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The Comparison of Food Waste Policies in Malaysia and Selected Asean Countries

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ABSTRACT: Food waste has emerged as one of the most pressing global sustainability challenges, contributing significantly to environmental degradation, greenhouse gas emissions, resource depletion, and economic losses. While many countries have introduced policies to address food waste, considerable differences remain in legislative frameworks, governance structures, implementation mechanisms, and resource recovery strategies. This study comparatively analyses food waste management policies in Malaysia, Japan, South Korea, and Germany to identify critical success factors and derive policy implications for strengthening sustainable food waste governance in Malaysia. A qualitative comparative policy analysis was conducted using government legislation, policy documents, institutional reports, and peer-reviewed literature. The analysis examined legislative and institutional frameworks, policy instruments, implementation mechanisms, food waste prevention initiatives, resource recovery strategies, and overall policy effectiveness within a circular economy perspective. The findings indicate that high-performing countries integrate comprehensive legislation, strong institutional coordination, mandatory implementation measures, economic incentives, advanced resource recovery infrastructure, and continuous monitoring into coherent governance systems. Japan and South Korea demonstrate the effectiveness of dedicated food waste legislation and mandatory source separation, while Germany illustrates the benefits of embedding food waste management within a broader circular economy framework. In contrast, Malaysia has established a solid institutional foundation but continues to face challenges related to fragmented governance, limited mandatory implementation, inconsistent data management, and dependence on landfill disposal. The study proposes a hybrid policy framework that integrates international best practices while considering Malaysia's institutional and socio-economic context. The findings contribute to the growing literature on food waste governance by providing a comparative policy perspective and practical recommendations to support the transition towards a circular food economy, enhance resource efficiency, reduce greenhouse gas emissions, and advance Sustainable Development Goal 12.3.

INTRODUCTION

Food waste has become one of the most critical sustainability challenges of the twenty-first century, attracting increasing attention from governments, international organisations, researchers, and industry stakeholders due to its profound

environmental, economic, and social implications [1], [2]. Despite continuous improvements in agricultural productivity and global food supply systems, food waste remains a persistent problem throughout the entire food supply chain, extending from agricultural production and post-harvest handling to food processing, distribution, retailing, food services, and household consumption. The Food and Agriculture Organization (FAO) estimated that approximately one-third of all food produced for human consumption is either lost or wasted annually, representing nearly 1.3 billion tonnes of edible food that could otherwise contribute to global food security [1]. More recently, the United Nations Environment Programme (UNEP) reported that approximately 1.05 billion tonnes of food waste were generated globally in 2022, with households accounting for nearly 60% of the total, followed by food service establishments and retail sectors [2]. These statistics demonstrate that food waste is not merely a waste management issue but a multidimensional challenge that directly affects sustainable production, responsible consumption, environmental protection, and global food security.

The consequences of food waste extend far beyond the physical loss of edible products. Every kilogram of discarded food represents the unnecessary consumption of natural resources, including fertile land, freshwater, fertilisers, energy, transportation, labour, and financial capital invested throughout the food production process [1]. Consequently, food waste reduces overall resource-use efficiency while simultaneously increasing production costs and environmental pressures. From an environmental perspective, food waste contributes substantially to greenhouse gas emissions through resource extraction, agricultural production, transportation, processing, and final disposal. Organic waste deposited in landfills undergoes anaerobic decomposition, generating methane (CH_4), a greenhouse gas with a significantly greater warming effect than carbon dioxide over a 100-year period (IPCC, 2023). Furthermore, excessive disposal of biodegradable waste accelerates landfill depletion, increases leachate generation, contributes to soil and groundwater contamination, and imposes additional operational costs on municipal waste management systems [2],[3]. Therefore, reducing food waste has become an essential strategy for mitigating climate change, improving resource efficiency, and supporting sustainable urban development.

Beyond environmental considerations, food waste presents significant economic and social challenges. The global economic cost associated with food loss and waste has been estimated to exceed hundreds of billions of United States dollars annually, reflecting lost production value, inefficient logistics, increased waste management expenditure, and reduced economic productivity [4]. Simultaneously, approximately 735 million people worldwide continue to experience chronic hunger and food insecurity, highlighting a striking paradox between excessive food wastage and unequal food distribution [5]. This contradiction has prompted researchers and policymakers to recognise food waste reduction not only as an environmental necessity but also as a fundamental component of sustainable development, social equity, and responsible resource management [6],[7]. Consequently, effective food waste management has become increasingly integrated into national sustainability strategies, climate action plans, and circular economy initiatives.

Recognising the urgency of addressing food waste, the United Nations incorporated food waste reduction into the 2030 Agenda for Sustainable Development through Sustainable Development Goal (SDG) 12.3, which calls for halving global per capita food waste at the retail and consumer levels while reducing food losses along production and supply chains by 2030 [8]. The inclusion of food waste within the Sustainable Development Goals reflects a growing international consensus that reducing food waste contributes simultaneously to environmental conservation, economic resilience, food security, responsible consumption, and climate change mitigation. Nevertheless, achieving SDG 12.3 requires more than technological innovation or public awareness campaigns alone. Numerous studies have demonstrated that long-term reductions in food waste depend upon coherent policy frameworks, effective governance systems, institutional coordination, financial incentives, and active participation from governments, industries, local authorities, and consumers [2], [7].

The growing emphasis on sustainability has also accelerated the global transition from a traditional linear economy towards a circular economy model. Under the conventional linear economic model, food is produced, consumed, and subsequently discarded, resulting in continuous resource depletion and increasing environmental burdens. In contrast, the circular economy promotes the principles of reducing, reusing, recycling, and recovering resources to maximise material value while minimising waste generation [9]. Within food systems, circular economy strategies encourage food waste prevention, redistribution of edible surplus food, composting, anaerobic digestion, animal feed production, nutrient recovery, and renewable energy generation from unavoidable organic waste [10]. Rather than viewing food waste solely as an environmental liability, the circular economy recognises discarded organic materials as valuable secondary resources capable of generating environmental, economic, and social benefits.

Although considerable technological advances have been achieved in food waste valorisation, including biogas production, biofertiliser development, insect bioconversion, and biochemical extraction, technological solutions alone cannot guarantee effective food waste management. Previous research consistently demonstrates that technological innovation must be supported

by comprehensive legislative frameworks, effective institutional governance, economic incentives, stakeholder collaboration, and continuous policy evaluation to ensure successful implementation and long-term sustainability [11],[7],[3]. Consequently, policy intervention has become one of the most influential determinants of national food waste management performance, distinguishing countries that have successfully transitioned towards circular food systems from those that remain heavily dependent on landfill disposal. Understanding how policy frameworks facilitate sustainable food waste governance therefore represents an essential prerequisite for developing effective national strategies capable of balancing environmental protection, economic efficiency, and social well-being.

Building upon these global developments, Malaysia has increasingly recognised food waste as a strategic environmental and socio-economic issue that requires comprehensive policy intervention. Rapid urbanisation, population growth, changing dietary patterns, increasing household income, and expanding commercial activities have contributed to a continuous rise in municipal solid waste generation over the past two decades [12],[13]. Food waste consistently represents the largest component of municipal solid waste in Malaysia, accounting for approximately 40–50% of the total waste stream generated daily [14]. Despite various national initiatives promoting waste minimisation, recycling, and source separation, the majority of food waste continues to be disposed of in landfills, resulting in inefficient resource utilisation, increasing greenhouse gas emissions, and escalating waste management costs [13],[15]. These trends indicate that Malaysia's food waste management system remains predominantly disposal-oriented rather than resource-oriented, highlighting the need for stronger policy integration and circular economy implementation.

The Malaysian Government has introduced several legislative and policy instruments to strengthen solid waste management, including the Solid Waste and Public Cleansing Management Act 2007 (Act 672), the National Solid Waste Management Policy, the National Strategic Plan for Solid Waste Management, and more recently the Roadmap Towards Zero Single-Use Plastics 2018–2030 [12]. Collectively, these initiatives demonstrate the Government's commitment to improving environmental sustainability and promoting responsible waste management practices. Nevertheless, unlike several developed nations, Malaysia does not yet possess a dedicated national policy that specifically governs food waste prevention, redistribution, recycling, and resource recovery across the entire food supply chain. Existing responsibilities are distributed among multiple ministries, local authorities, and regulatory agencies, often resulting in fragmented governance, overlapping institutional functions, inconsistent implementation, and varying enforcement capacities across different states [16],[17]. Such institutional fragmentation has frequently been identified as one of the principal barriers limiting the effectiveness of food waste management programmes in developing countries [3].

In contrast, several developed countries have successfully transformed their food waste management systems through long-term legislative commitment, integrated governance, technological innovation, and sustained stakeholder participation. Japan is widely recognised for its Food Recycling Law, originally enacted in 2001 and continuously strengthened through subsequent amendments. The legislation obliges food-related businesses to reduce food waste while promoting the recycling of unavoidable food residues into animal feed, compost, fertilisers, and renewable energy [18]. The Japanese approach is characterised by strong collaboration between government agencies, private industries, academic institutions, and local communities, supported by measurable recycling targets and continuous performance monitoring. Consequently, Japan has become one of the leading examples of circular resource utilisation within the food sector [19].

Similarly, South Korea has established one of the world's most comprehensive food waste management systems through mandatory source separation, volume-based waste charging, advanced recycling infrastructure, and strict restrictions on landfill disposal of organic waste [20]. The introduction of the "Pay-As-You-Throw" (PAYT) system fundamentally changed consumer behaviour by directly linking waste generation to disposal costs, thereby encouraging households and commercial establishments to minimise food waste generation. Coupled with extensive investments in anaerobic digestion, composting facilities, livestock feed production, and smart information technologies, South Korea has achieved food waste recycling rates exceeding 90%, demonstrating the effectiveness of combining regulatory measures with economic incentives [3],[21].

Germany represents another important international benchmark through its integration of food waste prevention within broader circular economy and sustainable resource management policies. The German Circular Economy Act (Kreislaufwirtschaftsgesetz) prioritises waste prevention, material recovery, recycling, and producer responsibility in accordance with the European Union Waste Framework Directive and the Circular Economy Action Plan [10]. Rather than relying solely on end-of-pipe waste treatment technologies, Germany emphasises preventive strategies, efficient resource utilisation, consumer education, food donation programmes, industrial symbiosis, and market-based incentives that collectively reduce food waste generation while maximising resource recovery [3],[10]. These experiences demonstrate that effective food waste governance requires policy coherence extending beyond waste management legislation alone, encompassing agricultural policy,

environmental protection, climate mitigation, industrial development, and sustainable consumption.

The growing body of international literature consistently indicates that successful food waste management depends upon the interaction between governance structures, institutional capacity, technological readiness, stakeholder engagement, and socio-economic conditions rather than technological capability alone. For example, Principato et al. [22] argued that legislative consistency and stakeholder participation are fundamental prerequisites for achieving long-term food waste reduction. Likewise, Brancoli et al. [23] emphasised that resource recovery technologies generate meaningful environmental benefits only when supported by appropriate policy instruments and reliable waste segregation systems. Recent reviews have similarly concluded that countries adopting integrated circular economy policies consistently achieve higher recycling performance and lower landfill dependency than countries relying primarily on conventional waste disposal practices [2],[24]. These findings collectively suggest that governance quality, rather than technology alone, is the principal determinant of sustainable food waste management performance.

Although food waste management has become an increasingly active field of research, existing studies remain characterised by several important limitations. A considerable proportion of published literature focuses on food waste generation, consumer behaviour, life-cycle assessment, greenhouse gas emissions, or treatment technologies such as composting and anaerobic digestion [23],[24]. Comparatively fewer studies have undertaken systematic evaluations of national policy frameworks, legislative effectiveness, institutional coordination, and governance mechanisms that underpin successful food waste reduction. Furthermore, many comparative studies remain descriptive, examining policy characteristics without critically assessing how legislative instruments, institutional arrangements, enforcement mechanisms, and economic incentives interact to influence policy outcomes across different national contexts. Consequently, the transferability of successful policy instruments from developed countries to developing economies remains insufficiently explored.

This knowledge gap is particularly relevant for Malaysia, where increasing food waste generation continues to challenge existing waste management infrastructure while national aspirations towards sustainable development, carbon neutrality, and circular economy implementation require more integrated policy responses. A comprehensive comparison between Malaysia and internationally recognised leaders such as Japan, South Korea, and Germany therefore provides an important opportunity to identify transferable governance strategies, institutional best practices, and policy instruments that may strengthen Malaysia's food waste management system while supporting broader environmental and socio-economic sustainability objectives.

Despite substantial progress in food waste research over the past decade, the literature reveals a continuing need for more comprehensive comparative policy analyses that integrate legislative frameworks, institutional governance, implementation mechanisms, and circular economy principles within a single analytical perspective. Most previous studies have evaluated food waste generation patterns, technological innovations, environmental impacts, or consumer behaviour independently, while relatively limited attention has been devoted to understanding how governance systems, policy instruments, and institutional arrangements collectively influence national food waste management performance [22],[23],[24]. Consequently, policymakers often encounter difficulties in identifying which policy mechanisms can be effectively transferred from developed countries to developing economies with different socio-economic conditions, administrative structures, and institutional capacities.

Furthermore, recent international commitments towards climate neutrality, resource efficiency, and sustainable consumption have significantly altered the policy landscape surrounding food waste management. National food waste policies are increasingly expected to contribute not only to waste reduction but also to greenhouse gas mitigation, renewable energy generation, circular economy development, sustainable agriculture, and food security [2],[10]. These evolving policy expectations require governance systems that are adaptive, integrated, and evidence-based. Therefore, comparative policy evaluations have become increasingly valuable for identifying best practices capable of supporting policy reform while promoting sustainable resource management.

Against this background, the present study conducts a comparative analysis of food waste management policies implemented in Malaysia, Japan, South Korea, and Germany. These countries were intentionally selected because they represent different stages of policy development while sharing common commitments towards sustainable waste management and circular economy implementation. Japan and South Korea have demonstrated internationally recognised success in reducing food waste through comprehensive legislation, mandatory waste segregation, and advanced recycling infrastructure, whereas Germany has integrated food waste prevention within a broader circular economy strategy supported by European Union environmental legislation. Malaysia, meanwhile, represents a rapidly developing economy that has made significant progress in solid waste management but continues to encounter challenges associated with institutional fragmentation, landfill dependency, and limited food waste-specific legislation. Comparing these contrasting policy environments provides valuable insights into governance effectiveness, institutional coordination, and policy transferability.

Accordingly, this study pursues four primary objectives. First, it examines and compares the legislative and policy frameworks governing food waste management in Malaysia, Japan, South Korea, and Germany. Second, it evaluates the effectiveness of governance structures, institutional responsibilities, and implementation mechanisms supporting national food waste management systems. Third, it identifies policy strengths, limitations, and best practices that have contributed to successful food waste reduction and resource recovery in developed countries. Finally, the study proposes evidence-based policy recommendations that may strengthen Malaysia's food waste governance while supporting national sustainability aspirations, circular economy development, and the achievement of Sustainable Development Goal 12.3.

The significance of this research extends beyond descriptive policy comparison. Academically, the study contributes to the growing body of literature by integrating legislative analysis, governance evaluation, circular economy principles, and comparative policy assessment into a unified analytical framework. Unlike many previous studies that primarily focus on treatment technologies or waste generation statistics, this research emphasises the interaction between policy design, institutional capacity, implementation effectiveness, and sustainable resource management. Such an integrated perspective provides a more comprehensive understanding of the factors influencing successful food waste governance across different national contexts.

From a practical perspective, the findings are expected to provide valuable guidance for policymakers, regulatory agencies, local authorities, industry practitioners, and researchers seeking to improve food waste management strategies in Malaysia and other developing countries. The identification of transferable policy instruments, governance models, and institutional best practices may assist decision-makers in strengthening legislative frameworks, improving inter-agency coordination, promoting stakeholder participation, and expanding investment in sustainable food waste treatment technologies. Ultimately, these improvements have the potential to reduce landfill dependency, minimise greenhouse gas emissions, enhance resource efficiency, and strengthen national commitments towards sustainable development and climate resilience.

Overall, this study argues that sustainable food waste management cannot be achieved through technological innovation alone. Instead, long-term success depends upon coherent public policies, effective governance systems, institutional collaboration, economic incentives, and active stakeholder participation operating within an integrated circular economy framework. The following section therefore describes the research methodology employed to systematically compare food waste management policies across the selected countries and to develop evidence-based recommendations for strengthening Malaysia's food waste governance.

MATERIALS AND METHODS

Research Design

This study employed a qualitative comparative research design to evaluate food waste management policies implemented in Malaysia and three selected developed countries, namely Japan, South Korea, and Germany. A qualitative comparative approach was considered appropriate because the primary objective of this research was to analyse legislative frameworks, governance structures, institutional arrangements, implementation strategies, and policy instruments rather than to quantify food waste generation or evaluate treatment technologies experimentally [25],[26].

Comparative policy analysis has become an increasingly recognised research approach in environmental governance studies because it enables researchers to identify similarities, differences, strengths, weaknesses, and transferable best practices across multiple jurisdictions [27]. Unlike single-country policy reviews, comparative analyses provide a broader understanding of how different legislative and institutional contexts influence policy implementation and environmental performance. Consequently, this methodology was considered suitable for identifying governance practices that may strengthen Malaysia's food waste management system.

The research followed a document-based comparative policy analysis supported by systematic literature synthesis. Rather than relying on primary surveys or interviews, this study examined authoritative policy documents, government reports, legislation, international guidelines, and peer-reviewed scientific publications to ensure comprehensive coverage of national food waste management strategies.

Selection of Countries

Malaysia was selected as the primary case study because it is currently undergoing significant transformation in municipal solid waste management while facing increasing challenges associated with food waste generation, landfill dependency, and circular economy implementation [14]. Despite recent policy improvements, food waste management remains fragmented across

multiple government agencies and continues to rely predominantly on landfill disposal.

Three developed countries Japan, South Korea, and Germany were selected as comparative benchmarks based on four principal criteria.

First, these countries have established comprehensive legislative frameworks specifically addressing food waste prevention, recycling, and resource recovery [10],[28].

Second, all three countries demonstrate internationally recognised success in reducing landfill dependency through integrated waste management systems.

Third, each country has implemented different policy instruments that provide valuable comparative perspectives. Japan emphasises food recycling legislation and industrial collaboration; South Korea employs mandatory source separation and volume-based waste charging; Germany integrates food waste prevention within broader circular economy legislation and European Union environmental policy.

Finally, these countries consistently report relatively high recycling performance and mature institutional governance, making them suitable reference models for evaluating Malaysia's existing policy framework.

Data Collection

Secondary data were collected from multiple authoritative sources to ensure data credibility, comprehensiveness, and triangulation. The primary data sources included national legislation, government policy documents, official reports, international publications, and peer-reviewed journal articles published between 2015 and 2025. Earlier seminal publications were also incorporated where necessary to establish theoretical foundations and historical policy development.

Government documents included the Solid Waste and Public Cleansing Management Act 2007 (Act 672), National Solid Waste Management Policy, Roadmap Towards Zero Single-Use Plastics 2018–2030, Food Recycling Law of Japan, the German Circular Economy Act, relevant European Union directives, and official reports published by the Ministry of Environment, Ministry of Housing and Local Government Malaysia, SWCorp Malaysia, the Ministry of Agriculture, Forestry and Fisheries of Japan, the Korean Ministry of Environment, and the European Commission.

International publications produced by the Food and Agriculture Organization (FAO), United Nations Environment Programme (UNEP), Organisation for Economic Co-operation and Development (OECD), and Intergovernmental Panel on Climate Change (IPCC) were also reviewed to establish the global policy context.

Comparative Policy Analysis Framework

The comparative analysis was conducted using a structured policy evaluation framework adapted from previous environmental governance studies [3],[27]. Six evaluation dimensions were established to facilitate systematic comparison among the selected countries.

The first dimension examined legislative frameworks, including national acts, regulations, policy objectives, and legal enforcement mechanisms. The second evaluated governance and institutional arrangements by analysing the responsibilities of government agencies, local authorities, and private stakeholders. The third assessed policy implementation strategies, including mandatory waste segregation, recycling programmes, food donation initiatives, economic incentives, and public awareness campaigns. The fourth focused on technological and infrastructure development, including composting facilities, anaerobic digestion, food recycling systems, and renewable energy recovery. The fifth examined monitoring, compliance, and performance indicators, while the sixth evaluated policy outcomes in terms of landfill reduction, recycling performance, circular economy implementation, and long-term sustainability.

The use of multiple evaluation criteria enabled a comprehensive comparison of governance systems rather than limiting the analysis to legislative differences alone.

Data Analysis

Data analysis followed a qualitative thematic content analysis approach. All collected documents were systematically reviewed, coded, categorised, and synthesised according to the six analytical dimensions established in the comparative framework [29]. Similar policy characteristics were grouped into thematic categories, while differences in legislative approaches, governance systems, implementation strategies, and institutional performance were identified through cross-country comparison.

Thematic synthesis enabled recurring patterns, emerging trends, policy innovations, implementation challenges, and transferable best practices to be identified. Rather than simply describing each country's policy individually, the comparative analysis focused on explaining why certain policy instruments produced better outcomes and how these experiences may inform future policy

development in Malaysia.

Reliability and Research Validity

Several measures were undertaken to improve the reliability and validity of the research findings. First, methodological triangulation was achieved by integrating multiple sources of evidence, including legislation, government reports, international publications, and peer-reviewed scientific literature. Second, only official government documents and internationally recognised publications were used as primary policy references whenever available. Third, peer-reviewed journal articles indexed in Scopus or Web of Science were prioritised to ensure scientific credibility.

Finally, the structured comparative framework ensured analytical consistency across all four countries, thereby reducing researcher bias and enhancing the transparency and reproducibility of the comparative policy evaluation. The combination of document analysis, thematic synthesis, and cross-country comparison provides a robust methodological foundation for identifying policy strengths, implementation challenges, and evidence-based recommendations for strengthening food waste governance in Malaysia.

RESULTS AND DISCUSSION

Comparative Overview of National Food Waste Policies

The comparative analysis revealed considerable differences in the maturity, comprehensiveness, and implementation effectiveness of food waste management policies among Malaysia, Japan, South Korea, and Germany. Although all four countries acknowledge food waste as an important environmental issue, their policy priorities, legislative approaches, institutional arrangements, and resource recovery strategies differ substantially according to their respective socio-economic contexts, governance capacities, and sustainability agendas. Overall, Japan, South Korea, and Germany have developed integrated policy frameworks that position food waste management within broader circular economy and climate change strategies, whereas Malaysia continues to rely primarily on municipal solid waste management policies with comparatively limited emphasis on dedicated food waste governance [9],[14],[28].

One of the most significant findings concerns the evolution of policy objectives across the selected countries. Malaysia's existing policy framework remains largely centred on improving waste collection, landfill management, and public cleanliness through the Solid Waste and Public Cleansing Management Act 2007 (Act 672) and the National Solid Waste Management Policy [12]. Although these initiatives have strengthened institutional responsibility for municipal solid waste management, they do not specifically regulate food waste prevention, redistribution, or mandatory resource recovery throughout the food supply chain. Consequently, food waste management is frequently addressed as one component of municipal solid waste rather than as a distinct resource stream requiring specialised legislative, technological, and institutional interventions [15].

By comparison, the three developed countries have progressively shifted from conventional waste disposal towards resource-oriented policy frameworks. Japan's Food Recycling Law requires food-related businesses to reduce waste generation while promoting the recycling of unavoidable food waste into animal feed, compost, fertilisers, and renewable energy [28]. Similarly, South Korea has introduced mandatory source separation, volume-based waste charging, and strict landfill restrictions, thereby transforming food waste from an environmental burden into a valuable economic resource [21]. Germany integrates food waste prevention within the Circular Economy Act and the European Union Circular Economy Action Plan, prioritising waste prevention, material recovery, producer responsibility, and sustainable resource utilisation throughout the product life cycle [10]. These contrasting policy approaches demonstrate a fundamental transition from waste disposal to resource circularity, reflecting broader commitments to sustainable development and carbon neutrality.

Institutional governance also emerged as a critical determinant of policy effectiveness. In Malaysia, responsibilities for food waste management remain distributed among several ministries and government agencies, including the Ministry of Housing and Local Government, the Department of Environment, SWCorp Malaysia, local authorities, and state governments. While this multi-agency structure enables broad stakeholder involvement, previous studies have reported overlapping responsibilities, inconsistent policy implementation, and varying enforcement capacities across different jurisdictions [16],[17]. Similar governance challenges have been observed in several developing countries where fragmented institutional arrangements reduce administrative efficiency and delay policy implementation [3].

Conversely, Japan, South Korea, and Germany demonstrate higher levels of institutional integration supported by clearly defined legislative responsibilities and long-term strategic planning. Government agencies coordinate closely with local authorities, private industries, academic institutions, and civil society organisations to implement food waste reduction

programmes through measurable performance indicators and continuous policy evaluation [3],[30]. Such integrated governance enables more effective enforcement of mandatory waste separation, recycling obligations, public awareness campaigns, and resource recovery initiatives. These findings support previous observations by Principato et al. [22], who argued that governance quality and institutional coordination are fundamental determinants of successful food waste management regardless of technological capability.

The comparative assessment further indicates that economic instruments play an increasingly important role in influencing waste management behaviour. South Korea's volume-based waste charging system provides a direct financial incentive for households and commercial establishments to minimise food waste generation, while Japan encourages food recycling through regulatory obligations and industrial partnerships. Germany combines extended producer responsibility, landfill restrictions, recycling targets, and circular economy incentives to encourage waste prevention across the food supply chain [3],[10]. In contrast, Malaysia continues to rely predominantly on educational campaigns, voluntary participation, and conventional municipal waste collection services. Although public awareness initiatives remain essential, evidence from developed countries suggests that combining educational programmes with regulatory and economic instruments generally produces greater long-term reductions in food waste generation [2],[22].

Resource recovery represents another important point of divergence. Malaysia has introduced several composting, food donation, and organic waste recycling initiatives through government agencies, universities, and local authorities. However, implementation remains relatively limited and uneven, with landfill disposal continuing to dominate municipal waste management [14]. By comparison, Japan, South Korea, and Germany have established extensive infrastructure supporting composting, anaerobic digestion, livestock feed production, biogas generation, and nutrient recovery, enabling food waste to be reintegrated into productive economic systems [21],[23]. These findings illustrate that successful circular economy implementation depends not only on technological availability but also on coherent legislation, long-term investment, market incentives, and institutional commitment.

Overall, the comparative analysis demonstrates that the effectiveness of national food waste management policies is determined by the interaction of legislative frameworks, governance quality, economic instruments, technological infrastructure, and stakeholder participation rather than by any single policy intervention. Countries adopting integrated and preventive policy approaches consistently exhibit stronger resource recovery performance and lower reliance on landfill disposal than those emphasising downstream waste collection alone. These findings provide an important foundation for the subsequent detailed evaluation of legislative structures, institutional arrangements, and policy implementation mechanisms across the selected countries.

Legislative and Institutional Frameworks

The comparative assessment identified substantial variation in the legal specificity, regulatory coverage, and institutional coordination of food waste governance across the four countries. The most important distinction lies in whether food waste is regulated as a dedicated material stream or treated more generally as part of municipal solid waste. Japan and South Korea have developed targeted regulatory arrangements that directly address food waste generation, separation, collection, recycling, and resource recovery. Germany regulates food waste within an integrated circular economy and European Union waste hierarchy framework. Malaysia, in contrast, primarily manages food waste under broader solid waste legislation, with no single comprehensive national law governing the entire food waste hierarchy from prevention to final recovery.

In Malaysia, the principal legal instrument for solid waste governance is the Solid Waste and Public Cleansing Management Act 2007 (Act 672). The Act provides a regulatory foundation for solid waste collection, transportation, treatment, disposal, licensing, enforcement, and public cleansing services. It has contributed to greater federal coordination and professionalisation of solid waste management in participating states. However, its primary orientation remains focused on service delivery and environmentally sound disposal rather than food waste prevention and circular resource recovery. Food waste is generally classified within the broader municipal solid waste stream, and the legislation does not establish binding national targets for food waste reduction, mandatory commercial food waste reporting, edible-food redistribution, or compulsory organic waste recycling.

The institutional implementation of Act 672 is principally coordinated through the Ministry of Housing and Local Government and the National Solid Waste Management Department, with SWCorp Malaysia undertaking regulatory, enforcement, public awareness, and implementation-related functions. Local authorities, concessionaires, state governments, businesses, and waste facility operators also hold important operational responsibilities. Nevertheless, the federalised legal framework is not applied uniformly across all Malaysian states. Differences in state participation, local authority capacity, infrastructure availability, and

enforcement intensity have contributed to geographical variation in waste management performance. This uneven institutional landscape makes it difficult to establish a consistent national food waste system, particularly for source separation, separate collection, data reporting, and organic waste recovery.

Malaysia's policy environment also involves multiple agencies with responsibilities that intersect with food waste management. Agricultural agencies are concerned with food production and post-harvest loss, health authorities regulate food safety, welfare organisations support food redistribution, environmental agencies oversee pollution control, and local governments manage markets, restaurants, public cleansing, and municipal waste. Although this distribution of responsibilities reflects the multidimensional nature of food waste, it can produce governance fragmentation when roles, reporting procedures, enforcement authority, and strategic objectives are not sufficiently coordinated. The absence of a central food waste governance mechanism therefore limits the integration of prevention, donation, recycling, treatment, and monitoring activities across the food supply chain.

Japan presents a more specialised legal model. Its food waste governance framework is centred on the Act on Promotion of Recycling and Related Activities for Treatment of Cyclical Food Resources, commonly referred to as the Food Recycling Law. The legislation specifically targets businesses involved in food manufacturing, wholesale, retail, and food services. It encourages the prevention of food waste generation and requires greater recycling of unavoidable food residues into animal feed, fertiliser, methane energy, and other useful products. The law also establishes sectoral responsibilities and supports measurable recycling targets, allowing policy progress to be monitored more systematically than under a general municipal waste framework.

The institutional strength of the Japanese system lies in the coordination of central ministries, municipal governments, food-related businesses, farmers, recycling operators, and consumers. The Ministry of Agriculture, Forestry and Fisheries plays an important role because food waste recycling is connected directly with agricultural production, livestock feed, and fertiliser use. Environmental authorities contribute to waste regulation and resource circulation, while municipalities support local collection and recycling arrangements. This cross-sectoral design facilitates the development of recycling loops in which food businesses supply separated organic residues to recycling enterprises, and the recovered products are returned to agricultural or energy systems. Japan's legal framework therefore extends beyond waste disposal and establishes a relationship between food industries, recycling markets, and resource users.

South Korea's regulatory framework is characterised by stronger mandatory instruments and direct economic accountability. The country progressively restricted the landfilling of food waste and introduced compulsory source separation, differentiated collection systems, and volume-based charging. Under this model, households and businesses are required to separate food waste from general refuse and pay according to the quantity discarded. Municipalities administer collection arrangements, while central government authorities establish national standards, technological guidance, environmental requirements, and policy direction.

The South Korean institutional model combines national regulatory leadership with technologically supported municipal implementation. Local governments may use designated containers, prepaid bags, or radio-frequency identification-based systems to measure food waste disposal. The data generated through these systems can improve billing accuracy, behavioural monitoring, and operational planning. Importantly, the legal and institutional framework assigns a direct financial consequence to waste generation. This feature distinguishes South Korea from systems that rely largely on voluntary participation, because waste prevention is reinforced through both regulatory obligation and household-level economic incentives.

Germany regulates food waste through a broader circular economy framework rather than a single food waste-specific law. Its Circular Economy Act establishes the waste hierarchy, under which prevention is prioritised over preparation for reuse, recycling, recovery, and disposal. Food and biodegradable waste are also influenced by European Union directives, national bio-waste requirements, municipal collection systems, environmental standards, and policies addressing sustainable consumption and food waste prevention. This legal architecture embeds food waste within an integrated system of resource efficiency, producer responsibility, separate collection, recycling, and environmental protection.

Institutional responsibility in Germany is distributed across federal, state, and municipal levels, but the allocation of legal authority is comparatively well established. Federal authorities develop overarching legislation and national strategies, state authorities support implementation and enforcement, and municipalities organise waste collection and local treatment systems. Private waste companies, retailers, food manufacturers, charities, consumer organisations, and research institutions also participate in prevention and recovery initiatives. Although decentralisation can create regional variation, it is supported by binding environmental standards and the wider European Union regulatory framework. As a result, decentralised implementation does not necessarily produce the same degree of policy fragmentation observed in systems where national food waste targets and institutional responsibilities remain less clearly defined.

Table 1: Comparative legislative and institutional frameworks for food waste management

Evaluation component	Malaysia	Japan	South Korea	Germany
Primary legal orientation	Municipal solid waste management and public cleansing	Dedicated food recycling and resource-circulation legislation	Mandatory food waste separation, charging, and recycling	Integrated circular economy and waste-hierarchy legislation
Treatment of food waste	Primarily a component of municipal solid waste	Distinct recyclable resource stream	Separately regulated organic waste stream	Bio-waste and food waste governed within circular economy policies
Prevention emphasis	Emerging but largely voluntary	Incorporated into business obligations and recycling targets	Reinforced through user charges and quantity reduction	Prioritised under the waste hierarchy and prevention strategies
Source separation	Implemented selectively and unevenly	Supported through business and municipal systems	Mandatory and widely institutionalised	Required for relevant waste streams under national and EU frameworks
Economic instruments	Limited direct charging specifically for food waste	Compliance obligations and recycling incentives	Volume-based charging and measured disposal	Waste fees, producer responsibility, landfill restrictions, and market incentives
Main national institutions	Ministry of Housing and Local Government, National Solid Waste Management Department, and SWCorp Malaysia	Ministry of Agriculture, Forestry and Fisheries and environmental authorities	Ministry of Environment and municipal governments	Federal environmental authorities, state governments, municipalities, and EU institutions
Institutional coordination	Multi-agency but fragmented and geographically uneven	Strong cross-sectoral coordination involving food and agricultural sectors	Strong national-local coordination supported by monitoring technologies	Multi-level governance supported by binding national and EU standards
Monitoring and reporting	Limited food waste-specific national reporting	Sectoral targets and business reporting mechanisms	Quantity-based data and municipal monitoring	National, municipal, and EU-aligned waste monitoring
Overall legislative maturity	Developing	Mature and sector-specific	Mature and enforcement-oriented	Mature and systemically integrated

The findings presented in Table 1 demonstrate that legislative maturity is not determined solely by the existence of waste management laws. Rather, effective food waste governance depends on the degree to which legislation clearly defines the material stream, establishes measurable objectives, allocates institutional responsibilities, requires monitoring, and provides enforceable implementation mechanisms. Malaysia has an established solid waste governance structure, but it lacks the food waste-specific regulatory detail evident in Japan and South Korea and the system-wide circularity embedded in Germany's policy framework.

The comparison also reveals three institutional characteristics associated with stronger policy performance. First, successful systems establish clear responsibility for each stage of the food waste hierarchy. In Japan, businesses are linked to recycling obligations and resource users; in South Korea, households, businesses, municipalities, and treatment operators participate in a mandatory separation and charging system; and in Germany, different levels of government operate within a clearly structured circular economy framework. By contrast, Malaysia's responsibilities are distributed across numerous agencies without a unified food waste governance platform.

Second, stronger institutional systems connect legal obligations to measurable performance. Japan uses recycling targets and business-sector requirements, South Korea quantifies disposal through volume- or weight-based charging, and Germany operates within national and European reporting frameworks. Malaysia's food waste data remain comparatively fragmented, with variations in definitions, sampling methods, geographical coverage, and reporting frequency. Without standardised measurement, policymakers face difficulties in establishing baselines, evaluating programmes, and determining whether national interventions are producing measurable reductions.

Third, effective legislation is closely linked to infrastructure and market development. Legal requirements for source separation are unlikely to succeed where separate collection, treatment capacity, and markets for recovered products remain inadequate. Japan's food recycling loops are supported by demand for animal feed, fertiliser, and energy products. South Korea's compulsory separation system is connected to organised recycling and treatment infrastructure. Germany's bio-waste collection is integrated with composting, anaerobic digestion, energy recovery, and environmental quality standards. Malaysia's more limited organic waste infrastructure reduces the feasibility of imposing comprehensive mandatory separation without parallel investment in collection systems and treatment facilities.

These findings imply that Malaysia does not necessarily need to replicate a single foreign model. A more appropriate strategy would combine selected elements from each system while adapting them to national governance conditions. Japan offers a useful model for assigning responsibilities to food-related businesses and developing food recycling loops. South Korea demonstrates the behavioural effectiveness of mandatory source separation and quantity-based charging. Germany illustrates how food waste prevention can be embedded within a broader circular economy and waste-hierarchy framework. An adapted Malaysian framework could therefore establish a dedicated national food waste policy, clarify institutional leadership, introduce phased mandatory separation for major commercial generators, standardise food waste data collection, and support markets for compost, animal feed, biogas, and other recovered resources.

Overall, the legislative comparison confirms that Malaysia's principal policy gap is not the complete absence of waste legislation but the lack of a coordinated, food waste-specific framework that links prevention, redistribution, source separation, recycling, infrastructure, enforcement, and performance monitoring. Addressing this gap would provide the legal and institutional foundation required for the implementation mechanisms examined in the following section.

Policy Instruments and Implementation Mechanisms

The effectiveness of food waste management policies depends not only on legislative provisions but also on the policy instruments and implementation mechanisms employed to translate legal objectives into practical outcomes. The comparative analysis demonstrates that Japan, South Korea, and Germany have developed integrated implementation systems combining regulatory measures, economic incentives, technological infrastructure, stakeholder collaboration, and continuous public engagement. Malaysia has introduced several important initiatives in these areas; however, implementation remains fragmented and uneven, limiting the overall effectiveness of national food waste management.

One of the principal differences among the selected countries concerns the balance between mandatory regulatory instruments and voluntary behavioural approaches. Malaysia's current food waste management initiatives largely rely on public education campaigns, voluntary source separation, awareness programmes, recycling campaigns, and community-based composting projects coordinated by SWCorp Malaysia, local authorities, educational institutions, and non-governmental organisations [14]. These programmes have increased public awareness regarding waste minimisation and recycling, particularly within schools, universities, and urban communities. Nevertheless, voluntary participation alone has produced relatively modest reductions in food waste generation because participation rates vary considerably across regions and demographic groups. Previous studies indicate that awareness programmes are most effective when supported by complementary regulatory measures and economic incentives that reinforce behavioural change [2],[22].

In contrast, Japan employs a regulatory framework that combines mandatory obligations with collaborative implementation. The Food Recycling Law requires businesses within the food manufacturing, retail, wholesale, and food service sectors to implement waste reduction measures and increase the recycling of unavoidable food residues. Rather than imposing purely

punitive regulations, the Japanese model encourages cooperation among industries, recycling companies, farmers, and government agencies to establish closed-loop resource systems. Food residues are converted into livestock feed, compost, fertilisers, and renewable energy, creating economic value while reducing landfill disposal. This cooperative implementation model illustrates how regulatory obligations can stimulate innovation and market development when supported by appropriate institutional arrangements [28].

South Korea adopts a more interventionist approach through mandatory source separation and the "Pay-As-You-Throw" (PAYT) system. Under this mechanism, households and commercial establishments are required to separate food waste from other municipal waste and pay disposal charges based on the quantity generated. The charging system creates a direct financial incentive for waste reduction by internalising disposal costs at the point of generation. Municipal authorities support implementation through dedicated food waste collection systems, specialised treatment facilities, and digital monitoring technologies, including radio-frequency identification (RFID)-enabled collection bins in many urban areas [21]. Numerous studies have demonstrated that quantity-based charging has significantly reduced food waste generation while simultaneously improving recycling efficiency and public participation. Importantly, the South Korean experience highlights that behavioural change can be accelerated when economic incentives complement legal requirements and environmental education.

Germany demonstrates a different implementation pathway by embedding food waste prevention within a comprehensive circular economy framework. Rather than relying exclusively on mandatory food waste legislation, Germany employs a combination of waste hierarchy principles, extended producer responsibility, landfill restrictions, sustainable procurement policies, voluntary agreements with the food industry, and consumer awareness initiatives. Supermarkets, food manufacturers, restaurants, charities, and civil society organisations actively participate in food donation programmes that redirect edible surplus food to vulnerable populations before it becomes waste. At the same time, unavoidable organic waste is channelled into composting and anaerobic digestion facilities that recover nutrients and renewable energy. This integrated implementation strategy illustrates how regulatory frameworks, market incentives, and stakeholder collaboration can collectively support circular resource management while minimising environmental impacts [3],[10].

Another significant finding concerns the role of stakeholder engagement in determining policy success. The three developed countries demonstrate that effective food waste management extends beyond government intervention and requires active participation from multiple actors throughout the food supply chain. Government agencies establish regulatory frameworks and policy direction, while local authorities coordinate collection services and infrastructure development. Food manufacturers, retailers, restaurants, agricultural producers, recycling companies, research institutions, and consumers each contribute to different stages of prevention, redistribution, recycling, and resource recovery. This multi-stakeholder governance approach promotes shared responsibility and facilitates the exchange of knowledge, technology, and financial resources necessary for long-term policy implementation [22],[23].

Malaysia has also witnessed increasing stakeholder participation in food waste reduction through initiatives such as food bank programmes, university-based composting projects, community recycling campaigns, and private-sector sustainability initiatives. Organisations including Yayasan Food Bank Malaysia, SWCorp Malaysia, local authorities, and numerous non-governmental organisations have successfully diverted edible food from disposal while raising public awareness regarding responsible consumption. However, many of these initiatives remain project-based or geographically concentrated rather than systematically integrated into a national food waste governance framework. Consequently, implementation outcomes vary considerably across different regions and sectors, limiting opportunities for nationwide policy standardisation and performance evaluation.

The comparison further demonstrates that monitoring and enforcement mechanisms are essential components of successful implementation. Japan requires periodic reporting from regulated businesses regarding food waste reduction and recycling activities, enabling government agencies to monitor compliance and evaluate policy performance. South Korea similarly collects detailed information through municipal monitoring systems linked to quantity-based charging programmes, allowing authorities to assess behavioural changes and operational efficiency. Germany benefits from well-established environmental monitoring systems supported by national legislation and European Union reporting requirements. By comparison, Malaysia continues to experience challenges associated with inconsistent food waste data collection, limited reporting requirements, and differences in waste characterisation methodologies among local authorities. These limitations reduce the ability of policymakers to establish national performance indicators, benchmark regional progress, and evaluate the long-term effectiveness of policy interventions. Economic incentives also emerged as an important determinant of implementation effectiveness. Countries with mature food waste management systems increasingly utilise combinations of financial incentives and regulatory instruments to encourage sustainable behaviour. Examples include reduced disposal costs for waste minimisation, financial support for anaerobic digestion and composting facilities, tax incentives for food donation programmes, and investment in recycling infrastructure.

Such instruments help create economically viable markets for recovered organic resources while encouraging private-sector participation in circular economy activities. Malaysia has begun expanding investment in organic waste recycling and compost production; however, financial incentives specifically targeting food waste prevention and resource recovery remain comparatively limited. Strengthening economic instruments may therefore increase investment in food recycling technologies while improving the commercial viability of recovered products.

Table 2: summarises the principal implementation mechanisms adopted by each country and highlights the policy instruments associated with higher implementation effectiveness.

Policy instrument	Malaysia	Japan	South Korea	Germany
Public awareness programmes	Extensive	Extensive	Extensive	Extensive
Mandatory source separation	Limited implementation	Sector-specific	Nationwide mandatory	Widely implemented
Food donation programmes	Emerging	Well established	Moderate	Highly developed
Quantity-based charging	Limited	Limited	Comprehensive PAYT system	Municipal waste fee systems
Business reporting requirements	Limited	Mandatory for relevant sectors	Mandatory	Supported through regulatory reporting
Recycling infrastructure	Developing	Advanced	Advanced	Advanced
Composting and anaerobic digestion	Expanding	Extensive	Extensive	Extensive
Economic incentives	Limited	Moderate	Strong	Strong
Digital monitoring technologies	Emerging	Moderate	Advanced RFID-based systems	Advanced information systems
Overall implementation maturity	Developing	High	Very High	High

The comparative findings indicate that countries achieving the greatest reductions in food waste share several common implementation characteristics. First, regulatory requirements are reinforced by practical implementation mechanisms rather than relying solely on legislative provisions. Second, economic incentives encourage behavioural change among households and commercial sectors. Third, infrastructure investment ensures that separated food waste can be effectively recycled or recovered. Finally, continuous monitoring and stakeholder collaboration enable governments to evaluate policy performance and adapt implementation strategies over time.

For Malaysia, these findings suggest that future policy development should extend beyond introducing new legislation. Greater emphasis should be placed on strengthening implementation capacity through mandatory source separation for high-volume waste generators, harmonised national food waste reporting systems, expanded food donation networks, investment in composting and anaerobic digestion facilities, and the gradual introduction of appropriate economic incentives. Such measures would strengthen the transition from a predominantly disposal-oriented waste management system towards a resource-efficient circular economy capable of delivering long-term environmental, economic, and social benefits.

Food Waste Prevention and Resource Recovery Strategies

Food waste prevention is widely recognised as the most effective strategy within the waste hierarchy because it eliminates waste generation before environmental and economic losses occur. Nevertheless, complete prevention is rarely achievable due to unavoidable food residues generated throughout agricultural production, food processing, distribution, retailing, hospitality services, and household consumption. Consequently, countries with mature food waste management systems increasingly combine prevention initiatives with resource recovery strategies that maximise the value of unavoidable organic waste through reuse, recycling, composting, anaerobic digestion, animal feed production, and bioenergy generation. The comparative analysis indicates that Japan, South Korea, and Germany have successfully integrated these approaches within national circular economy policies, whereas Malaysia remains at an earlier stage of transitioning from disposal-oriented waste management towards resource recovery.

The first level of food waste management focuses on prevention at the source. All four countries have implemented educational campaigns encouraging consumers to purchase food responsibly, reduce overconsumption, improve meal planning, and minimise unnecessary food disposal. However, the effectiveness of prevention strategies differs considerably depending on whether behavioural interventions are supported by regulatory and economic instruments. Malaysia has implemented numerous awareness campaigns through SWCorp Malaysia, educational institutions, local authorities, and community organisations, promoting responsible food consumption and household waste reduction. Campaigns such as "Love Food, Hate Waste", school-based environmental education programmes, and public recycling initiatives have contributed to increasing public awareness regarding sustainable consumption practices. Nevertheless, food waste generation remains high, suggesting that behavioural change alone is insufficient without complementary policy measures, incentives, and monitoring systems [14],[16]. Japan has adopted a broader prevention strategy that extends beyond households to encompass the entire food supply chain. Food manufacturers, wholesalers, retailers, supermarkets, and restaurants are encouraged to improve inventory management, optimise production planning, reduce overstocking, and minimise avoidable food losses. The Food Recycling Law promotes food waste prevention as the highest priority before recycling and resource recovery. Businesses are expected to improve operational efficiency while reporting progress towards national food recycling targets. This integrated approach demonstrates that food waste prevention is most effective when supported by legal obligations, industrial cooperation, and continuous performance monitoring rather than relying exclusively on consumer education [28].

South Korea similarly places considerable emphasis on preventing unnecessary food waste through behavioural and economic mechanisms. The mandatory "Pay-As-You-Throw" (PAYT) charging system directly links household expenditure to food waste generation, encouraging consumers to reduce excessive purchasing and improve food utilisation. Studies have shown that quantity-based charging has significantly influenced consumer behaviour by increasing awareness of disposal costs while promoting waste minimisation at the household level [21]. Unlike awareness campaigns alone, economic incentives create continuous behavioural reinforcement, making waste prevention an integral component of everyday consumption practices.

Germany approaches food waste prevention through sustainable production and consumption policies aligned with the European Union Circular Economy Action Plan and Farm to Fork Strategy. National campaigns encourage retailers, restaurants, food manufacturers, and consumers to reduce avoidable food waste by improving supply chain efficiency, extending product shelf life through better inventory management, promoting clearer food date labelling, and increasing consumer awareness regarding food preservation and meal planning [10]. Importantly, Germany emphasises collaboration between government agencies, retailers, charities, and consumers to prevent edible food from entering the waste stream, thereby reducing environmental impacts while strengthening food security.

Where prevention is no longer possible, the second priority involves redistributing edible surplus food. Food donation programmes have become increasingly important policy instruments because they simultaneously reduce waste disposal and address food insecurity. Germany has developed an extensive network of food banks, charitable organisations, and volunteer groups that redistribute edible surplus food from supermarkets, restaurants, food manufacturers, and wholesalers to vulnerable communities. Japan has similarly expanded food donation partnerships involving municipalities, non-governmental organisations, and private companies, while South Korea increasingly supports food redistribution initiatives alongside its recycling programmes. Malaysia has also demonstrated encouraging progress through initiatives such as Yayasan Food Bank Malaysia, food bank programmes organised by universities, supermarkets, religious institutions, and civil society organisations. However, food donation activities remain relatively fragmented and are often dependent upon local initiatives rather than integrated into a comprehensive national food redistribution policy. Strengthening legal protection for food donors, establishing clearer operational guidelines, and improving logistics infrastructure could substantially increase the recovery of edible surplus

food before disposal.

For unavoidable food residues unsuitable for human consumption, biological recycling technologies constitute the third level of the food waste hierarchy. Composting remains one of the most widely adopted resource recovery strategies due to its relatively simple operation and ability to convert biodegradable waste into nutrient-rich organic fertiliser. Malaysia has implemented numerous small-scale composting initiatives through local authorities, universities, schools, agricultural agencies, and community organisations. Although these programmes contribute positively to public awareness and local waste reduction, large-scale commercial composting infrastructure remains limited compared with developed countries. Consequently, a significant proportion of biodegradable waste continues to be disposed of in sanitary landfills, representing a considerable loss of recoverable nutrients and organic matter [14].

Japan, South Korea, and Germany have established considerably more advanced biological treatment systems. Large-scale composting facilities are integrated with municipal collection programmes and agricultural sectors, enabling compost products to be returned to farms and landscaping industries. This closed-loop approach reduces dependence on chemical fertilisers while promoting soil health and sustainable agriculture. The success of these systems reflects not only technological capability but also stable market demand, quality assurance standards, and policy support that encourage the commercial utilisation of recovered organic products.

Anaerobic digestion has also become an increasingly important resource recovery technology because it simultaneously produces renewable energy and nutrient-rich digestate suitable for agricultural application. Germany has emerged as a global leader in anaerobic digestion through substantial investment in biogas infrastructure supported by renewable energy policies, feed-in tariffs, and agricultural cooperation. Organic waste collected separately from households, food industries, and commercial establishments is converted into methane-rich biogas for electricity and heat generation, while digestate is recycled as fertiliser. Japan has similarly expanded anaerobic digestion facilities, particularly within municipal waste treatment systems and industrial food processing sectors. South Korea combines anaerobic digestion with other recycling technologies to maximise resource recovery from organic waste. In contrast, Malaysia has only recently begun expanding anaerobic digestion projects, and implementation remains concentrated within selected municipalities, research institutions, and pilot-scale facilities. Limited investment, inconsistent feedstock quality, and insufficient collection infrastructure continue to constrain wider adoption.

Another distinguishing feature of Japan's resource recovery system is the extensive conversion of food waste into livestock feed. The Food Recycling Law encourages the production of eco-feed from processed food residues that meet strict quality and safety standards. This practice reduces dependence on imported feed ingredients while simultaneously diverting large quantities of organic waste from disposal. Although Malaysia possesses a significant livestock sector, the utilisation of processed food waste as regulated animal feed remains comparatively limited because of food safety concerns, inconsistent waste segregation, and limited commercial processing capacity. Establishing national quality standards and strengthening regulatory oversight could facilitate greater utilisation of food waste-derived feed resources while maintaining public health protection.

The comparative analysis indicates that successful resource recovery depends on more than technological availability. Countries demonstrating the highest recovery performance have integrated prevention, redistribution, biological treatment, renewable energy production, and market development within coherent national policy frameworks. Technologies are supported by legislative requirements, stable financial incentives, dedicated collection systems, quality standards, research and innovation, and long-term investment. By contrast, technological adoption in Malaysia frequently occurs through isolated pilot projects or local initiatives without equivalent nationwide policy integration. This fragmentation limits economies of scale and reduces investor confidence in organic waste recycling industries.

Table 3: Comparison of food waste prevention and resource recovery strategies

Strategy	Malaysia	Japan	South Korea	Germany
Consumer awareness campaigns	Extensive	Extensive	Extensive	Extensive
Supply chain waste prevention	Developing	Highly developed	Highly developed	Highly developed

Mandatory business waste reduction	Limited	Yes	Yes	Partially through broader regulations
Food donation programmes	Emerging	Well established	Developing	Highly developed
Community composting	Common	Moderate	Moderate	Moderate
Industrial composting	Limited	Extensive	Extensive	Extensive
Anaerobic digestion	Developing	Extensive	Extensive	Extensive
Animal feed production from food waste	Limited	Highly developed	Moderate	Limited
Renewable energy recovery	Pilot and developing	Well established	Well established	Highly developed
Circular economy integration	Emerging	High	High	Very High

The findings summarised in Table 3 demonstrate that the transition from food waste disposal to resource recovery requires a coordinated system in which prevention, redistribution, recycling, and energy recovery function as complementary rather than independent strategies. Countries achieving the greatest environmental and economic benefits consistently prioritise waste prevention, maximise edible food redistribution, and recover value from unavoidable organic waste through diversified treatment technologies. Malaysia has established a promising foundation through national awareness programmes, food donation initiatives, and expanding composting and recycling activities. However, achieving comparable levels of circular economy performance will require stronger legislative support, improved collection infrastructure, expanded biological treatment capacity, greater private-sector participation, and market development for recovered organic products.

Overall, the comparative analysis confirms that prevention and resource recovery should not be viewed as separate policy objectives but as mutually reinforcing components of an integrated circular economy. Their successful implementation depends upon coherent governance, supportive legislation, technological readiness, economic incentives, stakeholder collaboration, and continuous monitoring. Strengthening these interconnected elements will enable Malaysia to reduce landfill dependency while simultaneously improving resource efficiency, renewable energy production, agricultural sustainability, and national progress towards Sustainable Development Goal 12.3 and broader climate resilience objectives.

Comparative Policy Effectiveness

The comparative evaluation demonstrates that the effectiveness of national food waste management policies cannot be attributed to a single legislative instrument, technological innovation, or institutional arrangement. Instead, policy performance reflects the interaction between governance quality, regulatory enforcement, stakeholder participation, technological readiness, financial incentives, and continuous policy evaluation. The experiences of Japan, South Korea, and Germany indicate that successful food waste governance is achieved through integrated policy ecosystems in which prevention, recycling, resource recovery, and circular economy principles are embedded across the entire food supply chain. Malaysia has established an important legislative and institutional foundation; however, several structural and implementation gaps continue to constrain policy effectiveness and limit the transition towards a circular food system.

A major finding of this comparative analysis is that policy integration is a stronger predictor of successful food waste management than the existence of individual waste management laws. Although Malaysia possesses comprehensive legislation governing municipal solid waste under the Solid Waste and Public Cleansing Management Act 2007 (Act 672), food waste management remains dispersed across multiple policy domains, including environmental protection, public health, agriculture, local government, and food security. The absence of a dedicated national food waste policy reduces coordination among implementing agencies and limits opportunities for integrating prevention, redistribution, recycling, renewable energy production, and circular economy development into a unified governance framework. By comparison, Japan and South Korea

have established specialised policy systems in which food waste reduction is recognised as a national priority supported by clearly defined legal responsibilities, measurable performance targets, and coordinated institutional implementation.

The analysis also demonstrates that countries adopting preventive policy approaches consistently outperform those relying primarily on downstream waste treatment. Japan and Germany place considerable emphasis on preventing food waste generation through improved supply chain management, inventory optimisation, sustainable production practices, consumer education, and food redistribution programmes before considering recycling or disposal options. These preventive strategies reduce environmental impacts while simultaneously lowering waste management costs and improving resource efficiency. South Korea complements prevention with strong economic instruments that directly influence consumer behaviour through quantity-based charging, creating financial incentives to minimise waste generation at the household level. Malaysia has successfully implemented numerous awareness campaigns promoting responsible consumption; however, preventive interventions remain predominantly voluntary and therefore have achieved more modest behavioural impacts than integrated regulatory and economic approaches.

Another important finding concerns the role of economic instruments in supporting policy effectiveness. Countries that internalise the environmental cost of food waste through financial mechanisms generally achieve stronger waste reduction outcomes than those relying solely on education and voluntary participation. South Korea's "Pay-As-You-Throw" system represents one of the most effective examples of behavioural economics applied to waste management. By requiring households and commercial establishments to pay according to the quantity of food waste generated, the system creates continuous incentives for waste prevention while generating reliable data for policy evaluation. Germany similarly employs economic instruments through landfill restrictions, waste fees, producer responsibility schemes, and financial support for renewable energy and recycling infrastructure. Japan uses regulatory obligations supported by industrial partnerships and market incentives that encourage businesses to convert unavoidable food waste into economically valuable products. In contrast, Malaysia's financial incentives remain comparatively limited, particularly with respect to commercial food waste reduction, organic waste recycling, and private-sector investment in resource recovery infrastructure.

The comparative analysis further indicates that institutional coordination substantially influences implementation effectiveness. Countries exhibiting high food waste recovery rates consistently demonstrate clear allocation of institutional responsibilities, strong inter-agency collaboration, standardised reporting systems, and continuous policy monitoring. Japan coordinates food waste governance through collaboration among ministries responsible for agriculture, environment, industry, and local government, thereby linking food recycling directly with agricultural production and renewable resource utilisation. South Korea combines central government policy direction with technologically advanced municipal implementation systems that facilitate accurate monitoring and enforcement. Germany operates within a multi-level governance framework integrating federal, state, municipal, and European Union institutions under common environmental objectives. Malaysia, while possessing capable institutions such as SWCorp Malaysia and the National Solid Waste Management Department, continues to experience challenges associated with overlapping responsibilities, differing implementation capacities among local authorities, and inconsistent policy application across jurisdictions. These institutional characteristics reduce implementation efficiency and complicate nationwide policy coordination.

Technological infrastructure also emerged as a critical determinant of policy success, although the analysis suggests that technology alone cannot explain national performance differences. Japan, South Korea, and Germany have invested extensively in composting facilities, anaerobic digestion plants, food recycling systems, renewable energy generation, and separate organic waste collection infrastructure. However, these technological systems operate effectively because they are supported by enabling legislation, stable markets, economic incentives, and reliable waste segregation practices. Malaysia has made encouraging progress through pilot composting programmes, food recycling initiatives, and the gradual expansion of anaerobic digestion technologies. Nevertheless, insufficient organic waste segregation, inconsistent feedstock quality, and limited large-scale treatment capacity continue to constrain technological performance. These findings support previous research indicating that governance quality is a prerequisite for successful technology adoption rather than merely a complementary factor [22],[23].

The study further reveals that stakeholder participation significantly enhances policy effectiveness when institutional arrangements encourage shared responsibility across the food supply chain. Developed countries increasingly view food waste management as a collaborative responsibility involving governments, industries, retailers, consumers, academic institutions, charities, and civil society organisations. Food manufacturers improve production efficiency, retailers optimise inventory management, consumers reduce avoidable waste, charities redistribute edible surplus food, and recycling industries recover valuable resources from unavoidable residues. This collaborative governance model strengthens circular economy implementation by ensuring that food waste prevention and recovery occur at multiple stages of the supply chain rather than

relying solely on municipal waste management systems. Malaysia has demonstrated increasing stakeholder engagement through food bank programmes, university initiatives, corporate sustainability programmes, and community composting activities. However, these initiatives remain relatively fragmented and would benefit from stronger institutional integration within national policy frameworks.

To synthesise the comparative findings, five critical success factors consistently distinguish high-performing food waste management systems from developing systems.

Table 4: Critical success factors influencing national food waste management effectiveness

Success factor	Malaysia	Japan	South Korea	Germany
Dedicated food waste policy	Partial	Yes	Yes	Yes, within circular economy framework
Strong institutional coordination	Moderate	High	High	High
Mandatory implementation mechanisms	Limited	High	Very High	High
Economic incentives	Limited	Moderate	Very High	High
Circular economy integration	Emerging	High	High	Very High
Monitoring and performance evaluation	Moderate	High	Very High	High
Advanced resource recovery infrastructure	Developing	High	High	Very High
Multi-stakeholder collaboration	Moderate	High	High	High
Overall policy effectiveness	Moderate	High	Very High	Very High

The evidence presented in Table 4 indicates that policy effectiveness is cumulative rather than isolated. Countries achieving the highest levels of food waste reduction consistently perform well across multiple dimensions simultaneously. Strong legislation without institutional capacity is insufficient; advanced technology without reliable source separation yields limited benefits; and public awareness campaigns without supporting economic incentives rarely achieve sustained behavioural change. Effective food waste governance therefore requires policy coherence that integrates legal frameworks, governance systems, technological investment, stakeholder participation, market development, and continuous performance evaluation into a unified national strategy.

For Malaysia, the findings suggest that future policy reform should prioritise the development of a comprehensive National Food Waste Management Policy aligned with circular economy principles and Sustainable Development Goal 12.3. Such a framework should clearly define institutional responsibilities, establish measurable national food waste reduction targets, standardise food waste data collection and reporting, strengthen mandatory source separation for major commercial waste generators, expand food redistribution networks, encourage investment in biological treatment technologies, and introduce phased economic instruments that incentivise waste prevention and resource recovery. Rather than replicating a single international model, Malaysia should adopt a hybrid governance approach that combines Japan's business-oriented food recycling system, South Korea's behavioural and economic instruments, and Germany's integrated circular economy framework while adapting these elements to national institutional capacities, socio-economic conditions, and cultural practices.

Overall, the comparative evaluation confirms that effective food waste management is fundamentally a governance challenge rather than solely a technological or environmental issue. Countries demonstrating sustained success have established integrated policy systems that coordinate legislation, institutions, markets, infrastructure, and stakeholder behaviour within a common

circular economy vision. Malaysia possesses many of the essential institutional and legislative foundations required for this transition. However, strengthening policy integration, implementation consistency, and resource recovery infrastructure will be essential for achieving long-term improvements in environmental sustainability, food security, climate resilience, and circular economic development.

Challenges, Lessons Learned, and Policy Implications for Malaysia

The comparative analysis undertaken in this study demonstrates that Malaysia has made important progress in strengthening municipal solid waste management through legislative reform, institutional development, and increasing public awareness regarding sustainable waste practices. Nevertheless, food waste management remains one of the country's most significant environmental challenges due to the absence of an integrated governance framework that connects prevention, redistribution, recycling, renewable energy recovery, and circular economy development. Although various initiatives have been introduced by government agencies, local authorities, universities, private organisations, and civil society groups, these efforts continue to operate largely as independent programmes rather than components of a coordinated national food waste management strategy. One of the principal challenges identified is the fragmentation of governance responsibilities. Food waste management intersects with multiple policy sectors, including environmental protection, agriculture, food safety, public health, local government, social welfare, renewable energy, and climate change mitigation. Consequently, responsibility is distributed among numerous ministries, statutory bodies, local authorities, and private organisations. While this multi-sectoral structure reflects the complexity of food waste management, it also creates overlapping responsibilities, inconsistent implementation practices, duplicated initiatives, and difficulties in monitoring policy effectiveness. Experiences from Japan, South Korea, and Germany demonstrate that successful food waste governance depends upon strong institutional coordination supported by clearly defined leadership, integrated planning mechanisms, and shared national objectives.

Another significant challenge concerns the continued dependence on landfill disposal. Although sanitary landfill practices have improved considerably over the past two decades, landfill remains the dominant destination for municipal food waste in Malaysia. This practice contributes to methane emissions, landfill capacity shortages, odour generation, leachate production, and the loss of recoverable organic resources. From a circular economy perspective, landfill disposal represents the least desirable option because valuable nutrients, renewable energy potential, and recyclable organic materials are permanently removed from productive economic cycles. The experiences of Germany and South Korea illustrate that reducing landfill dependence requires simultaneous investment in source separation, biological treatment technologies, recycling markets, and supporting policy instruments rather than relying solely on expanding disposal infrastructure.

The analysis also highlights persistent weaknesses in food waste data management. Reliable policy formulation requires accurate information regarding food waste generation, composition, sectoral distribution, treatment pathways, recycling performance, and greenhouse gas emissions. However, Malaysia continues to experience inconsistencies in waste characterisation methodologies, reporting procedures, institutional responsibilities, and geographical data coverage. These limitations complicate evidence-based policymaking and reduce the capacity of government agencies to evaluate programme effectiveness or measure progress towards Sustainable Development Goal 12.3. By comparison, Japan and South Korea employ structured reporting systems that generate consistent national datasets, enabling policymakers to monitor implementation outcomes, identify emerging trends, and refine policy interventions using empirical evidence.

Financial and technological barriers constitute another important constraint. Although Malaysia has introduced several composting facilities, food recycling initiatives, and anaerobic digestion projects, many remain at pilot or local implementation levels. Scaling these technologies nationally requires substantial investment in separate collection systems, treatment facilities, logistics networks, quality assurance systems, skilled human resources, and long-term operational financing. Moreover, technological investment alone cannot guarantee successful implementation if waste segregation at source remains inconsistent. The comparative evidence presented in this study confirms that technological performance is strongly influenced by governance quality, regulatory certainty, market development, and public participation. Therefore, technological expansion should be accompanied by institutional strengthening and supportive policy reforms.

The experiences of Japan provide important lessons regarding the integration of food waste management with agricultural development. Rather than treating food waste solely as an environmental liability, Japan recognises unavoidable food residues as valuable resources capable of supporting livestock production, fertiliser manufacture, renewable energy generation, and regional agricultural sustainability. This integrated resource circulation model demonstrates how environmental protection and economic development can be pursued simultaneously through circular resource management. Malaysia possesses substantial agricultural and agro-industrial sectors that could similarly benefit from greater utilisation of compost, digestate, organic

fertilisers, and appropriately regulated food waste-derived livestock feed, provided that quality standards and food safety requirements are maintained.

South Korea offers valuable lessons regarding behavioural change and regulatory enforcement. The success of mandatory source separation and the Pay-As-You-Throw (PAYT) system illustrates the effectiveness of combining economic incentives with regulatory obligations. Rather than relying exclusively on environmental awareness campaigns, South Korea aligns household financial behaviour with environmental objectives, thereby encouraging continuous waste minimisation. Although immediate nationwide implementation of PAYT may present administrative and social challenges in Malaysia, phased application beginning with commercial food waste generators, hotels, shopping complexes, food courts, institutional kitchens, and urban municipalities could provide practical experience while strengthening public acceptance. Such an incremental approach would allow policymakers to evaluate operational feasibility before expanding implementation to additional sectors. Germany demonstrates the importance of embedding food waste management within broader circular economy and climate policies. Instead of viewing food waste as an isolated environmental issue, Germany integrates prevention, resource efficiency, renewable energy production, producer responsibility, sustainable consumption, and greenhouse gas mitigation within a unified policy framework. This systems-based approach enables multiple environmental and socio-economic objectives to be achieved simultaneously. Malaysia could similarly strengthen policy coherence by aligning future food waste strategies with the National Circular Economy Framework, the National Energy Transition Roadmap (NETR), the Twelfth and Thirteenth Malaysia Plans, the National Climate Change Policy, and the Sustainable Development Goals. Such policy integration would improve resource allocation while reducing duplication among government agencies.

Based on the comparative findings, this study proposes several strategic policy implications for strengthening food waste governance in Malaysia. First, a dedicated National Food Waste Management Policy should be developed to provide a unified strategic direction for prevention, redistribution, recycling, renewable energy recovery, and circular resource management. The policy should establish measurable national reduction targets, define institutional responsibilities, and incorporate performance indicators aligned with international sustainability commitments.

Second, institutional coordination should be strengthened through the establishment of a national inter-agency food waste coordination mechanism involving relevant ministries, local authorities, research institutions, industry representatives, and civil society organisations. Such a platform would facilitate policy harmonisation, information sharing, coordinated implementation, and long-term strategic planning while reducing institutional fragmentation.

Third, Malaysia should gradually strengthen mandatory implementation mechanisms by introducing phased source separation requirements for high-volume commercial food waste generators, accompanied by investment in separate collection systems, composting facilities, anaerobic digestion plants, and other organic waste treatment infrastructure. Phased implementation would allow technical, financial, and social challenges to be addressed progressively while minimising disruption to existing waste management systems.

Fourth, economic instruments should complement regulatory reforms by encouraging waste prevention and resource recovery. Potential measures include fiscal incentives for composting and anaerobic digestion facilities, tax incentives for food donation programmes, green financing mechanisms for organic waste recycling technologies, preferential procurement policies for recycled organic products, and carefully designed quantity-based charging mechanisms where appropriate. These instruments would stimulate private-sector investment while improving the commercial viability of circular economy activities.

Fifth, greater investment should be directed towards research, innovation, and digital technologies supporting food waste management. Artificial intelligence, Internet of Things (IoT) sensors, smart waste collection systems, digital food donation platforms, blockchain-based supply chain monitoring, and predictive analytics offer significant opportunities to improve waste prevention, operational efficiency, and policy evaluation. Collaboration among universities, government agencies, and industry partners will therefore be essential for accelerating technological innovation and evidence-based policymaking.

Finally, sustained public participation should remain a central component of national food waste governance. Educational programmes, community engagement initiatives, university partnerships, industry collaborations, and consumer awareness campaigns continue to play an important role in promoting responsible food consumption and sustainable lifestyles. However, international experience demonstrates that public awareness is most effective when integrated with supportive legislation, financial incentives, technological infrastructure, and continuous policy evaluation. Behavioural change should therefore be viewed as one component of a broader governance framework rather than the sole solution to food waste management challenges.

Overall, the comparative evidence confirms that Malaysia possesses considerable opportunities to strengthen food waste governance by adapting selected international best practices to local institutional, socio-economic, and cultural conditions.

Rather than replicating any single foreign model, Malaysia should adopt a hybrid policy framework that combines Japan's integrated food recycling system, South Korea's behavioural and economic policy instruments, and Germany's circular economy governance approach. Such an adaptive strategy would support long-term environmental sustainability, strengthen national food security, improve resource efficiency, reduce greenhouse gas emissions, and accelerate Malaysia's progress towards achieving Sustainable Development Goal 12.3 and broader sustainable development objectives.

CONCLUSIONS

This study conducted a comparative analysis of food waste management policies in Malaysia, Japan, South Korea, and Germany to evaluate how different legislative frameworks, governance structures, policy instruments, and resource recovery strategies influence the effectiveness of national food waste management systems. As food waste has become a major global sustainability challenge with significant environmental, economic, and social implications, understanding the policy characteristics of high-performing countries is essential for informing evidence-based reforms in developing economies. Using a qualitative comparative policy analysis, this study examined legislative and institutional arrangements, implementation mechanisms, food waste prevention strategies, resource recovery technologies, and overall policy effectiveness to identify best practices applicable to the Malaysian context.

The findings demonstrate that successful food waste management extends beyond the existence of waste legislation or technological capability. Instead, policy effectiveness depends upon the integration of multiple governance components, including clearly defined legal responsibilities, institutional coordination, regulatory enforcement, stakeholder collaboration, economic incentives, technological infrastructure, and continuous policy monitoring. Japan, South Korea, and Germany have each developed comprehensive governance systems that prioritise food waste prevention while maximising the recovery of unavoidable organic waste through composting, anaerobic digestion, renewable energy production, food redistribution, and other circular economy approaches. Although each country adopts different regulatory mechanisms, all demonstrate strong policy coherence, measurable implementation targets, and well-established institutional collaboration that collectively contribute to high levels of resource recovery and reduced dependence on landfill disposal.

The comparative analysis further reveals that Malaysia has established an important institutional foundation through the Solid Waste and Public Cleansing Management Act 2007 (Act 672), the National Solid Waste Management Policy, and the implementation roles of the Ministry of Housing and Local Government, the National Solid Waste Management Department, and SWCorp Malaysia. These initiatives have significantly improved municipal solid waste governance and public awareness regarding environmental sustainability. However, food waste management continues to face several structural challenges, including fragmented institutional responsibilities, the absence of a dedicated national food waste policy, inconsistent food waste reporting systems, limited mandatory source separation, insufficient large-scale organic waste treatment infrastructure, and continued reliance on landfill disposal. These challenges reduce the effectiveness of existing initiatives and constrain Malaysia's transition towards a circular food economy.

One of the principal contributions of this study is the identification of critical success factors that consistently characterise high-performing food waste management systems. The comparative evaluation indicates that effective governance requires the simultaneous integration of five mutually reinforcing elements: comprehensive legislation, strong institutional coordination, mandatory implementation mechanisms supported by economic incentives, advanced resource recovery infrastructure, and active stakeholder participation across the food supply chain. Countries performing well across these dimensions demonstrate substantially greater success in reducing food waste generation, improving recycling rates, recovering renewable resources, and supporting broader environmental sustainability objectives. These findings suggest that policy integration is a more significant determinant of long-term success than isolated legislative reforms or technological investments implemented independently.

The study also contributes to the growing body of literature on circular economy governance by demonstrating that food waste should be managed not merely as a waste disposal issue but as a strategic resource capable of contributing to renewable energy production, sustainable agriculture, climate change mitigation, food security, and green economic development. The experiences of Japan, South Korea, and Germany illustrate that integrating food waste management within broader circular economy strategies creates multiple environmental, economic, and social benefits while improving overall resource efficiency. Consequently, future Malaysian policies should adopt a systems-based governance approach that links waste management with agriculture, renewable energy, environmental protection, climate policy, industrial innovation, and sustainable consumption.

Based on the comparative findings, this study recommends that Malaysia develop a dedicated National Food Waste Management Policy supported by measurable national reduction targets, harmonised institutional responsibilities, standardised food waste reporting systems, phased implementation of mandatory source separation for major commercial waste generators, expanded food redistribution programmes, strengthened investment in composting and anaerobic digestion infrastructure, and greater utilisation of economic incentives that encourage waste prevention and resource recovery. Rather than replicating any single international model, Malaysia should adopt a hybrid governance framework that combines Japan's food recycling system, South Korea's behavioural and economic policy instruments, and Germany's circular economy principles while adapting these approaches to local governance structures, socio-economic conditions, and cultural practices.

Despite its contributions, this study has several limitations. First, the analysis relied primarily on policy documents, government reports, and published academic literature rather than empirical field investigations or quantitative performance modelling. Consequently, variations in implementation effectiveness at regional and municipal levels could not be examined comprehensively. Second, the comparative analysis focused on four countries representing different stages of policy maturity; therefore, the findings may not fully capture the diversity of food waste governance models implemented globally. Third, policy implementation is inherently dynamic, and future legislative reforms, technological innovations, and institutional developments may influence national performance over time.

Future research should therefore expand comparative investigations by incorporating additional countries, particularly those within Southeast Asia, to better understand regional governance characteristics and opportunities for policy harmonisation. Longitudinal studies evaluating the impacts of newly implemented food waste policies would also provide valuable evidence regarding policy effectiveness over time. Furthermore, quantitative modelling approaches integrating life cycle assessment, material flow analysis, cost-benefit analysis, greenhouse gas accounting, and circular economy indicators could strengthen future evaluations of environmental and economic performance. Emerging technologies such as artificial intelligence, digital supply chain monitoring, Internet of Things (IoT)-enabled waste collection systems, blockchain-based food traceability, and smart city platforms also warrant further investigation as tools for improving food waste prevention, operational efficiency, and policy monitoring.

In conclusion, achieving sustainable food waste management requires a fundamental transition from conventional waste disposal practices towards integrated circular economy governance. The comparative evidence presented in this study demonstrates that effective policy systems are characterised by coherent legislation, coordinated institutions, behavioural incentives, technological innovation, stakeholder collaboration, and evidence-based decision-making. Malaysia possesses a strong institutional foundation upon which further reforms can be developed. By adopting an integrated and adaptive governance framework informed by international best practices while remaining responsive to national priorities, Malaysia will be better positioned to reduce food waste generation, recover valuable organic resources, strengthen food security, mitigate greenhouse gas emissions, and contribute meaningfully to the achievement of Sustainable Development Goal 12.3 and broader national sustainability aspirations.

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Author Contributions

M.A.A.S: Conceptualization, investigation, reviewing, data curation, writing, and editing and project administration; M.S.S: Investigation, methodology, writing an original draft, research design, data analysis. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors utilized the ChatGPT tool to enhance the language and readability of the manuscript.

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