Assessing Carbon Impact: Sustainability Insights from a Hotel Case Study

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***Abstract*— With the increasing population density worldwide and technological advancements, energy consumption has risen, leading to global warming. The carbon footprint measures the total greenhouse gas emissions caused directly or indirectly by individuals, institutions, or products, expressed as the equivalent of tons of carbon dioxide (CO_2). Among human activities contributing significantly to the carbon footprint, the tourism sector, with its energy consumption and associated activities like food usage, involves high levels of consumption. This study calculates the carbon footprint of a hotel in Istanbul by focusing on its highest consumption areas. Contributions to the carbon footprint from various activities such as energy and food consumption, water usage, waste management, and transportation are evaluated. Based on the collected data, the total greenhouse gas emissions of the hotel were calculated in tons of CO_2 equivalent, and the results were discussed.**

***Index Terms*— Global Warming, Greenhouse Gas, Carbon Footprint, Hotel**

I. INTRODUCTION

Since the 1980s, environmental issues have affected nations globally, accelerating the search for solutions to meet present needs without compromising future generations' resources. Sustainability aims to establish a system that ensures equitable distribution of resources across generations, allowing future generations to benefit equally from today's opportunities. In this context, tools like the carbon footprint, which measures human and institutional impacts on nature, have gained importance alongside efforts to address global environmental problems such as climate change, greenhouse effects, and biodiversity loss. Carbon footprint assessment helps quantify the harm caused by consumer and institutional activities to support sustainability efforts.

I.A. Carbon Footprint

The carbon footprint refers to the total greenhouse gas emissions during a product's lifecycle or an activity, expressed as CO_2 equivalent. Carbon dioxide (CO_2), a by-product of metabolizing carbon-containing substances, has a profound impact on global warming despite constituting only 0.03% of the atmosphere. CO_2 is the most prevalent greenhouse gas emitted by human activities. In 2023, global carbon emissions reached record levels, exceeding 40 billion tons, primarily from fossil fuels, as reported by the Global Carbon Project.

I.B. Carbon Footprint in Turkey

In Turkey, greenhouse gas emissions are prominently derived from sectors such as industry, energy production, transportation, and agriculture. The heavy reliance on fossil fuels for energy consumption significantly contributes to the country's carbon footprint. Recent investments in renewable energy and energy efficiency projects have aimed to reduce this impact. In Turkey, the per capita carbon footprint stands at approximately 5.26 tons, surpassing the global average of around 4 tons.

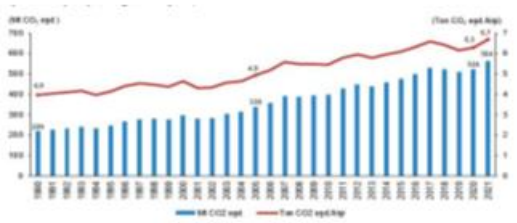

Fig. 1. Carbon footprint change in Turkey.

I.C. Methods to Reduce Carbon Footprint

Renewable Energy Usage: By transitioning to renewable energy sources such as wind turbines or photovoltaic panels, the CO_2 emissions associated with electricity consumption can be reduced significantly.

Recycling: Recycling materials like glass, paper, and aluminum within institutions lowers emissions since reusing materials requires less energy than producing new raw materials.

Switching Fuels: Opting for low-emission fuels or hybrid and electric vehicles reduces emissions from transportation.

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II. MATERIALS AND METHODS

This study selected a four-star hotel in Istanbul, famous for its historical and cultural richness. The selected hotel consists of 13 floors and 164 rooms in total. Not all rooms in the hotel are the same type, there are rooms of different sizes and designs. There are three different room types as standard, superior suite and premium suite. These rooms have 1+0, 1+1 and 2+1 configurations. The hotel was built in 2019 and provides service in a total closed area of 11,520 m2. The hotel area includes 1 restaurant, 2 cafes, 1 kitchen, 1 laundry, 13 various commercial shops with a total area of 1240 m2, 1 children's playground, 1 indoor adult swimming pool, 1 indoor children's swimming pool, 956 m2 garden and walking area, 1 steam room, 1 sauna room, 1 Turkish bath, 1 gym, 1 spa and massage room and 1 nurse and doctor's room. Data on energy, water, and natural gas consumption, along with waste generation, were collected for carbon footprint analysis.

II.A. Room Types and Features

Fig. 2. The appearance of the Hotel under review .

The breakdown of room types and their respective areas is as following Table.1:

TABLE I : Room Features of the Hotel Studied

Room Type	**Quantity**	**Configuration**	**Area (m²)**	**Total Area (m²)**
Standard	62	1+0	34	2,108
Superior Suite	83	1+1	54	4,482
Premium Suite	13	2+1	78	1,014
King Suite	6	1+1	38	228
Total	**164**			**7,832**

II.B. Hotel Accommodation and Staff Information

Thanks to special agreements established with various health institutions, the hotel ensures that patients from abroad and their companions have a comfortable treatment process. It also offers a unique accommodation experience for tourists from all over the world. With a total of 81 staff working at the hotel, high-level service quality is provided to both guests from the health sector and tourists.

TABLE 2 : Occupancy rate and number of staff of the inspected hotel over the years

Years	Number of Guests	Hotel Occupancy Rate (%)	Number of Staff	Number of Overnight Stays
2021	101,841	77.68	70	45,780
2022	110,257	90.2	75	53,397
2023	81,155	71.88	77	48,107

The data table in Table.2 presents the performance indicators of the hotel business for the years 2021, 2022 and 2023; The hotel started with 101841 guests and 77.68% occupancy rate in 2021, reached its peak with 110257 guests and 90.2% occupancy rate in 2022, but in 2023 the number of guests decreased to 81155 and the occupancy rate to 71.88%; the number of staff increased by 70 in 2021, 75 in 2022 and 77 in 2023, and the number of overnight guests were 45780, 53397 and 48107, respectively.

This data table, covering the period from January to December, details various performance metrics of the hotel business, such as the number of room nights, number of guest nights, number of beds sold, number of rooms sold, and number of staff. Starting with 4965 room nights and 7169 guest nights in January, the hotel business achieved its highest number of guests in July with 10224 guests, during which time the number of beds sold was recorded as 5112 and the number of rooms sold was recorded as 2300, while the number of staff remained constant throughout the year and was determined as 77 people per month.

In addition, a significant increase was observed in the number of overnight guests and the number of rooms sold during the summer months, and it is understood that the occupancy rates of the business peaked especially in July and August, and this situation occurred in parallel with the seasonal tourist flow. In December, the number of overnight rooms was recorded as 2980, the number of overnight guests was 5338, the number of beds sold was 2669 and the number of rooms sold was 1201, and these data reveal that there are seasonal fluctuations and demand changes in terms of annual performance evaluation in the hotel business.

TABLE 3: Hotel occupancy rate and number of staff over the years

Months	Number of Overnight Rooms	Number of Overnight Guests	Number of Beds Sold	Number of Rooms Sold	Number of Staff
January	4,965	7,169	3,585	1,613	77
February	4,481	5,900	2,950	1,328	77
March	4,883	6,110	3,055	1,375	77
April	4,618	5,913	2,957	1,330	77
May	3,831	6,911	3,456	1,555	77
June	3,894	7,488	3,744	1,685	77
July	4,603	10,224	5,112	2,300	77
August	3,625	7,631	3,816	1,717	77
September	3,430	6,161	3,081	1,386	77
October	3,480	6,512	3,256	1,465	77
November	3,317	5,798	2,899	1,305	77
December	2,980	5,338	2,669	1,201	77

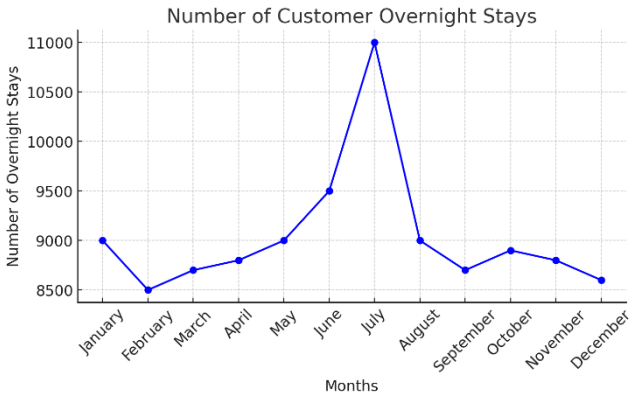

Fig. 3. Change in the number of guest nights of the hotel in question in 2023.

II.B. Data Collection

The study collected monthly data from the hotel to analyze its carbon footprint. Key areas of focus included:

Energy Consumption: Monthly electricity and natural gas usage.

Water Usage: Total water consumption across the hotel, including guest and operational usage.

Waste Management: Types and amounts of waste generated, including recyclable and non-recyclable materials.

III. RESULTS AND DISCUSSION

III.A. Energy Consumption and Carbon FootPrint Analysis

1. **Electricity Usage:** The hotel's electricity consumption exhibited seasonal fluctuations, with the highest usage recorded during summer months due to increased air conditioning demands. In 2023, electricity-related carbon emissions peaked in July, reaching approximately **60,000 kg CO_2**.

2. **Water Usage:** Efficient water management practices significantly impact the carbon footprint. The hotel's water consumption generated a carbon footprint of **100,737 kg CO_2** in 2022. Following the implementation of conservation measures, this was reduced to **95,995 kg CO_2** in 2023.

3. **Natural Gas Usage:** Natural gas consumption showed a marked increase during winter months due to heating requirements. In 2023, the total emissions from natural gas usage were calculated at **389,594 kg CO_2**, with the highest emissions recorded in January and February.

In this section, carbon footprint calculations were made for 2022 and 2023 based on electricity, water and natural gas consumption.

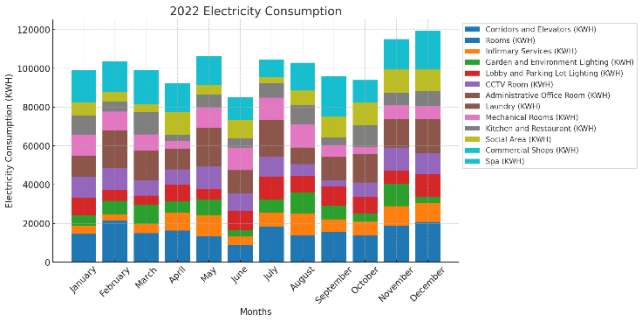

Fig. 4. Energy consumption distribution for 2022

In 2022, the carbon footprint due to electricity consumption reached its highest level in July and August. Throughout the year, the carbon footprint varied in parallel with the fluctuations in electricity consumption. The carbon footprint was at its highest level in July, at approximately 50,000 kg CO2 eq./fu.

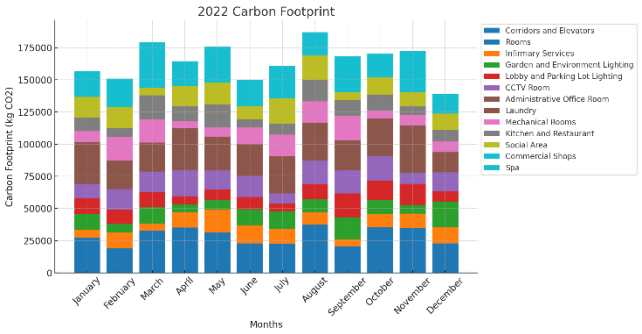

Fig. 5. Carbon Footprint distribution for 2022

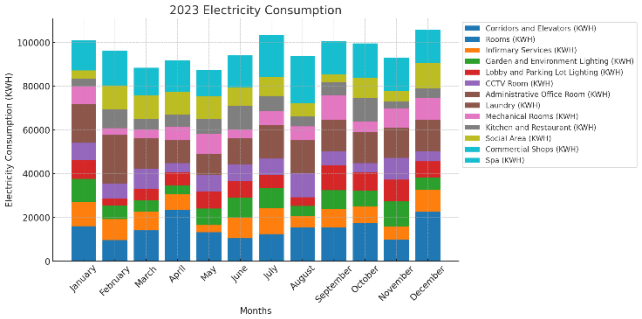

Fig. 6. Energy consumption distribution for 2023

III.B. Waste Management and Recycling

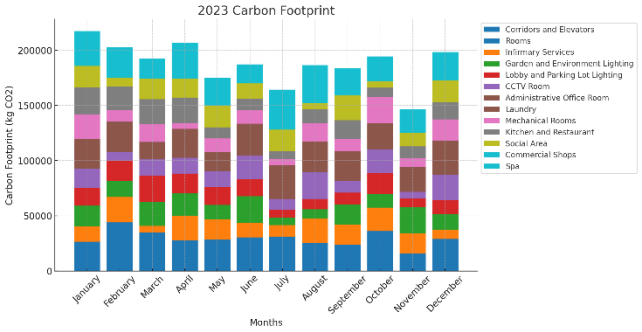

Fig. 7. Carbon Footprint distribution for 2023

In 2023, the carbon footprint increased in parallel with the increase in electricity consumption. In January and July, the carbon footprint started at a higher level than in 2022 and reached its highest level in July. In 2023, the carbon footprint was approximately 60,000 kg CO2 eq./f.u in July.

III.B Carbon Footprint Due to Water Consumption

Efficient use of water resources is of great importance for environmental sustainability. In businesses with high water consumption, such as hotels, monitoring and management of water consumption plays a critical role in both keeping costs under control and reducing environmental impact. In this study, a hotel's water consumption data for 2022 and 2023 and the effects of this use on its carbon footprint were comparatively analyzed.

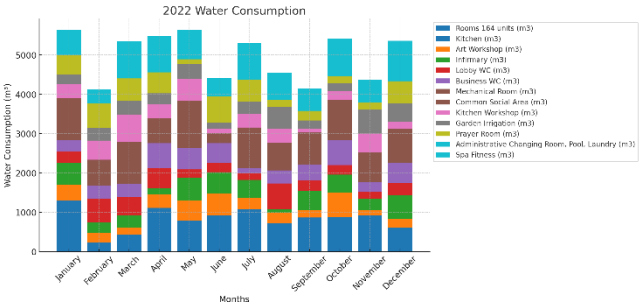

Fig. 8. Water consumption distribution for 2022

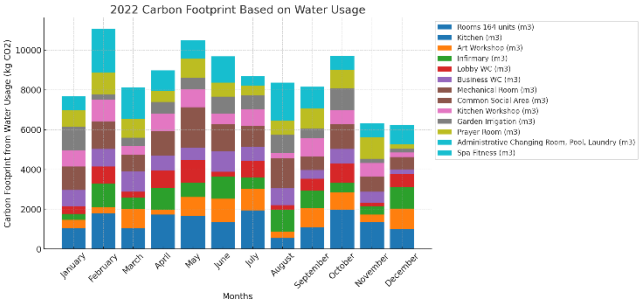

Fig. 9. Carbon Footprint distribution due to Water Consumption in 2022

The carbon footprint due to water use in 2022 was 100,737 kg, reaching its highest level in July and August. Throughout the year, the carbon footprint varied by month and peaked in July.

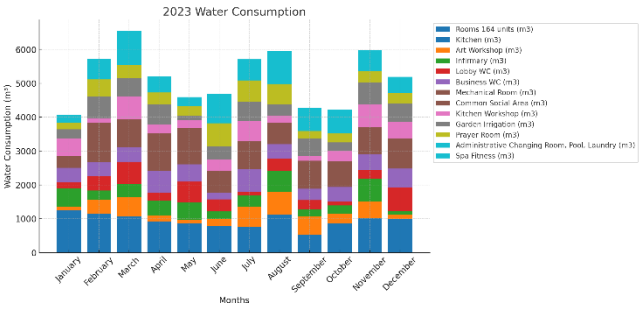

Fig. 10. Water consumption distribution for 2023

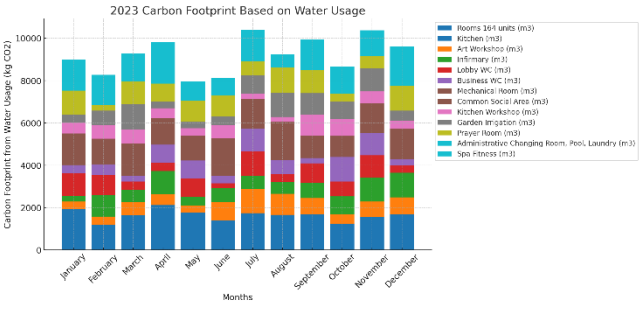

Fig. 11. Carbon Footprint distribution due to Water Consumption in 2023

The carbon footprint due to water consumption in 2023 was 95,995 kg, which decreased in parallel with the decrease in water consumption. In January, the carbon footprint started at a higher level than in 2022, but remained at lower levels throughout the year. The highest level was reached in July, but lower carbon footprint levels were observed overall compared to 2022.

III.C. Carbon Footprint Due to Natural Gas Consumption

The carbon footprint in 2023 is 389,594 kg, which is high in January and February and reaches its peak in March. It decreases in April and May, and decreases to lower levels in the summer months. It increases again in November and December, reaching its highest levels at the end of the year. The carbon footprint due to natural gas consumption in 2022 is 449,047 kg, which is high in January and February. The carbon footprint reaches its highest point in March. The carbon footprint decreases from May onwards and reaches its lowest levels in the summer months (June, July, August). It increases again in the autumn (September and October) and rises in November and December.

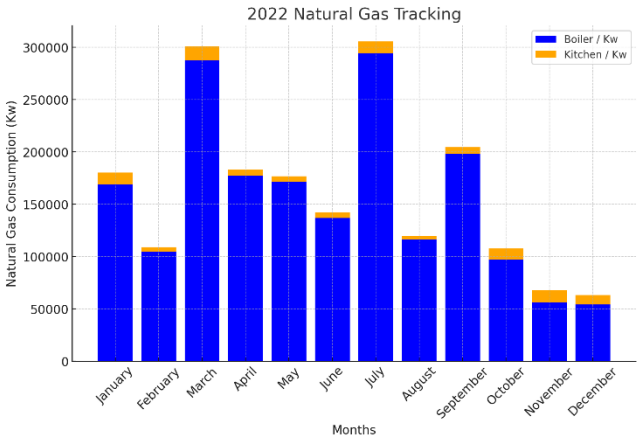

Fig. 12. Natural Gas consumption distribution for 2022

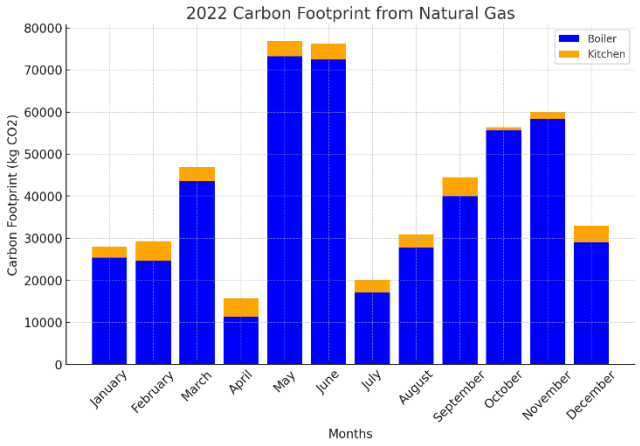

Fig.13. Carbon Footprint distribution due to Natural Gas Consumption in 2022

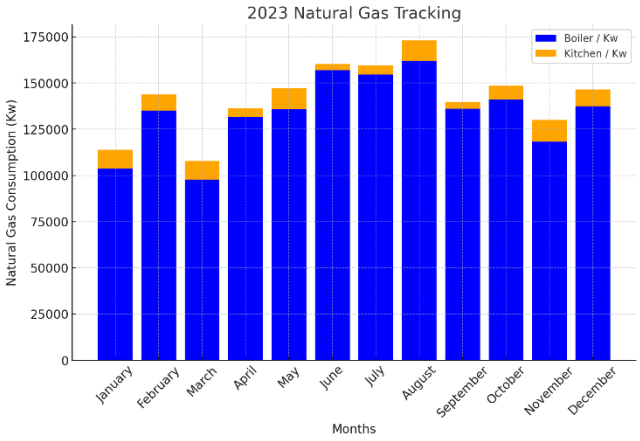

Fig. 14. Natural Gas consumption distribution for 2023

The hotel's waste management practices contributed to its overall carbon footprint. By implementing recycling programs for materials such as paper, glass, and plastics, the hotel reduced emissions associated with waste disposal and resource extraction.

III.D. Transportation Impact

Transportation for logistics, guest arrivals, and staff commutes was another contributor to the carbon footprint. Transitioning to low-emission vehicles or optimizing transportation routes can help mitigate this impact.

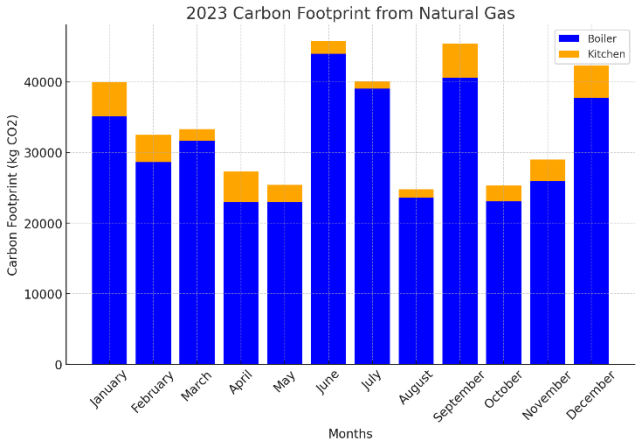

Fig. 15. Carbon Footprint distribution due to Natural Gas Consumption in 2023

III.E. Overall Carbon Footprint

The total carbon footprint of the hotel was calculated by aggregating emissions from electricity, water, natural gas, waste management, and transportation. The data indicates that energy consumption remains the largest contributor, followed by water usage and waste generation.

III. DATA-DRIVEN CONCLUSIONS

In this study, the carbon footprint of a hotel located in Istanbul was investigated. While calculating the carbon footprint, the hotel's recent water consumption, electricity consumption, natural gas consumption and waste consumption were taken as basis. Researching the carbon footprint plays an important role in determining the measures that can reduce the carbon footprint.

- Water Consumption

In 2022, the total water consumption was 100,737 kg and the carbon footprint due to water use reached the highest level in July and August. The carbon footprint varied by month throughout the year and peaked in July. In 2023, the carbon footprint was 95,995 kg and decreased in parallel with the decrease in water consumption. In January, the carbon footprint started at a higher level compared to 2022 but remained at lower levels throughout the year.

- Electricity Consumption

In terms of carbon footprint, the increased electricity consumption in 2023 also caused a significant increase in the carbon footprint. This situation shows that more effective energy management strategies should be developed to reduce the environmental impact of electricity consumption.

- Natural Gas Consumption

Natural gas consumption is high in the winter months (January, February, March) and decreases in the summer months (June, July, August) in both 2022 and 2023. Similar high consumption levels are observed in December of both years. In 2023, higher consumption is observed in some months (especially August and November) compared to 2022.

IV. RECOMMENDATIONS

Based on the findings, the following measures are recommended to reduce the hotel's carbon footprint and improve sustainability:

1. **Install Solar Panels:**
   - Utilizing solar panels for electricity generation can significantly reduce dependency on fossil fuels and lower energy costs.
   - This renewable energy source can offset emissions from electricity consumption.
2. **Implement Smart Thermostats:**
   - Smart thermostats can optimize heating and cooling systems by adjusting temperatures according to occupancy and weather conditions.
   - This measure minimizes unnecessary energy use, particularly during low-occupancy periods.
3. **Improve Insulation:**
   - Enhancing insulation in walls, windows, and doors can reduce heating and cooling losses, decreasing energy consumption for maintaining indoor comfort.
4. **Adopt Water-Saving Fixtures:**
   - Installing low-flow faucets, showerheads, and dual-flush toilets can reduce water usage by **30-50%** without compromising guest satisfaction.
   - This measure also indirectly reduces emissions related to water heating and treatment.
5. **Establish Recycling Programs:**
   - Encouraging recycling for glass, paper, and plastic can decrease waste sent to landfills and reduce emissions from raw material production.
   - Providing clear instructions and designated bins for recycling improves participation.
6. **Promote Employee and Guest Awareness:**
   - Conducting training programs for employees and providing information to guests about energy and water conservation practices can enhance sustainability efforts.

- Small behavioral changes, such as turning off lights or reusing towels, can collectively make a significant impact.

7. **Invest in Low-Emission Transportation:**

- Transitioning to electric or hybrid vehicles for guest shuttles and staff transportation can reduce emissions associated with travel.
- Collaborating with local transportation providers to offer greener options for guests is another viable solution.

V. CONCLUSION

This study highlights the importance of calculating and analyzing the carbon footprint of a hotel to identify key areas for improvement in energy efficiency and sustainability. The findings emphasize that energy consumption, water usage, and waste management are the primary contributors to the carbon footprint. By implementing the proposed measures, such as adopting renewable energy sources, improving insulation, optimizing resource usage, and promoting recycling programs, the hotel can significantly reduce its environmental impact. These actions not only help achieve sustainability goals but also enhance operational efficiency and cost savings, providing a competitive advantage in the tourism sector. Moreover, the strategies outlined in this study can serve as a model for other establishments in the hospitality industry, contributing to broader efforts to mitigate climate change. As global awareness of environmental issues continues to grow, adopting sustainable practices will become increasingly crucial for businesses seeking to align with consumer expectations and regulatory requirements.

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