

Calculating Scope 3 Emissions: An Overlooked Aspect of Our Manufacturing Carbon Footprint

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ABSTRACT

Scope 3 emissions are the indirect emissions from a company's supply chain. Companies typically report Scope 1 (direct product production) and Scope 2 (purchased electricity) emissions. Reducing the seldom-reported Scope 3 emissions, which can comprise around 60% of the reported emissions, can help in industrial decarbonization. This work simplifies the complex calculation of Scope 3 emissions with the development of 15 Microsoft Excel calculators (one per Scope 3 category), and a case study of the steel sector's Scope 3 emissions. For steel, Scope 1 emissions range from ~15-88%, whereas Scope 3 emissions range from ~9-66%. The U.S. Environmentally-Extended Input-Output (EEIO) modeling results report primary metals' Scope 1 emissions as ~45% and Scope 3 emissions as ~33%. This variability requires further investigation and may stem from factors such as Scope 3 calculation complexities and differences in sectors' products. The next step will be publishing a journal article on these findings.

Table of Contents

ABSTRACT.....	ii
1. INTRODUCTION.....	1
2. SCOPE 3 CALCULATORS.....	4
3. SCOPE 3 CASE STUDY	8
4. CONCLUSION	13
ACKNOWLEDGMENTS	14
APPENDIX: SCOPE 3 CATEGORIES.....	15
REFERENCES.....	19
Figure 1: Diagram representing Scope 1, Scope 2, and Scope 3, as well as 15 categories within Scope 3 emissions. ¹²	1
Figure 2: A list containing the name and illustration for each Scope 3 category, adapted from SULI project poster. ¹⁵	2
Figure 3: A graph showing Scope 1, Scope 2, and Scope 3 emissions within manufacturing sectors. Data is sourced from the Carbon Disclosure Project (CDP). ³	2
Figure 4: A depiction of the Scope 3 calculation methods, sorted by level of accuracy. ⁶	5
Figure 5: Calculation simulation for Category 7 (Employee Commuting). These values are for illustrative purposes only and do not represent actual data. User input values are in the golden cells, while calculated results are in the orange cells.	6
Figure 6: Calculation simulation for Category 10 (Processing of Sold Products). These values are for illustrative purposes only and do not represent actual data. User input values are in the golden cells, while calculated results are in the orange cells.	6
Figure 7: An example calculation for Category 7 (Employee Commuting), based on a 2010 ORNL survey. ¹¹ The percentages are exact values, while other values are extrapolated from the survey.....	8
Figure 8: A graph depicting the carbon intensities of BF-BOF steel production, courtesy of the Global Efficiency Intelligence. ⁹	9
Figure 9: A graph depicting the carbon intensities of EAF steel production, courtesy of the Global Efficiency Intelligence. ⁹	10
Figure 10: Scope 1+2+3 emission intensities for the American steel sector , based on data from the EEIO. ⁴	11
Figure 11: Scope 1+2+3 emission data from Metallus , based on company sustainability reporting. ¹	11
Figure 12: Scope 1+2+3 emission data from Nippon Steel , based on company sustainability reporting. ¹⁰	11
Figure 13: Scope 1+2+3 emission data from POSCO , based on company sustainability reporting. ⁵	12
Figure 14: Scope 1+2+3 emission data from U.S. Steel Corporation , based on company sustainability reporting. ⁸	12
Figure 15: Optimal methods for Category 1 (Purchased Goods and Services) based on emission data availability. ¹²	15

1. INTRODUCTION

Industrial activities account for around 23% of all carbon dioxide (CO₂) emissions in the United States,¹⁵ which need to be addressed and properly evaluated to achieve various net-zero targets. Industrial and manufacturing emissions can be categorized as Scope 1 (direct product production emissions), Scope 2 (emissions from purchased electricity), or Scope 3 emissions. This project was centered around Scope 3 emissions and the importance of reducing them. Scope 3 emissions are comprised of all the indirect emissions occurring in a reporting company's supply chain, including upstream (company to supplier) and downstream (company to consumer) operations. Due to the wide range of Scope 3 emission sources, there are 15 categories of such emissions, of which the first eight are upstream and the rest are downstream.⁷ Examples of these categories include employee commuting (Category 7) and processing of sold products (Category 10). Figure 1 represents Scope 1, Scope 2, and Scope 3 emissions, along with the detailed categories within Scope 3, as also presented in Figure 2.

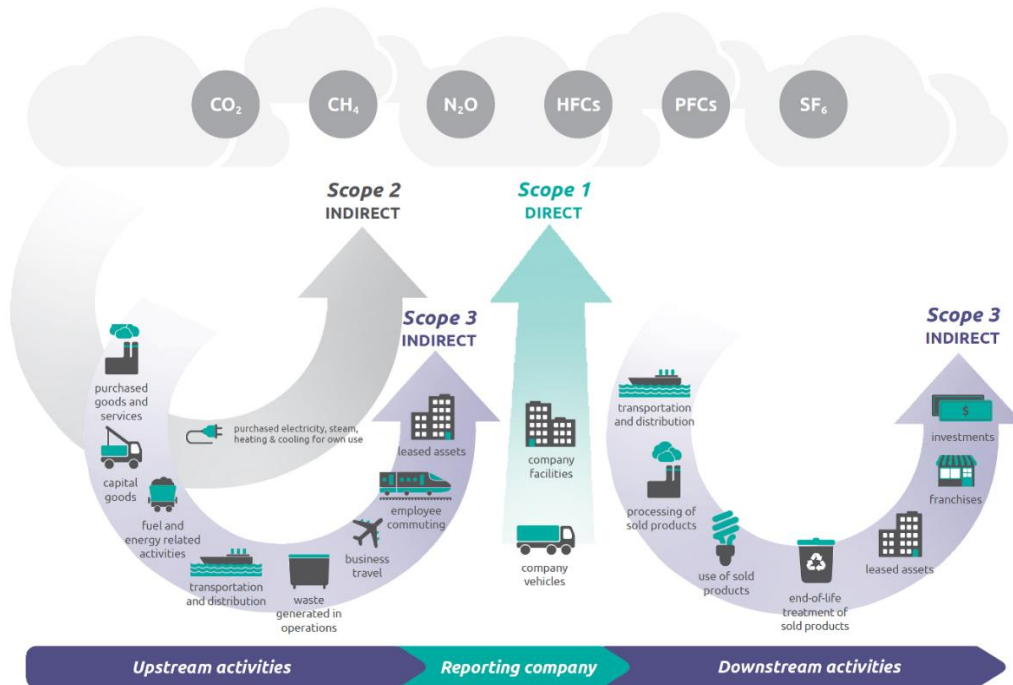


Figure 1: Representation of industrial Scope 1, Scope 2, and Scope 3 emissions, as well as 15 categories within Scope 3 emissions.¹²

SCOPE 3 EMISSIONS CATEGORIES

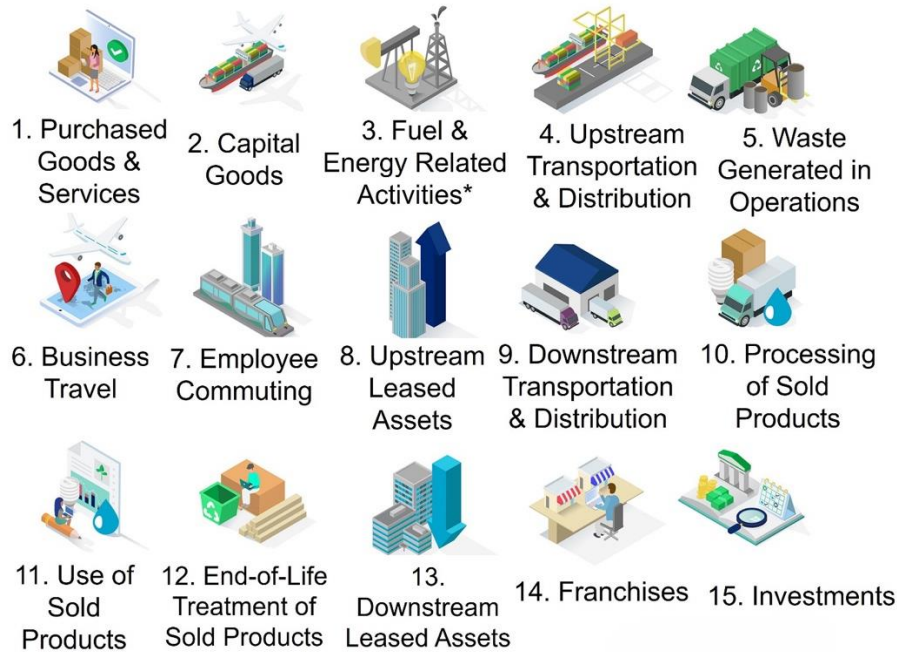


Figure 2: A list containing the name and illustration for each Scope 3 category, adapted from GHG Protocol's Technical Guidance for Calculating Scope 3 Emissions.¹⁶

Companies typically report Scope 1 and Scope 2 emissions. Reducing the seldom-reported Scope 3 emissions, which can comprise around 60% of the reported emissions, can help in industrial decarbonization⁷. Figure 3 represents the prevalence of Scope 1, Scope 2, and Scope 3 emissions within select manufacturing sectors, along with averages among the sectors, as identified by the Carbon Disclosure Project (CDP).

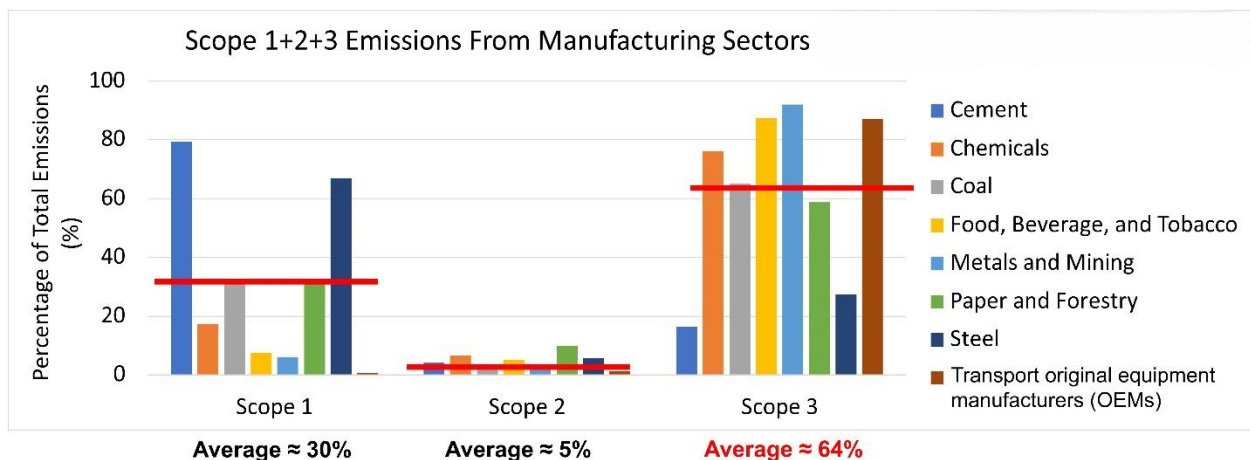


Figure 3: A graph showing Scope 1, Scope 2, and Scope 3 emissions within manufacturing sectors. Data is sourced from the Carbon Disclosure Project (CDP).³

The process of calculating Scope 3 emissions can be complex due to the different methods, categories, and the volume of data required. Thus, the objective of this project was to address the complexity of the Scope 3 emission situation with the development of a set of 15 Microsoft Excel calculators (one per Scope 3 category), which would allow reporting companies to fully understand their Scope 3 emissions and the ways they should go about reducing them. In each calculator, companies can enter carbon dioxide (CO₂) emission data and receive emission measurements. This project was focused mainly on manufacturing sectors. Since the steel sector has a major impact on some other manufacturing sectors, the second phase of this project was a case study of Scope 3 emissions within the steel sector. The investigation of sustainability reports from four primary steel companies and comparison of the related emission data with that from the U.S. Environmentally-Extended Input-Output (EEIO) Models led to finding a wide variability in Scope 3 emissions, which range from ~9-66% of the companies' total emissions.⁴ The case study also included an examination of two major types of steelmaking processes. Carbon intensity refers to the amount of CO₂ emissions (including Scope 1, Scope 2, and Scope 3) per unit value - in this case, metric tons of steel produced. It was found that the electric arc furnace (EAF) has a carbon intensity of about one-third that of the blast oxygen furnace (BF-BOF), and that the overall carbon intensities of steel produced in the United States are lower than those of many countries.⁹ More details regarding steel Scope 3 emissions will be discussed in the *Scope 3 Case Study* section.

2. SCOPE 3 CALCULATORS

As mentioned in the introduction, the first phase of this project involved the developing a set of 15 Microsoft Excel calculator tools in which companies can input emission data and receive Scope 3 emission calculations tailored to their business goals. An all-encompassing calculator tool to calculate the total Scope 3 emissions can be helpful for companies, but only if all necessary data are available. When all necessary data are available, companies might only focus on and report certain Scope 3 categories that are assumed to be relevant to them, as shown in the *CDP Technical Note: Relevance of Scope 3 Categories by Sector*.³ For example, a company without franchises would likely forego emissions for Category 14, or a company that does not offer business travel would eliminate Category 6. However, it should be noted that there is still uncertainty around the relevant Scope 3 categories as seen in the relevancy and evaluation status of the categories reported by sector in the CDP Technical Note.³ Additionally, some Scope 3 categories focus on the same activity and are only different in being upstream or downstream. This would include Categories 4 and 9 (Transportation and Distribution) and Categories 8 and 13 (Leased Assets). Companies may choose to calculate one category from each pair if their operations are almost exclusively upstream *or* downstream.

One example Scope 3 calculation method is the *supplier-specific method*, which can be carried out if all the required emission and activity data is known. For instance, if the emission factor for steel is 0.27 metric tons of CO₂ per metric ton of steel, a company calculating Category 1 emissions who has purchased 68,000 metric tons of steel within the last year can input 68,000 and 0.27 and find their total Scope 3 emissions for the category to be 18,360 metric tons of CO₂. However, another option should this data not be available would be the *average-data method*, which estimates the emissions based on the general weight of purchased goods and relevant emissions factors. Some companies may find it useful to perform the *spend-based method*; as the name suggests, this would require indicating the amount of money spent on purchased goods and an emission factor determining the mass of CO₂ emitted per dollar (or other unit of economic value) spent.

Additional formulas include the *site-specific method* (if emission data -- including fuel and electricity use as well as fugitive emissions such as refrigerant leakage -- is available from the site of the work in question) and the *project-specific method* (if the calculation concerns a

specific project or investment with known proceeds, such as Category 15). In general, supplier-specific methods tend to be more accurate than activity-based or spend-based methods, as depicted in Figure 4.⁶ Companies with further inquiries about category-related details or the corresponding formulas can consult the GHG Protocol’s *Technical Guidance for Calculating Scope 3 Emissions*.¹²

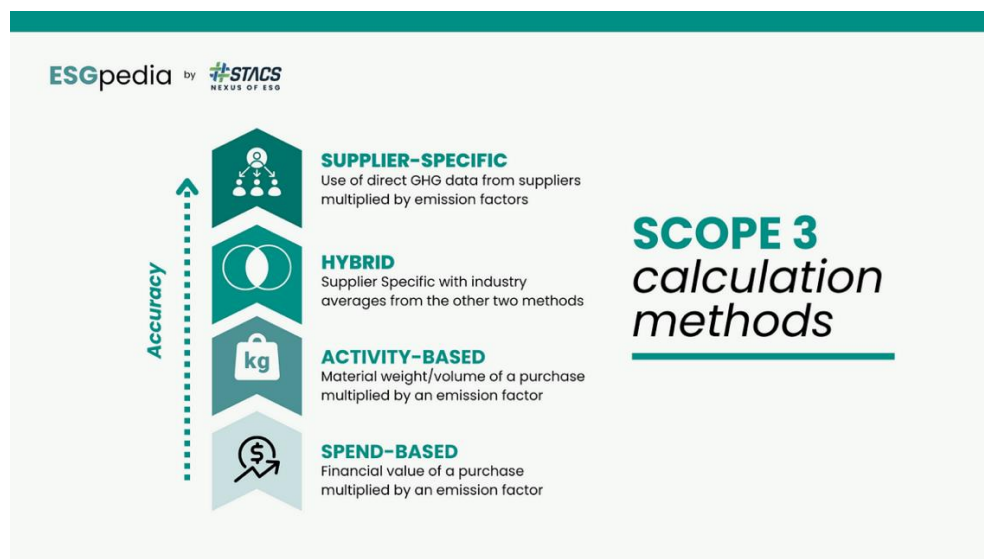


Figure 4: A depiction of the Scope 3 calculation methods, sorted by level of accuracy.⁶

Each calculator consists of a data table with golden cells identifying the desired locations to input emission values, and orange cells identifying the calculated results. Figure 5 and Figure 6 represent calculation simulations for Category 7 (Employee Commuting) and Category 10 (Processing of Sold Products), respectively, with the user input values shown in golden cells and the calculated results shown in orange cells.

Name of Quantity	Value	Units
Quantity of Fuel Consumed		250 gallons
Fuel Emission Factor		8.78 kg CO ₂ /gallon
Fuel Emissions		2195 kg CO ₂
Quantity of Electricity Consumed		6000 kWh
Electricity Emission Factor		0.3733518 kg CO ₂ /kWh
Electricity Emissions		2240.1108 kg CO ₂
Quantity of Refrigerant Leakage		0.5 lb
Refrigerant Global Warming Potential		872.710682 kg CO ₂ /kg
Refrigerant Emissions		197.9272179 kg CO ₂
TOTAL EMISSIONS		4633.038018 kg CO₂
		10214.08828 lb CO₂

Figure 5: Calculation simulation for Category 7 (Employee Commuting). These values are for illustrative purposes only and do not represent actual data. User input values are in the golden cells, while calculated results are in the orange cells.

Site-specific method: Fill in the golden cells and replace emission factors as needed.							
#	Name of Quantity	Amount	Units	Life Cycle Emission Factor	Emission Factor Units	Emissions	Emission Units
1	Fuel	10	gallons	4.5	kg CO ₂ /gallon	45	kg CO ₂
2	Electricity	7500	kWh	0.3733518	kg CO ₂ /kWh	2800.1385	kg CO ₂
3	Refrigerant Leakage	3.25	lb	872.710682	kg CO ₂ /lb	2836.3097	kg CO ₂
4	Process Emissions	1500	lb CO ₂			680.388	kg CO ₂
5	Waste Output	250	lb	1.16	kg CO ₂ /lb	290	kg CO ₂
TOTAL						6651.8362	kg CO₂
						14664.771	lb CO₂

Figure 6: Calculation simulation for Category 10 (Processing of Sold Products). These values are for illustrative purposes only and do not represent actual data. User input values are in the golden cells, while calculated results are in the orange cells.

Finally, with the calculation of Scope 3 emissions being complex in nature and there being uncertainty regarding the relevance of each category for the considered sector, a set of calculators was developed in conjunction with a Microsoft Office Forms questionnaire to inform companies of relevant Scope 3 emission categories. While the CDP has indicated the categories that are typically relevant for each sector,³ there may still be uncertainties as to which categories are the relevant ones. The form includes questions that pertain to specific categories and elicit information about suppliers, customers, employee counts, waste treatment, franchises, leased assets, long-term investments, and storage facilities. At the end of the form is a message recommending which calculations a reporting company should perform based on how they had responded. For instance, a company with several storage facilities and multiple suppliers may be encouraged to calculate emissions for Category 4 (Upstream Transportation and Distribution).

After completing the form and gaining valuable insight in the process, companies may use the set of calculators to more thoroughly calculate their Scope 3 emissions.

3. SCOPE 3 CASE STUDY

The second phase of this work was a case study of Scope 3 emissions within the steel sector. As touched on earlier, this sector has a major impact on other manufacturing sectors, as suppliers and customers of steel companies often fall into sectors like transport original equipment manufacturers (OEMs). Additionally, per the Global Efficiency Intelligence, steel accounts for approximately 21% of global industrial energy use and around 24% of global industrial CO₂ emissions.⁹ After delving into emission data from company sustainability reports, considerable variability in Scope 3 emissions was discovered within the steel sector.

The case study started with a review of data from sustainability plans for Oak Ridge National Laboratory (ORNL). This was to develop a better understanding of ORNL's sustainability policies and practices, in addition to compiling data to compare with that of reporting companies or entire manufacturing sectors. It also allowed the testing and validation of the calculator tools using real values prior to any company receiving them. Figure 7 is an example calculation for Category 7 (Employee Commuting), based on a real 2010 ORNL survey.¹¹ The percentages in the second column from left are exact values taken from that survey, while the rest of the values are extrapolated from the survey's analytic descriptions. For example, it was determined that over 89% of employees (as of the release of the survey) drove alone to commute to work, and the next most common practice was to carpool (around 5%). The emission factors are from the U.S. Environmental Protection Agency (EPA),¹⁴ and it is assumed that two commuting trips per day were taken.

Number of Employees:	6000	**Enter in the green column if electric vehicles are taken into account.											
Mode	Percent (%)	Commute Distance	Distance Units	Percentage of Employees	EV Emission Factor	Commuting Percentage	Emission Factor	Emission Units	Trips per Day (per Employee)	Daily Emissions	Daily Emission Units	% of Emissions	
Drove alone	89	15	mi	1	66.25869462	1	306.0	gCO2/mi	2	48637.1	kg CO2/day	88%	
Public transportation	0	0	mi	0	21.43663649	1	99.0	gCO2/mi	2	0.0	kg CO2/day	0%	
Bicycle	1	5	mi	0		1	0.0	gCO2/mi	2	0.0	kg CO2/day	0%	
Carpool	5	25	mi	0.5	33.12934731	2	153.0	gCO2/mi	2	2286.0	kg CO2/day	4%	
Walked	0	0	mi	0		1	0.0	gCO2/mi	2	0.0	kg CO2/day	0%	
Taxi, motorcycle, etc.	3	30	mi	0.5	81.41591234	1	376.0	gCO2/mi	2	4044.9	kg CO2/day	7%	
Worked at home	2	0	mi	0		1	0.0	gCO2/mi	2	0.0	kg CO2/day	0%	
Average mode		133	mi				291.3	gCO2/mi	2	7852.0	kg CO2/day	14%	
Annual Number of Employees	260									Subtotal	54968.03659	kg CO2/day	
										TOTAL	14291689.51	kg CO2	
										TOTAL	31507807.71	lb CO2	
										TOTAL	14291.68951	MT CO2	

Figure 7: An example calculation for Category 7 (Employee Commuting), based on a 2010 ORNL survey.¹¹ The percentages are exact values, while other values are extrapolated from the survey.

As covered earlier, steel companies use one of two types of furnaces to produce and sell their desired products. The more conventional steelmaking technique involves a blast furnace-basic oxygen furnace (BF-BOF) in which steel is produced from iron ore that results from the melting of raw materials from companies in the metals and mining sector. On the other hand, the more modern and environmentally friendly option is the electric arc furnace (EAF), in which new steel is produced from the melting of recycled scrap steel. This cuts down on the need for iron ore manufacturing, leading to a carbon intensity of around one-third that of the BF-BOF.⁹ Below are two graphs of the overall CO₂ emission intensities within countries, of which the first (Figure 8) represents steel made using BF-BOFs and the second (Figure 9) represents steel made from EAFs. These graphs indicate that the steel sector fares in the United States well compared to most other countries from a sustainability perspective, with only three countries having lower BOF intensity values and only five countries having lower EAF intensity values.⁹ This can be attributed to the fact that within the United States, 70% of all steel production is carried out using EAFs.²

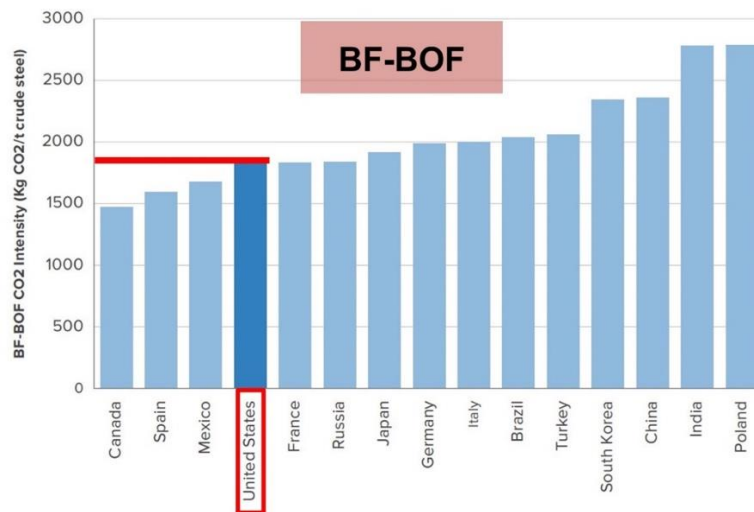


Figure 8: A graph depicting the carbon intensities of blast furnace-basic oxygen furnace (BF-BOF) steel production, courtesy of the Global Efficiency Intelligence.⁹

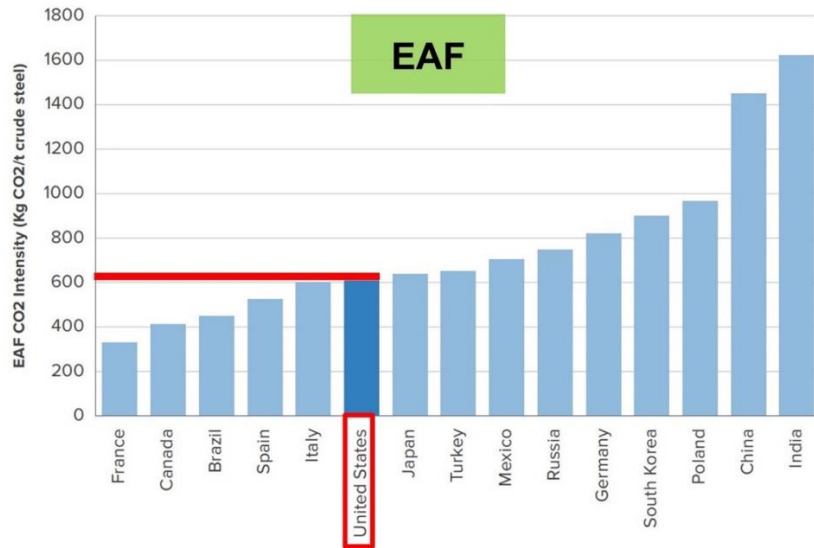


Figure 9: A graph depicting the carbon intensities of electric arc furnace (EAF) steel production, courtesy of the Global Efficiency Intelligence.⁹

The investigation into steel company emission reports revealed a general lack of Scope 3 data availability, as companies tend to prioritize reporting the emissions that are under their control (Scope 1 and Scope 2). Few companies have provided Scope 3 data in any capacity, and even fewer have included categorical evaluations. For these reasons, four companies were selected for comparison with general data for the steel sector in the United States (sourced from the EEIO and represented in Figure 10).⁴ Of these, two are based in the United States (Metallus¹ and U.S. Steel Corporation⁸, shown in Figure 11 and Figure 14, respectively), the third is based in South Korea (POSCO⁵, depicted in Figure 13), and the fourth is based in Japan (Nippon Steel¹⁰, represented in Figure 12). In the pie charts for the CO₂ emission intensities (including Scope 1, Scope 2, and Scope 3) for the steel sector in the United States and the studied companies, Scope 3 emissions are shown to range from ~9-66%, while Scope 1 emissions are shown to range from ~15-88%.

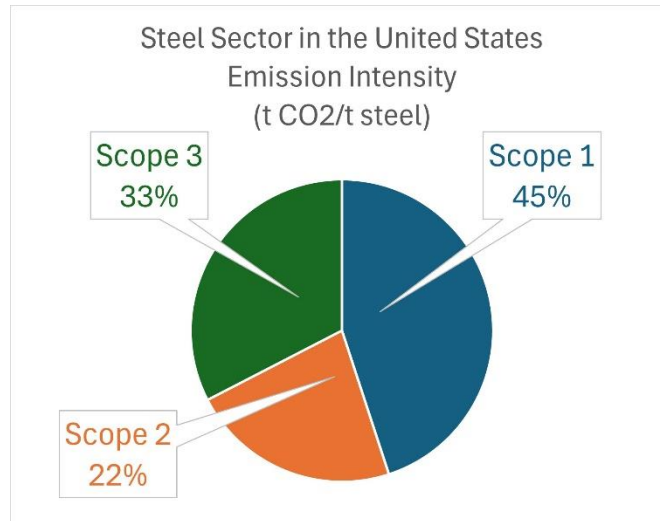


Figure 10: Scope 1+2+3 emission intensities for the steel sector in the United States, based on data from the Environmentally-Extended Input-Output (EEIO) model.⁴

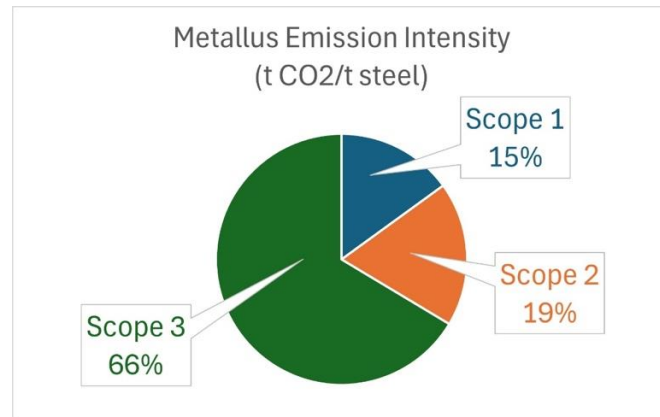


Figure 11: Scope 1+2+3 emission data from Metallus, based on company sustainability reporting.¹

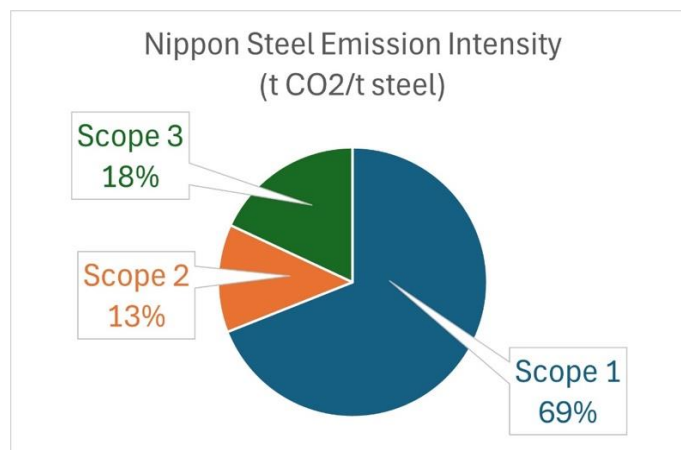


Figure 12: Scope 1+2+3 emission data from Nippon Steel, based on company sustainability reporting.¹⁰

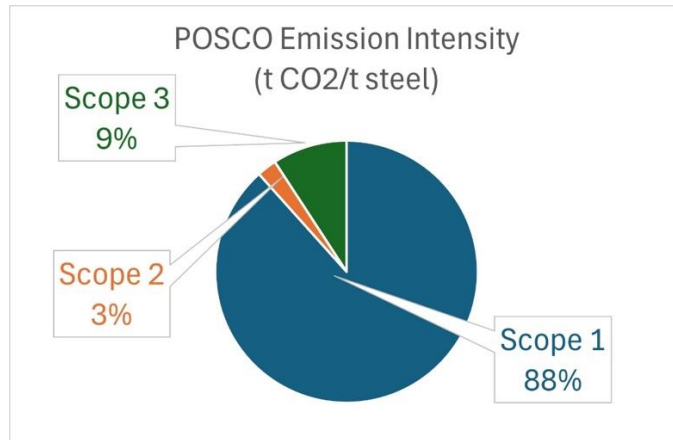


Figure 13: Scope 1+2+3 emission data from POSCO, based on company sustainability reporting.⁵

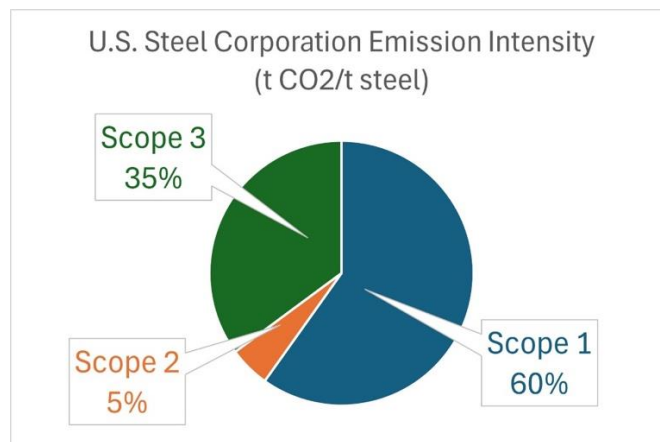


Figure 14: Scope 1+2+3 emission data from U.S. Steel Corporation, based on company sustainability reporting.⁸

4. CONCLUSION

In conclusion, the development of the Scope 3 emission calculators and accompanying questionnaire can help provide clear guidance and resources for the complex task of reporting these indirect emissions. The next step will be to publish these findings in a journal article. The steel sector case study has revealed the limited extent of the availability of company-reported Scope 3 data. This means that not much Scope 3 data is available for the steel sector globally as well as for the United States. This in turn leads to a significant gap in reporting when comparing the available Scope 3 data to the available Scope 1 and Scope 2 data. One main goal of this project is narrowing this gap, and engaging the stakeholders to improve the calculators would be instrumental in supporting the calculation and reporting of Scope 3 emissions. These calculators and the questionnaire can then help to quantify their Scope 3 emissions more easily. Due to the prevalence of Scope 3 emissions within many manufacturing companies and sectors, simplifying the calculation process would allow for understanding the relevant Scope 3 categories and identify solutions to lower Scope 3 emissions, leading to potential advancements in industrial decarbonization and permitting more entities to achieve their net zero targets.

ACKNOWLEDGMENTS

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APPENDIX: SCOPE 3 CATEGORIES

As previously mentioned, Scope 3 emissions are divided into 15 categories, all of which are explained in detail by the GHG Protocol's *Technical Guidance for Calculating Scope 3 Emissions*.¹² Category 1 is known as *Purchased Goods and Services*. It includes all emissions from purchasing, extracting, transporting, selling, and using goods that are not accounted for in greater detail by Categories 2-8. It focuses mainly on upstream emissions, or emissions from the interaction and collaboration between reporting companies and their suppliers. Depending on the amount of relevant emission data provided by suppliers, reporting companies can carry out one of several methods to diagnose their CO₂ emission levels: supplier-specific methods, average-data methods, spend-based methods, project-specific methods, site-specific methods, fuel-based methods, distance-based methods, or hybrid methods combining aspects of the others. Due to the broad nature of Category 1, any company that is not a financial institution (financial institutions are covered in Category 15) should perform calculations using an appropriate method. The category serves as useful knowledge for companies across numerous sectors, as it can often comprise a larger percentage of companies' total carbon emissions, and an illustration of the applicable calculation methods is shown in Figure 15.³

Figure [1.1] Different data types used for different calculation methods

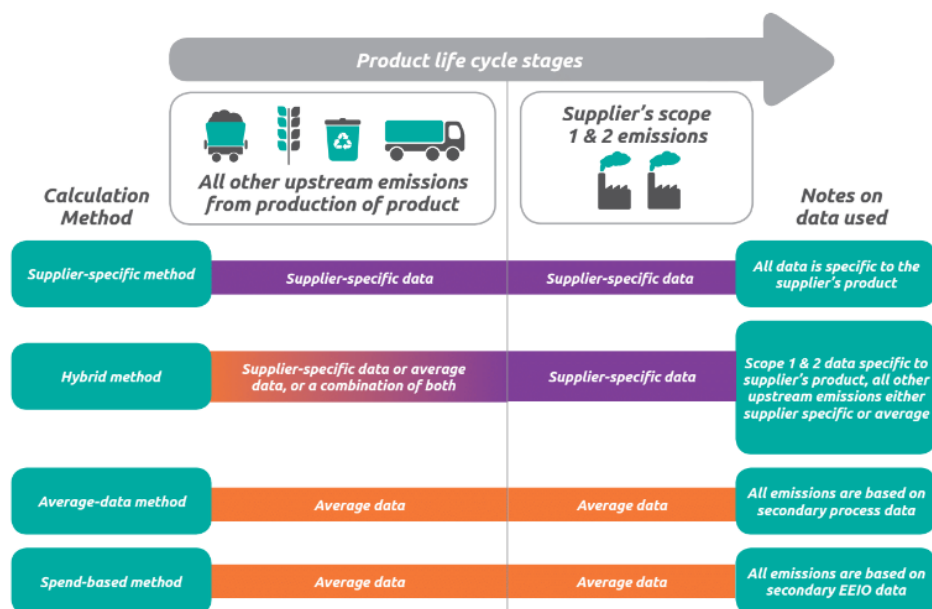


Figure 15: Optimal methods for Category 1 (Purchased Goods and Services) based on emission data availability.¹²

The formulas from Category 1 also apply to Category 2, which is known as *Capital Goods*. Rather than accounting for all purchased goods of a company, this category focuses on goods intended for company use instead of consumer sales, such as tables and chairs in a restaurant. Therefore, Category 2 can be considered one of the least relevant categories and make up a smaller percentage of the overall emissions within companies or sectors.³

However, Category 3 – known as *Fuel-and-Energy-Related Activities* – covers a broader scope and can be more relevant, as it accounts for the extraction, production, and transportation of fuel and energy sources used by the reporting company *other* than what is accounted for in Scope 1 and/or Scope 2. It focuses on the upstream emissions of purchased fuels and electricity, the generation of electricity being resold and transmission, and distribution (T&D) losses. While Category 3 may not always make up the bulk of Scope 3 emissions, it is usually notable enough for companies to want to include this category in their calculation process.³

Upstream emissions are related to the cooperation between reporting companies and primary suppliers, while downstream emissions are associated with the interactions between reporting companies and consumers. Therefore, some Scope 3 categories feature identical calculation approaches, with one being upstream and the other being downstream. The main examples of this are Categories 4 and 9 (respectively focusing on *Upstream* and *Downstream Transportation and Distribution*) and Categories 8 and 13 (respectively covering *Upstream* and *Downstream Leased Assets*). Depending on whether a company relies more on upstream or downstream operations, it is usually recommended that companies perform calculations for either Category 4 or Category 9. Both categories focus on Scope 1 and Scope 2 emissions from transportation providers, distributors, and retailers, and can include information about the life cycles of manufactured products. Meanwhile, Categories 8 and 13 focus on a company's leased assets, where lessors (i.e., owners of rented property) should perform calculations for Category 8 and lessees (i.e., recipients of rented property) should calculate emissions for Category 13. These categories are seldom relevant for manufacturing companies.³

Category 5 accounts for emissions from *Waste Generated in Operations*, which involves the disposal and treatment of waste generated by the reporting company, the Scope 1 and Scope 2 emissions of waste treatment providers, and the transportation of waste. Since most companies will generate waste in some capacity, it is generally recommended that reporting companies

perform the appropriate calculations. A similar category in Category 12 – known as the *End-of-Life Treatment of Sold Products* – may be less relevant for some sectors. Manufacturing-related sectors that may have noticeable shares of Category 12 emissions include chemicals, paper and forestry, and food, beverage, and tobacco.³

Categories 6 and 7 are similar in that they have to do with the transportation of employees; however, their calculations have no overlap. Category 6 covers *Business Travel* and is only relevant for companies that offer it, hence why it may have a lesser impact on the emissions of manufacturing companies, as well as companies in some non-manufacturing sectors. It accounts for the Scope 1 and Scope 2 emissions of transportation providers and can include the life cycle emissions of different vehicle types. Category 7 covers *Employee Commuting* and would be more relevant if a company has a greater number of employees who commute daily in any other way than biking or walking. Neither Category 6 nor Category 7 usually make up a large share of sectors' overall emissions, especially since some companies have allowed employees to work remotely in recent years.³

Categories 10 and 11 are respectively concerned with the *Processing* and *Use of Sold Products*. As a result, these companies can comprise a large percentage of manufacturing emissions, and Category 11 may also have a large effect on non-manufacturing emissions. Category 10 covers the downstream Scope 1 and Scope 2 emissions of manufacturers (this includes energy use) during the processing of intermediate products, while Category 11 refers to any greenhouse gases being emitted directly from consumers using finalized products. Sectors like transport original equipment manufacturers (OEMs), electric utilities, and oil and gas have larger proportions of Category 11 emissions. For Category 10, the metals and mining sector has the largest share among manufacturing sectors, and agricultural commodities has the largest share among non-manufacturing sectors.³

The final two categories may be irrelevant for many companies but are essential for companies that have franchises (Category 14) or investments (Category 15). For Category 14, the reporting company is the franchisor and the emissions stem from the Scope 1 and Scope 2 emissions of franchisees, in addition to the construction and manufacturing processes associated with those franchisees. On the other hand, Category 15 concerns the emissions resulting from equity investments, debt investments, and long-term project financing. This category is mainly

relevant for companies within the financial services sector (such as banks) and makes up over 99% of emissions from financial institutions. No other sector, including any manufacturing sector, has a significant share of Category 15 emissions.³

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