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Food Waste Reduction as a Strategy for Enhancing Global Food Security: A Narrative Review of Policy and Practice

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ABSTRACT: Food waste poses a critical threat to food security, environmental sustainability, and economic efficiency worldwide. This study aims to explore how food waste reduction strategies contribute to enhancing global food security through a comprehensive narrative review. A systematic search of peer-reviewed literature was conducted across databases including Scopus, PubMed, and Google Scholar, targeting studies published between 2010 and 2024. The review focused on five thematic areas: public policies and regulations, technological and logistical innovations, behavioral change interventions, food redistribution networks, and circular economy practices. Findings show that while legislative frameworks in countries like France, South Korea, and Denmark have significantly advanced national food waste reduction efforts, persistent challenges remain due to policy fragmentation and cultural norms. Technological interventions such as IoT, cold chain logistics, and digital inventory systems have proven effective in reducing post-harvest losses, while behavioral campaigns and mobile applications demonstrate potential in changing consumer habits. Food banks and valorization techniques further contribute to waste recovery and resource optimization. Despite these successes, disparities in infrastructure, governance coherence, and nutritional adequacy of redistributed food present ongoing barriers. Integrating food waste reduction into national strategies that align environmental, economic, and health objectives will be essential. This review underscores the importance of multi-sector collaboration, innovation, and inclusive policy-making in addressing food waste as a pathway toward sustainable and secure food systems.

Keywords: Food Waste Reduction, Global Food Security, Circular Economy, Food Policy, Sustainability, Behavioral Intervention, Supply Chain Innovation.

INTRODUCTION

Food waste constitutes a critical challenge in the global food system, undermining efforts to achieve food security, environmental sustainability, and economic resilience. Estimates from the Food and Agriculture Organization (FAO) suggest that approximately 1.3 billion tons of food are wasted

annually, equivalent to nearly one-third of all food produced for human consumption (Naikare, 2021). This substantial volume of waste reflects pervasive inefficiencies throughout the entire food supply chain, encompassing production, post-harvest handling, processing, retail, and household consumption. Particularly in low- and middle-income countries (LMICs), food loss and waste occur due to a range of structural deficiencies, including inadequate harvesting practices, poor storage infrastructure, and limited access to stable markets (Bloem & Farris, 2022). Simultaneously, in high-income countries, supermarkets and retailers discard significant quantities of edible food based on cosmetic standards and arbitrary expiration dates rather than actual spoilage (Gatto & Chepeliev, 2023).

At the consumer level, behavioral drivers such as over-purchasing, poor food management, and lack of understanding regarding labeling terminology contribute to considerable household food waste (Naikare, 2021). In urban centers with high purchasing power, these behaviors are often exacerbated, especially in the absence of effective awareness campaigns (Rusyda, 2024). Consequently, the cumulative effect of food waste across the supply chain is not only a reflection of logistical failures but also an indicator of systemic disconnects in food governance, education, and policy integration. These inefficiencies not only increase pressure on agricultural production systems but also contribute to the unjust paradox of simultaneous food surplus and hunger.

The relationship between food waste and food insecurity is particularly alarming in LMICs, where a significant share of the population remains undernourished. Research underscores that food waste intensifies food insecurity by diverting food from those in need, leading to nutrition deficits, increased disease burdens, and compromised developmental outcomes among vulnerable groups such as children and the elderly (Asiseh et al., 2018). In these contexts, the failure to utilize edible food not only perpetuates hunger but also limits the availability of essential nutrients that could have mitigated undernutrition and its long-term consequences (Qasrawi et al., 2024).

The compounding effect of recent economic disruptions, notably the COVID-19 pandemic, has further exposed the fragility of food systems in LMICs. Pandemic-related supply chain disruptions, income reductions, and labor shortages have exacerbated food insecurity, leading to increased reliance on insufficient food assistance mechanisms (Mueller et al., 2021). As highlighted by Christopher et al. (2020), these dynamics demonstrate the urgent need to develop food systems that are both resilient and capable of mitigating crises through more effective distribution and waste reduction mechanisms (Christopher et al., 2020).

The health implications of food insecurity are profound and enduring. Households experiencing food insecurity are more likely to suffer from malnutrition, higher rates of infectious and chronic diseases, and negative psychosocial outcomes (Iqbal et al., 2020). Children in food-insecure households are particularly vulnerable to developmental impairments, cognitive delays, and heightened risk of mortality due to nutrient deficiencies (Mugambiwa & Makhubele, 2023). Additionally, chronic exposure to food insecurity correlates with elevated psychological stress, depression, and anxiety, compounding the challenges faced by impoverished communities (Osei-Owusu et al., 2024).

The interrelation between food waste and its environmental, economic, and nutritional impacts underscores the need for urgent action. Environmentally, food waste contributes significantly to greenhouse gas emissions—accounting for an estimated 8-10% of global emissions—as decomposing organic matter releases methane, a potent greenhouse gas (Reinesch et al., 2022). The agricultural inputs used to produce wasted food, including water, land, fertilizer, and energy, further amplify its ecological footprint. It is estimated that food waste consumes nearly 28% of the world's agricultural land, representing a severe loss of biodiversity and ecosystem services (Javourez et al., 2024).

From an economic standpoint, global food waste results in an annual loss of approximately $1 trillion, considering the costs of production, transportation, and disposal (Attiq et al., 2021). In LMICs, poor infrastructure contributes to substantial post-harvest losses, reinforcing poverty cycles and economic vulnerability (Swamilaksita, 2022). Households also bear the brunt of economic losses, with studies estimating that food waste can represent up to $370 in annual lost value per household (Conrad, 2020). These figures emphasize the need for cost-effective and scalable interventions to reduce waste and protect household food budgets.

Nutritionally, the waste of nutrient-dense foods such as fruits and vegetables exacerbates malnutrition in food-insecure populations. An estimated 931 million tons of food are wasted annually, much of which contains essential micronutrients (Reyes et al., 2024). This nutrient loss has direct implications for public health, particularly in areas where dietary diversity is limited and access to fresh produce is constrained (Kusumasari et al., 2024). Spiker et al. (2017) argue that minimizing food waste could simultaneously improve population health outcomes and alleviate healthcare burdens through better nutritional intake (Spiker et al., 2017).

Despite widespread recognition of the food waste crisis, several persistent challenges inhibit global progress. First, a lack of public awareness, especially regarding the broader implications of food waste, limits behavioral change. Consumers often underestimate the impact of their food disposal habits, and in the absence of targeted education, efforts to reduce household waste are frequently ineffective (Haas et al., 2022). Second, food supply chains in both developed and developing regions suffer from inadequate cold storage, poor logistics, and misaligned distribution systems, which increase spoilage rates and prevent surplus redistribution.

Cultural factors and economic disincentives also present formidable barriers. Many consumers remain reluctant to purchase "imperfect" food due to aesthetic biases, while businesses often regard surplus food as a liability rather than a resource for redistribution (Qi & Roe, 2017). Moreover, policies designed to reduce food waste remain fragmented, with insufficient alignment across sectors such as agriculture, health, and environment. Without comprehensive and integrated policy frameworks, the root causes of food waste remain inadequately addressed (Indriyani et al., 2023).

A significant gap in the literature concerns the intersection of food waste reduction and food security, particularly in LMICs. Most existing research has focused on consumer behavior and food recovery technologies in high-income countries, overlooking the socio-cultural and infrastructural realities of

food systems in resource-constrained settings (Abusin et al., 2023). Additionally, discrepancies in data collection methodologies across countries hinder cross-comparative analyses and the development of evidence-based policies (Shen et al., 2023).

This review aims to examine the role of food waste reduction as a strategy for enhancing global food security. Specifically, it analyzes the multidimensional linkages between food waste and food insecurity, identifies barriers to effective policy implementation, and evaluates innovative practices in reducing waste across different socio-economic contexts. Emphasis is placed on assessing strategies that align food waste reduction with nutritional and environmental outcomes.

The scope of this narrative review includes a global assessment of food waste and food security interlinkages, with a particular focus on LMICs. Studies are drawn from diverse regions including Sub-Saharan Africa, South and Southeast Asia, Latin America, and selected high-income countries for comparative insights. The review includes peer-reviewed articles, policy reports, and systematic reviews published in reputable academic journals and international databases such as Scopus, ScienceDirect, and Google Scholar. By integrating cross-contextual findings, this review seeks to inform the development of comprehensive frameworks that simultaneously advance waste reduction and food security goals.

METHOD

This study employed a narrative review approach to examine the interlinkages between food waste reduction and global food security. A comprehensive literature search was conducted using leading academic databases, including PubMed, Scopus, and Google Scholar, targeting peer-reviewed studies published primarily between 2010 and 2024. The search strategy integrated predefined keywords and Boolean operators to ensure relevance, specificity, and coverage of the topic. Keywords used in various combinations included "food waste reduction," "food waste management," "policies," "food security," "circular economy," "food recovery," and "waste prevention." Boolean logic was applied to refine search results, for example: ("food waste reduction" OR "food loss prevention") AND ("policies" OR "practices") AND ("sustainability" OR "food security").

Inclusion criteria required studies to be peer-reviewed and to either empirically or theoretically assess food waste reduction initiatives, policy interventions, sustainability implications, or behavioral aspects influencing food waste. Systematic reviews, meta-analyses, and case studies focusing on households, the foodservice industry, or regional policy frameworks were also included. Studies were excluded if they lacked empirical data, were not peer-reviewed, focused on non-food waste topics, or were not published in English. An initial screening based on titles and abstracts was followed by full-text reviews to determine methodological robustness and relevance.

To enhance reliability, a multi-stage screening process was adopted. Four independent reviewers evaluated the studies against the established inclusion criteria to ensure methodological alignment.

Thematic synthesis was used to identify recurring patterns across selected literature, particularly focusing on how regulatory frameworks, technological innovations, and socio-cultural factors influence food waste mitigation. The findings offer insights into the effectiveness of policy and practice in diverse contexts and contribute to understanding the role of food waste reduction in achieving food security objectives globally.

RESULTS AND DISCUSSION

The literature reveals a diverse array of strategies employed globally to reduce food waste, structured around key themes including government policies and regulations, technological and logistical innovations, behavioral interventions, food redistribution systems, and circular economy integration. These themes collectively underscore the multifaceted nature of food waste reduction and its intrinsic connection to food security.

Government policies and regulations have played a critical role in shaping national approaches to food waste. France, for example, implemented a groundbreaking 2016 law mandating that supermarkets donate unsold food rather than discarding it. This legal mandate has fostered robust collaboration between retailers and food banks, significantly increasing food donations and contributing to improved food access for underserved populations (Szulecka et al., 2024). In contrast, South Korea's strategy emphasizes waste management through mandatory food waste separation and a pay-as-you-throw system, leading to a 50% reduction in food waste from 2005 to 2019 (Salemdeeb et al., 2017). Denmark's approach integrates public engagement and policy support through campaigns and platforms that connect industry, NGOs, and the public sector, enhancing consumer awareness and behavioral change (Rahmasary et al., 2019).

Comparative analysis demonstrates that France's redistributive policies primarily address retail-level surplus, while South Korea focuses on infrastructural efficiency and citizen accountability. Denmark's strategy lies at the intersection of regulation and social collaboration. These case studies highlight that effective food waste reduction depends on harmonizing legal frameworks, civic participation, and targeted incentives tailored to each country's socio-cultural context.

Technological and logistical innovations further bolster food waste reduction across supply chains. Cold chain logistics, particularly temperature-controlled storage and transport, have proven vital in minimizing spoilage. Solar-powered refrigeration systems, especially in rural or off-grid regions, have expanded market access for perishable goods while reducing waste (Bottani et al., 2022; Shi et al., 2024). The adoption of Internet of Things (IoT) technologies enhances real-time monitoring of food conditions during transit, allowing stakeholders to preempt spoilage and adjust logistics dynamically (Abideen et al., 2021).

Blockchain technology introduces traceability and transparency, offering verifiable data throughout the food supply chain. This capability helps identify bottlenecks or inefficiencies that contribute to

waste, improving trust and accountability among suppliers and consumers. Coupled with digital inventory management powered by AI and machine learning, businesses are better equipped to forecast demand and optimize stock turnover, thus reducing overproduction and expiry-related waste (Jain et al., 2021).

Cold chain systems, in particular, have demonstrated the capacity to reduce spoilage by up to 50% in certain perishable categories such as fruits and vegetables (Shi et al., 2024). When integrated with digital inventory tools, they enable proactive identification of products nearing spoilage, facilitating timely redistribution or price adjustments. This integration supports responsive and efficient supply chains, which are critical for aligning supply with consumer demand and minimizing loss.

Behavioral interventions and public campaigns have emerged as influential tools in shifting consumer behavior. Awareness campaigns, including financial messaging and visual storytelling, have succeeded in communicating the real cost of food waste, promoting behavioral shifts in food purchasing and preparation. Nudging techniques, such as point-of-sale prompts and portion planning suggestions, subtly influence consumer choices, decreasing over-purchasing and enhancing food utilization (Jagau & Vyrastekova, 2017).

Digital tools, particularly mobile apps, have gained popularity by offering meal planning, leftover recipes, and expiration alerts. These platforms support consumer decision-making and promote a culture of waste reduction (Agmapisarn et al., 2024). Culinary education programs have likewise demonstrated success in modifying wasteful habits, especially when integrated into community settings. Cooking shows and school-based initiatives have proven effective in instilling food literacy and reducing household food waste (Elhoushy, 2022).

Consumer perceptions and knowledge significantly influence food-related behaviors. Attitudinal factors, such as ethical concerns, correlate strongly with waste reduction behaviors like careful shopping and meal planning (Nonomura, 2020). Perceived behavioral control also plays a role; consumers who feel capable of managing food efficiently are more likely to engage in waste-reducing practices. Social norms further reinforce behavior, with peer influence and community engagement bolstering individual efforts (Blondin & Attwood, 2022). Emotional drivers such as guilt and pride also motivate change, while addressing knowledge gaps on shelf life and food safety remains critical for sustainable behavior transformation.

Food banks and redistribution systems are instrumental in converting surplus food into resources for food-insecure populations. These systems not only mitigate waste but also contribute to equitable food access. In Italy, food redistribution initiatives have been credited with significantly improving food availability for low-income communities amidst rising poverty levels. Environmental benefits are also evident, as diverting food from landfills reduces methane emissions, aligning with climate goals (Feingold et al., 2018).

Food banks enhance community resilience by promoting social solidarity through services like community kitchens and social supermarkets. These platforms also serve as centers for nutrition

education and awareness, reinforcing long-term dietary improvements. However, logistical challenges, including transportation and storage limitations, remain major barriers. Regulatory constraints on food safety, while necessary, can inhibit the acceptance of perishable foods, reducing diversity in distributed items (Tarasuk et al., 2019).

Public awareness and engagement are uneven, and socioeconomic inequalities limit access in some communities. Moreover, food banks' dependency on charitable models has drawn criticism for failing to address systemic causes of food insecurity, such as low wages and housing instability (Royer, 2024). Expanding the reach of food recovery systems requires coordinated policy support, infrastructure investment, and normalization of food donation practices.

Finally, recent advances in food waste valorization technologies exemplify the practical application of circular economy principles. Anaerobic digestion remains a widely adopted method for converting food waste into biogas and digestate, offering dual benefits of renewable energy production and reduced greenhouse emissions (Tsegaye et al., 2021). Composting technologies, particularly aerobic and thermophilic systems, have improved soil enrichment processes while reducing processing time and environmental nuisances.

Biorefinery approaches expand the potential uses of food waste, producing bioplastics, biofuels, and nutritional additives. This innovation transforms food waste into multifunctional materials with economic and health value. Moreover, industries such as cosmetics and pharmaceuticals are beginning to utilize recovered bioactive compounds, demonstrating the cross-sector utility of food waste valorization (Osorio et al., 2021).

Blockchain has entered the valorization process by enhancing traceability and ensuring quality assurance for secondary applications. However, integrating circular economy principles into national strategies remains complex. Disparate regulatory frameworks and limited institutional coordination often hinder comprehensive implementation. Financial viability is also a concern, especially in low-income contexts where investment in processing infrastructure is constrained (Sadhukhan et al., 2020).

Public awareness and behavioral change remain foundational to circular economy success. Campaigns and educational initiatives must align public understanding with systemic goals to generate support for waste-to-resource strategies (Sousa et al., 2021). Infrastructural readiness and technological adoption are equally critical. Investment in composting facilities, digestion plants, and biorefinery hubs is necessary to achieve scale and impact.

In sum, the integration of valorization technologies with circular economy principles offers substantial promise for addressing both environmental and food security challenges. Progress in this domain will depend on inclusive policies, multisector collaboration, and sustained public engagement. These findings collectively highlight the importance of a systems-based approach in reducing food waste while promoting sustainable, secure, and resilient food systems globally.

Systemic Issues Contributing to Persistent Food Waste

Food waste continues to persist as a critical global issue due to a multitude of systemic factors. These include policy fragmentation, misaligned market incentives, and entrenched cultural norms. Policy fragmentation refers to the disconnection among different regulatory frameworks governing agriculture, food safety, environmental protection, and public health. As Przezbórska-Skobiej and Wiza (2021) argue, policies designed to ensure food safety may inadvertently limit opportunities for surplus redistribution, thereby reinforcing food waste. Regulatory silos across ministries or agencies often result in redundancies or conflicts that deter comprehensive action (Przezbórska-Skobiej & Wiza, 2021). For example, food safety regulations may prohibit the donation of near-expiration products, despite their nutritional adequacy, thus discouraging retailers from participating in donation schemes (Jagau & Vyrastekova, 2017).

Market incentives also exacerbate food waste. The demand for perfect-looking produce leads to substantial rejection of cosmetically imperfect yet edible items. Retailers and producers cater to aesthetic expectations, a practice that significantly contributes to upstream food losses (Mumtaz et al., 2022). Additionally, promotional marketing strategies, such as bulk discounts and multi-buy offers, promote consumer over-purchasing, which ultimately increases food waste at the household level. Compounding this, businesses often lack incentives to donate surplus food. Without financial rewards, liability protections, or logistical support, many opt to dispose of edible food.

Cultural norms further perpetuate wasteful behavior. Porpino (2016) notes that in some cultures, the stigma associated with leftovers or shared meals undermines waste-conscious practices. Likewise, societal expectations surrounding hospitality and abundance normalize food over-preparation, particularly during celebrations or in service settings (Setti et al., 2018). These practices are rarely accompanied by awareness about the implications of food waste, including its environmental toll and contribution to food insecurity.

Successes and Failures of Existing Interventions

The efficacy of food waste reduction interventions has been mixed. Successful interventions are often those that simultaneously address environmental, behavioral, and social dimensions. Educational campaigns that link food waste to financial costs and environmental damage have proven effective in reducing waste at the household level. When consumers are provided with information about how to store food properly or interpret expiration labels, they tend to make more informed choices, thereby reducing waste (Babbitt et al., 2021).

Community-based redistribution initiatives also stand out as effective, not only in minimizing waste but in enhancing local food security. Programs connecting food donors with food banks have created networks that divert food from landfill to vulnerable populations. Seo and Yoon (2022) report that

such initiatives foster a sense of social responsibility, helping normalize donation and reduce the stigma associated with food aid.

However, numerous interventions fail to address the nutritional adequacy of redistributed food. Tsai et al. (2020) find that many food bank offerings lack diversity and essential nutrients, often being composed of processed or shelf-stable items. Alattar and Morse (2021) emphasize the importance of nutrition-sensitive interventions, particularly for vulnerable groups like children, pregnant women, and the elderly. Failure to consider dietary needs limits the health benefits of redistribution and may perpetuate forms of hidden hunger even when caloric needs are met (Alattar & Morse, 2021).

Environmental strategies such as composting or anaerobic digestion offer viable alternatives to landfill disposal. Nevertheless, Filipová et al. (2017) argue that these interventions often address the symptoms rather than the root causes of waste. Processing food waste without tackling consumer habits, overproduction, or retail-level inefficiencies may result in a continued cycle of waste generation. As Setti et al. (2016) explain, sustainable change requires behavioral transformation, which many interventions fail to achieve (Setti et al., 2018).

Holistic and Sustainable Food Waste Reduction Models

In response to the limitations of fragmented approaches, integrated governance models have emerged. These frameworks prioritize cross-sector collaboration and policy alignment. For instance, food waste management systems that facilitate interaction among governments, private actors, and civil society tend to generate more effective results. Kilibarda et al. (2019) highlight how partnerships among municipalities, retailers, and non-profits improve logistics, data sharing, and public engagement. Chaudhary and Sharma (2023) further assert that integration with education campaigns fosters lasting behavioral shifts (Kilibarda et al., 2019).

Circular economy principles present another promising model. Instead of treating food waste as disposable, these strategies reframe waste as a resource. Practices such as composting, biorefining, and bioenergy production reclaim nutrients and energy, creating closed-loop systems. The South Korean model exemplifies this approach, where food waste is systematically collected, repurposed into animal feed and biogas, and reinvested into the agricultural cycle (Cerciello et al., 2018). By integrating circular economy approaches into national policies, countries can achieve both environmental sustainability and economic efficiency.

Engaging youth and local communities is essential to sustaining long-term change. Chen and Chen (2018) show that school-based programs significantly influence students' consumption behaviors, instilling values of conservation and sustainability. Community involvement in designing and implementing food recovery programs ensures cultural appropriateness and higher participation. Apps and digital platforms that gamify food saving efforts have been particularly effective among young users, enhancing both reach and retention of knowledge (Chen & Chen, 2018).

Policy coherence plays a crucial role in successful implementation. Pullman and Wikoff (2017) argue that misaligned policies hinder integrated approaches. Countries that align food production, distribution, and waste management under unified frameworks tend to achieve better results. In the European Union, policy alignment has facilitated the uptake of waste hierarchy models, allowing for coordinated action and harmonized reporting standards (Setyaningtyas et al., 2022). Romani et al. (2018) demonstrate that cross-ministerial policy coherence fosters synergies between health, agriculture, and environmental objectives (Romani et al., 2018).

Behavioral economics tools, including financial incentives and disincentives, can also drive effective food waste reduction. Cook et al. (2022) document how tax breaks for food donors have encouraged greater participation from the private sector. Filippini et al. (2019) show that pay-as-you-throw schemes lead to measurable reductions in household waste by making disposal costs visible (Cook et al., 2022; Filippini et al., 2019). These economic tools, grounded in behavioral science, help translate awareness into action, especially when designed to resonate with diverse demographics.

Limitation

This review, while comprehensive in scope, is limited by its reliance on secondary sources, which may present methodological inconsistencies across studies. The diversity of regional contexts also poses challenges in generalizing findings. Some interventions may be highly effective in certain socio-economic or cultural environments but less so in others. Additionally, the availability of peer-reviewed studies in low-income countries is limited, potentially underrepresenting valuable local initiatives. This limitation suggests the need for caution in extrapolating best practices universally.

Implication

The findings indicate that future research should explore integrated models that simultaneously address food waste, nutritional security, and environmental sustainability. Emphasis should be placed on evaluating the long-term impacts of behavioral interventions and the effectiveness of digital tools in diverse settings. Comparative studies across different governance structures could illuminate scalable strategies and identify context-specific enablers or barriers. Future work should also prioritize participatory research that includes underrepresented communities in the design of food recovery programs to ensure inclusivity and equity. Greater interdisciplinary collaboration is required to build resilient, just, and sustainable food systems capable of meeting global challenges.

CONCLUSION

This narrative review has examined the intersection of food waste reduction and global food security through an analysis of government policies, technological interventions, behavioral strategies, food

redistribution systems, and circular economy practices. The findings highlight the persistent impact of systemic barriers such as policy fragmentation, market incentives that reward overconsumption, and cultural norms that tolerate wasteful behavior. While interventions like educational campaigns, digital tools, and food recovery programs have yielded measurable improvements, their reach and sustainability vary across socio-economic contexts. In particular, many efforts lack integration across sectors, and few adequately address the nutritional quality of redistributed food or the root causes of waste generation.

The urgency of the food waste issue—both as a sustainability challenge and a moral imperative—is reinforced by its dual consequences: significant environmental degradation and widespread food insecurity. Countries such as South Korea, Denmark, and France have demonstrated successful models by combining legal mandates with citizen engagement, infrastructural investments, and value-chain innovations. However, broader implementation is still constrained by regulatory inconsistency, limited public awareness, and technological disparities.

To overcome these obstacles, policy coherence, investment in circular technologies, and inclusive governance models must be prioritized. Future research should focus on participatory approaches that evaluate context-specific solutions, especially in low- and middle-income countries. Strengthening the link between food waste prevention and nutritional outcomes, while expanding community-driven interventions and digital behavior change tools, will be essential for building equitable and resilient food systems. As shown in this review, integrating food waste reduction into holistic food policy is not only viable but necessary for sustainable development.

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