



Environmental Sustainability in the Technology Industry: Challenges and Opportunities

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The technology industry is growing exponentially. With the increase in data centers for cloud computing, personal computers, as well as cell phone access for a large percentage of the world's population, it will soon be difficult to meet the growing global demand for electronics, computing, and digital data storage. First, it will be hard to sustain this growth due to its reliance on rare earth elements that are hard to extract due to limited availability. Second, electronic waste (E-waste), which is the fastest-growing segment of solid waste, contains hazardous metals such as lead, mercury, and cadmium which pollute the environment and are extremely dangerous and toxic to human health. Environmental regulations are tightening across the globe and many developing countries have stopped accepting e-waste from developed countries, making it harder to recycle or dispose of electronics products.

Although technology companies, which include both hardware and software companies, contribute about 4.4% of total Greenhouse Gas (GHG) emissions, a large share of GHG emissions for tech companies is from Scope 3 emissions that get underreported. Also, while companies like Microsoft, Apple, Google, Facebook are classified as software companies, they have significant hardware businesses too. Similarly, while Amazon is classified in the Retail segment, it has a significant hardware and software business. Hence, the technology space has become more complex necessitating an accounting of Scope 1, Scope 2, and Scope 3 emissions as illustrated in the table below:

Tech Company	Hardware: Electrical & Electronic Equipment	Software: IT & Software Development	HW+SW (Data centers)
Scope 1	Burning gases & chemicals during chip manufacturing	Emissions from fuels, heating sources, company- owned vehicles	Natural gas, diesel
Scope 2	Energy usage for fabrication & office spaces	Energy usage for offices	Energy for data centers and offices
Scope 3	Raw material (rare earth metals), use of hardware, employee travel,	Chip manufacturing and usage of hardware, employee travel	Hardware manufacturing and construction of server farms

Table 1: Scope 1, 2, and 3 emissions examples for hardware and software companies

This study investigates how the hardware and software tech sector is addressing Scope 1, Scope 2, and Scope 3 emissions and the challenges and opportunities these companies face in addressing their sustainability issues using the following research questions:

1. Hardware companies are modifying hardware chip manufacturing processes and constructing fabrication facilities to reduce GHG emissions and manage their environmental impact. The investment in these initiatives translates to longer payback periods. On the other hand, a software company does not have to worry about the manufacturing and construction investments to reduce GHG emissions; their emissions reductions come mainly from making their facilities' energy efficiency and by reducing their energy dependency on fossil fuels. This leads to the following hypothesis:

Hypothesis 1: The average payback period for investments in sustainability initiatives made by hardware companies is greater than the average payback periods for software companies.

2. Scope 3 emissions are the indirect emissions that account for a large share of a firm's carbon footprint. These emissions occur in the value chain of the reporting corporation and include emissions from sourcing, supply chain emissions, business travel, employee commuting, and how a firm's product is used until it reaches the landfill. Since corporations have lesser control over their partner's actions than their own actions, I hypothesize that:

Hypothesis 2: Percentage investments in Scope 3 projects for firms are less than percentage investment in Scope 1 and Scope 2 projects, while CO₂ emissions savings from Scope 3 projects are higher in hardware companies as compared to software companies.

3. In the world of GHG emissions reductions projects, the energy efficiency of buildings and equipment as well as reducing fossil fuel consumption is described as "low-hanging fruit." Although embracing energy efficiency improvements come with a price tag, it is cost-effective in the long run since consumers see monetary savings after implementing these initiatives. Firms invest in sustainable opportunities starting with the most economically attractive ones first because the costs of the remaining opportunities are likely higher, leading to the following hypothesis:

Hypothesis 3: Tech companies are investing mostly in "low hanging fruit" projects.

Background and Literature on Carbon Disclosure:

The Carbon Disclosure Project (CDP) is a voluntary sustainability reporting framework that allows investors and companies to measure and understand their environmental impact and take necessary action towards building a truly sustainable economy. CDP started their first reporting in 2003 with only 200 companies, and by 2019 more than 8400 companies participated in the CDP survey making it the world's most comprehensive collection of self-reported environmental databases. CDP disclosure is a robust scoring mechanism with a tiered grading scale that helps companies progress towards environmental stewardship.

For this project, I decided to focus on CDP data for 2011-2019 to help me understand and analyze disclosures of carbon footprint and investments in sustainability initiatives by tech companies.

Method and Sample:

The CDP dataset provides a separate Excel file for each year starting from 2011 to 2019 covering various industries. To perform data analysis on this huge dataset, I used SAS software to create a single database for the 9 years of data by merging these files. This allowed me to review each company's investment, annual monetary savings from the investment, CO2 savings from these initiatives, and the payback period of these initiatives along with the Scope (1, 2, or 3) that was addressed by these initiatives. I used Pivot Tables in Excel to separate the companies into two categories: Hardware Companies with Primary Sector as "Electrical & Electronic Equipment" and the Software Companies with Primary Sector as "IT & Software Development." This allowed me to quantify the potential opportunities for Hardware and Software companies.

Results:

Analyzing CDP data reported by technology companies over a 9-year period (2011-2019) reveals that they have contributed to 711.1 million metric tons of CO2 emissions savings which are 4.4% of the total CO2 emissions savings across all industries in this dataset. They have spent \$1.9 trillion in total investments over this period which is 8.14% of the total spending across all the industries, and in return got annual monetary savings of \$10.7 trillion which is 59% of the total annual monetary savings across all the industries. The data analysis of emissions reduction initiatives implemented by hardware (electrical and electronic equipment) and software (IT and software development) companies are summarized in Table 1 in the Appendix section. Figure 3 in the Appendix highlights total investment in sustainability initiatives by hardware and software companies and their CO2 emissions savings. And Figure 4 in the Appendix highlights total investment in sustainability initiatives and the total annual monetary savings for hardware and software companies.

1. Payback: The payback period reported by companies in the CDP questionnaire is a range of years (i.e., 1-3 years or <1 year or 4-10 years) instead of an absolute number. For my analysis, I calculate the payback period for each project as total investment in an initiative divided by annual monetary savings from the initiative if the annual monetary savings is positive. The average payback period for investments in sustainability initiatives made by hardware companies is greater than payback periods by software companies as seen in the table below, thus, providing support for Hypothesis 1.

	Hardware	Software
Project Average Payback Period	19.77 years	4.18 years
Project Average Investment	\$383.04 million	\$93.3 million
Project Median Payback Period	1.19 years	1.56 years
Project Median Investment	\$112125	\$42000

Table 2: Payback Period and Investment for hardware and software companies

2. Scope 3: The table below provides support for my hypothesis that percentage investments in Scope 3 projects are less than percentage investment in Scope 1 and Scope 2 projects. Similarly, the hypothesis that CO2 emissions savings from Scope 3 are higher in hardware companies as compared to software companies is supported by the table below:

	Hardware	Software
Investments in Scope 3	\$.14 trillion	\$3 billion
Total Investments	\$1.78 trillion	\$.17 trillion
% Investments in Scope 3	7.69%	2.57%

Table 3: Scope 3 Investments for hardware and software companies

	Hardware	Software
Emission savings from Scope 3	232.46 million metric tons of CO2e	4.25 million metric tons of CO2e
Total Emission savings	297.4 million metric tons of CO2e	20.31 million metric tons of CO2e
% Emission savings from Scope 3	78.17%	20.94%

Table 4: Emissions Reduction from Scope 3 projects for hardware and software companies

Because of the complexity of measuring and quantifying Scope 3 emissions, research (USA Today: citations) suggest that many companies in the tech sector fail to disclose about half their emissions in this category. Figure 1 in the Appendix shows the total CO2 emissions savings from Scope 3 of hardware and software companies and Figure 2 in the Appendix shows the total CO2 emissions savings from Scope 1 and Scope 2 of hardware and software companies.

3. “Low-hanging-fruit” Projects: The majority of tech company investments are in “low hanging fruit” projects. My hypothesis that firms invest in sustainable opportunities starting with the most economically attractive ones first is correct as shown in the table below:

	Hardware	Software
Investments in “low hanging fruit” projects	\$1.27 trillion	\$.11 trillion
Total Investments	\$1.78 trillion	\$.17 trillion
% Investments in “low hanging fruit” projects	71.26%	91.13%

Table 5: Investments in “Low-hanging fruit” projects for hardware and software companies

The table below summarizes examples of emissions reduction initiatives implemented by hardware (electrical and electronic equipment) and software (IT & software development) companies for the last 10 years. The results highlight that companies from both technology sectors are investing mostly in their campus buildings’ energy efficiency including HVAC, lighting, or energy efficiency processes like heat recovery, cooling technology or refrigeration, etc. This is followed by low-carbon energy installation and purchases. These initiatives mostly translate to Scope 1, and Scope 2 emissions as shown below:

Electrical & electronic equipment	1.64179E+11
	39915776
Energy efficiency: Building fabric	692966689
Energy efficiency: Building services	55856801039
Energy efficiency: Processes	59285393091
Low-carbon energy installation	23007281621
Low-carbon energy purchase	749475088
IT & software development	12863896286
Energy efficiency: Building fabric	273451675
Energy efficiency: Building services	165730783
Energy efficiency: Processes	554208377
Low-carbon energy installation	405965332
Low-carbon energy purchase	2130169

Table 6: Breakdown of “low-hanging fruit” project investments

Conclusion:

The CDP data analysis reveals that most GHG emissions from the tech sector come from hardware manufacturing and not from the day-to-day operations of an organization such as building energy consumption. However, the data highlights that most tech companies (hardware as well as software) have been focused on reducing their Scope 1 and Scope 2 emissions which are under their control and are related to their operational energy consumption at their own facilities, as well as energy procurement. Thus, there exists a gap between the GHG emissions impact of organizations, and the investments made by the tech sector to reduce GHG emissions. Going forward, as companies make net-zero commitments, they must address Scope 3 emissions which are indirect emissions that mainly come from the hardware manufacturing and infrastructure and are interconnected to their entire value chain. Similarly, most investments made by the tech sector have gone towards “low-hanging fruit” projects such as building energy efficiency and low-carbon energy purchase which have a short payback period. Tech companies will need to identify and invest in projects which have a long-term GHG emissions impact, but also have a longer payback period. This could be potentially achieved by increasing the life of hardware equipment to more than three years to further reduce GHG emissions impact. Another potential solution to enable faster reduction of GHG emissions is to make electronic devices modular in order to extend the life of these devices. This will help to amortize the carbon footprint created by their manufacturers. Given that many tech companies are cash-rich, the tech sector needs to look at long-term investments to reduce GHG emissions even if it results in investing in projects that have a longer payback period.

Citations:

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Appendix:

Table 1: Summary of CO2 savings, Investment, and Annual Monetary Savings for hardware and software companies

Row Labels	Sum of CO2e savings	Sum of Total Investment	Sum of Annual Monetary Savings
Electrical & electronic equipment	516998120.8	1.77793E+12	1.0524E+13
2011		1.00254E+11	88876078637
2012	55289432	65726928703	1.1043E+11
2013	57302767.94	2.05503E+11	2.07547E+12
2014	106823396.7	2.79603E+11	3.90215E+12
2015	90028514.41	3.46311E+11	3.26375E+12
2016	80688043.66	2.13506E+11	6.07689E+11
2017	37952132.32	1.91817E+11	1.88506E+11
2018	39095977.19	2.08624E+11	1.67157E+11
2019	49817856.65	1.66585E+11	1.19963E+11
IT & software development	194106333.8	1.17388E+11	1.6083E+11
2011		9263638837	839126591
2012	169572654	11769868061	1276699073
2013	2272268	4791759087	1194039179
2014	1949387.05	2916761002	1306181688
2015	2811371.36	13566729305	2771631759
2016	3017457.28	24740885254	67838389330
2017	9683933.49	17491535596	81565662451
2018	2702088.97	19982821150	1776029814
2019	2097173.62	12863896286	2261956195
Grand Total	711104454.6	1.89532E+12	1.06848E+13

Figure 1: Total CO2 Emissions Savings from Scope 3 of hardware and software companies

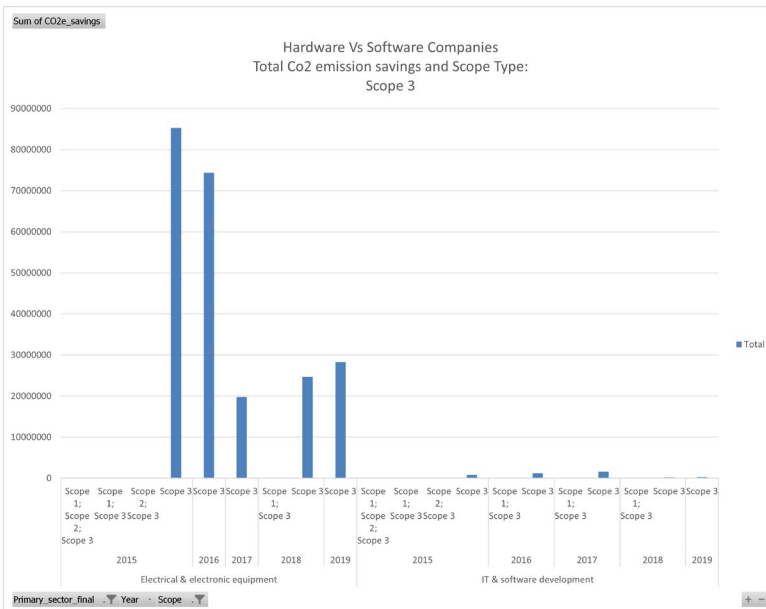


Figure 2: Total CO2 Emissions Savings from Scope 1 and Scope 2 of hardware and software companies

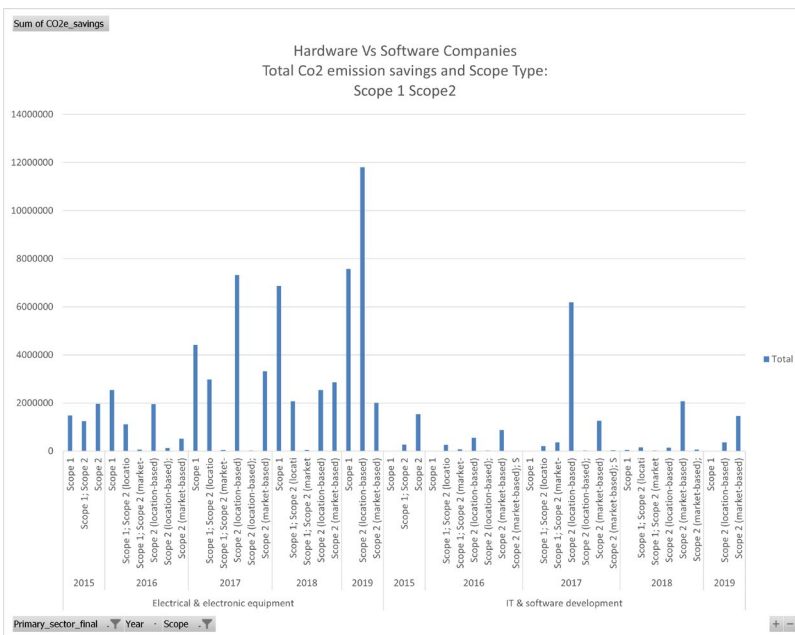


Figure 3: Total Investment in sustainability initiatives and the CO2 emissions savings for hardware and software companies

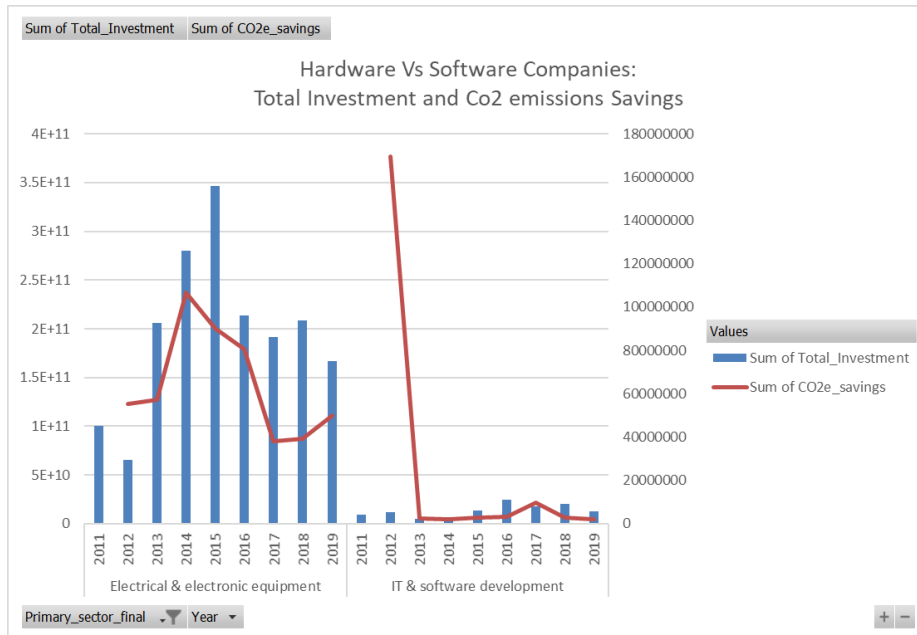


Figure 4: Total Investment in sustainability initiatives and the Total Annual Monetary savings for hardware and software companies

