Enhancing Scope 3 Emissions Estimations for Cloud Computing

by

Ashley Choi

and

Zoltan Potorke

Submitted on May 8th, 2026 in Partial Fulfillment of the
Requirements for the Degree of Master of Applied Science in Supply Chain Management at
the Massachusetts Institute of Technology

ABSTRACT

This capstone project addresses the critical data gap in estimating Scope 3 greenhouse gas (GHG) emissions from cloud-computing at MIT, where existing spend-based frameworks lack the granularity and transparency required for effective emissions management. The rapid growth of cloud services, AI workloads, and data centers has increased electricity consumption and carbon emissions, making accurate cloud-emissions accounting an urgent sustainability challenge. The project aims both to highlight and quantify the shortcomings of the current approach and to move beyond these limitations by integrating financial data with granular supplier usage-based metrics to identify emissions seasonality and forecast emission portfolio until 2030. Although the study faced significant challenges due to data availability and siloed departments, it successfully establishes a theoretical framework for more credible carbon accounting. Recommendations include a phased implementation strategy, beginning with the standardization of procurement processes and progressing toward a full usage-based methodology that utilizes region-specific carbon intensity factors to align with industry's best practices.

Capstone Advisor: Sreedevi Rajagopalan
Title: Director, MIT Sustainable Supply Chain Lab

Capstone Co-Advisor: Camilo Andrés Mora Quiñones
Title: Postdoctoral Associate at the MIT Center for Transportation & Logistics

Table of Contents

1. Introduction **3**
1.1 Background 3
1.2 Motivation 3
1.3 Problem Statement and Key Questions 4
1.4 Project Goals and Expected Outcomes 5

2. State of the Practice **5**
2.1 Discussion of Literature Review 5

3. Methodology **8**
3.1 Methodology Selection 8
3.2 Data Collection and Preparation 8
3.3 Model Application 9

4. Results and Discussion **10**
4.1 Results 10
4.2 Implications 17
4.3 Limitations 17

5. Recommendations **18**
5.1 Management Recommendations 18
5.2 Future Work 19

6. References **20**

1. Introduction

1.1 Background

This project is sponsored by the MIT Sustainable Supply Chain Lab in collaboration with the MIT Office of Sustainability (MITOS)[1]. The MIT Sustainable Supply Chain Lab is a research lab, part of the MIT Center for Transportation & Logistics, that focuses on improving supply chains by integrating environmental and social sustainability into operational decision making. The lab works directly with organizations and industry partners to translate academic research into real-world strategies that help companies leverage their supply chains to pursue and meet their sustainability goals. The missions of the Sustainable Supply Chain Lab and MITOS are a complementary pairing that supports the development of data-driven approaches to realizing sustainability across research, academic, and operational contexts.

1.2 Motivation

As companies and organizations, including academic institutions, increasingly rely on digital infrastructure, the environmental impact of cloud computing and data center operations has become a growing concern, especially since greenhouse gas (GHG) emissions from these services are difficult to measure and manage. According to the International Energy Agency's (IEA) "*Energy and AI*" report, data centers accounted for around 1.5% of the world's electricity consumption in 2024, growing at approximately 12% per year since 2017 — more than four times faster than the rate of total electricity consumption growth — with demand expected to more than double by 2030 (IEA, 2025). The World Economic Forum (WEF) emphasizes the critical need to invest in solutions that mitigate resource usage and emissions as AI and digital infrastructure drive significant increases in electricity demand by 2030 (Jensen, 2026).

This trend presents an opportunity for MITOS to develop a clearer understanding of the university's Scope 3 emissions that are associated with cloud computing. In FY2024, MIT's Scope 3 GHG Emissions Dashboard showed 8% of total spend-based emissions on IT services and 1% on cloud computing, totaling 497 Metric Tons of Carbon Dioxide Equivalent (MtCO2e). Currently, MITOS relies on a spend-based framework that offers only a high-level

[1] MITOS complements the mission of the Sustainable Supply Chain Lab at the campus level. MITOS is dedicated to positioning MIT as a model of sustainable solutions by integrating environmental responsibility into campus operations. MITOS's overarching goals include achieving net-zero carbon emissions by 2026 and eliminating direct emissions by 2050. MITOS regularly measures and reports on GHG emissions, including Scope 1, 2, and 3 categories. MITOS's annual data and Scope 3 Dashboard reporting provide insights that guide strategies for GHG emissions reduction and strengthen MIT's sustainability performance.
For further information, please refer to MITOS's webpage: https://sustainability.mit.edu/

view of emissions and does not capture the complexity and weighted impact of computing-related activities. Without accurate baseline data of the Scope 3 emissions related to cloud computing, it will remain challenging to identify effective reduction strategies and better define progress towards MIT's carbon goals.

1.3 Problem Statement and Key Questions

MIT faces a critical data gap in estimating the GHG emissions that are associated with cloud computing and digital infrastructure. The current spend-based framework applied by MITOS only provides a generalized picture of emissions, missing the accuracy and transparency needed to create impactful emissions-reduction strategies. As MIT works toward achieving its institutional sustainability goals, the absence of a baseline and a robust methodology to account for Scope 3 GHG emissions from cloud computing services is a barrier to comprehensive emissions management.

To address this challenge, our key objective is to review the current spend-based methodology and develop a more sophisticated, data-driven methodology for estimating GHG emissions from cloud computing that is not constrained by the limitations of a spend-based approach. This project aims to establish a more reliable baseline for MIT's cloud computing-related emissions and propose practical strategies for ongoing measurement, tracking, reporting, as well as management recommendations on ways of working among different departments. The new methodological framework would be replicable for other institutions or companies to better track, report and potentially reduce their scope 3 emissions as well.

The key question to be answered is the following:

- How can Scope 3 emissions from cloud -computing be more accurately estimated than what the current methodology offers?

Figure 1 represents the main process steps that we aim to follow throughout our capstone.

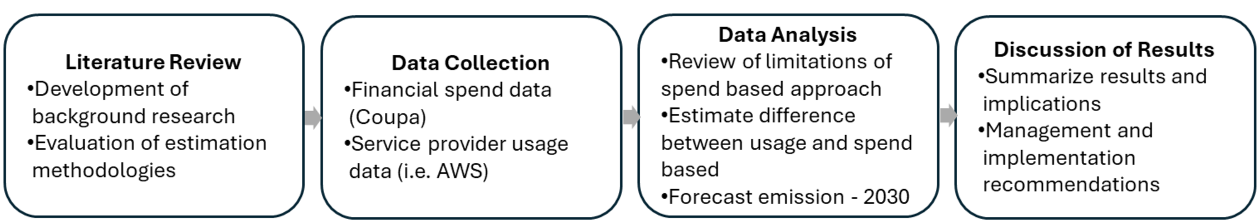


Figure 1. Methodology Process Steps

1.4 Project Goals and Expected Outcomes

The main goal of the project is to develop a more sophisticated estimation methodology that provides a more accurate, credible, and data-driven accounting of MIT's cloud computing-related Scope 3 emissions. The project also aims to propose management recommendations to ensure tangible impacts and accountability in addition to the theoretical framework.

The project outcome is the review of the current spend-based methodology, including its limitations and inaccuracy and a proposal to introduce a more sophisticated methodology that enables more accurate and data-driven accounting of MIT's Scope 3 emissions from cloud computing. By implementing a new estimation methodology, MIT and other stakeholders will be able to account for and manage Scope 3 emissions from cloud computing more accurately.

2. State of the Practice

The primary objective of our capstone is to define a methodology that will more accurately estimate Scope 3 emissions from cloud computing services. Currently, MITOS relies on and uses a spend-based framework for estimating GHG emissions. This methodology is limited to one factor and lacks transparency of true usage and impact. In order to define a new estimation methodology, it is crucial to understand the definition of cloud computing; existing emissions-estimation frameworks; best practices of cloud computing service providers (in our case, Amazon Web Services, AWS); and the overall operations and sustainability impacts of cloud computing. This section discusses all necessary context of cloud computing and the industry best practices on how to measure emissions.

2.1 Discussion of Literature Review

2.1.1. Definition of Cloud Computing

Cloud computing is a model for delivering computing services over a network that allows users to access shared resources, including storage, servers, applications, and other services on demand, without the need to own, manage, and maintain the underlying infrastructure i.e. physical hardware or software maintenance (Mell & Grance, 2011). Key characteristics include on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service.

From an informational security standards perspective, cloud computing is defined as a model that provides access to a scalable, elastic pool of shareable physical or virtual resources through self-service provisioning and on-demand administration (ISO & IEC, 2014). The perspective of leading cloud service providers also reinforces the definitions of

NIST and ISO/IEC in a practical, business sense. AWS defines cloud computing as the on-demand delivery of IT resources over the internet with pay-as-you-go pricing, emphasizing cost efficiency and removing the need for upfront infrastructure investments (Amazon Web Services, n.d.).

When considering these definitions together, cloud computing can be best understood as a service-oriented computing model that provides scalable shared computing resources over a network that provides on-demand access and usage-based pricing without a large infrastructure investment. This comprehensive definition highlights cloud computing as both a technical framework and business model and allows institutions and businesses to efficiently manage, deploy, and scale their digital resources all while reducing cost and complexity.

2.1.2 Existing Scope 3 Emissions Estimation Methodology

According to the *GHG Protocol Corporate Value Chain (Scope 3) Accounting and Reporting Standard* ("Standards"), Scope 3 emissions encompass all indirect GHG emissions that occur throughout an organization's value chain, other than the emissions from the organization's own operations (i.e., Scope 1) and purchase of energy (i.e., Scope 2) (WRI & WBCSD, 2011). The Standards provide the foundational framework for identifying, estimating, and reporting Scope 3 greenhouse gas emissions across organizational value chains. Scope 3 boundaries (e.g., entity, time and activities) are defined in the Standards through 15 upstream (suppliers) and downstream (customers) categories together with the establishment of core accounting principles—relevance, completeness, consistency, transparency, and accuracy (WRI & WBCSD, 2011). The *GHG Technical Guidance for Calculating Scope 3 Emissions* ("Guidance") supplements the original definition from Standards and explicitly recognizes and defines multiple calculation approaches. Such estimation approaches include supplier-specific, activity-based, hybrid, and spend-based methods. The Guidance promotes a data-quality hierarchy that prioritizes primary, supplier-specific data where feasible, with lower-precision methods (e.g., a spend-based approach) used only when more accurate data are unavailable (WRI & WBCSD, 2023).

Cloud computing service purchases fall under Category 1 – Purchased Goods & Services of the Scope 3 categories, and according to the Guidance, supplier-specific, product-level data would be the most appropriate for estimating the corresponding emissions. However, the choice of calculation methodology or methodologies (i.e., hybrid) may depend on several factors such as data availability and quality; and resources. (WRI & WBCSD, 2023).

Due to the novelty of the Scope 3 emissions estimations that are related to cloud computing, to date, there has been limited academic research done on the subject. Schneider and

Mattia (2024) leverage Scope 3 methodology and principles to address a key challenge of allocating emissions from shared data-center infrastructure to individual users (i.e., for Scope 2 purposes). Their study proposes a granular allocation methodology based on actual machine-level energy use, workload distribution, and region-specific electricity carbon intensities. By operationalizing Scope 3 accounting and calculation principles in a shared-service context, the study demonstrates how supplier-specific data can significantly improve accuracy compared to aggregated or spend-based estimates, while highlighting transparency and data access as critical enabling factors. Soares et al. (2025) critically examine methodological uncertainties in estimating GHG emissions from cloud computing, comparing location-based and use-based approaches. The authors identify several key sources of inaccuracy, including assumptions about data-center energy efficiency, renewable energy claims, geographic averaging, and the treatment of embodied emissions from hardware and infrastructure. Their analysis underscores the limitations of generic estimation methods. It also highlights the need for harmonized methodologies, improved provider disclosure, and clearer guidance on the treatment of indirect and lifecycle emissions within Scope 3 inventories.

The learnings from the literature review confirmed our initial assumptions from our discussions with stakeholders: Scope 3 emissions accuracy depends largely on data quality and methodological choice. Supplier-specific and activity-based methods are generally prioritized above spend-based estimates from an accuracy point of view. The sources agreed that Scope 3 emissions estimation is an iterative process, where several different factors should be taken into consideration when developing the research methodology. As a next step, we analyzed the methodological framework developed by the most significant suppliers of cloud computing services.

2.1.3 Emissions Estimation Methodology – Best Practices for Cloud Computing

As one of the biggest cloud-computing service providers, AWS has its own Customer Carbon Footprint Tool (CCFT), which estimates emissions related to cloud computing services. Customers are able to track their usage and have transparency to their cloud computing emissions. Emissions are calculated and allocated using a consumption-based approach, which shows the relative share of AWS infrastructure usage, and location and market-based accounting methods are provided to align with GHG Protocol guidance (Amazon Web Services, 2025).

Best Practices for Cloud Computing Emissions Estimations:

When defining calculation methodologies and frameworks, cloud service providers can rely on and leverage several best practices for a comprehensive emissions-estimation methodology. Lifecycle assessments (LCAs), consumption-based allocation models, and SKU-/project-level granularity are shown to be appropriate for measuring shared infrastructure while aligning with GHG Protocol principles. Cloud service providers emphasize the need for transparency for accurate carbon accounting as well as the continuous iteration of methodologies and improvement of data quality. The best practices of leading service providers will be instrumental in creating a comprehensive and accurate accounting of cloud computing emissions.

3. Methodology

In this section, we will explain our proposed methodology and justification; the data collection and preparation process; and how we will practically apply the methodology with MITOS to address our capstone's primary objective.

3.1 Methodology Selection

Based on the literature review and discussions with the MIT Sustainable Supply Chain Lab and MITOS, we have decided to move forward with the following main methodology steps:

- Identify and quantify cloud computing services
- Compare spend-based and usage-based Scope 3 emissions
- Create hybrid forecast model to predict hotspots and demand spikes to drive reduction strategies

This approach will allow us to understand MIT's cloud computing usages as well as its primary users/organizations; formulate a baseline of cloud computing services; create a hybrid emissions estimation framework; and create a hybrid forecast model to identify hotspots and allow MIT to take a proactive approach to reducing GHG emissions. The new estimation framework will consider the best practices of service providers today and take a hybrid approach that utilizes both spend and usage data. A deeper level of granularity can promote transparency of cloud service usage to better understand true emissions impact.

3.2 Data Collection and Preparation

In this phase of our capstone, we explore and analyze two datasets. The first source consists of financial data (i.e., invoices) retrieved from Coupa, a business spend management platform used for MIT's procurement. The second source is usage data from AWS's Customer Carbon Footprint Tool (CCFT).

3.2.1 Data Source 1: Coupa Invoices (Spend Data)

Relevant features of and considerations for this data source include:

- Supplier
- Price / invoice total (USD)
- General Ledger (GL) code
- Commodity type
- Customer / department

As part of our data preparation process, a key step is to review if GL codes are properly considered so that the invoices related to IT Services – Cloud Computing are accurately categorized. We exported FY2022-FY2025 financial data (i.e., invoices) from the Coupa database, performed the data cleaning process, and conducted cross-validation of the GL/commodity classification of invoices and amounts as cloud computing services. We will discuss our finding in the later sections.

3.2.2 Data Source 2: Service Provider (Usage Data) – AWS CCFT data

Relevant features of and considerations for this data source include:

- Usage data of computing services
- Cost metrics, pricing/rates
- Location metrics (market, region)
- Scope 3 emissions (market based, location based)

These are features and metrics available from the AWS CCFT tool. It is important to note that the data availability from this source was constrained to one account due to limited stakeholder engagement from MIT's Information Security & Technology (IS&T). The emissions data available from AWS CCFT was limited to the main IS&T AWS account, however, we could not investigate the platform data directly, only the emission outputs.

3.3 Model Application

Figure 2 summarizes the steps of applying the model / methodology that is described in Section 3.1.

Figure 2. Model Application Steps

The cloud computing emissions estimation process begins with collecting cloud usage data which we have received from AWS. We compared spend based data for AWS to CCFT data from AWS which showed the gap between estimation methods and solidifies the need for MIT to implement a more accurate estimation framework. Using the provided emissions data, we created a hybrid forecasting model to predict when there would be hot spots or spikes in cloud computing usage. This model would give insights to when to expect higher demand, how to best procure cloud computing services, and support future IT procurement decisions.

4. Results and Discussion

4.1 Results

4.1.1 Emission estimation under spend based methodology

Our analysis draws primarily on invoice data extracted from MIT's Coupa procurement system for FY2022 through FY2025. After filtering the purchase order (PO) commodity category "IT Services – Cloud Computing" and removing voided invoices, the final dataset comprised 3,617 invoices across 89 unique suppliers over the four-year period.[2] Applying the spend-based emission intensity factor of 0.077 kg CO2e[3] per USD to the filtered Coupa data, we estimated monthly Scope 3 cloud computing emissions for MIT's entire cloud vendor portfolio and for AWS as the main supplier of cloud-computing services. Figure 3 shows the monthly total cloud computing emissions for all vendors versus AWS between FY2022-2025.

[2] The data spans July 2021 through June 2025, aligning with MIT's fiscal years (July – June).
[3] The current spend based methodology of MIT applies a 0.077 kg CO2e per USD emission factor.

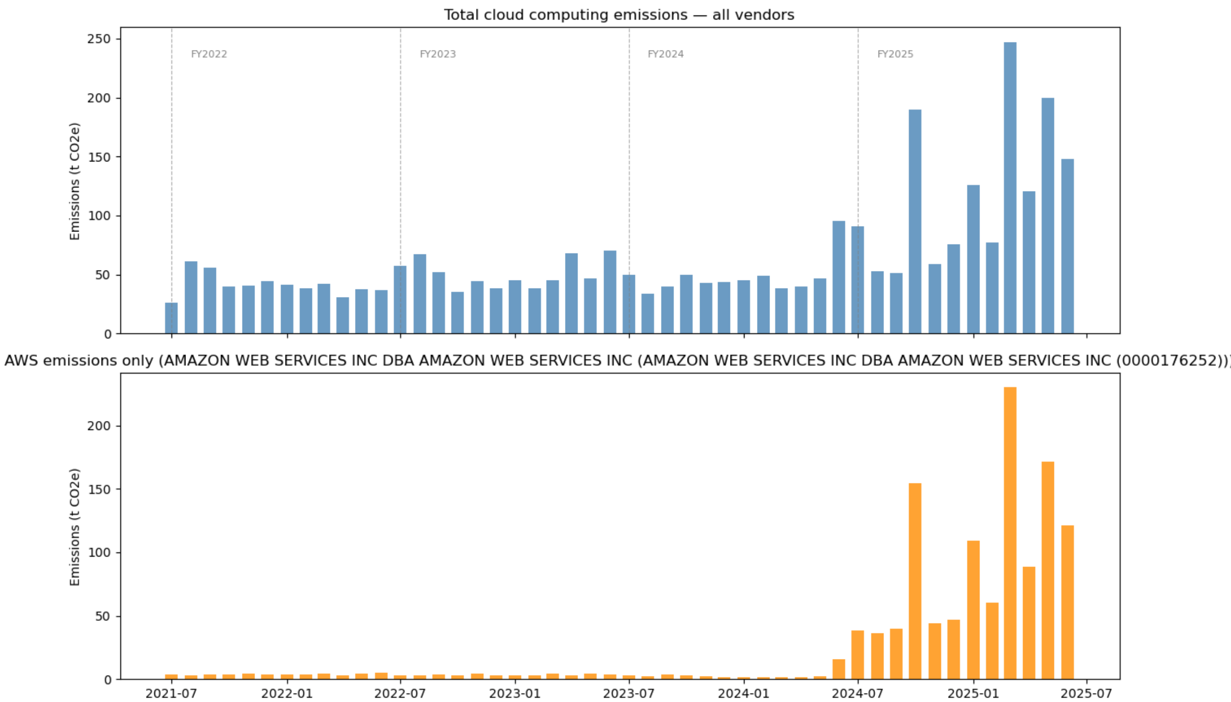


Figure 3: Total MIT cloud computing versus AWS specific emissions

Based on Figure 3, we have identified a significant data issue: AWS invoices were largely absent from the filtered dataset prior to FY2025, despite AWS CCFT data confirming active usage of the same account from at least January 2024. Investigation of the unfiltered procurement data suggests that AWS invoices were likely categorized under a different commodity classification before the introduction of a new purchase order in June - July 2024, most specifically under "IT Services – Software Maintenance," which accounted for approximately $11.0M of AWS spend in FY2023 alone.

Figure 4 illustrates the potential volume of miscategorization. It compares the AWS spend categorized under "IT Services – Cloud Computing" against the spend categorized under "IT Services – Software Maintenance" between FY2022 and FY2025.

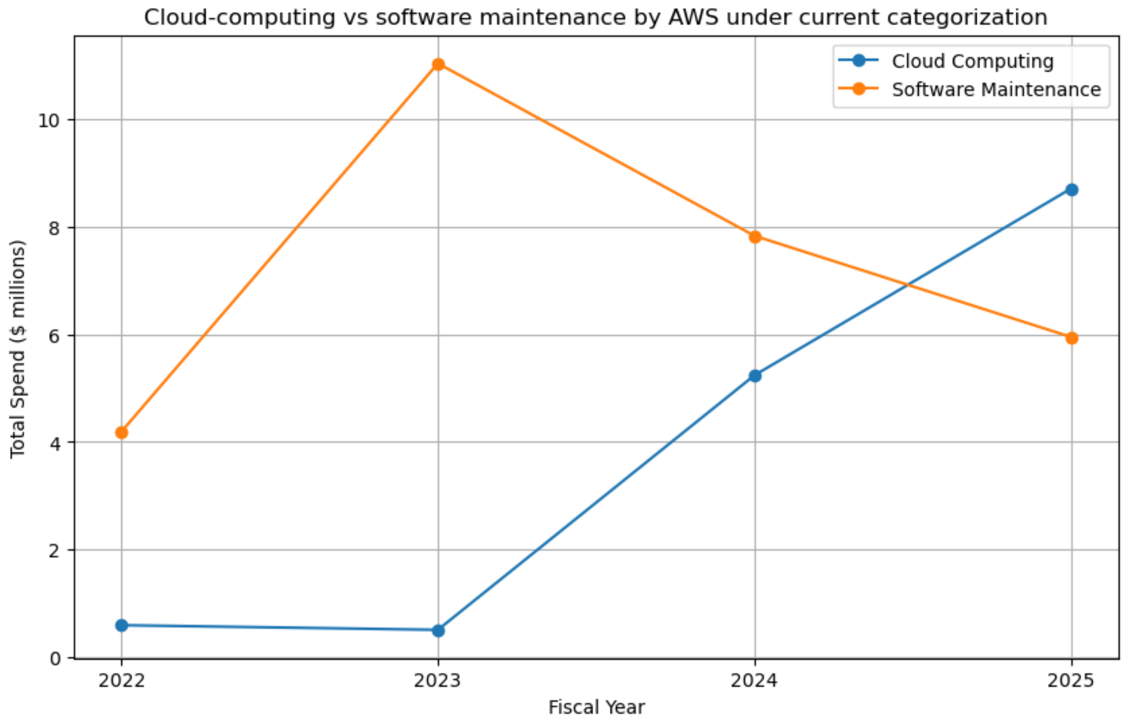


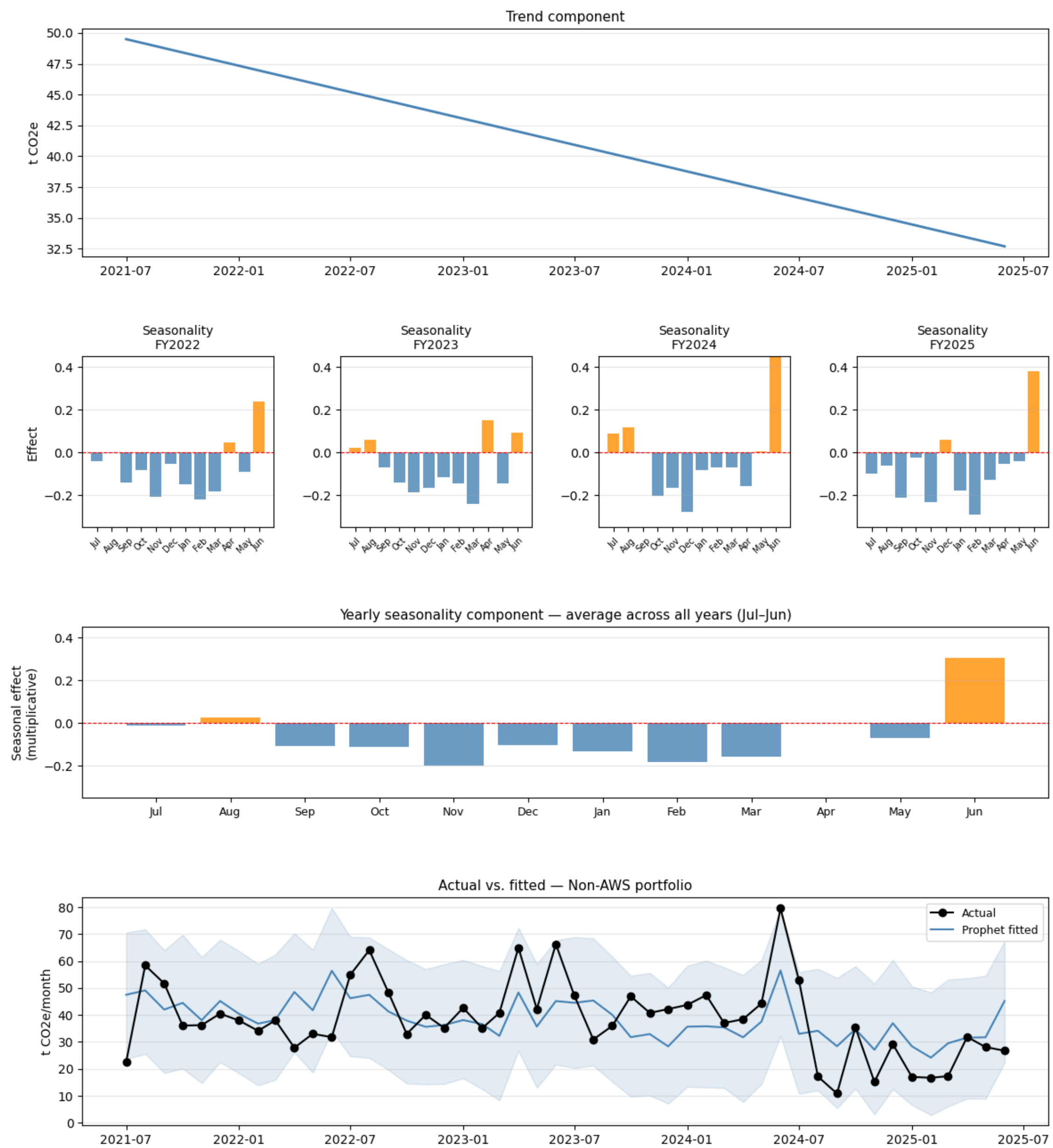
Figure 4: AWS spend categorization, software maintenance vs. cloud computing

The above finding has two relevant implications. First, the FY2022–FY2023 portfolio emissions are significantly understated in the filtered dataset because the majority of AWS spend was invisible to the "IT Services – Cloud Computing" filter. Second, the apparent spike in FY2025 is - at least partially - a reclassification artifact rather than a reflection of purely organic growth in cloud usage.

This finding underscores a broader challenge with spend-based Scope 3 estimation: its accuracy is highly dependent on the consistency and granularity of procurement categorization across departments. We understand from discussions with MITOS that purchaser / admin personnel at MIT categorize each spend into a commodity category and there is no additional or central review of the correctness of such categories. Introduction of training and/or standardization to achieve consistent categorization would mitigate the gaps that our current finding revealed.

4.1.2 Emission forecasting

Given the data quality discussed in section 4.1.1, we chose to analyze the non-AWS portfolio of 88 vendors separately as a consistent four-year series, excluding AWS-related spend data. Facebook Prophet forecasting methodology was applied to decompose monthly emissions into trend, seasonality, and residual components (see Figure 5).



<u>Figure 5: Trend, seasonality, residuals of scope 3 emissions - cloud computing</u>

The trend component shows a gradual decline from approximately 50 t CO2e/month in FY2022 to 32 tCO2e/month by FY2025. This (along with the increasing AWS data) may be attributed to vendor consolidations: smaller vendors may have been partially displaced, reducing the organization's spend and associated emissions across the broader non-AWS portfolio.

The seasonality component shows a clear pattern over the years, with June exhibiting the strongest positive seasonal effect (+0.30 multiplicative), consistent with the year-end budget cycle of MIT. The months of January through March as well as the month of November show the strongest negative effects, reflecting post-holiday and end-of-semester slowdowns that could be explained by the academic calendar[4].

Building on these trend and seasonality findings, a hybrid forecasting approach was used to forecast total portfolio emissions through FY2030. The Facebook Prophet model was applied separately to the non-AWS portfolio and to the AWS CCFT series (location based method, LBM and market based method, MBM), with the two forecasts summed into a combined total. This approach directly operationalizes the hybrid methodology recommendation, applying spend-based estimation where supplier data is unavailable and supplier-reported data where it exists.

As shown in Figure 6, total portfolio emissions are projected to grow from 528–618 tCO2e in FY2025 to 810–969 tCO2e by FY2030 which accounts for a 55–65% increase. The stacked breakdown reveals the structural shift under way: AWS grows from a smaller share of MIT's emissions in FY2025 to approximately 85% of the total portfolio by FY2030, while the non-AWS portfolio gradually declines. This makes accurate AWS emission tracking (i.e., using supplier-reported data rather than spend-based estimation) an important recommendation for MIT's cloud carbon management going forward. However, we would like to recommend that MIT should treat these projections as directional indicators and revisit the models as additional data accumulates.

[4] It is important to note again that this seasonality finding is based on the non-AWS portfolio only. AWS data was excluded from this analysis due to the insufficient and structurally inconsistent history in the filtered Coupa dataset.

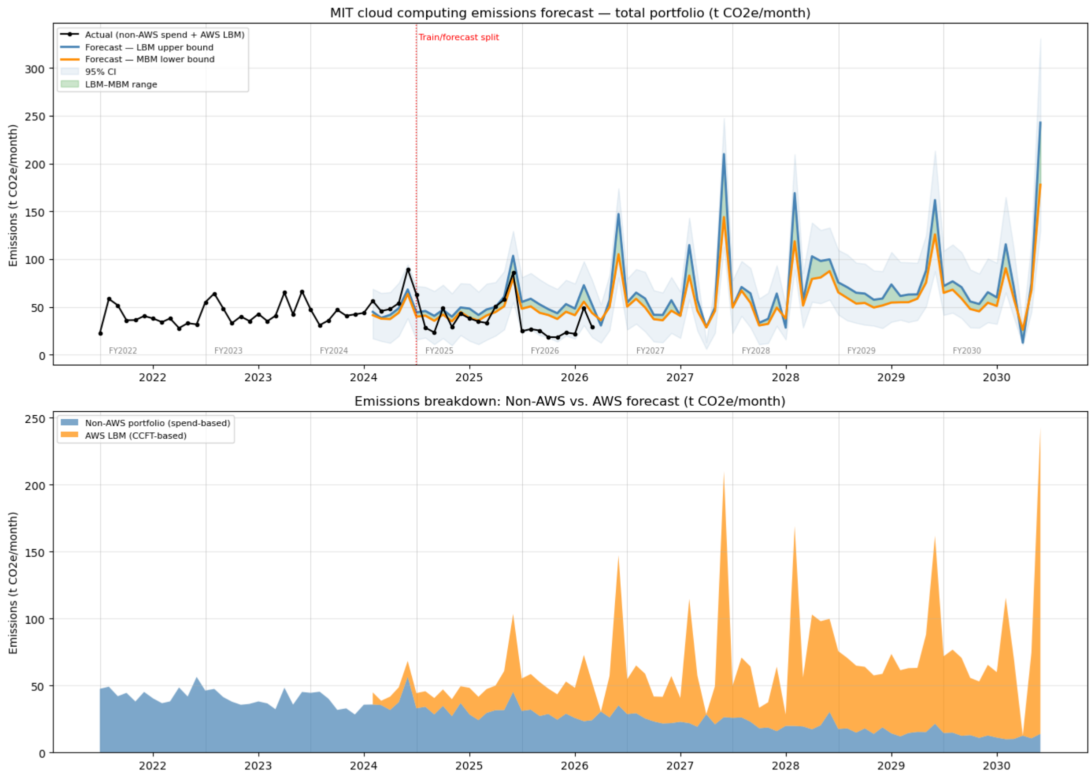


Figure 6: 5-year Forecast MIT Scope 3 Emissions – Cloud Computing

4.1.3 Comparison of Spend-Based and Usage-Based Estimations

To compare spend-based emission estimates based on AWS Coupa invoices against AWS's own reported figures, we utilized the AWS CCFT data for MIT's primary AWS account, covering January 2024 through February 2026. The CCFT reports emissions under two methodologies: the LBM, which applies average grid emission intensities, and the MBM, which accounts for AWS's renewable energy procurement.

As identified in section 4.1.1, the most significant AWS Coupa invoices were recategorized as cloud-computing in June - July 2024. To compensate for this, we chose a primary comparison window of 12 months covering FY2025 (July 2024 – June 2025)[5]. As an additional sensitivity analysis, we extended the window to 17 months (from February 2024 to June 2025) by reconstructing AWS spend from the "IT Services – Software Maintenance" category for the period when AWS invoices were miscategorized in Coupa (i.e., January to June 2024).

Based on the results, we can conclude that the spend-based approach consistently and significantly overestimates AWS emissions across all 12 months of the primary comparison

[5] A one-month reporting lag was applied to align the CCFT series with Coupa invoice dates.

window. The sensitivity analysis has also confirmed the overestimation. The results are summarized in Figure 7.

Metric	**Option A: Primary (FY2025)**		**Option B: Sensitivity (FY2024–FY2025)**	
	vs. LBM	vs. MBM	vs. LBM	vs. MBM
Window	Jul 2024 – Jun 2025	Jul 2024 – Jun 2025	Feb 2024 – Jun 2025	Feb 2024 – Jun 2025
Months compared	12	12	17	17
Spend-Based ($t\ CO_2e$)	1140.15	1140.15	1331.33	1331.33
CCFT Actual ($t\ CO_2e$)	236.47	144.01	282.97	171.92
Mean ratio (spend-based / CCFT)	5.34x	8.76x	5.03x	8.29x

Figure 7: Spend based method overestimation compared to AWS CCFT

Figure 8 shows the monthly comparison of spend-based vs AWS usage-based estimations under the primary window. It's important to note that the comparison in Figure 8 is not exactly 1:1 due to the lacking access of MIT AWS enterprise data, the spend data is comprehensive, but the AWS usage estimates are only representing one, albeit the largest, AWS account on campus, the main IS&T account.

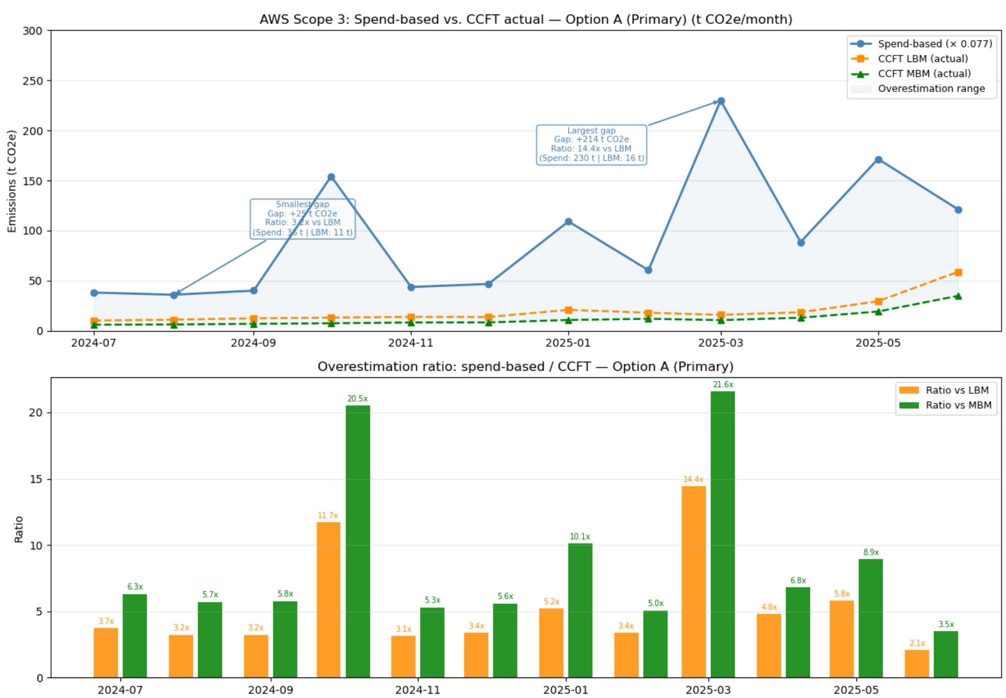


Figure 8: Monthly comparison between spend-based and AWS usage-based estimation

The results paint a clear picture: The spend-based approach overestimates AWS's self-reported usage-based Scope 3 emissions by approximately 5x vs. LBM and 9x vs. MBM.

Large invoice months such as October 2024 and March 2025 appear to reflect consolidated billing cycles rather than proportional increases in computing hour usage, causing spend-based estimates to spike while actual CCFT emissions remain relatively stable.

These findings strongly support prioritizing supplier-reported CCFT data over spend-based estimates for AWS — and by extension for the use of Microsoft Azure and Google Cloud, which offer equivalent carbon reporting tools. The spend-based approach retains practical value only for the long tail of smaller vendors for whom no supplier-reported data exists. A hybrid methodology that combines supplier-reported data for the service providers and spend-based estimation for the remainder would meaningfully improve the accuracy of MIT's Scope 3 cloud computing reporting while remaining operationally feasible.

4.2 Implications

The implications of this capstone are directly tied to its motivations, which are to develop a clearer understanding of MIT’s Scope 3 emissions for cloud computing. As companies and institutions increasingly rely on digital infrastructure, finding an accurate way to quantify the environmental impact of cloud computing and data center operations will only become more of a concern. It is essential for MIT to develop a more accurate estimation methodology so that it can then develop a baseline of current emissions, specific goals towards mitigating scope 3 emissions, and improve the overall visibility of emissions. Getting ahead of the curve on this will allow MIT to be a leading institution in terms of sustainability initiatives and share best practices with other organizations to collectively reduce our cloud computing carbon footprint.

4.3 Limitations

This capstone had limitations that directly affected the project scoping and ultimately the implementation of our proposed methodology. The two main limitations we encountered were focused on stakeholder relationships and data availability.

The cornerstone of our capstone relied on a partnership with MIT’s IS&T so that we could best understand the usage of cloud computing services on campus. IS&T owns the relationship with service providers and financial accounting when it comes to usage and pricing. Not having this collaboration made it incredibly difficult for our team to develop a comprehensive understanding of cloud computing services, requiring us to work around the department to piece together functional knowledge through various sources.

The main functional limitation was data availability, both in quantity and quality of data. Primarily due to the non-existing stakeholder relationship with IS&T, we were unable to obtain data from them for the main cloud services account on campus. Ultimately, we have received data from AWS, the service provider, directly. However, we could not verify the data directly within IS&T's own platform, and that created an additional constraint.

5. Recommendations

As MIT works to steadily improve the accuracy of its cloud computing emissions estimates, we recommend a phased approach, shown in Figure 9. Due to the limitations outlined in Section 4.3, it is more realistic to achieve steady progress and strengthen the current procurement foundations first, then to follow industry best practices in the future.

The siloed nature of each department combined with inconsistent purchasing practices has led to incorrect and disorganized financial reconciliation. The first recommendation is to tackle the internal, organizational challenge of standardizing MIT's procurement process. Once this is complete, it will be easier to progress towards implementing a more efficient and accurate spend-based methodology. Lastly, a usage-based methodology that considers market and/or region emissions factors can be developed and implemented. This last phase will follow what is considered industry standard to accurately factor emissions specifically based on the market or region of the cloud service facility. All these steps will serve MIT to establish an accurate baseline and use as a benchmark for future Scope 3 reduction targets.

Figure 9. Future Recommendations – Phased Approach

5.1 Management Recommendations

In addition to our functional recommendations, there are several management recommendations we believe would improve ways of working. Due to the current siloed ways of working between departments, there are many untapped areas of opportunity to improve collaboration, communication, and data sharing. Throughout our capstone we encountered numerous roadblocks because of the fragmented ownership of and limited knowledge that each department has about each part of a process. There may be existing data; but it may not be readily available or shareable within the current structure. A collaborative operating model with shared forums, aligned priorities, and shared resources could increase visibility and knowledge sharing in an otherwise decentralized structure.

Implementing a standardized procurement process would enhance financial reconciliation by eliminating inaccurate and inconsistent spend data. Purchases made outside of Coupa will not accurately represent cloud computing services emissions because the spend-based data set is sourced solely from Coupa.

5.2 Future Work

This capstone has the opportunity to be a launching pad for future projects. Due to the limitations encountered during our project, our scope had to be narrowly defined, focusing on only one department and a single service provider. Future capstone projects have the potential to capture the entirety of campus and all service providers, while also exploring additional sourcing practices through alternative computing sources such as the Massachusetts Green High Performance Computing Center (MGHPCC). Near future work could include following through on the recommended phased approach for MIT to reach an accurate, usage-based methodology with market and region-specific emissions factors.

6. References

Amazon Web Services. (2025). *AWS customer carbon footprint tool: Scope 3 emissions data*. https://aws.amazon.com/about-aws/whats-new/2025/10/aws-customer-carbon-footprint-tool-scope-3-emissions-data/

Amazon Web Services. (n.d.). *What is cloud computing?* https://aws.amazon.com/what-is-cloud computing/

International Energy Agency. (2025). *Energy and AI*. IEA. https://www.iea.org/reports/energy-and-ai

IOS & IEC (International Organization for Standardization & International Electrotechnical Commission). (2014). *Information technology — Cloud computing — Overview and vocabulary*. https://www.iso.org/standard/60544.html

Jensen, Bent. (2026). *Enhancing AI Digital Infrastructure within Planetary Boundaries*. https://www.weforum.org/stories/2026/01/enhancing-value-of-digital-infrastructure/

Mell, P., & Grance, T. (2011). *The NIST definition of cloud computing* (NIST Special Publication 800-145). National Institute of Standards and Technology. https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-145.pdf

Schneider, L., & Mattia, G. (2024). *Carbon accounting in the cloud: A methodology for allocating emissions across data center users*. arXiv. https://arxiv.org/abs/2406.09645

Soares, I., Yarime, M., & Klemun, M. (2025). Estimating greenhouse gas emissions from cloud computing: Sources of inaccuracy, opportunities and challenges in location-based and use-based approaches. *Climate Policy, 25*(9), 1335-1353. https://doi.org/10.1080/14693062.2025.2450054

WRI & WBCSD (World Resources Institute, & World Business Council for Sustainable Development). (2011). *Corporate value chain (Scope 3) Accounting and Reporting Standard*. Greenhouse Gas Protocol. https://ghgprotocol.org/corporate-value-chain-scope-3-standard

WRI & WBCSD (World Resources Institute, & World Business Council for Sustainable Development). (2023). *Technical Guidance for Calculating Scope 3 Emissions*. https://ghgprotocol.org/sites/default/files/2023-03Scope3_Calculation_Guidance_0%5B1%5D.pdf