No explanation for the exclusion

Figure *18* shows the result of the above classification for each supply chain category and aggregated across all supply chain categories. The results are also shown for companies in the manufacturing and services, and companies in manufacturing and services aggregated.

The emissions in the grey colour scheme have either transparency or completeness issues. First, the emissions Calculated-not transparent, Excluded-no specific explanation, and Excluded-without explanation have transparency issues (as mentioned in section 3.1.6). Overall, 39% of emissions in both industries have transparency issues with companies in services (31%) outperforming those in the manufacturing (50%). Second, excluded emissions (i.e., Excluded-no specific explanation, Excluded-without explanation, and Excluded-others) are excluded because of reasons other than irrelevancy of emissions – for example, they were excluded because of data and accounting issues. These emissions could likely be relevant and calculated. Overall, 32% of emissions in both industries have this issue with companies in services (25%) outperforming those in the manufacturing (43%).

As a result, transparency and completeness of emissions for services companies are higher than those for manufacturing companies. This is in line with the third-party assurance status of emissions. Also, the figure shows the assurance status of supply chain categories, and companies in services (24%) have more assurance in place or in progress than those in manufacturing (15%).

The emissions with the colour scheme are transparently calculated or excluded as not relevant or included elsewhere. These emissions constitute 42% of manufacturing companies, 61% of services, and 53% of both industries. In other words, transparency, completeness, and accuracy issues were not identified for these emissions. Considering both industries, 6% of emissions are transparently calculated using supplier emission data and 21% using only secondary databases.

Also, regarding each supply chain category, leased assets category has the highest performance (i.e., emissions with colour schemes) for each industry –56% in manufacturing, 72% in services, and 64% in both industries. The lowest performance for manufacturing companies was identified for upstream transportation and distribution (35%) followed by purchased goods and services (37%). The lowest performance for services companies was identified for purchased goods and services category (52%). And finally, considering both industries, the purchased goods and services category has the lowest performance (44%). However, purchased goods and services tend to be the most important emission category (e.g., a significant emission source) of companies' scope 3 emissions (Johannes et al., 2019; SBTi, 2018), and the total emissions reported for each supply chain category by companies in manufacturing and services industries for the year 2020 to CDP shows that the purchased goods and services has the highest emissions compared with other emission categories.

Overall, considering both industries, based on GHG Protocol principles, for close to half of the emissions (53%) no completeness, accuracy, and transparency issues was identified. Combining these principles with SCPM metric elements, the emissions that are entirely based on secondary data do not reflect what is happening is supply chain; hence, by not considering them, at most 32% of emissions are following both GHG Protocol elements and SCPM metric elements.

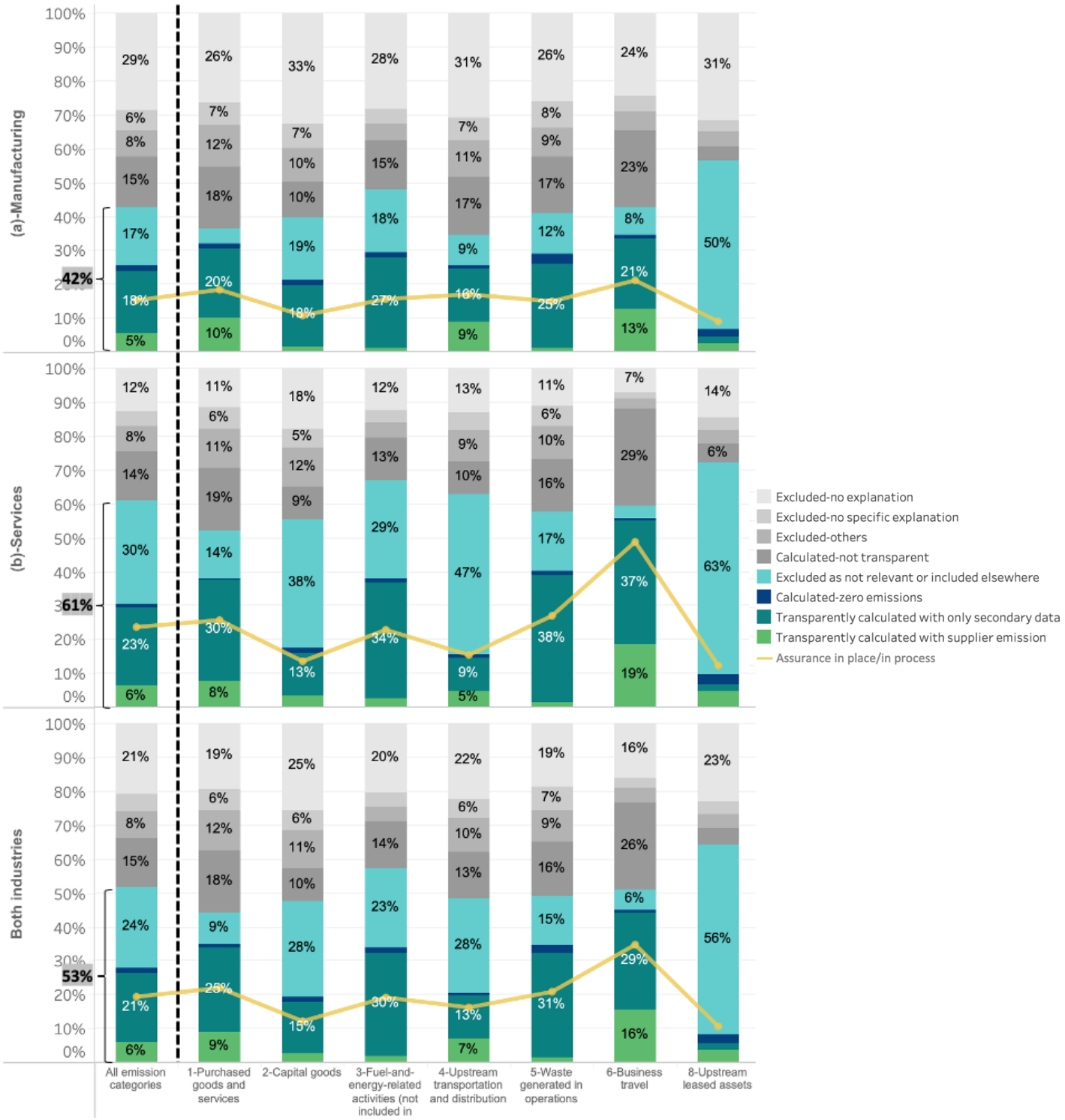

Figure 18. Combination of indicators assessed

CHAPTER 4

4 DISCUSSION

4.1 Summary of Findings

The results of this study showed different issues associated with completeness, accuracy, and transparency of emission disclosures.

Regarding completeness issues, emissions explanations of estimate in progress, data/accounting issues, not yet calculated for other reasons, specific explanation not provided, and blank (no explanation) are emission exclusion explanations that could potentially be calculated. These exclusions account for 32% of emissions across both industries. Moreover, completeness can be diminished by misidentifying emission categories as not relevant. The categories and subcategories exclusion explanation reasons due to lack of relevance are provided appendix 5.1 (i.e., low contribution, no emissions, and not relevant for other reasons) and subcategories. The size criterion was (i.e., low contribution, no emissions) the most common explanation for emission categories that were excluded due to lack of relevance. However, the subcategories show that companies may interpret the size criterion differently. For example, some companies mention that the emissions are low due to the nature of their business activities, whereas some companies reported low emissions based on emission screening. Thus, it seems that it seems that the decision of an emission relevance can be subjective and based on companies' discretion rather than science or guidelines. Considering both industries, the capital goods category has the highest level of incompleteness.

Regarding transparency issues, companies are not transparent in emission calculations or exclusions in different ways. In the case of calculating an emission category, the company may provide no calculation methodology description, the calculation methodology that they provide may be not sufficient to identify the methodology, or the used emission databases may not be provided. In case of excluding an emission category, the company may provide no explanation, or they may provide an explanation that is not specific (e.g., the emission is not evaluated, or they provide information that does not address the question). The emissions with transparency issues account for 39% of emissions across both industries with a low variance between different supply chain categories.

Regarding accuracy issues, the assumption of the study was that the supplier or supplier/secondary emission has a higher level of accuracy in comparison with emissions that are entirely based on secondary data sources. Although both emission calculations comply with the accounting principles of the scope 3 standard. Emission categories that are entirely based on secondary data likely do not reflect the real supply chain emissions. Secondary data, however, can be useful in providing a complete GHG inventory (Ballard, 2022). Considering both industries, 6% of emissions are calculated using supplier or supplier/secondary emission and 21% using only secondary data. Waste generated in operations, Fuel- and energy-related activities not included in scope 1 and scope 2, and capital goods have the lowest use of supplier or supplier/secondary emission data source. The study also found that the indicator of the percentage of companies that

reported using data from suppliers to calculate emissions refers to diverse types of data (e.g., spend, activity, emission data), and hence, it is not interpretable

Overall, services companies showed a better performance in terms of completeness and transparency indicator; however, the performance level for accuracy indicators between the two industries was similar.

The assurance status of supply chain emissions was also studied. Considering both industries, 20% of emissions have verification in place or process. The calculated emissions tend to be more verified than excluded emissions. Also, the study found a connection between assurance and transparency of calculation descriptions and explanations of exclusion reasons. For calculated emissions, more transparently described calculated emissions tend to be more verified. Also, for excluded emissions, the explanation reason of included elsewhere was more verified than the remaining explanation reasons and emission exclusion of not relevant for other reasons has the second highest verification. Those emissions that are specified as not relevant for other reasons and consider more than one criterion in assessing the relevance of an emission category are more verified, and hence, they are more likely correctly excluded as not relevant. Also, between the three explanations related to the relevance of emissions, the no emission category has the lowest assurance.

4.2 Implications for Managing Greenhouse Gas Emissions

Companies likely choose different calculation methods depending on their business goals. The specificity of calculation methods and the use of primary emissions tend to affect most of these goals. According to the GHG protocol, the emissions should be complete, accurate, and transparent, and based on SCPM, the emission should quantify what is happening in supply chains in a verifiable way. Based on these two lenses, this study proposed some indicators and assessed companies' supply chain accounting practices accordingly. The combination of the indicators showed that at most 32% of emissions' disclosures follow both SCPM elements and GHG Protocol principles. Not following SCPM elements and GHG Protocol principles would impede achieving most of scope 3 emission calculation business goals. More specifically, the goal of "identifying GHG reduction opportunities, setting reduction targets, and tracking performance does not seem to be achievable" with identified completeness, accuracy, and transparency issues. As mentioned earlier in section 1.1.5, these issues would affect other supply chain emissions reporting goals. For example, accuracy issues would impede "communication and engaging value chain partners in GHG management and incomplete and not transparent disclosure would not contribute to "enhancing stakeholder information and corporate reputation through public reporting" (Pucker, 2021). The next section suggests some improvement aspects for the shortcomings that were identified in this study.

4.2.1. Recommendations

The results and discussions of each indicator proposed based on three Scope 3 Standard accounting principles SCPM metric elements can benefit different stakeholders to understand the current practices and use them for further improvements and research. The following paragraphs provide some recommendations for CDP, GHG Protocol, and researchers for potential future research.

CDP can be more detailed for the questions regarding scope 3 so that companies can be more specific and transparent in their disclosures. First, the data definition in Q6.5.C4 (i.e., Percentage of data coming from suppliers or value chain partners) could be specific. CDP can break down this question into activity data and emission factor, so companies can report the percentage of data coming from suppliers for the two parameters separately. Second, a separate question can be allocated to whether the reported emission from suppliers (if the emission is coming from suppliers) is specific to suppliers' activities, or they are estimated based on only average emissions (i.e., secondary databases). Third, in the case of using the emission databases to estimate the emissions, the company should also specify the database(s) (e.g., DEFRA emission factor database). Lastly, for excluded emissions, the answer to the question (of exclusion explanations) can be more specific. For example, companies can choose from a set of predefined options based on the explanation categories identified in this study (appendix 5.1). As a result, exclusion explanations reasons can be more consistent and transparent between all companies.

GHG Protocol can provide further support to assist companies to improve the completeness, accuracy, and transparency of emissions. For completeness of emissions, the decision of identifying an emission category as not relevant (i.e., no emissions, low contribution, and not relevant for other reasons categories), seems to be subjective and based on companies' discretion. Further guidelines (e.g., based on companies' industry sectors and activity) may be needed, so that the decision of excluding an emission category as not relevant can be more accurate, as it was observed that excluded emissions tend to have a lower assurance compared with calculated emissions. For the accuracy of emissions, it seems that there should be more detailed guidelines and support to assist companies in collecting specific emissions from suppliers. Specifically, for those emission categories that the results showed a lower use of supplier emissions (i.e., waste generated in operations, fuel- and energy-related activities, and capital goods) it seems that further support is needed to help the related suppliers provide emissions to companies. For transparency of emission disclosure, this study showed a positive connection between assurance and transparency of calculated and excluded emissions. It seems that requiring companies to more verified emission disclosures more would enhance transparency accordingly. Moreover, the results showed that companies tend to provide limited/moderate assurance rather than high/ reasonable assurance. It is not clear why companies do not provide high/ reasonable assurance. GHG Protocol needs to look into this as the current verification mechanism might be insufficient to provide a high/ reasonable assurance (Talbot and Boiral, 2013).

Researchers can also consider the following pathways for further investigation.

- Transparency of emissions exclusion because of their relevance can be further investigated. Scope 3 Standard specifies a set of criteria so that companies can identify emissions relevance according to their activities. However, the explanation reasons (appendix 5.1) show that this decision could be subjective and potentially erroneous. Future research, for example, can evaluate explanation reasons based on companies' industry sectors and activities (e.g., using CDP questionnaire categorization) to further analyse the accuracy of emission relevance accuracy.

- This study also did not evaluate the consistency accounting principle of supply chain emission reporting. Future research can study this by focusing on changes in companies' supply chain emission measurement practices.

- Given the growing importance of supply chain emissions and the emergence of initiatives to capture supplier emission data and increase emission transparency, the same research could be repeated in the future. For example, in five years, the researcher can assess the possible changes in companies' supply chain emission completeness, accuracy, and transparency of emissions.

- Given the importance of primary data and specificity of calculation methods, academic and industry researchers and initiatives have been recently exploring primary emission data collection from suppliers. For example, the WBCSD Pathfinder project proposes guidance for the accounting and exchange of product life cycle emissions to create more comparable, consistent, and verified product-level GHG emissions across the value chain (WBCSD, 2021). Kaplan and Ramana argued that current GHG-accounting standard discourages supply-chain decarbonization, and there is a need for better carbon accounting based on actual supply-chain emissions. They proposed an e-liability accounting system inspired by well-established practices from inventory and financial accounting (Ballard, 2022; Kaplan and Ramana, 2022). Horizon Zero is another project focusing on product-level greenhouse gas accounting proposing tracking real emissions using state-of-the-art technology ("Horizon Zero," 2022). Issues that impede adaptation of the proposed systems for supplier emission data collections should be further investigated, such as complexities of emission allocation (Shrimali, 2022; WRI/WBCSD, 2011), scalability of some of these initiatives (Sunny et al., 2020) and maintaining the confidentiality of stakeholders (Dagnet et al., 2019).

- Finally, future research can evaluate the efficacy of the Industry collaboration calculation methodology. This study showed that companies used the industry collaboration to account for their supply chain emissions less than any other calculation methodology -–overall, less than 1%. However, it seems that this method can likely help companies to collect more suppliers' emission data, find the relevance of supply chain categories, and provide emission calculation resources and guidelines specific to companies in the same industry.

4.3 Limitations

This study aimed to adopt a rigorous approach to evaluating and coding companies' supply chain emission measurement and disclosures. Apart from some analysis limitations mentioned in different parts of the text, such as the exclusion of companies that provide their emission information in other languages. Two other limitations are as follows.

First, this study does not evaluate emission activity data as it does not seem to be possible to do so with the current available questions of the CDP questionnaire; companies may estimate the activity data or may extract it from suppliers' reports and invoices. This issue was addressed in the Percentage of companies that reported using data from suppliers to calculate emissions indicator that the "data" in this context can refer to a diverse type of data.

Secondly, the results of this research are based on companies' voluntary disclosures to CDP, and companies may not be precise enough when addressing disclosure questions. This can eventually result in erroneous emission calculation or exclusion coding and categorization. However, this study tried to minimize these errors in the coding process, by adopting an iterative approach –i.e., coding the information in multiple iterations.

4.4 Conclusion

Supply chain emission measurement practices may not necessarily lead to their management. The current practices of supply chain emission accounting for the companies of two major industries regarding their completeness, transparency, accuracy (GHG Protocol principles) and also whether these emissions are verifiable and reflect what is happening in supply chains were analysed (SCPM metric elements). The results showed that, at most, 32% of disclosures follow both SCPM elements and GHG Protocol principles. A small fraction of emissions (6%) is calculated using the emission coming from suppliers. Emissions that are calculated based on only secondary data potentially fall short to reflect supply chain real emissions. Fuel-and-energy-related activities not included in scope 1 and scope 2, waste generated in operations, and capital goods have the lowest use of supplier emission data. The results also show that at least 39% and 32% of emissions have transparency and completeness issues, respectively. Providing no or insufficient calculation and exclusion description decreases the transparency of disclosures. Emissions incompleteness also happens when companies exclude emissions because of reasons other than including the emission category elsewhere or excluding emissions due to lack of relevance. Also, excluding emission categories due to lack of relevance seems to be based on companies' discretion rather than requirements and guidelines. This study also found that although assurance is not mandatory based on the scope 3 standard, the more transparent emission calculations tend to be more verified. Overall, achieving the goals of supply chain emissions calculation needs to be accompanied by more transparency, completeness, and real emissions from supply chains. CDP by addressing more detailed questionnaires, GHG Protocol by providing further guidelines, and researchers by focusing on areas that need to be investigated can help companies with these improvements.

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APPENDIX

5.1 Emission Exclusion Reasons Breakdown by Category and Subcategory.

The table shows the breakdown of exclusion explanation categories and subcategories for the manufacturing and services companies. Overall, for both industries, the inclusion of emissions in other emission scopes (i.e., scope 1 and/or scope 2) (10.9%) and no emissions because of no activity (6.1%) have the highest share of exclusions explanations in the manufacturing and services, respectively.

Exclusion category	Exclusion subcategory	(a)-Manufacturing	(b)-Services
Specific explanation not provided	Not yet calculated	6.5%	5.8%
	Unclear/ not explained	3.3%	2.5%
Not yet calculated-for other reasons	Do not report every year	0.0%	
	The focus is on other scopes or categories	0.3%	0.7%
Data/accounting issue	Data gaps	1.3%	1.4%
	Difficult to allocate	-	0.1%
	Difficult to report separately	0.1%	0.0%
	Do not control data	1.2%	1.3%
	Emissions are not verified yet	0.2%	0.1%
	Lack of knowledge/ training/ resources	0.9%	0.6%
	Low data quality	0.3%	0.6%
	No available/ not accurate methodology	0.6%	0.9%
	No data collection process	2.8%	2.0%
	Value chain/ operational complexity	1.0%	1.1%
Estimate in progress	Building/ acquiring capacity	2.1%	1.4%
	Engaging with value chain partners	0.2%	0.1%
	Expanding the inventory boundary	0.4%	-
	In progress	2.0%	3.7%
	To set an SBT	0.2%	0.0%
Not relevant for other reasons	Lack ownership, control, or influence	0.4%	0.7%
	Not material/ not relevant	0.7%	2.1%
	Not relevant according to Table 6.1 criteria	0.7%	1.6%
	Not requested by stakeholders	-	0.1%
	Not within selected boundary	1.6%	1.2%
Low contribution	Low activity	2.3%	5.0%

	Low activity for the reporting year	-	0.0%
	Nature of business	0.5%	7.6%
	No significant source identified	0.4%	0.4%
	Relatively low emissions assumed	1.1%	2.2%
	Relatively low emissions based on screening	3.8%	2.5%
	Small size company	-	0.5%
No emissions	Nature of business	0.7%	4.5%
	No activity	6.8%	9.3%
	No activity for the reporting year	0.4%	0.2%
	Not applicable	2.1%	2.6%
Included elsewhere	Other category	0.8%	2.9%
	Other scope	6.1%	10.9%
	Other scope and category	0.2%	0.5%
	Unspecified	0.2%	0.3%

5.2 Emission Calculation Sources Identified

The table shows the calculation sources used and their corresponding calculation type for companies in the manufacturing and services shows, and for both industries combined. The table is adjusted in decreasing order for both industries column. Activity-based emission factor extracted from the DEFRA database with 16.6% have the highest use percentage. Also, the top ten emission calculation sources account for 61% of calculation methods used in both industries.

Row	Emission calculation source	Calculation type	(a)-Manufacturing (%)	(b)-Services (%)	Both industries (%)
1	DEFRA EF	Activity-based EFs	10.21%	21.97%	16.60%
2	Emission factor - Unspecified	Activity-based EFs	13.53%	8.93%	11.03%
3	Supplier (Emissions Data)	Supplier-direct	8.80%	7.47%	8.08%
4	Spend data with GHG Protocol scope 3 Evaluator tool -Quantis	Spend-based method	6.25%	3.69%	4.86%
5	Spend data with Emission factor (Unspecified)	Spend-based method	4.67%	4.42%	4.54%
6	Database of Emission Intensity for Calculation of Greenhouse Gas Emissions by Organizations throughout the Supply Chain, Japan-Physical EF	Activity-based EFs	7.33%	1.82%	4.34%
7	ecoinvent EF	Activity-based EFs	4.02%	3.78%	3.89%

8	Spend data with Databases of Emission Intensity for Calculation of Greenhouse Gas Emissions by Organizations throughout the Supply Chain, Japan	Spend-based method	4.83%	1.05%	2.78%
9	ADEME Bilan Carbon Tool-physical EF	Activity-based EFs	2.82%	2.69%	2.75%
10	EPA Emissions Factors	Activity-based EFs	1.96%	2.69%	2.35%
11	Spend data with DEFRA EF	Spend-based method	1.90%	2.37%	2.16%
12	National EF	Activity-based EFs	1.14%	2.46%	1.86%
13	IEA	Activity-based EFs	1.68%	1.87%	1.78%
14	EPA WARM	Activity-based EFs	1.03%	2.10%	1.61%
15	Emission factor - Unspecified	Energy-based EFs	1.47%	1.46%	1.46%
16	CEDA	Spend-based method	0.60%	1.82%	1.26%
17	GHG Protocol emissions coefficient database	Activity-based EFs	0.87%	1.19%	1.04%
18	CDP Supply Chain Responses	Disclosure systems	0.76%	1.28%	1.04%
19	eGrid EF	Activity-based EFs	0.71%	1.28%	1.02%
20	GHG Protocol scope 3 Evaluator tool -Quantis	Activity-based EFs	1.36%	0.68%	0.99%
21	Spend data with ADEME Bilan Carbon EF	Spend-based method	1.20%	0.68%	0.92%
22	DEFRA EF	Energy-based EFs	0.38%	1.28%	0.87%

23	ICAO Carbon Emissions Calculator	Activity-based EFs	0.87%	0.87%	0.87%
24	IPCC EF	Activity-based EFs	0.71%	0.91%	0.82%
25	Supplier (Emissions Data) - Publicly available sources	Publicly available resources	0.11%	1.41%	0.82%
26	Emission factor - LCA studies	Activity-based EFs	0.60%	1.00%	0.82%
27	LCA conducted by the firm w/ supplier engagement-unspecified database	Life cycle assessment (LCA)	1.36%	0.32%	0.79%
28	NGERS EF	Activity-based EFs	0.11%	1.23%	0.72%
29	EIO-LCA	Spend-based method	0.33%	0.82%	0.59%
30	Carbon Footprint Calculation Platform (Taiwan EPA)	Activity-based EFs	0.71%	0.41%	0.55%
31	EPA Emissions Factors	Energy-based EFs	0.33%	0.59%	0.47%
32	Supplier Data -Product environmental report	Publicly available resources	0.33%	0.59%	0.47%
33	Mobile Combustion GHG Emissions Calculation Tool	Activity-based EFs	0.33%	0.55%	0.45%
34	National EF	Energy-based EFs	0.11%	0.68%	0.42%
35	IPCC EF	Energy-based EFs	0.49%	0.36%	0.42%
36	Korean National LCI EF	Activity-based EFs	0.65%	0.23%	0.42%
37	VfU EF	Activity-based EFs		0.77%	0.42%
38	Trucost IO	Spend-based method	0.27%	0.50%	0.40%

39	Gabi EF	Activity-based EFs	0.76%	0.05%	0.37%
40	Energy Information Administration (EIA)	Activity-based EFs	0.22%	0.46%	0.35%
41	Environmental Paper Network, Paper Calculator	Activity-based EFs	0.05%	0.59%	0.35%
42	LCA conducted by the firm w/o supplier engagement-unspecified database	Life cycle assessment (LCA)	0.65%	0.05%	0.32%
43	Ministry of Environment EF, New Zealand	Activity-based EFs		0.55%	0.30%
44	Ecometrica tool	Activity-based EFs		0.55%	0.30%
45	ADEME Bilan Carbon Tool-physical EF	Energy-based EFs	0.43%	0.14%	0.27%
46	Taiwan EPA EF	Activity-based EFs	0.27%	0.27%	0.27%
47	USEEIO	Spend-based method	0.38%	0.18%	0.27%
48	Exiobase	Spend-based method	0.22%	0.32%	0.27%
49	EPA Simplified GHG Calculator	Activity-based EFs	0.38%	0.18%	0.27%
50	IEA	Energy-based EFs	0.16%	0.32%	0.25%
51	LCI database IDEA physical EF	Activity-based EFs	0.49%	0.05%	0.25%
52	EPA Victoria	Activity-based EFs		0.46%	0.25%
53	Embodied Energy and Emission Intensity Data (3EID)	Spend-based method	0.43%	0.05%	0.22%
54	World Bank EF	Activity-based EFs	0.22%	0.18%	0.20%
55	SimaPro EFs	Activity-based EFs	0.38%	0.05%	0.20%

56	Estell 6	Spend-based method	0.43%		0.20%
57	EcoTransIT tool	Activity-based EFs	0.43%		0.20%
58	Korea Environmental Industry and Technology Institute LCI	Activity-based EFs	0.22%	0.14%	0.17%
59	NTMCalc emission calculation model	Activity-based EFs	0.38%		0.17%
60	Estell 4	Spend-based method	0.38%		0.17%
61	PlasticsEurope LCI	Activity-based EFs	0.33%		0.15%
62	Open-IO	Spend-based method	0.27%	0.05%	0.15%
63	LCA conducted by the firm w/supplier engagement-ecoinvent database	Life cycle assessment (LCA)	0.27%	0.05%	0.15%
64	GREET tool	Activity-based EFs	0.16%	0.14%	0.15%
65	Database of Emission Intensity for Calculation of Greenhouse Gas Emissions by Organizations throughout the Supply Chain, Japan-Physical EF	Energy-based EFs	0.16%	0.09%	0.12%
66	EPA SmartWay emissions tool	Activity-based EFs	0.27%		0.12%
67	Canadian Government's National Inventory Report EF	Activity-based EFs		0.23%	0.12%
68	AusLCI-physical EF	Activity-based EFs	0.11%	0.14%	0.12%

69	LCA conducted by the firm w/ supplier engagement-GaBi database	Life cycle assessment (LCA)	0.22%	0.05%	0.12%
70	Input-output tables of Japan	Spend-based method	0.05%	0.18%	0.12%
71	Carbon Footprint Project JEMAI	Activity-based EFs	0.22%	0.05%	0.12%
72	Carbon Footprint Communication Program Basic Database	Activity-based EFs	0.16%	0.09%	0.12%
73	BSR Clean Cargo Working Group EF	Industry collaboration	0.27%		0.12%
74	eGrid EF	Energy-based EFs		0.18%	0.10%
75	The Climate Registry EF	Activity-based EFs	0.16%	0.05%	0.10%
76	Worldsteel	Industry collaboration	0.22%		0.10%
77	Supplier Questionnaire	Supplier-direct	0.16%	0.05%	0.10%
78	SoFi tool	Activity-based EFs	0.05%	0.14%	0.10%
79	GHG Protocol Calculator for Transport Emission	Activity-based EFs		0.18%	0.10%
80	EU27 IO	Spend-based method	0.22%		0.10%
81	Carbon Footprint of Products Program EF database	Activity-based EFs	0.05%	0.14%	0.10%
82	GHG Protocol emissions coefficient database	Energy-based EFs	0.05%	0.09%	0.07%
83	NGERS EF	Energy-based EFs		0.14%	0.07%
84	Mobile Combustion GHG Emissions Calculation Tool	Energy-based EFs	0.16%		0.07%

85	Korean National LCI EF	Energy-based EFs	0.11%	0.05%	0.07%
86	EPA SmartWay emissions tool	Energy-based EFs	0.16%		0.07%
87	Canadian Government's National Inventory Report EF	Energy-based EFs		0.14%	0.07%
88	Brazil's GHG Protocol Program EF	Activity-based EFs		0.14%	0.07%
89	Ministry of Land, Infrastructure, Transport and Tourism EF, Japan	Activity-based EFs	0.11%	0.05%	0.07%
90	HBEFA EF	Activity-based EFs	0.16%		0.07%
91	GLEC EF	Activity-based EFs	0.11%	0.05%	0.07%
92	Covec, Hale & Twomey and Exergi Consulting EF	Activity-based EFs		0.14%	0.07%
93	PAIA	Industry collaboration	0.11%	0.05%	0.07%
94	LCA conducted by the firm w/o supplier engagement-proprietary database	Life cycle assessment (LCA)	0.16%		0.07%
95	EPA GHG equivalencies calculator	Activity-based EFs		0.14%	0.07%
96	EORA database	Spend-based method	0.16%		0.07%
97	Environment and Climate Change Canada EF	Activity-based EFs	0.05%	0.09%	0.07%
98	ELCD EF	Activity-based EFs	0.16%		0.07%
99	Chinese EEIOA database	Spend-based method		0.14%	0.07%
100	Catalan Office for Climate Change EF	Activity-based EFs		0.14%	0.07%

101	ecoinvent EF	Energy-based EFs		0.09%	0.05%
102	Energy Information Administration (EIA)	Energy-based EFs	0.11%		0.05%
103	The Climate Registry EF	Energy-based EFs	0.05%	0.05%	0.05%
104	Brazil's GHG Protocol Program EF	Energy-based EFs		0.09%	0.05%
105	Australian Government National Greenhouse Accounts EF	Activity-based EFs		0.09%	0.05%
106	Australian Government National Greenhouse Accounts EF	Energy-based EFs		0.09%	0.05%
107	National Greenhouse and Energy Reporting Determination for Australian operations EF	Activity-based EFs	0.05%	0.05%	0.05%
108	Climate Active EF	Activity-based EFs		0.09%	0.05%
109	The Norwegian Water Resources and Energy Directorate EF	Activity-based EFs		0.09%	0.05%
110	Supplier Data -Suppliers website	Publicly available resources		0.09%	0.05%
111	Spend data with emissions factor published by University of Sydney	Spend-based method		0.09%	0.05%
112	Spend data with Climate Active EF	Spend-based method		0.09%	0.05%
113	METI and MLIT EF	Activity-based EFs	0.05%	0.05%	0.05%
114	LCA conducted by the firm w/ supplier engagement-proprietary database	Life cycle assessment (LCA)	0.11%		0.05%

115	International Aerospace Environment Group tool-physical EF	Industry collaboration	0.11%		0.05%
116	International Aerospace Environment Group tool-monetary EF	Spend-based method	0.11%		0.05%
117	India Rail Transport EF	Activity-based EFs	0.05%	0.05%	0.05%
118	Hotel Footprinting Tool	Activity-based EFs		0.09%	0.05%
119	GEMIS EF	Activity-based EFs	0.05%	0.05%	0.05%
120	Environmental Defense Fund	Activity-based EFs		0.09%	0.05%
121	CEPI EF	Activity-based EFs	0.05%	0.05%	0.05%
122	Carbon footprint calculator	Activity-based EFs		0.09%	0.05%
123	Carbon Footprint Labeling DB	Activity-based EFs		0.09%	0.05%
124	British Columbia Ministry of Environment & Climate Change EF	Activity-based EFs		0.09%	0.05%
125	Austrian Umweltbundesamt.	Activity-based EFs	0.11%		0.05%
126	Ministry of Environment EF, New Zealand	Energy-based EFs		0.05%	0.02%
127	Taiwan EPA EF	Energy-based EFs		0.05%	0.02%
128	Korea Environmental Industry and Technology Institute LCI	Energy-based EFs	0.05%		0.02%
129	AusLCI-physical EF	Energy-based EFs		0.05%	0.02%

130	Ministry of Land, Infrastructure, Transport and Tourism EF, Japan	Energy-based EFs		0.05%	0.02%
131	HBEFA EF	Energy-based EFs	0.05%		0.02%
132	GLEC EF	Energy-based EFs	0.05%		0.02%
133	Covec, Hale & Twomey and Exergi Consulting EF	Energy-based EFs		0.05%	0.02%
134	National Greenhouse and Energy Reporting Determination for Australian operations EF	Energy-based EFs		0.05%	0.02%
135	Climate Active EF	Energy-based EFs		0.05%	0.02%
136	IAI industry average EF	Activity-based EFs	0.05%		0.02%
137	IAI industry average EF	Energy-based EFs	0.05%		0.02%
138	IAE EF	Activity-based EFs		0.05%	0.02%
139	IAE EF	Energy-based EFs	0.05%		0.02%
140	German Federal Environment Agency EF database (ProBas)	Activity-based EFs	0.05%		0.02%
141	German Federal Environment Agency EF database (ProBas)	Energy-based EFs		0.05%	0.02%
142	Deutsche Bahn EF	Activity-based EFs	0.05%		0.02%
143	Deutsche Bahn EF	Energy-based EFs		0.05%	0.02%
144	BlueSky EF	Activity-based EFs		0.05%	0.02%
145	BlueSky EF	Energy-based EFs		0.05%	0.02%

146	atmosfair EF	Activity-based EFs		0.05%	0.02%
147	atmosfair EF	Energy-based EFs		0.05%	0.02%
148	WSTA Carbon Calculator	Activity-based EFs	0.05%		0.02%
149	Webflyer calculator	Activity-based EFs		0.05%	0.02%
150	University of Texas Waste Calculator	Activity-based EFs		0.05%	0.02%
151	United Nation Framework Convention on Climate Change EF	Activity-based EFs	0.05%		0.02%
152	UNFCCC	Activity-based EFs	0.05%		0.02%
153	UNEP World Meteorological Organisation Climate Change And Tourism EF	Activity-based EFs	0.05%		0.02%
154	UNECE/EMEP Emission Inventory	Energy-based EFs		0.05%	0.02%
155	UL platform EFs	Activity-based EFs	0.05%		0.02%
156	Trip.com	Activity-based EFs		0.05%	0.02%
157	Transportation Energy Data Book (TEDB)	Activity-based EFs		0.05%	0.02%
158	Swiss Federal Office of Energy	Activity-based EFs		0.05%	0.02%
159	Swedish EPA EF	Activity-based EFs	0.05%		0.02%
160	Sustainable Supply Chain Initiative questionnaire	Disclosure systems	0.05%		0.02%
161	Spend data with LCI database IDEA	Spend-based method	0.05%		0.02%

162	Spend data with KoSIF EF	Spend-based method	0.05%		0.02%
163	Spend data with Japan Rubber Manufacturers Association EF	Spend-based method	0.05%		0.02%
164	Spend data with EIME	Spend-based method	0.05%		0.02%
165	Spend data with EFs from studies	Spend-based method	0.05%		0.02%
166	Spend data with Convenant of Mayors EF	Spend-based method		0.05%	0.02%
167	Spend data with British Columbia Ministry of Environment & Climate Change	Spend-based method		0.05%	0.02%
168	Spend data with AusLCI	Spend-based method		0.05%	0.02%
169	Solid Waste Management and Greenhouse Gases EF	Activity-based EFs	0.05%		0.02%
170	Small Emitters Tools (SET)	Activity-based EFs		0.05%	0.02%
171	Skye EF	Activity-based EFs	0.05%		0.02%
172	Russian Railways EF	Activity-based EFs		0.05%	0.02%
173	Recycled Content (ReCon) Tool	Activity-based EFs		0.05%	0.02%
174	RBA tool	Industry collaboration	0.05%		0.02%
175	Quebec Action Fund for Sustainable Development calculator	Activity-based EFs		0.05%	0.02%
176	Postnord's environmental calculator	Activity-based EFs		0.05%	0.02%
177	National Renewable Energy Laboratory	Activity-based EFs	0.05%		0.02%

178	National Inventory of Atmospheric Emissions by Road Motor Vehicles	Energy-based EFs		0.05%	0.02%
179	NABERS rating	Energy-based EFs		0.05%	0.02%
180	NAB Group by the Edinburgh Centre for Carbon	Activity-based EFs		0.05%	0.02%
181	Multiple Interface Life Cycle (MiLCA) Emission Intensity Database	Activity-based EFs	0.05%		0.02%
182	Motu IO	Spend-based method		0.05%	0.02%
183	Makersite LCA	Life cycle assessment (LCA)	0.05%		0.02%
184	Life Cycle Assessment Society of Japan (JLCA) EF	Activity-based EFs	0.05%		0.02%
185	LCA conducted by the firm w/o supplier engagement-Life Cycle Assessment Society of Japan (JLCA) EF	Life cycle assessment (LCA)	0.05%		0.02%
186	Lancaster University IO	Spend-based method		0.05%	0.02%
187	Japan Rubber Manufacturers Association EF	Industry collaboration	0.05%		0.02%
188	Japan Environmental Management Association for Industry EF	Activity-based EFs	0.05%		0.02%
189	ISA input-output model	Spend-based method		0.05%	0.02%
190	International Council on Clean Transportation EF	Activity-based EFs	0.05%		0.02%

191	INIES EF	Activity-based EFs		0.05%	0.02%
192	ICLEI EF	Activity-based EFs	0.05%		0.02%
193	ICCT ef	Energy-based EFs	0.05%		0.02%
194	Guidelines for Carbon Offsetting in Japan	Activity-based EFs		0.05%	0.02%
195	Greener Climate EF	Activity-based EFs		0.05%	0.02%
196	Global Environmental Strategies - GHG calculator	Activity-based EFs	0.05%		0.02%
197	German EF (VDA)	Activity-based EFs	0.05%		0.02%
198	Generalitat de Catalunya	Activity-based EFs		0.05%	0.02%
199	Freight Transport Association	Activity-based EFs	0.05%		0.02%
200	Franklin Associates EF	Activity-based EFs	0.05%		0.02%
201	Finnish WWF´s climate calculator	Activity-based EFs		0.05%	0.02%
202	Finnish Lipasto	Activity-based EFs		0.05%	0.02%
203	Finnish Environment Institute	Activity-based EFs		0.05%	0.02%
204	FEFCO EF	Activity-based EFs	0.05%		0.02%
205	Federal State Statistics Service of the Russian Federation EF	Activity-based EFs		0.05%	0.02%
206	Federal environment agency Austria Ef	Activity-based EFs		0.05%	0.02%
207	European emission standards EF	Activity-based EFs		0.05%	0.02%
208	Envizi tool	Energy-based EFs	0.05%		0.02%

209	Energy Conservation Center, Japan EF	Energy-based EFs	0.05%		0.02%
210	EMEP/EEA emission inventory guidebook	Activity-based EFs		0.05%	0.02%
211	EIME (Environmental Improvement Made Easy)	Activity-based EFs	0.05%		0.02%
212	EEIO- Proprietary database	Spend-based method		0.05%	0.02%
213	Ecodesign directive for energy using products (EUP) EF	Activity-based EFs	0.05%		0.02%
214	CSR report of company	Publicly available resources	0.05%		0.02%
215	Cornell Hotel Sustainability Benchmarking EF	Activity-based EFs		0.05%	0.02%
216	Convenant of Mayors EF	Activity-based EFs		0.05%	0.02%
217	COMMERCIAL BUILDINGS ENERGY CONSUMPTION SURVEY (CBECS)	Energy-based EFs	0.05%		0.02%
218	CO2 Baseline Database for the Indian Power Sector	Energy-based EFs		0.05%	0.02%
219	CIRAIG EEIOA	Spend-based method	0.05%		0.02%
220	Central Electricity Authority (CEA)	Energy-based EFs		0.05%	0.02%
221	CEMAsys EF	Activity-based EFs		0.05%	0.02%
222	CDP's industry average intensities EF	Activity-based EFs		0.05%	0.02%
223	Canadian Government T&D emissions factors	Activity-based EFs		0.05%	0.02%
224	Boustead Model EF	Activity-based EFs	0.05%		0.02%

225	ASSET LCI database	Activity-based EFs	0.05%		0.02%
226	ANA calculator	Activity-based EFs		0.05%	0.02%
227	Industrial Technology Research Institute's carbon footprint calculation platform	Activity-based EFs		0.05%	0.02%
228	AerClub Travel	Activity-based EFs		0.05%	0.02%
Total			100%	100%	100%