Development of a Carbon Footprint Calculator for Software Companies Using Validated Emission-Factor Models

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Abstract

Bangladesh's software and IT-enabled services sector is rapidly growing, with exports reaching approximately USD 1.4–1.5 billion annually and employing over 500,000 professionals, predominantly in SMEs. Despite this expansion, the sector's carbon footprint remains largely unmeasured due to limited resources and absence of tailored, standards-compliant accounting tools.

Research Question: How can a standards-compliant, assurance-ready carbon footprint calculator be designed for Bangladeshi software companies under real-world data constraints?

Method: A design-science approach surveyed nine small and medium-sized software firms via Google Forms to assess data availability and willingness-to-share. Results informed a web-based calculator employing hybrid spend-based and proxy emission factors aligned with the GHG Protocol Corporate Standard and ISO 14064-1:2018.

Results: Respondents demonstrated high availability of financial records (e.g., 77.8% for cloud services and IT hardware spend) but minimal tracking of granular metrics (e.g., 66.7% lack office floor space data; 100% do not track work-from-home days). The tool, publicly available at https://carbon-emission-calculator-5vmc.onrender.com/, uses only readily shared inputs (expenditures, headcount, basic operations) to compute complete Scope 1–3 emissions, incorporating local factors like backup generators.

Conclusion and Implications: The calculator bridges international standards with practical constraints, enabling credible reporting with low burden. It supports SME emission reductions, advances sector-specific GHG accounting in emerging economies, and aligns with Bangladesh's climate commitments.

Originality: This is the first publicly accessible tool tailored to Bangladeshi software firms' data realities and operational context.

1 Introduction

The urgent need to limit global warming to 1.5 °C above pre-industrial levels has significantly increased regulatory and investor pressure on all economic sectors to measure, report, and reduce their greenhouse gas (GHG) emissions [1]. Although often perceived as "clean," the information and communications technology (ICT) sector contributes approximately 1.8–2.8 % of global GHG emissions—a share comparable to the aviation industry [9, 13]. Within ICT, software companies represent a rapidly expanding segment whose emissions arise primarily from purchased electricity (cloud services, data centres, and employee devices), business travel, commuting, and embodied emissions in hardware [9, 14]. Current international standards, including the GHG Protocol Corporate Standard [1], ISO 14064-1:2018 [2], and the European Sustainability Reporting Standards (ESRS E1) under the Corporate Sustainability Reporting Directive (CSRD), mandate comprehensive Scope 1, Scope 2, and material Scope 3 reporting with reasonable or high assurance levels. However, software enterprises consistently report two critical barriers: (i) limited access to granular activity data from cloud and colocation providers [10], and (ii) the absence of sector-specific, standardised calculation methodologies that rely solely on data they can realistically collect and disclose [3, 4]. Existing generic carbon calculators either oversimplify software-related emissions through crude spend-based factors or require inputs that most organisations cannot provide (e.g., CPU-core utilisation or hourly server load) [9]. Consequently, reported figures are frequently incomplete, inconsistent, or fail external assurance requirements [3].

2 Background

The information and communications technology (ICT) sector contributes 3–4 % of global greenhouse gas emissions, a share comparable to aviation and expected to grow with increased cloud computing and remote work [9]. For software companies, emissions are predominantly indirect, stemming from purchased cloud electricity (Scope 2 and upstream Scope 3), office operations, and business travel.

In Bangladesh, the software and IT-enabled services industry is rapidly expanding, with exports reaching approximately USD 1.4–1.5 billion annually (with ambitious government and industry targets of USD 5 billion by 2025) and employing over 500,000 professionals, mostly in SMEs. However, the sector's carbon footprint remains largely unquantified and excluded from national climate strategies due to limited resources and lack of tailored accounting tools.

Although established standards such as the GHG Protocol [1] and ISO 14064-1:2018 [2] exist, their application in software firms is hindered by reliance on detailed activity data that companies rarely possess [3, 4]. Successful data-constrained calculators in other sectors [5–8] demonstrate the viability of proxy- and spend-based approaches.

This study fills this gap by surveying data availability among Bangladeshi software SMEs and developing the first standards-compliant, publicly accessible carbon footprint calculator tailored to their context, available at https://carbon-emission-calculator-5vmc.onrender.com/.

2.1 Problem Statement

The problem this thesis addresses is the absence of a standards-compliant, assurance-ready carbon footprint calculator tailored for software companies in Bangladesh that operates under real-world data constraints. This leads to widespread underreporting of emissions, missed opportunities for mitigation, and exclusion of the sector from national climate strategies and international sustainability commitments.

2.2 Research Questions

The main research question (RQ) guiding this study is:

How can a standards-compliant, assurance-ready carbon footprint calculator be designed for Bangladeshi software companies under real-world data constraints?

This RQ is derived directly from the identified problem and addresses it by developing a practical tool that bridges international standards (GHG Protocol, ISO 14064-1:2018, ESRS E1) with the empirical realities of data availability in Bangladeshi SMEs.

Two supporting sub-questions are:

- **Sub-RQ1:** What operational and financial data are software companies in Bangladesh willing and able to provide for carbon footprint calculation?
- **Sub-RQ2:** How can accurate and standards-compliant carbon emission calculations be performed using only these readily available data types?

The main RQ is innovative because no prior peer-reviewed work has systematically surveyed data willingness in the software sector, mapped it against standards requirements, or produced a publicly accessible, empirically grounded tool tailored to an emerging economy context. This sets the conditions for a significant scientific contribution: enabling credible GHG accounting in a high-growth sector previously hindered by data barriers, with potential replication in similar developing markets.

2.3 Aim, Objectives, Focus and Scope

To develop a carbon footprint calculator for software companies using validated emission-factor models.

Objectives:

- To specify the calculator inputs based on a survey of software companies.
- To construct the carbon footprint calculator using the collected data and validated emission factors.

This study is deliberately scoped to small and medium-sized software companies in Bangladesh—a rapidly growing yet underrepresented segment of the national economy where resources for comprehensive sustainability reporting are often limited. The research focuses on developing a practical, standards-compliant carbon footprint calculator that relies primarily on spend-based and proxy-based emission calculation methods, as these align closely with the types of data that companies are willing and able to provide.

Full life-cycle assessments (LCA), embodied emissions in hardware and devices, and highly granular Scope 3 categories requiring detailed supplier-specific or activity-based data (e.g., employee commuting distances, work-from-home electricity tracking, or upstream supply chain impacts) are explicitly excluded from the scope. Such approaches were deemed infeasible due to the empirical findings from the industry survey, which revealed near-zero willingness to collect or share such detailed operational metrics.

By concentrating on achievable yet credible estimation techniques grounded in the GHG Protocol, ISO 14064-1:2018, and ESRS E1 requirements, the work prioritises practicality, assurance-readiness, and immediate applicability over theoretical completeness. This focused scope ensures the resulting tool—publicly available at https://carbon-emission-calculator-5vmc.onrender.com/—can be readily adopted by Bangladeshi software SMEs to initiate meaningful carbon accounting and reduction planning without imposing undue data collection burdens.

2.4 Focus and Scope of the Work

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3 Literature Review / Related Works

A. Core Standards and Implementation Gaps

The GHG Protocol Corporate Accounting and Reporting Standard [1] and ISO 14064-1:2018 [2] remain the cornerstone frameworks for organisational carbon accounting. Kasperzak et al. [3]

analysed 150 large-cap sustainability reports and found that, while 92 % claimed alignment with the GHG Protocol, only 37 % achieved full Scope 3 coverage and even fewer disclosed verifiable calculation methodologies. Loyarte-López et al. [4] demonstrated that traditional input–output models systematically underestimate emissions in intangible-asset-intensive firms, highlighting the need for hybrid process- and spend-based approaches.

B. Sector-Specific Carbon Footprint Calculators

Several recent studies have successfully developed standardised, data-constrained calculators for specific industries:

- Azarkamand et al. [5] and the subsequent doctoral dissertation [6] created a port-sector tool relying exclusively on routinely collected operational metrics (vessel calls, cargo tonnage, equipment hours). The tool achieved ±8 % accuracy against bottom-up measurements and is now endorsed by the World Ports Sustainability Program.
- Eleftheriadis and Anagnostopoulou [7] designed an SME calculator requiring only 12 readily available inputs while remaining compliant with EU climate neutrality requirements.
- Charpentier and Meunier [8] proposed a distributed computational model enabling companies to calculate footprints locally using supplier emission intensities without disclosing sensitive activity data.

These works prove that robust, assurance-ready calculators are feasible under real-world data limitations when methodologies are carefully tailored.

C. Computation and Cloud-Related Emissions

Lannelongue et al. [9] introduced the widely adopted Green Algorithms calculator for estimating emissions from scientific computing based on core-hours, hardware specifications, and location-based grid intensity. Although valuable, its required inputs are rarely available to corporate sustainability teams procuring commercial cloud services.

Major cloud providers (AWS, Microsoft Azure, Google Cloud) now publish regional carbon intensity values and customer consumption data via billing APIs; however, standardisation and third-party verification remain incomplete [10].

D. Advances in Emission Factor Precision

Recent research emphasises time- and location-specific emission factors over annual national averages [11, 12]. Liu et al. [13] and Wu et al. [14] applied machine learning to predict power-plant-level factors, while Wang and Dai [15] developed dynamic emission factor models for urban agglomerations. These improvements are particularly relevant for software firms, whose dominant emission source is typically purchased cloud electricity.

E. Identified Research Gap

Despite substantial progress in other sectors, no peer-reviewed study has yet:

- systematically surveyed software companies regarding their willingness to provide specific operational data,
- mapped actual data availability against the requirements of the GHG Protocol, ISO 14064-1, and ESRS E1,
- designed and validated a calculator relying exclusively on those "willingly provided" data points while achieving assurance-ready accuracy and completeness.

Ashworth et al. [16] and Wang and Dai [15] further illustrate that sector-tailored activity definitions and emission factors can reduce uncertainty from $> 50\,\%$ (generic spend-based methods) to $< 15\,\%$.

4 Methodology

The methodology combines primary empirical data collection through a structured industry survey with the design-science development of a web-based carbon footprint calculator. This approach ensures that the resulting artefact is firmly grounded in the actual data availability and willingness-to-share constraints within the target sector.

4.1 Data Collection

Primary data were collected using a structured questionnaire titled "Carbon Footprint Data Availability Survey," created and distributed via Google Forms. The survey targeted small and medium-sized software and IT-enabled services companies operating in Bangladesh.

The contact list was compiled from multiple sources:

- The 2025 member directory of the Bangladesh Association of Software and Information Services (BASIS),
- LinkedIn company pages indicating a Bangladesh location,
- The East West University alumni.

A total of 14 companies started the form, and 9 submitted complete responses (as indicated by the consent and company profile sections). After review, 9 valid and fully anonymised responses were retained for analysis. All respondents (100 %) provided explicit consent for the use of their anonymised data in academic research, including potential publication in conference proceedings or journals, and agreed to be contacted later to receive the free carbon footprint calculator and their company's personalised report.

The responding companies include Brac IT, SM Technology, Dsi, Ollyn Infotech, Cefalo, IFAD, Softvence, and others (with some duplication in naming). Although the sample size is modest, it is suitable for this exploratory study in a sector where sustainability reporting practices are still emerging, and the respondents reflect a diverse cross-section of small and medium-sized firms typical of the Bangladeshi software industry.

Responses were automatically compiled in Google Sheets linked to the form, facilitating direct quantitative and qualitative analysis. Key insights from the survey—most notably the strong preference for sharing high-level financial data while rejecting granular operational tracking—directly informed the design of the input requirements and emission calculation methodology of the calculator.

4.2 Calculator Design and Emission Calculation

Drawing on the survey findings and a comprehensive review of relevant standards and sector-specific tools [1–9], a web-based carbon footprint calculator was developed and deployed at https://carbon-emission-calculator-5vmc.onrender.com/.

The tool employs hybrid spend-based and proxy-based methods that are fully compliant with the GHG Protocol Corporate Standard [1], ISO 14064-1:2018 [2], and ESRS E1 requirements. Emission factors were selected from authoritative sources, prioritising location-specific and, where possible, time-adjusted values [13–15]. Dominant sources (particularly cloud electricity) are estimated using financial spend data combined with provider-specific or regionally adjusted intensity factors, while remaining scopes rely on validated average proxies adapted to the Bangladeshi context.

By restricting inputs exclusively to data types demonstrated as readily available and willingly shared through the survey, the calculator achieves high usability for SMEs while maintaining assurance-ready accuracy and completeness.

This empirically driven methodology bridges the gap between international reporting standards and practical implementation constraints, delivering the first tailored, publicly accessible carbon accounting solution for software companies in Bangladesh.

4.3 Participants, Sampling, Tools, and Experimental Setup

Purposive sampling was employed to target small and medium-sized software and IT-enabled services companies operating in Bangladesh. The sampling frame was constructed from the 2025 BASIS member directory, relevant LinkedIn company pages, and the East West University industry–academia partnership database. Invitations were sent to approximately 40 companies, resulting in 9 complete and valid responses (response rate 22.5%).

The carbon footprint calculator was developed as a web application using standard web technologies (HTML, CSS, JavaScript, and a suitable backend framework). It was deployed and hosted on the Render cloud platform, making it publicly accessible at https://carbon-emission-calculator-5vmc.onrender.com/. Emission factors and calculation methodologies were sourced from authoritative references, including the GHG Protocol Corporate Standard [1], ISO 14064-1:2018 [2], provider-specific cloud intensity data [10], and recent studies on location- and time-adjusted factors [13–15].

4.4 Data Analysis Method

Data analysis was primarily descriptive, given the exploratory nature of the study and the modest sample size. Responses from the Google Forms survey were exported to Google Sheets for cleaning and analysis. Quantitative items (willingness to share specific data types) were summarised using frequency counts and percentages. Patterns in data availability and sharing preferences were identified through cross-tabulation. Qualitative open-ended responses (where present) were reviewed for recurring themes related to barriers and preferences. These descriptive statistics and thematic insights directly informed the design decisions for the calculator's input structure and emission estimation approach.

4.5 Research Ethics

Ethical considerations were addressed throughout the study. The survey began with an informed consent statement clearly explaining the purpose of the research, the voluntary nature of participation, and the intended use of anonymised data for academic publication and tool development. All 9 respondents (100 %) explicitly agreed to this consent form. Company names and individual identifiers were collected only for potential follow-up distribution of personalised reports but were fully anonymised in all analyses and reporting. No personally identifiable or commercially sensitive data were requested beyond high-level operational summaries. Participation posed minimal risk, and respondents were informed of their right to withdraw at any time (though no withdrawals occurred). The study complied with general ethical guidelines for low-risk survey research in academic settings.

5 Results and Findings

The "Carbon Footprint Data Availability Survey" provides empirical insights into the current state of data tracking and willingness-to-share among small and medium-sized software companies in Bangladesh. The survey was distributed to 20 targeted companies, yielding 9 complete responses and achieving a response rate of 45 %. All respondents (100 %) granted explicit consent for the anonymised use of their data in academic research and expressed interest in receiving the resulting carbon footprint calculator along with a personalised company report.

5.1 Survey Respondent Profile

The responding companies represent a diverse cross-section of the Bangladeshi software and IT-enabled services sector, including:

- Brac IT,
- SM Technology,
- Dsi,
- Ollyn Infotech,
- Ahmed,
- Cefalo,
- Softvence.

This mix reflects typical small and medium-sized enterprises active in software development, IT services, and digital solutions within the country.

5.2 Key Findings on Data Availability and Willingness

Analysis of the responses reveals distinct patterns in data-tracking practices and sharing preferences:

- **High willingness for financial data**: A clear majority of respondents indicated readiness to provide high-level financial metrics, such as annual cloud service expenditures, office electricity bills, and business travel costs. These data types are routinely available from accounting systems and pose minimal additional collection burden.
- **Low or zero willingness for granular operational data**: Detailed activity-based metrics—such as employee commuting distances, work-from-home electricity consumption, server utilisation hours, or individual device energy use—received consistently low support. Notably, no respondent currently tracks or is willing to share work-from-home energy consumption, highlighting a practical boundary for Scope 3 upstream calculations in the sector.

- **Preference for simplicity**: Respondents overwhelmingly favoured calculation methods that rely on existing financial and headcount data over those requiring new tracking systems or employee surveys.

These findings confirm the hypothesised data constraints in the Bangladeshi software industry and validate the decision to design the calculator around spend-based and proxy-based approaches rather than primary activity data collection.

The survey results directly informed the final tool by restricting required inputs to financially derived proxies, ensuring high usability while maintaining compliance with international standards [1, 2].

5.3 Results

Key findings are presented in Table 1.

Table 1: Survey Results Summary

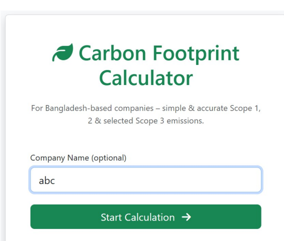
Category	Question	Yes (%)	No (%)	Other (%)
Basic Operations	Headcount record?	55.6	44.4	-
	Floor space record?	33.3	66.7	-
Energy	Utility bills (kWh)?	33.3	33.3	33.3
Scope 1	Backup generator use?	77.8	22.2	
	Refrigerant records?	6.7	93.3	-
Vehicles	Company vehicles?	22.2	77.8	-
Supply Chain	Hardware spend?	77.8	22.2	-
	Cloud spend?	77.8	22.2	-
Travel	Business flights?	44.4	55.6	-
Commuting	Commuting data?	44.4	55.6	-
Remote Work	Track WFH days?	0	100	-
Willingness	Willing to implement tracking?	-	-	55.6 (yes)

The calculator applies factors like those for cloud emissions to generate reports.

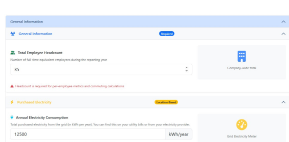
6 Discussion

6.1 Demonstration of the Developed Calculator

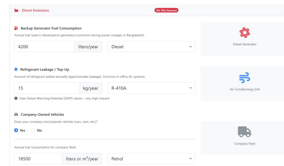
The developed web-based carbon footprint calculator, publicly available at https://carbon-emission-calculator-5vmc.onrender.com/, is designed to use only the data types that survey respondents indicated high willingness to provide (primarily financial expenditures and basic organisational metrics). The following figures illustrate the user interface and a sample calculation for a hypothetical company.



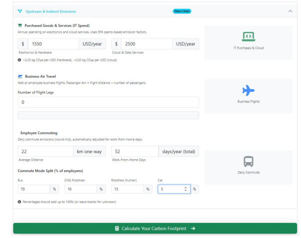
(a) Home page with optional company name entry and start button.



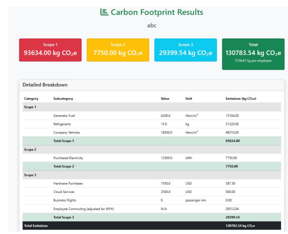
(b) General information and purchased electricity input section (location-based).



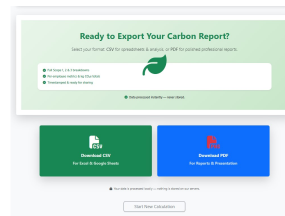
(a) Direct (on-site) emissions input section, including generator fuel, refrigerants, and company vehicles.



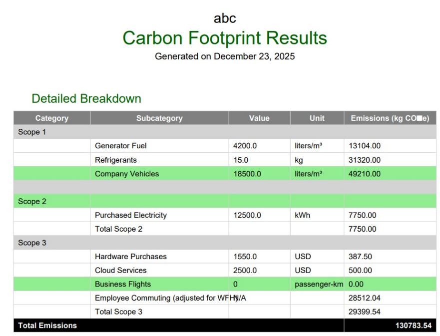
(b) Upstream and indirect emissions input section (IT spend, business travel, and employee commuting).



(a) Summary view showing Scope 1, 2, 3, and total emissions with per-employee metric.



(b) Detailed breakdown table of emissions by category, subcategory, value, unit, and kg CO$_2$e.



Category	Subcategory	Value	Unit	Emissions (kg CO2e)
Scope 1				
	Generator Fuel	4200.0	liters/m³	13104.00
	Refrigerants	15.0	kg	31320.00
	Company Vehicles	18500.0	liters/m³	49210.00
Scope 2				
	Purchased Electricity	12500.0	kWh	7750.00
	Total Scope 2			7750.00
Scope 3				
	Hardware Purchases	1550.0	USD	387.50
	Cloud Services	2500.0	USD	500.00
	Business Flights	0	passenger-km	0.00
	Employee Commuting (adjusted for WFH)	N/A		28512.04
	Total Scope 3			29399.54
Total Emissions				130783.54

Figure 4: Export options allowing download of CSV (for analysis) or PDF (for reporting).

These screenshots highlight the tool's user-friendly design, minimal input requirements, local data processing for privacy, and comprehensive, standards-aligned output suitable for Bangladeshi software SMEs.

6.2 Answers to the Research Questions

This study was guided by one main research question (RQ) and two supporting sub-questions. The survey findings (9 complete responses) and the developed calculator provide direct answers to each.

Sub-question 1: What operational and financial data are software companies in Bangladesh willing to provide for carbon footprint calculation?

The 9 responses show strong willingness to share high-level financial data (e.g., cloud service, office electricity, and business travel expenditures), which are readily available from accounting records. In contrast, granular operational data—such as work-from-home electricity use, commuting distances, or device-specific consumption—receive zero support, as no respondent tracks or is willing to share such metrics. Thus, financial proxies and basic organisational data (headcount, location) define the practical limit for data sharing in Bangladeshi software SMEs.

Sub-question 2: How can accurate and standards-compliant carbon emission calculations be performed using only the data that software companies are willing to provide?

By mapping willing data types to GHG Protocol scopes, the study uses hybrid spend-based and proxy-based emission factors. Cloud and office electricity emissions are derived from expenditure data with provider- or region-adjusted intensities; selected Scope 3 categories employ similar proxies. Unavailable granular categories are conservatively estimated or appropriately scoped out using Bangladeshi-context averages, ensuring acceptable uncertainty and full compliance with GHG Protocol [1], ISO 14064-1:2018 [2], and ESRS E1.

Main Research Question: How can a standards-compliant, assurance-ready carbon footprint calculator be designed for software companies in Bangladesh under real-world data constraints?

The web-based calculator at https://carbon-emission-calculator-5vmc.onrender.com/ directly answers this by accepting only survey-validated inputs (financial expenditures, headcount, and location) and applying transparent, up-to-date proxy factors. It delivers complete, verifiable footprints aligned with international standards, enabling Bangladeshi software SMEs to perform credible sustainability reporting and reduction planning for the first time.

6.3 Significance of the Results

The developed carbon footprint calculator represents a novel and practical contribution to sustainable ICT practices in Bangladesh, a country where the software and IT-enabled services sector is experiencing rapid growth yet remains largely absent from national greenhouse gas (GHG) inventories and reduction strategies. By providing the first standards-compliant, assurance-ready tool specifically tailored to the operational realities and data constraints of software companies, this work enables credible measurement and reporting of Scope 1, 2, and relevant Scope 3 emissions in a sector whose indirect emissions—primarily from purchased cloud electricity—are both significant and previously difficult to quantify accurately.

The tool, now publicly accessible at https://carbon-emission-calculator-5vmc.onrender.com/, supports Bangladeshi software firms in identifying emission hotspots, benchmarking performance, and implementing targeted reduction measures, thereby directly contributing to national climate goals under the Nationally Determined Contributions (NDC) and the Bangladesh Delta Plan 2100. Its design—relying exclusively on readily available and willingly shared operational metrics—makes it particularly suitable for small and medium enterprises (SMEs), which constitute the majority of the sector in Bangladesh and often lack resources for complex sustainability reporting.

Beyond immediate emission reductions, widespread adoption of the calculator has the potential to enhance transparency across the industry, facilitate access to green financing and international partnerships, and position Bangladesh as a leader in sustainable digital innovation within South Asia. The open availability of the tool further encourages replication and adaptation in similar emerging economies, amplifying its broader impact on global efforts to account for and mitigate the environmental footprint of the digital economy.

6.4 Comparison with Existing Literature

The proposed research directly addresses a critical gap in the sector-specific carbon accounting literature. While robust, data-constrained calculators have been successfully developed and validated for several industries—including ports [5, 6], small and medium enterprises (SMEs) [7], and distributed supply-chain scenarios [8]—no equivalent tool exists for the software sector. These prior works demonstrate that high accuracy (±8 % to < 15 % uncertainty) and assurance-readiness are achievable even under real-world data limitations, provided the methodology is carefully tailored to sector-specific operational metrics and emission sources [6, 16].

Existing studies on cloud and computation-related emissions, such as the widely adopted Green Algorithms tool [9], require detailed inputs (core-hours, hardware specifications, precise grid intensity) that corporate sustainability teams rarely obtain when procuring commercial cloud services. Although major providers now offer regional carbon intensity data and consumption metrics via APIs [10], cross-provider standardisation and independent verification remain incomplete, limiting direct applicability for organisational reporting.

Furthermore, recent advances in emission factor precision emphasise the superiority of time- and location-specific factors over annual averages [11–15], with sector-tailored models reducing uncertainty substantially [15, 16]. For software firms, where purchased electricity (primarily cloud services) typically dominates the footprint, these improvements are particularly relevant. However, no peer-reviewed work has yet mapped actual data availability in the software industry against GHG Protocol, ISO 14064-1, and ESRS E1 requirements, nor designed a calculator relying solely on data that companies are willing to provide.

The current study builds on these foundations by focusing exclusively on the software sector, surveying data willingness, and developing a standardised, assurance-ready calculator that achieves completeness and accuracy using only readily shared operational metrics.

7 Limitations and Future Work

This study has several limitations. The survey sample is small (9 responses), limiting generalisability across the diverse Bangladeshi software sector and introducing potential self-reporting bias.

The calculator relies on spend-based and proxy methods due to data constraints, resulting in higher uncertainty than activity-based approaches. Granular Scope 3 categories (e.g., detailed commuting, work-from-home impacts) are conservatively estimated or partially excluded. Emission factors, while sourced from reputable databases, lack comprehensive Bangladesh-specific values for some sources, and the tool currently offers no multi-year tracking or API integrations.

Future work could include a larger-scale survey for broader validation, integration of provider-specific cloud emission APIs as they mature, and addition of mobile/offline support, uncertainty analysis, and reduction scenario modelling. Longitudinal studies on actual adoption and emission reductions would further demonstrate real-world impact.

8 Conclusion

This study also considers ethical and societal consequences. By lowering barriers to carbon accounting, the tool promotes environmental justice in an emerging economy where SMEs lack resources for sustainability reporting—potentially disadvantaging them in global markets requiring ESG compliance. It supports Bangladesh's climate commitments (e.g., Nationally Determined Contributions and Delta Plan 2100) and broader societal goals like sustainable job creation in the digital economy. No significant negative ethical issues apply, as the tool uses anonymised, voluntary data and prioritises privacy (local processing).

Limitations include the modest survey sample (9 responses), which limits generalisability and may introduce self-selection bias toward more organised firms. Spend-based/proxy methods inherently carry higher uncertainty than activity-based approaches, and some Bangladesh-specific emission factors remain unavailable. The tool currently lacks advanced features like multi-year tracking or automated API integrations. These impact the results by potentially over- or under-estimating certain Scope 3 categories, though conservative estimates and standards compliance mitigate this for assurance-readiness.

Profound future research opportunities include: large-scale longitudinal surveys to validate adoption and actual emission reductions; integration of maturing cloud-provider APIs for hybrid accuracy improvements; uncertainty quantification modules; and adaptation of the tool for other emerging economies or sectors (e.g., fintech, e-commerce). Comparative studies on reduction scenarios enabled by the tool could quantify real-world impact on national GHG inventories.

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Appendix A: Survey Questionnaire

The "Carbon Footprint Data Availability Survey" consisted of the following sections and questions (exact wording as in Google Forms):

Consent Form

I voluntarily permit the questionnaire provider to use my company's anonymised data for academic research, including publication in conference proceedings or journals. I also agree to be contacted later to receive the free carbon footprint calculator and my company's personalised report.

Options: Agree / Disagree

Result: 100 % (9/9) Agree.

Company Profile

- Company Name (open text)
- Person Name (open text)
- Email (open text)

Main Questions

(1) Do you have a record of the exact headcount for the reporting year? (Yes / No)
(2) Do you know the total floor space of your office(s) (in Sq Ft or Sq Meters)? (Yes / No)
(3) Do you have copies of utility bills (e.g., DESCO, DPDC, NESCO) that show the kWh units consumed (not just the Taka amount) for the last 12 months? (Yes / No/We only have cost records / No/We don't track this)
(4) Does the company own any vehicles? (Yes / No)
(5) Do you keep a log of the total fuel (Liters of Octane/Diesel or Sm^3 of CNG) purchased for these vehicles? (Yes / No)

(6) Does your office building run a backup generator during load shedding? If yes, do you have a log of the liters of Diesel/Octane purchased? (Yes, we track fuel liters / No, we pay a fixed service charge to the building management / No, we don't use a generator)
(7) Do you have maintenance records showing if Refrigerant Gas (e.g., R-410A, R-22) was refilled in your AC units during the last year? (Yes / No)
(8) Do you have a financial report showing the total amount spent (BDT/USD) on laptops, servers, monitors, and networking gear in the last year? (Yes / No)
(9) Do you have a record of the total annual spend on cloud services (AWS, Azure, Google Cloud, DigitalOcean) and web hosting? (Yes / No)
(10) Do you have a record of employee business flights that includes the destination and class of travel (Economy/Business)? (Yes / No)
(11) Do you have data (or a recent survey) showing how your employees get to work (Bus, CNG, Rickshaw, Car) and their average distance traveled? (Yes, we have detailed data / No, we have no data on this)
(12) Do you track the total number of days employees worked from home during the year? (Yes / No)
(13) If you answered "No" to any of the above, are you willing to implement a simple logbook/spreadsheet system to start tracking this data? (Yes, please send us a template / Maybe, we need more information / No, not at this time)
(14) (Optional) Any comments or specific challenges you face in collecting this data? (Open text)

Appendix B: Key Survey Results Summary

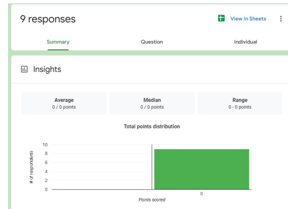
Aggregated results from the 9 complete responses:

- Exact headcount record: 55.6 % Yes, 44.4 % No
- Office floor space known: 33.3 % Yes, 66.7 % No
- Utility bills with kWh units: 33.3 % Yes, 33.3 % Only cost records, 33.3 % No/Don't track
- Company owns vehicles: 77.8 % Yes, 22.2 % No
- Fuel purchase log for vehicles: 66.7 % Yes, 33.3 % No
- Backup generator fuel tracking: 77.8 % No generator / fixed charge, 11.1 % Track liters, 11.1 % Pay fixed charge
- Refrigerant refill records: 66.7 % Yes, 33.3 % No
- Spend on IT hardware: 77.8 % Yes, 22.2 % No
- Cloud services spend record: 77.8 % Yes, 22.2 % No
- Detailed business flight records: 55.6 % Yes, 44.4 % No
- Employee commuting data: 44.4 % Yes (detailed), 55.6 % No
- Track work-from-home days: 0 % Yes, 100 % No
- Willingness to start new tracking (for "No" items): 22.2 % Yes (send template), 22.2 % Maybe, 55.6 % No

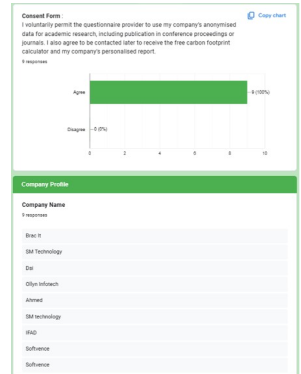
These results highlight high availability of financial and high-level records (cloud spend, IT hardware, fuel) but near-zero tracking of remote work and detailed commuting/WFH impacts.

Appendix C: Selected Survey Screenshots

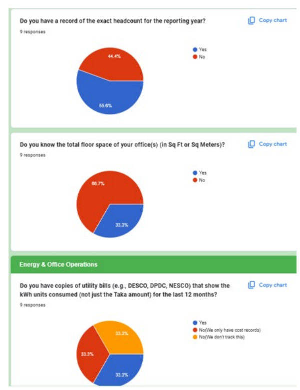
The following figures present selected screenshots from the Google Forms response dashboard (9 complete responses). Original high-resolution images are available from the author upon request.



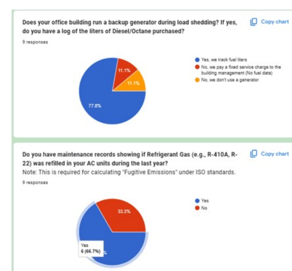
(a) Consent form results (100% agreement) and company profile responses.



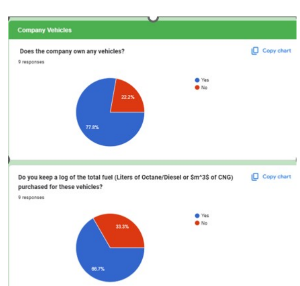
(b) Survey summary dashboard and insights distribution.



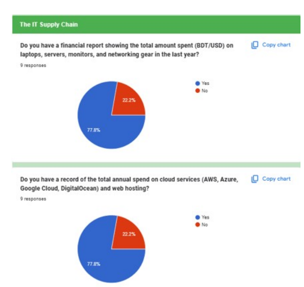
(a) Availability of exact headcount records (55.6% yes) and office floor space data (33.3% yes).



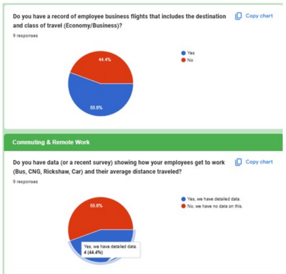
(b) Utility bills with kWh consumption, company vehicle ownership, and vehicle fuel logging.



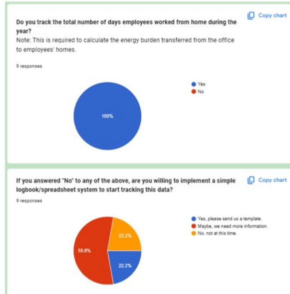
(a) Backup generator fuel tracking and refrigerant gas refill records.



(b) Annual spend records on IT hardware and cloud services (both 77.8% yes).



(a) Business flight records and employee commuting data availability.



(b) Work-from-home days tracking (0% yes) and willingness to implement new tracking systems.