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Towards Sustainability: Tracking Carbon Footprint Trends at Ezemvelo KZN Wildlife

Kgaphudi Wendy Madiope[1], Jacob Adedayo Adedeji[2], Sebataolo Rahlao[1]

[1]*Ezemvelo KZN Wildlife, 1 Peter Brown Drive, Pietermaritzburg, 3201, South Africa.*

[2]*Department of Civil Engineering Midlands, Durban University of Technology, Pietermaritzburg, 3201, South Africa.*

Abstract

Carbon footprint assessment is important to combat global warming and promote sustainability. Globally, organizations committed to biodiversity conservation are essential for maintaining ecosystems and the people who inhabit them. Nonetheless, these organizations produce a carbon footprint due to their operating operations. Hence, this study aimed to assess the specific carbon footprint of the Ezemvelo KZN Wildlife (EKZNW) to improve its understanding of its environmental implications and encourage sustainable behaviors within its particular missions. Using the greenhouse gas protocol corporate accounting and reporting standard as a guide, the study methodology examines greenhouse gas emissions from direct (Scope 1) and indirect (Scopes 2 and 3) sources related to Ezemvelo wildlife activities over five years (2014/2015--2018/2019). The results show that 34,016.62 tons of carbon dioxide equivalent (tCO2e) are emitted on average each year. The majority of these emissions are caused by Scope 2 electricity consumption, which accounts for 23,475.82 tCO2e, and Scope 1 emissions, which account for 7,826.20 tCO2e. Furthermore, there was a noticeable difference in emissions between the reserves, with the Imfolozi Game Reserve having the highest emissions. The findings of this study direct EKZNW toward ecologically conscious behaviors by acting as a catalyst for educated decision-making. The insight gained paves the way for proactive steps to lower carbon emissions, coordinating conservation efforts with more general goals of sustainability and climate resilience.

Keywords: *Climate change, sustainability, GHG protocol, emission sources, Paris agreements*

1. Introduction

Climate changes are more evident than ever before, as there has been a continuous rise in global air and ocean temperatures and rising global sea levels [1], [2], [3]. However, numerous studies have established an indisputable link between the acceleration of climate change and the ongoing increase in greenhouse gas or carbon emissions [2], [4], [5], [6]. The sharp increase in global temperatures that has been observed in recent decades is primarily the result of greenhouse gas emissions, which are caused predominantly by human activities [1], [2], [7]. According to an IPCC [8] report, human activity has contributed to global warming, mainly through the emission of greenhouse gases, and between 2011 and 2020, the average global surface temperature increased by 1.1°C over preindustrial levels. This rise has stemmed from unsustainable energy practices, land use alterations, migration, patterns of consumption and production across various regions, nations, and individual lifestyles [1], [3], [7], [8]. Additionally, the burning of fossil fuels, deforestation, agricultural practices, and the manufacturing of cement are the main causes of the increase in atmospheric CO_2 concentrations [9], [10].

Numerous studies from around the globe have assessed carbon footprints at the national, regional, and organizational levels, revealing various trends and

Corresponding author: *Kgaphudi Wendy Madiope (2011037765@ufs4life.ac.za)*
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mitigation approaches [11], [12], [13], [14], [15], [16]. According to Meng and Xu [13], China has implemented various carbon reduction policies; however, 12 of these policies have been evaluated, and the quality of the carbon reduction policies is good, whereas some countries, such as Canada, Japan, China, and South Korea, have demonstrated success in reducing their carbon footprint through the use of nuclear energy [12], [13]. These findings provide valuable benchmarks and context for understanding and addressing emissions globally.

Furthermore, the nationally determined contributions (NDCs) announced before COP26 suggest that projected global greenhouse gas emissions would likely surpass the 1.5°C threshold and significantly impede efforts to constrain warming to below 2°C beyond 2030 [8], [17]. Nevertheless, there are still global reduction commitments from various countries. In South Africa, there is a heavy reliance on coal for energy generation. With average annual carbon dioxide emissions per person equivalent to those of developed countries, South Africa is currently the continent's top emitter [18], [19].

1.1. Carbon emissions in South Africa

South Africa's national power utility, Eskom, faces many operational and business hurdles, significantly affecting the nation's energy landscape [20]. The ramifications of these challenges are unmistakably felt through the persistent implementation of the country's “load-shedding” initiative, which was initiated in 2007 [20], [21]. This program orchestrates a systematic approach of rotating power cuts, typically lasting between two and four hours, aimed at preventing the collapse of the grid due to insufficient available capacity [22]. Ninety percent (90%) of Eskom’s generating capacity stems from the combustion of coal [2], [21], [23]. In the 2018/19 financial year, a staggering 114 million tonnes of coal were consumed, leading to 221 million tonnes of CO_2 being emitted. This substantial carbon output solidifies Eskom as the nation’s predominant emitter, contributing to a staggering 42% of South Africa’s total emissions [24].

According to the latest greenhouse gas inventory report, the dominant gas fuel of South Africa's emissions (excluding FOLU) remains CO_2, with its share declining slightly from 84.8% to 83.6% between 2000 and 2020. In 2020, CO_2 emissions totaled 391,993 Gg CO_2 (excluding FOLU) and 363,677 Gg CO_2 (including FOLU). Notably, the energy sector stands out as the primary source of CO_2 emissions in South Africa, accounting for a substantial 94.7% of the total contribution in 2020. The energy sector in South Africa continues to be the main contributor to GHG emissions and has been found to be a key sector each year [19], [25].

Comparatively, the top ten manufacturing countries have integrated energy policy activities and developed energy strategy consistency, resulting in a significant reduction in emissions from their energy sectors [12], [26]. For example, China’s investment in wind and solar energy led to a reduction in the carbon footprint, illustrating potential pathways for South Africa to reduce its reliance on coal [27], [28].

The Paris Agreement introduced a novel strategy known as NDCs, which gives each country the authority to chart its own path for climate change mitigation. Aligned with this framework, South Africa presented its mitigation plans in the 2016 NDC, defining a target range for greenhouse gas emissions between 398 and 614 Mt CO_2-eq for 2025 and 2030. This comprehensive framework includes all national emissions, including those derived from land use. Recalibrating these objectives to adopt a more targeted and potentially even more ambitious strategy is recommended by a recent draft update. The revised target ranges are 398--510 Mt CO_2-eq for 2025 and 398--440 Mt CO_2-eq for 2030. This modification demonstrates South Africa's unwavering dedication to addressing climate change and indicates a concentrated effort towards improved mitigation efforts [29].

According to the objectives outlined in the Paris Agreement, South Africa is prepared to make significant progress in reducing its emissions. SA-LEDS is South Africa's first low-emission development plan, which was created to help the country reach its NDCs. In an effort to achieve a 1.5°C increase in global warming, efforts are being made to maintain temperatures far below 2°C over preindustrial levels [2], [25]. In its UNFCCC submission, South Africa reaffirms its dedication to the goals of the Paris Agreement. The South African strategy, or SA-LEDS, addresses important areas such as waste management, forestry, energy, industry, and land use. It advances the SDGs and is in line with global climate objectives. To encourage emission reduction, South Africa implemented a multimodal approach to combating climate change, which included a carbon tax that was adopted in June 2019. Strategies for adaptation and mitigation for a low-carbon economy are outlined in the National Climate Change Response White Paper. South Africa's commitment to addressing climate change will be strengthened by the upcoming Climate Change Bill, which will create a strong legislative framework [30], [31]. Efforts are continuing to increase in South Africa to achieve and stabilize greenhouse gas concentrations in the atmosphere, thereby lowering its carbon footprint, in collaboration with climate change stakeholders and key actors (such as nature-based conservation management estates) [2].

1.2. Conservation management services context

Ezemvelo KZN Wildlife, as an organization and a nature-based conservation management estate, must acknowledge that its operations, such as land management practices, infrastructure development [32], [33], and visitor activities, might unintentionally increase emissions [34]. As a result, they may be responsible for reducing emissions to lessen their environmental impact and align with broader sustainability goals [2]. The pledge to reduce emissions is in line with larger international and national initiatives to combat climate change and lower greenhouse gas emissions [35]. Nature-based conservation management estates such as SANParks can fulfil their environmental obligations and serve as role models for the community and the larger conservation and tourist sector by incorporating these ideas into their operations [2].

Evaluations of carbon footprints in conservation services globally, such as Acadia National Parks in the USA [15], Yosemite National Park in the USA [14], Castel Porziano Nature Reserve in Italy [16] and South African National Parks in South Africa [2], underscore the potential for integrating alternative energy generation sources, information campaigns and public opinion and replacing fleet cars with best performers in operations to achieve emission reductions. For example, a case study of national parks in South Africa demonstrated how promoting green and smart building management can reduce emissions while enhancing sustainability in conservation management [2].

According to [35], [36], and [37], carbon footprint assessments are essential tools for promoting sustainable development agendas because they enable individuals and organizations to develop a deeper understanding of the interdependence between human activities and environmental impacts. The primary aim of this evaluation is to improve the standard of living on a local and global scale. Furthermore, it will aid in the implementation of national and international policies and initiatives that address carbon footprint concerns while preserving the integrity of our natural ecosystems [2], [35], [37].

Research conducted in China, the United States, and England has shown that carbon footprint assessments have had a direct effect on policy changes, technology adoption, and community engagement to reduce emissions [12], [13], [38], [39]. These examples demonstrate the practical benefits of such evaluations for conservation organizations around the world and serve as a model for organizations such as Ezemvelo KZN Wildlife.

To evaluate the greenhouse gas emissions within EKZNW operations and parks and to provide recommendations for monitoring and lowering emissions, the overall objective of this study was to perform a thorough carbon footprint assessment. Additionally, the assessment aims to support the creation of mitigation plans and encourage positive behavioural changes in parks and EKZNW activities. By monitoring the sources of emissions inside the operations of the organization, it is possible to strategically pinpoint areas that need to be improved and addressed.

2. Materials and Methods

2.1. Study area

Ezemvelo, a prominent conservation authority in South Africa, manages more than 120 protected areas, including diverse terrestrial, coastal, and marine reserves, crucial for biodiversity preservation [32], [33], [34] (Figure 1). Ecologist teams conduct applied research to underpin management operations and ensure compliance with environmental regulations. With extensive ecotourism operations offering 2,500 beds per night and camping facilities for more than 10,000 visitors, Ezemvelo facilitates public engagement with nature [34].

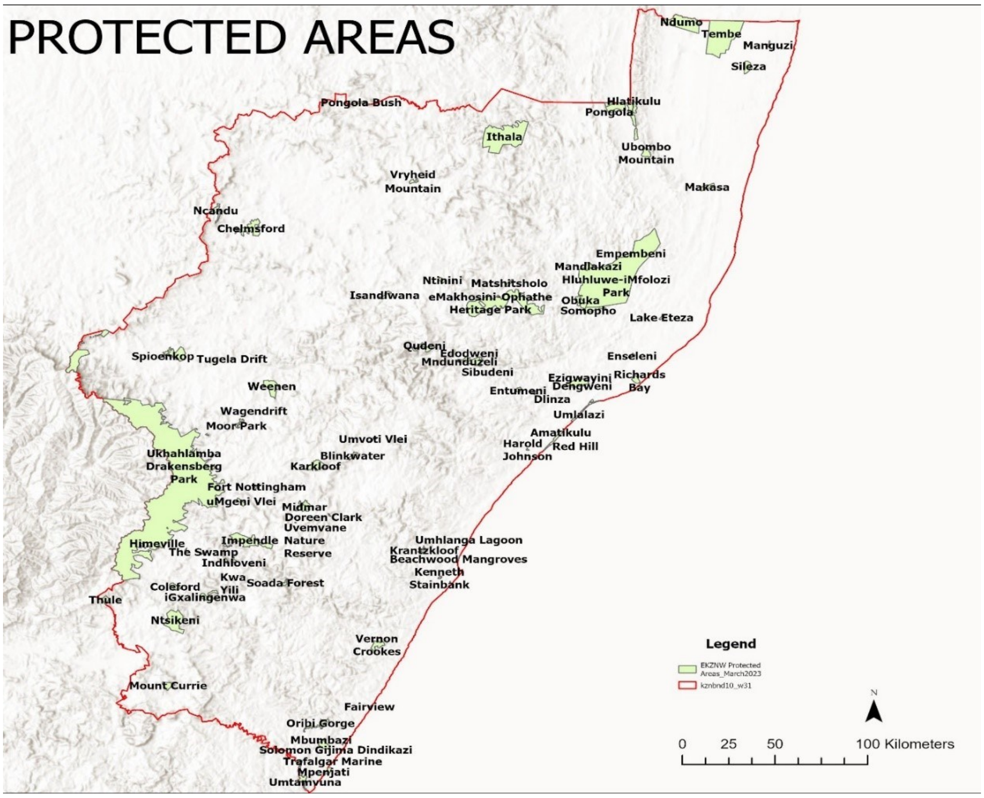

Figure 1. Map of the study area showing all the EKZNW parks.

The organization spans various geographical regions, from the Maloti-Drakensberg Park World Heritage Site in the west to the large game reserves of Zululand in the east and the iSimangaliso Wetland Park along the coast. Notably, parks such as the Imfolozi and Hluhluwe game reserves, which were initially established in 1895, attract the most visitors, reflecting their importance in South Africa's conservation landscape [40]. Ezemvelo's stewardship extends to iconic reserves such as Ndumo, Tembe Elephant Park, and Ithala, contributing to the protection of the nation's natural and cultural heritage across diverse ecosystems [33].

2.2. Research methodology

2.2.1. *Scope and calculation tool*

The concept of dividing greenhouse gas emissions into three scopes was indeed established by the Greenhouse Gas Protocol, developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) [2], [35]. The GHG Protocol is regarded as the predominant global accounting instrument utilized by governments and numerous entities within the conservation sector, aiming to comprehend, measure, and oversee greenhouse gas emissions. It has gained widespread recognition as the normative approach for conducting assessments related to GHG emissions, providing a comprehensive framework for organizations to identify and measure their direct and indirect emissions across various scopes, thus enabling informed decision-making towards mitigating climate change impacts. Following the GHG protocol, Scope 1 examines the direct emissions attributed to the organization's own vehicles, liquid petroleum gas, and diesel generators. Scope 2 delves into electricity consumption, and Scope 3 broadens the analysis to include all indirect emissions from water usage, waste generation, hotel stays and flights [2], [35], [37].

2.2.2. *Setting operational boundaries/data collection*

The study included a literature review, thorough load surveys, compilation of load data from various records pertaining to different scopes, and onsite verification through interviews. The study's organizational scope concentrated on conducting a thorough evaluation of EKZNW's carbon footprint, encompassing Scope 1, 2, and 3 emissions. The operational boundaries of the carbon footprint assessment are detailed in Table 1.

Table 1. Activity data and data providers for each emission source reported on [41].

Scope	Emission Sources	Activity Data	Data Collection and Status Evaluation	Formula Applied
Scope 1: Direct emissions	EKZNW vehicles	km and vehicle details	Data for years of study were not provided, the study used the average of 2022/2023 financial year. (Assumption based on 2022/23 for 83.6% diesel and 16.4% petrol).	km = [(Amount (Rand) X Fuel Type)/Average year Price per liter]/Average distances travelled per km
	Fuel usage	Litres and fuel type	Data for years of study were not provided, the study used the average of 2022/2023 financial year. (Assumption based on 2022/23 for 83.6% diesel and 16.4% petrol).	Liters = Amount (Rand)/Average year Price per liter
	Gas	Kilograms	Data captured from financial year statement.	Liters = (Amount (Rand)/Average year Price per kg) X 1.969 (1.969 Conversion factor from kg to L)
	Generator Diesel	Litres and fuel type	Data captured from financial year statement.	Liters = Amount (Rand)/Price per liter
Scope 2: Indirect emissions	Electricity	KwH used	Data captured from financial year statement.	KwH = Amount (Rand)/Average year Price per KwH
Scope 3: Indirect emissions	Water	Kilolitres	Data captured from financial year statement.	Kl = Amount (Rand)/Average year Price per Kl
	Sewage	Kilolitres		R13.6 for 200kl
	Solid Waste	Tons		R150/Per
	Hotel Stay	Room per night		R1065-R1225/night local R1600 international
	Flight	passenger. km		-

Table 1 provides a detailed explanation of how the data were obtained and the assumptions made regarding EKZNW's carbon footprint. For Scope 1 emissions related to EKZNW vehicles used for conservation-related fieldwork and business/workshop meetings, data for the reporting period were unavailable. Therefore, the study utilized average data from the 2022/2023 financial year, with a distribution of 83.6% diesel and 16.4% petrol. A formula was derived using the data from this year, accounting for vehicle models and distances travelled (km). Similarly, fuel usage was estimated on the basis of 2022/2023 data, with a breakdown of 83.6% diesel and 16.4% petrol, and a formula was derived accordingly. The data for gas and diesel generators were obtained from financial year statements (invoices) provided by the finance department. Additionally, interviews were conducted with finance personnel to determine which operational divisions utilized diesel generators, as not all reserves operated on diesel, with consumption mainly due to load shedding. For Scope 2, for electricity consumption, actual invoices and bills provided by the finance department were utilized. For Scope 3 emissions, data concerning water usage and solid waste generation were obtained from financial records. Air travel encompasses both domestic and international trips by officials funded by the organization.

2.2.3. *Calculating the carbon footprint*

In conducting this assessment, Microsoft Excel spreadsheets served as the primary tool for data input, calculation, and analysis, without the use of any specific software. This approach was selected for its efficiency in data processing and its effectiveness in generating figures that represent the study's findings accurately. To compute the carbon footprint, the following formula was applied (Equation 1) [2], [37]:

$$CF = \text{Activity Data X Emission Factor} \quad (1)$$

where CF = Carbon footprint.

This formula enables the quantification of emissions for each scope, ensuring a standardized and consistent approach aligned with international best practices. The study converted emissions into kilograms of carbon dioxide equivalent by multiplying the activity data with conversion factors obtained from the Department of Environment, Food, and Rural Affairs (Table 2) [42].

3. Results and Discussion

3.1.1. *EKZNW emissions*

Over the reference period, Ezemvelo emitted an average of 34,016.62 tCO_2e per year. Most emissions came from scope 2 electricity, accounting for 23,475.82 tCO_2e, followed by scope 1 emissions at 7,826.20 tCO_2e (Figure 2). Within scope 1 emissions, fuel usage was the main contributor, amounting to 6,588.20 tCO_2e. Additionally, electricity accounted for 69.01% of Ezemvelo's total emissions.

On an annual basis, total emissions were 31,946.69 tCO_2e for 2014/2015, showing a decrease of 6.22% from the previous year, which emitted 36,177.62 tCO_2e in 2015/2016, indicating an increase of 13.22% compared with the previous year. In 2016/2017, emissions rose slightly to 36,248.20 tCO_2e, with a marginal increase of 0.19%. However, in 2017/2018, emissions decreased to 34,378.21 tCO_2e, representing a reduction of 5.14% from the previous year. Finally, in 2018/2019, emissions decreased further to 31,332.39 tCO_2e, indicating a decrease of 8.87% from the previous year.

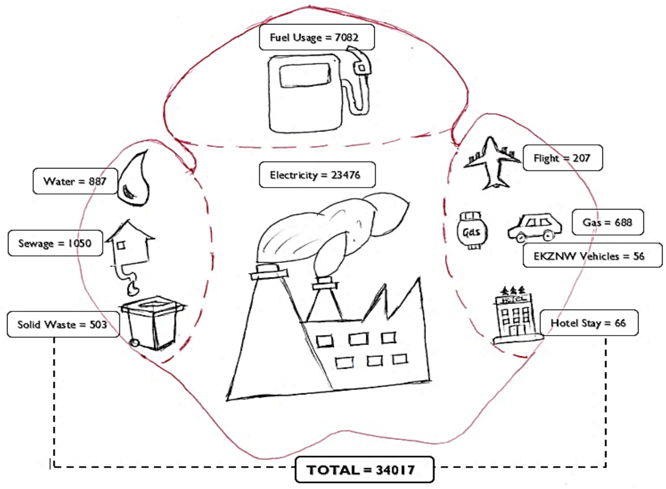

Figure 2. Rhinoceros Carbon Footprint for the Average EKZNW Emission Activities for 2014/2015–2018/2019. The "Rhinoceros footprint" is used metaphorically in this study to symbolize the positive environmental impact of EKZNW conservation efforts, particularly in the context of protecting Rhinoceros populations in South Africa.

Table 2. Emission factors utilized in the carbon footprint analysis for the period from 2014/2015--2018/2019 [23], [42].

Emission Source	Description	Emission Factor	Factor unit
Fuel	1 L of diesel combusted	2.66	$kgCO_2e/L$
	1 L of Petrol combusted	2.35	$kgCO_2e/L$
	1 km travelled in a small petrol car <1.7 L	1.1408	kg CO_2e/km
	1 km travelled in a medium petrol car	0.017819	kg CO_2e/km
Cars (by size)	1 km travelled in a large petrol car	0.27224	kg CO_2e/km
	1 km travelled in a small diesel car	0.13931	kg CO_2e/km
	1 km travelled in a medium diesel car	0.16716	kg CO_2e/km
	1 km travelled in a large diesel car	0.20859	kg CO_2e/km
Gas	1 litre of LPG	1.56	kg CO_2e/L
Electricity	1 KwH used	1.06	kg CO_2e/KwH
Water	1 kl of water used	0.177	kg CO_2e/Kl
Solid waste	1 ton of municipal waste transported to landfill	520.335	kg CO_2e/ton
Sewage	cubic metres	0.201	kg CO_2e/cubic metres
Hotel stay	Room per night	51.4 South Africa 33.0 Average international	kg CO_2e/Room per night
Flights	Passenger.km	0.27258	kg CO_2e/Passenger.km

The average rise in emissions for Ezemvelos for the five-year period was 0.15%. There was a 0.6% increase in global emissions from 2018--2019 [43]. Ezemvelo's growth rate exceeded that of SANParks, which was 0.02% for the same reference period, but it was lower than the national and worldwide rates [2]. This study also examined Ezemvelo's contribution to the agriculture, forestry, and other land use (AFOLU) sector and South Africa. Using data from 2015, 31,946 tCO_2e were used in the study, compared with 531 million tCO_2e for the country and 49.5 million tCO_2e for the AFOLU sector. The contribution of Ezemvelo amounts to 0.01% for the AFOLU sector and 0.001% for overall national emissions.

3.1.2. *Contribution of scope emissions to total emissions and individual park emissions*

Most GHG emissions from Ezemvelo originated from Scope 2 and Scope 1 (Figure 3 and Figure 4), with Scope 2 emissions totaling 23,475.82 tCO_2e from electricity (Figure 4) and Scope 1 accounting for an equivalent amount. Among the Scope 1 emissions, fuel usage was the largest contributor, accounting for 19.37% of the total emissions, followed by gas (2.02%), diesel generators (1.45%), and Ezemvelo vehicles (0.16%) (Figure 3). Overall, these two scopes represented approximately 92% of Ezemvelo's total emissions. These results were similar to those of the study by [2], where the total first-order scope was 92% of the total SANPark emissions. Additionally, Scope 2 emissions contributed 64% of UCT's total carbon footprint in 2021 [44].

Scope 3 emissions made up the remaining 8% of EKZNW emissions, with water accounting for 2.61%, sewage accounting for 3.09%, solid waste accounting for 1.48%, hotel stays accounting for 0.19%, and flights accounting for 0.61% of total emissions (Figure 5). This breakdown highlights the significance of electricity consumption and fuel usage in contributing to Ezemvelo's overall carbon footprint, emphasizing the importance of targeted mitigation strategies in these areas. Furthermore, this study categorized emissions within parks into two groups: conservation reserves dedicated solely to conservation and commercial service reserves aimed at revenue generation, as reported in the preceding section.

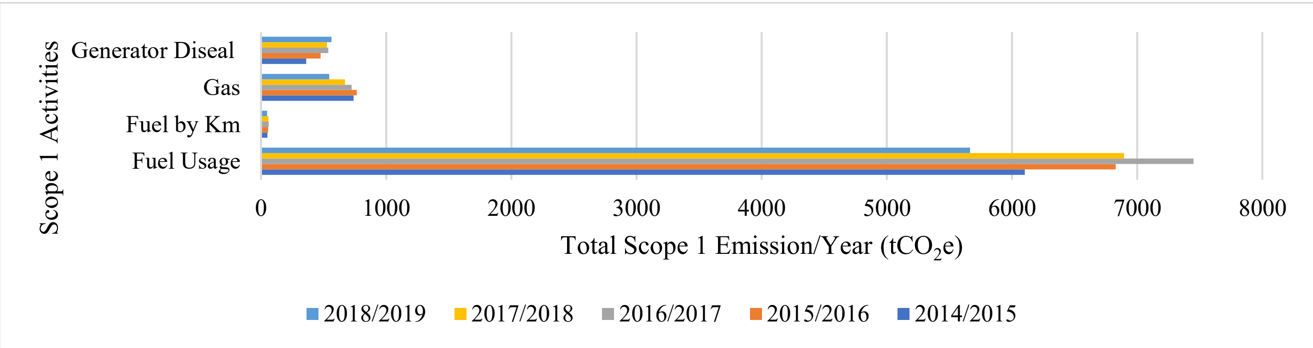

Figure 3. Summary of Scope 1 for all EKZNW operations per activities.

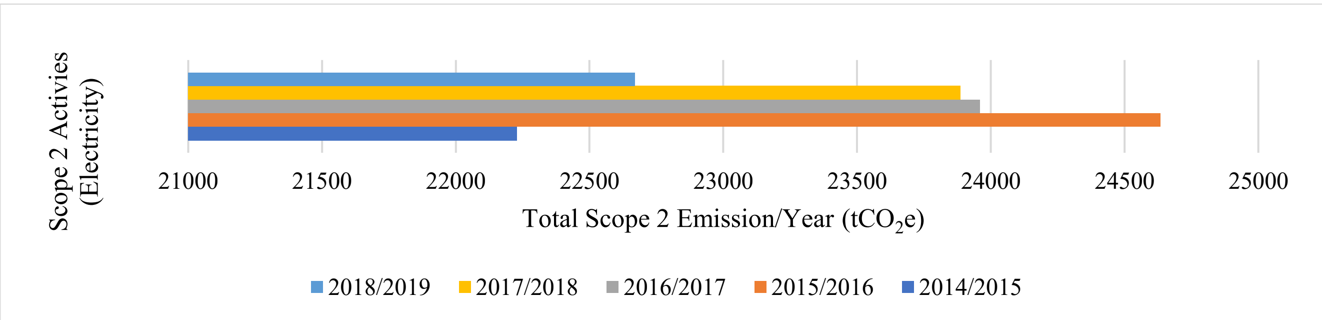

Figure 4. Summary of Scope 2 for all EKZNW operations per electricity.

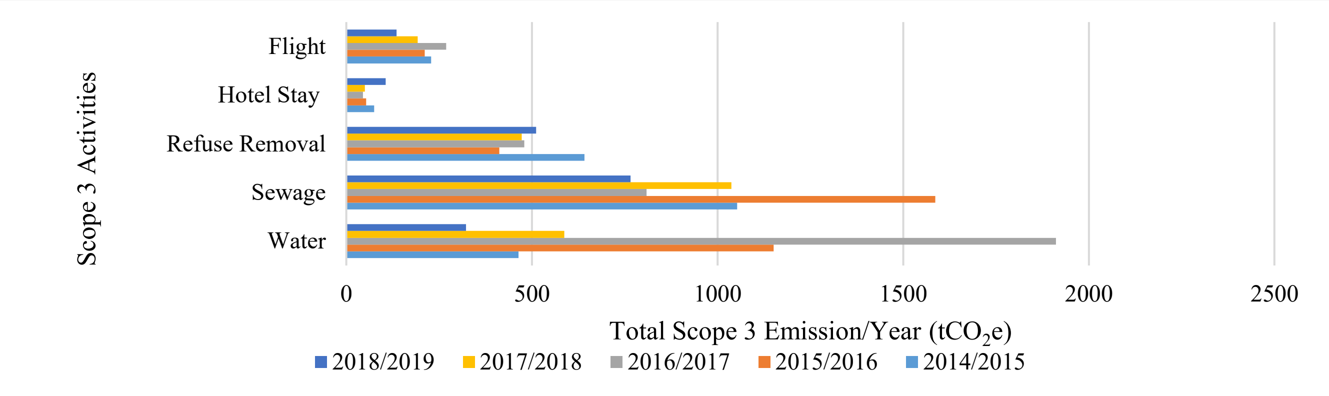

Figure 5. Summary of Scope 3 for all EKZNW operations per activities.

3.1.3. *Emission per park conservation*

The emissions within each conservation-focused park significantly impacted the overall emissions of the respective park. Notably, the Imfolozi Game Reserve exhibited the highest contributions to park emissions, particularly in terms of Scope 1 and Scope 2 emissions (Figure 6). Moreover, when the contributions of individual reserves to Ezemvelo's total carbon footprint were analysed, certain conservation reserves were distinguished for their roles in various aspects of Scope 3 emissions. For example, the St. Lucia Conservation Reserve played a significant role in water-related emissions, whereas the Pongola/Hlathikulu Reserve made substantial contributions to sewage emissions. Additionally, district conservation initiatives in marine and coastal reserves have proven particularly effective in reducing waste emissions.

3.1.4. *Emissions per park commercial*

In terms of commercial services (revenue-generating reserves), specific contributions were also observed. Notably, the Mpila Camp presented the highest emissions in terms of Scope 1. Similarly, when Scope 2 emissions were considered, the Sondwana Bay Reserve emerged as the leader (Figure 7). Additionally, individual contributions within commercial service reserves were identified. The hilltop reserve played a significant role in water-related emissions, the Cape Vidal Reserve led in sewage emissions, and waste removal activities at the Umlalazi Reserve notably influenced Scope 3 emissions. Umlalazi experienced a significant surge in visitor numbers during the years 2017/2018 and 2018/2019. This spike could be attributed to the considerable volume of visitors, which subsequently led to a rise in refuse removal emissions at the reserve, with a 71.3% increase to 48 039 visitors in 2018–2019.

3.1.5. *EKZNW GHG emissions per capita*

When considering the results of Ezemvelo's greenhouse gas (GHG) emissions per capita, calculated from the number of employees over the reference period from 2014/2015 to 2018/2019, distinct trends emerge across scope 1, scope 2, and scope 3 emissions. Scope 1 emissions per capita fluctuated slightly over the years, with values of 3.27 tonnes in 2014/2015, 3.26 tonnes in 2015/2016, peaking at 3.72 tonnes in 2016/2017, and decreasing to 3.04 tonnes in 2018/2019 (Table A). Similarly, the scope 2 emissions per capita varied, ranging from 10.01 tonnes in 2014/2015 to 10.09 tonnes in 2018/2019, with a peak of 10.66 tonnes in 2017/2018. Notably, scope 2 emissions presented the highest emissions per capita over the reference period. Conversely, scope 3 emissions per capita demonstrated a different trend, with fluctuations from 1.11 tons in 2014/2015 to 0.82 tons in 2018/2019. According to Statista, South Africa's per capita CO_2 emissions were approximately 7.34 tons in 2021, which is higher than the average of approximately one metric ton per capita for Africa and 1.22 times the average of the G20 countries. Comparing this national baseline with that of EKZNW, it is worth noting that the EKZNW per capita average of the referenced period is twice the baseline at 14.71 tons. Furthermore, comparing the results from this assessment with those of SANPark (13.3 tons per capita) for the same reference period [2], it was discovered that there is a close similarity in the per capita CO_2 emission results. Overall, the CO_2 emissions reported here are not only generated by the employees of EKZNW but also contributed by the visitors to the reserves and temporary employees.

Nevertheless, these findings highlight the importance of understanding and addressing emission patterns within Ezemvelo to mitigate its environmental impact effectively, especially in the context of South Africa's significant energy consumption.

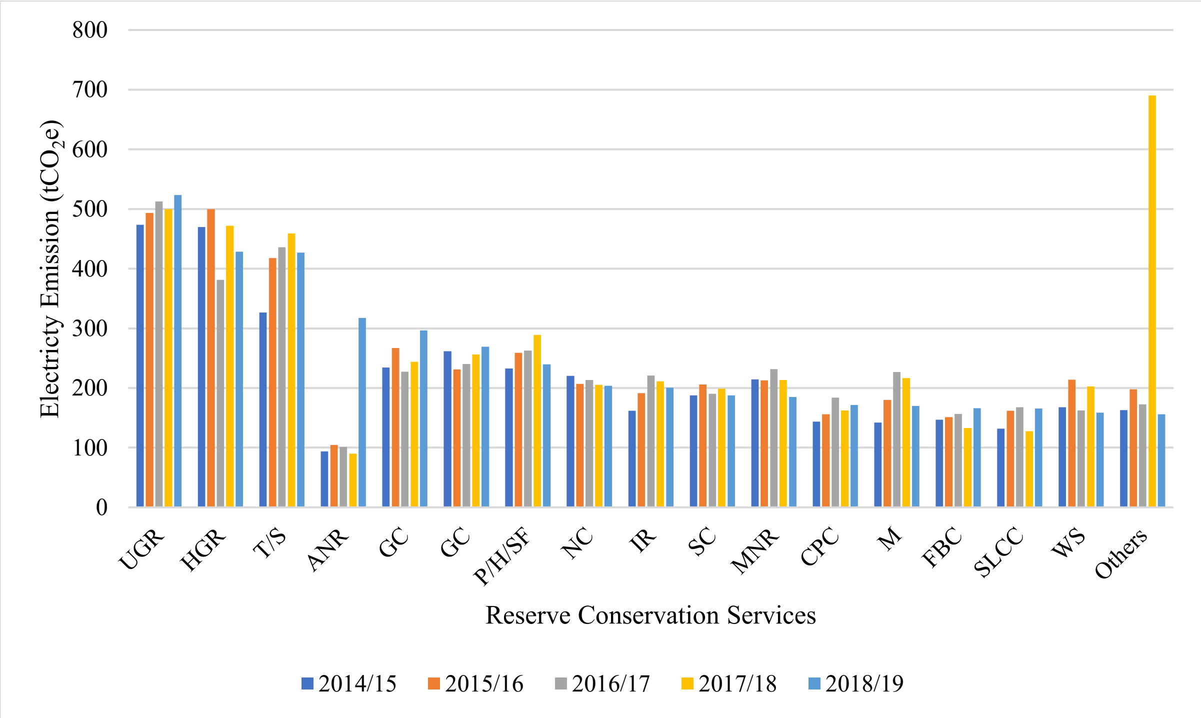

Figure 6. Electricity emissions for EKZNW reserve conservation services.

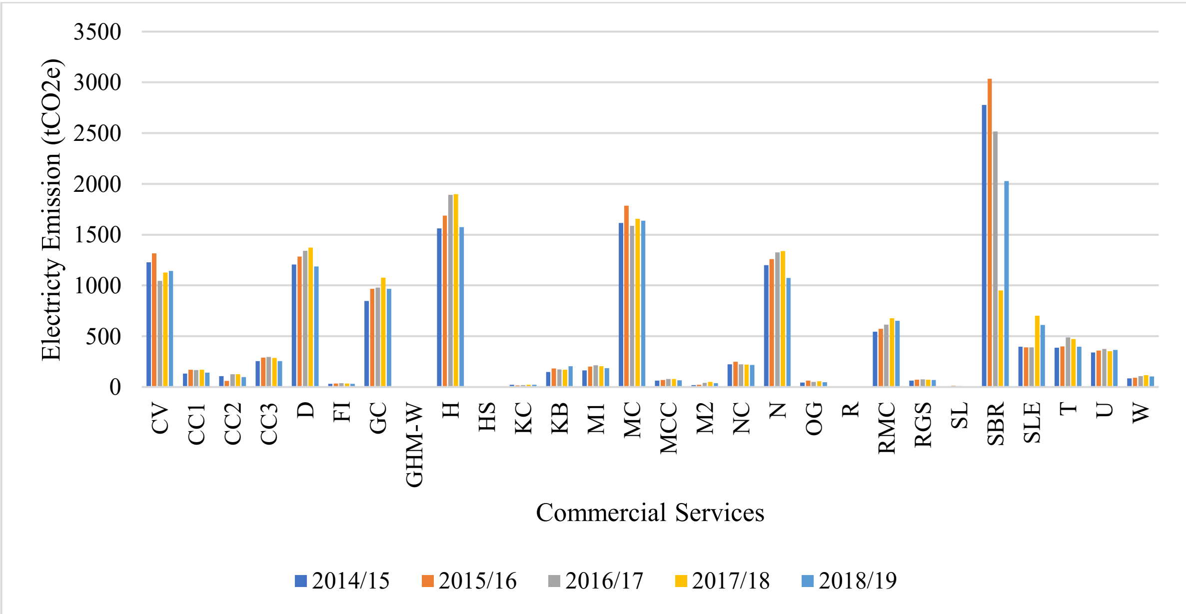

Figure 7. Electricity emissions for EKZNW commercial services.

4. Discussion

The results indicate the trends and highlight that the majority of carbon emissions from Ezemvelo KZN Wildlife are attributed to Scope 2 (electricity usage) at 69% and Scope 1 sources, totaling a significant 94% of the overall emissions. This outcome resonates with the conclusions drawn in a study on the greenhouse gas emissions of amusement parks in Taiwan. The study revealed that each park's average energy consumption was 7699 MW h, with electricity accounting for 91% of this consumption, highlighting electricity as the primary contributor to greenhouse gas emissions [45]. Similarly, analyses of the carbon footprint of Acadia National Park in 2015 and 2018 identified stationary combustion, purchased electricity, and mobile combustion as the primary contributors to emissions [15]. These parallels underscore the worldwide challenges faced by conservation areas and recreational sites in managing and mitigating their environmental impact.

According to local studies focused on carbon footprint assessment, high Scope 2 emissions, particularly from electricity usage at 69%, are supported by the findings of various investigations. For example, SANPark recorded electricity emissions at 40,681 tCO_2e, representing 55% of its total carbon footprint [2]. Similarly, the University of Cape Town's carbon footprint reports for 2020 and 2021 identified electricity as the primary contributor, comprising 69% and 64% of emissions, respectively [44]. Within Sanlam's GHG footprint for 2022, purchased electricity accounts for 64% of total emissions [46]. Moreover, the latest South African greenhouse gas inventory underscores the energy sector as the leading source of CO_2 emissions in the country, constituting a substantial 94.7% of the total contribution in 2020, largely owing to heavy reliance on coal for energy generation [19]. Therefore, EKZNW and other conservation entities must prioritize transitioning to renewable energy sources, such as solar or wind, to mitigate Scope 2 emissions effectively. Deploying localized renewable energy solutions, such as solar installations within reserves, can reduce emissions while providing sustainable energy for operations.

Following electricity usage, transportation emerged as the second most significant source of emissions in our study, accounting for 7082 tCO_2e. This finding is in line with research conducted by Lin (2010), who emphasized two primary factors influencing CO_2 emissions: travel distance and transport mode. Notably, CO_2 emissions increase with increasing travel distance. In this study, conservation reserves focused on both conservation efforts and revenue generation from visitors presented higher emissions associated with fuel usage. The link between higher emissions and the dual purpose of conservation areas (conservation activities and revenue generation through tourists) is evident. Conservation reserves that actively engage in commercial activities face increasing transportation demands for logistical operations, visitor access, and fuel-intensive conservation efforts, resulting in higher emissions. To reduce these emissions, conservation organizations should use fuel-efficient vehicles, encourage tourists to carpool, and investigate alternate forms of transportation, such as electric or hybrid vehicles. Furthermore, the creation of carbon-offset activities within reserves, such as tree planting or habitat restoration, can help offset transportation emissions.

Scope 3 emissions, which account for 4.5% of total EKZNW emissions, are mostly from solid waste and sewage. Despite being lower than Scopes 1 and 2, their environmental significance should not be underestimated. Similar emission levels were found in both the national environmental sector and SANParks [2]. However, the Scope 3 emissions of EKZNW present a unique opportunity to prioritize waste management and recycling programs. By implementing a robust recycling program, composting organic waste and limiting landfill contributions can considerably reduce these emissions. Collaborative efforts with local municipalities to manage sewage and install energy recovery systems, such as biogas generation, could further increase Scope 3 emission reduction methods.

Comparatively, EKZNW’s carbon footprint aligns with global trends in the conservation and recreational sectors but highlights areas for targeted improvement. For example, Acadia National Park and Grand Canyon National Park in the United States reported similar primary sources of emissions, with a focus on electricity and transportation [14], [15]. However, Acadia's implementation of shuttle buses and renewable energy projects provides a model for reducing emissions in these categories. Internationally, the UK’s National Trust has set ambitious goals of achieving net-zero carbon emissions by 2030, with extensive reliance on renewable energy and reforestation projects [47]. EKZNW can draw from these examples to adopt a more aggressive carbon neutrality strategy, focusing on renewable energy adoption, emissions monitoring, and community engagement in conservation efforts.

Moreover, the tourism sector's influence on EKZNW's carbon footprint is significant [11]. Tourism activities contribute substantially to global energy consumption and carbon emissions, estimated at 3.2% and 4.4%, respectively, according to Peeters et al. [48]. The Imfolozi and Hluhluwe Game Reserves, attracting the highest visitor numbers within EKZNW, exemplify this impact [40]. With 39% of total visitors in 2014/2015 and consistently high numbers in subsequent years, these reserves remain critical to the local tourism industry. Managing their environmental impact through initiatives such as green certifications for accommodations, sustainable tourism campaigns, and energy-efficient infrastructure becomes imperative. In practice, installing renewable energy systems in visitor facilities and promoting low-impact tourism practices could significantly reduce the carbon footprint [2], [10], [11], [12].

Overall, EKZNW’s carbon footprint reflects broader challenges faced by conservation entities worldwide. However, by adopting actionable conservation strategies such as transitioning to renewable energy, enhancing transportation efficiency, and addressing waste management comprehensively [2], [10], [12], [38], [39], organizations can significantly mitigate its environmental impact. Collaboration with global and local stakeholders to share best practices and leverage innovations will further bolster efforts to achieve sustainability goals.

5. Conclusion

This study provides a comprehensive evaluation of Ezemvelo KZN Wildlife's (EKZNW) carbon footprint over a five-year period, highlighting significant insights into its greenhouse gas (GHG) emissions. The findings underscore that Scope 2 (electricity usage) contributes the most to EKZNW’s emissions, representing 69% of the total carbon footprint. Scope 1 emissions, driven by fuel usage and stationary combustion, account for an additional 23%. Collectively, these scopes constitute 92% of the organization’s total emissions. Scope 3 emissions, while smaller at 8%, include significant contributors such as water, sewage, and solid waste, which remain crucial for a holistic approach to emission management.

These findings are consistent with broader global patterns in the conservation and tourism industries, where electricity and transportation have persistently high carbon footprints. Comparisons with global standards, such as Acadia National Park in the United States and SANParks in South Africa [2], [15], reveal parallel emission patterns and provide useful insights for EKZNW in implementing proven mitigation techniques. The findings underline the need for conservation organizations such as EKZNW to embrace sustainable energy practices, enhance operational efficiency, and link with global sustainability objectives to prevent climate change impacts.

6. Recommendations

6.1. Energy efficiency and renewable energy adoption

Addressing Scope 2 emissions should be the top focus of EKZNW. Transitioning to renewable energy sources such as solar or wind power can considerably reduce the reliance on coal-generated electricity, which remains South Africa's primary source of emissions [2], [15]. Installing solar panels in high-energy-use buildings, together with battery storage devices, would provide a dependable and sustainable energy source. Furthermore, renovating existing buildings with energy-efficient technologies such as LED lighting and modern HVAC systems can significantly reduce energy use. These approaches are consistent with global best practices, as evidenced by the UK's National Trust and Acadia National Park, where the use of renewable energy has significantly reduced emissions while improving operating sustainability [2], [10], [15].

6.2. Transportation emissions management

Transportation accounts for a significant percentage of Scope 1 emissions because of fuel usage in vehicles used for organizational operations and visitor access. To address this, EKZNW should implement fuel-efficient or electric vehicles throughout its fleet. This change not only lowers emissions but also demonstrates leadership in sustainable operations. Encouraging guests to use shared transportation, such as eco-friendly tour buses, can further reduce travel-related emissions [49]. A similar technique was successfully used at Acadia National Park, where shuttle buses considerably decreased the carbon footprint of visitor transportation. Furthermore, EKZNW should create and promote carbon offset activities, such as tree planting and habitat restoration programs, to counterbalance unavoidable emissions from transportation.

6.3. Emissions reduction initiatives

Although Scope 3 emissions account for a smaller portion of EKZNW's total footprint, mitigating them is crucial to attaining overall sustainability. Priority should be given to improved waste management strategies, such as recycling programs, organic waste composting, and reducing landfill inputs. Water conservation strategies, such as the development of water recycling systems and policies promoting efficient use, can also help reduce emissions. Collaborating with municipalities to improve sewage treatment systems and investigating biogas production as a renewable energy source will further reduce Scope 3 emissions. These projects not only match South Africa's national climate goals but also highlight EKZNW's dedication to improving sustainable methods in conservation management 10], [15], [16].

6.4. Community and stakeholder engagement

Community engagement is critical for promoting sustainable practices within and outside of EKZNW's operations. Collaborating with local communities to create carbon offset programs, such as tree planting campaigns, can help achieve conservation aims while also improving socioeconomic conditions [16]. Education initiatives aimed at raising awareness of sustainable practices can inspire visitors and stakeholders to modify their behaviour. Collaboration with international stakeholders and conservation groups is also critical for exchanging best practices, capitalizing on technical improvements, and increasing EKZNW's capacity for emission monitoring and mitigation. This collaborative strategy ensures that EKZNW's activities are informed by global expertise while also addressing the specific problems of its operating context [10], [16].

By implementing these strategies, EKZNW can position itself as a leader in sustainable conservation management, significantly reducing its carbon footprint while contributing to broader climate change mitigation efforts.

Nomenclature

EKZNW Reserve Conservation	Abbreviations
iMfolozi Game Reserve	IGR
Game Capture	GC
Hluhluwe Game Reserve	HGR
Co-ordinator Law Enforcement, Liaison & Investigation	CLEL&I
Umkhuze Game Reserve	UGR
Tembe/Sileza	T/S
Ithala Reserve	IR
Midmar Nature Reserve	MNR
Ozabeni	O
Weenen Conservation	WC
Hluhluwe Research Centre	HRC
Ndumo Cons	NC
Rhino Security	RS
Ophathe Game Res	OGR
iSimangaliso Law Enforcement & Prosecutions Manager	ILE&PM
Community Conservation	CC
Spioenkop Conservation	SC
Western Shores	WS
Witteberg	W
Community Conservation SZ	CCS
Pongola/Hlathikulu/Swanko Forest	P/H/SF
Chelmsford NR, iNcandu & Richgate	CNI&R
Eco-Advice Marine	EM
Others	Others

EKZNW Commercial Services	Abbreviations
Amatikulu Profit	AP
Business Development	BD
Cape Vidal	CV
Centenary Centre	CC1
Charters Creek	CC2
Chelmsford Camp	CC3
Customer Care and Loyalty	CCAL
Didima	D
Giants Castle	GC
Hilltop	H
Injesuthi Camp	IC
Kamberg Camp	KC
Kosi Bay	KB
KZN-Busingatha Lodge	KL
Lotheni Camp	LC
Mantuma	M1
Maphelana	M2
Marketing & Sales Management	M&SM
Midmar Camp	MC
Monks Cowl Camp	MCC
Mpila	M3
Ndumo Camp	NC
Ntshondwe	N
Ntsikeni Lodge Upgrade	NLU
Oribi Gorge	OG
Phongolo Controlled Hunting Area	PCHA
Reservations	R
RNNP Mahai Camp	RMC
Santa Lucia	SL
Sodwana Bay Resort	SBR
St Lucia Estuary	SLE
Thendele	T
Umlalazi	U
Wagendrift	W

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Competing Interest Statement

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

Data and Materials Accessibility

Supplementary materials and data used in this research are accessible upon request. For access, please contact the corresponding author via *2011037765@ufs4life.ac.za*.

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7. Appendix

Table A. Overview of EKZNW GHG emissions and per capita emissions calculated from the number of employees over the reference period.

Emission Sources per Scope	2014/2015 (TCO_2e)	Per Capita Using 2220 Employees	2015/2016 (TCO_2e)	Per Capita Using 2496 Employees	2016/2017 (TCO_2e)	Per Capita Using 2360 Employees	2017/2018 (TCO_2e)	Per Capita Using 2241 Employees	2018/2019 (TCO_2e)	Per Capita Using 2247 Employees	Annual Average GHG Emissions (TCO_2e) over 5 Years	%	Average Per Capita Using 2313 Employees
Scope 1: Direct emissions													
EKZNW vehicles	52,00	0,02	58,00	0,02	63,00	0,03	58,00	0,03	48,00	0,02	55,80	0,16	0,02
Fuel usage	6102,00	2,75	6828,00	2,74	7450,00	3,16	6895,00	3,08	5666,00	2,52	6588,20	19,37	2,85
Gas	739,00	0,33	766,00	0,31	723,00	0,31	671,00	0,30	545,00	0,24	688,80	2,02	0,30
Generator Diesel	362,00	0,16	476,00	0,19	538,00	0,23	528,00	0,24	563,00	0,25	493,40	1,45	0,21
Total Scope 1 Emissions	7255,00	3,27	8128,00	3,26	8774,00	3,72	8152,00	3,64	6822,00	3,04	7826,20	23,01	3,38
Scope 2: Indirect Emissions													
Electricity	22228,69	10,01	24634,62	9,87	23960,20	10,15	23886,21	10,66	22669,39	10,09	23475,82	69,01	10,15
Total Scope 2 Emissions	22228,69	10,01	24634,62	9,87	23960,20	10,15	23886,21	10,66	22669,39	10,09	23475,82	69,01	10,15
Scope 3: Indirect Emissions													
Water	464,00	0,21	1152,00	0,46	1912,00	0,81	587,00	0,26	322,00	0,14	887,40	2,61	0,38
Sewage	1053,00	0,47	1586,00	0,64	809,00	0,34	1038,00	0,46	766,00	0,34	1050,40	3,09	0,45
Solid Waste	642,00	0,29	412,00	0,17	479,00	0,20	473,00	0,21	511,00	0,23	503,40	1,48	0,22
Hotel Stay	75,00	0,03	54,00	0,02	45,00	0,02	50,00	0,02	106,00	0,05	66,00	0,19	0,03
Flight	229,00	0,10	211,00	0,08	269,00	0,11	192,00	0,09	136,00	0,06	207,40	0,61	0,09
Total Scope 3 Emissions	2463,00	1,11	3415,00	1,37	3514,00	1,49	2340,00	1,04	1841,00	0,82	2714,60	7,98	1,17
Total Emissions per year	31946,69	14,39	36177,62	14,49	36248,20	15,36	34378,21	15,34	31332,39	13,94	34016,62	100,00	14,71