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ASSESSMENT OF THE GREENHOUSE GAS EMISSIONS PATTERNS OF HOTELS IN ABUJA, NIGERIA

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ABSTRACT
A study on the assessment of the greenhouse gas emissions patterns of sellected hotels in Abuja, Nigeria was carried out. Two hotels were considered and categorized as Cases1 and Case 2 respectively. Four major emission sources: electricity; transportation; solid waste and cooking fuels were considered. Data on the sources were obtained using records from relevant departments, questionnaires, surveys, and interviews. This data was analyzed and used for calculating the GHG emissions of the hotels using IPCC standard guidelines and formulae. The annual GHG emissions of the Case 1 was found to be 479.98 tCO2e, electricity usage (from grid and generators) represents 71.90% of the total emissions, emission from solid waste represents 18.23%, emissions from transportation and burning of fuels for cooking ranked third with 7.40% and fourth with 2.50% respectively. Also, the annual GHG emission of the Case 2 was found to be 384.40 tCO2e, electricity usage (from grid and generators) represents 71.73% of the total emissions, emission from solid waste represents 17.64%, emissions from transportation and burning of fuels for cooking ranked third with 7.76% and fourth with 2.87% of the total emission of the hotel respectively. The findings in both scenarios lead to consistent trends, with small deviations only, indicating that the scale of operation has negligible effect on proportions of emissions. Such stability highlights the merit of putting emphasis on energy management particularly the transition from fossil-fuel generators to clean alternatives as a front-line strategy in emissions reduction.. The results obtained could be used as a baseline for observing and controlling these emissions.

1.0 INTRODUCTION
Climate change is one of the most important issues the world is presently confronting. Human actions have played an important role in the increase of greenhouse gas emissions over the past decades, which has resulted in global warming (Luansak, 2015). There has been scientific evidence to prove that the global GHG emission is still on the rise which also contributes to the increasing global temperatures. The main source of this rise in temperature is linked to rising fossil-fuel use and other human activities (Malla, 2009). The tourism industry alone accounts for about 5% of these emissions (UNWTO, 2009). In fact, carbon dioxide emissions from global tourism are likely to grow by 130% by 2035. The effects of climate change are being felt across tourist destinations worldwide, reaching not only the environment, but also the tourism industry and the individuals who rely on it. As one of the largest economic sectors in the world, tourism is a major driver of national and local economies (Luansak, 2015).
Within the tourism industry, the hotel sector stands out as one of its most significant branches. Hotels contribute to greenhouse gas emissions mainly carbon dioxide through their daily use of large amounts of energy, water, and non-renewable resources to maintain their operations (Luansak, 2015).

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Nearly all human activities contribute to greenhouse gas (GHG) emissions, either directly or indirectly. Routine energy use such as lighting, heating, and transportation is primarily fueled by fossil sources, which release considerable quantities of carbon dioxide (CO_2) and other greenhouse gases into the atmosphere (IPCC, 2023; IEA, 2022). Furthermore, the end-of-life disposal of products is another significant source of emissions (UNEP, 2022). Intergovernmental Panel on Climate Change (IPCC) reported that there are 18 greenhouse gases with different global warming capabilities. But under the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol, only Carbon dioxide (CO_2), Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF6) are considered for the purposes of carbon accounting, with others being regulated elsewhere (Ologun et al 2014).

These cumulative emissions accelerate global warming and contribute to the ongoing climate crisis. According to recent data, global surface temperatures have increased by approximately 1.1°C since the pre-industrial era, prompting urgent calls for action to limit further warming (IPCC, 2023). The resulting imbalances in natural systems are becoming increasingly evident through the growing frequency and severity of extreme weather events such as floods, droughts, and heat waves (WMO, 2023).

Monitoring and measuring carbon footprints is essential for identifying the extent of individual and institutional contributions to GHG emissions, as well as for promoting more sustainable energy practices (Carbon Trust, 2022). Effectively addressing climate change requires integrated approaches that encompass both mitigation and adaptation strategies, supported by coherent policy frameworks and institutional cooperation (UNFCCC, 2023). IEA (2015) data on showed that total carbon dioxide emissions from the consumption of fuel is 64.6million tons(mt) and per capita carbon dioxide emissions from consumption of energy is 0.38mt.

1.1 Intergovernmental Panel on Climate Change (IPCC) Guideline for GHG Emissions Inventory

According to established emissions assessment protocols, greenhouse gas (GHG) emissions can be quantified solely in terms of carbon dioxide (CO_2), with all other GHGs converted into CO_2 equivalents (CO_2e) to enable standardized reporting. Furthermore, emissions inventories are systematically organized based on the origin of emissions, with sources classified according to defined organizational or operational boundaries within which the emissions are generated (IPCC, 2006).

1.1.1 Organizational Boundaries

This refers to all operational activities that take place within the clearly defined physical boundaries of the organization under evaluation. These boundaries typically include facilities, buildings, and sites that are owned, operated, or directly controlled by the organization. Emissions and resource usage occurring within these physical premises are considered part of the organization's direct environmental impact and are accounted for accordingly in emissions assessments or sustainability reporting frameworks (Intergovernmental Panel on Climate Change (IPCC, 2006)

1.1.2 Operational Boundaries

Operational boundaries refer to the process of identifying emissions linked to an organization's activities and classifying them into direct and indirect sources. According to the Intergovernmental Panel on Climate Change (IPCC, 2007:13), these boundaries are defined as 'scopes,' and they fall into three main categories:

Scope 1 (Direct GHG Emissions): These are emissions that come directly from sources owned or controlled by the organization or household. They occur within the physical premises and include activities like generating electricity, heat, or steam; operating vehicles; incinerating waste; and emissions from unintentional leaks (also known as fugitive emissions).

Scope 2 (Indirect GHG Emissions): These emissions are generated outside the organization's direct boundaries but are a result of its energy consumption. For example, emissions from purchased electricity, steam, or heat fall into this category, as they are indirectly caused by the organization's operations.

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Scope 3 (Other Indirect GHG Emissions): These include all other indirect emissions that the organization does not directly control, such as those from its supply chain or external service providers.
However, to simplify data collection and processing, many organizations focus primarily on Scopes 1 and 2 to simplify data collection and reporting.
This paper presents an assessment of greenhouse gas emissions of selected hotels in Abuja, Nigeria, contributing to the broader understanding of emissions within the tourism and hospitality sector.

2.0 MATERIALS AND METHODS

Analytical questionnaires of various types, observation and structured interviews were used to collect the data needed for the study.

2.1 Data Analysis in GHG Emissions Assessment

Formulae and steps as provided and outlined by IPCC (2006) as guidelines for assessment of greenhouse gas emissions were employed as follows:

2.1.1 Data Analysis for Electricity Use

Data from electricity used was analyzed using the following steps:

Purchased Electricity

For purchased (grid) electricity, consumption data and electricity emission factor were used to determine the amount of greenhouse gas emission from this category by employing equation 1:

$$E_{grid}\,(kgCO_2e) = AME \times EEF \times n \quad (1)$$

AME = Average monthly grid electricity consumption (kWh), Electricity Emission Factor (EEF) = 0.4157342 $kgCO_2e/kWh$, n = Number of months being evaluated

Power Generators

Data for fuel consumption of power generators and the emission factors for stationary combustion engines were used to calculate the amount of GHG emitted due to power (IPCC, 2006). For ease of analysis, this section is divided into two categories. The first being generators that use diesel as fuel and then petrol powered generators.
Equation 2 was used to determine the amount of CO_2e emitted due to power generation in the households.

$$E_g\,(kgCO_2e) = AMF \times FEF_{(d/p)} \text{ x } n \quad (2)$$

Where,
AMF = Average Monthly Fuel Consumption (litres), FEF = Fuel Emission Factor, n = Number of months being evaluated

Emissions from Petrol Generators

Emission from petrol generator was evaluated using equation 3.

$$E_{pg} = \text{AMF of all petrol generators} \times FEF_P \times n \quad (3)$$

Emissions from Diesel Generators

Emission from diesel generator was evaluated using equation 4.

$$E_{dg} = \text{AMF of all diesel generators} \times FEF_d \times n \quad (4)$$

It was then summed up thus:

$$E_g = E_{dg} + E_{pg} \quad (5)$$

Where,
E_g = Total power generator emission, E_{dg} = Emission from diesel generators, E_{pg} = Emission from petrol generators.
Thus,

$$\text{Total Emissions from Electricity use} = E_{grid} + E_g \quad (6)$$

2.1.2 Data Analysis for Transportation

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The emission from transportation for each category of vehicle is determined thus:

$$Emission = NV \times ATD \times VEF \quad (7)$$

Where, NV = Number of Vehicle, ATD = Average Travel Distance, VEF = Vehicles Emission Factor

Federal High Way Administration's method of determining average annual traffic can be determined using equation 8 (FHWA, 2015).

Thus:

$$AAT = x\left(\frac{5}{m}\right)p + y\left(\frac{2}{n}\right)q \quad (8)$$

Where,

AAT = Average annual traffic

x = Number of vehicles sampled during the weekdays

m = Number of weekdays for which sample was taken

y = Number of vehicles sampled during weekends

n = Number of weekends for which sample was taken

p = Number of weekend on the Calendar

q = Number of weekdays on the calendar

2.1.3 Data Analysis for Cooking Fuel

This analysis is in three categories based on the type of fuel used, the fuels are LPG, kerosene and solid biomass (fuel wood).

Liquefied Petroleum Gas

Emissions from burning of LPG were calculated using the emission factor of LPG and the activity data i.e. the quantity of LPG using equation 9:

Emission from LPG = Quantity of LPG used × LPG EF (9)

Emission from Kerosene

Emissions from burning of kerosene were calculated using the emission factor of Kerosene and the quantity of kerosene burnt using equation 10.

Emission from Burning of Kerosene = Kerosene used (l) × Kerosene EF (10)

Emission from Burning of Fuel wood

The emission from burning of fuel wood was calculated using equation 11.

$$Emission\ from\ burning\ of\ fuelwood = MWB \times EF \quad (11)$$

Where, MWB = $Mass\ of\ Wood\ b(kg)$, EF = $Emission\ Factor$

Total emission from cooking fuels was calculated by employing equation 12.

$$E_{CF} = E_{FW} + E_{LPG} + E_K \quad (12)$$

Where, E_{FW} = Emission from fuel wood, E_{LPG} = Emission from liquefied petroleum gas, E_K = Emission from kerosene

2.1.4 Data Analysis for Solid Wastes

The emission from landfilling of Solid Waste was calculated using equation 13, 14 and 15 (IPCC, 2006).

$$E_{SW} = CH_4\ Emissions\ x\ GWP\ of\ CH_4 \quad (13)$$

Global Warming Potential (GWP) of CH_4 = 28 (IPCC, 2014)

$$CH_4\ Emissions = MSWX \times L_O \times (1 - frec) \times (1 - OX) \quad (14)$$

Where,

$CH_4\ Emissions$ = Total CH_4 emission (tons of methane)

MSWX = Mass of solid waste sent to landfill in inventory year (metric tons)

L_O = Methane generation potential (m^3/ton)

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frec = Fraction of methane recovered at the landfill (flared or energy recovery)
OX = Oxidation factor (0.1 for managed sites, 0 for unmanaged sites)
L_O = MCF × DOC × DOCF × F ×16/12
MCF = Methane correction factor which is based on type of landfill.

a. For managed landfills = 1.0
b. For unmanaged landfills which have depth of 5m or more = 0.8
c. For unmanaged landfills which have depths less than 5m = 0.4
d. For uncategorized landfills = 0.6

DOC = Degradable organic carbon, fraction (tons C/tons waste)
DOCF = Fraction of DOC that ultimately degrades (0.6). This shows that some organic carbon does not degrade, or degrades very slowly when deposited in SWDS.
F = Fraction of methane in landfill gas (0.5)
16/12 = Stoichiometric ratio between methane and carbon

$$DOC = (0.15 \times A) + (0.2 \times B) + (0.4 \times C) + (0.43 \times D) + (0.24 \times E) + (0.15 \times F) \quad (15)$$

A = Fraction of solid waste that is food
B = Fraction of solid waste that is garden waste and other plant debris ,
C = Fraction of solid waste that is paper
D = Fraction of solid waste that is wood
E = Fraction of solid waste that is textiles
F = Fraction of solid waste that is industrial waste

3.0 RESULTS AND DISCUSSION

3.1 Greenhouse Gas Emissions of Hotels in Abuja

Electricity consumption emerged as the most significant source of emissions in both case studies. In Case 1, electricity use accounted for 71.90% of the total emissions, translating to 345.10 tCO_2e annually as presented in Table 1 and Figure 1. Similarly, in Case 2, this category contributed 71.73%, equivalent to 275.74 tCO_2e as presented in Table 1 and Figure 2. These figures clearly demonstrate the pivotal role of energy usage in shaping the carbon footprint of hotels. A closer look reveals that on-site power generation within the hotel facilities was responsible for the majority of these emissions. In Case 1, internally generated power contributed 207.29 tCO_2e, representing 60.07% of the hotel's total emissions. Case 2 reported a slightly lower share, with 160.90 tCO_2e, or 58.36% of its total emissions. The remaining emissions were attributed to electricity sourced from the national grid, which accounted for 39.93% (137.81 tCO_2e) in Case 1 and 41.65% (114.84 tCO_2e) in Case 2.

Solid waste disposal was another notable emission category. In Case 1, emissions from solid waste amounted to 87.48 tCO_2e, which represented 18.23% of the hotel's total emissions as presented in Table 1 and Figure 1. Case 2 followed closely with 67.80 tCO_2e, accounting for 17.64% as presented in Table 1 and Figure 2. While these figures are considerably lower than those from electricity use, they nonetheless reflect a significant environmental impact, particularly when scaled across the industry.

Improper waste handling and the absence of recycling or composting programs can exacerbate emissions from this category. The findings point to a need for better waste management practices as part of hotel sustainability strategies.

Transportation-related activities, including employee commutes and guest transfers, contributed 7.40% and 7.76% to total emissions in Case 1 and Case 2, respectively. In absolute terms, this translated to 35.54 tCO_2e for Case 1 and 29.84 tCO_2e

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for Case 2. These emissions, while smaller in proportion, are still relevant, especially when considering larger hotel chains with high logistical demands.

Cooking activities within hotel kitchens also contributed to the overall emissions profile, though to a lesser extent. In Case 1, cooking fuels were responsible for 11.86 tCO_2e or 2.50% of total emissions as presented in Table 1 and Figure 1. In Case 2, this figure stood at 11.02 tCO_2e, representing 2.87% of the total as presented in Table 1 and Figure 2. These emissions stem from the use of liquefied petroleum gas (LPG), charcoal, or other fossil-based fuels commonly used in commercial kitchens.

Table 1: Summary of GHG Emission of the Hotels

S/No	**Source**	**Amount (tCO_2e) Case 1**	**Amount (tCO_2e) Case 2**
1	Cooking Fuels	11.86	11.02
2	Electricity	345.10	275.74
3	Transportation	35.54	29.84
4	Solid Waste	87.48	67.80
	Total	**479.98**	**384.40**

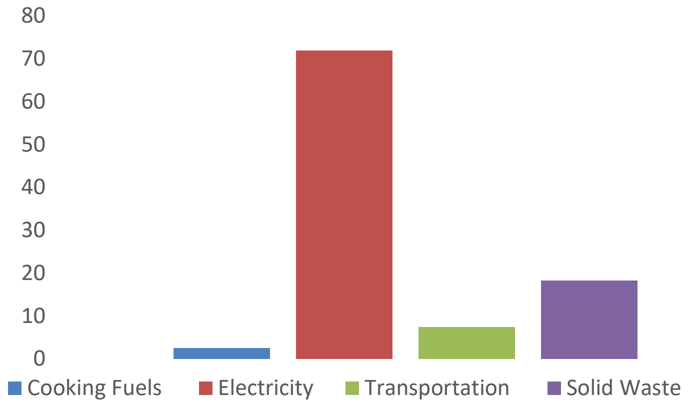

Figure 1: Distribution of GHG by Emission Source for Case 1

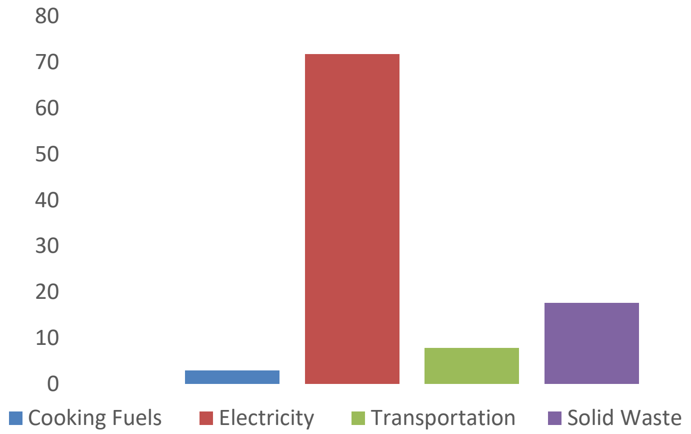

Figure 2: Distribution of GHG by Emission Source for Case 2

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3.2 GHG Emissions of the Hotels When Categorised by Scope

The emission of the households falls within two of the three Scopes outlined by IPCC: Scope 1 and Scope 2, Scope 3 is not included in this assessment because none of the sources considered fell into that category.

3.2.1 GHG Emissions from Scope 1

For Case 1, Scope 1 emissions comprising cooking fuels, power generators, and transportation amounted to 254.69 tCO_2e, which represents 53.06% of the hotel's total emissions (479.98 tCO_2e), as shown in Table 2. This means that more than half of the hotel's carbon footprint arises from activities entirely within its operational control. A breakdown of Scope 1 emissions reveals that: On-site power generation is the primary contributor, accounting for 81.39% of all direct emissions. Transportation emissions make up 13.94%., and Cooking fuels contribute 4.66%. As visualized in Figure 3, power generation overwhelmingly dominates the emissions profile. This highlights a critical area for intervention: the dependence on fossil-fuel-based generators significantly drives the hotel's carbon footprint. Given the high proportion of emissions from an internal source, the hotel has a strong opportunity to reduce its environmental impact through targeted energy reforms.

In Case 2, Scope 1 emissions totaled 201.76 tCO_2e, which represents 52.49% of the hotel's total emissions (384.40 tCO_2e), as detailed in Table 2. While the total emissions are lower than in Case 1, the relative contribution of Scope 1 emissions remains virtually the same underscoring the consistent role of in-house operations in shaping the hotel's carbon profile. The distribution of Scope 1 emissions in Case 2 shows that power generation again leads with 79.75%, transportation contributes 14.79% and cooking fuels make up 5.46%. Figure 5 illustrates a similar trend to that observed in Case 1: power generation is the primary driver of Scope 1 emissions. The slight increase in transportation and cooking fuel emissions may reflect differences in logistics, kitchen energy use, or operational practices.

3.2.2 GHG Emissions from Scope 2

In Case 1, the Scope 2 emissions which are those resulting from indirect sources such as purchased electricity and waste management amounted to 225.29 tCO_2e, accounting for 46.94% of the total greenhouse gas (GHG) emissions, as detailed in Table 2. This category is limited to two major contributors: electricity purchased from the national grid and emissions from solid waste disposal. Among these, purchased electricity is the dominant source, responsible for 61.17% of Scope 2 emissions, while solid waste contributes the remaining 38.83%, as illustrated in Figure 4.

Although these emissions occur outside the hotel's direct operational boundaries, they can still be influenced and mitigated by strategic management practices within the hotel. For instance, emissions from solid waste can be significantly reduced by implementing waste-to-energy initiatives and promoting recyclable and reusable materials. On the other hand, emissions from grid electricity can be minimized through energy-efficient practices, such as upgrading to LED lighting, investing in energy-saving appliances, or utilizing smart energy management systems.

Similarly, in Case 2, Scope 2 emissions totalled 182.64 tCO_2e, making up 47.51% of the hotel's overall emissions profile, as shown in Table 2. As with Case 1, these emissions originate solely from the use of purchased electricity and waste management. Here, electricity usage contributes 62.88%, while solid waste accounts for 37.12%, as shown in Figure 6.

Again, despite being outside the direct control of the hotel's physical premises, these emissions are not beyond the hotel's influence. By adopting sustainable waste disposal methods and improving the efficiency of electricity usage, the hotel can reduce its carbon footprint significantly. These actions represent a valuable opportunity for the hotel to take responsibility for its indirect emissions and align with broader environmental sustainability goals.

Table 2: Summary of GHG Emissions of the Hotels when Categorized by Scope

S/No	Source	Amount (tCO_2e) Case 1	Amount (tCO_2e) Case 2	Scope

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1	Cooking Fuels	11.86	11.02	Scope 1
2	Electricity Generated	207.29	160.90	Scope 1
3	Transportation	35.54	29.84	Scope 1
4	Solid Waste	87.48	67.80	Scope 2
5	Electricity from Grid	137.81	114.84	Scope 2

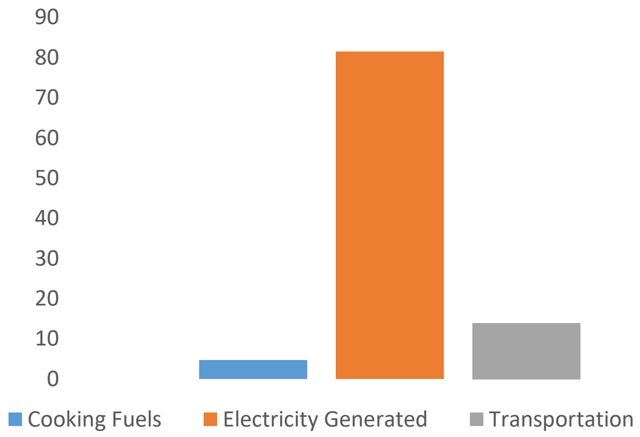

Figure 3: Distribution of GHG Emission of Case 1 from Scope 1

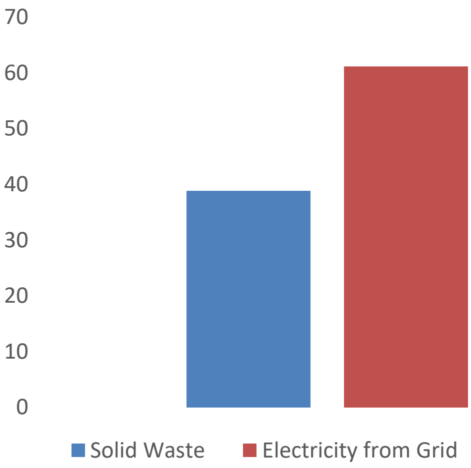

Figure 4: Distribution of GHG Emission of Case 1 from Scope 2

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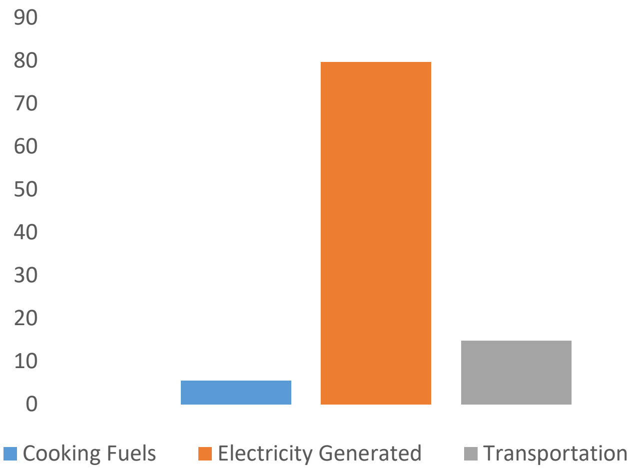

Figure 5: Distribution of GHG Emission of Case 2 from Scope 1

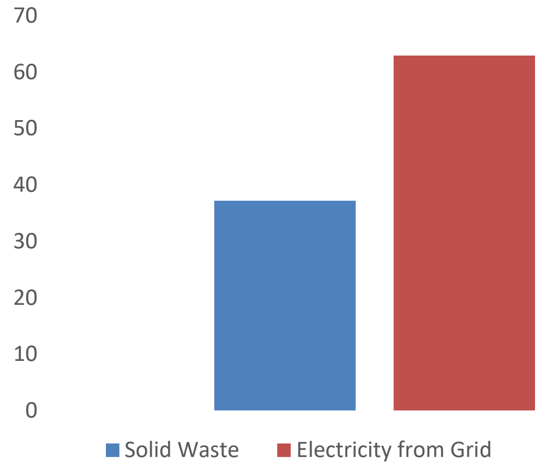

Figure 6: Distribution of GHG Emission of Case 2 from Scope 2

4.0 CONCLUSION

The assessment of the greenhouse gas emissions from the selected hotels in Abuja reveals that electricity consumption particularly from on-site generation plays the most substantial role in shaping the overall emissions profile. Solid waste disposal, transportation, and cooking fuel use also contribute to varying degrees, emphasizing the multifaceted nature of emissions sources within hotel operations.

When categorized by emission scopes, more than half of the emissions fall under Scope 1 those generated directly from the hotels' internal operations, particularly through power generation. This emphasizes the potential for impactful emission reductions through better energy practices. Scope 2 emissions, comprising electricity from the grid and waste disposal, form a substantial portion as well, further reinforcing the need for hotels to consider energy-efficient solutions and eco-friendly waste strategies.

The data across both cases suggest consistent patterns, with only minor variations, indicating that the scale of operation has limited effect on emission proportions. This consistency highlights the importance of focusing on energy management particularly the transition from fossil-fuel generators to cleaner alternatives as a key strategy for reducing emissions.

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Overall, the findings suggest that hotels have significant opportunities to reduce their carbon impact through improved energy sourcing, enhanced waste practices, and greater operational efficiency. Such efforts not only support environmental responsibility but also contribute to the long-term sustainability of the hospitality sector in Abuja.

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