ISSN (E): 2959-3921 Ethiopian International Journal of Engineering and Technology (EIJET)
(P): 2959-393X Volume 2, Issue 2, 2024
DOI: https://doi.org/10.59122/164CFC17

INTEGRATING SUSTAINABILITY FRAMEWORKS FOR ASSESSMENT OF ENVIRONMENTAL PERFORMANCE IN HIGHER EDUCATION INSTITUTIONS VIA ENERGY, FUEL, AND WASTE MANAGEMENT AUDITS

Tsegaye Getachew Alenka[1*], Mulugeta Tadese Wotango[2], Sileshi Kore Dube[3]

[1, 2]Wolaita Sodo University, Ethiopia

[3]State Owned Enterprises Standing Committee, FDRE, Addis Ababa, Ethiopia

**Corresponding Author's Email: tsegaye.getachew@ethernet.edu.et*

Abstract

There are over forty-five universities in Ethiopia, with an expected increase in the upcoming years which necessitates studies on their environmental impact. However, the environmental impact of these large institutions, particularly regarding resource consumptions such as electricity, diesel fuel, and water remains largely uninvestigated. This study employed the IPCC SCOPE 3 approach to assess the environmental impact of selected Ethiopian universities. This study collects primary data through surveys and observations and complements this with relevant secondary sources such as government records, organizational data, and existing literature. It utilizes IPCC SCOPE 3 guidelines to comprehensively analyze emissions and sustainability in Ethiopian higher education. The finding revealed substantial resource consumption, with notable electricity use accounting for the largest proportion of total emissions. The university's transition to electric cooking primarily powered by hydroelectric energy has effectively decreased emissions from traditional stoves across two of its four campuses, impacting 75% of residents. Electricity still represents 78% of the greenhouse gas emissions followed by waste generation which is 17.81%. This highlights the urgent need for sustainable policies to mitigate environmental impacts. The research identified economic constraints and underlined the need for policy support to enhance sustainability and environmental outcomes. Existing youth engagement programs in solid waste sorting, composting, recycling, and water treatment for reuse or recycling of clean water are in their initial development stages. The study suggests strengthening these practices while recognizing the potential to integrate renewable energy sources with appropriate policies, which could significantly impact institutional sustainability efforts.

Keywords: ***corporate impact, electricity use, emission, environmental impact audit, fuel economy, kilowatt hour, pollution***

Received: *August 2024;* ***Revised:*** *25 October 2024;* ***Accepted:*** *22 November 2024;* ***Published:*** *31 December 2024*

Corresponding author- ***Tsegaye Getachew***

ISSN (E): 2959-3921 *Ethiopian International Journal of Engineering and Technology (EIJET)*
(P): 2959-393X *Volume 2, Issue 2, 2024*
DOI: *https://doi.org/10.59122/164CFC17*

I. INTRODUCTION

Africa is one of the smallest contributors to global greenhouse gas emissions, accounting for only 4%. Climate change is a complex issue, and Ethiopia's technological advancements require ecological trade-offs [1]. Universities in Ethiopia play a crucial role in shaping sustainable operations. The impact of corporate activities is essential for sustainable development goals, addressing direct impacts like electricity use, solid waste management, and emissions contributions [2].

According to the Paris Climate Agreement, the sustainable development of an institution involves consideration of the triple Ps (People, Profit, and Planet) in its functional activities aimed at attaining its economic, social, and environmental goals [3]. The BPIE 2022 report highlighted process optimization, standardization, and data-driven decision-making for sustainable operations. It proposed optimization of electricity demand and supply, addressing climate performance issues, and identifying energy-intensive utilities [4-8].

According to studies' reports, energy use is given a high priority in a corporate environmental impact audit, and it is consequently a significant CO2 producer, second only to automobile emissions [9]. The King Saud University (KSA) has implemented a machine learning-assisted building management system (BMS) to optimize HVAC energy consumption in higher education institutions. The system saved 3% in just two months, suggesting the use of smart buildings technology and adaptive BMS for further HVAC system optimization [10-11]. The authors proposed five subsequent clustering steps in ascending energy demand orders for an accurate and relevant energy audit for university buildings based on functional and weighed energy performance categories. The clusters include arts, sciences, hospitals, data centers, and research centers. The electricity use (E) of equipment is established in kilo-watt-hours (kWh) [10].

There are many techniques for incorporating automobile emissions, depending on the availability of data, monitoring technology, and vehicle technology. The European driving cycle consists of urban and extra-urban categories with fuel consumption causing CO2 emissions. Researchers modified the rule-based control strategy, resulting in high energy content and power generation efficiency without pollution. Constraints introduced resulted in fuel saving and reduced stresses. Carbon Trust 2023 suggests global hydrogen-based integrated energy systems could reach "Net

Received: *August 2024;* ***Revised:*** *25 October 2024;* ***Accepted:*** *22 November 2024;* ***Published:*** *31 December 2024*
Corresponding author- ***Tsegaye Getachew***

ISSN (E): 2959-3921 Ethiopian International Journal of Engineering and Technology (EIJET)
(P): 2959-393X Volume 2, Issue 2, 2024
DOI: https://doi.org/10.59122/164CFC17

Zero by 2030", advising stakeholders to transition towards renewable energy generation [11-12]. Factors contributing to vehicle emissions include vehicle type, service status, fuel characteristics, driving conditions, and roads [13-14]. According to the research, fuel economy is inversely proportional to gasoline consumption, while the relationship is regarded as exponential. Fuel consumption is the amount of fuel consumed in a vehicle engine per trip distance, whereas fuel economy is the amount of fuel used per 100 kilometers. In typical contexts such as Africa and Europe, the measure of fuel economy in fixed vehicle distance with a certain amount of fuel, is represented in liters per hundred kilometers (equal to the US's 235.2 miles per gallon) [15].

Educational institutions generate a variety of solid waste, including paper, cardboard, plastics, wood, food waste, glasses, metals, and hazardous waste. Effective food waste management strategies include source reduction, repacking, methane production, energy recovery, and incineration. Socio-economic factors contribute to food waste generation, necessitating proactive initiatives for food security. Challenges include improper segregation, inadequate policies, limited public awareness, and disregard for by-products [16].

Ethiopian universities are focusing on optimizing energy use to achieve independence and sustainability. They are encouraging open discussions about energy-intensive features and implementing dedicated operators and load forecasting systems to improve electricity consumption control, reduce monthly expenses, and maximize power generation. As Ethiopia undergoes a digital transformation, it is important to gather fact-based baseline data for future environmental performance assessments. The impact assessment should cover various business activities like solid waste management and energy use, including common energy-intensive features such as outside lighting and scientific equipment. This study aims to evaluate energy usage trends in a public Ethiopian university using data from multiple buildings, vehicles, and offices. The goal is to enhance baseline data for the adoption of best practices and ensure long-term university operations.

II. METHODOLOGY

A. Introduction

The two outcomes.

Received: *August 2024;* ***Revised:*** *25 October 2024;* ***Accepted:*** *22 November 2024;* ***Published:*** *31 December 2024*
Corresponding author- ***Tsegaye Getachew***

According to Our World in data metrics, global territorial production annual emissions have increased dramatically, despite individual contributions have shown little reduction by 2021 compared to the previous year [8]. Another research reported an annual global per capita CO2 emission factor of 4.69 tonnes by 2021, compared to the global average of 4.69 tonnes. Emission Factors are calculated in appropriate units using emission factor data obtained from reputable sources such as Our World in Data, IRENA, UNFCC, and others [17-19].

Ethiopian higher education institutions have been classified over recent the five years as applied science, comprehensive, and research universities, with more than 45 public universities across the country [20]. Based on the idea from a study [10], the current research examines electricity consumption, fuel usage, and waste generation at four anonymous Ethiopian universities, employing primary and secondary data collection procedures and strategies to maintain institutional privacy and confidentiality. The data was gathered from a public Ethiopian higher education institutions [14, 17] and included vehicle possessions, machinery, buildings, offices, students, waste, and staff. It utilizes a method to estimate total CO2 emissions from diesel vehicles, which serves as the basis for fuel use estimation, emissions analysis, waste generation rate, and energy. The estimation idea matches the estimations considered in the studies [21-22].

The building's impact assessment involved surveys observed lighting and electrical appliances, and verified information by cross-checking and consulting with electricians and technicians. The waste generation data was collected from student dormitories and staff apartments with a focus on liquid and solid waste. The method of data collection employed was structured questions, interviews, and field observations. This study attempts to identify trends and implement sustainable operations for higher education institutions. The information came from the university's website, which listed campuses, colleges, school offices, and other vital resources in the institution with 45,000 employees.

A. Analysis Description

The convenient standard value-chain-based emissions estimation prioritized category identification that requires: (1) considering risks and opportunities within the value chain, (2) prospective direction for sustainable operation, and (3) stakeholder engagement. The selection of the Scope 3 emissions calculation method is recommended considering the following factors: data-relevant parameters such as availability & quality of data, analysis cost, and amount of emissions. IPCC Scope 3 offers various formulae under fifteen distinct categories for almost all kinds of CO2 emission analysis. Major corporate activities identified based on the

ISSN (E): 2959-3921 *Ethiopian International Journal of Engineering and Technology (EIJET)*
(P): 2959-393X *Volume 2, Issue 2, 2024*
DOI: https://doi.org/10.59122/164CFC17

standard include the institutions building information with function, electricity use, employers' commuting, business travel, product transportation, and waste generation [2,10-11,14].

The data relevant for encompassing the listed activities collected include: lists of the university-owned vehicles and corresponding weekly distances covered by each, number of employees, working hours and shifts, lists of electrical appliances and relevant usage, number of annual events hosted as well as invited along with average business distances, annual products and goods recruitment with transportation distance, waste generation and treatment trends, etc. [10, 15]. Fig. 1 summarizes the IPCC Scope 3 enterprise/corporate requirements that have been carefully tailored to Ethiopian universities.

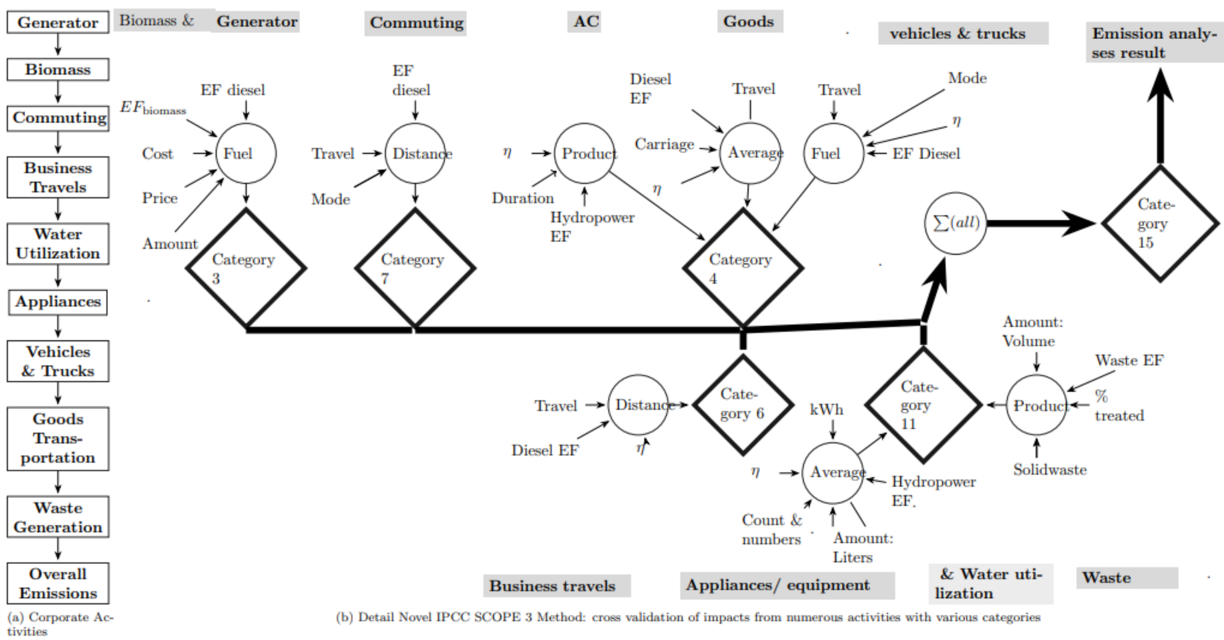

Fig.1. Corporate impact analysis based on IPCC SCOPE 3 Guidelines: (a) Typical corporate activities (b): Detail Scope 3 calculation method, Categories selected on relevance & attainability of dataset

The IPCC (Scope 3) accounting and reporting standard covers fuel-electricity and waste-related calculations, with categories 3, 4, 6, 7, 11, 13, and 15 included. The average-data method was chosen as illustrated in Fig. 1, and data was collected through a combination of processes/products. The SCOPE 3 methodology is based on relevant data presented in a visual chart and detailed in Appendix Table V. The circular shapes in Fig. 1 correspond to pertinent categories with leader

Received: *August 2024;* ***Revised:*** *25 October 2024;* ***Accepted:*** *22 November 2024;* ***Published:*** *31 December 2024*
Corresponding author- ***Tsegaye Getachew***

ISSN (E): 2959-3921
(P): 2959-393X
DOI: https://doi.org/10.59122/164CFC17
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

arrows annotating data label texts. Appendix Table V summarizes the Scope 3 methodology employed and the activities involved.

III. RESULTS AND DISCUSSION

A. Vehicles Travel and Fuel Consumption

The bus shift hours include morning employee's arrival, lunchtime travel to home & return, and evening departure for academic & admin staff where there are night shift office/class sessions. Vehicle travel information is summarized in Table I.

Table I: Weekly travel information and diesel fuel consumption of light duty (LD) & heavy duty (HD) vehicles and fuel expenditure of diesel generator

Items	Number	Standard	Amount	Unit
Generator (Stationary)	6	Fuel	5357	Liters
LD Automobile (Passenger)	12	Distance	370	km
LD Truck (pickups)	13	Distance	450	km
HD Truck (Bus & trucks)	14	Distance	214	km

When employees' entry outnumbers the vehicle seats, two rides in each travel along with early morning report & late evening departures of cafeteria transport services count four up to twelve runs counts. The turn for special purpose cars like ambulances depends on several emergencies and services that their average fuel bill converted into run counts to maintain consistency. The university's annual report for the academic year 2021/2022 reported a quarterly generator fuel cost of 6,000,000 birr and a monthly firewood expenditure of 1,000,000 birr. The local market price per an 18 m^3 freshly cut eucalyptus was 11,500 birr. The research found that the experimental mean dry compact mass of eucalyptus (20% moisture) was 0.41tone/ m^3. The amount of diesel oil purchased for emergency generators was 5,357 liters.

B. Electricity Consumption

The list of 36 electrical equipment items can be categorized into four functional themes based on their context. Recommendations for each theme should be aligned with the current operation, in contrast to generic approaches for classrooms, offices, laboratories, cafeterias, dorms, and residential areas. The equipment within each theme is ordered by their initial viability, from

***Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024*
*Corresponding author- **Tsegaye Getachew***

ISSN (E): 2959-3921
(P): 2959-393X
DOI: *https://doi.org/10.59122/164CFC17*
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

highest to lowest [4, 8, and 10]. The five-kWh classification of either generic clustering (arts, sciences, hospitals, data centers, and research centers) proposed or sophisticated grouping in five effective practical patterns (lighting, HVAC, electronics, laboratory, and appliances) can also be addressed but the latter methods can be effectively incorporated in the next phase of sustainable development of an institution after the baseline trend set in this study [1, 3-4, 7, 10, 24].

Two distinct patterns of electricity consumption were identified in addition to the established theme. The three major electric consumption themes are functional, usage, and categorical. The former captures administrative or facility management supervision structure while the last theme captures equipment types. Established studies grouped electric consumption in a categorical structure. However, the functional category provides a clearer view of practical resource management structure and utilities for potential integration with improvement schemes for similar higher education institutions. The marked distinction of the functional theme confirms carefully designed approaches during the assessment. The effective management tool can be installed thereafter.

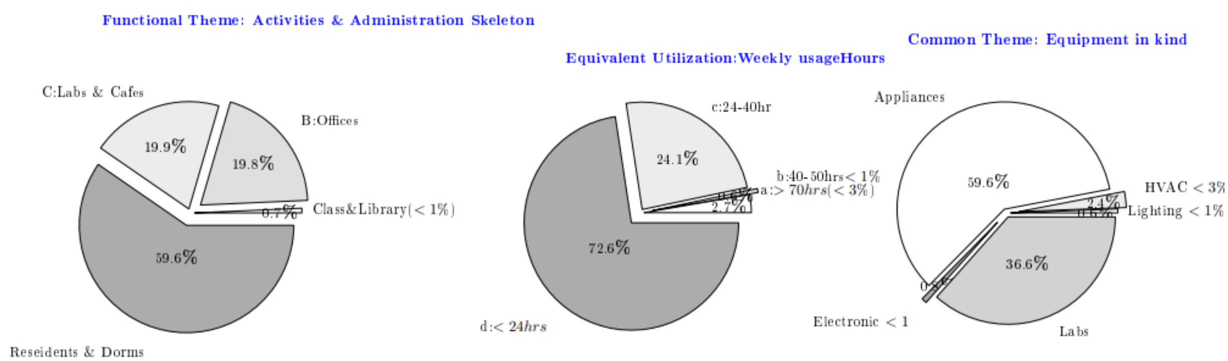

Fig. 2. Electric consumption themes identified electric (in % use from total kWh)

The university's electricity consumption can be divided into three themes: functional, usage, and categorical. Functional themes include teaching, offices, cafes/labs, and residential/dorms providing consistent supervision but challenging-to-match assessment tools. The usage theme groups equipment based on weekly usage, while the categorical theme captures the type of equipment. The functional theme seems the most effective, with well-organized energy monitoring systems. The university consumes twenty times more electricity than the national average with residential appliances and dorms accounting for 60% of total consumption. Heavy-duty machines

***Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024*
*Corresponding author- **Tsegaye Getachew***

account for over two-thirds of total energy use. All kitchen appliances combined do not use as much electricity as heavy-duty machines.

C. Waste Generation

Cafeteria wastes include kitchen waste, vegetable oils, firewood ashes, and food waste that consists of leftovers and expired recipes to be measured using mass balance. Table II summarizes major waste generations by source & management scenario by sections. The existing solid waste management involved the temporary site collection of plastics through the youth's association for recycling, transportation, open destiny site disposal, drying, & firing.

Table II: Weekly waste trend of the institution

Types Waste	Sources	Methodof Segregation	Truck Carrying Capacity	Total (Weight/Volume)
Solid Waste	528 Dorms	Plastic Recycli-Temp.Store. Dumping, drying, & burning	16.2 m^3or 30 ton	129.6
Residential	328 Staff family rooms	Plast. Recycling from Temp. Store. Dumping, drying, & Burning	16.2 m^3 or 30 ton	113.4
Cafeteria	3cafeteria,6loung es	Temp. Store. Dumping on farms	16.2 m^3 or 30 ton	113.4
Liquid wastes	fromall safety tanks	Temporary. Wastewater treatment & Recycling	10,000 liters	14,640,000

Note: 16.2 m^3 (about half the volume of a large U-Haul truck)

The university's solid waste collection from dormitories, residential compounds, and cafeterias showed a decrease in waste from over 600 rooms and 30,000 active students. The total solid waste from the university was 356.4 tons, slightly above the national average. The wastewater collected from these areas was transported to a wastewater treatment plant, resulting in 191 liters (about twice the volume of a mini fridge) per capita per day. The actual amount of treated waste is subject to the treatment plant's performance and future investigations [26-29].

D. Corporate Activities (Overall)

This study audited the university's weekly activities using the SCOPE 3 guidelines of WRI, WBC, and GHG Protocol. [2], and Carbon Trust. It evaluated corporate activities under fuel use &

***Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024*
*Corresponding author- **Tsegaye Getachew***

ISSN (E): 2959-3921
(P): 2959-393X
DOI: https://doi.org/10.59122/164CFC17
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

transport, energy use & kWh electric consumption, and waste management. The study found electricity kWh usage as the most significant corporate activity.

Table III: Sources of emission: university activities amount on a weekly base

Activities	Business Travels in km	Goods Transpiration in km	Generator Fuel Consumption (Liters)	University Vehicles Fuel Consumption (Liters)	Firewood Consumption (kg)	Electric Power Consumption (MWh)	Wastewater Generation (Liters)	Solid Waste (kg)
Amount	2351	50	6.207	5877.056	116.352	38470.17	51912	117

The university's operational and emissions accounts show a significant reduction in biomass fuel usage, with a minimum of 9 m^3 per week. This shift towards electric appliances has led to a significant reduction in biomass use for cooking. The university also has a low transportation of goods, with only 49.43 km a week of biomass fuel. Wastewater usage is minimal, mainly due to the university's functional treatment facility. The university covers 2,351 km (about half the width of the United States) per week for guests and employers, with a total weekly diesel fuel usage of 12,546 liters (about half the volume of a large U-Haul truck).

E. Corporate Emission Analysis Results (Overall)

The emission factors (EF) data relevant to the contexts were collected by consulting databases of credible journals and websites through convenient calculation of unit conversions. The review of the emission factor used is outlined in Table IV where the detailed calculation along with the source citations can be seen in Section 6 of Appendix in Table VII. Subsequent corporate analysis used emission factors summarized in Table IV.

Table IV: Emission factor used

Activities	Diesel Generator	Passenger	LD trucks	HD vehicles	kWh	SW	Waste water
Emission factor	2.66kg CO_2/L	0.248kg CO_2/L	0.33kg CO_2/L	1.011kg CO_2/L	0.02kg CO_2/kWh	3.84kg CO_2/Lkg	0.42kg CO_2/L

***Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024*
*Corresponding author- **Tsegaye Getachew***

ISSN (E): 2959-3921
(P): 2959-393X
DOI: https://doi.org/10.59122/164CFC17
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

The following polar plot (spiral chart) in Fig. 3 portrays weekly equivalent CO2 emissions from the corporate activities and their relative importance from the stated emission analysis results. The axes that correspond to individual activities with distinct measurement units in subsection 4.4 compiled in Table III consistent system units of kg of CO2 to enable coherent comparison and adjusted in logarithmic scale to facilitate distinguishable visibility.

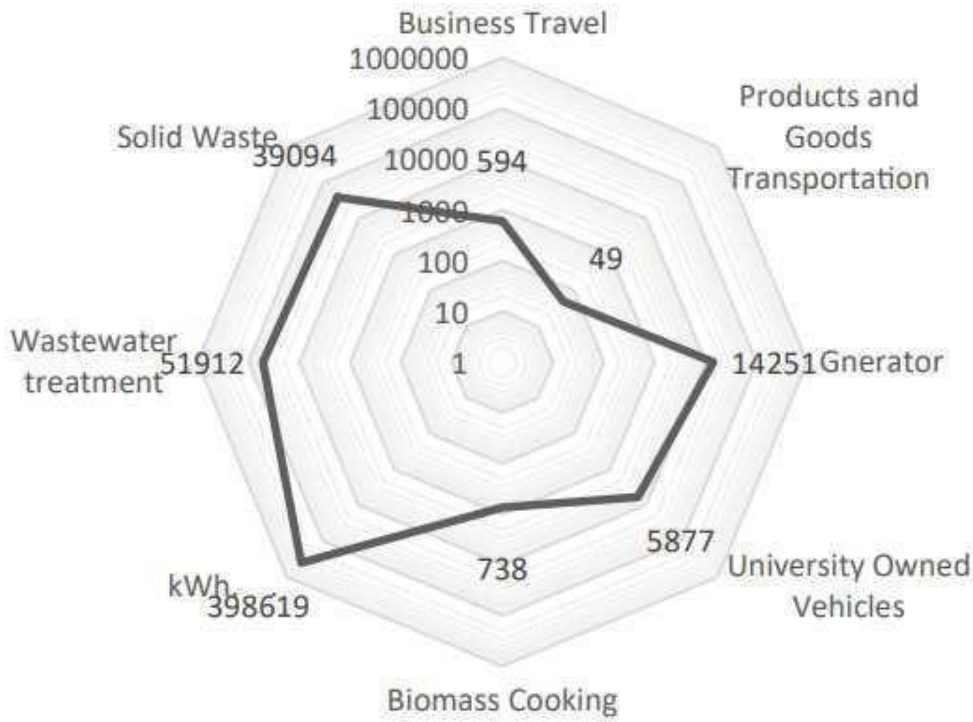

Fig. 3. Corporate emission constituents of the Ethiopian university

The university's electricity usage was the most detrimental activity, emitting 398.86 tons of CO2e. Other major environmental adversities included wastewater, diesel generators, and solid waste generation. Vehicles had the worst environmental performance, accounting for 6 tons of CO2e emissions. Product transportation had the least emissions, with 49 kg CO2e. The majority of the university's total CO2e emissions, over 511 tons, comes from electricity kWh usage. The bar chart in Fig. 4 illustrates the relative importance of these activities. As discussed in the preceding analyses under Table III, the majority 78% of the university's total CO2e emission of over 511 tones comes from kWh usage of electricity.

Received: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024
Corresponding author- **Tsegaye Getachew**

ISSN (E): 2959-3921 *Ethiopian International Journal of Engineering and Technology (EIJET)*
(P): 2959-393X *Volume 2, Issue 2, 2024*
DOI: https://doi.org/10.59122/164CFC17

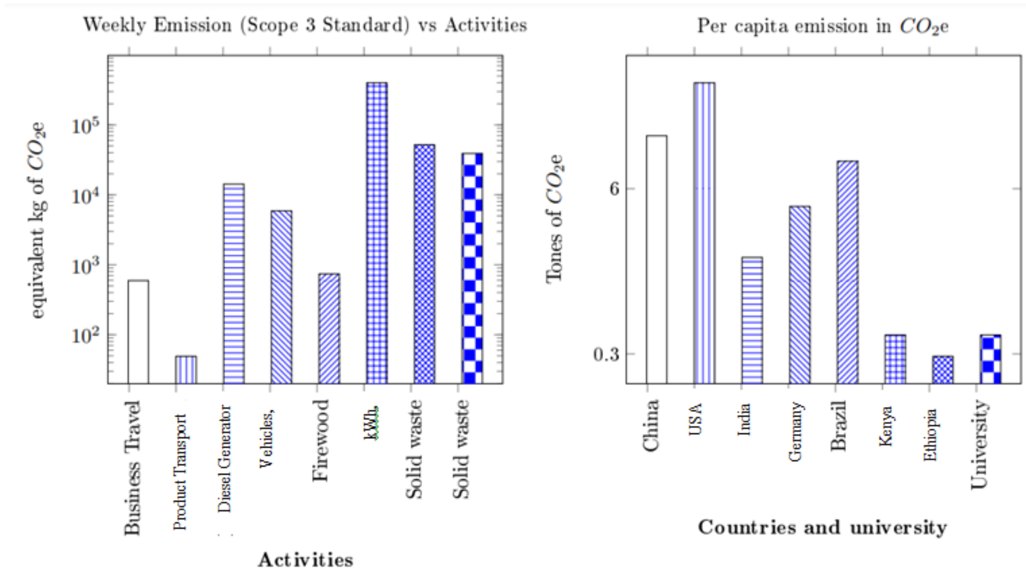

Fig. 4 Sector emissions from various university activities

Waste sectors are the dirtiest remaining with wastewater contributing just over 10% followed by solid waste with 7.65% as seen in Fig. 4. The next significant polluting university operations of over 14 tons of CO2e (2.79%) emissions a week is contributed by electricity production via diesel generators while vehicles pollute 5.877 tones. The remaining three operations: firewood, product transportation, and business travel, constitute below 0.3% of the total emissions according to the results of the analysis. The two bar charts in Fig.4 are added to aid the standard literature comparisons. The second bar chart in Fig. 4 is plotted by using per capita emission from Our World in Data considering five consecutive years' data of cumulative total emission data [22]. The total weekly corporate emission analysis of the university is estimated to be 511.114 tones (0.589 tones per capita per annum) as illustrated in Fig. 4 way beyond the national per capita emission of the year 2021, reported capita 0.15 kg CO_2e according to previous research also illustrated in the second chart of Fig. 4. The emission data of the countries in Fig. 4 by energy consumption is extrapolated for the year 2021 from data corresponding to the previous four years using Lagrange polynomial estimation [9, 22].

Assuming all 45 government universities' emissions are virtually proportional, they contribute a substantial 6.3% of the national annual CO2e emissions total reported to be 19.04 million tones according to Our World in Data (see the second chart in Fig. 4) [22]. The baseline environmental

***Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024*
*Corresponding author- **Tsegaye Getachew***

performance assessment of the Ethiopian higher education institution revealed the need for policy development and review intervention in the supervision of kWh electricity usage and waste management sectors. The results implied that the integrated electricity system and introduction of digital control alongside assessment strategies established in this study have enormous potential for energy optimization and the environmental sustainability of Ethiopian universities according to references [3-7, 24].

Factors such as budget deficits and shortages, unplanned energy-intensive operations like the simultaneous use of heavy machinery in machine shops, mass cooking equipment in cafeterias, and cereal grinders significantly contribute to peak hour energy demands. Additionally, energy-inefficient practices in dormitories combined with waste mismanagement in residential areas and environmentally harmful behaviors within the community hinder the university's long-term objective of achieving efficient, sustainable, and eco-friendly operations.

The university's electricity consumption in the context of almost no air conditioning systems with significant consumption or zero cooling load was discovered to be twenty times higher than the national average. This is even though over 70% of the population reported a lack of access to electricity notwithstanding significant strides in increasing electricity access, highlighting Ethiopia's challenges in achieving universal electricity access. The result implies an increase in the significant potential for consumption reduction primarily through the implementation of energy-efficient practices and consideration of the use of renewable energy sources [25-29].

The finding also highlights insufficient efforts to improve energy access through renewable sources and decentralized systems, as reported in technical reports emphasizing the need for immediate intervention in decentralized energy solutions. Further, it demonstrates that urgency in resident-targeted behavior change campaigns can help reduce environmental impacts, particularly for kitchen appliances, as a secondary priority. Focusing on effective management practices can help avoid peak demand, particularly for heavy-duty machines such as manufacturing workshops that use more than two-thirds of total energy [28-30].

Furthermore, wastewater and solid waste generations of the Ethiopian university were identified as major potential areas for improvement and implementing established best practices. The study

***Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024*
*Corresponding author- **Tsegaye Getachew***

ISSN (E): 2959-3921
(P): 2959-393X
DOI: *https://doi.org/10.59122/164CFC17*
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

determined that waste management is a priority area of effective initiatives prioritizing waste management in Ethiopian universities. The benefit of environmental performance enhancement tools prioritizing waste management as implied by the results of this study as a benchmark can have multifaceted gains such as biogas generation for cooking and electricity, fertilizer manufacturing, environmental protection, waste reduction, and overall sustainability [3,27-28,31].

IV. CONCLUSION

This study presents a preliminary integrated environmental impact assessment of Ethiopian higher education institutions, with the method illustrated in Fig. 1 encompassing key activities such as fuel uses of diesel generators and vehicles, electricity consumption, transportation, and waste management. It employed a comprehensive methodology based on IPCC SCOPE 3 standards and relevant literature. [1-2, 27-28, 30-31]. Valuable insights were provided about the associated emissions, energy usage, and waste trends. The university has made significant strides in transitioning to electric cooking powered by hydroelectric energy, reducing emissions from traditional stoves for 75% of residents across two campuses. However, electricity still accounts for 78% of greenhouse gas emissions, with waste generation contributing 17.81%. This underscores the urgent need for sustainable policies to address environmental impacts.

Although the adoption of renewable energy sources like solar power may offer advantages, economic constraints pose challenges to integration. Weekly emissions from vehicle and generator fuel usage reach 6 tons of CO_2e, while electricity consumption trends reveal four key utility themes, illustrating that residential and cafeteria facilities comprise 60% of the university's weekly total electricity usage of 1.931 GWh. Implementing integrated electricity-waste management systems could enhance energy efficiency and operational gains. Unplanned energy-intensive operations and inefficient practices hinder sustainable goals, indicating a need for supportive higher education policies to improve environmental outcomes. Moreover, focusing on waste sorting, recycling, and utilizing food waste could strengthen the university's sustainability initiatives, particularly through youth engagement.

The university's electricity consumption is alarmingly twenty times higher than the national average, despite the lack of significant air conditioning or cooling loads, indicating severe challenges in Ethiopia's pursuit of universal electricity access. More than 70% of the population

***Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024*
*Corresponding author- **Tsegaye Getachew***

still lacks reliable electricity, underscoring the need for energy-efficient practices and the adoption of renewable energy sources. There is a notable deficiency in efforts to enhance energy access through decentralized systems, calling for urgent interventions as highlighted in various technical reports. The urgency for behavioral change campaigns aimed at residents could facilitate a reduction in environmental impacts, particularly concerning kitchen appliances. Additionally, effective management strategies are essential to mitigate peak energy demand, especially from heavy-duty appliances that account for over two-thirds of total energy usage.

V. ACKNOWLEDGMENTS

Our heartfelt gratitude goes out to the leaders, technicians, and facilitators from collaborating universities who provided invaluable guidance and professional expertise throughout the research process. Their years of institutional reports, technical advice, and contributions during observations and data collection were instrumental in this project's success. Without their support, this research would not have been possible.

REFERENCES

[1]. E. Serene et al., "The role of clean hydrogen in achieving net zero," Carbon Trust, 2023. https://www.carbontrust.com/news-and-insights/insights/worth-the-hype-the-role-of-clean-hydrogen-in-achieving-net-zero.

[2]. C. Cynthia et al., "Technical guidance for calculating scope 3 emissions (version 1): Supplement to the corporate value chain for accounting & reporting standard," World Resources Institute, World Business Council for Sustainable Development, GHG Protocol, & Carbon Trust, 2013. https://doi.org/10.22438/jeb/42/4(SI)/MRN-1534a.

[3]. F. Sofwan et al., "A systematic literature review: Determinants of sustainability reporting in developing countries," *Sustainability*, vol. 14, 2022. https://doi.org/10.3390/su141610222

[4]. G. Jesse and B. Rutger, "Industrial prefabrication solutions for building renovation June 2022 innovations and key drivers to accelerate serial renovation solutions in Europe," 2022.

[5]. S. Sibyl and R. Oliver, "Minimum standards, maximum impact: How to design fair and effective minimum energy performance standards," Buildings Performance Institute Europe, 2023. https://www.bpie.eu/publication/minimum-standards-maximum-impact-how-to-design-fair-and-effective-minimum-energy-performance-standards/

***Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024*
*Corresponding author- **Tsegaye Getachew***

ISSN (E): 2959-3921
(P): 2959-393X
DOI: https://doi.org/10.59122/164CFC17
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

[6]. B. Alfonso et al., "Energy optimization using a case-based reasoning strategy," *Sensors*, vol. 18, 2018. https://doi.org/10.3390/s18030865

[7]. S. Sergey et al., "Optimizing the energy efficiency of higher education institutions," *Web of Conferences*, vol. 244, 2021. https://doi.org/10.1051/e3sconf/202124411029

[8]. D. Florin, D. Otilia, and E. Elena, "Distributed power generation from renewable energy resources a framework for load forecasting in low voltage power grids," in *UKSim-AMSS 6th European Modelling Symposium*, 2012.

[9]. H. Hongwen et al., "Model predictive control with lifetime constraints-based energy management strategy for proton exchange membrane fuel cell hybrid power systems," 2020. https://doi.org/10.1109/TIE.2020.2977574

[10]. G. Sonetti and D. Cottafava, "Enhancing the accountability and comparability of different campuses energy profiles through an energy cluster approach," *Energy Efficiency*, 2022. https://doi.org/10.1007/s12053-022-10024-.

[11]. A.-D. Ahmad et al., "Multi-agent system for energy consumption optimization in higher education institutions," *Journal of Computer and System Sciences*, vol. 81, pp. 958–965, 2015. https://doi.org/10.1016/j.jcss.2014.12.010.

[12]. P. Hoornweg and D. Bhada-Tata, "A global review of solid waste management," World Bank, 2012. https://documents1.worldbank.org/curated/en/302341468126264791/pdf/68135-REVISED-What-a-Waste-2012-Final-updated.pdf.

[13]. B. Aissa et al., "Improvement of autonomy, efficiency, and stress of fuel cell hybrid electric vehicle system using robust controller," *Sustainability*, 2023. https://doi.org/10.3390/su15075657.

[14]. G. Michael and H. I. José, "Real emissions, driving patterns and fuel consumption of in-use diesel buses operating at high altitude," *Transportation Research Part D*, 2019. https://doi.org/10.1016/j.trd.2019.10.004.

[15]. W. Yiwei and M. Qing, "The impact of the corporate average fuel economy standards on technological changes in automobile fuel efficiency," *Resource and Energy Economics*, 2020. https://doi.org/10.1016/j.reseneeco.2020.101211.

Received: *August 2024;* ***Revised:*** *25 October 2024;* ***Accepted:*** *22 November 2024;* ***Published:*** *31 December 2024*
Corresponding author- ***Tsegaye Getachew***

[16]. M. Nuhu et al., "Food waste management current practices and sustainable future approaches: A Saudi Arabian perspective," *Journal of Material Cycles and Waste Management*, 2018. https://doi.org/10.1007/s10163-018-0808-4.

[17]. F. Asefa, "Ethiopia's third national communication to the United Nations Framework Convention on climate change (UNFCCC)," 2022. https://rb.gy/wo36z.

[18]. G. R. Darío and W. D. John, "Stationary combustion (EFDB emission factor database)," 2006. https://rb.gy/0s57w.

[19]. R. Hannah, R. Max, and R. Pablo, "CO2 and greenhouse gas emissions," *Our World in Data*, 2020. https://rb.gy/evrl3.

[20]. "Ethiopian University List 2023 ranking & top private and public university," 2023. https://www.neaea.com/ethiopianuniversity/.

[21]. K. C.G. et al., "Estimation of carbon footprint in Tamil Nadu agricultural university, Coimbatore," *Journal of Environmental Biology*, 2020. https://doi.org/10.22438/jeb/42/4(SI)/MRN-1534a.

[22]. F. Teshome, "Municipal solid waste management in Ethiopia: The gaps and ways for improvement," *Mater Cycles Waste Manag*, pp. 18–31, 2021. https://bit.ly/3UL4cX9.

[23]. IRENA, "IRENA country energy profile (Ethiopia)," 2023, https://rb.gy/j1hhc.

[24]. H. Jochen et al., "Mobile combustion (EFDB emission factor database)," 2006. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2%20Volume2/V2_3_Ch3_Mobile_Combustion.pdf.

[25]. UNFCC, "Greenhouse gas emissions in Ethiopia," 2017. https://pdf.usaid.gov/pdf_docs/pa00msr8.pdf.

[26]. D. G. Pezzano, "Argentina unida diapositiva 1: Implanted forests," FAO, 2021. https://doi.org/10.1016/B978-0-12-804491-9.00003-3.

[27]. TRANSPOCO, "How is fuel consumption calculated?," 2023. https://www.transpoco.com/knowledge/how-is-fuel-consumption-calculated.

[28]. A. Graham et al., "A global review of solid waste management," 2021. https://rb.gy/fow94.

[29]. R. Edward et al., "Country-level and gridded estimates of wastewater production, collection, treatment and reuse," *Earth System Science Data*, pp. 237–254, 2021. https://doi.org/10.5194/essd-13-237-2001.

***Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024*
*Corresponding author- **Tsegaye Getachew***

[30]. C. Gomez et al., "Adaptable model for assessing sustainability in higher education," *Journal of Cleaner Production*, pp. 1–11, 2014. www.elsevier.com/%20locate/jclepro.

[31]. M. Meyer, "Eco-management and audit scheme (EMAS)," 2023. https://green-business.ec.europa.eu/eco-management-and-audit-scheme-emas.

***Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024*
*Corresponding author- **Tsegaye Getachew***

ISSN (E): 2959-3921
(P): 2959-393X
DOI: https://doi.org/10.59122/164CFC17
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

APPENDIX

Table V: Standard Emission Assessment Tools & Relevant Activities

Selected IPCC Scope 3 Categories	**Activity Measurement**	**Relevant Emission Factor**	**Method of analysis**
Category 3: Fuel based for Diesel Generators	Annual fuel expenditure, price, and relevant unit conversion factors	kg of CO_2 per liter diesel	$CO_2e = \sum(Expenditures/Price_i)*EF_i$
Category 4 i: Distance-based for Commuting	Employees commuting per week, weekly work hours, & vehicles models	kg of CO_2 per liter diesel for HD trucks/buses	$CO_2e = \sum[kmi * \eta_i(l/km) *Load/Capacity_{Maximum}]$
Category 4 ii. Products-Based for goods	Products/goods, travel distance, amount	kg of CO_2 per liter diesel for HD trucks	$CO_2e = (Amount_i \times km \times EF_i)$
Category 4 iii: Average Based for Appliances	Appliances & Weekly Usage to be used in Cat.7	kg of CO_2 per kWh	$CO_2e = (Amount_i \times Duration_i \times EF_i)$
Category 6: Business Travel (Events & re-late)	number of events hosted or invited, number & distance traveled by employees on third parties owned vehicles	kg of CO_2 per liter diesel for HD trucks/buses	$CO_2e = \sum[(kmi /\eta_i)* (Number_{Passenger}/Number_{Employees}) EF]$

Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024 Corresponding author- **Tsegaye Getachew

ISSN (E): 2959-3921
(P): 2959-393X
DOI: https://doi.org/10.59122/164CFC17
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

Category 7: vehicles	Distance traveled by each vehicle owned	kg of CO_2 per kWh liter fuel	CO2e = P(km_{oneWay} ×$Counts_i$ ×EFi)
Category 11: Electricity	Work hours & no. of (bulbs, computers, printers, stoves, lab. machines, microscopes etc.)	kg of CO_2 per kWh	CO_2e = P(kW_i × $hours_i$ × no. × EF_i)
Category 12: Waste	Amount of solid waste (SW) & wastewater (WW)	Kg of CO2 per kg of SW or liter of WW	CO2e = X($Amount_{Waste}$.i × %$WasteTreatd._i$ × EF_i)
Category 15: summary	All categories except construction projects	Results of the above categories	Total_CO_2e = ∑E_{CO2} i_s

Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024 Corresponding author- **Tsegaye Getachew

ISSN (E): 2959-3921
(P): 2959-393X
DOI: https://doi.org/10.59122/164CFC17
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

Table VI: Vehicles and Travel Information

Parameters	Buses	Medium bus	5Seat Station-wagen	5Seat Parado	Mini-bus, New	Minibus, Old	Light Duty Truck	Ambu-lance 4 Doors	Auto-mobile, Exec	HD Truck
Year/Model	2004-2020	2020	2020	2009	2012	2020	2012	2010	2008	2015 & 2018
Avg. oneway in km	9	9	10	10	9	9	15	25	10	10
No. of Shift b/n stops	12	6	4	4	12	12	12	10	4	2
Daily avg. distance(km)	154	54	40	40	108	108	180	250	40	20
No. of vehicles	9		4	2	3	2	6	2	2	2

Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024 Corresponding author- **Tsegaye Getachew

ISSN (E): 2959-3921
(P): 2959-393X
DOI: https://doi.org/10.59122/164CFC17
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

Table VII: Building Types & Numbers in the main campus and nearby staffs' residential compounds where short forms MFA, FR, CR, S, H, O & R designate multifamily apartment family room, class room, studio, Halls, office & rooms, respectively

Building Types (Col)/ Parameters (Rows)	G+1 CR	G+2 CR + O	G+3 CR + O	Labs	LH	Lib	G+2 MFA	G+4 MFA	G+2 Dorms	G+3 Dorms	G+4 Dorms	Cafe	Lounges
Building Count	8	26	6	18	10	4	16	5	23	4	2	3	6
Room Count	8CR 3Os	10CR 5Os	16CR 4Os 2S	2CR 2Ss 1H	2O 1S 1H	1CD 8O 3Ss 2H	12FR 3S	20 FR	16R 1O 1S	24R 1O 2Ss	32R 1.O 3S	2K 2.O 3S	1K 1.O 2H

ISSN (E): 2959-3921
(P): 2959-393X
***DOI:** https://doi.org/10.59122/164CFC17*
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

Table VIII: Emission Factor: Source activities & corresponding emission factor identified in reputable publishing websites and peer-reviewed academic articles or calculated based on IPCC guidelines

Source (Rows) /Unit Conversion (Columns)	**Reported EF**	**Conversion**	**EF in Convenient Unit** **EF in Convenient kg of *CO_2* /Unit**
Energy use (Combined)		0.15 tones per capita a year [19]	0.15 tone CO_2 per capita
Diesel (Stationary)	74.1 kgCO_2/GJ (Dar´1o and John)	0.03586 GJ/litre	2.66 kg/liter
Diesel (Passenger)	0.237 kg/km or 3.17231 kg/kg [24]	1 with advanced control	0.237 kg/ km
Diesel (Passenger l)	0.248 kg/km or 3.17231 kg/kg	1 with moderate contro	0.248 kg/km
Diesel (Passenger)	0.319 kg/km or 3.17231 kg/kg	1 uncontrolled	0.319 kg/km
Diesel (LD truck)	0.33 kg/km or 3.17231 kg/kg	1 advan./mod. Control	0.33 kg/km
Diesel (LD truck)	0.415 kg/km or 3.17231 kg/kg [24]	1 for uncontrolled	0.415 kg/km
Diesel (HD truck)	0.987 kg/km or 3.17231 kg/kg [24]	1 for advanced controlled	0.987 kg/km
Diesel (HD truck)	1.011 kg/km or 3.17231 kg/kg	1 for moderate controlled	1.011 kg/kmm

Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024 Corresponding author**- Tsegaye Getachew

ISSN (E): 2959-3921
(P): 2959-393X
DOI: https://doi.org/10.59122/164CFC17
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 2, Issue 2, 2024

Diesel (HD truck)	1.097 kg/km or 3.17231 kg/kg [24]	1 for uncontrolled	1.097 kg/km
Electricity	0.02 kg CO_2 /kWh, [17,22-23]	ratio 93 : 4 : 2 : 1, Hydro : Wind : Geothermal:Diesel (23)	0.02 kg/kWh
Waste (Combined)	3.876×10^9kg of CO_2 a year	Solid waste (SW) to wastewater ratio 18.2 : 1	
Solid Waste (Landfill)	CO_2e EF = (Waste × %degradable) ×(1 − CH4 OxidnFactr.) × CH_4 Correction Factor.×(1 − Recovery)x(16/12)	CO_2e EF = 0.15 × 0.5 × 0.5× 0.4 × (1 − 0) × (16/12) × (1 − 0)	200 kg CO2/kg a year
Wastewater (treated)	0.202×10^9kg of CO_2 a year	CO_2e EF = O_2 DemandWaste × CH_4 Correction Factor.× CH_4 emissn Factor	EF=0.06*0.1*0.25*28=0.42kg CO_2/year [17,25]
Firewood	CO_2e EF =(44/12) × Cal. $Value_{net}$ × (1 − ηstove)×(1 + Moisturepercent) + (GW PCO_2 + GW PCH_4)[3]	CO_2e EF =(44/12) × 15 × (1 − 0.1) × (1 + 0.2)×(1 + 0.0067)	6.06kgCO2/kg

Received**: August 2024; **Revised:** 25 October 2024; **Accepted:** 22 November 2024; **Published:** 31 December 2024 Corresponding author- **Tsegaye Getachew