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WASTE WATCHERS: ANALYSING CONSUMPTION SHIFTS AND FOOD WASTE MANAGEMENT STRATEGIES

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Abstract

Food waste and loss present significant obstacles to both environmental sustainability and global food security. Waste occurs across the supply chain, from production to consumption, driven by factors such as inefficiencies, overproduction, and insufficient infrastructure. Loss primarily happens during production and storage due to issues like pests, diseases, and spoilage. According to the FAO, approximately one-third of all food produced for human consumption, totalling about 1.3 billion tons, is lost or wasted annually worldwide. This squanders valuable resources, contributes to environmental degradation, greenhouse gas emissions, and biodiversity loss, and worsens food insecurity and hunger for millions globally. Addressing this crisis requires concerted action from governments, businesses, civil society, and individuals. Strategies encompass reducing, reusing, and recycling food waste, enhancing supply chain efficiency, investing in infrastructure and technology, and advocating for sustainable consumption habits. Additionally, raising awareness and changing consumer behaviour are vital. Tackling food waste and loss is crucial for achieving Sustainable Development Goals and ensuring the well-being of future generations, fostering a more resilient, equitable, and sustainable food system while reducing our ecological footprint.

Keywords: Food-waste, Food Supply Chain, Food loss prevention

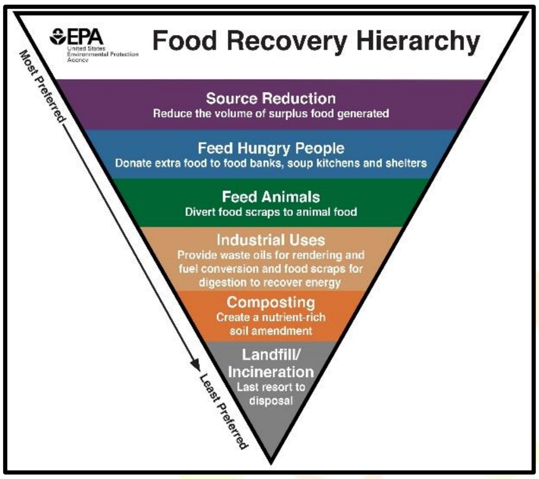
I. Introduction

At the conclusion of the nineteenth century, **Atwater (1895)** published one of the earliest scientific works incorporating insights on household food wastage, albeit with a focus on its nutritional aspects. Food, regarded as a social construct, embodies one of the fundamental elements of human social existence. It transcends its role as merely a source of energy and nutrients, instead serving as a cornerstone that shapes social structures, fosters interpersonal connections, forges identities, and influences human behaviour **(Bourdieu, 1984; Douglas, 2005; Lévi-Strauss, 1969; Wilk, 2006)**. Food loss and waste pose a global challenge, impacting food security and sustainability on a worldwide scale. This issue not only reduces the efficiency of our food system but also negatively affects farmers' incomes and increases costs for consumers. It occurs at various stages along the food supply chain, spanning from production to consumption. Establishing clear targets for reducing food loss and waste is crucial, with developed nations focusing on waste reduction and developing nations addressing food loss, while also considering future waste reduction strategies. This review delves into essential data and literature to uncover insights and identify knowledge gaps, aiming to advocate for diverse solutions to mitigate food loss and waste and enhance food security. Short-term solutions involve identifying gaps in the food supply chain, utilizing e-commerce platforms for marketing, re-evaluating aesthetic standards for produce, and establishing shorter value chains to facilitate direct connections between farmers and markets. Long-term approaches include investing in agtech, biotechnology, and smart packaging, alongside educating consumers on efficient food utilization and resource management.

II. Hierarchy of Food Waste

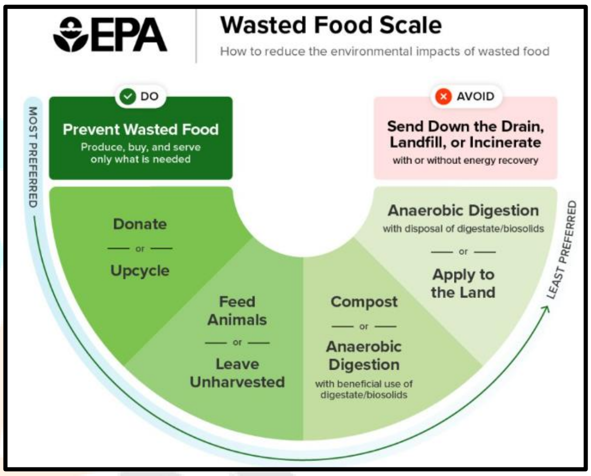
The waste hierarchy is a systematic approach that ranks waste management options based on their environmental impact, prioritizing actions that are most beneficial to the environment. It consists of five stages: Prevention, Reuse, Recycle, Recovery, and Disposal. Prevention, the top priority, focuses on avoiding waste generation altogether. Reuse involves preparing waste for re-use, while recycling entails processing waste materials into new products. Recovery involves extracting useful materials or energy from waste, and disposal, such as landfilling, is considered a last resort. In line with efforts to reduce food waste, the Environmental Protection Agency (EPA) developed a Food Recovery Hierarchy **(Figure 1)**. This hierarchy prioritizes efforts to reduce and divert food waste, ranking methods from most to least preferred. While not all diversion methods are suitable for every type of food waste, this hierarchy serves as a guide for companies and organizations to select the most effective approach for reducing or diverting food waste, considering environmental, social, and economic factors. The Wasted Food Scale **(Figure 2)** represents an updated approach to managing food waste, taking into account advancements in science, technology, and operational practices since the development of the Food Recovery Hierarchy. This scale categorizes pathways into tiers based on their equivalent performance, with a focus on prevention and diverting food waste from pathways such as sewer/wastewater treatment, landfill, and controlled combustion (e.g., incineration). **Figure 3** illustrates the sources of food waste identified within the scale, highlighting areas where interventions can be targeted to reduce waste generation and improve waste management practices.

Figure 1 - EPA Hierarchy of Food Recovery



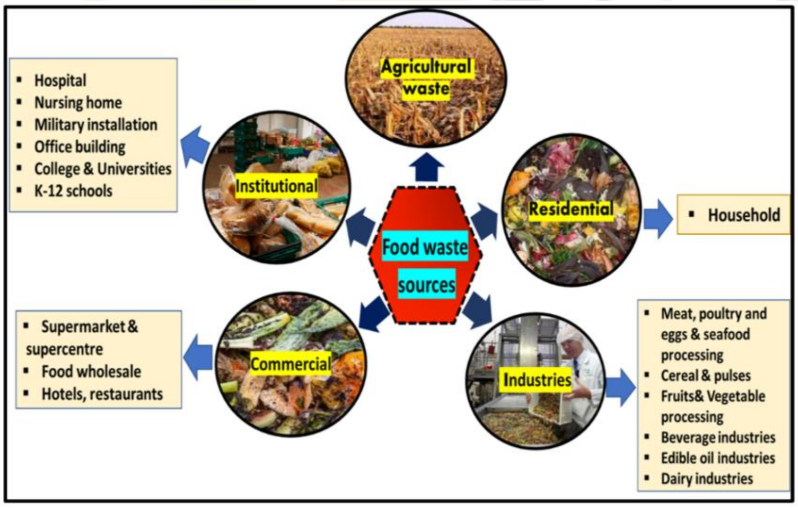
Source: FWRA, 2016

Figure 2 – EPA Wasted Food Scale



Source: USEPA and ERG, Inc. 2023

Figure 3 - Different sources of food waste



***Source**: Sahoo et al. (2024)*

The causes of food loss and waste and their occurrence along the value chain are also discussed in a collaborative piece by the UNEP and WRI **(Lipinski et al. 2013)**

Table 1 - Food loss and waste along the value chain

Production →	Handling and Storage →	Processing and Packaging →	Distribution and Market →	Consumption
Definition				
During or immediately after harvesting on the farm	After produce leaves the farm for handling, storage, and transport	During industrial or domestic processing and/or packaging	During distribution to markets, including losses at wholesale and retail markets	Losses in the home or business of the consumer, including restaurants/caterers
Includes				
Fruits bruised during picking or threshing	Edible food eaten by pests	Milk spilled during pasteurization and processing	Edible produce sorted out due to quality	Edible products sorted out due to quality
Crops sorted out post-harvest for not meeting quality standards	Edible produce degraded by fungus or disease	Edible fruit or grains sorted out as not suitable for processing	Edible products expired before being purchased	Food purchased but not eaten

Crops left behind in fields due to poor mechanical harvesting or sharp drops in prices	Livestock death during transport to slaughter or not accepted for slaughter	Livestock trimming during slaughtering and industrial processing	Edible products spilled or damaged in market	Food cooked but not eaten

Source: *Based on Lipinski et al., 2013.*

III. Food waste and global hunger: A critical note

$1 Trillion Dollars' Worth of Food Is Wasted Each Year: The staggering figure of $1 trillion worth of food wasted annually highlights a global issue of immense economic significance. This waste represents not only lost resources but also lost opportunities to alleviate hunger and food insecurity worldwide.

Food Waste Is One of the Largest Producers of Carbon: Food waste stands as one of the leading contributors to carbon emissions, exacerbating climate change and environmental degradation. The decomposition of wasted food releases methane, a potent greenhouse gas, into the atmosphere, intensifying the impact on our planet's climate.

30-40 per cent of Food in the US Is Wasted: The United States grapples with a significant food waste problem, with an alarming 30-40 per cent of all food produced going to waste. This waste occurs across the supply chain, from farms to households, representing a substantial loss of resources and a missed opportunity to address hunger and food insecurity.

Rich Countries Waste as Much Food as Sub-Saharan Africa Produces: The disparity in food waste between affluent nations and Sub-Saharan Africa is striking, with rich countries discarding as much food as the entire region produces. This stark contrast underscores the urgent need for more equitable and sustainable food systems worldwide.

Our Food Systems are Exhausting Soil and Water: Modern food production practices are placing significant strain on soil and water resources. Intensive farming methods, coupled with unsustainable irrigation practices, are depleting soil fertility and freshwater reserves, threatening the long-term viability of our food systems.

Cutting Global Food Waste Is a Top U.N. Goal: Recognizing the urgency of addressing food waste, the United Nations has prioritized cutting global food waste as a key sustainable development goal. Efforts to reduce waste not only contribute to food security but also promote environmental sustainability and economic resilience.

The United Nations World Food Programme (WFP) Helps Reduce Food Loss: The United Nations World Food Programme (WFP) plays a crucial role in reducing food loss and waste worldwide. Through various initiatives and interventions, WFP works to improve food storage and distribution systems, minimize losses along the supply chain, and ensure that food reaches those in need efficiently.

WFP Finds New Ways to Distribute Food: In its mission to combat food waste and hunger, the World Food Programme (WFP) continually seeks innovative approaches to distribute food effectively. From leveraging technology to implementing community-based distribution networks, WFP adapts and evolves to meet the diverse needs of populations facing food insecurity around the globe.

In one part of the world, there is plenty of food being wasted and in the other part of the world people are suffering from hunger and poverty **(Box 1)**.

Box 1
Food Security and Nutrition Working Group, Kenya 2024

- ✓ According to IPC2 data, an estimated 58.1 million individuals in 10 out of 13 countries monitored by the FSNWG experienced severe food insecurity in January 2024.
- ✓ Approximately 4 million individuals in the northern region of Ethiopia are believed to be affected by the ongoing drought.
- ✓ Sudan's food crisis continued to deteriorate due to armed conflict disrupting agricultural activities, including main-season harvesting and winter wheat cultivation.
- ✓ Across the region, food assistance levels remained high, with an estimated 58.1 million people classified as acutely or severely food insecure (CPS Phase 3+) by January 2024.
- ✓ South Sudan faced one of the most severe food crises globally until March 2024, with close to 5.8 million people expected to experience crisis or worse levels of acute food insecurity.
- ✓ The food crisis in Sudan deepened further as conflicts extended into new areas, resulting in widespread population displacement, disruptions to market and trade distribution, damage to essential infrastructure, and restricted humanitarian access.
- ✓ In Kenya, 332,861 and 159,886 children under the age of five were admitted for moderate acute malnutrition and severe acute malnutrition, respectively, in 2023.
- ✓ In Somalia, approximately 1.7 million children under the age of five faced acute malnutrition through December 2024.
- ✓ More than 1.65 million children under the age of five in South Sudan were reported to suffer from acute malnutrition.

Source: *https://www.icpac.net/documents/807/FSNWG_Statement_January_2024.pdf*

IV. About Food Waste and Food Loss

Food is defined as "any substance or product, whether processed, partially processed, or unprocessed, intended to be, or reasonably expected to be ingested by humans," excluding live animals unless they are prepared for human consumption and plants before harvesting **(European Commission, 2002**). Food losses denote the decrease in edible food mass throughout the human food chain, with losses occurring at the consumption stage termed as food waste. Food Losses and Waste (FLW) present a significant social, economic, and ecological challenge, alongside being an ethical concern. FAO data reveals that approximately one-third of food produced for human consumption is lost or wasted. "Food losses" specifically refer to the reduction in edible food mass throughout the supply chain leading to human consumption, encompassing production, post-harvest, and processing stages. Losses occurring at the end of the food chain, namely retail and consumption, are termed "food waste." Moreover, food waste may be further categorized as food loss when it occurs during the early stages of the food supply chain and as food waste during later phases **(Gustavsson et al. 2011; High-Level Panel of Experts on Food Security and Nutrition [HLPE], 2014)**.

In recent decades, amidst the backdrop of climate change, food waste has emerged as a significant global issue, posing a threat to food security due to its multifaceted impacts, encompassing economic, social, technical, managerial, and public health dimensions. Despite widespread calls for food security, millions worldwide continue to suffer from malnutrition, highlighting the persistent challenges. The issue of food insecurity extends beyond mere hunger, encompassing imbalances in diets as well. Previous studies have indicated that saving just a quarter of the food currently wasted could provide enough sustenance for all those currently undernourished. In the United States, over 40 per cent of food produced goes unconsumed, leading to substantial waste annually. Similarly, in the European Union, a staggering 88 million tonnes of food are wasted each year, equating to 174 kg of food per person, 143 billion euros, and 170 million tonnes of CO_2 emissions. The distinction between "food loss" and "food waste" lies in where along the supply chain the loss occurs, with food loss occurring from farm to just before retail and food waste occurring at retail, food service, and household levels. The concept of "potential food loss and waste" introduced by **Schuster and Torero** include pre-harvest losses due to pest and disease attacks, inefficiencies in harvesting machinery, crop losses due to unfavourable climatic events, and failure to produce food due to insufficient agricultural inputs and technology. These losses are influenced by a range of factors including pre- and post-harvest pests and diseases, inadequate agricultural inputs, inefficient harvesting techniques, improper storage conditions, ineffective processing and packaging methods, fluctuating prices, gaps in distribution chains, and inadequate consumption patterns. Food loss and waste can occur at various stages along the food value chain, including production, post-production, processing, transport, and consumption. Excessive purchasing leading to substantial food wastage is common, with between 35-50 per cent of food being discarded across all categories, with fruits and vegetables, roots and tubers, experiencing the highest losses at 45 per cent, followed by cereals at 30 per cent, and fish and seafood at 30 per cent.

Food waste not only results in the squandering of food itself but also leads to the wastage of other vital natural resources. Approximately 1.4 billion hectares of land and 25 per cent of the world's fresh water are utilized in producing food that ultimately ends up discarded. For instance, discarding orange wastes about 80 litres of water, while throwing away 1 kg of lettuce squanders around 240 litres of water **(Owen, 2005)**. Annually, the economic value of food loss is estimated at a staggering $400 billion, with significant environmental repercussions such as greenhouse gas emissions **(UNEP, 2020)**. Food waste and loss not only drain financial resources but also inflict severe environmental harm by releasing greenhouse gases, notably methane, which is 23 times more potent than carbon monoxide and 25 times more potent than carbon dioxide. About 8-10 per cent of global greenhouse gas emissions are associated with unconsumed food **(UNEP, 2021)**. Different food types have varying impacts on the environment; for instance, cereals and vegetables contribute significantly to the carbon footprint, accounting for 25-30 per cent of the global food wastage's carbon footprint. Despite meat comprising only 5 per cent of total food waste, it substantially impacts climate change, contributing over 20 per cent to our carbon footprint **(FAO, 2015)**. Employing environmentally-friendly practices such as composting can help mitigate food waste **(Santeramo et al., 2018)**. Additionally, innovative approaches such as e-commerce platforms for product marketing, reevaluating aesthetic standards for fruits and vegetables, establishing shorter value chains to connect farmers directly with markets and consumers, enhancing packaging for fresh produce during transportation, and investing in agricultural technology (agtech) can all play significant roles in reducing food waste. Leveraging intelligent technologies like disposable sensors with Internet-of-Things capabilities to monitor optimal storage conditions for perishable products is another viable solution. In Australia alone, food waste in the cold food chain costs the economy $3.8 billion annually **(Picker, 2019)**. Marketing "ugly produce" with moderate price discounts can also help mitigate food waste. Various factors such as crop pests and diseases, extreme weather conditions, harvest and post-harvest operations, fluctuating food prices, and consumer habits and incomes all contribute to food loss and waste throughout the food supply chains. It is essential to address these challenges comprehensively, considering the specific conditions within each country, to effectively combat food waste at all stages of the food supply chain. The increase in global population coupled with shifts in dietary preferences has spurred the development of unsustainable food systems, culminating in a critical challenge: food waste and loss (FWL). Approximately one-third of the world's food production is squandered annually, manifesting at various stages across the entire supply chain. This study delves into FWL dynamics through an analysis of scientific literature, employing methodologies such as social network analysis and bibliometrics. The findings underscore a mounting interest in FWL concerns since 2010, alongside a notable pivot towards sustainable interventions, including pre-emptive measures and policy frameworks. Given the profound ethical, environmental, and economic ramifications of FWL, adopting interdisciplinary approaches becomes imperative for fostering a comprehensive understanding and implementing effective solutions.

V. Sustainable Development Goals and Food Waste and Food Loss

Food loss holds significant importance as recognized in the UN 2030 Agenda for Sustainable Development, particularly under SDG 2. One crucial reason is the substantial investment of money and resources across the entire lifecycle of food production, storage, transportation, and handling, only for it to not fulfil its primary purpose of nourishing people **(Buzby et al., 2011)**. Additionally, food loss carries negative externalities that impact both society and the environment throughout its lifecycle. These externalities emerge during food production and become exacerbated when food is wasted unnecessarily. Examples include greenhouse gas emissions from cattle production **(Lundqvist et al. 2008)**, air pollution from farm machinery and transportation, water pollution and damage to fisheries due to agricultural chemical run-off, and soil degradation caused by unsustainable production and irrigation practices **(Nellemann et al. 2009)**. Thus, addressing food loss is critical not only for economic reasons but also for mitigating environmental and societal impacts. FWL in the food supply chain is presented in **Table 2**.

Table 2 - FWL in the Food Supply Chain

Food Supply Chain Stages	Food Waste or Loss	Causes
Primary production (agriculture, livestock production, and fisheries)	Food loss	Pests, diseases, market fluctuating prices, variable climatic conditions, inefficient materials, and technical problems.
Storage and handling	Food loss	Poor storage facilities, inadequate temperatures, and technical problems.
Processing, manufacturing, and packaging	Food loss	Inefficient material, logistic problems, industrial waste.
Distribution	Food loss	Increased distances, technical problems.
Retail	Food waste	Poor storage, expiry date, aesthetic standards, poor packaging.
Household	Food waste	Expiry date, over preparation, aesthetic, and food preferences.
Hospitality	Food waste	Over preparation, poor storage, large portion size, and over-ordering.

According to **FAO (2011)**, food waste at the retail and consumer level in high-income countries amounted to 220 million tonnes, which is approximately equivalent to the total food production in Sub-Saharan Africa (230 million tonnes). However, household food waste per capita remains a significant issue across both high- and low-income countries. In 2019, at the global level, 61 per cent of the total food waste (931 million tonnes) was attributed to households. Food waste at the household stage can largely be attributed to factors such as over-purchasing, over-preparation, large portion sizes, confusion regarding labels and expiry dates, storage issues, and unsuitable packaging, particularly for highly perishable items. United Nations Sustainable Development Goal 12 (SDG 12) on "Ensuring sustainable consumption and production patterns" includes a specific food waste reduction target: "by 2030, to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses". The SDG 12 target of 50 per cent food waste reduction is hereby combined with assumptions on feasible food loss reduction ratios, for each commodity group, to calculate a possible scenario **(Box 2)**.

Box - 2

Assumptions for food wastage reduction ratios achievable by 2030
Phases "Agricultural production" and "Processing"
• 5% reduction of 2011 food wastage in developed countries • 15% reduction of 2011 food wastage in developing countries (a larger progress margin is assumed for developing countries)
Phase "Post-harvest handling and storage"
• 5% reduction of 2011 of food wastage in developed countries • 54% reduction of 2011 food wastage in developing countries (reduction estimated to be needed to reach the average percentage of wastage observed in developed countries for most commodity groups)
Phases "Distribution" and "Consumption"
• 50% reduction of 2011 food wastage amounts in all regions

VI. Causes and Prevention of Food Losses and Waste

Harvesting and Handling Practices: Improper harvesting techniques or handling practices can lead to physical damage or contamination of food items, rendering them unsuitable for consumption.

Storage Conditions: Inadequate storage facilities or improper storage conditions such as temperature fluctuations, humidity, and pest infestations can accelerate food spoilage and deterioration.

Transportation Issues: Poor transportation infrastructure, long transit times, and inadequate packaging can result in physical damage, spoilage, or contamination of food products during transit.

Market Dynamics: Fluctuations in market demand, pricing, and consumer preferences can lead to excess inventory or unsold produce, contributing to food loss.

Processing and Packaging: Inefficient processing methods or packaging techniques can compromise the quality and shelf life of food products, leading to spoilage or contamination.

Quality Standards and Aesthetic Preferences: Strict quality standards or cosmetic appearance requirements imposed by retailers or consumers may lead to the rejection of perfectly edible food items based on superficial imperfections.

Lack of Infrastructure and Technology: Limited access to appropriate infrastructure, such as cold storage facilities or processing equipment, and inadequate technology for food preservation and handling can exacerbate food loss in certain regions.

Post-Harvest Loss: Losses occurring after harvest but before reaching the market, including spillage, bruising, and decay during sorting, grading, and packing processes.

Climate and Environmental Factors: Natural disasters, extreme weather events, and environmental conditions such as droughts, floods, and pests can damage crops, disrupt supply chains, and contribute to food loss.

Inefficient Supply Chains: Complex and fragmented supply chains with multiple intermediaries and a lack of coordination among stakeholders can result in delays, inefficiencies, and increased opportunities for food loss.

Lack of Access to Markets: Farmers in remote or rural areas may face challenges in accessing markets due to poor infrastructure, limited transportation options, and inadequate market information, resulting in surplus production and eventual food loss.

Financial Constraints: Small-scale farmers and food producers may lack the financial resources to invest in proper storage facilities, transportation, or technology to prevent food loss, leading to increased vulnerability to spoilage and waste.

Inadequate Food Safety Practices: Failure to adhere to proper food safety protocols and regulations during production, processing, and handling can result in contamination, foodborne illnesses, and the subsequent disposal of affected food items.

Seasonal and Cyclical Production: Seasonal fluctuations in agricultural production can lead to temporary surpluses or shortages of certain food items, resulting in food loss due to insufficient storage or market demand during off-peak seasons.

Lack of Education and Training: Limited knowledge and awareness among farmers, food producers, and consumers about proper handling, storage, and preservation techniques can contribute to avoidable food loss and waste.

Overproduction and Excess Inventory: Inefficiencies in production planning, overestimation of market demand, and contractual obligations to meet supply quotas can lead to overproduction and accumulation of excess inventory, increasing the risk of food loss.

Food Distribution Challenges: Inadequate distribution networks, logistical constraints, and bureaucratic hurdles can impede the timely and efficient delivery of food aid or surplus produce to communities in need, resulting in avoidable food loss.

Consumer Behaviour: Consumer preferences for fresh and visually appealing produce, coupled with misconceptions about food safety and expiration dates, can lead to premature discarding of edible food items at the household level, contributing to food waste.

Market Volatility and Price Fluctuations: Sudden changes in market conditions, such as price volatility or disruptions in global trade, can impact the profitability of food production and distribution, leading to financial losses and potential food waste.

Policy and Regulatory Constraints: Inconsistent or restrictive policies, regulations, and trade barriers related to food labelling, packaging, and distribution can hinder efforts to minimize food loss and waste across national and international supply chains.

VII. Multipronged approach for Food Waste Management

Preventing food loss requires a multifaceted approach that addresses various stages of the food supply chain and considers the unique challenges faced by different stakeholders. Here are some preventive measures for the causes of food loss outlined earlier:

Improving Harvesting and Handling Practices: Provide training and education to farmers on proper harvesting techniques and handling practices to minimize physical damage and contamination. Invest in appropriate harvesting equipment and tools to ensure gentle handling of crops and reduce post-harvest losses. Implement quality control measures at the farm level to identify and segregate damaged or diseased produce before storage and distribution.

Enhancing Storage Conditions: Upgrade storage facilities with proper ventilation, temperature control, and pest management systems to prolong the shelf life of perishable food items. Promote the use of affordable and sustainable storage solutions such as silos, cold rooms, and hermetic bags, especially in rural and remote areas. Conduct regular maintenance and inspections of storage facilities to identify and address potential issues that may compromise food quality and safety.

Optimizing Transportation: Improve transportation infrastructure and logistics networks to reduce transit times, minimize handling, and prevent damage to food products during transit. Invest in appropriate packaging materials and techniques to protect perishable goods from physical damage, moisture, and contamination during transportation. Implement cold chain management practices to maintain optimal temperature conditions for temperature-sensitive food items throughout the supply chain.

Adapting to Market Dynamics: Foster collaboration and communication between producers, traders, retailers, and consumers to better align supply with demand and reduce market volatility. Encourage diversification of markets and distribution channels to reduce reliance on a single market and mitigate the risk of surplus production. Support initiatives that promote the consumption of imperfect or surplus produce through awareness campaigns, discount programs, and value-added processing.

Investing in Technology and Innovation: Develop and deploy innovative technologies for food preservation, packaging, and processing to extend the shelf life of perishable food items and reduce losses. Harness data analytics and supply chain management tools to optimize inventory management, forecast demand, and prevent overproduction and waste. Support research and development initiatives focused on developing sustainable and cost-effective solutions for food loss prevention, such as post-harvest treatments and packaging materials.

Promoting Sustainable Practices: Encourage the adoption of sustainable farming practices, such as crop rotation, conservation tillage, and integrated pest management, to improve yield stability and reduce post-harvest losses. Provide incentives and support for small-scale farmers to invest in organic farming methods, agroforestry, and soil conservation measures that enhance resilience to climate change and minimize environmental impact.

Raising Awareness and Capacity Building: Offer training programs, workshops, and extension services to farmers, food producers, and other stakeholders on best practices for food handling, storage, and waste reduction. Educate consumers about the importance of reducing food waste, proper storage techniques, and ways to interpret food labels and expiration dates to make informed purchasing decisions. Collaborate with government agencies, NGOs, and community organizations to develop and disseminate educational materials and campaigns on food loss prevention and sustainable consumption practices.

Strengthening Policy and Regulatory Frameworks: Enact and enforce policies and regulations that promote sustainable food production, distribution, and consumption practices while minimizing food loss and waste. Implement supportive measures such as tax incentives, subsidies, and grants to incentivize investments in food loss reduction technologies and infrastructure. Foster international cooperation and knowledge sharing to address global food loss and waste challenges through initiatives such as the UN Sustainable Development Goals and regional agreements on food security and trade.

Reducing consumer food waste can have a positive impact on a wide range of social, economic, and environmental outcomes. Key reasons to act on food loss and waste are outlined below:

Table 3 - Key reasons to take action on food loss and waste

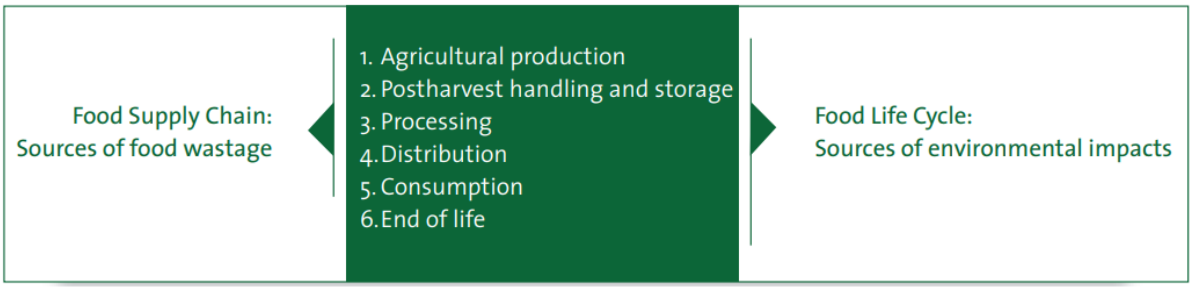
COST	HEALTH	HUNGER	PLANET
More than one-third of all the food produced on the planet every year is wasted, worth well over $1 trillion.	According to the Food and Agriculture Organisation of the United Nations (FAO), a staggering 3 billion people cannot afford a healthy diet. Minimising food waste can increase food availability and reduce consumer prices.	Although calorific intake has increased globally by 20 per cent in the past 50 years, the FAO estimates that between 720 and 811 million people experienced hunger in 2020, a number that is expected to rise sharply post-COVID-19. Reducing food waste can increase food availability and get more food to those in need.	Food waste is responsible for an estimated 8-10 per cent of greenhouse gas emissions. 1.4 billion hectares of land – 28 per cent of the world's agricultural area – is used to produce food that is lost or wasted

***Source**: World Bank. 2020*

VIII. Impact of FWL on different facets of society

Environmental Impact: The environmental impacts of food chains are aggravated when food is lost or wasted. **Kummu et al. (2012)** stated that global FWL accounts for about 24 per cent of the total farmland, freshwater, and fertilizer consumption used for food production. In addition to these environmental costs, managing all the organic waste generated by households, food services, industrial processes, and farm sectors generates significant GHG emissions and other downstream environmental impacts due to the disposal of FWL.

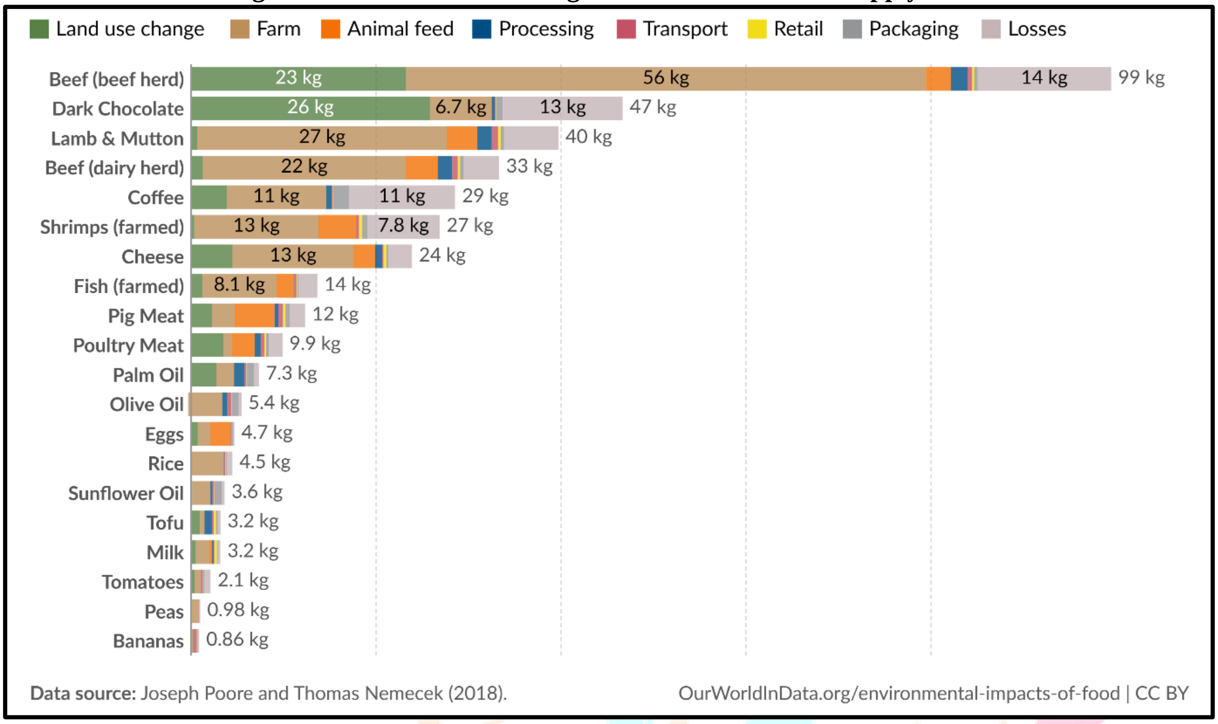
Figure 4 - Sources of food wastage and sources of environmental impacts in the food life cycle



***Source**: Nadia et al. (2013).*

Food wastage within the Food Supply Chain (FSC) stems from various causes, including spillage, breakage, degradation during handling or transportation, and losses occurring during distribution. A comprehensive assessment of these components provides a holistic understanding of the environmental and economic impacts of food wastage, essential for informing policy decisions, promoting sustainable practices, and advocating responsible consumption and production patterns. Food Balance Sheets (FBSs) offer insights into the total amount of food available for human consumption within a country or region over a year. Six per cent of greenhouse gas emissions originate from food losses and waste, with food production alone responsible for 26.0 per cent of global greenhouse gas emissions. A study by **Joseph Poore and Thomas Nemecek (2018)** revealed that nearly one-quarter (24.0 per cent) of food emissions arise from losses in supply chains or wastage by consumers. Approximately two-thirds of this figure (15.0 per cent of emissions) result from losses in the food supply chain, attributed to inadequate storage and handling practices, insufficient refrigeration, and spoilage during transportation and processing. The remaining 9.0 per cent stems from food discarded by retailers and consumers. Food production contributes to more than a quarter (26 per cent) of global greenhouse gas emissions, while agriculture utilizes half of the world's habitable land, defined as land free of ice and desert. Furthermore, 70 per cent of global freshwater withdrawals are allocated for agricultural purposes. Agriculture is also a significant contributor to environmental pollution, with 78 per cent of global ocean and freshwater eutrophication caused by agricultural activities. Eutrophication entails the pollution of water bodies with nutrient-rich substances. Livestock farming accounts for a substantial portion of non-human mammal biomass, representing 94 per cent and outweighing wild mammals by a factor of 15-to-1. When considering only land-based mammals, this share rises to 97 per cent. Poultry livestock also significantly contribute to bird biomass, representing 71 per cent, outweighing wild birds by more than 3-to-1. Addressing our dietary choices and transforming food production practices are vital steps in mitigating climate change, alleviating water stress and pollution, reclaiming land for forests or grasslands, and safeguarding the planet's biodiversity.

Figure 5 – Food: Greenhouse gas emissions across the supply chain



Beef from beef herds has the highest total emissions across all categories, with significant contributions from farm-related activities (56.23 kg), land use (23.24 kg), and animal feed (2.68 kg). Emissions from packaging (0.35 kg) and losses (14.44 kg) are also notable. Beef from dairy herds also exhibits considerable emissions, particularly from farm-related activities (21.92 kg) and animal feed (3.50 kg). Land use emissions (1.27 kg) are significantly lower compared to beef from beef herds. Cheese production contributes to emissions mainly through farm-related activities (13.10 kg) and processing (0.74 kg). Emissions from packaging (0.17 kg) and losses (2.58 kg) are relatively minor compared to other categories. Coffee production contributes to emissions primarily through farm-related activities (10.75 kg) and processing (0.61 kg). Notably, emissions from retail (1.69 kg) are relatively high compared to other food items. Dark chocolate surprisingly has high emissions, particularly from land use (25.81 kg) and farm-related activities (6.69 kg). Emissions from packaging (0.72 kg) and losses (12.94 kg) are also significant. Farmed fish exhibit moderate emissions, with significant contributions from farm-related activities (8.06 kg) and processing (0.04 kg). Emissions from packaging (0.14 kg) and losses (2.03 kg) are relatively low. Lamb and mutton have substantial emissions, primarily from farm-related activities (27.03 kg) and processing (1.54 kg). Emissions from losses (5.90 kg) are also notable. Olive oil production contributes to emissions mainly through farm-related activities (3.67 kg) and processing (0.57 kg). Emissions from packaging (0.74 kg) are also significant. Both peas and tomatoes have minimal emissions across all categories, indicating their relatively low environmental impact compared to other food items **(Figure 5)**.

Social Impact: Food waste and loss (FWL) represent a critical ethical concern, particularly considering the millions of people worldwide who still lack the means to fulfil their basic nutritional requirements (828 million individuals according to the **Word Food Programme (2022)**. The issue of FWL is often viewed from a social perspective, closely linked to food security. **Abbade (2020)** estimated that global FWL could potentially provide sustenance for 939 million adults with a daily caloric intake of 2000 kcal/day/person and a daily protein intake of 50 g/day/person. Moreover, FWL incurs indirect social costs, contributing to the intensification of farming systems, which in turn exposes inhabitants reliant on these practices to potentially harmful substances such as pesticides and heavy metals. Additionally, FWL depletes natural resources, exacerbates energy insecurity, fosters poverty, leads to health issues, and contributes to rising conflicts. **Serafini and Toti (2016)** investigated excess food intake, resulting in surplus body fat in overweight and obese individuals, as a form of metabolic food waste, analysing its environmental impact in terms of carbon, water, and land footprint across different food categories. Furthermore, food waste can be viewed as nutritional waste, where each quantity of wasted food translates into lost nutritional elements. **Chen et al. (2020)** assessed the daily loss of nutritional elements and the environmental impacts associated with global food waste.

Economic Impact: The economic costs associated with food waste and loss (FWL) are significant, particularly concerning the expenses incurred in waste disposal and the investments required to support the production process. Globally, FWL amounts to approximately USD 1 trillion annually, with an estimated value of USD 2.6 trillion when factoring in environmental and social costs **(Chen et al. 2020)**. High-income countries, in particular, face substantial costs during the consumption stage. For instance, in the USA, a family of four generates waste valued at around USD 1600 per year, while an average UK family wastes food valued at approximately USD 890 per year **(FAO, 2013; Lipinski et al., 2013; WRAP, 2021; World Bank, 2011; Read and Muth, 2021)**. The reduction of food waste is crucial for optimizing the utilization of agricultural land and ensuring the sustainable use of natural resources. Implementing measures to minimize food waste not only enables countries to identify areas where food is lost or wasted but also provides valuable insights for governments, citizens, and the private sector to effectively reduce food waste. The Food Waste Index Report - 2024 was recently released by the United Nations Environment Programme (UNEP) and Waste & Resources Action Programme (WRAP), a UK-based non-profit organization. It tracks the global and national generation of food and inedible parts wasted at the retail and consumer (household and food service) levels. It was first launched in 2011. It was conceived as a tool to monitor progress towards international targets, such as those outlined in SDG 12.3, which calls for halving food waste by 2030. In 2022, the global generation of food waste reached 1.05 billion tonnes, with households contributing 60 per cent to the total, followed by food services at 28 per cent, and retail at 12 per cent. On average, each person generated 132 kilograms of food waste during the year. The economic impact of food loss and waste is estimated to amount to $1 trillion. Food loss and waste play a significant role in greenhouse gas emissions, contributing 8-10 per cent to the annual global emissions. Food waste levels show minimal variation across income groups. Regions with warmer climates tend to produce more household food waste due to consumption patterns and infrastructure constraints, while rural areas generally exhibit lower levels of food waste compared to urban areas. Only 21 countries, including Australia, Japan, the United Kingdom, the United States, and the European Union, have incorporated food loss and waste reduction strategies into their climate plans or Nationally Determined Contributions (NDCs).

IX. Key findings of Food Waste Index 2021 & 2024

Though food waste has been discussed since the 19th century, world leaders and policy decision-makers have come together to produce policy documents concerning food waste and food loss. The first report was published in 2021, followed by another in 2024. The key findings of the reports are provided in **Box 3 and Box 4**.

Food losses and waste (FLW) occurring throughout global food supply chains (FSC) have been identified as significant contributors to climate change **(Porter et al., 2016)** and depletion of natural resources **(Lipinski et al., 2013)**. These phenomena pose threats to economic stability **(Parry et al. 2015)** and undermine humanity's efforts to achieve global food security **(Foley et al. 2011)**. Today, the development of consistent policies for addressing FLW faces three major barriers. The first obstacle stems from the absence of harmonized global FLW estimates **(UNEP, 2021)**. A second challenge arises from conflicting methodologies used to quantify FLW. Finally, a third barrier is the lack of a multidisciplinary framework capable of effectively addressing the diverse challenges related to FLW.

Food waste has been identified as one of the major factors that constitute numerous anthropogenic activities, especially in developing countries. There is a growing problem with food waste that affects every part of the waste management system, from collection to disposal; finding long-term solutions necessitates involving all participants in the food supply chain, from farmers and manufacturers to distributors and consumers. In addition to food waste management, maintaining food sustainability and security globally is crucial so that every individual, household, and nation can always get food. “End hunger, achieve food security and enhanced nutrition, and promote sustainable agriculture” are among the main challenges of global sustainable development (SDG) goal 2. Therefore, sustainable food waste management technology is needed. Recent attention has been focused on global food loss and waste. One-third of food produced for human use is wasted every year. Source reduction (i.e., limiting food losses and waste) and contemporary treatment technologies appear to be the most promising strategies for converting food waste into safe, nutritious, value-added feed products and achieving sustainability. Food waste is also employed in industrial processes for the production of biofuels or biopolymers. Biofuels mitigate the detrimental effects of fossil fuels. Identifying crop-producing zones, bioenergy cultivars, and management practices will enhance the natural environment and sustainable biochemical process. Traditional food waste reduction strategies are ineffective in lowering GHG emissions and food waste treatment.

The main contribution of this study is an inventory of the theoretical and practical methods of prevention and minimization of food waste and losses. It identifies the trade-offs for food safety, sustainability, and security. Moreover, it investigates the impact of COVID-19 on food waste behaviour.

Box 3 Key findings of Food Waste Index Report 2021	Box 4 Key findings of Food Waste Index Report 2024
✓ It has revealed that 17.0 per cent of all food available at the consumer level in 2019 and around 690 million people had to go hungry. ✓ It presents the most comprehensive food waste data collection, analysis and modelling data, generating a new estimate of global food waste. ✓ This report estimates that around 931 million tonnes of food waste was generated in 2019 61.0 per cent of which came from households, 26.0 per cent from food services and 13.0 per cent from retail. ✓ Food waste occurs in both food and inedible parts like bones and shells 150 food waste data points were identified in 54 countries. ✓ It aims to advance progress on SDG 12.3. That is by 2030 halve per capita food waste at the retail and consumer levels and reduce food losses along the production and supply chain including post-harvest losses. ✓ About 8.0 to 10.0 per cent of global green-house gas emissions are associated with food that is not consumed. Thus, tackling food wastage issues can further achieve the Paris Agreement.	✓ In 2022, the world wastes 1.05 billion tonnes of food amounting to one-fifth (19.0 per cent) of food available to consumers being wasted at the retail, food service and household level. That is in addition to 13.0 per cent of the world food lost in the supply chain as estimated by FAO, from post-harvest up to and excluding retail. ✓ Food loss and waste generate 8-10 per cent of global greenhouse gas emissions – almost five times the total emission from the aviation sector. It is while a third of humanity faces food insecurity. Across high-income, upper-middle-income, and lower-middle-income countries, the observed average levels of household food waste differ by just 7 kg per capita per year. ✓ Hotter countries appear to have more food waste per capita in households, potentially due to increased consumption of fresh loans with substantial inedible parts and lack of a robust cold chain. Higher seasonal temperatures, extreme heat events and droughts make it more challenging to store, process, transport and sell food safely, often

- ✓ At the same time, food waste occurs while 821 million people are hungry and 3 billion are unable to afford a health diet.
- ✓ On a global per capita level, 121 kg of consumed food is wasted each year with 74 kg of this happening in households.
- ✓ Developed countries like Austria produce very low amounts of waste at 39 kg/capita/year.
- ✓ On the other hand countries like Nigeria are producing waste at 189 kg per capita per year. Food waste in kg per capita per year was 50.
- ✓ Food Loss Index (FLI) focuses on food losses that occur from production up to (and not including) retail levels.
- ✓ It measures the change in percentage losses for a basket of 10 main commodities by counting in comparison with a base period.

leading to a significant volume of food being wasted or loss.

- ✓ Middle-income countries display variants between urban and rural populations with rural areas generally wasting less. Possible explanations include greater diversion of food scraps to pets, animal feed and home composting in rural areas.
- ✓ Many low- and middle-income countries continue to lack adequate systems for tracking progress to meet SDG 12.3 of halving total waste by 2030, particularly in retail and food services.
- ✓ At present only four G20 countries (Australia, Japan, the UK, US) and one European Union have food waste estimates suitable for tracking progress to 2030. Countries like India, Indonesia and South Korea have only substantial estimates regarding food waste, highlighting a gap in comprehensive national data.

***Source**: Compiled by authors*

X. Food Sustainability Index (FSI) and Food Loss Index (FLI)

The Food Sustainability Index (FSI) assesses the sustainability of food systems across 78 countries, focusing on three main pillars: food loss and waste, agriculture, and nutritional challenges. Comprising 38 indicators and 95 sub-indicators, the Index scores range from 0 to 100. A score of 100 indicates the highest level of sustainability and the most significant progress towards achieving environmental, societal, and economic key progress indicators (KPIs). Canada and Italy excel in addressing food loss and waste, with Canada ranking 1st in food loss and Italy ranking 1st in end-user-level food waste. In sustainable agriculture, Tanzania, Nigeria, Uganda, and Cote d'Ivoire stand out for scoring full marks for climate change mitigation and adaptation among the top-performing countries. Japan is a leader in addressing nutritional challenges, boasting top rankings for life expectancy rates and low mortality rates from noncommunicable diseases.

Food Loss Index: It measures the percentage of food lost from the farm level up until retail. It is compared to percentage losses in 2015. Values greater than 100 show increased waste since 2015; lower values indicate a decrease.

Table 4 - Food Loss Index

Country or region	2016	2021	Change	
			Absolute	Relative
Central and Southern Asia (UN)	96.8	88.7	-8.1	-8%
Eastern and South-Eastern Asia (UN)	99.1	100.0	+0.9	+1%
Europe and Northern America (UN)	99.5	100.9	+1.5	+1%
Latin America and the Caribbean (UN)	99.8	101.0	+1.2	+1%
Least Developed Countries (LDCs)	97.8	99.9	+2.1	+2%
Northern Africa (UN)	93.2	102.5	+9.3	+10%
Northern America (UN)	101.5	100.7	-0.8	-1%
Small Island Developing States (SIDS)	99.1	100.0	+1.0	+1%
Sub-Saharan Africa (UN)	99.3	98.9	-0.4	-0%
World	98.7	98.3	-0.4	-0%

***Data source:** Food and Agriculture Organization of the United Nations*

Table 5 – Per capita food waste in selected countries

S.No.	Country	Food waste per capita (KG)			Total	S.No.	Country	Food waste per capita (KG)			Total
		Retail	Out-of-home consumption	Households				Retail	Out-of-home consumption	Households	
1	Malaysia	78.82	89.56	91.44	259.82	33	Ireland	12.81	56.15	54.7	123.66
2	Nigeria	15.64	27.65	188.8	232.09	34	Thailand	15.64	27.65	78.69	121.98
3	Rwanda	15.64	27.65	164.36	207.65	35	Nepal	15.64	27.65	78.63	121.92
4	Israel	51.41	27.44	99.58	178.43	36	Bhutan	15.64	27.65	78.63	121.92
5	Greece	7.38	25.57	141.69	174.64	37	Indonesia	15.64	27.65	77.37	120.66
6	Bahrain	12.81	25.57	131.71	170.09	38	World	15.32	31.39	73.77	120.48
7	Iraq	15.64	27.65	120.44	163.73	39	Vietnam	15.64	27.65	76.16	119.45
8	Saudi Arabia	19.65	25.57	104.88	150.1	40	Ukraine	15.64	27.65	76.03	119.32
9	South Sudan	15.64	27.65	102.69	145.98	41	Sri Lanka	15.64	27.65	75.87	119.16
10	Somalia	15.64	27.65	102.69	145.98	42	Libya	15.64	27.65	75.71	119
11	Democratic Republic of Congo	15.64	27.65	102.69	145.98	43	Singapore	12.81	25.57	80.17	118.55
12	Burundi	15.64	27.65	102.69	145.98	44	Pakistan	15.64	27.65	73.64	116.93

13	Kenya	10.96	31.14	99.24	141.34	45	Canada	12.81	25.57	78.54	116.92
14	Sudan	15.64	27.65	97.22	140.51	46	Venezuela	15.64	27.65	72.43	115.72
15	United States	15.65	63.62	58.83	138.10	47	Ecuador	15.64	27.65	72.43	115.72
16	Mexico	15.64	27.65	93.9	137.19	48	Cuba	15.64	27.65	72.43	115.72
17	Ethiopia	15.64	27.65	92.14	135.43	49	Iran	15.64	27.65	70.98	114.27
18	Gabon	15.64	27.65	91.94	135.23	50	Sweden	10.00	20.50	81.00	111.50
19	Equatorial Guinea	15.64	27.65	91.94	135.23	51	South Korea	12.81	25.57	71.41	109.79
20	Botswana	15.64	27.65	91.94	135.23	52	Brazil	15.64	27.65	59.60	102.89
21	Algeria	15.64	27.65	91.02	134.31	53	Germany	5.97	20.58	75.00	101.55
22	United Arab Emirates	12.81	25.57	94.53	132.91	54	Finland	12.81	23.31	65.42	101.54
23	Qatar	12.81	25.57	94.53	132.91	55	United Kingdom	4.20	16.50	77.00	97.70
24	Oman	12.81	25.57	94.53	132.91	56	Norway	13.77	4.96	78.80	97.53
25	Kuwait	12.81	25.57	94.53	132.91	57	Italy	3.63	25.57	67.05	96.25
26	Australia	9.45	21.68	101.7	132.83	58	India	15.64	27.65	50.32	93.61
27	Denmark	29.80	20.64	81.33	131.77	59	New Zealand	3.12	25.57	61.00	89.69
28	Ghana	15.64	27.65	84.01	127.30	60	Japan	8.63	14.75	64.32	87.70
29	China	15.64	45.60	63.92	125.16	61	Netherlands	11.00	25.57	50.00	86.57
30	Afghanistan	15.64	27.65	81.73	125.02	62	Bangladesh	15.64	3.34	65.12	84.10
31	Switzerland	12.81	40.00	71.68	124.49	63	Austria	8.63	28.39	39.00	76.02
32	North Korea	15.64	27.65	80.67	123.96	64	Russia	13.72	27.65	33.38	74.75

Source*: United Nations (2023), Department of Economic and Social Affairs: SDG Indicators Database.*

Table 4 presents changes in the Food Loss Index across different regions from 2016 to 2021. Central and Southern Asia experienced a notable decrease from 96.8 to 88.7, representing an absolute reduction of 8.1 and a relative decline of 8 per cent. In contrast, Eastern and South-Eastern Asia showed a marginal increase from 99.1 to 100.0, with an absolute growth of 0.9 and a relative increase of 1 per cent. Europe and Northern America demonstrated a similar trend, with the index rising from 99.5 to 100.9, indicating an absolute increase of 1.5 and a relative growth of 1 per cent. Latin America and the Caribbean also saw a positive shift, moving from 99.8 to 101.0, reflecting an absolute increase of 1.2 and a relative growth of 1 per cent. The Least Developed Countries (LDCs) notably improved, with the index increasing from 97.8 to 99.9, marking an absolute rise of 2.1 and a relative growth of 2 per cent. Northern Africa showed significant progress, with the index soaring from 93.2 to 102.5, indicating an absolute increase of 9.3 and a substantial relative growth of 10 per cent. Conversely, Northern America witnessed a slight decrease from 101.5 to 100.7, representing an absolute reduction of 0.8 and a relative decline of 1 per cent. Small Island Developing States (SIDS) experienced a modest increase, climbing from 99.1 to 100.0, reflecting an absolute rise of 1.0 and a relative growth of 1 per cent. Sub-Saharan Africa saw a minor decrease from 99.3 to 98.9, indicating a slight absolute reduction of 0.4, with the relative change remaining neutral at 0 per cent. Globally, the Food Loss Index declined marginally from 98.7 to 98.3, denoting a small absolute decrease of 0.4 and a relative change of 0 per cent. These findings underscore diverse trends in food loss management across different regions, with some regions making significant strides while others face challenges or experience minor setbacks.

Analysis of per capita food waste across different countries, as presented in **Table 5**, illustrates unique patterns and difficulties. Malaysia emerges as the leading contributor to food waste, with a total of 259.82 KG per capita, predominantly stemming from households. Similarly, Nigeria and Rwanda exhibit significant household waste, resulting in totals of 232.09 KG and 207.65 KG per capita, respectively. Conversely, countries like Israel demonstrate a more balanced distribution of food waste across retail, out-of-home consumption, and households, totalling 178.43 KG per capita. The United States and China present notable scenarios with substantial out-of-home consumption waste, contributing to totals of 138.1 KG and 125.16 KG per capita, respectively. In contrast, European countries generally display lower total food waste per capita, with varying emphases on retail, out-of-home consumption, and household waste. Developing nations like India and Bangladesh show significant household waste, with India's total at 93.61 KG per capita and Bangladesh at 84.1 KG per capita, indicating differing levels of waste management infrastructure and consumer behaviours. These findings emphasize the need for targeted interventions tailored to address specific sources of food waste across different countries, encompassing consumer education, behaviour change initiatives, and policy measures targeting retail and out-of-home consumption sectors.

XI. Strategies and Policies for reducing food waste and food loss

The surge in global population, income, and meat consumption has propelled a heightened demand for food, presenting a multifaceted challenge. To address this, four primary options are suggested: expanding cultivated land, enhancing productivity, optimizing distribution, and altering consumption habits. Additionally, the Foresight Global Food and Farming Futures project emphasizes the need for comprehensive action across various fronts simultaneously. This includes sustainable production methods, reducing demand for resource-intensive foods, minimizing waste, and improving political and economic governance within the food system to ensure long-term productivity and sustainability. The strategies and policies for mitigating food waste and food losses are:

To reduce food waste and combat hunger: Collaborate with food businesses and civil society to redistribute edible food and establish composting schemes. Estimate greenhouse gas emissions from food waste to shape waste collection policies. Implement compost standards and training, designate production sites, and promote compost use in gardening and farming. Encourage home composting and explore food waste utilization in animal feeds. Support pilot programs, provide microfinance for farmers, and facilitate knowledge-sharing events **(C40 Cities, 2019; Stehouwer et al., 2022; Caplin, 2022)**.

To reduce disease, illnesses and injuries from waste: Address health risks from poor waste management by assessing the impacts of waste dumping and burning. Aim for universal waste collection to eliminate dumping and burning where services exist **(Reinhart and Townsend, 2018; McClelland et al., 2022; Olatunji, 2022)**. Manage healthcare waste, of which 15 per cent is hazardous, to mitigate risks of infection and toxicity **(WHO, 2018)**. Prioritize the health of waste workers, especially those in informal settings like dumpsites, who face occupational hazards and health risks, with women often at higher risk **(Zolnikov et al., 2021; Sara et al., 2022; Pintas Marques et al., 2021)**.

To improve waste management knowledge and skills: Promote waste awareness among youth with tailored educational lessons on waste reduction and sustainable management. Integrate waste management modules into higher and adult education curricula, emphasizing practical learning and aligning with national requirements. Support waste managers' capacity building through online learning resources for both public and private sectors. Ensure inclusivity by providing internet access and educational materials for local women and marginalized groups **(United Nations, 2019)**.

To achieve gender equality in waste management: Research women's waste-related knowledge, attitudes, and practices using gender-disaggregated data. Engage women in designing targeted information campaigns, recognizing their evolving roles in household management **(Hassan and Elsehry, 2022; Nakamura, 2022)**. Protect women's health and well-being in waste management by addressing their specific risks and vulnerabilities through policies, programs, and awareness initiatives **(Pintas Marques et al., 2021)**. Promote women's participation in waste picker cooperatives' governance structures and enhance their economic opportunities **(Dias and Ogando, 2015)**. Monitor the effectiveness of these measures for future interventions. Develop gender-sensitive waste policies, programs, and budget allocations by understanding women's needs, ensuring representation, and facilitating access to training and leadership roles **(Falth, 2019; UNEP-IETC and Grid-Arendal, 2019; Nakamura, 2022; UNEP-IETC, 2022; UN Women, 2022)**.

To protect water sources from waste and improve sanitation: Put an end to the detrimental practice of waste disposal in rivers and lakes by closely monitoring the quality of freshwater sources, identifying populations affected by water pollution, and comprehensively assessing its health, environmental, and economic impacts **(Damania et al., 2019; Koudenoukpo et al., 2022)**. Conduct awareness campaigns to discourage waste dumping in freshwater bodies while promoting waste collection and clean-up initiatives in these areas. Safeguard freshwater sources against leachate pollution by exploring strategies to divert food waste away from disposal sites, conducting thorough hydrogeological studies before selecting landfill locations, and implementing leachate collection and treatment systems **(Imtinan et al., 2020)**. Consider integrating the management of food waste and faecal sludge as a unified waste stream, fostering collaboration between sanitation and solid waste operations, and potentially merging container-based sanitation services with food waste collection and treatment efforts to enhance efficiency **(UNICEF, 2020; IRC, 2020; de Vreede, 2022)**.

To use organic waste as an affordable and sustainable energy supply: Promote biogas as a sustainable solution for meeting national energy needs by assessing its feasibility and sustainability, especially for households, schools, and farms **(Surendra et al., 2014; Osei-Marfo et al., 2022)**. Advocate for biogas adoption in collaboration with the Ministry of Finance. Establish a national biogas market, supporting local entrepreneurs with accessible information and prioritizing domestic technology providers **(B-energy, 2021)**. Ensure energy-from-waste technologies align with local and national goals, considering emissions and contributions to a zero-waste society **(UNEP, 2018)**. Evaluate the local capacity for operating and regulating proposed waste treatment facilities.

To create decent job creation and protect labour rights in waste management: Recognize the significant potential of the waste management and recycling sector, both formal and informal, in driving economic growth, employment, natural resource conservation, and climate change mitigation **(OECD, 2019)**. Support sectoral growth by backing high-value-added and labour-intensive enterprises. Improve working conditions and environmental standards, especially in e-waste management, through legislation ensuring equal pay and protection from sexual harassment **(ILO, 2019)**. Collaborate with employers' and workers' organizations to develop and implement coherent policies, strategies, and measures to enhance working conditions and provide health and social protections for workers and their families. Promote the professionalization of enterprises, cooperatives, and workers in the informal e-waste economy, while creating an enabling environment for enterprises of all sizes within the e-waste value chain.

To encourage national innovation and develop sustainable and resilient waste management infrastructure: Create an environment conducive to increasing financing and investment while supporting national waste management businesses. Foster collaboration between the private and public sectors to finance and mitigate risks related to waste management services, promote innovation, and gather data for informed waste management and circular economy strategies. Utilize digitalization to improve service delivery and financial inclusion for waste collectors, with a focus on closing the digital divide and promoting women's participation **(ITU, 2021; UNEP, 2019; Maldonado, 2022)**. Develop and implement a national roadmap for upgrading waste management infrastructure, ensuring ongoing access for existing waste workers to recyclable materials. Encourage decentralized waste management systems where appropriate to reduce costs and encourage recycling entrepreneurship.

To address inequalities through sustainable waste management systems: Legally recognize the human right to a clean and healthy environment and work towards universal access to efficient waste management services. Promote initiatives that incorporate gender equality and rights-based approaches. Retain government oversight and coordination over Extended Producer Responsibility (EPR) models, ensuring fair benefits for waste workers throughout the value chain. Evaluate proposed new systems to ensure an equitable transition to a circular economy, tailored to local needs, and aligned with national and local priorities. Avoid selective extraction of valuable materials and ensure representation of waste workers and local communities in decision-making processes.

To deliver sustainable waste management in cities and communities: Encourage initiatives aimed at minimizing waste generation, such as promoting home composting and zero-waste refill services. Engage in knowledge-sharing activities to enhance waste data collection and utilize data to shape national waste strategies and circular economy roadmaps. Implement a phased approach to enhance waste management systems, leveraging advancements to attract investment. Explore diverse financing mechanisms for waste management services, including co-financing and cross-subsidization from businesses and importers.

To promote sustainable consumption and production patterns: Promote zero-waste initiatives by focusing on key intervention areas, taking into account consumer behaviour, local customs, and the needs of affected populations, including independent traders. Recognize potential trade-offs and risks of shifting environmental burdens. Support businesses and organizations advocating for eco-friendly alternatives **(UNEP, 2021d; UNEP, 2021e)**. Address waste reduction in the hospitality sector through collaboration with tourism stakeholders to minimize food waste and single-use plastics. Encourage management commitment to sustainability **(Champions 12.3, 2018; UNEP and WTTC, 2021)**. Develop Sustainable Public Procurement Strategies to leverage public purchasing power for waste prevention and recycling **(Sönnichsen and Clement, 2020; Lord et al., 2022; UNEP, 2022a)**.

To use waste management for climate action: Raise awareness and enhance capacity among finance actors about waste management's significant role in achieving climate goals, integrating this insight into strategies, financing, and investment decisions. Implement key actions to reduce greenhouse gas emissions from waste, including universal waste collections to curb open burning, food waste prevention, and composting or biogas conversion. Utilize online tools like the Solid Waste Emissions Estimation Tool (SWEET) and WasteMAP to compare emissions from various waste management scenarios and devise methane reduction plans. Integrate waste management initiatives into Nationally Determined Contributions (NDCs) to bolster climate commitments. Strengthen the resilience of waste management infrastructure by mapping and incorporating it into Disaster Risk Reduction plans, implementing measures to prevent waste blockages in drainage channels, and devising maintenance plans for waste management services and infrastructure during extreme weather events **(Kaza et al. 2018; IPCC, 2022)**.

To prevent marine pollution from waste, and especially plastics: To combat marine pollution, employ standardized methods to comprehend its sources and costs **(UNEP, 2020; GESAMP, 2019)**. Utilize this data to spur action, ensuring broad consultation and diverse representation **(Convention on Biological Diversity, 2022)**. Implement measures, monitor outcomes, and periodically reassess effectiveness, making necessary adjustments. Small Island Developing States should prioritize preventing waste leakage and explore participation in the ISLANDS initiative for collective waste management endeavours **(IISD, 2019)**. Furthermore, incorporate waste management into Disaster Risk Reduction Strategies to bolster resilience.

To protect terrestrial ecosystems from mismanaged waste: To mitigate soil pollution risks, assess heavy metal contamination near waste sites as an indicator for other pollutants. Educate residents on soil and water pollution risks, and promote separate food waste collection and composting for agricultural use. Engage rural communities, particularly women, to develop waste reduction strategies. Use traditional art for awareness and introduce source-segregated waste collection with composting or biogas. Assess waste in mountainous regions and national parks, implementing measures like behaviour change campaigns and deposit return schemes. Empower local communities, especially women and youth, with the knowledge for change **(Convention on Biological Diversity, 2022)**.

To build effective and accountable waste governance: Ensure effective coordination among national and local government bodies, involving all stakeholders including public and private finance actors, with a focus on traditionally marginalized groups. Establish accessible feedback channels and maintain transparent communication to foster trust in new policies **(EBRD, 2018; International Bank for Reconstruction and Development and World Bank, 2021; UNDP, 2021)**. Prioritize hazardous waste governance, adhering to Basel Convention requirements and regional agreements. Combat waste crime by registering waste handlers, promoting transparency in procurement, and implementing robust monitoring. Internationally cooperate and utilize tools like those provided by Waste Force to tackle waste crime **(IMPEL, 2020)**.

To maximise the benefits of partnerships for waste management: Facilitate coordinated policy initiatives across the value chain to drive investment, emphasizing both upstream (waste reduction) and downstream (recycling and waste management) activities. Prioritize fostering enterprise, especially among women-led Micro, Small, and Medium Enterprises (MSMEs) and the informal sector. Partner with financial institutions to secure funding for service providers. Engage stakeholders from both formal and informal sectors to offer complementary services. Collaborate with similar regions to learn from successful models and tailor them to local contexts. Participate in South-South Cooperation programs for knowledge exchange.

XII. Conclusion

Food waste is a pressing global issue arising from multiple factors, including production, consumer behaviour, and retail practices. While developed nations mainly contribute to waste at the consumer level, developing countries face losses due to inadequate postharvest facilities. Efforts to tackle food waste should prioritize eliminating surplus and curbing overproduction. Composting offers a sustainable solution, although conventional disposal methods pose environmental risks. Disparities in food waste between nations stem from various challenges in harvesting, storage, and infrastructure. Quality standards, natural factors, and consumer behaviour also contribute to waste. The impact of food waste extends beyond environmental concerns, affecting financial and social sustainability. Urgent scientific investigations are needed to provide accurate estimates of food loss, highlighting the importance of converting food waste into bioproducts. With one-third of global food production wasted annually, addressing food waste is crucial for societal and environmental well-being.

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