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Greenhouse gas emissions from the healthcare facilities in Bangladesh

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ABSTRACT

Health sector contributes to both direct and indirect greenhouse gas (GHG) emissions through its supply chain, energy consumption, transportation, services delivery, and use of technologies in Bangladesh. This study aimed to identify emission sources following Global Greenhouse Gas Protocol and to estimate emissions from primary, secondary, and tertiary hospitals. A quantitative method was applied using the Aga Khan Development Network's (AKDN) Carbon Management Tool, which employed a four-tiered hybrid approach aligned with international GHG Protocol. A total of nine healthcare facilities were purposively selected based on bed capacity and geographical coverage, comprising three primary, three secondary, and three tertiary-level hospitals. Results showed that Sylhet MAG Osmani Medical College Hospital, Kurmitola General Hospital, Mymensingh Medical College Hospital, Bandarban 250-Bed District Hospital, Sirajganj 250-Bed General Hospital, Satkhira District Hospital, Gournadi Upazila Health Complex (UHC), Saidpur UHC, and Sreemangal UHC emitted 10755, 6653, 7978, 774, 1252, 682, 374, 73, and 315 t CO_2-e annually, respectively. Scope 1 emissions were associated with travel and building energy in primary facilities, anesthetic gases and travel in secondary facilities, and anesthetic gases, building energy, refrigerants, and travel in tertiary facilities. Scope 2 emissions across all facilities came from purchased grid electricity, while Scope 3 emissions were associated with supply chains, waste, travel, inhalers, and logistics. The study found substantial variation of greenhouse gas emissions by facility type and Scope, with total emissions strongly correlated with number of beds. The findings provide practical evidence for policymakers to prioritize emission reduction, sustainable procurement, waste management, energy efficiency, and low-carbon health policies.

1. Introduction

The principal greenhouse gases (GHG) include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halogenated gases (such as fluorocarbons), and water vapor (H_2O) and are released from both natural and human activities. Natural sources include forest fires, oceans, wetlands, permafrost, volcanoes, mud volcanoes, and earthquakes, while human-driven sources include the burning of coal, oil, and natural gas; industrial processes; agriculture; deforestation; and waste generation. A study estimated that anthropogenic emissions account for approximately 55.46% of total global GHG emissions, indicating a natural-to-anthropogenic emission ratio of about 0.8 (Yue and Gao, 2018). Globally, the energy sector is the dominant contributor, responsible for 73.2% of emissions, followed by agriculture, forestry, and land use (AFOLU) at 18.4% (Ritchie et al., 2020), industrial processes at 5.2%, and waste at 3.2%. The health sector alone is estimated to contribute around 5% of net global emissions (Zeynep and Seppänen, 2024; Pichler et al., 2019). In Bangladesh, total GHG emissions in the base year 2012 were 169.05 million tons of carbon dioxide equivalent (t CO_2-e). The energy sector contributed the largest share at 55%, followed by AFOLU at 27% and industrial processes and product use (IPPU) at 3% (Nationally Determined Contributions (NDCs), 2022). The remaining emissions originated from other sectors, including the health sector.

The health sector is a significant contributor to GHG emissions, both in Bangladesh (Raihan et al., 2022a) and globally. The delivery of healthcare services generates direct and indirect emissions through the

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procurement of goods, energy use, transportation, services, and technologies - many of which are embedded in carbon-intensive supply chains. Greenhouse Gas Protocol Corporate Accounting and Reporting Standard of World Resources Institute, & World Business Council for Sustainable Development (WBCSD) categorized the GHG emission into three categories (World Resources Institute and & World Business Council for Sustainable Development, 2004). The IPCC guidelines provide the methodological basis for national greenhouse gas inventories and greenhouse gas accounting (Intergovernmental Panel and on Climate Change, 2006). As per the definition direct emissions from sources that the entity owns or controls are covered by Scope 1. Indirect emissions from the production of purchased energy, steam, heating, or cooling are included in Scope 2. Scope 3 includes all other indirect emissions from sources that the entity does not own or directly control that occur upstream and downstream throughout the value chain. Healthcare-related carbon emissions can be classified using this framework and are strongly associated with health expenditure (Karliner et al., 2019). While the relationship is not perfectly linear, in general, higher national health spending corresponds to higher per capita healthcare-related GHG emissions (Raihan et al., 2022b).

Bangladesh is a relatively modest contributor to GHG emissions, accounting for an estimated 0.4% of the global total in 2018 (World Bank Group, 2022). The national baseline GHG emission inventory, established in 2012, covered emissions from the energy sector, industrial processes and product use (IPPU), agriculture, forestry and other land use (AFOLU), and waste. This inventory provided the foundation for developing a comprehensive national GHG inventory in 2021. Nationally Determined Contributions (NDCs) of Bangladesh commit to reducing GHG emissions across all sectors. The health system continues to be a largely ignored source of emissions despite the country's commitment to reducing GHG emissions through its NDCs. There is no nationally representative data on the amount, distribution, or primary drivers of GHG emissions related to healthcare. This information gap retards evidence-based policy and investment decisions for creating low-carbon health systems, as well as the integration of the health sector into national climate mitigation efforts.

In order to address this gap, the present study was conducted with the objective of identifying sources of healthcare-related GHG emissions and estimating emissions across primary, secondary, and tertiary hospitals. This study provides the first comparative assessment of greenhouse gas emissions primary, secondary, and tertiary healthcare facilities in Bangladesh using the AKDN Carbon Management Tool aligned with the GHG Protocol Corporate Accounting and Reporting Standard. The study findings will provide baseline information to enable the development of a focused mitigation strategies, healthcare decarbonization plans, and climate-resilient health policies by identifying significant emission sources across Scope 1, Scope 2, and Scope 3. The methodology and findings will be useful to other LIMCs to conceptualize the carbon emission issues of health care facilities.

2. Materials and methods

2.1. Study design

The study method was quantitative with a cross-sectional design. A Carbon Management Tool (Carbon footprint calculators for healthcare) (Aga Khan Development Network, 2023), developed by Aga Khan Development Network (AKDN), which was specifically designed for healthcare operations, was used to collect data and information. In accordance with the international Greenhouse gas protocol(Baddley and Rasheed, 2023), which followed the Corporate Accounting and Reporting Standard, the tool uses a four-tiered hybrid methodology. Considering the four tiers, direct activity data (e.g., fuel, electricity, and medical gases) were collected first. Where these were unavailable, expenditure data were used to estimate emissions. If expenditure data were also unavailable, proxy indicators (e.g., hospital beds, patient volume, or floor area) were applied. Finally, activity, expenditure, and proxy-based estimates were integrated using a hybrid approach to calculate GHG emissions. Most emission factors were sourced from the UK Department for Environment, Food and Rural Affairs (DEFRA) datasets (Greenhouse gas reporting; Baddley, 2021), with currency conversion applied at a rate of United States Dollar (US$) 1 = Bangladesh Taka (BDT) 110. The study method is illustrated in Fig. 1. A total of nine healthcare facilities were purposively selected to assess the carbon footprint: three tertiary (divisional level), three secondary (district level), and three primary (sub-district level) hospitals. Selection criteria included data availability, bed capacity, and geographical coverage across Bangladesh. Primary data were collected on multiple parameters, including buildings, energy consumption, vehicle fuel and mileage, staff travel by external vehicles (vehicles that are not owned by the healthcare facility), anesthetic and refrigerant gases, water use, waste generation, inhalers, contractor logistics, construction materials, and procurement. Data were obtained through consultations with facility managers and relevant departments, as identified by hospital administrations. Data collection covered a three-month period (July–September 2023). The collected information was then entered into the AKDN tool, and the carbon footprint of each facility was obtained accordingly.

2.2. Sample type and size

The study purposively selected nine healthcare facilities comprising three primary, three secondary, and three tertiary hospitals from a total of 434 primary, 63 secondary, and 36 tertiary healthcare facilities in Bangladesh. Their locations are presented in Fig. 2. Hospitals were selected according to predetermined inclusion criteria *viz* the availability of comprehensive activity data required for greenhouse gas accounting, bed capacity, operational diversity, and geographic representation across the country. Purposive sampling was used to ensure that facilities with various operational characteristics and levels of healthcare service delivery were included.

The primary healthcare facilities (sub-district level) were Sreemangal Upazila Health Complex, Moulvibazar (Sylhet); Gournadi Upazila Health Complex, Barisal (Barisal); and Saidpur Upazila Health Complex, Nilphamari (Rangpur). The secondary hospitals (district level) were Sirajganj 250-Bed General Hospital (Rajshahi); Bandarban 250-Bed District Hospital (Chittagong); and Satkhira District Hospital (Khulna). The tertiary hospitals (divisional or medical college level) were Kurmitola General Hospital (Dhaka); Mymensingh Medical College and Hospital (Mymensingh); and Sylhet MAG Osmani Medical College Hospital (Sylhet). There are notable differences in health service provision among these hospital categories. Primary facilities provide basic care, maternal and child health services, and minor emergency treatment, with capacities of 50–100 beds. Secondary facilities deliver general and specialized care, including surgery, with capacities ranging from 100 to 500 beds. Tertiary facilities offer advanced and specialized medical services, such as complex surgeries and intensive care, with bed capacities generally exceeding 500 beds.

2.3. Data collection

A technical work group facilitated and oversaw the data collection process. The group included representatives from the Institute of Epidemiology, Disease Control and Research (IEDCR), the Health Services Division of the Directorate General of Health Services, the Ministry of Health and Family Welfare, and the World Health Organization (WHO). Two Study Associates collected data using the AKDN Carbon Management Tool through direct observation, consultations, and interviews with facility managers and relevant departments, as well as by reviewing registers, reports, bills, vouchers, and other records. Hospital administrations identified the relevant departments and personnel in consultation with facility managers, following AKDN tool guidelines.

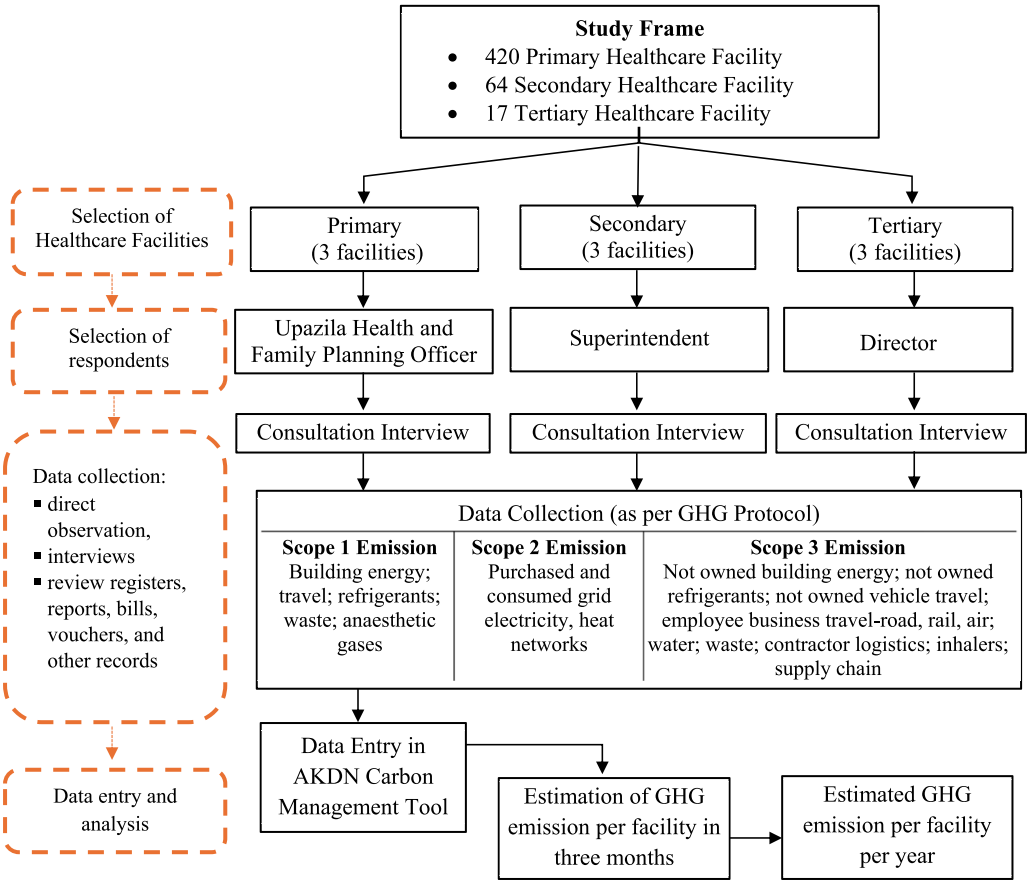


Fig. 1. Data collection methodology for assessing the greenhouse gas emissions of healthcare facilities in Bangladesh.

A structured checklist (Annex 1) was used to ensure consistency and completeness in data collection of different items. Data on buildings, construction materials, contractor logistics and energy sources (including grid-supplied electricity, renewable electricity, grid-supplied gas, gas cylinders/tanks, solid fuel, liquid fuel, and heat networks) were collected from the Public Works Department, Ward Master, Accountant, and Store Officer. Information on anesthetic gases, refrigerant gases, and waste management was obtained from the Store Officer, while water and inhaler data were collected from the Ward Master. Vehicle-related information—covering both internal (facility owned the vehicles) and external vehicles (facility did not own the vehicles) and travel distances—was collected from the Driver and Head Assistant. Procurement data, including the annual budget, were provided by the accountant. The reporting period for all hospitals was July–September 2023.

2.4. Assumptions

A checklist was developed in accordance with the AKDN Carbon Management Tool, and it was used to collect the available activity data. Annual greenhouse gas emissions were estimated by assuming that the activity data collected during the reporting period (July–September 2023) were representative of routine 3months hospital operations. Procurement expenditures were assumed to reflect actual annual resource consumption where item-specific activity data were unavailable. An exchange rate of USD 1 = BDT 110 was consistently applied for expenditure-based emission calculations. Missing activity data were supplemented using expenditure-based estimates or validated proxy indicators following the tool's hybrid accounting approach. Emission factors incorporated within the AKDN Carbon Management Tool were assumed to be appropriate for the Bangladesh healthcare context and were applied consistently across all participating hospitals. The organizational and operational boundaries were defined in accordance with the GHG Protocol Corporate Accounting and Reporting Standard. It needs to be noted that the organizational boundary comprises each participating healthcare facility, including all hospital departments and activities under its operational control and the operational boundary included all relevant direct and indirect emission sources associated with hospital operations that were captured by the AKDN Carbon Management Tool and classified according to Scope 1, Scope 2, and Scope 3 of the GHG Protocol.

2.5. Data analysis

General information for each hospital was entered into the Cover Sheet of the AKDN Carbon Management Tool. Activity data is then entered into the corresponding module where greenhouse gas emission was estimated using emission factors (Annex 2) which were embedded within the tool and are applied to activity data to calculate greenhouse gas emissions and the tools hybrid accounting approach in accordance with the GHG Protocol Corporate Accounting and Reporting Standard. Expenditure based data and validated proxy-based indicators were used where primary data, i.e., direct activity data was unavailable. Emissions were quantified and automatically aggregated under Scope 1 (direct emissions), Scope 2 (purchased electricity), and Scope 3 (other indirect emissions, including procurement, transportation, travel, water, waste, and supply-chain activities). Since data were collected for a three-month period (July–September 2023), emissions were annualized by multiplying the quarterly estimates by four, assuming that the reporting period represented routine hospital operations. Finally, cross-tabulation and percentile analyses were performed to compare greenhouse gas emissions across hospital levels and geographical locations. Because the sample was limited and non-random, the results could not be entirely

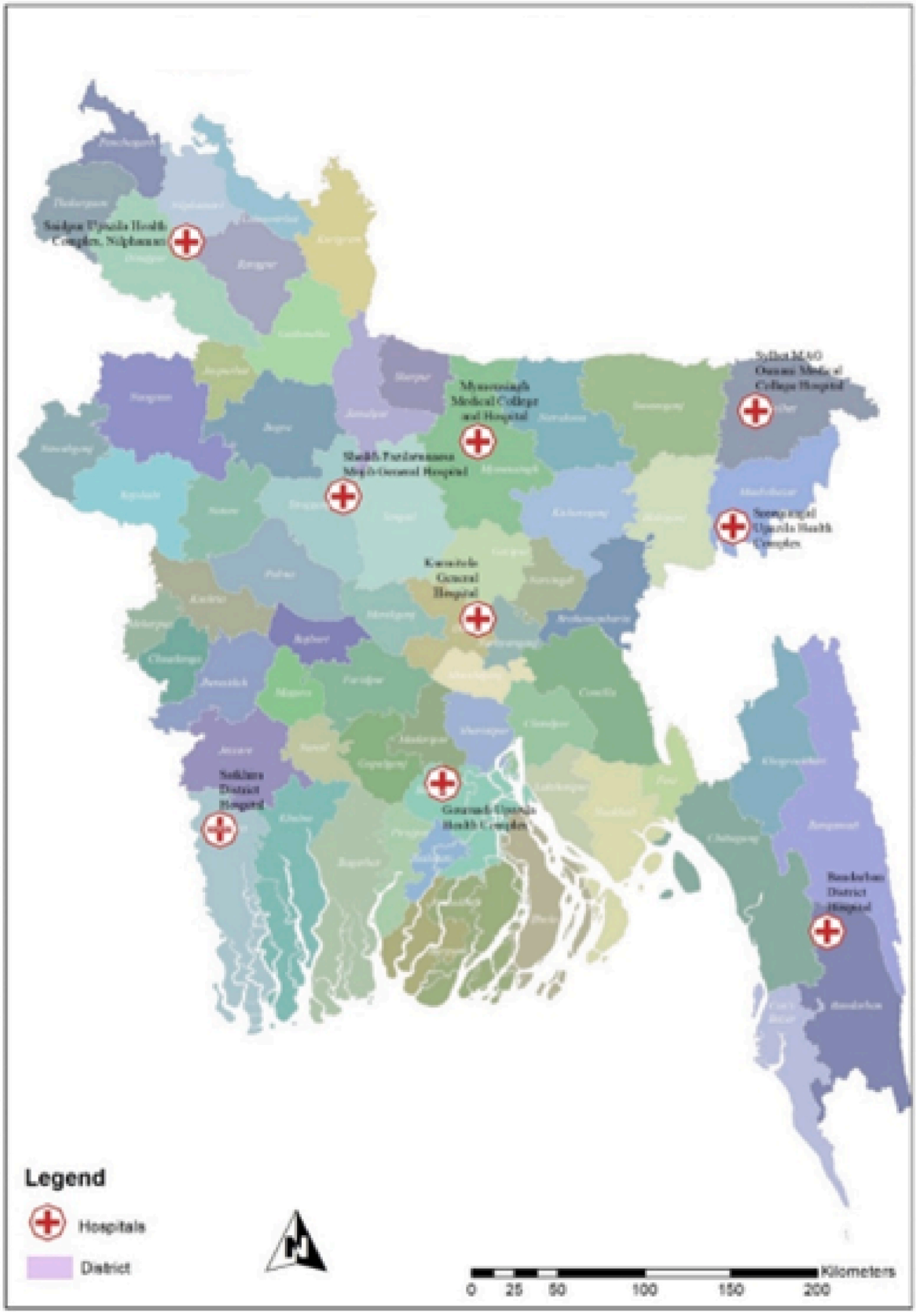


Fig. 2. Locations of the study hospitals.

representative of all Bangladeshi healthcare institutions, and they should be evaluated in light of the facilities that were chosen.

3. Results

The carbon emissions from different healthcare facilities were categorized according to the Global Greenhouse Gas Protocol, using emission 'Scopes' to avoid double counting. These include building energy from non-owned buildings, contractor logistics (Indirect emissions from transportation and distribution of goods and services performed by third-party contractors e.g., medical supplies, pharmaceuticals, food deliveries, outsourced transport), employee business travel (indirect emissions from employees travelling for official hospital business using vehicles not owned or controlled by the healthcare facility e.g., commercial flights, trains, buses, taxis, rental vehicles), inhalers, refrigerants from non-owned buildings, supply chain activities, travel in non-owned vehicles (direct emissions from fuel combustion in vehicles not owned or controlled by the healthcare facility), as well as waste and water. The results of the carbon footprint analysis, categorized by hospital level, emission Scope, and geography, are presented in Table 1.

The table shows that Sylhet MAG Osmani Medical College Hospital emits 10755 t CO_2-e per year, Kurmitola General Hospital emits 6653 t CO_2-e per year, and Mymensingh Medical College Hospital emits 7978 t CO_2-e per year. Among district hospitals, Bandarban 250-Bed District Hospital emits 774 t CO_2-e per year, Sirajganj 250-Bed General Hospital emits 1252 t CO_2-e per year, and Satkhira District Hospital releases 682 t CO_2-e per year. For Upazila Health Complexes (UHCs), Gournadi UHC emits 374 t CO_2-e per year, Saidpur UHC releases 73 t CO_2-e per year, and Sreemangal UHC emits 315 t CO_2-e per year. The average emissions from each category of healthcare facilities, based on three hospitals per category, are presented in Fig. 3. The average total emission per primary healthcare facility was 254 t CO_2-e per year, per secondary healthcare facility was 903 t CO_2-e per year, and per tertiary healthcare facility was 8462 t CO_2-e per year.

Overall, Fig. 3 presents the proportional contribution of Scope 1, Scope 2, and Scope 3 emissions to the total greenhouse gas emissions for each hospital type. The relative contribution of greenhouse gas emission scopes varied across hospital levels (Table 1). In primary healthcare facilities, Scope 3 was the dominant source of emissions, accounting for 89.7% of total emissions, while Scope 2 and Scope 1 contributed 9.7% and 0.6%, respectively. In secondary hospitals, Scope 3 remained the largest contributor (59.6%), followed by Scope 2 (21.7%) and Scope 1 (18.6%). Similarly, tertiary hospitals showed the highest contribution from Scope 3 (52.4%), with Scope 2 and Scope 1 accounting for 24.2% and 23.4%, respectively. Across all participating healthcare facilities, Scope 3 emissions constituted the largest share (54.0%) of total greenhouse gas emissions, followed by Scope 2 (23.6%) and Scope 1 (22.4%).

The relative contribution of major Scope 3 emission sources varied across hospital levels. Supply chain activities were the largest contributor in tertiary hospitals, accounting for 41.1% of total Scope 3 emissions, followed by waste (9.4%), inhalers (2.2%), employee business travel (0.2%), and contractor logistics (0.0%). In secondary hospitals, Scope 3 emissions were primarily driven by waste (35.6%), followed by supply chain activities (29.0%), inhalers (0.8%), contractor logistics

Table 1
Results of carbon footprint with respect to Scope and source of emission, type of hospitals and geography.

No.	Scope of Emission	Source of Emission	Tertiary Level HCF			Secondary Level HCF			Primary Level HCF		
			t CO_2-e/Year			t CO_2-e/Year			t CO_2-e/Year		
			Sylhet MAG Osmani Medical College Hospital	Kurmitola General Hospital	Mymensingh Medical College Hospital	Bandarban 250 Bed District Hospital	Sirajganj 250 Bed General Hospital	Satkhira District Hospital	Gournadi UHC	Saidpur UHC	Sreemangal UHC
1	Scope 1	Anesthetic gases	2193	95	2311		413				
2	Scope 1	Building energy	229	46	503						1
3	Scope 1	Refrigerants	294	230	0						
4	Scope 1	Travel	22	4	15	41	34	17		4	
5	Scope 1	Waste									
6	Scope 2	Heat networks									
7	Scope 2	Purchased and consumed grid electricity	1404	1875	2871	65	368	156	30	2	41
8	Scope 3	Building energy (building not owned)									
9	Scope 3	Contractor logistics	3	0	3	3	1	1	0		
10	Scope 3	Employee business travel-road, rail, air	4	12	0	0	0	0	0	62	0
11	Scope 3	Inhalers	1	227	80		10	6	1		6
12	Scope 3	Refrigerants (building not owned)									
13	Scope 3	Supply chain	4895	3802	1655	105	239	371	86	2	239
14	Scope 3	Travel (vehicles not owned by hospital)									
15	Scope 3	Waste	1710	361	541	561	187	132	257	3	28
16	Scope 3	Water									
Grand Total			10755	6653	7978	774	1252	682	374	73	315

NB: All values were rounded to the nearest whole number.

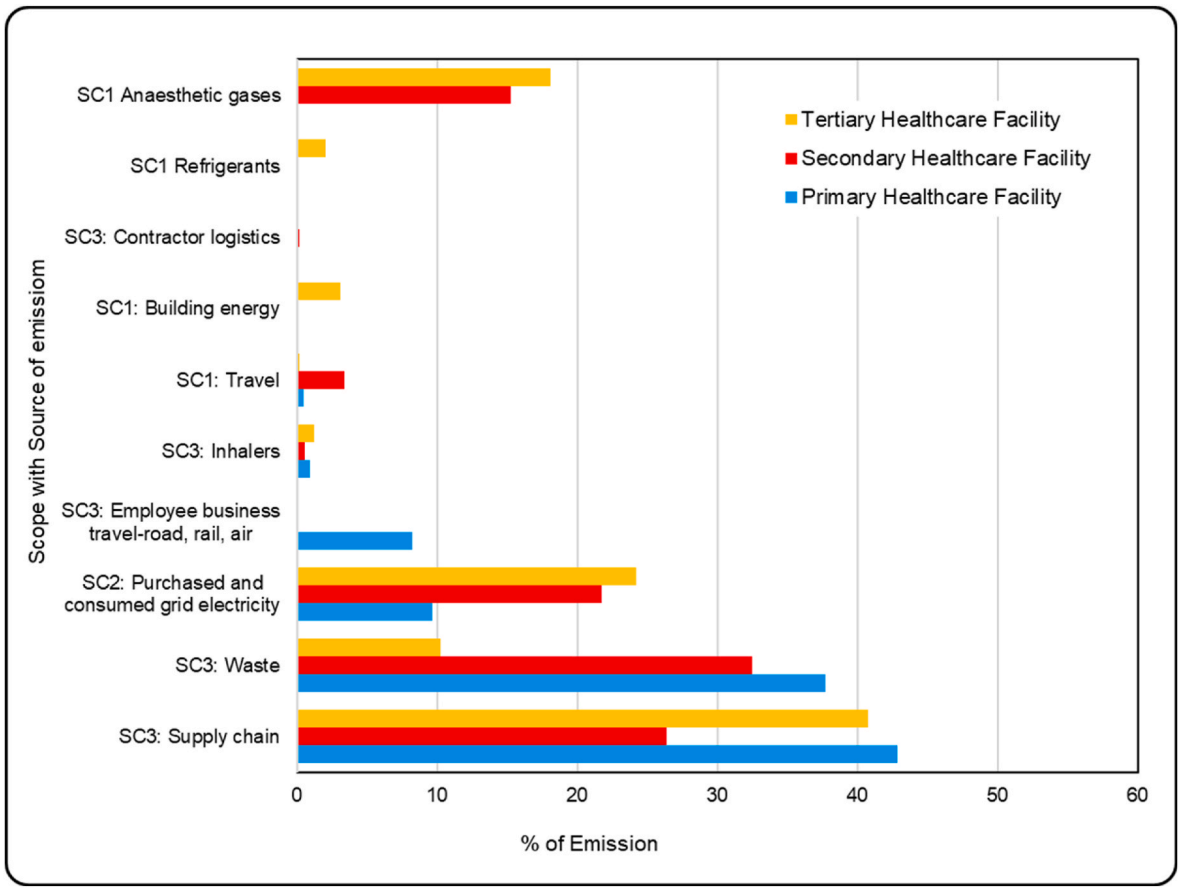


Fig. 3. Average carbon emission from different level of hospitals.

(0.2%), and employee business travel (0.1%). In contrast, primary healthcare facilities showed comparable contributions from supply chain (33.9%), employee business travel (28.5%), and waste (27.0%), while inhalers contributed 1.1% and contractor logistics were negligible (0.0%). Although detailed procurement data were collected, the AKDN Carbon Management Tool reports supply chain emissions as an aggregated category, limiting further disaggregation of individual procurement-related emission sources. Future studies should incorporate more detailed procurement-based life cycle assessment methods to identify specific supply chain emission hotspots.

An exploratory assessment was conducted to examine the relationship between hospital bed capacity and total greenhouse gas emissions (Figure_4). The scatter plot demonstrated a strong positive linear association, indicating that hospitals with larger bed capacities generally produced higher greenhouse gas emissions. Although the relationship appeared strong ($R^2 = 0.998$), no inferential regression analysis was performed because the study included only nine purposively selected hospitals. Therefore, the observed relationship should be interpreted

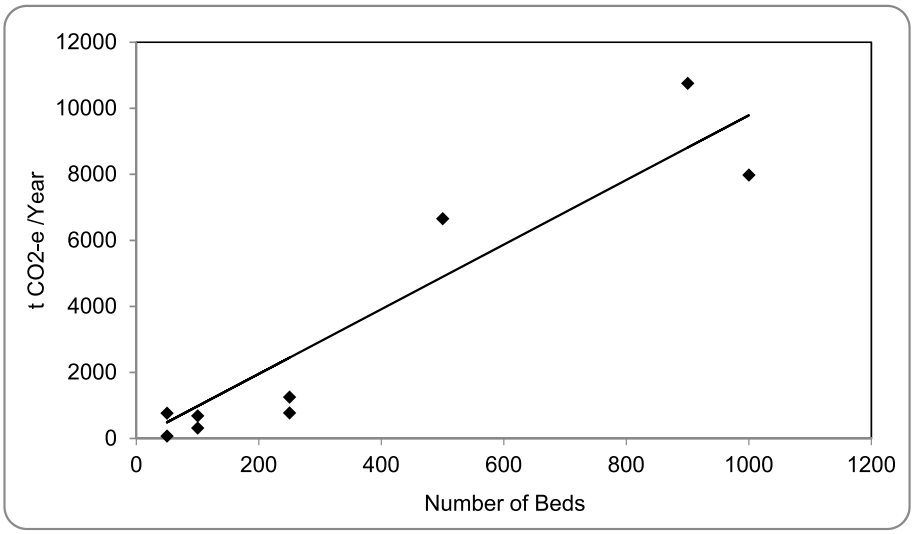


Fig. 4. Analysis of carbon emission vs bed capacity of different hospitals facility.

descriptively and not generalized beyond the participating healthcare facilities.

4. Discussion

This quantitative cross-sectional study identified the sources of GHGs in accordance with the Global Greenhouse Gas Protocol Corporate Accounting and Reporting Standard for healthcare facilities in Bangladesh. The study found travel and building energy to be the major contributors to Scope 1 emissions (i.e., direct emissions from healthcare facilities) in primary healthcare facilities; anesthetic gases and travel in secondary healthcare facilities; and anesthetic gases, building energy, refrigerants, and travel in tertiary healthcare facilities. Scope 2 emissions in all healthcare facilities whether primary, secondary, or tertiary, primarily arise from purchased and consumed national grid electricity. Scope 3 emissions are attributed to the supply chain, waste, employee business travel (by road, rail, and air), inhalers, and contractor logistics. Among the total emissions observed in this study, the three dominant sources were supply chain and waste (both under Scope 3), followed by purchased and consumed grid electricity (Scope 2).

The findings of this study are consistent with previous research showing that healthcare facilities are important sources of greenhouse gas emissions and that standardized carbon accounting is essential for identifying emission hotspots and guiding mitigation strategies. Different observations have been reported in a systematic review of healthcare carbon footprints and studies from the NHS in England (Tennison et al., 2021; Rodríguez-Jiménez et al., 2023)and hospitals in Germany (Quitmann et al., 2025), supporting the relevance of the present findings in Bangladesh. Other studies have reported that energy consumption, supply chain activities, waste transportation, and anesthetic gases are the major contributors to carbon emissions in healthcare facilities (Eckelman et al., 2020; Wu, 2019). Similarly, the present study identified indirect emissions, particularly those associated with supply chain activities, as the largest contributors to the overall carbon footprint of healthcare facilities. The similarities observed across different healthcare systems suggest that the major emission sources and mitigation priorities identified in this study are broadly applicable to other low- and middle-income countries with comparable healthcare infrastructure and resource constraints.

The study results indicated that total carbon emissions varied both by type of healthcare facility and by emission Scope within each facility. In primary healthcare facilities, Scope 3 emissions dominated, accounting for nearly 90% of total emissions, followed by Scope 2 emissions at 10%. In secondary hospitals, Scope 1 (19%) and Scope 2 (22%) emissions were similar, while Scope 3 emissions were considerably higher at 60%. In tertiary hospitals, Scope 1 (23%) and Scope 2 (24%) emissions were nearly equal, with Scope 3 emissions remaining higher at 52%. Similar findings have been reported in other reviews (Iyer et al., 2022). Across healthcare facilities, the relative proportion of Scope 1 and Scope 2 emissions decreases with increasing facility level, while the contribution of Scope 3 emissions increases in higher-level facilities. This pattern illustrates that larger facilities with more beds tend to have higher emissions due to greater energy consumption for heating, cooling, and powering equipment, as well as increased waste generation and resource utilization, consistent with findings from other studies (Prasad et al., 2022).

Healthcare facilities in Bangladesh are categorized as primary, secondary, and tertiary (Directorate General of Health Services (DGHS and), 2023). Primary healthcare facilities (31–50 beds) provide outpatient and inpatient care, emergency services, minor surgeries, deliveries, and referral services. Secondary healthcare facilities (100–250 beds) offer specialist care, surgery, trauma care, advanced inpatient services, and diagnostic facilities. Tertiary hospitals (≥500 beds) provide specialized and sub-specialized clinical care, teaching, research, and advanced diagnostic services. The bed capacity and service provision increase from primary to tertiary healthcare facilities. Accordingly, greenhouse gas emissions are expected to be higher in tertiary hospitals than in secondary hospitals, and higher in secondary hospitals than in primary hospitals, since larger facilities generate greater emissions from identified sources. The study results support this expectation, showing that greenhouse gas emissions are highest in tertiary hospitals, followed by secondary and then primary facilities. Furthermore, the results show a strong positive association between hospital bed capacity and emission levels. Furthermore, the results demonstrate a direct and highly significant correlation between the number of beds and the amount of emissions in the studied healthcare facilities.

This study provides the first comparative assessment of greenhouse gas emissions across primary, secondary, and tertiary healthcare facilities in Bangladesh using the AKDN Carbon Management Tool aligned with the GHG Protocol Corporate Accounting and Reporting Standard. The findings revealed that Scope 3 emissions, particularly those associated with the supply chain and waste management, were the dominant contributors to the overall carbon footprint, while purchased electricity represented the major source of Scope 2 emissions across all hospital levels. These findings highlight the importance of prioritizing indirect emission sources through sustainable procurement, improved waste management, and enhanced energy efficiency. A carbon mitigation plan integrating waste management improvement, compost production with carbon offset opportunities, tree plantation, energy-efficient lighting, and renewable solar energy demonstrated practical strategies for reducing healthcare-related greenhouse gas emissions and advancing climate-resilient healthcare systems. The study contributes to the growing evidence base on healthcare decarbonization by demonstrating the applicability of a hybrid greenhouse gas accounting approach in data-constrained settings and provides a methodological foundation for future carbon accounting, mitigation planning, and evidence-based policymaking in Bangladesh and other low- and middle-income countries with similar healthcare systems and resource constraints.

This study provides the first comparative assessment of greenhouse gas emissions across primary, secondary, and tertiary healthcare facilities in Bangladesh using the AKDN Carbon Management Tool aligned with the GHG Protocol Corporate Accounting and Reporting Standard. The findings demonstrated that Scope 3 emissions, particularly those associated with supply chain activities and waste management, were the dominant contributors to the overall carbon footprint across all hospital levels, while purchased grid electricity was the principal source of Scope 2 emissions. These results highlight the importance of prioritizing indirect emission sources through sustainable procurement, improved waste management, enhanced energy efficiency, and the transition to low-carbon energy systems to achieve meaningful reductions in healthcare-related greenhouse gas emissions.

A carbon mitigation plan integrating improved waste management, compost production with carbon offset opportunities, tree plantation, energy-efficient lighting, and renewable solar energy demonstrated practical and scalable strategies (Bozoudis et al., 2021, 2022) for reducing emissions while supporting climate-resilient and environmentally sustainable healthcare facilities. By applying a hybrid greenhouse gas accounting approach in a resource-constrained setting, this study contributes to the growing evidence base on healthcare decarbonization and demonstrates the feasibility of conducting comprehensive carbon footprint assessments where activity data are often limited. The findings provide a methodological foundation for routine carbon accounting and monitoring, evidence-based mitigation planning, and policy development (Assimacopoulos et al., 2025; Sebos and Kallinikos, 2023) within the Bangladesh health sector. Furthermore, the methodological framework and mitigation priorities identified in this study are transferable to other low- and middle-income countries with similar healthcare systems, resource constraints, and data limitations, thereby supporting broader efforts toward sustainable, low-carbon, and climate-resilient healthcare systems.

5. Conclusion

The study generated the estimations of the total carbon footprint of the healthcare facilities of different types for the first time in Bangladesh. The tertiary healthcare facilities contributed the highest share of emissions, followed by secondary and primary facilities. The relative proportion of Scope 1 emissions decreased with increasing facility level, while the relative proportions of Scope 2 and Scope 3 emissions increased in higher-level facilities. Greenhouse gas emissions were also positively associated with the number of hospital beds, indicating that larger healthcare facilities generally produced higher emissions. Overall, this study provides an important foundation for broader-scale assessments to estimate the total carbon footprint of Bangladesh's healthcare sector and advances the evidence base for healthcare carbon accounting in resource-constrained settings through the application of a standardized hybrid accounting approach. The findings provide practical evidence for policymakers to prioritize emission reduction strategies, strengthen sustainable procurement and waste management practices, improve energy efficiency, and integrate low-carbon measures into national health planning and climate policies. Furthermore, the methodological framework and mitigation priorities identified in this study are transferable to other low- and middle-income countries with similar healthcare systems and data constraints, supporting the development of sustainable, low-carbon, and climate-resilient health systems.

CRediT authorship contribution statement

Ahammadul Kabir: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Mohammad Ferdous Rahman Sarker:** Writing – review & editing, Formal analysis, Data curation. **Anthony Eshofonie:** Writing – review & editing. **Golam Kibria Nury:** Formal analysis, Data curation. **Mohi Uddin Al Helal:** Writing – review & editing. **Tahmina Shirin:** Writing – review & editing.

Ethics approval

The study was conducted under a programme of WHO Environmental Health Unit of Bangladesh as part of the programme implementation, the operational data were collected. Verbal consent was taken from the participants of the healthcare facility before data collection and letter was sent from appropriate authority of the health ministry of the government to provide data and information.

Availability of data and materials

The data sets used and analyzed during the current study are available from the corresponding author on reasonable request.

Disclaimer

The authors alone are responsible for the views expressed in this article, and they do not necessarily represent the views, decisions, and policies of the institution with which they are affiliated with.

Generative AI statement

Artificial intelligence (AI) is used only for improving grammar, spelling, and sentence structure. No AI tools were used for the generation, interpretation, analysis of data, or development of scientific content. The author(s) declared that generative AI was not used in the creation of this manuscript. If you identify any issues, please contact us.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Acronyms

AFOLU: agriculture, forestry, and land use, AKDN: Aga Khan Development Networks, CO_2-e: Carbon dioxide equivalent, DEFRA: Department for Environment Food and & Rural Affairs, GHG: Greenhouse Gas, HCF: Healthcare facility, IEDCR: Institute of Epidemiology Disease Control and Research, IPCC: Intergovernmental Panel of Climate Change, IPD: Inpatient Department, IPPU: Industrial processes and product use, MAG: Mohammad Ataul Gani, NDC: Nationally Determined Contributions, OPD: Outpatients department, UHC: Upazila health Complex, USC: Union Sub-centre, USD: US Dollar, WHO: World Health Organization.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cesys.2026.100507.

Data availability

Data will be made available on request.

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