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The Carbon Footprint of a Kenyan Healthcare Setting

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ABSTRACT

Objectives: This research sought to address the paucity of information on the carbon footprint of the Kenyan Healthcare Sector.
Methods: An analysis of the greenhouse gases emissions of Kericho County Referral Hospital, Kericho County, Kenya, was done, using the 2022 Greenhouse Protocol. The Aga Khan Development Network Carbon Management Tool – version 1.6.3., was employed to calculate and identify the hospital's carbon emissions and hotspots, retrospectively, over a twelve-month period.
Results: The total carbon emissions at Kericho County Referral Hospital between the month of July, 2023 and June, 2024 were 318,155.37 $kgCO_2e$. The highest carbon hotspot identified at the facility, was consumption of grid electricity, amounting to 52% of the total emissions. The medium carbon hotspots were from waste incineration, vehicle fuel and liquid fuel use. The low carbon hotspots were solid fuel, anesthetic gases, inhalers dispensed and refrigerants used.
Conclusion: Kericho County Referral Hospital releases a substantial amount of greenhouse gases from its operations. Policy frameworks should incentivize the adoption of energy-efficient technologies, and support the transition to renewable energy. Initiatives such as reducing, re-using and recycling should be put in place to decrease the quantity of waste generated and incinerated.

Keywords: Carbon footprint, Healthcare, Emissions, Carbon Hotspots
Metric Units: $kgCO_2e$ – Kilograms of carbon dioxide equivalent

INTRODUCTION

The core principle in the ethical code of conduct of healthcare practitioners is to do no harm. However, as the implications of climate change become more apparent, particularly with regard to human health, it becomes paradoxical that the very systems – the healthcare systems – that were established to help people recover from their illnesses, also account for between four to five percent of global greenhouse gas emissions [(1)]. During service delivery, the greenhouse gases emitted from the healthcare sector cause direct harm to the environment which in turn exacerbate climate change and pose risks to human health

In the 2012 Doha Amendment to the Kyoto protocol, the United Nations Framework Convention on Climate Change (UNFCCC)

identified seven greenhouse gases (GHG): Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6) and Nitrogen trifluoride (NF_3) [(2)]. These gases have global warming potential since they trap heat in the atmosphere causing a gradual rise in global temperatures.

A carbon footprint is an estimation of the impact that an individual, organization or activity has on climate change through the various greenhouse gases emitted. The Greenhouse Gas Protocol (2022) – the current standard used in carbon footprint analysis – classifies carbon emissions into three scopes. Scope One emissions involve direct emissions from the organization's own operations and assets, for instance fuel used in generators or vehicles owned by the organization. Scope Two emissions are indirect emissions that arise from the purchase and utilization of electricity, steam or heating. Scope Three emissions encompass all other indirect emissions that relate to the supply chain and the distribution of goods and services, most of which the organization has no control over, namely: construction, water use and pressurized metered dose inhalers [(3)].

Studies done in high-income countries have identified fuel consumed in the supply chain, energy usage in buildings, water use, release of anesthetic gases, transportation and medical waste disposal as the major sources of these emissions [(1)]. In an effort to combat climate change, the healthcare sector should have an analysis of their carbon footprint done to quantify the total greenhouse gases emitted, identify their carbon hotspots and put measures in place to reduce the emissions and rate of environmental pollution.

In accordance with the Paris Agreement's goal of limiting global warming to below two degrees Celsius, the health sector must participate in its endeavor to achieve a reduction of 45% of total emissions by 2030, with the ultimate end goal of zero emissions in 2050 [(4)].

Currently, very few studies have been done to analyze and mitigate these emissions and their effects, particularly in low- and middle-income countries. Healthcare workers may also not be well versed on the effect of their services on the environment. This study sought to address that gap by calculating the carbon footprint of Kericho County Referral Hospital (KCRH), Kericho, Kenya. Findings from this study may be generalizable to the Kenyan public health sector of a similar setting.

MATERIALS & METHODS

Analyzing the carbon footprint of a healthcare setting requires the development of a very specific methodology and categories of emissions. For example, unique to the healthcare setting is the use of anesthetic gases such as nitrous oxide which is one of the seven greenhouse gases and pressurized meter dose inhalers which contain hydro propellants. The Aga Khan Health Services (AKHS) and The Aga Khan University (AKU) developed a tool tailored to the needs of Lower Middle-Income Countries (LMIC) and Low-Income Countries (LIC). It employs a hybrid approach, combining both the top-down and bottom-up life cycle assessment (LCA). This is an important tool that can be used to analyze the carbon footprint of the Kenyan health sector as a whole.

This study was done at Kericho County Referral Hospital, in Kericho Town, Kericho County, Kenya. A retrospective analytical study design was used to analyze the carbon footprint of the hospital in one year from 1st July 2023 to 30th June 2024. Quantitative data for the various scopes of emissions was collected from various departments in the hospital and input into the data collection tool, the Aga Khan Development Network (AKDN) Carbon Management Tool – version 1.6.3 created on 1st April 2024. The tool, an Excel-based calculator, gave guidance on entry of data to account for all the scopes and converted the primary data into carbon dioxide equivalents. Additionally, it generated

graphics of total carbon footprints and the individual components.

In order to have a true picture of the carbon footprint of the facility as a whole, available data was entered into the AKDN tool. Modifications were made to the tool to omit entries with inadequate or inaccurate data records at the facility. These included data on business travel, hotel stay, contractor logistics, construction materials and procurement. Data required for the inputs was collected from the records in the finance, biomedical, transport, public health and pharmacy departments. The data collected was on the amount of electricity used, anesthetic gases, inhalers dispensed, waste collected, water utilized, fuel used on generators, the incinerator, the kitchen and vehicles, and the refrigerant gases used.

Permission to access the data from the relevant departments was sought from the Medical Superintendent of the hospital. No personal details of patients in form of names, hospital numbers or other personal data were collected during the study.

RESULTS

Total Carbon Emissions

The total carbon emissions at Kericho County Referral Hospital (KCRH) between July 2023 and June 2024 was 318,155.37 $kgCO_2e$.

Carbon Hotspots

As shown in Figure 1 below, the highest carbon hotspot identified by the AKDN Carbon Management Tool is consumption of grid electricity (166,414.29 $kgCO_2e$). The medium carbon hotspots were waste incineration (73,458.20 $kgCO_2e$), vehicle fuel (38,457.17 $kgCO_2e$) and liquid fuel use (21,051.32 $kgCO_2e$). The low carbon hotspots, all with emissions less than 10,000 $kgCO_2e$, were solid fuel (6,583.99 $kgCO_2e$), anesthetic gases (5,837.68 $kgCO_2e$), inhalers dispensed (4,578.09 $kgCO_2e$), and refrigerants used (1,774.62 $kgCO_2e$).

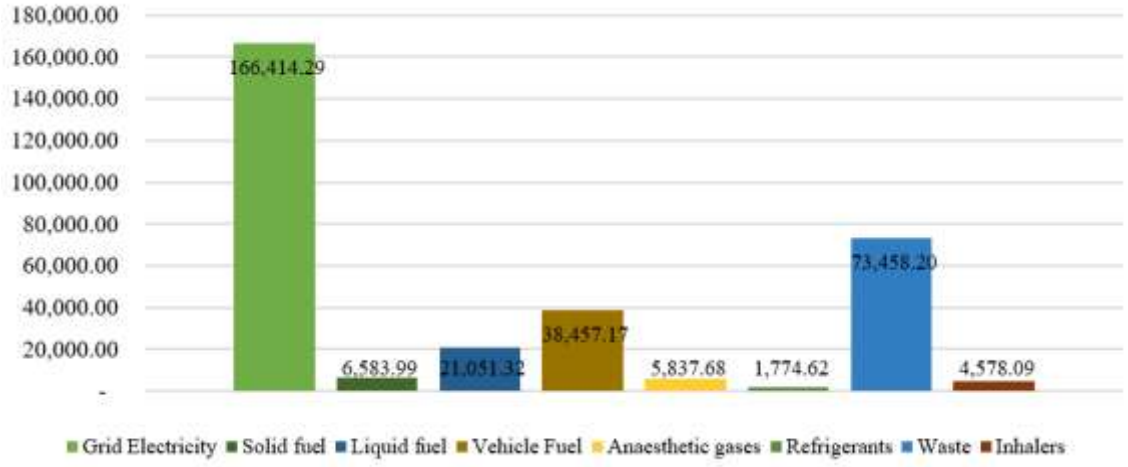

Figure 1: Sources of carbon emissions at Kericho County Referral Hospital.

The electricity consumed during the reporting period was 606,780 Kilowatt hours (KWh), emitting 166,414.29 $kgCO_2e$, which was the hospital's largest source of emissions. A total of 58,488,000 liters of water were used at KCRH during the reporting period. The total emissions from incineration of the waste produced at the hospital, which equaled 81,108 kilograms, was 73,458 $kgCO_2e$. Glass waste and sharps were processed using the Sterilwave 250® which sterilizes and converts the waste into dry inert waste using microwave technology. There were no records on the quantity of the dry inert waste which was later disposed in the landfill and the pathologic waste generated at the hospital which was buried in a pit. The hospital had eight vehicles, all light duty trucks. Four of the vehicles were ambulances while the other four vehicles were used for community health outreaches and other

hospital related activities. All the eight vehicles had diesel powered engines. The total amount of fuel used by the vehicles during the reporting period was 14,461 litres emitting a total of 38,457.17 $kgCO_2e$.

The liquid fuel used in the generators and the incinerator produced 21,051.32 $kgCO_2e$ of emissions. Diesel fuel was used to run the two generators and at the incinerator, with 7,000 litres used to power the generators and 640 litres used as ignition fuel at the incinerator, during the reporting period. A total of 150,000 kilograms of solid fuel – firewood, was used for cooking at the facility. It generated 6,583.99 $kgCO_2e$.Volatile emissions from the use of anesthetic gases totaled 5,837.68 $kgCO_2e$. Isoflurane and halothane were the only anesthetic gases used during the reporting period. 10 bottles of Halothane and 30 bottles of Isoflurane each containing 250 millilitres of solution were used. A total of 556 pressurized metered dose inhalers (PMDI) were dispensed at KCRH during the reporting period. Symbicort, a budesonide-based inhaler, and salbutamol-based inhalers were dispensed. The former, uses hydrofluoroalkane 227a (HFA) as the propellant, whereas the latter uses HFA134a as the propellant. These contributed to 4578.09 $kgCO_2e$ of the greenhouse gases emitted. Refrigerants used at the facility had the least emissions, 1,774.62 $kgCO_2e$. There were 15 medium stationary air conditioning units, six small hermetic stand-alone refrigeration units and 14 domestic refrigeration units present at the hospital. The most frequently used refrigerant gas at KCRH was R410a, used in 15 cooling units. R134a, used in 13 cooling units was the second most commonly used refrigerant gas. R600a was used in six units and the least used refrigerant gas was R507a, used in a single unit.

Scope One, Two and Three Emissions

Scope one emissions analyzed included building energy, travel, refrigerants, waste, and anesthetic gases. Grid electricity consumed, was the only source of scope two emissions. Scope three emissions analyzed were from the total inhalers dispensed at the hospital (Figure 2).

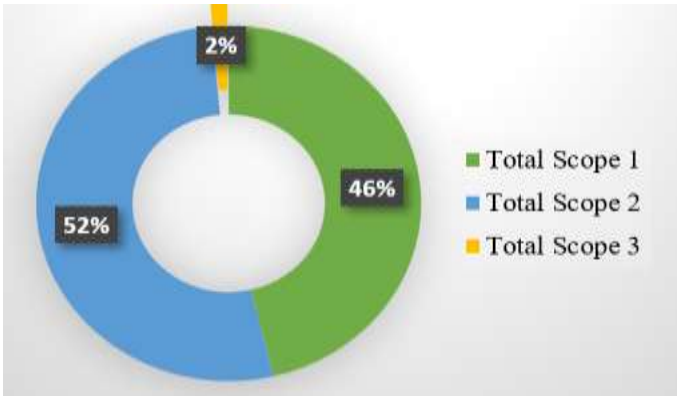

Figure 2: Total Emissions from Scope One, Two and Three Categories.

The emission areas that fall under scope two, were the largest source of GHG emissions contributing to 52%. Scope one emission sources contributed to 46% whereas scope three emission sources contributed to only 2%.

DISCUSSION

This study analyzed the total carbon emissions of Kericho County Referral Hospital (KCRH) from 1st July 2023 to 30th June 2024, which was determined to be 318,155.37 $kgCO_2e$. This is equivalent to carbon emissions from a small car driven for 2,259,650 kilometers or circumnavigating the earth 56 times. These emissions would also be produced by burning 109,522 kilograms of coal. To absorb all these emissions, the hospital

would need to plant 5,303 trees annually for the next ten years.

Carbon Hotspots at Kericho County Referral Hospital

Grid Electricity

The consumption of grid electricity was the largest hotspot at Kericho County Referral Hospital. Similar findings were noted in a multi-specialist hospital in Ghana where 57% of the total emissions were from electricity consumption [5].

Electricity is intrinsic to the practice of modern medicine. Not only do the equipment utilized in medical procedures use electricity, they are also majorly energy intensive. Examples of energy intensive equipment utilized in medical diagnostic modalities are the radiographic imaging machines such as Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Ultrasound, and Plain Radiography. All the aforementioned imaging modalities were utilized at the facility, save for the MRI machine. A study carried out in Switzerland revealed that when about 7000 patients had CT scan images taken in one year, the energy consumed was comparable to that utilized by five households of four occupants each, over a one-year period [6].

The mechanism by which consumed electrical power from the grid is responsible for greenhouse gas emission is multi-faceted. It entails the total amount of greenhouse gases that are produced from the generation, storage, transmission, and distribution of grid power. In Kenya, according to the Energy and Petroleum Regulatory Authority (EPRA), the bulk of electrical energy produced is sourced from geothermal and hydro-electric power plants, at 41.7% and 24.7%, respectively. Wind and solar power, which are the other so-called 'green energy sources', account for 13.1%, and 3.5%. Thermal (primarily heavy fuel oil sources) account for 8.2% of the total power disseminated to the Kenyan grid while the remaining 8.8% is imported [6, 7]. It may be argued that the prominent sources of grid power in Kenya are 'green', renewable sources. However, an example in literature that may refute this claim is that of hydro-electric power reservoirs (dams), that release greenhouse gases, mostly methane, of up to 24 gCO_2eq/kWh – this is the grams of carbon dioxide equivalent per kilowatt-hour of electricity generated allocated over its life-cycle [8].

Energy-saving techniques ought to be used at Kericho County Referral Hospital in order to lower these emissions. It is important to take simple precautions like turning off lights and electronics while not in use. Moreover, energy can be saved by using lighting products that use less electricity such as light emitting diode bulbs. When purchasing medical equipment, priority should be given to energy-efficient equipment.

Waste

The facility generates all types of healthcare waste with the exception of radioactive waste as the hospital does not provide any services that requires the use of radionuclides.

In the post COVID-19 pandemic era, there has been an increase in the use of personal protection equipment (PPE) by healthcare workers to prevent the transmission of the SARS-CoV-2 virus. These include masks, gloves, surgical caps, gowns, eye googles, shoe covers and face shields – most of which (if not all), are single-use. This contributes to the increased quantity of waste produced not only at KCRH, but by the global healthcare sector. In addition to the use of PPE, the pandemic caused an increase in the demand and utilization of single-use medical products during provision of healthcare [9]. These products, despite reducing the chances of cross-contamination and saving on the energy and water that would have otherwise been used to sterilize and autoclave the re-usable products, increase to the constantly growing quantity of healthcare waste which proportionately increases the total emissions produced during the disposal of the waste.

At KCRH, most waste is disposed by incineration using a controlled-air incinerator. Diesel is used as the ignition fluid and electricity used to initiate the combustion process. With reference to the Aga Khan Development Network (AKDN) Carbon Management Tool, 0.90 $kgCO_2e$ are released into the atmosphere for every kilogram of waste incinerated. In addition to the GHGs emitted, particulate matter, acid gases, dioxins and furans are also released during combustion, further contributing to environmental pollution [10].

After primary waste management at KCRH by either using microwave technology or incineration, the residues are buried in a landfill. This process emits up to 1.02 $kgCO_2e$ per kilogram of waste with reference to the data collection tool. Pathologic waste such as placenta and amputated limbs were also deposited underground in placenta pits. Aerobic decomposition initially occurs but as the oxygen concentration decreases, anaerobic decomposition ensues, thereby generating methane gas, which is a more potent global warming gas [11]. Other environmental concerns are pollution of underground water sources by leached substances, decreased quality of air by malodour and suspension particles, and by ecosystem degradation [11].

To reduce these emissions, KCRH needs to apply other waste management strategies – reuse, reduce and recycle whenever possible. Waste disposal methods that have a lower carbon footprint per tonne of waste such as recycling (21 – 65 $kgCO_2e$), and low temperature incineration with energy generation from the waste (172 – 249 $kgCO_2e$), should be employed [12].

Vehicle Fuel

Transportation services serve as a key sector in healthcare delivery. They facilitate movement of goods within the supply chain, patient referral, community health outreaches and commuting by healthcare workers.

The vehicles owned by KCRH run on diesel-powered engines. During internal combustion, these engines produce carbon dioxide, nitrogen oxides, carbon monoxide and black carbon particulate matter, which has a high global warming potential. The particulate matter can have serious health effects as they can result in exacerbation of asthma, or may cause cardiopulmonary diseases and/or cancer. The toxicity of black carbon is enhanced by its small size (less than 2.5 microns), making it easier to inhale into the deepest parts of the lower respiratory tract [13].

To decarbonize the healthcare transport sector and reduce emissions from hospital vehicles, there is need to explore alternatives to fossil fuel powered vehicles. The use of electric vehicles, which are battery powered are a greener alternative since they have relatively lower carbon emissions ([12]).

Liquid Fuel

In Africa, hydroelectric power is the largest source of electricity providing approximately 40% of the total renewable energy in Sub-Saharan Africa [14]. However, a review done in 2018 by Shu *et al*., reveals that with the increasing global temperatures, the reliability of this energy source is constantly under threat [15]. The increased rate of evaporation of water from the reservoirs and changes in rainfall patterns and quantity leads to a decreased amount of water available for hydropower generation. Subsequently, most of these countries then face inconsistent grid supply of electricity.

By 2013, an average of only 34% of 13 hospitals surveyed in sub-Saharan Africa had a reliable supply of electricity [16]. The intermittent supply of electricity severely disrupts service delivery since constant energy supply is essential for healthcare services provision. This causes hospitals to resort to fossil-fuel powered generators which are more expensive to run and cause more environmental pollution. The burning of one litre of diesel fuel emits 2.7 $kgCO_2e$. During the reporting period, the generators at KCRH, which provided backup electricity

during power outages, released 19,288 kg CO_2e.

Solid Fuel

Solid fuel in form of wood logs was used for cooking at KCRH. They are generally cheaper than liquid petroleum gas, hence would be the most preferred option in such an institution. Some sources cite the use of firewood as carbon neutral – with no emissions of carbon into the environment [17]. However, burning of wood fuel is responsible for emissions of carbon dioxide, methane and black carbon. The latter is a very potent light-adsorbing component of particulate matter and has a global warming potential that is 900 times more than carbon dioxide [17]. When compared to other sources of cooking fuel such as liquid petroleum gas, wood fuel generally has less emissions of carbon dioxide equivalents, which collectively supports the relatively low amounts of CO_2e emitted at KCRH, despite the high quantities of firewood used.

Anesthetic Gases

At Kericho County Referral Hospital, halothane and isoflurane were the only anesthetic gases used during the reporting period. After inhalation, a small percentage of these agents are metabolized by the body (0.2% of isoflurane and approximately 20% for halothane) and the rest are exhaled into the atmosphere [18].

Isoflurane, a fluorinated hydrocarbon, releases 508.98 $kgCO_2e$ per for every litre used whereas halothane, a bromide-based agent, emits 40 $kgCO_2e$ per litre. Atmospheric observations done in Antarctica in 2012/2013 found concentrations of 8.5 parts per quadrillions of halothane per dry air mole fraction. The same study found 0.12 parts per trillion of isoflurane per dry air mole fraction in Jungfraujoch, Switzerland, in 2014 [19]. These compounds not only cause global warming, but also play a role in ozone layer destruction due to the chloride and bromine compounds in their composition. Caution therefore needs to be taken to avoid further accumulation of these gases in the atmosphere. The greater use of intravenous anesthetics, whenever clinically possible, would lead to reduced consumption of these agents and less impact on the environment.

Inhalers

The pressurized metered-dose inhalers contain propellants which help to maintain the pressure required to create an aerosol. They also sustain the pressure in the can long enough to allow the patient to utilize the contents of the can to its maximum.

After the phase-down of chlorofluorocarbons (CFC), hydrofluoroalkane (HFA) 134a (Norflurane) and 227a (Apaflurane) are currently in use as inhaler propellants. These propellants, despite having no ozone-depleting capacity, have global warming potential (GWP). When compared to carbon dioxide, HFA 134a and 227a have GWPs that are 1,430 and 3,220 times greater than carbon dioxide, respectively, per metric tonne of emission [20]. New research is currently underway to determine the efficiency of hydrofluoroolefin (HFO) 1234ze, which has a GWP less than carbon dioxide, with no ozone-depleting properties as a substitute propellant [21].

It is however important to note that the propellants are not the only source of emissions from an inhaler. The materials used to assemble the inhaler cannister also play a role in carbon emissions. According to the AKDN data collection tool, when a patient fully uses one pressurized metred dose inhaler, the emissions are equal to that from a small car driven around for 290 kilometres. As more environmentally friendly propellants are being developed, physicians must review how the inhalers are prescribed and dispensed. Patient education on how to use inhalers effectively also needs to be done in order to ensure maximum utilization of the inhaler contents while preventing further harm to the environment.

Refrigerant Gases

Refrigerant gases absorb and transfer heat into a cycle which then causes cooling in air conditioners and refrigerators. In hospitals, these low temperatures are vital in storage of vaccines, biologic samples, some medicines and blood. Air conditioners, are essential in maintaining the indoor air quality and keep the buildings well aerated.

In the year 2015, approximately three billion refrigeration, air conditioning and heat pump units were being used globally [(22)]. With the current unpredictability in global temperature, there is more demand for these units whose functioning depends on the refrigerant gases. It is crucial to highlight that in addition to the GHGs emitted secondary to leakage of the refrigerants by these equipment – which can occur during normal functioning of the equipment or during repair and assembly, energy related emissions also occur [(23)].

At KCRH, the total emissions related to refrigerants used were 1,774.6 $kgCO_2e$. The refrigerants utilized were R410a, R600a, R507a and R134a. These refrigerants contribute to global warming since they have global warming potential but no ozone depleting properties.

Water

According to Gonzalez *et al*., the consumption of water ranges from 109 – 552 cubic metres per bed in Spanish hospitals [(24)]. Italian hospitals consumed an average of 481 cubic metres of water per day in 2016 [(25)]. This water is mainly used in the kitchen for cooking, sanitation, cooling and heating, laundry, in restrooms and in various equipment such as dialysis machines.

At KCRH, 58,488,000 litres of water were used during the reporting period. The AKDN Carbon Management Tool, classifies water consumption as non-carbon intensive and thus has no carbon conversion factor. Studies analyzing the carbon impact of water use, offer a different point of view suggesting that water use is actually a major source of GHG emissions [(26)]. This is because, during its life cycle as it is being used by humans, energy is required during its acquisition, cleaning, distribution, consumption, and sewerage collection and treatment. These emissions vary based on various factors such as the source of the water and the distance to its consumers.

Surface water, which is the source of water used at KCRH, has emissions of 0.07 $kgCO_2e$ for every cubic metre of water used [(27)].

Since water is a scarce resource, whose supply is also affected by climate change, more effort should be put in place to conserve it, and as a result reduce carbon emissions generated by water use. This includes managing the amount of water used. Other avenues such as collection and storage of rain water should also be explored.

Scope One, Two and Three Emissions

Albeit having some omissions, all the three scopes of emissions were evaluated in this study. From the analysis, Scope Two emissions from the grid electricity consumed were the highest source of emissions. A study done in Ghana had similar findings with electricity consumption contributing to more than half (57%) of the total emissions [(5)]. A systematic review conducted by Rodriguez-Jimenes *et al*. (2023), concluded that Scope Three emissions, encompassing all other indirect emissions not included in Scope One and Two, frequently account for the majority of a healthcare facility's carbon footprint [(1)]. In the review, Scope Three was the largest contributor of emissions, ranging from 50% to 75%. These findings differ significantly from this study, which had a total of only 2% from Scope Three emissions were primarily from the inhalers prescribed at the facility. This was due to lack of data on procurement of disposables, equipment and pharmaceuticals, as well as contractor logistics, all of which contribute to Scope Three emissions. The inclusion of these emissions in the analysis could have

modified the overall percentage of Scope Three emissions.

Kenya's healthcare carbon footprint, as reported by Lenzen *et al*. (2020), shows that Scope One emissions make up 44% of the country's overall emissions, while Scope Two and Three emissions account for 56% of all healthcare-related emissions [(28)]. However, this study does not provide further details on these emissions. In 2020, a similar analysis was conducted at two of AKDN's Kenyan healthcare facilities in Mombasa and Kisumu. The conclusions of that study indicated that the supply chain was the primary source of the high emissions from Scope Three. In Mombasa, they accounted for 94% of the emissions and 96% in Kisumu. The inhalers prescribed and dispensed contributed to 0.3% of the GHGs emitted from both facilities [(29)].

CONCLUSION

The consequences of climate change are already upon us. Every industry must acknowledge its role in contributing to climate change and take responsibility.

Kericho County Referral Hospital contributed to climate change through the greenhouse gases emitted during service delivery. A total of 318,155.37 $kgCO_2e$ were emitted during the reporting period; between 1st July, 2023 and 30th June, 2024.

The high carbon hotspot noted was consumption of grid electricity. The medium hotspots were the waste produced, vehicle and liquid fuel. Solid fuel, anesthetic gases, inhalers dispensed and refrigerant gases used were the low carbon hotspots at the facility.

The insights gained from this research underscore the need for healthcare facilities to adopt comprehensive sustainability strategies that address their levels of greenhouse gasses emissions. Policy frameworks should incentivize the adoption of energy-efficient technologies, and support transition to renewable energy.

Declaration by Authors

Ethical Approval: Approved.

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Conflict of Interest: The authors declare no conflict of interest.

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