

Sustainable Food Waste Management in the Hospitality Industry: Innovations and Best Practices

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Abstract: *The tourism industry plays a significant role in the economic and social development of many countries. However, it also presents considerable environmental challenges. In particular, the hospitality sector, which is an essential part of tourism, is under increasing pressure to adopt sustainable practices due to the growing impact of tourism on natural resources and ecosystems. In response to consumer demands for eco-friendly products and services, hotels are now implementing environmental management practices to stay competitive. This paper examines the current food waste management practices in the hotel industry, showcasing case studies and technological advancements, including AI tools, to highlight best practices and innovative solutions. The purpose is to provide insights into sustainable food waste management and contribute to the overall environmental sustainability of the hospitality industry.*

Key Word: *sustainability; green practices; hotel operations; food waste.*

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I. Introduction

Tourism is an integral part of economic and social development efforts in many countries around the globe. Tourism's economic impact goes beyond generating income and employment. It helps drive growth, stimulates investment in infrastructure, promotes sustainable development and helps preserve cultural and natural heritage. Tourism is fundamental to global economic development because of these multiple impacts. However, the industry brings about various environmental challenges [1]. The increasing tourism activity applies substantial pressure on natural resources and ecosystems throughout its entire value chain. Driven by the augmenting demand for environmental stewardship, the hospitality sector is placing more emphasis on environmental management practices [2], with an increasing number of hotels adopting a multitude of existing available alternatives. This has not only to do with preserving and promoting environmental health [3-5], but also with gaining a competitive edge [6,7]. There is a growing trend of consumers who prefer environmental products and services [8]. It is common, nowadays, that tourists' environmental concerns influence their choice of hotel, with many seeking environmentally friendly accommodation and sometimes willing to pay extra for this choice [9-11]. In the past, environmental concerns were often overlooked in favor of profitability. However, increasing social pressures and environmental regulations have compelled hospitality organizations to manage their environmental systems actively [12]. Furthermore, government-imposed environmental regulations and rising consumer awareness of environmental issues have prompted the hospitality and tourism industry to reassess its practices [13].

The concept of green accommodation, that has emerged thereafter, refers to hotels committed to environmental preservation [14]. Green hotels are expected to adopt environmentally friendly policies and practices, such as conserving electricity and water, reducing emissions, and minimizing solid waste [15,16]. Hospitality brands seeking green accommodation certification are those that prioritize the conservation of natural resources and the reduction of greenhouse gas emissions [17]. The main reason for implementing green practices in the hospitality industry is to achieve profitability [18,19] through cost reduction and ensure long-term financial gains rather than solely focusing on environmental benefits. Research has shown that, indeed, green initiatives can lead to profitability, employee and customer loyalty, and effective risk management [20].

It is widely acknowledged that hotels contribute significantly to waste generation, producing substantial amounts of solid, food, and other forms of waste [21,22]. Studies have estimated that approximately 1.6 kg of waste is produced per tourist per day [23], resulting in the tourism industry generating over 35 million tons of solid waste annually [24]. Minimizing food waste enables hotels to conserve resources, energy, and money spent on food procurement, water usage, and labor costs related to food processing and disposal [25,26].

This paper examines current practices for reducing and managing food waste in the hotel industry. It aims to provide a comprehensive understanding of the benefits and challenges of sustainable hotel operations. It also uses case studies to showcase effective food waste strategies, explores technological advancements, and examines the use of AI tools to highlight best practices and innovative solutions for food waste management in hotels. Through

this analysis, the paper aims to offer insights into sustainable food waste management practices that can improve the environmental sustainability of the hospitality industry.

II. Food Waste Management in the Hotel Industry

Hotels play a significant role in waste generation, producing various waste materials such as glass, aluminum, steel, plastics, food, and cardboard [27,28]. Organic waste [22] and household waste are among the primary sources of waste, including food/kitchen waste, food preparations, leftover food, and further discarded materials [29,30]. The food service segment contributes the largest portion of hotel waste [31], particularly from food and beverage service areas where various solid and organic waste is produced. To address this issue, common practices that have been developed include implementing new kitchen processes at the planning stage [32], regular stock control using the First In, First Out method at the handling stage [33] and offering à la carte services instead of buffets at the restaurant operation [34].

The hospitality industry, including hotels and restaurants, is estimated to generate substantial amounts of waste, with hotels alone producing about 160–200 kg of CO₂ per square meter [35]. On average, a hotel guest can produce 1 kg of waste a day, amounting to thousands of tons of waste annually [36,37]. Additionally, hotels consume large amounts of water, energy, and non-durable products [38].

It is important to note that hotels generate significantly different amounts of waste daily. This difference can be linked to factors such as the size and type of the hotel, the activities of guests and staff, and the characteristics of the guests [30,39]. For instance, guests at a four-star hotel tend to produce more waste than those at one—or three-star hotels. High-rated hotels have higher waste generation rates [40,41], and this difference can be attributed to the hotel's spending on each guest or the specific attributes of the guests. Furthermore, the increasing number of tourists is leading to a rise in solid food waste [42], highlighting the need for sustainable waste management strategies.

By identifying and addressing the various types of waste generated by hotels, sustainable practices can be implemented to promote waste reduction in hotel operations [43].

Stakeholders need to be aware of waste management measures [44]. This requires involvement not only from the establishment's staff at different operation stages (front-of-house and back-of-house) but also from the management. Additionally, management must produce strategies to encourage guests to minimize waste production [30] and face challenges concerning their behavior. Research suggests that water conservation and waste management increase guests' environmental awareness [45], leading them to adopt green practices when staying in eco-friendly hotels [46].

In drafting an environmental management policy, hotels should prioritize green purchasing, eco-labeling, certification, waste management, and recycling [47]. Simultaneously, policymakers must develop sustainable strategies suitable for the community and integrate them with responsible practices [48]. The public sector can promote responsible tourism by facilitating the engagement of industry stakeholders through the provision of educational resources, financial incentives, marketing support, and access to social networking platforms [49]. This approach aims to effectively raise public awareness and shift the public's perception of unsustainable tourism practices towards more environmentally friendly alternatives [50].

Currently, many hotel facilities lack behind on measures to reduce their environmental impact. This phenomenon mainly occurs in small hotels, which tend to envisage such measures as secondary targets [51]. Small hotels typically produce minimal waste, which may not meet the waste collection quantity requirements of recycling companies [51,52]. Furthermore, while developed countries have shown gradual progress in implementing practices and tools for food waste management, there remains a significant gap between sustainable innovation and recycling practices in the hospitality industry in developing economies [53].

As a major driver for change, prevention and proper management of food waste can lead to increased revenues and decreased operational costs [54,55]. Additionally, reducing food waste can enhance the accommodation's reputation and image among competitors [56]. However, managers must overcome negative perceptions about food waste initiatives, concerns about using leftovers, and the need to reduce food waste while maintaining value and customer satisfaction [57].

a. Reducing Food Waste in Hotel Operations

The significance of food loss and food waste has grown substantially during the last decade [58]. Reducing food waste is a crucial part of making the food system more sustainable hence, it is specifically highlighted in the UN Sustainable Development Goals [59].

Food waste is edible food that is discarded [60] and food that spoils before disposal [61] due to operational inefficiencies or irresponsible behavior of food providers and consumers [62].

In the hospitality industry, avoidable food waste represents the sole category of food waste that remains within the control of food service providers, either entirely or to a big percentage. This waste results from

inefficient transportation, inadequate storage facilities, and suboptimal preparation techniques [63]. It also includes edible portions not consumed after a meal, known as plate waste [64].

However, managing external factors, such as unanticipated guest absences [65], presents challenges. This is particularly crucial when planning a menu, especially for hotels offering buffets. It involves estimating food demand based on guest numbers, maintaining accurate product inventory, and meticulously organizing and arranging ingredients for food preparation [66]. A fundamental component of an effective intervention entails measuring and monitoring food waste. The absence of a standardized methodology for quantifying food waste is also a significant challenge regarding comparing results from different organizations [66].

The Food Loss and Waste Accounting and Reporting Standard [67] has been used to find a balance between the resources used for waste quantification and the data's importance, completeness, consistency, transparency, and accuracy. The standard can help determine effective measures for waste prevention and monitor the performance of those measures [63, 66]. Conducting a detailed waste quantification in each kitchen is recommended due to the unique reasons for food waste. This approach can uncover different opportunities to reduce waste [68]. Waste analytics generate valuable information by directly weighing discarded food at its source. The data collected can help optimize food management and streamline related planning and preparation processes. Recent research has extended the quantification methodology to illustrate the comparative evaluation and design of disparate datasets within a unified framework [69]. However, there are no specific recommendations regarding the categories to be recorded or the duration for which food waste should be quantified in order to support waste reduction efforts. [69].

Today, many businesses use food waste tracking systems to help kitchens measure their food waste. These tracking tools have similar basic functions but can differ in their additional services, such as employee training or creating customized waste reduction plans. Other variances include optional features like taking photos of the waste and using artificial intelligence to identify different food waste items automatically. Some efforts have been made to use artificial intelligence and machine learning to predict and model waste generation rates in the hotel industry, to address waste management challenges in hotels [70].

The management of food waste in culinary practices is characterized by two primary factors: preparing excessive amounts of food [71] and inadequate knowledge of utilizing leftovers [72]. Installing measuring devices in kitchen facilities necessitates additional responsibilities, as culinary staff must weigh and document discarded food items, leading to reduced food waste [73]. This methodological approach facilitates the precise determination of food quantities for culinary endeavors [74]. Furthermore, implementing educational interventions is essential for proficiently managing and assessing the edibility of leftover food items [75].

The hotel sector has often considered food waste management as a marketing mechanism [76] redistributing unsold or surplus food [77,78] by selling it at a lower price, donating it to underprivileged people, reusing it for consumption by employees or as “doggy bags” [79]. Leftover food that can no longer be consumed is recycled [80] and used for composting or, in some cases, used in fish food [81,82].

Moreover, by leveraging technology such as digital platforms and mobile apps, innovative opportunities exist to sell unsold and surplus food to consumers at discounted prices [53]. Companies could repurpose this surplus food for use as pet and animal feed, high-value products, or bioenergy production [83].

Reducing food waste not only provides savings for consumers and businesses but also facilitates the recovery and distribution of surplus food, which could lead to the generation of nutrients, feed, and secondary raw materials [84].

b. Recycling and Composting Initiatives in Hotels

The hospitality industry is emphasizing on sustainability, with recycling and composting initiatives becoming crucial for responsible environmental practices in hotels. There has been a call for adopting circular economy models as an alternative way to manage, recycle, and reuse resources and waste in the tourism sector, particularly within the hotel industry [85,86]. The hotel industry is a significant contributor of organic/wet waste to landfills, which is a leading cause of greenhouse gas (GHG) emissions. A sizable hotel can produce up to eight tons of waste daily, with approximately 60 percent of this waste being recyclable [87]. Implementing recycling programs for these materials can divert them from landfills and promote a circular economy within the hotel industry. A recent study [88] found that landfilling produces more greenhouse gases than incineration and recycling, which is consistently the more effective option (see Figure 2).

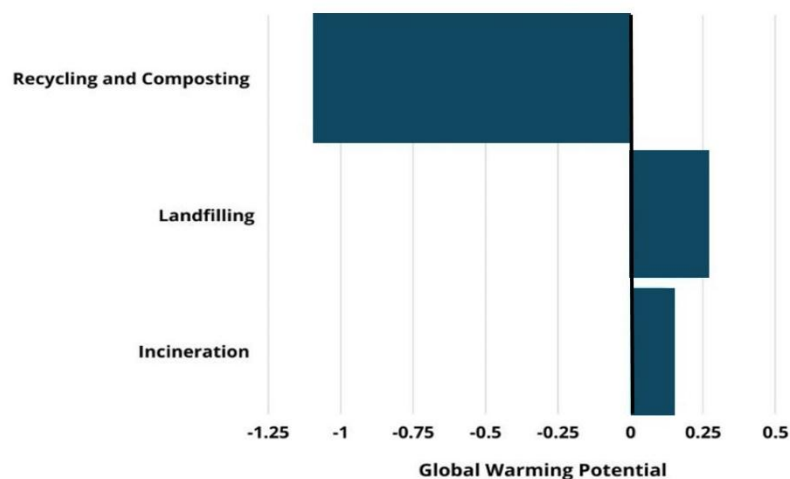


Figure 1: Global Warming Potential for recycling/composting, landfilling, incineration adapted from Yaman et al., 2020 [88].

According to this research, recycling helps to reduce carbon emissions, with metals providing the largest savings. It is important to note that the study did not factor in the transportation and operating costs of recycling plants, incinerators, and landfills. For recycling to effectively combat climate change, it should be integrated into a comprehensive, minimalist, and energy-efficient waste management approach.

Recycling has been proven beneficial for organic waste management in the hospitality industry, particularly for high and average-scale hotels in developed countries [89,90]. Even though small hotels produce a lot of recyclable waste such as plant material, food scraps, and paper products, they still encounter challenges when it comes to recycling [90].

Composting is a highly recommended waste management practice in the hospitality industry. This process involves the decomposition of organic and biodegradable waste materials to produce compost or manure. The compost generated can be utilized in hotel farms to cultivate agricultural products for use within the hotel, and it can also be sold to generate revenue [91]. The application of compost can substitute for fertilizers and peat, thereby avoiding the impacts of industrial fertilizer production and peat extraction, as well as reducing related global greenhouse gas emissions. This approach can also positively impact local economies [92]. Despite the numerous benefits of composting, it is the least practiced waste management method in hotels. This finding could be attributed, among other factors, to the lack of required resources and the associated costs [93]. The challenge of resources can be addressed by establishing community-level, small-scale composting projects through teamwork and partnerships with relevant stakeholders in the local communities or beyond.

Several factors influence a property's waste management practices and its incorporation of recycling and composting. These factors encompass the property's location, the types of recycled materials, and the area's availability of sorting and recycling facilities. The success of a recycling program hinges on the availability of buy-back centers, waste management contractors' willingness to participate in recycling initiatives, and effective employee education programs [94]. By assessing the social costs and benefits associated with recycling and composting programs, hotels can improve their environmental impact and establish themselves as leaders in sustainable hotel operations.

III. Case Studies

a. Marriott International's Waste Reduction Program – A Successful Hotel Initiative

Marriott International has initiated a comprehensive and ambitious effort to decrease food waste across its vast portfolio of over 6,500 hotels. Their goal is to have all hotels certified to a recognized sustainability standard, as well as achieve a 50 percent reduction in food waste by 2025 (from a 2016 baseline) [95].

The company [96] has stated that it is developing comprehensive resources to support this initiative. These resources will cover baseline awareness, guidance on how to get started, best practices, source reduction, technology, donation, and landfill diversion. With this holistic approach, Marriott ensures that it addresses all facets of food waste management, from raising initial awareness to implementing advanced practices like landfill diversion.

The company also emphasizes the need for continuous learning and adaptation to drive the company to innovate in addressing food waste. Employees' engagement and ongoing education are necessary for achieving food waste reduction goals. Moreover, technology seems important in Marriott's strategy. By integrating technological solutions as part of its resources, including advanced tools like waste tracking systems and data analytics, Marriott can accurately identify sources of waste and implement targeted interventions. In a testament to its commitment to collective action, Marriott is fostering collaborations with its largest customers to explore and test joint solutions for food waste reduction. This collaborative approach not only enhances Marriott's efforts but also fosters a broader industry-wide movement towards sustainability.

Marriott attests that intends to continue using the Hotel Waste Measurement Methodology (HWMM) throughout its worldwide hotel portfolio to track its advancements toward the 2025 waste reduction targets. To further this objective, the company will continue implementing waste reduction programs. For instance, in 2023, Marriott launched a global Food Waste Reduction Rally to inspire hotels to adopt and exchange food waste reduction techniques and data.

Marriott produces a Serve 360 Report annually, outlining its sustainability and social impact progress. The company actively involves customers in supporting its Serve 360 Goals and ESG strategy by providing environmental and social data, collaborating on sustainability practices, and sharing information on diversity, equity, and inclusion (DEI) programs.

Table 1: 2023 SERVE 360 REPORT Reducing Food Waste Global Highlights for 2022 [95].

Country	Action implemented
Indonesia	18 hotels collaborated with a food rescue application to facilitate the purchase of surplus meals from restaurants, hotels, and other food retailers, reducing over 100 kg of food waste.
Thailand	27 hotels donated over 33,000 kg of food and surplus items to Scholars of Sustenance (SOS).
Brazil	The Renaissance® São Paulo Hotel diverted more than 7,000 kg of organic waste from landfills using biodigester.
China	A pilot program using big data and artificial intelligence technologies to monitor, manage, and mitigate food waste across 30 hotels reduced nearly 11,000 kg of food waste across nine participating hotels.
UAE	The Ritz-Carlton® Ras Al Khaimah, Al Wadi Desert reused over 2,000 kg of fruit and vegetable peels in the first seven months of 2022.

b. Hilton's Green Ramadan and Green Breakfast Program - Innovative Technologies and Approaches

Hilton is a major global hospitality company with over 7,500 properties and 213 million guests as of 2023 [97]. In 2018, Hilton set a goal for 2030 called "Travel with Purpose," which aims to promote responsible travel and tourism aligned with the United Nations' Sustainable Development Goals and the Paris Climate Agreement. Under this initiative, Hilton aims to have a positive environmental and social impact across its operations, supply chain, and communities. One of its goals for 2030 is to reduce landfilled waste intensity in its managed operations by 50% based on 2008 levels.

To support these goals, Hilton has partnered with organizations such as the United Nations Environment Programme (UNEP) West Asia, Winnow, and Goumbook to launch initiatives to reduce food waste and improve sustainability. In the Middle East, Hilton has introduced Green Ramadan and Green Breakfast initiatives to minimize waste, promote local sourcing, and reduce food waste during religious and social festivities.

The Green Ramadan initiative, first introduced in 2023 in hotels in Qatar, the UAE, and Saudi Arabia, aims to reduce food waste during the holy month of Ramadan, aligning with Hilton's Travel with Purpose 2030 Goals. Reports from UNEP West Asia show that food waste in the region increases by 25% - 50% during religious and social festivities [98]. In response, Hilton is implementing measures to minimize waste and raise awareness about local sourcing and food waste. Participating hotels are implementing measures such as composting food waste, sourcing food locally, promoting plant-based dishes, reducing plastic use, and collaborating with food banks. Additionally, Hilton is utilizing Winnow's AI technology to track food waste and predict future needs.

In the UAE, Hilton has introduced an innovative Green Breakfast initiative across 13 hotels to reduce food waste in breakfast service substantially. This initiative is the first of its kind and serves as a model for food waste management in the region's hospitality sector. Each participating hotel has installed Winnow AI systems to monitor production, plate waste, and behavioral nudges and interventions. The project also involves composting, local sourcing, sustainable gastronomy, and food donations.

- During the Green Ramadan campaign in 2024, food waste was reduced by an additional 21% compared to the 61% reduction achieved in Green Ramadan 2023. This means that more than 1.7 tons of food waste were avoided, which could have provided 4,300 meals. Additionally, over 7.4 tons of CO2 emissions were

prevented. As part of the initiative, 50 to 90 portions of food were donated daily, and the remaining waste was composted for local farms. This approach ensured that no edible food was wasted [99].

- The pilot Green Breakfast initiative's implementation yielded a 62% reduction in pre- and post-consumer food waste. This reduction will provide more than 400,000 meals and prevent nearly 726 tons of CO₂ emissions annually. Specifically, pre-consumer waste was reduced by over 76%, while post-consumer waste decreased by 55%. The analysis revealed that bread and pastries were the most commonly discarded items among post-consumer waste, prompting targeted interventions such as portion and size adjustments [97].
- Implementing Winnow in 24 countries has enabled Hilton Hotels to achieve annual savings exceeding \$2 million. 96 Hilton hotels globally have adopted Winnow, a food waste measurement system, to precisely quantify and oversee their food waste. As of the end of 2023, this initiative had reduced 2,050 tons of CO₂e [97].

IV. Summary of Key Findings

Several factors significantly influence waste management in hotel operations. These factors include unit characteristics such as location, size, services offered, and the hotel type based on its rating.

Integrating smart technologies, such as IoT and artificial intelligence, improves efficiency and personalization in waste reduction by enabling continuous monitoring and evaluation. Recycling is an effective practice for sustainable operations and plays a crucial role in waste management through reusing and composting. These practices can substantially decrease environmental impacts and operating costs. Government and industry interventions, such as financial incentives and education, can enhance waste management practices.

Employee and consumer behavior are crucial in shaping sustainable and circular practices, ensuring the long-term success of businesses and infrastructure [100]. Analysis of individuals' awareness of such issues reveals the key to sustainability and circularity [101]. Engaging guests through educational initiatives and incentives has been identified as a critical factor in encouraging sustainable behaviors and promoting a culture of environmental responsibility in the hotel industry.

The case studies of Marriott International and Hilton illustrate the significant steps the hospitality industry can make toward sustainability through comprehensive waste management initiatives. Marriott's ambitious goals and holistic approach, encompassing baseline awareness, technological integration, and collaborative efforts, highlight the importance of a multi-faceted strategy in addressing food waste. The company's global initiatives and measurable successes in reducing food waste demonstrate how large-scale implementation and continuous learning can drive substantial environmental benefits.

Similarly, Hilton's Green Ramadan and Green Breakfast programs showcase the effectiveness of innovative technologies and local sourcing in minimizing food waste. Hilton has remarkably reduced food waste and CO₂ emissions by utilizing AI-powered systems and fostering partnerships with environmental organizations.

Both companies emphasize the vital role of employee engagement, ongoing education, and stakeholder collaboration in achieving sustainability goals. Their initiatives not only contribute to environmental conservation but also enhance their reputations as leaders in responsible tourism. These efforts exemplify how the hospitality sector can adopt sustainable practices, making a significant impact on global food waste reduction and promoting a greener future for the industry.

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