Best Practices for Food Loss and Waste Regulatory Enabling Environment

Guideline for Government

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Authors:

Seta Tutundjian
Dima Maroun
Robin Shrestha

Thriving Solutions
Reimagining our food systems to sustain our future

Tufts University | GERALD J. AND DOROTHY R. Friedman School of Nutrition Science and Policy

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List of Abbreviations and Acronyms

AI	Artificial Intelligence
BAMX	Banco de Alimentos de México
BP	Best Practices
BSF	Black Soldier Fly
CDM	Clean Development Mechanism
CoC	Code of Conduct
CSO	Civil Society Organization
CSR	Corporate Social Responsibility
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FEBA	European Federation of Food Banks
FEFO	First Expired, First Out
FFAR	Foundation for Food and Agriculture Research
FIT	Feed-in Tariff
FLA	Food Loss Analysis
FLAPP	FAO Food Loss App
FLI	Food Loss Index
FLW	Food Loss and Waste
FSC	Food Supply Chain
FUSIONS	Food Use for Social Innovation by Optimizing Waste Prevention Strategies
FVC	Food Value Chain
FWI	Food Waste Index
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GPS	Global Positioning System
HFSS	High in Fat, Salt, and Sugar
ICT	Information and Communications Technology
IDB	Inter-American Development Bank
IFPRI	International Food Policy Research Institute
IMC	Indore Municipal Corporation
IoT	Internet of Things
IT	Information Technology
KPI	Key Performance Indicator
M&E	Monitoring and Evaluation
MSP	Multiple Stakeholder Platform
MW	Megawatt
NGO	Non-governmental Organization
NRDC	Natural Resources Defense Council
OECD	Organisation for Economic Co-operation and Development
PICS	Purdue Improved Crop Storage
PMGSY	Pradhan Mantri Gram Sadak Yojana

POP	Point of Purchase
PPP	Public-private Partnerships
R&D	Research and Development
R4D	Research for Development
REFRESH	Resource Efficient Food and Drink for the Entire Supply Chain
RFID	Radio Frequency Identification
SAWBO	Scientific Animations Without Borders
SDG	Sustainable Development Goal
SMART	Specific, Measurable, Achievable, Relevant, Time-bound
SME	Small- and Medium-sized Enterprises
SMS	Short Message Service
TAHA	Tanzania Horticultural Association
TMA	Target-Measure-Act
TPD	Tons Per Day
UAE	United Arab Emirates
UNEP	United Nations Environment Programme
UNFSS	United Nations Food Systems Summit
UNIDO	United Nations Industrial Development Organization
UNSD	United Nations Statistics Division
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WG	Working Group
WOW	War on Waste
WRAP	Waste and Resources Action Programme
WRI	World Resources Institute
WWF	World Wildlife Fund
UN	United Nations
US	United States
ZECC	Zero Energy Cool Chamber

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Abstract

Food loss and waste (FLW) poses significant challenges to global food security, environmental sustainability, and economic efficiency. Approximately 40% of food produced globally is wasted, translating to over $1 trillion in economic losses annually and accounting for 10% of global greenhouse gas emissions.

This report presents a comprehensive exploration of best practices for establishing a regulatory enabling environment to reduce FLW. Drawing upon global frameworks, methodologies, and case studies, the report provides actionable insights for policymakers to mitigate these issues through a regulatory and policy-driven approach that is evidence-based and context-specific.

It proposes "Target-Measure-Act" as the guiding framework and presents 14 best practices to shape effective FLW strategies. These include implementing robust measurement systems, leveraging fiscal measures and technological innovations, fostering collaboration, and knowledge sharing and capacity building. A supporting assessment framework provides policymakers with a checklist to analyze their current FLW strategies, identify gaps, and develop targeted interventions.

Introduction

Food loss and waste (FLW) is a global issue with implications in the social, economic, and environmental sectors. According to findings by the World Wildlife Fund (WWF) in their "Driven to Waste" report, the proportion of uneaten food globally that goes to waste is approximately 40% (WWF, 2021). This is a significant increase from the previously estimated 33%. This waste attributes to a global economic loss of over 1 trillion US Dollars annually (WB, 2020). Additionally, wasted food accounts for 10% of worldwide greenhouse gas emissions, consumes 25% of the freshwater resources allocated for food production (Kummu et al. 2012), represents 23% of the world's total fertilizer consumption (Flanagan, Robertson and Hanson, 2019), and originates from 28% of the land dedicated to agricultural use (FAO, 2013).

Concurrently, according to the Food and Agriculture Organization (FAO) of the United Nations (FAO, 2023), in 2022 approximately 29.6% of the global population experienced moderate to severe food insecurity, while hunger affected about 783 million people—an increase from the 2019 figure of 122 million. Given the social ramifications of food and nutrition insecurity, it is unconscionable to tolerate these high levels, much of which involves edible food, amidst such widespread hunger.

Efforts to combat FLW globally have increased since the adoption of the Sustainable Development Agenda 2030 in 2015. Sustainable Development Goal 12 (SDG12), which focuses on ensuring sustainable consumption and production patterns, includes a specific target related to FLW. Target 12.3 aims 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, by 2030” (UN. n.d.). To reach this target, a collaborative effort is required by multiple stakeholders, with a common understanding of FLW definitions, measurement methodologies, and best practice implementation efforts.

Climate change agreements require nations to act on climate mitigation and adaptation; reducing FLW is a strategy that addresses both. The critical role of reducing FLW is emphasized not only for its importance in enhancing food security but also for its significant contributions to climate action (Champions 12.3, 2016) and methane reduction efforts. This is further highlighted by the selection of the “Food is Never Waste” initiative as one of the finalist coalitions by participating countries at the United Nations Food Systems Summit (United Nations Food Systems Coordination Hub, 2022). This recognition underscores the global consensus on the importance of addressing food waste as a multifaceted challenge with implications for environmental sustainability, climate change mitigation and adaptation, and food security. **Error! Reference source not found.** depicts the main benefits of FLW reduction.

The “Target-Measure-Act” (TMA) approach stands as a strategic framework designed to tackle food waste by setting clear objectives, quantifying the magnitude of the problem and progress, and implementing actionable solutions. This method begins with “Target,” or establishing specific goals for reducing FLW. “Measure” involves accurately assessing the extent of food waste, the drivers and causes behind the waste, and tracking progress towards these goals. Finally, “Act” focuses on executing policies and strategies to meet the targets (FLW Protocol [n.d.]; Champions 12.3. [n.d.]; World Resources Institute. [n.d.]; Waste and Resources Action Programme. [n.d.]).

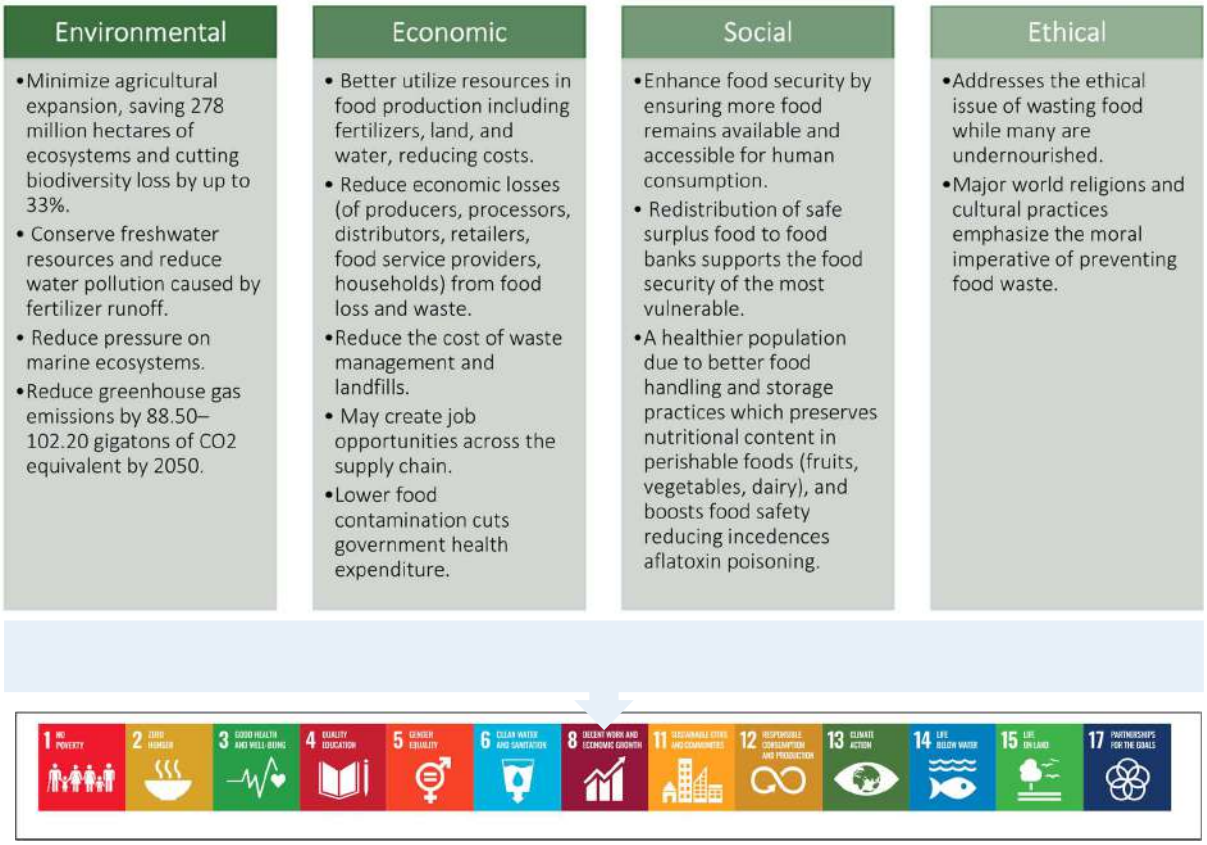
Objectives and Scope of this Document

Policies and regulations play a dual role in the context of FLW: they can both accelerate or impede its mitigation. Because of this, there is a vital need for the comprehension of regulatory and policy frameworks to effectively harness their potential for positive change. The objective of this study is to identify internationally recognized best practices (BP) to be used as a guiding framework for policy makers when developing or improving strategies aimed at reducing FLW.
A detailed review of FLW related key documents by leading international organizations, the major FLW frameworks, and key reduction strategies was carried out. To this end, the study conducted a

comprehensive analysis to discern common themes and approaches that have proven successful in the past, and to identify the policy frameworks and legislative actions that may facilitate or hinder their effectiveness. This targeted review ensures that the policy recommendations are actionable and consistent with the proven practices within the Target-Measure-Act paradigm. By doing so, it fosters a more sustainable and efficient global approach to mitigating FLW.

Based on the identified BPs, a supporting assessment framework in the form of a detailed checklist that governments can use to perform situational analysis was developed. This checklist will help pinpoint gaps, weaknesses, and hotspots in current FLW strategies, identify existing strengths, and categorize suitable interventions effective within the local context. The goal of this assessment framework is to provide policymakers with a foundational, easy-to-use tool to facilitate comprehensive analysis that can be utilized by all working within the FLW field. Policymakers can use this tool to develop or refine their strategies, ensuring they are evidence-based and aligned with broader environmental sustainability and food security objectives.

Figure 1: Benefits of Reducing Food Loss and Waste



Source: Prepared by Author based on information derived from the following reports:
Flanagan, Robertson and Hanson, (2019), Project Drawdown (n.d.).

Methodology

This study utilized a mixed-method approach to analyze policies and regulations affecting FLW and identify best practices for mitigation. A thorough desk study that reviewed key reports, publications, and case studies on FLW policies and regulations including academic literature, international guidelines, major FLW reduction strategies, as well as reports and case studies from non-governmental and governmental organizations and industry associations, was carried out. The aim was to map out existing knowledge, identify main drivers of FLW, highlight innovative and successful prevention and reduction approaches, and assess trends in policy effectiveness. Based on this, the team recommended BPs for governments and created an assessment framework for decision-makers to evaluate the enabling environment for FLW prevention in their countries. The assessment framework will be a separate addendum.

For validation, feedback on the identified BPs and assessment framework was solicited from attendees of the "Circular Food Economy" workshops in Nepal and Malawi, including policymakers and civil society representatives from Nepal, Bangladesh, Malawi, and Mozambique. The list of BPs and framework was also presented at the "Reducing Food Loss and Waste: Dual Impact Actions to Address Climate Change and Improve Nutrition" workshop in Aspen, organized by USAID, USDA, and the Aspen Global Change Institute. Discussions from the Aspen workshop further informed this analysis.

The desk study, workshop discussions, questionnaire results, and the discussion at the Aspen workshop provided a robust foundation for the research, enabling a comprehensive understanding of the policy and regulatory environment surrounding FLW. The findings were synthesized into evidence-based recommendations of BPs for policymakers and the accompanying assessment framework, aiming to inform more effective global FLW reduction strategies.

Research questions guiding the desk-review and subsequent discussions:

1. What are the key drivers of FLW across the food supply chain, and how do policies address these drivers? What policies contribute to or mitigate FLW, and what evidence supports the success of these policies in prevention, recovery, and recycling?
2. What are the best practices currently advocated for FLW prevention and reduction? How do policies and legislative actions facilitate or hinder efforts to reduce FLW within each best practice framework?
3. What methods and metrics are currently used to measure FLW, and how effective are these in capturing the full scope of the issue? How can regulations facilitate or impede the accurate measurement and reporting of FLW?
4. What lessons can be learned from comparing FLW policies and regulations across different countries and regions?
5. How can an assessment framework be developed to help governments perform situational analyses and identify gaps, weaknesses, and strengths in their current FLW strategies?

Definitions

FLW has received a lot of attention locally, regionally, and internationally. Although this issue is of utmost importance, the definitions of FLW are not always consistent. Different government agencies adopt varying definitions depending on their context and needs (Food Systems Nutrition Innovation Lab [e], 2022). The definitions that are used globally often stem from classifications by the European Parliament, the US Environmental Protection Agency (EPA), the Food and Agriculture Organization (FAO), United Nations Environment Programme (UNEP), the Food Loss and Waste Accounting and Reporting Standard (UNEP, WRAP, and WRI) (Breewood H., 2019). **Table 1** presents the different definitions for FLW by these key agencies.

Before delving into the specific definitions of FLW adopted by this document, it is essential to understand the widely accepted definition of food. According to the Codex Alimentarius Commission Procedural Manual (FAO and WHO, 2019), food is defined as, "**any substance** (processed, semi-processed, raw) **intended for human consumption**. It includes drinks and substances used in the manufacture, preparation, or treatment of food. It doesn't include cosmetics, tobacco or substances used only as drugs."

For this document, the following definitions for "food loss" and "food waste" will be used:

Food loss: Food intended for human consumption that exits the supply chain between harvest and retail, including wholesale markets.

Food waste: Food intended for human consumption that exists the supply chain between retail and consumption points and does not include wholesale markets.

Wasted food: Food intended for human consumption that exists the supply chain at any point (this includes food loss and food waste).

Food markets: Markets are referred to as primary, secondary, and alternative when discussing food. All markets offer routes for food products to be sold, but their structure, focus, and purpose all differ.

Primary markets are the conventional and mainstream channels through which food products and produce are sold and distributed to consumers (e.g., supermarkets, grocery stores, wholesalers, and food service providers). Farmers and manufacturers use primary markets by directly selling their products to consumers, or through other businesses such as retail shops, etc. These markets usually have established large-scale distribution systems driven by demand and consumer needs.

Secondary markets cater to surplus production, produce and food that have not been sold in the primary market due to its appearance, or produce nearing expiry dates. The primary aim of these markets is to reduce food waste by redistribution of edible food that cannot be distributed and sold through primary markets. Examples include discount stores, food banks, and charities.

Alternative markets serve the same purpose as primary markets but are considered non-traditional channels that offer producers direct sales to consumers. They usually emphasize local and organic products, and tend to support artisan producers, small and medium-sized enterprises (SMEs), small scale farmers, and organic growers. Examples include online platform catering only for small scale producers, farmers markets, farm-to-table initiatives, and other community-supported agricultural activities (Cicatiello, 2020).

This report also introduces the "**waste-to-value market**," which encompasses byproducts of food or waste materials not traditionally consumed and otherwise discarded (e.g., inedible and leftover parts of animals, fish, and plants; expired produce). These virtual or physical markets provide a platform for producers to connect with innovators who create value from these non-edible food components. Examples of valorization include transforming spent grains from brewing into baking flour, producing jams from bruised fruits, or creating animal feed from food scraps. Upcycled products like these illustrate the potential for converting waste into valuable commodities, supporting a circular economy that maximizes the intrinsic value of materials and minimizes waste.

Table 1: Food Loss and Food Waste Definitions

	US EPA	European Parliament	UNEP	FAO
Food Loss	**Food loss** often refers to unused product from the agricultural sector, such as unharvested crops. For purposes of Sustainable Development Goal Target 12.3, food loss occurs from production up to (and not including) the retail level.		**Food Loss** is defined as all the crop and livestock human-edible commodity quantities that, directly or indirectly, completely exit the post-harvest/slaughter production/supply chain (by being discarded, incinerated, or otherwise), and do not reenter in any other utilization (such as animal feed, industrial use, etc.), up to, and excluding, the retail level. Losses that occur during storage, transport, and processing, also of imported quantities, are therefore all included. Losses include the commodity as a whole with its non-edible parts, otherwise removed from the edible mass at the production, post-harvest and processing phases of the food supply chain (FAO, 2022).	**Food loss** is the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers, and consumers. Empirically, the term refers to any food that is discarded, incinerated, or otherwise disposed of along the food supply chain, which starts with harvest/slaughter/catch up to but excluding the retail level, and the food does not re-enter the supply chain for any other productive use, such as for feed or seed. (State of Food and Agriculture, 2019)
Food Waste	**Food waste** often refers to food not ultimately consumed by humans that is discarded or recycled, such as plate waste (i.e., food that has been served but not eaten), spoiled food, or peels and rinds considered inedible. For purposes of SDG Target 12.3, food waste occurs at the retail, food service, and residential levels and is managed by landfill, controlled combustion, sewer, litter, discards and refuse, co/anaerobic digestion, compost/aerobic digestion, and land application.	**Food Waste** is all food (as defined in Article 2 of Regulations [EC] No. 178/2002) that has become waste.	**Food waste** is defined as food and the associated inedible parts removed from the human food supply chain. "Wholesale food remains under the Food Loss Index and therefore should not be reported under the Food Waste Index." (UNEP, 2024)	**Food waste** refers to the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers, and consumers (State of Food and Agriculture, 2019).
Wasted Food	The EPA uses the overarching term "wasted food" instead of "food waste" for food that was not used for its intended purpose because it conveys that a valuable resource is being wasted, whereas "food waste" implies that the food no longer has value and needs to be managed as waste.			
Excess Food	Surplus food or food that is donated to feed people.			
FLW Accounting and Reporting Standard	Allows for the measurement and reporting of FLW, and to define food loss and food waste according to their purpose of measurement (edible vs. inedible food, destinations). Food is categorized as edible and inedible food. The food that is not consumed and inedible is sent to possible destinations (animal feed, biomaterial/processing, co/anaerobic digestion, composting/aerobic process, controlled combustion, land application, landfill, not harvested/plowed-in, refuse/discards/litter, and sewer/wastewater treatment).			

Source: (US EPA, 2021), (UNEP, 2024), (FAO, 2024), (Hanson et al., 2016), (FAO, 2019)

Drivers of Food Loss and Waste

There are numerous factors, both deliberate and accidental, that result in food exiting the human supply chain, ranging from concerns over food safety or suitability for consumption to superficial issues like appearance, alongside systemic problems like excessive supply, lack of buyer demand, and seasonal fluctuations. These direct causes, whether they involve the disposal of food deemed unsafe or unattractive, or the discarding of excess produce due to market dynamics, are symptomatic of deeper, underlying drivers. These drivers can be technological, managerial, behavioral, or structural in nature. For instance, technological barriers hindering access to proper storage can lead to quality deterioration and spoilage, while abrupt changes in retailer demands can result in waste even before food is transported from farms.

The underlying drivers of FLW are multifaceted and manifest across the entire food supply chain (FSC), involving various actors from farmers to consumers. They can be influenced by regional variations, with certain issues being more prevalent in specific income regions. For instance, a farmer's inability to secure financing for better storage solutions can lead to spoilage, a clear illustration of how multiple drivers can converge on a single point of failure. The ripple effects of actions at one stage affecting outcomes downstream—such as rough handling of produce reducing its shelf life and thus leading to waste at retail or consumption stages—underline the systemic nature of FLW.

This complex web of causes manifested throughout the FSC demands comprehensive strategies aimed at addressing the foundational issues. Moreover, interconnectivity necessitates a holistic understanding and approach by both public and private sector stakeholders to effectively mitigate FLW. Addressing FLW effectively requires identifying its direct causes and comprehending the underlying drivers within specific contexts, emphasizing the need for interventions that go beyond treating symptoms to tackle the root causes. Such a comprehensive approach not only curtails FLW but also enhances food security and sustainability by ensuring more food remains within the human supply chain, thus reducing the environmental footprint of food production. This approach supports broader objectives of environmental conservation, economic efficiency, and global sustainability by minimizing the resources expended on food that ultimately goes unconsumed. The challenge and opportunity lie in crafting and implementing strategies that address the complex and interconnected drivers of FLW, paving the way for more resilient and sustainable food systems worldwide.

Figure 2: Direct and Underlying Drivers of F, adapted from Flanagan, Robertson and Hanson, 2019 and the HLPE, 2017, presents the direct drivers of FLW along with various underlying drivers, highlighting the necessity for a comprehensive approach that considers the entire FSC. Tables 1-4 present the technological, managerial, behavioral, and structural drivers, respectively.

Figure 2: Direct and Underlying Drivers of Food Loss and Waste

Source: Prepared by Author based on information derived from the following reports: Flanagan, Robertson and Hanson (2019), HLPE (2017).

Table 2: Technological Drivers of Food Loss and Waste

1. Deficient public and private infrastructure along the food supply chain and at consumption points
Infrastructure, both public and private, plays a pivotal role in the efficient operation of societies and economies, significantly impacting the dynamics of FLW. Public Infrastructure Essentials: reliable public infrastructure, including stable electricity, dependable communication networks, and accessible roads and ports, is crucial for the seamless transfer of food from farms to consumers. Insufficiencies in this area, such as poorly maintained roads or those susceptible to flooding, can disrupt food transportation, leading to spoilage and increased FLW. Maintaining cold chains in areas lacking reliable electricity leads to less spoilage before food reaches markets. Role of Private Infrastructure: private sector investments in storage solutions, cold chains, processing facilities, secondary and alternative markets, and distribution networks infrastructure is crucial for maintaining food freshness, enhancing product longevity, ensuring efficient distribution, and recovering surplus food. This creates a resilient supply chain focused on minimizing FLW. Importance of Cold Storage Facilities: the lack of adequate cold storage facilities significantly increases the risk of food spoilage for perishable goods such as fruits, vegetables, meat, fish, and dairy during transit or storage. Research in India and sub-Saharan Africa emphasized storage, particularly accessible low-cost cold storage options, as a key strategy in reducing food loss. Deficient Water Infrastructure: inadequate water infrastructure can lead to FLW by affecting agricultural production and food safety. Insufficient irrigation or water treatment facilities can result in under-watered or contaminated crops, increasing spoilage and disease and elevating pre-and-post harvest losses. While lack of clean water at consumption forces consumers to discard contaminated or unsafe food.
2. Inadequate & outdated equipment
The efficacy and appropriateness of equipment throughout the FSC is crucial in minimizing FLW. Equipment used in harvesting, storage, distribution, merchandising, and food preparation plays a vital role in maintaining the FSC's integrity. Challenges in Agricultural Production: farmers face significant hurdles due to outdated or inappropriate equipment. Inadequate harvesting machinery can lead to inefficient harvesting, unharvested crops, and reduced yields. Lack of proper irrigation systems or water treatment facilities can lead to insufficiently watered or contaminated crops, increasing the likelihood of spoilage and disease and raising both pre-and-post harvest losses. Storage and Spoilage: traditional granaries and silos, unreliable cold storage, open air storage, and inadequate dry storage areas can hasten food spoilage and result in pest infestation, aflatoxins, and fungus. Other storage solutions such as plastic bags and non-breathable packaging can increase the ripening process and food spoilage. Overloaded refrigerators and freezers in warehouses and households also increase the rate of spoilage due to the lack of even cooling. Post-harvest Processing: inadequate processing facilities and equipment leads to FLW due to constraints on transforming fresh perishable foods into long-shelf-life products or products with a higher value such as packaged items, ready-to-eat meals and sauces, dried goods, and other products that can be distributed to national and international markets. In Kenya, adoption of simple post-harvest tools such as solar dryers to dry mangoes and package them in transparent bags improved mango availability during the off-peak season, reduced the risk of spoilage, and produced a high-quality product. Distribution Difficulties: during distribution, the lack of suitable handling tools can damage food, rendering it unsuitable for consumption. For example, transporting temperature-sensitive produce in non-refrigerated trucks or the absence of cushioning in containers for the transport of delicate items such as eggs.

Retail Equipment Inefficiencies: inadequate merchandising equipment, such as malfunctioning refrigerators and freezers, can cause food to spoil faster and reduce sales. Poor lighting and display units can also fail to attract customers, leaving items unsold and increasing waste.

Food Preparation Equipment: insufficient kitchen equipment like inefficient stoves that partially cook or overcook meals, leading to food that cannot be served to customers and is discarded. Inadequate refrigeration can spoil food.

3. Suboptimal packaging

Packaging plays a crucial role in preserving food quality and freshness, extending shelf life and protecting food from contamination. From harvest until consumption, the lack of proper protective measures can lead to significant losses.

Suboptimal Pack Sizes: packaging that does not align with consumer or retailer consumption patterns or storage capabilities often leads to food being discarded prematurely. Too large or too small pack sizes can prevent food from being consumed before it spoils. For example, family sized salad packs are too big for a single customer, while single-pack condiments are not enough for restaurant needs.

Inadequate Protection: packaging that fails to offer sufficient protection to safeguard food effectively can exacerbate food's vulnerability to spoilage, physical damage, pest infestation, and contamination. For example, packaging that does not allow air circulation accelerates food spoilage or mold.

Multi-purpose Packaging: Effective packaging should protect food quality and safety during transport and storage by maintaining freshness, prolonging shelf life, and protecting food from contamination while satisfying market and consumer demands. When packaging fails in these roles, the risk of FLW increases. For example, single use packaging that cannot be heated or properly sealed for ready to eat meals can cause leftovers to be discarded instead of saved.

Contribution to Supply Chain Inefficiency: inadequate and insufficient packaging prevents food's smooth transition across the supply chain and can compromise its quality and safety. For example, non-stackable shipping containers may require several trips to transport a specific quantity, leaving products in transit and handling for a longer period of time, increasing the chance of spoilage.

4. Innovation gaps

Innovation can contribute to the advancement or impediment of the global FSC. Innovation in technology, processes, and business models can reduce FLW.

Complex, Inconsistent Regulations: laws and regulations that differ from one jurisdiction to another can make it difficult for companies to roll out innovation designs to reduce FLW across these different jurisdictions. Lack of regulations, or old regulations that do not meet international targets can discourage companies from investing in innovative solutions due to uncertainty. For example, nonexistent regulations for different valorization options such as black soldier flies will discourage investors in funding a project within a jurisdiction that does not have these specific regulations.

Lack of Incentives for Innovation: without policy and/or financial incentive, businesses big and small will not pursue new technologies or processes that will mitigate FLW. For example, not providing tax breaks to reduce FLW within a manufacturing facility will not encourage that company to pursue new technologies or processes to reduce their FLW.

Complex, Expensive, and Restrictive Intellectual Property Laws: these laws can discourage access to patented technologies, causing limitations in the sharing of knowledge to reduce FLW. Though intellectual property laws are created to protect inventors, access to these laws and to the patent can be difficult to navigate and expensive to acquire. For example, a smallholder farmer may not have access to available patented technologies that reduce on-farm food loss and increase crop yield.

Lack of Regulatory Focus on Sustainability: by default, policies and regulations tend to prioritize economic gains over sustainability, which may lead to policies that disregard FLW. For example, subsidies to produce

certain crops that are in high demand, leading to overproduction of these crop that are then left on the field due to oversupply.

Lack of Environment for Collaboration and Partnerships: lack of collaboration between public-private and civil society institutions can inhibit innovations and streamlining of processes to improve efficiency. Policies and regulations that encourage and facilitate collaboration platforms can increase the effectiveness of FLW interventions. For example, the development of an app to connect food recovery networks and food donors with local food banks and charities to redistribute food and reduce food waste.

Sources: (Flanagan, Robertson and Hanson, 2019); (IDB, 2022a); (Chepwambok et al., 2021); (Nwokolo et al., 2024); (HLPE, 2017.)

Table 3: Managerial Drivers of Food Loss and Waste

1. Insufficient food management practices, proper skills, and knowledge
The nexus between management practices, knowledge, skills, incentives, and the effective use of equipment is critical in mitigating FLW. At every stage of the FSC, from production to consumption, deficiencies in these areas can have a profound impact on the amount of food that goes to waste.
Deficiencies in Harvesting and Production Practices: inadequate use of mechanical harvesters, improper fishing techniques, poor harvesting, handling and packing techniques, inadequate animal care practices, and the scarcity of economically viable labor can result in fruit bruising, crops left in the field, and excess meat trimming. These issues often stem from a gap in knowledge and skills, and a lack of motivation to adopt better practices or utilize equipment effectively and correctly.
Handling and Transition Challenges: improving handling practices during loading and unloading is crucial for maintaining the integrity of food as it moves through the supply chain. Mishandling can cause immediate physical damage to produce and perishables, quickening deterioration and the risk of spoilage. Innovative solutions such as equipping the handling trucks for transport to reduce physical damage to produce can reduce food loss by approximately 80% (WB, 2019).
Consumer Education and Behavior: at the consumption end, households encounter difficulties with meal planning and preparation, determining product freshness, and correctly interpreting date labels, largely due to insufficient knowledge or skills in these areas.
Lack of Proper Skills, Knowledge, and Information Transfer: at the production level, inadequate knowledge of crop handling, pest management, and harvesting techniques can damage fruits and vegetables, making them unsellable or inedible. In the processing stage, insufficient training can result in poor handling and packaging, exposing food to spoilage. At the distribution and retail levels, training employees in effective stock rotation, food storage, and handling practice can reduce food waste risks.
2. Rigid procurement practices
Rigid contractual practices that amplify the need for stringent quality and cosmetic standards present both operational and financial challenges for suppliers and can increase FLW.
Rigid Contractual Practices: last-minute order changes, cancellations, take-back clauses, and unilateral or retroactive contract modifications, coupled with strict quality and cosmetic standards, demand that food meet certain aesthetic criteria, often leading to the exclusion of nutritious and edible food.
Inadvertent Removal of Edible Food: procurement requirements intended to minimize the transfer of unsuitable food can inadvertently cause the discarding of perfectly good food from the human consumption cycle. The inflexibility of contracts and policy-induced barriers can compel suppliers to eliminate food that does not meet narrowly defined aesthetic standards, despite its nutritional value.
Disruption to Supplier Stability: these stringent contractual obligations can lead to a sudden loss of market for products intended for sale, undermining trust between trading partners. This also destabilizes the financial and operational efficiency of suppliers in the agricultural and food sectors, which can increase food waste.

Barriers to Food Redistribution: whether due to policy issues, scarcity of trained health inspectors and unavailability of food redistribution organizations (e.g., food banks, social supermarkets, food sharing initiatives and platforms) compounds the problem and prevents safe food from reaching those who need it.

3. Poor forecasting and planning of supply and demand

Poor forecasting and the lack of efficient information flow between buyers and suppliers leads to inefficiencies that exacerbate FLW across the FSC.

Suboptimal Crop Scheduling at the Production Stage: poor forecasting and communication at the production level can lead to either overproduction or underproduction. This misalignment with market demand often results in unnecessary wastage or shortages, directly impacting the efficiency of food production.

Inefficient Inventory Management in the Supply Chain: midway through the supply chain, inadequate forecasting translates into poor inventory management among retailers leading to overstocking of perishable goods that cannot be sold before spoiling, or shortages that lead to missed sales opportunities and consumer dissatisfaction.

Excess Purchasing and Preparation by Households: the culmination of upstream inefficiencies becomes evident at the consumption stage, where households, influenced by inconsistent supply levels, may end up buying and preparing more food than is needed. This leads to avoidable waste, highlighting the critical need for improved forecasting and information flow.

4. Marketing strategies

There is a complex relationship between consumer behavior spurred by marketing efforts, which in turn affects FLW through.

Over-Purchasing from Promotions and Bulk Sales: aggressive promotions, discounts, bulk sales, and offers such as "Buy One Get One Free" entice consumers to over-purchase food that cannot realistically be consumed before expiring.

Seasonal and Limited-time Offers: marketing campaigns that promote seasonal or limited-time products can lead to overstocking in stores and in consumers' homes. The perishable nature of many seasonal items means they may not be sold or consumed before spoiling.

Packaging Design: packaging that emphasizes larger sizes or multi-packs, which consumers opt for due to perceived value (even when smaller quantities would better meet their needs), can lead to over-purchasing.

Product Placement: product placement within stores near the checkout or highlighting certain products through endcap displays can influence consumers to purchase items that were not on their shopping list or needed.

Lack of Promotion for Imperfect Produce: under-marketing or poor presentation of “imperfect” or “ugly” produce can lead to these items being overlooked by consumers, despite being perfectly edible.

Impact of Merchandising Displays: eye-catching merchandising displays designed to draw consumer attention can encourage consumers to over-purchase. Moreover, the emphasis on aesthetic appeal and abundance often necessitates overstocking or frequent restocking leading to waste as items are displaced, over-handled, and sometimes discarded to make space for new stock.

5. Globalization and trade

Globalization and international trade have transformed food systems worldwide, facilitating greater access to diverse food products and expanding markets for agricultural producers. Simultaneously, they have introduced complex challenges related to extended supply chains, diverse regulatory standards, and the varying quality demands across markets, which contribute to increased FLW.

Extended Supply Chains: driven by globalization, products travel great distances from producer to consumer across different countries and continents. The lengthening of the supply chain increases the risk of FLW at multiple points, particularly for perishables (e.g., fruits and vegetables) susceptible to spoilage during long

transit times if not managed under optimal conditions. Inadequate handling during transportation or not maintaining cold storage throughout the chain can also accelerate spoilage.

Diverse Regulatory Standards: discrepancies in country standards and regulations regarding food safety, quality, and packaging can make it difficult for exporters and importers to make certain that products meet the destination's standards and ensure that they are not rejected at the border. For example, the European Union has strict aesthetic standards regarding fruits and vegetables that are generally higher than other countries. If imported fruits and vegetables do not meet this high standard (even though they are perfectly edible) they will be rejected and most probably wasted.

Shift in Market Demand: global markets often demand high-quality, uniform products, which pressures producers to select only the best produce to export, resulting in considerable waste of products that do not meet these visual or size specifications, despite being perfectly suitable for consumption. Additionally, consumer preferences in developed markets favoring convenience foods, which require more packaging and processing, increase the potential for waste in these segments of the FSC.

Economic and Policy Impacts: trade policies (e.g., tariffs, subsidies, import quotas) influence FLW. For example, subsidies for certain crops might encourage overproduction, leading to surplus outputs that exceed market demand and result in waste. Similarly, import restrictions can disrupt local markets, causing either over-supply or shortages, both effecting FLW.

Sources: (Flanagan, Robertson and Hanson, 2019), (HLPE, 2017), (Kirci, Isaksson & Seifert, 2022), (European Union, 2022)

Table 4: Behavioral Drivers of Food Loss and Waste

1. Societal norms and attitudes
Social norms and attitudes play a significant role in shaping behaviors related to food production, consumption, and the resultant FLW, as societal values determine what is considered desirable or acceptable in terms of food types, appearances, and consumption practices.
Aesthetic Preferences for Food: societal preferences for blemish-free produce lead to the exclusion of perfectly edible food from the supply chain.
Cultural Displays of Abundance: cultural practices that equate displaying food abundance with wealth or hospitality can result in excess food that often goes to waste.
Attitudes Towards Leftovers and Variety: a widespread aversion to leftovers and a desire for constant variety or exclusively "fresh" products further fuel FLW, as perfectly good food is discarded in pursuit of these ideals.
Acceptance of Resource Waste: societal acceptance of wasting resources, combined with a lack of awareness about FLW's environmental and social impacts, amplifies the problem.
2. Women's empowerment
Women comprise 37% of the world's agricultural workforce. This figure increases to 48% in low-income countries. Women are involved in several post-harvest handling processes such as drying, threshing, de-husking, shelling, grading, cleaning, and storage of food grains. These tasks are labor intensive but also prone to food loss, especially if the tools and methods are insufficient. Despite their importance in food production and processing, women face several barriers that exacerbate post-harvest losses.
Limited Capacity Building: equipping women with the necessary skills and knowledge to efficiently manage post-harvest processes and reduce FLW is key, particularly in developing countries where women receive significantly less training compared to their male counterparts. This disparity undermines their effectiveness in managing agricultural processes, perpetuating higher food waste levels. Targeted training programs can strengthen women's roles and expand sustainable practices, enhance productivity, and reduce spoilage.
Lack of Decision-Making Power: often, cultural and social norms restrict women's roles to labor and allows them limited influence over decision-making in agricultural operations. Empowering women with greater

decision-making authority can lead to the adoption of more sustainable agricultural practices and technologies, directly impacting the reduction of FLW.

Lack of Access to Financial Resources: women farmers typically have lower access to credit and financial services, which restricts their ability to invest in quality seeds, better storage facilities, or more efficient machinery. Initiatives like microfinance programs tailored for women can provide the necessary capital to invest in efficient technologies and infrastructures crucial for reducing FLW such as better storage solutions, or renewable energy enabled equipment.

Lack of Access to Modern Technologies and Facilities: women often face significant barriers to accessing technologies such as cold storage and improved packaging systems due to lack of awareness or high costs. Projects such as the introduction of solar dryers and improved cookstoves in Uganda have shown that when women are provided with modern tools, there can be a noticeable decrease in FLW alongside an improvement in the quality of the food processed. Providing women with better access to such technologies not only promotes gender equality but also enhances the overall efficiency of the agricultural sector.

3. Limited awareness

The challenge of FLW is intensified by a lack of awareness among stakeholders such as farmers, business managers throughout the supply chain, and consumers. This lack of awareness contributes to misperceptions about their roles in FLW and overlooks the potential benefits of reducing waste.

Underestimation of FLW Volumes: there is a widespread underestimation of the actual amount of food lost or wasted, partly due to insufficient awareness about the scale of the problem and its implications. There is a disconnect between stakeholders' perception of how much they contribute to FLW, and how much they actually waste, which is significantly higher.

Limited Understanding of FLW: many stakeholders lack an understanding of the broader environmental, economic, and social consequences of FLW, underscoring the need for enhanced education and information dissemination.

Ignorance of Benefits from Reducing FLW: stakeholders often do not recognize the direct benefits that can be gained from reducing FLW, such as enhanced product freshness, cost savings, and increased operational efficiency.

Lack of Knowledge on FLW Reduction Methods: a significant barrier to minimizing FLW is the widespread unawareness among stakeholders of effective methods and practices for reducing waste, indicating a critical need for practical guidance and resources.

4. Risk aversion

Risk aversion, driven by concerns over food safety, labeling, reputation, and liability, significantly influences FLW within the FSC. This cautiousness affects various stakeholders, from producers to retailers to consumers, leading to the unnecessary disposal of safe, nutritious food.

Overly Cautious Food Safety Concerns: stakeholders' apprehensions about food safety and potential health risks often result in the premature disposal of food that remains safe to consume. This is exacerbated by confusion about labels.

Strict Regulatory Interpretations: rigid interpretations of food safety and labeling regulations may lead to the unnecessary removal of edible food from the supply chain, as stakeholders err on the side of caution to avoid potential risks.

Liability and Reputational Fears: potential legal consequences or reputational damage may discourage businesses from donating surplus food. Instead, they opt to discard it, despite its safety and nutritional value.

Sources: (Flanagan, Robertson and Hanson, 2019), (HLPE, 2017), (Sidhu, K., 2007), (UN Women and UNIDO, 2023), (ILO, 2020).

Table 5: Structural Drivers of Food Loss and Waste

1. Demographics
Demographic factors, including household size, urbanization, and the expansion of the middle class, influence food production and consumption patterns, and consequently FLW. Shifts in Household Composition: changes in household size and the trend towards urban living alter food purchasing and consumption behaviors. Smaller households and urban lifestyles often waste more food due to mismatched portion sizes and the purchasing of perishables that spoil before consumption. Urbanization's Impact on Food Production: the move towards urban areas can decrease labor availability for rural food production, leading to challenges in managing food production efficiently due to a lack of proper skills, knowledge, and adherence to effective food management practices. This can increase FLW. Middle Class Growth and Dietary Changes: the expansion of the middle class and its associated disposable income change how food is acquired, consumed, and managed. Increased wealth leads to preferences for diverse, often perishable foods, larger portion sizes, and more frequent shopping, which if not managed with awareness and care, can increase food waste. Population and Age Distribution: population increase intensifies the demand for food, putting a strain on food distribution networks and existing infrastructure, and causing logistical challenges that lead to food waste. An older population will require special diets that are susceptible to spoilage (they may also waste less food and have a lower consumption rate), while a population with a large number of young people will have difference demands and nutritional needs. In both cases, if the food system cannot meet this demand, it will lead to FLW.
2. Climate
Climate conditions, marked by a diverse array of weather events such as rain, snow, ice, and wind, along with extreme cold and heat, are pivotal factors influencing the dynamics of FLW across the globe. These environmental elements, deeply intertwined with the impacts of a rapidly changing climate, have a profound effect on agricultural productivity and food security. Weather Extremes Disrupt Production: unpredictable or adverse weather events such as droughts, floods, and storms challenge growing conditions, damaging crops and disrupting food production schedules. This can result in either scarcity or excess produce, destabilizing markets. Reduced Crop, Animal, and Aquaculture Farm Efficiency: shifting weather patterns, more severe events, climate variability, and extreme conditions directly impacts crops, animal agriculture, and fisheries. They reduce the efficiency of crop farms by altering planting and harvesting schedules, decreasing arable land usability and increasing reliance on irrigation and other resource-intensive practices. Heavy rains and flooding can destroy crops, grazing lands, and aquaculture farms, while droughts limit water essential for crop growth, animals, and aquatic ecosystems. Extreme heat can stress livestock and fish, reducing productivity and increasing susceptibility to diseases. This reduces yields, increases food loss, and increases operational costs. Vulnerability of Foraged Foods: climate change disrupts natural habitats and sources of foraged foods, including wild crops, animals, and fish. This can decrease availability and quality of these resources, impacting traditional food systems and increasing reliance on commercial food sources, leading to higher FLW rates. Surplus Production in Favorable Conditions: favorable weather can lead to surplus produce, often exceeding market demand or storage capacity, leading to considerable wastage. Pests and Diseases: changing climate conditions accelerate the spread of pests and diseases, affecting crops, terrestrial, and aquatic animals. Warmer temperatures and higher humidity boost pest populations and disease spread, necessitating more intensive and potentially harmful chemical treatments.

Logistical Challenges: adverse climate conditions also disrupt transportation networks, crucial for moving food and feed resulting in delays, deterioration of fresh produce, contamination, reduced product quality, and higher mortality rates among animals and fish.

3. Policy and regulatory frameworks

The policy and regulatory landscape profoundly influence the dynamics of FLW within the FSC. When policies and regulations act as barriers, display a lack of coordination, or are altogether absent, this increases food waste. These barriers can span a wide range of areas, including but not limited to:

Food Safety and Quality Standards: overly stringent or poorly defined food safety and quality standards can lead to the rejection of food that is safe and nutritious but fails to meet certain aesthetic criteria such as discarding perfectly edible fruits and vegetables due to their shape, size, or color.

Labeling and Packaging Requirements: confusing or inconsistent labeling and packaging regulations can mislead consumers and retailers, leading to premature disposal of food. For instance, the lack of standardization and clarity between "use by," "sell by," and "best before" dates often result in good food being thrown away due to misunderstandings about the food's actual safety and quality.

Trade and Customs Procedures: complex trade regulations and lengthy customs processes can delay the transportation of perishable goods, increasing the risk of spoilage before products reach market and decreasing the days of use for end customers. Such hurdles can cause significant losses, particularly for cross-border food shipments of highly perishable produce (e.g., fruits, vegetables, meat, seafood).

Absence of Measurement Requirement and Guidelines for FLW: lack of clear policy guidelines for measuring FLW across the supply chain hinders the identification of hotspots and the quantification of waste by different actors. This complicates the identification and implementation of effective targeted interventions.

Regulations Governing the Use of Unsold Food: restrictions on the redistribution of unsold food to food banks or upcycling it, caused by policies or a shortage of trained health inspectors, make it difficult for businesses to donate edible surplus food to those in need, or to repurpose food waste in way that keeps the food in the human supply chain (e.g., animal or insect feed).

Inadequate Financial Incentives and Penalties for FLW Management: the absence or insufficiency of tax incentives for investments in waste measurement, reduction technologies or practices, alongside a lack of penalties for food waste disposal, weakens the motivation for companies to adopt FLW reduction strategies. Financial mechanisms that reward efforts to measure, reduce, and recycle food waste are essential for fostering sustainable practices within the industry. Without financial consequences for wasting food, the cost of disposal appears more favorable than investing in measures to prevent, recover, or recycle waste.

Agricultural Extension Services Across Sectors: the restricted availability of agricultural extension services can significantly impact crop, animal, and fish farmers, as well as handling and processing centers. Without sufficient extension services, crop farmers lack access to crucial knowledge and resources on optimizing harvest and post-harvest processes. Animal and fish farmers may lack guidance on best practices for animal husbandry and aquaculture management, affecting the efficiency of production. While handling and processing centers may miss out on advanced techniques and technologies for preserving the quality and safety of food through the supply chain. This is particularly true for small farmers and businesses.

4. Knowledge gaps as a structural driver of FLW

FLW is a challenge that has come to light only in the last two decades and is therefore not well-researched. As highlighted throughout this report, there are many aspects related to FLW that are still ambiguous, such as nonexistent baseline information in most countries. There is also a notable lack of knowledge, research, and information dissemination in many countries, which perpetuates inefficiencies and FLW throughout the food supply chain. These gaps reflect structural weaknesses in education systems, research funding, and institutional priorities.

Insufficient Investment in FLW Research: funding and attention to research on FLW mitigation strategies, particularly region-specific and context-relevant solutions, is still inadequate in most regions, which hinders progress.

Gaps in Education Systems: education systems often fail to integrate practical knowledge about FLW and sustainable food practices into curricula. This issue extends beyond food systems studies to other fields such as agriculture, business, engineering, environmental science, nutrition, and policy, leaving key stakeholders in these disciplines unprepared to address FLW effectively.

Weak Data Infrastructure and Limited Information Dissemination: the absence of comprehensive data collection and analysis systems makes it difficult to measure FLW accurately, identify critical intervention points, and track progress. The lack of standardized FLW measurement practices leads to disparities in data collection methods, complicating the identification of hotspots and the development of impactful solutions. Structural barriers, such as inadequate communication channels and inaccessible knowledge-sharing platforms, prevent stakeholders from accessing critical information on FLW hotspots and mitigation strategies.

5. Economic conditions

Economic considerations heavily influence the decisions of growers, processors, and consumers, where the costs of FLW prevention are often weighed against perceived benefits, driving practices across the FSC that contribute to FLW. Examples include:

High Costs of FLW Reduction for Growers: the expenses involved in adopting loss reduction practices or technologies can be prohibitively high, especially for smallholder farmers who may face financial constraints. This economic barrier discourages investment in more efficient harvesting and post-harvest handling techniques, increasing the likelihood of food loss.

Premature Harvesting Due to Economic Need: growers, particularly those in need of immediate income or facing high market prices, may opt to harvest crops prematurely, increasing the risk of food loss due to reduced crop quality and shelf life. This underscores the complex relationship between market dynamics and agricultural practices.

Non-harvesting When Costs Exceed Market Prices: if the costs of harvesting exceed the potential market earnings, growers often opt to leave crops unharvested. This situation is exacerbated in the absence of profitable alternative markets for second-grade products, leading to significant on-farm losses.

Food Processors' View of FLW as an Inevitable Business Cost: this is particularly relevant when disposal costs are low, thus deterring investments in more efficient processing methods or waste reduction technologies.

Low Household Expenditure on Food: when food constitutes a small portion of household expenses, the financial impact of discarding food is perceived to be minimal which can reduce the incentive for avoiding waste.

6. Access to finance

Access to finance plays a critical role in combating FLW, with insufficient funding posing significant barriers to implementing effective solutions.

Investment in FLW Reduction Technologies: without sufficient loans, grants, or investments, the procurement and adoption of innovative technologies that mitigate FLW by the public and private sectors becomes challenging. This includes everything from sophisticated storage systems to streamlined transportation methods.

Capacity-building Program Funding: the scarcity of financial resources can hinder developing and expanding capacity-building programs that educate and empower stakeholders across the FSC on best practices for minimizing FLW.

Enterprise Development and Scaling: without access to the necessary financial support, enterprises focused on reducing FLW often struggle to scale their operations or even sustain them.

7. Urbanization, migration, and forced displacement

Physical movement of populations due to urbanization, migration, and forced displacement significantly impact FLW by disrupting FSCs, challenging food distribution networks, and complicating efforts to provide consistent access to nutritious diets.

Urbanization: Rapid urbanization leads to increased demand for food in cities, straining existing supply chains. This can accelerate food spoilage and waste, particularly in urban areas where infrastructure may not be adequately developed to handle the influx of food products.

Migration: voluntary and involuntary migration disrupts local and international food supply systems, increasing FLW. Migrants that move from rural to urban areas or across borders (city or country) leads to a mismatch in food supply and food demand. This can lead to significant food waste, since food that is intended for local consumption may not reach the migrated population.

Forced Displacement: forced displacement due to natural disasters, climate change, or conflicts create a sudden and unplanned shift in population. Food systems often struggle to adapt to these changes, leading to disruptions in the supply chain and increased waste. Occasionally, displaced populations lack access to adequate storage and distribution facilities further exacerbating this problem.

8. Conflicts and other humanitarian crises

Conflicts and other humanitarian crises destabilize food systems and disrupt supply chains, increasing FLW. These crises also make it difficult to provide consistent access to nutritious food and impacts food insecurity.

Conflicts: in regions experiencing prolonged conflicts, food systems become highly unpredictable and unstable. Violent conflicts can destroy crops, livestock, and essential infrastructure such as roads and markets, leading to significant food losses. Additionally, conflicts often cause displacement, forcing people to abandon their farmland and livelihoods, which further disrupts food production and supply.

Humanitarian Crises: crises such as socioeconomic upheavals and natural disasters can lead to sudden population movement and increases in food demand in areas that are unprepared to handle these changes. If infrastructure is damaged, this will result in logistical challenges that will increase food waste. During humanitarian emergencies food aid may not reach those in need efficiently and quickly, leading to food spoilage and wastage.

Sources: (Flanagan, Robertson and Hanson, 2019), (IDB, 2022a), (HLPE, 2017).

Strategies and Approaches to Tackle Food Loss and Waste

In the global effort to combat FLW, understanding the multifaceted nature of this challenge is crucial. As presented previously, FLW affects every stage of the FSC, from agricultural production to consumer consumption, involving a wide range of stakeholders due to several direct drivers and underlying causes.

Addressing FLW's widespread impact on food security, economic efficiency, environmental sustainability, and socio-economic factors requires a comprehensive approach. By synthesizing insights gained from the desk review, this section provides an overview of frameworks, approaches, roadmaps, and interventions proposed by key international organizations and countries leading the way on FLW. It aims to offer a comprehensive understanding of the current landscape of FLW reduction efforts and encompasses the latest thinking on how to mitigate food waste effectively across all levels of the supply chain and at consumption points.

Think Eat Save Guidance

The “Prevention and reduction of food and drink waste in businesses and households - Guidance for governments, local authorities, businesses and other organizations, Version 1.0” released in 2014 by UNEP, FAO, and the Waste & Resources Action Programme (WRAP) as part of the Think.Eat.Save Food Initiative

and FAO-UNEP "Sustainable Food Systems Programme," is the first published document that provides a framework to help governments. This guidance document offers a flexible framework for tackling the complex issue of food waste at various consumption points (UNEP, 2014). It features four interlinked modules, each with a consistent structure based on specific objectives and needs. Government entities are identified as potential users of each of the four modules.

1. Mapping and measuring food and drink waste: offers a foundational strategy for preventing and reducing food and drink waste, essential for both new initiatives and enhancing existing programs. It focuses on two main areas: how to collect data to quantify waste across consumption points by outlining different methods, and how to map the food system to identify key stakeholders and the importance of establishing trust and collaborative relationships within the FSC to obtain accurate, consistent data necessary for tracking trends and measuring the effectiveness of interventions.

2. Options for developing national or regional policies and measures for food and drink waste prevention and reduction: highlights the various policy mechanisms that can influence food waste prevention and reduction. Specifically, the module focuses on: (a) policy and legislative mechanisms to prevent and reduce food waste, thus limiting the biodegradable waste destined for landfill, (b) fiscal mechanisms and financial incentive schemes (taxes, grants, economic incentives, subsidies) that encourage businesses to invest in measures that prevent food waste and promote collection and recycling of unavoidable waste, (c) information provision and guidance on how to reduce food waste, either as a standalone initiative or integrated into a well-planned, evidence-based strategy with motivational components to incentivize behavioral change, and (d) motivational strategies that harness policies, legislation, fiscal measures, and information dissemination to incentivize individuals and organizations to prevent and reduce food waste. These strategies include stimulating voluntary collective action with businesses and implementing consumer engagement programs, both designed to enhance participation and commitment to reducing food waste across various sectors.

3. Developing and implementing programmes to prevent and reduce household food and drink waste: presents five steps to scope, develop, and implement behavioral change programs aiming to prevent and reduce household waste. The five steps are: (a) plan and develop a strategy starting with measuring the amount of food waste generated by households, plus understanding what drives it, and the barriers and opportunities to changing behaviors, (b) establish a quantified and time-specific baseline and set an achievable target, (c) develop evidence-based guidance for developing a household and consumer engagement campaign, and for modifying products and labeling, (d) based on information gathered during previous steps, take action to prevent and reduce waste through delivering a household and consumer engagement campaign, and/or changing products, packaging, and labelling (for this step, it is vital to engage stakeholders and work collaboratively with an array of organizations), and (e) measure, monitor, and report changes through quantity metrics in food and drink waste reduction, alterations in products and packaging, and shifts in consumer behavior.

4. Preventing and reducing food waste in the food and drink business supply chain: outlines a process for planning, implementing, evaluating, and reporting on a program aimed at preventing and reducing waste in the retail and manufacturing supply chain and/or the hospitality and food services sector. For individual businesses, whether acting alone or as part of voluntary collective action, the process is divided into three main stages: (a) developing a corporate strategy with baselines and targets, (b) taking action with guidance on tools and examples, and (c) measurement and reporting. For those engaging in voluntary collective action, the module details a five-element process like the one in module three.

Target-Measure-Act Approach

In the pursuit of addressing this global challenge, the "Target-Measure-Act" approach, proposed by Andrew Steer and Shenggen Fan in their "3 Steps for Tackling Food Loss and Waste" article for the Chicago

Council on Global Affairs (Steer & Fan, 2016) and adopted and advanced by leading entities tackling FLW such as Champions 12.3, World Resource Institute (WRI), WRAP, ReFED and others, stands out as a method that has demonstrated efficacy in achieving rapid results.

It starts with "Target," or setting clear objectives and goals for reducing FLW. This is followed by "Measure," which involves quantifying the magnitude of the problem and progress by accurately assessing the extent of food waste, the drivers and causes behind the waste, and tracking progress towards achieving the goals. Finally, "Act" focuses on executing policies and strategies to effectively address the problems and meet the targets of FLW reduction (FLW Protocol. (n.d.); Champions 12.3. [n.d.]; World Resources Institute. [n.d.]; Waste and Resources Action Programme. [n.d.a.]).

The Target-Measure-Act framework encapsulates a pragmatic and systematic strategy for entities across the spectrum—governments, companies, farmers, and households—to significantly reduce FLW. The adoption of this methodology by a range of actors, from the United Kingdom and the city of London to global corporations and political blocs, underlines its versatility, potential for broad application, and effectiveness (Flanagan, Robertson and Hanson, 2019).

The "Food Loss and Waste Country Progress Index" published by the Inter-American Development Bank (IDB) in 2022, is a tool for stakeholders to assess the progress they are making in their FLW strategy implementation. This index will allow countries to compare their progress to-date on key aspects of FLW reduction. The index is anchored to the methodology of the Target-Measure-Act approach, gives guidance on what is needed to make effective progress, and can be revised over time to reflect new developments and practices for FLW reduction (IDB, 2022b).

EU Platform on FLW

In 2019, the EU Platform on FLW published its "Recommendations for Action in Food Waste Prevention," a comprehensive guide developed through extensive consultations. It underscores a holistic approach to reducing FLW across all stages of the supply chain, urging both public and private sectors to collaborate in implementing sustainable practices and innovations that address food waste at its source. Below are the recommended crosscutting recommendations as well as the recommendations across the supply chain and consumption points.

Crosscutting recommendations for action:

- ***In collaboration with civil society, national authorities to develop national strategies*** including roadmaps and action plans for preventing and reducing FLW. These must align with SDG Target 12.3 and the Target-Measure-Act approach.
- ***Integrate FLW reduction in national and EU food policies*** to ensure positive impacts on agriculture, health, nutrition, and food safety, supported by policy research.
- ***Incorporate FLW reduction in climate strategies*** such as nationally determined contributions and national energy and climate plans, to mitigate climate change.
- ***Scale up FLW prevention actions*** through multi-stakeholder platforms that expand knowledge, find solutions, and enhance waste prevention across the FSC.
- ***Fill data gaps*** by improving availability, quality, consistency, and transparency of data on FLW levels and impacts, thus contributing to global SDG monitoring.

- ***Improve action design, monitoring, evaluation, and knowledge-sharing*** through tools that build on existing research and common frameworks. Simplify access to longitudinal studies and data, fostering collaborative networks to support effective, sustainable practices.
- ***Integrate FLW in education and training*** in school curricula and professional training, including clear key performance indicators (KPIs) and training programs for businesses to promote lifelong learning opportunities.
- ***Raise consumer awareness*** through public campaigns that focus on the value of food and shift social norms to make wasting food socially unacceptable, utilizing behavioral science findings.
- ***Communicate FLW prevention actions*** implemented in operations to support behavioral change among all stakeholders.
- ***Improve use of date marking*** across the FSC. Improve terminology and presentation based on consumer research to reduce food waste linked to date confusion.
- ***Strengthen capacity for innovation and circularity*** utilizing research and financial instruments to support the development of innovations in the FSC that prevent FLW and create new market opportunities.
- ***Incentivize FLW prevention*** using economic instruments to change business practices to make food waste prevention more economically viable than waste treatment.
- ***Provide financial support and incentives*** to help SMEs and farmers implement FLW prevention strategies utilizing EU financial instruments and national funds.

Recommendations across the supply chain and consumption points:

- ***Enhance primary production efficiency by continuing research into the impact of marketing standards on FLW***. Protect and strengthen producer positions, improving access to market outlook data to help farmers align their supply with market demand. Improve resource efficiency by improving animal health and welfare and facilitating access to innovation. Strengthen financial support to drive modernization. Involve farmers and their cooperatives in research and innovation activities from the start to ensure solutions are tailored to meet real-world challenges.
- ***Enhance food manufacturers' efficiency*** by integrating food waste prevention across all operations and enhancing personnel training. This includes using digital tools for better raw material forecasting and waste monitoring, measuring, and reporting, developing innovative packaging to extend food shelf life, improving consumer understanding of date markings, offering a range of portion sizes, prioritizing food redistribution to humans over animal feed when surpluses occur, promoting the use of co-products to create new market opportunities, and launching collaborative efforts between public authorities and stakeholders.
- ***Enhance the efficiency of the wholesalers and retailers*** by improving supply chain efficiency and fairness through strengthening relationships, data sharing, and leveraging technology to effectively match supply with demand across markets. Encourage retailers to prioritize food waste reduction through staff training, incentives, KPIs, and strategic marketing that minimizes excess purchasing and promotes near-expiry products. Additionally, increase in-store repurposing of unsold items nearing shelf life. Other initiatives include harmonizing date marking practices, using consumer research to tailor products and promotions that reduce food waste at home, implementing digital tools, and launching awareness campaigns during holiday seasons.

- ***Enhance the efficiency of food service providers*** by equipping small businesses with training and resources and facilitating access to public funding. Encourage businesses to integrate food waste reduction into their corporate social responsibility (CSR) strategies, highlighting economic benefits and successful examples. Develop solutions for logistical challenges in food collection, promoting public-private cooperation, and community-based redistribution. Establish SMART (specific, measurable, achievable, relevant, and time-bound) objectives and KPIs for food waste management that include metrics like total prevented waste and business participation in waste reduction programs. Encourage businesses and public entities to influence consumer behaviors and expectations through effective communication and nudging techniques.
- ***Enhance consumer efficiency*** by encouraging individual and community actions that reduce food waste in all aspects of daily life and influence broader FSC behaviors. Develop diverse methods to understand and influence consumer behavior towards food waste, focusing on social norms and integrating synergistic approaches that highlight positive actions and benefits. Improve audience segmentation research to identify hotspots and tailor interventions effectively at various levels, supported by researchers and practitioners.
- ***Encouraging food donations*** through promoting the adoption of food donation guidelines and legislation coupled with initiatives that encourage all stakeholders in the FSC to facilitate and increase safe and nutritionally balanced food donations throughout the FSC. Support innovation and modernization in food donation through funding, partnerships, and financial incentives to enhance logistics and effectiveness.

Voluntary Code of Conduct for Food Loss and Waste Reduction

Recognizing the need for comprehensive regulatory measures, including the establishment of a functional and effective institutional framework, the FAO committee on agriculture initiated the development of the Voluntary Code of Conduct for Food Loss and Waste Reduction (CoC FLW). In June 2021, the FAO Conference endorsed a global Voluntary Code of Conduct for FLW that was developed through an inclusive, multi-stakeholder process to provide adaptable guiding principles and standards for responsible practices that governments and stakeholders can implement to reduce FLW, promoting sustainable and inclusive agricultural and agrifood systems (FAO 2022; Pasarín and Viinikainen, 2022). Published in 2022, it includes six Articles: (1) objectives, nature, scope, and target audience, (2) key terms, (3) guiding principles, (4) actions to address secondary and systemic causes of FLW, (5) practices and investments to address direct causes of FLW, and (6) implementation, monitoring, and evaluation. A summary of Articles 3, 4, 5, and 6 follows.

The primary ***guiding principle*** (Article 3) of the CoC FLW is to support the SDGs by ensuring that actions taken are economically, socially, and environmentally sustainable, while at the same time enhancing food security by improving availability, access, utilization, and stability of food, promoting healthy diets, and reducing malnutrition. It emphasizes principles such as human dignity, non-discrimination, equity, gender equality, consultation, rule of law, transparency, accountability, cultural respect, and ethical practices, ensuring all efforts are inclusive, fair, and transparent, adhering to both national and international laws and commitments.

Article 4 recommends 13 intervention areas to address secondary and systemic causes of FLW. Measures aim to create a holistic and integrated approach to reducing FLW, ensuring that policies and practices are aligned with broader environmental sustainability and food security objectives. It provides guidance to governments on several key aspects of FLW reduction, emphasizing the importance of measuring and reporting FLW using the Food Loss Index and Food Waste Index, establishing robust data gathering frameworks and incentives, developing a national strategy with the involvement of stakeholders,

monitoring, ensuring adequate resources, research and development, building public-private partnerships, and aligning efforts with international development partners. Furthermore, it stresses the criticality of policy coherence and having an appropriate institutional framework for FLW reduction and outlines various policy and legal instruments that governments can utilize, including financial services and risk mitigation mechanisms.

Article 5 outlines strategies and investments that actors across the supply chain, including producers, processors, distributors, wholesalers, retailers, and those in food service, can follow to address the direct causes of FLW while ensuring products meet safety and quality standards. Furthermore, it presents business practices that can lead to FLW.

Article 6 encourages all stakeholders to promote and use the Code of Conduct based on their needs and contexts, with governments leading the promotion, coordination, monitoring, and evaluation of FLW reduction efforts. It emphasizes inclusive, participatory, and sustainable processes, with support from development partners and international organizations for technical and financial assistance. It highlights that FAO will support implementation and periodic updates, while private sector, producer organizations, civil society, and academic institutions are invited to integrate and advocate for the Code in their activities.

FAO Regional Strategy on Food Loss and Waste Reduction in Asia and the Pacific

The FAO Regional Strategy on Food Loss and Waste Reduction in Asia and the Pacific developed through extensive research, FAO's prior activities, in-depth country studies, and a virtual regional consultation involving 19 countries in June 2021, emphasizes the socio-economic and environmental impacts of FLW (Bennett et al., 2022). It highlights how food loss affects producer returns, consumer nutrition, and GHG emissions across the supply chain, with a particular focus on climate change. The Strategy is built on five interconnected pillars with actionable items under each, providing a systemic approach to supporting FLW prevention and reduction:

1. ***Raise Awareness*** and building capacity about the levels, types, impacts and solutions of FLW throughout the supply chain by fostering collaboration and partnerships among state and non-state stakeholders through a regional awareness campaign and knowledge platform. The actionable steps include increasing knowledge on nutritional impacts of FLW, global and national FLI and FWI, FAOs Critical Loss Points (CLP) case study methods. It emphasizes informing climate finance actors about FLW prevention as a means of reducing GHG emissions and advocating for increased investment in FLW prevention. Key actions include developing a framework for Member Nations to recover and redistribute surplus food, publishing a policy brief on FLW commitments within NDCs and organizing regional and national events to highlight innovative socio-economic and technological solutions to FLW challenges.
2. ***Identify and Address Critical Loss and Waste Points*** by building capacity of actors to identify critical points of FLW and find interventions as means to improve the availability and quality of data. This Pillar is linked to Pillar 1 in terms of applying the FAO CLP case study methods to identify food loss percentages and root causes across supply chains, disseminating FAO e-learning courses on the CLP methodology for general supply chains and the fisheries sector, and facilitating stakeholder consultations. Actions include knowledge sharing, contributing to evidence based FLW causes and quantities, and supporting nations to address these CLP while integrating the information into SDG 12.3 indicators and exploring solutions. Partnerships with regional food banks are encouraged to redistribute food.
3. ***Enable Investments for FLW Prevention and Reduction*** that can be made based on national, local, and food business operator objectives by engaging stakeholders to assess trade-offs and perform cost-benefit analyses to guide investment decisions and to engage and consult with international

financial institutions. Actions focus on strategic investments for key initiatives to develop, improve and support the adoption of innovative technologies and methods for measuring FLW impacts throughout the FVC.

4. ***Facilitate SDG 12.3 Measurement and Reporting*** on target indicator SDG 12.3.1a that is under the custodianship of the FAO. Interventions under this pillar address the complexities of data collection, including identifying data needs, prioritizing commodities, and determining appropriate methodologies for direct measurement and modeling to produce accurate and actionable estimates. Actions focus on technical support to Member States based on need.
5. ***Support Governance on FLW Prevention and Reduction*** by building institutional capacity to promote behavioral change in FLW prevention and reduction efforts. It supports the development and implementation of national strategies, policies, laws, and action plans. Interventions include knowledge sharing, stakeholder engagement, technical consultations, evidence-based publications linking FLW prevention to food security and climate commitments with the aim of embedding FLW prevention strategies and targets within government plans and guiding investment decisions.

FAO FLW Framework

The "Enabling a Legal Environment for the Prevention and Reduction of Food Loss and Waste" Legal Brief 9 from October 2022 (Pasarín and Viinikainen, 2022), details the key national regulatory measures that create an enabling environment for preventing and reducing FLW throughout the agri-food system. It aligns with international standards, particularly the FAO Voluntary Code of Conduct for Food Loss and Waste Reduction.
This framework necessitates systemic coordination among multiple stakeholders with clear binding targets and identifies seven key mechanisms to address FLW, including:

1. ***Establish a functioning and effective institutional framework:*** when looking to establish an effective institutional framework, it is imperative to look at the framework through a systemic lens, involving multiple stakeholders with clearly defined roles from the public and private sectors as well as civil societies. Legislative measures should empower interinstitutional coordination. A country can choose from several approaches: having one institution that centralizes all FLW responsibilities and works with other authorities, having multiple agencies work towards the same goal, or having an interagency coordinating body that oversees FLW prevention and reduction, ensuring unified strategies. The goal is to establish a dedicated, efficient framework through integrated policies, targeted actions, and partnerships, which is essential for reducing FLW, enhancing food security, and promoting sustainable development.
2. ***Adopt a food material hierarchy:*** legislation can organize the activities related to FLW in a hierarchical fashion that prioritizes FLW reduction initiatives according to internationally recognized best practices, putting FLW reduction first, then FLW diversion and recycling, and ending with FLW disposal. This hierarchy can be adopted by all members of the FSC and will guide stakeholders to adopt priority actions higher in the hierarchy if possible. There are many versions of the Food Loss and Waste Hierarchy, but the general idea of priority actions is the same.
3. ***Enforce mandatory legal targets for FLW reduction:*** to effectively reduce FLW, legislation must establish baselines and adopt legally binding reduction targets, similar to those used in climate change mitigation efforts. Despite the complexities of creating such frameworks, their benefits are clear in ensuring compliance and achieving tangible reduction outcomes. Establishing these baselines requires robust mechanisms for FLW measurement and systematic data collection and

analysis. Additionally, regulatory mandates for transparent reporting by all entities in the FSC are crucial. These mandates should include detailed disclosures on FLW volumes, fostering a culture of accountability and continuous improvement. This approach not only aids in monitoring FLW reduction targets but also supports sustainable food system management.

4. ***Establish a system for food donations:*** to effectively mitigate FLW, establishing a system for food donations is crucial. This involves creating legislation to ensure surplus food, which is still safe and nutritious, is redistributed to those in need. The legislative framework should set stringent safety and nutritional standards for donated food, clearly defining the rights, duties, roles, responsibilities, liabilities, and obligations of all parties in the donation chain. This structured approach will encourage participation from potential donors by offering legal protection and will support FLW reduction efforts, promote social equity, and address food insecurity.
5. ***Ensure food safety and quality standards:*** to balance FLW reduction with food safety and quality, national legal frameworks should align with global standards like the Codex Alimentarius and use risk-based approaches. Legislation must ensure donated food meets the same safety standards as commercially sold food to reinforce consumer trust. Addressing liabilities related to donated food safety is crucial; innovative legislative solutions should adjust liability frameworks to remove disincentives for donations while maintaining consumer health. This will encourage food business operators to participate in charitable contributions, significantly reducing FLW and enhancing food security for vulnerable populations.
6. ***Define clear and transparent data labeling requirements:*** governments should enforce standardized national food labeling systems aligned with the Codex Alimentarius guidelines to support FLW reduction strategies. The Codex Alimentarius promotes harmonized labeling to provide clear, accurate, and relevant product information. By adopting these standards, national labeling systems can mitigate FLW by clarifying “use-by” and “best before” dates, which are often misunderstood by consumers. This clarity prevents the premature disposal of safe, nutritious food, thereby reducing waste. Standardized labeling also ensures ease of comprehension across different cultures and languages, benefiting all stakeholders throughout the FSC.
7. ***Introduce suitable financial measures:*** legislation should define incentives and taxes to influence FLW-related behaviors of businesses and consumers. Fiscal strategies, based on economic incentives, impact decision-making in food management. One approach is the “polluter pays” principle, where a landfill tax, or “pay as you throw” system, increases the cost of discarding food, making landfill disposal less attractive. Another approach is to provide tax incentives to entities that donate food and divert waste from landfills, encouraging businesses and consumers to align with government strategies for reducing FLW. These financial measures can effectively promote sustainable food management practices.

African Union Commission – Post Harvest Loss Management Strategy

The Post Harvest Loss Management (PHML) Strategy was developed by the Africa Union Commission with the support of the FAO, in 2018, in line with the target to halve the current levels of post-harvest losses (PHL) by 2025 under the Malabo Declaration commitment to end hunger in Africa by 2025. The purpose of the strategy is to introduce a flexible framework that accommodates commodity specific interventions, with the goal to enhance food and nutrition security in the Member States (Ethiopia, Kenya, Tanzania, Zambia and Zimbabwe) by addressing the challenges and constraints of post-harvest losses across all food sectors. The objectives of the strategy are grouped within four focus areas which form the Pillars of the PHLMS. These Pillars are:

1. ***Policy, Awareness, and Institutional Capacity*** focuses on building institutional capacity, strengthening governance and raising awareness to address PHL through the development and implementation of policies and strategies, creating awareness of the socio-economic impacts of PHL, supporting coordination and initiatives aimed at reduction and reducing overall impacts on food security.
2. ***Knowledge Management, Data, Skills, and Human Development*** focuses on the generation, application and dissemination of knowledge as well as skill development to improve PHL by capacity building through targeted training programs.
3. ***Technology, Markets, and Infrastructure*** focuses on technology solutions, improving market access, and enhancing infrastructure to support effective post-harvest management. It includes the development of markets and market infrastructure to include standards in PHLM thought the VC. Promotion of environmentally friendly, gender inclusive and labor-saving technology.
4. ***Finance and Investment*** facilitates funding and investment to drive interventions and innovations in PHLM by supporting governance, establishing PPP mechanisms to leverage private sector expertise in food and nutrition security.

The strategy will be implemented in five-year cycles, ensuring iterative improvements based on lessons learned. Prioritization of interventions will focus on achieving quick and measurable impacts. A robust monitoring and evaluation system will support the implementation process by tracking outcomes and assessing the effectiveness of post-harvest loss reduction plans, policies, and strategies.

ReFED

ReFED—a collaboration of more than 50 business, non-profit, foundation, and government leaders dedicated to reducing food waste in the United States—developed the *Roadmap to 2030: Reducing U.S. Food Waste by 50%* (ReFED, 2021). This roadmap outlines seven critical action areas and 42 targeted solutions throughout the FSC that align with the "Target-Measure-Act" framework:

1. ***Optimize the harvest*** by utilizing all produce regardless of appearance or size. Solutions include selling non-standard produce directly to consumers to bypass aesthetic filters of traditional retail, adjusting procurement specifications to accept a broader range of produce including cosmetically imperfect items, reviving the ancient practice of harvesting leftover crops from fields (gleaning), and enabling partial order acceptance of items that meet quality standards, rather than rejecting entire batches.
2. ***Enhance product distribution*** by improving the efficiency and effectiveness of food distribution channels to reduce spoilage and waste. These include utilizing advanced technologies to optimize distribution routes for perishables (intelligent routing), minimizing physical handling, and maintaining optimal conditions during transit. Also, decreasing transit time and prioritizing the sale or use of products close to their expiration dates ("First Expired, First Out" inventory management).
3. ***Refine product management*** by aligning inventories with actual demand and improved handling of surplus. Key strategies include utilizing advanced systems to refine forecasting store-level demand and minimize overstock, monitoring and analyzing where and why food waste occurs within foodservice operations, and monitoring cold storage temperature with built-in alert systems. Similarly, applications that alert consumers to discounted products that are near expiry, facilitate sales of surplus, off-spec, and nearly expired foods, or enable dynamic pricing based on shelf life, inventory levels, and demand patterns may also be useful. Other strategies include minimizing on-hand inventory in distribution centers and decreasing minimum order quantities for highly perishable products.

4. ***Maximize product utilization*** by encouraging the full use of products and the upcycling of by-products. Approaches include utilizing advanced packaging solutions that extend shelf life or provide real-time quality monitoring, converting waste materials into valuable products (e.g., animal feed, compost), and adjusting production processes to minimize waste during changeovers or downtimes.
5. ***Reshape consumer environments*** by altering how food is presented and consumed to influence consumer behavior. This includes introducing smaller menu portions, going trayless, or utilizing smaller plates in all-you-can-eat dining facilities, meal kits offering pre-measured ingredients for specific recipes at stores or direct-to-consumer channels, consumer education campaigns about effective food management practices (e.g., proper storage, reusing leftovers), optimized package design to reduce leftovers and simplify disposal, standardized date labels, use of strategic on-site signs in buffet dining areas to promote smaller portions, and K-12 education campaigns about the environmental and economic consequences of food waste coupled with lunch improvements focused on enhancing foodservice operations.
6. ***Strengthen food rescue*** through structures supporting the donation and redistribution of food. Initiatives include educating businesses about legal protections and safety standards for donation of surplus food, enhancing donation transportation, handling, temperature-controlled storage, and processing infrastructure to expand the reach and efficiency of food donation programs, and introducing donation value-added processing infrastructure to convert perishable donations into longer lasting products (e.g., soups, sauces, prepared meals).
7. ***Recycle remaining scraps*** to recover maximum value from food scraps. This can be done through large-scale (costly) centralized composting facilities, industrial centralized anaerobic digestion facilities, co-digestion at wastewater plants, home and community composting, and converting food scraps into livestock feed.

OECD Instruments for FLW Mitigation

The Organization for Economic Co-operation and Development (OECD) 2023b identifies six policy instruments that governments may adopt to facilitate action within the supply chain and consumption points to prevent and reduce FLW. These include:
(1) overarching strategy and/or regulatory frameworks,
(2) consumer behavioral change and awareness-raising initiatives,
(3) educational initiatives,
(4) voluntary collaboration with stakeholders,
(5) mandatory regulations, and,
(6) fiscal measures such as taxes and subsidies.

Feed the Future Food Systems for Nutrition Innovation Lab, Tufts University

Between May and December 2022, the USAID-funded Feed the Future Food Systems for Nutrition Innovation Lab at Tufts University conducted a series of global scoping exercises across the various stages of the agri-food systems supply chain, from farm to consumer. Five scoping reports aiming to identify innovations that can improve food safety, reduce FLW and protect nutrition-rich (mainly perishable) foods, that have the potential to be scaled-up in low- and middle-income countries, were published.[1] Of the

[1] https://foodsystemsnutrition.org/category/thematic-scoping-report/

identified innovations, 189 had some evidence of implementation in reducing FLW of highly perishable foods. Five teams across 20 institutions worked on the five thematic scopes,[2] covering:

i. ***Farm-based innovations***: 1905 innovations from the USAID Global Development Innovation Database, USAID's Agrilinks website and catalogue, and contributions from team members were screened. Of these, 153 advanced to stage two screening, which resulted in 63 innovations assessed using the Tufts prioritization tool comprised of 60 questions. Identified farm-based innovations fall under five groups: (1) agricultural inputs, (2) staples and staple grains, (3) horticultural crops, (4) animal-sources foods, and (5) post-harvest handling and on-farm storage. Below is an illustrative list of innovations compiled[3]:

1. HarvestPlus (Biofortification)
2. Hermetic/PICs bags for improved storage of legume and cereal grains and seed
3. Beauveria bassiana to manage Tuta absoluta
4. Metarhizium anisopliae to manage Tuta absoluta
5. Fruit Bagging to mitigate losses
6. Trichoderma to manage soil-borne veg diseases
7. Net Exclusion House to manage Tuta absoluta
8. Pheromone traps to manage tomato leaf miner
9. Portable low-cost device for rapid detection of aflatoxins in groundnut
10. Black soldier fly for poultry, fish, and pig feed
11. Orange-fleshed sweet potato
12. Root Capital
13. Drip irrigation in vegetables to empower women
14. Futurepump solar pumps
15. Scientific Animations Without Borders (SAWBO)
16. Biological control - Purpureocillium lilacinus
17. Biological control of Parthenium hysterophorus
18. Cellphone-based extension services
19. SunCulture AgroSolar Irrigation Kit
20. Mobile app-based feeding support tool to optimize dairy animal productivity
21. Bajra Food Cooling System
22. Evaporative cooling and cool storage technologies for horticultural crops
23. Small-scale cool rooms
24. BAU-STR Dryer - Rice Husks
25. Chimney solar dryer
26. Dehytray™
27. Dry chain concept
28. DryStore storage technology
29. Implementing drying beads for seeds in Asia and Africa
30. Index insurance
31. Small-scale cool rooms

[2] Participating institutions include: Purdue University; 1890 Universities Foundation; The American Indian Higher Education Consortium; Helen Keller International; International Crops Research Institute for Semi-Arid Tropics; Michigan State University; The National Cooperative Business Association - CLUSA International; Tufts University; Texas A&M University's Borlaug Institute; Action for Enterprise; International Food Policy Research Institute; Global Alliance for Improved Nutrition; California State University, San Bernardino; World Vegetable Center; Harvard T.H. Chan School of Public Health; Boston Children's Hospital; Boston University; and Johns Hopkins University.

[3] https://foodsystemsnutrition.org/semi-annual-report-year-1-test-2/

ii. ***Post farm-gate food processing, packaging, and storage innovations*** of perishable, durable, and non-perishable foods. Food processing included solar and mechanical drying innovations that can be easily applied to the field in low- and middle-income countries, food coating innovations, and education and training programs to build capacity at the farm level. Packaging solutions focused on post-harvest grains, retail, and processing to enhance food safety and maintain nutritional quality. Food storage covered climate controlled cold and dry storage technologies, portable products, and business models. Below is an illustrative list of innovations compiled:[4]

1. Post-Harvest Loss Toolkit
2. The GrainPro Cocoons
3. Climate Smart Dry Chain
4. Innovative post-harvest storage and an inclusive peer-to-peer micro-warehouse and grain trading platform (e.g., ZeroFly)
5. Off-grid renewable energy generation and storage for access to electricity
6. Farm from a Box: an off-grid toolkit for sustainable agriculture
7. A low-cost, smart, and stand-alone PV cold storage system using a domestic split air conditioner
8. AgroZ hermetic bags
9. Decision support system for designing sustainable multi-stakeholder networks of grain storage facilities
10. Elite hermetic bags
11. GrainPro hermetic bags
12. International Rice Research Institute bag
13. Zerofly hermetic bag - Vestergaard
14. Alternative ware potato storage technologies
15. Drying Beads technology
16. Edible food packaging, edible films, dissolvable packaging
17. Hermetic storage technologies
18. Innovative smart storage business solutions: SokoFresh
19. Low-cost cooling technologies (e.g., charcoal evaporative cooler, Coolbot, evaporative cooling system, silica gel and water-based adsorption cooling system, Zero Energy Cool Chamber (ZECC)
20. Solar-powered communal refrigeration: post-slaughter meat storage for pastoralist
21. Underground warehouses for food storage
22. A complete post-harvest management solution: FarmerPack model
23. Locally produced edible coating materials for food storage (e.g., beeswax, shea butter, cassava starch)
24. Netting bags (e.g., netting rice bags)
25. Low-cost moisture content measurement techniques (e.g., Equilibrium relative humidity and Infrared, DryCard)
26. Ethylene management shelf life enhancer
27. Mobile applications (the Postharvest Storage app)
28. Food Freshness Cards and other monitors
29. Micro-canning: Foodstream – with fish
30. The Solar-powered Ice Machine
31. Convenient fortified and non-fortified instant food products using low-cost extrusion for urban markets
32. Sensors in large packaging of grains
33. Traditional and indigenous knowledge and innovative practices
34. Arekapak
35. Active, bioactive, and intelligent packaging for fruits, vegetables, and animal-sourced products
36. Crates plastic redesigns
37. Reusable pallets and pallet pooling
38. Ahotor Oven
39. FTT-Thiaroye Oven
40. Tetra Pak ®
41. Solar Bubble Dryer
42. Cooking oil

[4] https://foodsystemsnutrition.org/semi-annual-report-year-1-test-2-4/

iii. ***The infrastructure, transport, and markets innovations*** scoping report covered three components. The first research for development was to identify and prioritize, through a comprehensive desk review, theme-related innovations ready for scaling. The second component included mapping of market actors and assessing their readiness to adopt recommended innovations, and the third component was related to assessing human and institutional capacity needs across the project's priority countries of Nepal, Bangladesh, Malawi, and Mozambique. Below are the promising innovations:[5]

1. Food testing equipment and systems
2. Cold chain packaging
3. Refrigerated truck boxes
4. Temperature/humidity sensors
5. Food safety management systems
6. Nutrition marketing and related strategies
7. Farmer-to-consumer integrated models
8. Electric powered cold storage units
9. Motorized vans with cooling units
10. Temperature cooling technologies/systems
11. Electric food delivery cycles/carts/scooters
12. Reusable crates/trays/pallets
13. Washing stations for vegetables and fruits
14. Tax break/incentive programs
15. Antimicrobial paper liners/interleaves/wraps/foils
16. B2B/B2C platforms/business models
17. Dry cards to detect humidity level
18. Electric mobile food trucks/vans
19. GPS systems for delivery management and tracking
20. Insulated food delivery bags
21. Leasing/rent of cold rooms (service)
22. Live fish transport systems
23. Point of sale systems for food retailers
24. Push/pull food carts
25. QR codes for nutritional information
26. Reusable thermal (hot/cold) grocery bags
27. Food delivery/consolidation models
28. Rapid testing kits for salmonella, etc.
29. Solar powered cold storage units
30. Participation in trade shows/exhibitions
31. Commercial grade refrigeration equipment
32. Dynamic pricing labels at retail level
33. Food traceability platforms (with Blockchain)
34. Heated food carts
35. Insulated only cold rooms (large)
36. Insulated pallet wrapper
37. Labeling requirements
38. Refrigerated lockers for neighborhood pickup
39. Shared cargo bike platform
40. Transport/cargo logistic management systems
41. Drones/robotic food delivery systems
42. Healthy food kiosk/vending machines
43. Surplus food online marketplace
44. Warehouse "pick/put-to-light systems"
45. National policies/strategies for cold chain

iv. ***Food environment, consumer choice and retail promotion innovations*** were collected from input by the team plus searching web platforms, academic reports, and innovation databases. The identified 205 innovations were then screened and prioritized according to the Tufts scoring criteria. Below are the promising innovations,[6] though some may not be very applicable to the digital infrastructure, consumer setting and acceptability, or the market dynamics of low- and middle-income countries:

1. Integrated digital platform for women's empowerment and financial inclusion in the food system
2. Marketing ugly produce
3. Using biofuel to make households self-sufficient in their energy use

[5] https://foodsystemsnutrition.org/semi-annual-report-year-1-test-2-3/

[6] https://foodsystemsnutrition.org/semi-annual-report-year-1-test-2-2/

4. Innovative approaches to breastfeeding promotion and support
5. Food4Education, produced in central community kitchens from locally farmed ingredients
6. Refocus digital marketing on good foods through policy restrictions on HFSS foods
7. Secondary markets for food waste
8. Urban youth digital engagement platform
9. App for selling about-to-expire food (e.g., Too Good To Go)
10. Farm-to-consumer links
11. Innovative multi-media campaigns to spread knowledge about healthy, sustainable diets and food waste
12. Refocusing of safety nets to support diet-quality goals
13. Social and behavior change communication to: a) improve child and mother feeding practices and b) promote healthier and sustainable food choices
14. Using heat retention bags for cooking in households
15. Easy-to-understand educational tools for infant feeding
16. Learning how to increase frequency of consumption
17. Elevating indigenous food systems
18. Ghost kitchens
19. Differentiating “good” foods from “bad” at the point of purchase (POP)
20. Dispenser for safe, affordable fortified yoghurt
21. Distribution of innovative recipes to increase consumption of under-used, nutrient-dense ingredients
22. Fresh food vending machines
23. Regreening infertile lands with women-led community gardens and orchards (in the Sahel)
24. Teaching young professionals in cooking schools to be a conscious and inspirational chefs
25. Rethinking food aid in humanitarian crises
26. Transforming communication in the food industry
27. TV ads for fruits and vegetables
28. Demand side differential taxation of products high in greenhouse gases (GHG)
29. Nano-encapsulated essential oils embedded in ice (improve the quality and shelf life of fresh whole seabream stored on ice)
30. Portable device for detecting food allergens
31. Root-to-stem youth cooking classes
32. Shelf space/table front organization
33. Unhealthy food taxes
34. Gender-sensitive online retail of foods
35. Don't just talk... Act!
36. Gamification for behavioral change for sustainable diets/peer learning platforms
37. Minimal processing for convenience
38. Using nudges in supermarkets to influence the healthiness and sustainability of dietary choices
39. Community-based regulations of wildlife hunting and collection of wild plants
40. Dynamic pricing for perishable food
41. Mirrored school and home interventions (in gardening)
42. Sensors for food safety assessment
43. Sharing seeds of easy-to-grow vegetables with vulnerable populations to grow themselves
44. Human-centered design approach to get school vendors to sell more nutritious foods
45. Improved labeling and standards for environmental health
46. Improved labeling and standards for nutrition
47. Street food innovations to increase nutritional value
48. Active cardboard packaging with encapsulated essential oils for enhancing the shelf life of fruit and vegetables
49. Civic crowd-funding projects for food projects within own community
50. Community-based radiation monitoring of foods to measure food safety
51. Policies to reduce food waste at the household level
52. Do-it-yourself meal boxes to make healthy, safe, and sustainable meals for the household
53. Local high-nutrient snacks

54. Plastic-free shopping with simplified dispensers to reduce waste and increase affordability of food.
55. Zoning laws in food desserts to restrict "fast food" outlets
56. Actively engaging rural consumers in food policy making
57. Smartphone-based food diagnostics
58. Fun fruit and vegetable packages for children
59. Mother empowerment by distributing straightforward planetary health guidelines
60. App to compare prices of food products in different shops in the area
61. Improving school meals and optimizing the nutrient content with new software tools
62. Food experience centers and museums for education around healthy and sustainable food systems
63. Change portion sizes in restaurant meals: more vegetables, less meat
64. Nudging consumers to make better food choices in restaurants
65. Urban community-led fruit and vegetable gardens
66. Community-based compost places for organic waste

v. ***Metrics for food systems for nutrition innovations*** aimed to identify the metrics that can support evaluating the use, potential adoption, and upscaling of the innovations identified in the previous scoping sessions. Utilize these metrics to develop a prioritization framework for future use. Among the findings relative to FLW, consistent metrics to assess food loss during storage and distribution are limited. Moreover, there is a need to develop field-friendly, cost-effective metrics to assess food safety and address the multiple sources of contamination.[7]

Carbon Credits[8]

The Kyoto Protocol, an international treaty adopted in 1997, was enacted to commit its parties to limit or reduce GHG emissions according to agreed targets. The concept of carbon credits as well as market-based mechanisms such as emissions trading and the Clean Development Mechanism (CDM) were developed.

Carbon credits are permits that represent the right to emit a certain amount of carbon dioxide or other GHGs. One carbon credit equals one metric ton of carbon dioxide or its equivalent in other GHGs (tCO2e) that has been avoided, reduced or removed from the atmosphere. Carbon credits are part of a broader effort to mitigate climate change by providing economic incentives for reducing emissions.

Emissions trading allows countries with spare emission units (emissions permitted but not used) to sell this excess capacity to countries exceeding their targets. The CDM mechanism supports emission reduction projects that generate tradable credits. It enables developing countries to implement projects that earn certified emission reduction credits, which can be traded or sold to developed countries.

Carbon credits help offset GHG emissions generated by companies, organizations or individuals, allowing them to achieve emission reduction goals, promote a transition to a low-carbon economy, and contribute to the fight against climate change. Innovative projects leveraging carbon credits to finance FLW reduction and valorization initiatives have emerged, typically involving:

[7] https://foodsystemsnutrition.org/theme-5-scoping-exercise-report/

[8] This content was created by Nicolas Dobler, VP of Sustainability and Carbon Solutions of Zero Waste Company, incorporating data and insights from sources such as the UNEP Food Waste Index Report 2021, the IPCC Special Report on Climate Change and Land, and other relevant studies.

- **Food loss prevention:** implementing measures to prevent food loss at various stages of the supply chain.
- **Food recovery and redistribution:** diverting food from waste streams to feed people in need, such as the Mexican Foodbanking Network.
- **Waste-to-energy:** converting food waste into biogas through anaerobic digestion.
- **Composting:** turning organic waste into compost to enrich soils and sequester carbon.
- **Biochar:** converting organic waste into biochar, a stable form of carbon, to improve soil health and sequester carbon.

To measure FLW's GHG reductions, several methodologies are available. Key examples include VM0046 for reducing food loss and waste, AMS-III.F for avoiding methane emissions through composting, AMS-III.AO for methane recovery via controlled anaerobic digestion, and VM0044 for biochar production. These methodologies provide standardized approaches to quantify and validate carbon reductions.

Government Leadership in Reducing Food Loss and Waste

The food system is influenced by billions of stakeholders, including producers, consumers, businesses, and workers, as each makes individual choices without control over sub-systems, let alone the entire system (Barrett et. al. 2020). Given the complexity and scale of FLW across the entire food system, substantial impact requires collective decisions and actions from all stakeholders, as no single entity can drive significant change alone. Governments play a crucial role in this process. Through effective legislation and governance, they can create an enabling environment that encourages decisions and actions that positively affect food systems and reduce FLW. Good governance and strong government leadership are essential to steer collective efforts towards sustainable food system practices.
Good governance seeks to enhance all aspects of the public sector, from rule-setting institutions to decision-making, resource allocation, administrative management, and citizen engagement (Grindle, Merilee S. 2007). It is needed at the global, regional, and national level to successfully address the challenge of FLW.

In 2015, the world community adopted the Sustainable Development Agenda 2030, with its 17 SDGs and 169 targets, of which SDG target 12.3 aims 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, by 2030" (UN. n.d.). The 2021 UN Food Systems Summit (UNFSS) identified essential actions for transforming the food system in line with the 2030 Agenda, agreeing on 27 priority intervention areas, including addressing FLW (United Nations, 2022). Following the Summit, 111 countries submitted their National Transformation Pathways, and of these 111, 72% prioritized reducing food loss (United Nations, 2022).

At the country level, setting up an appropriate institutional, policy, and regulatory framework is critical to addressing the systemic causes of FLW, as it facilitates the coordination of actors, enables investments, and supports and incentivizes the adoption and improvement of best practices. Governments should take the lead by ensuring a supportive enabling environment is in place to encourage action to prevent and reduce FLW. Further to this, governments must work with the private sector, producer organizations, academic and research institutions, and other stakeholders to build the evidence base for FLW reduction strategies and action plans. This includes conducting surveys and assessments of FLW magnitude, causes, and drivers. Interventions should align with national and international laws and commitments, and FLW data should be integrated into national accounting frameworks such as Food Balance Sheets and agricultural GDP accounts (FAO, 2022).

There is no universal solution to FLW, effective strategies must be tailored to the unique physical and social contexts of each country and region (Food Systems for Nutrition Innovation Lab [d], 2022).

Best Practices

Best practices (BPs) refer to "a procedure that has been shown by research and experience to produce optimal results and that is established or proposed as a standard suitable for widespread adoption" (Merriam-Webster. n.d.).

Recognizing the need of good governance and the critical role of governments and public policy in reducing FLW, this section offers a comprehensive collection of best practices for government officials and policymakers. These BPs can be employed to plan, implement, and advocate for measures that drive large-scale meaningful change in significantly curbing FLW. These BPs are drawn from the extensive review of various reports, academic papers, case studies, and frameworks, alongside thorough discussions undertaken by the authors. This section consolidates actionable and effective approaches that have been proven to address the multifaceted issue of FLW effectively. In total, 14 best practices are presented:

1. Target-Measure-Act approach
2. Supporting policy and regulatory environment for FLW prevention and reduction
3. Fiscal measures establishing financial incentives for FLW prevention and reduction
4. Measurement according to international standards and methodologies
5. Identifying the causes and underlying drivers of FLW
6. Shape environments for waste reduction
7. Food loss and waste hierarchy
8. Strong infrastructure
9. Integrated collaboration
10. Research for innovation
11. Utilizing technological innovations
12. Cultivating knowledge and skills to reduce FLW
13. Monitoring and evaluation coupled with transparent reporting
14. Context specific

As legislation is among the most effective tools for reducing FLW (Pasarín and Viinikainen. 2022), it is critical to address the inhibitive policies associated with each best practice and ensure that a supportive legislative environment is in place. Accompanying this report is an addendum, "Assessment Framework of the Regulatory Enabling Environment for Food Loss and Waste Prevention," that provides a checklist to carry out a multisectoral situational analysis of the existing enabling environment landscape in the country. The aim of this checklist is to equip governments with the necessary data to develop evidence-based action plans and interventions.

While many of these strategies may also benefit private sector entities, the emphasis in this report is on the public sector, underscoring the government's essential role in leading the charge towards sustainability, economic efficiency, and food security enhancements.

Finally, while the authors have endeavored to identify and summarize the best practices for FLW reduction from various frameworks and historical experiences, it is important to note that this collection is not exhaustive. Moreover, the developed action plans and mix of interventions adopted by countries, and how they deploy the best practices, will differ, as each country must adapt these recommendations to their local environmental, economic, social, and cultural contexts to achieve the most effective outcomes.

1. Target-Measure-Act Approach[9]

The three-step Target-Measure-Act framework has been shown to be successful when used by both public and private sector institutions to guide FLW reduction strategies.

Target: setting explicit targets is the critical first step that entails establishing clear and ambitious goals for reducing FLW, thereby directing attention and resources towards this pressing issue. The adoption of SDG 12.3 as a universal target—aiming for a 50% reduction in food waste and loss by 2030—offers a global benchmark that aligns with sustainable development objectives. Governments are encouraged to publicly commit to this target, thereby solidifying their dedication. Private entities, although not strictly bound by the SDGs, are urged to set parallel reduction targets. Optimally, FLW targets with specific timeframes, geographic boundaries, food categories, and lifecycle stages to be addressed provide a structured approach to achieving significant reductions.

SDG 12.3 covers food and inedible parts that exit the supply chain and thus are lost or wasted. This is tracked through two indicators:

- Indicator 12.3.1(a), the Food Loss Index (FLI), measures losses for key commodities in a country across the supply chain, up to but not including retail. The FAO is its custodian.
- Indicator 12.3.1(b), the Food Waste Index (FWI), measures food and inedible parts wasted at the retail and consumer levels (food service and households). The UNEP is its custodian. In contrast to the FLI, the FWI measures total food waste (rather than loss or waste associated with specific commodities).

By incorporating these indicators, the framework for setting and achieving FLW targets becomes more structured and measurable, ensuring that efforts are tracked and assessed accurately across different stages of the supply chain. This enhances the ability to identify critical areas for intervention and to implement effective strategies for reducing FLW globally.

Measure: the adage "what gets measured gets managed" holds particularly true for FLW. The measurement phase involves quantifying FLW within specified scopes to identify hotspots and prioritize intervention areas. This step is foundational and enables the development of targeted and effective mitigation strategies. Countries committed to reporting on SDG 12.3 indicator 12.3.1b are required to measure and report their food waste following the methodology outlined by UNEP in the FWI Report (UNEP, 2024). Similarly, countries reporting on SDG 12.3 indicator 12.3.1a are encouraged to measure and report food loss according to the methodology provided by FAO in the FLI Report (FAO, 2018). The FAO emphasizes the importance of improving data collection and measurement to support the objectives of SDG target 12.3.

Despite the challenges of achieving precise quantification, the benefits of measurement—such as the identification of reduction opportunities and monitoring progress toward targets—far outweigh the costs. Tools, standards, and methodologies for quantification and reporting (e.g., Food Loss and Waste Protocol and Standard), have been developed to support entities in this crucial phase.

Act: the final step, "Act," focuses on implementing specific interventions to address identified hotspots and underlying drivers of FLW. This phase is about translating targets and insights gained from measurement into concrete actions that can range from technological solutions and management practices to behavioral changes and policy interventions. The diversity of potential actions reflects the multifaceted nature of FLW and the need for tailored strategies across different sectors and stages of the

[9] This section is drawn from the following sources: (Flanagan, Robertson and Hanson, 2019); (IDB, 2022); (UNEP, 2024)

FSC. This phase is where tangible progress is made, necessitating a commitment to continuous improvement and adaptation based on the outcomes of implemented strategies.

The success of this approach has been proven by its adoption by leading nations and corporations including the UK government, US Government, WRAP, and WRI to name a few. Champions 12.3 has also endorsed the Target-Measure-Act approach.

Flanagan, Robertson, and Hanson (2019) identify 10 priority interventions that collectively aim to enhance the TMA approach for reducing FLW by accelerating the deployment of strategies that minimize FLW across the supply chain, target specific high-loss areas, and improve the conditions enabling these efforts. They serve as a starting point for progress. **Table 6** presents these priority interventions.

Table 6: 10 Priority Interventions to Enhance TMA Approach

Whole Supply Chain Approaches	1. Develop national strategies for FLW reduction, urging more countries to adopt national plans that align public policies, private sector actions, and consumer behaviors.
	2. Create national public-private partnerships to foster collaborations aimed at achieving Sustainable Development Goal (SDG) 12.3 on halving food waste.
	3. Launch a "10x20x30" supply chain initiative where at least 10 leading corporations commit to applying the Target-Measure-Act method themselves and involve their top 20 suppliers to halve FLW by 2030.
Hotspot-specific Approaches	4. Strengthen value chains to reduce losses among smallholder farmers during production and storage.
	5. Launch a "decade of storage solutions" to introduce affordable, climate-smart storage technologies globally, especially for farmers and distributors.
	6. Shift consumer social norms to make wasting food socially unacceptable, leveraging behavioral science and various community platforms.
	7. Target GHG emissions reductions in sectors like beef, dairy, and rice, integrating FLW reduction into climate change strategies under the Paris Agreement.
Enabling Approaches	8. Scale up financing for innovations and enterprises dedicated to reducing FLW.
	9. Overcome the data deficit with a concentrated effort over the next five years to measure FLW supporting the achievement of SDG 12.3.
	10. Advance the research agenda by addressing "next generation" questions to refine strategies for FLW reduction and advance global efforts.

In addition to the implementation of the TMA approach, the IDB (2022b) suggests the use of the "Food Loss and Waste Country Progress Index" to provide insight on which components of the FLW strategy are making progress and which components are not. The index allows for international comparison, providing a scoring system that is color-coded to correspond with the different degrees of progress. This can be used by government agencies tasked with FLW reduction, initiatives of FLW reduction, and stakeholders that are pivotal to FLW reduction in their countries.

The foundation of the Index is based on the "Target-Measure-Act" methodology, and its structure, components, and indicators are based on the descriptions in the Flanagan et al. (2019). The Index is divided into three pillars, each with at least two indicators of progress. Each indicator is then divided into a set of sub-indicators that reflect the targets that the country has set. Finally, there are metrics for sub-indicators, data sources about the metrics, and a maximum number of scoring that can be a awarded for that metric.

The index is designed to foster friendly competition among countries to take action on FLW. It is also designed to reflect the best practices taken in the country and give guidance on what needs to be done to make effective progress. Finally, the index can also be revised over time to reflect new developments and practices for FLW reduction (IDB, 2022b).

Application of the FLW Country Progress Index: The pilot application of the FLW Country Progress Index evaluated five countries based on their efforts to tackle FLW from farm to fork. The Index scores countries on three primary indicators: setting targets, measuring FLW, and implementing actions. The scores range from 0 to 100, with higher scores indicating better performance.

United Kingdom: the UK achieved the highest score of 90, marked by a green color code, signifying significant progress in FLW reduction. This high score corresponds to a 27 percent reduction in FLW from 2007 to 2019 (Lipinski, B., 2020). The UK scored full marks in both setting explicit FLW reduction targets (30/30) and measuring FLW (30/30). It also scored 30 out of 40 in implementing policies and processes to reduce FLW, showcasing its comprehensive approach.

Colombia: Colombia scored a total of 35. It scored 15 out of 30 for measuring FLW and 20 out of 40 for having processes and policies in place. However, it did not score any points for setting explicit FLW reduction targets, indicating an area for improvement.

Mexico: Mexico received a total score of 30. Similar to Colombia, it scored 15 out of 30 for measuring FLW and 15 out of 40 for its processes and policies. Mexico also did not score in the target-setting category, highlighting the need for a more strategic approach to FLW reduction.

Costa Rica: Costa Rica had the lowest score among the evaluated countries, with a total of 10 points. The country did not score in either target-setting or measurement but received 10 out of 40 for its existing policies and processes, suggesting that foundational work in policy implementation has begun but that significant enhancement in other areas is needed.

Argentina: Argentina scored a total of 72, demonstrating substantial progress in FLW reduction efforts. It scored 26 out of 30 in setting targets and measuring FLW, reflecting strong commitments and capabilities in these areas. Additionally, it earned 20 out of 40 points for its policies and processes, indicating active measures but room for further development.

In summary, the United Kingdom leads in FLW reduction efforts with a comprehensive and effective strategy, while Argentina also shows significant progress. Colombia, Mexico, and Costa Rica have made some strides but need to enhance their target-setting and measurement practices to achieve more substantial results. These findings highlight the varying stages of progress and the potential for shared learning and improvement across countries.

2. Supporting Policy and Regulatory Environment for Food Loss and Waste Reduction

National, regional, and global regulatory frameworks provide essential guidance and structure for preventing and reducing FLW across the FSC. Having an adequate institutional, policy, and regulatory framework is pivotal to addressing the systemic causes of FLW. It will facilitate the coordination of actors, enable investments, and support and incentivize the improvement of practices and the adoption of good practices (FAO, 2022).

At the global level, the Agreement on World Food Security (1974) introduced the concept of food security, and later the Convention on Biological Diversity (1992) and the Rome Declaration on World Food Security (1996) included provisions related to FLW (Shen et al., 2023). In 2015, the SDGs were adopted, with Target 12.3 specifically addressing FLW and setting a framework for action. In 2021, the Voluntary Code of Conduct for FLW Reduction was endorsed, providing a non-binding instrument of adaptable principles and standards for governments and stakeholders to voluntarily reduce FLW (Pasarín and Viinikainen, 2022).

Examples of FLW legislative action at the regional level can be drawn from the EU and South America. The EU has introduced several legislative measures targeting FLW in member states such as the Circular Economy Package (2015), EU Guideline on Food Donations (2017), Waste Framework Directive (2018), European Green Deal (2019), and Food Redistribution in the EU (2020) (Shen et al., 2023). In South America, the Latin American and Caribbean Parliament approved a Model Law on Prevention and Reduction of FLW in 2022 (Pasarín and Viinikainen. 2022).

The first step, at the national level, is for governments to have national FLW reduction strategies that address the complex issue of FLW systematically, allowing for tailored interventions to the unique economic, social, and environmental conditions of different regions within a country, supporting regulatory adjustments that incentivize waste reduction, and fostering collaboration among stakeholders. By setting clear targets and establishing a dedicated institutional framework with a defined budget and monitoring plan, countries can ensure accountability, facilitate coordinated efforts, and measure progress effectively. Given that 10% of worldwide greenhouse gas emissions stem from lost and wasted food, integrating FLW prevention into climate mitigation strategies and action plans can significantly impact broader climate objectives and contribute to the country's commitment (Nationally Determined Contributions) to the Paris Agreement, strengthening the case for their implementation. Enhanced collaboration among stakeholders, including government agencies, private sector entities, non-governmental organizations, and consumers, is a key benefit of a participatorily developed national FLW reduction strategy. This collaborative approach ensures that all relevant parties are engaged and working towards common goals, leveraging their unique strengths and resources to achieve significant reductions in FLW.

National Waste Reduction Strategy for Spain: in 2013, Spain launched its "More Food, Less Waste" strategy, which was updated for 2017-2020. This initiative aligns with the EU Action Plan for the Circular Economy and the FAO Voluntary Code of Conduct for Food Loss and Waste Reduction (European Commission, n.d.b). Key actions:

1. Accurately measuring household food waste.
2. Training and awareness to educate the public about food waste reduction, including school programs.
3. Fostering best practices through practical guides, audit tools, and competitions among stakeholders in the FSC.
4. Frameworks for collaboration and agreements between stakeholders from different sectors.
5. Facilitate food donations and redistribution.
6. Align national policies with international standards for effective FLW management.
7. Encourage research and innovation partnerships with universities and institutes to develop new technologies to reduce FLW.
8. Integration of food waste reduction in broader environmental and climate-related policies.

The initial phase of the strategy saw significant progress, including the consolidation of reliable measurement methods for household food waste and the successful implementation of awareness campaigns. Spain actively participates in international forums, allowing it to share the knowledge and experience it gained through its national strategy. The updated strategy for 2017-2020 focuses on areas needing further development, aiming for a holistic approach from primary production to final

consumption. Spain's national waste reduction strategy serves as a comprehensive approach to tackling FLW.

To enable the successful implementation of national FLW reduction strategies it is fundamental to have the required legislative environment in place. Existing legal frameworks often indirectly cover FLW, but it is essential for governments to carry a thorough assessment of current laws to identify how they might encourage or discourage FLW reduction (e.g., food safety regulations may impede secondary resale or redistribution of food) and integrate FLW considerations into all relevant legal instruments governing agrifood systems. Pasarín and Viinikainen (2022) highlight that enacting one comprehensive framework legislation focused specifically on FLW could be instrumental in addressing the issue holistically. Whether governments decide to integrate FLW in different legislations or issue one comprehensive governing legislation, they must make sure that frameworks and actions minimize trade-offs, deliver policy objectives, advance sustainability, comply with existing national and international laws, and consider voluntary commitments under relevant regional and international agreements (FAO, 2022). Furthermore, as FLW programs influence and are influenced by various dimensions of food policy (including agricultural production, health, nutrition, and food safety) and climate action, it is advisable to integrate FLW policies into both existing and future policy frameworks related to all these dimensions. This integration will facilitate synergistic effects across multiple outcomes, such as waste prevention, improved public health, and sustainable agricultural practices, while effectively managing potential trade-offs. Supporting this integration with policy research will enhance understanding of the interdependencies, interactions, and impacts between FLW prevention and its effects on agricultural productivity, land use, and environmental and socio-economic sustainability. This holistic approach ensures that policy measures are comprehensive and aligned with broader food system and climate objectives (EU, 2019). Moreover, the lack of a regulatory framework leads to poor food waste recycling, primarily caused by disposal to landfills, as seen in Nigeria, Ghana, India, Brazil, and Mexico (Shurson, Dierenfeld and Dou, 2023).

Regulations can be tailored to support the scaling of food waste reduction solutions by creating favorable conditions for businesses to operate and sell food products that might otherwise be wasted and/or providing financial incentive to make it financially viable for companies to participate in food waste reduction efforts. Legislation can also be enacted to support the implementation and enforcement of various best practices presented in this section. These range from measuring FLW according to international standards, enforcing the FLW hierarchy, shaping food environments, ensuring capacity-building activities, mandating monitoring and evaluation, and facilitating public-private partnerships, among others.

Effective implementation, monitoring, and enforcement of a legal framework to reduce FLW requires the identification of implementing authorities and allocation of responsibilities. Since addressing FLW is a cross-cutting issue that necessitates collaboration among various entities (public, civil society, private sector), legislation should ensure interinstitutional coordination. Countries are encouraged to establish a national institutional framework on FLW that assigns overall responsibility to a single coordinating institution, delineates the responsibilities of other state authorities and private actors, sets binding reduction targets, mandates the development of targeted policies, instructions and enforcement mechanisms, and designates an interagency coordinating body.
There are numerous examples of countries passing laws that tackle FLW, from comprehensive laws on food waste to specific laws targeting some aspects (e.g. food waste tax, food donation, organic waste recycling, etc.). **Table 7** presents key examples.[10]

[10] This list presented in the table is by no means an exhaustive list.

Trade Agreements

Food security relies on the constant physical availability of food, as economic access is irrelevant without it, and global imbalances occur because high population areas often lack sufficient food production, making the free movement of food from surplus to deficit areas essential (Mujahid and Kalkuhl, 2014). Trade agreements, whether bilateral or multilateral, are contracts between states to reduce trade barriers and improve trade relationships. They typically include reciprocity (mutual concessions on tariffs and quotas), most-favored-nation clauses (preventing lower barriers for other countries), and national treatment of nontariff barriers (Britannica, 2018). Since the General Agreement on Tariffs and Trade in 1948 and subsequently, the World Trade Organization in 1995, global tariffs have dropped significantly, expanding world trade (Britannica, 2018). An analysis on the impact of trade agreements on the flow of food and food price volatility found that regional trade agreements have successfully increased food trade among member countries. While the World Trade Organization agreement has had negative implications for food trade on average, it has been more beneficial for developing countries than developed ones (Mujahid and Kalkuhl, 2014).

A main topic of discussion during the "Reducing Food Loss and Waste: Dual Impact Actions to Address Climate Change and Improve Nutrition" workshop was the effect of trade agreement on FLW, what role power dynamics play, and how this aspect of trade has not been researched at all. A Google Scholar search on the topic yielded no results. A working paper by the United Nations Industrial Development Organization (UNIDO) (Henson and Olale, n.d.) examined border rejections of food commodities by the US and EU markets, and found that most EU rejections are due to restrictions on levels of mycotoxins and most US rejections are due to non-compliance with labelling and company and/or process registration requirements.

Reducing Levels of Rejections of Food Commodities from International Trade (UNIDO, n.d.): technical regulations and standards in international trade for food commodities are increasing and evolving. Safety and quality compliance pose a challenge for many developing countries, leading to increased rejections, economic losses, and reputational risks. To decrease rejections, limited financial resources must be allocated effectively to build human capacity on the most acute compliance challenges (e.g., products and markets with the highest rejection rates).

Trade rejection information can help exporting countries identify the most pressing issues to helping better comply with market requirements. However, rejection data is usually scattered due to varying national and regional standards, excludes emerging markets, limited in terms of type of output, and is not readily available or standardized. This prevents meaningful analysis! Consequently, UNIDO developed the Standards Compliance Analytics tool that uses rejection data to identify compliance challenges, assess export performance impact, and estimate compliance capacity.

Table 7: Policies and Legislation to Prevent Food Loss and Waste

Country	Law	Year	Main Substance
Argentina[11]	Argentine Food Code (CAA)[12]	1969	The federal legal framework for food safety and labeling in Argentina; includes food inspection system.
	Food Donation Law	2004	Legal regime for regulating the donation of food to those in need.
	Updated Food Donation Law	2018	Included liability provisions to the original Food Donation Law.
	National Plan for the Reduction of Food Loss and Waste	2019	Reduce and eliminate FLW through empowerment and mobilization of value chain actors with particular attention to food needs of the vulnerable populations. Promotes awareness and innovative solutions.
Bulgaria	The Food Act 32	2017	Identifies the food products eligible for donation, defines food bank activities, and sets the process for acquiring a license to operate as a foodbank.
China	Public Benefit Endowment Act	1999	Provides federal tax benefits for those donating property and material for public welfare.
	Draft Food Law for Review	2014	Promotes food conservation and loss reduction during storage, transportation, processing, and consumption. Includes a national penalties system for FLW.
	Food Safety Law	2015	Shelf life of food is defined as "the period during which the food retains its quality under indicated storage conditions."
	People's Republic of China Law on Food Waste	2021	The law sets out penalties on food waste, primarily targeting the consumption side, with less emphasis on the production side.
Colombia[13]	National Food Law for the Protection of Human Health[14]	1979	Established specific rules for the safe transportation, manufacture, sale, labeling, and packaging of food.
	National Plan for Food Security and Nutrition	2007	Established to inform actions from 2012-2019, as a response to hunger and food insecurity in the country.
	Reform Tax Law	2016	Provides tax incentives to support food donations.
	Policy Against Food Loss and Waste	2019	Endorses the FLW hierarchy, with the top goal of reducing FLW, followed by the recovery and redistribution of safe, surplus food for human consumption; includes a chapter on calculating FLW.
Croatia	Ordinance donating food and feed (Official Gazette, No. 119/15)	2015	Identifies type of food that can be donated.

[11] Information gathered from unofficial English translations.

[12] Código Alimentario Argentino [Cód. Alim.] [Health Code] [hereinafter "CAA"](Arg. 1969)

[13] Information gathered from unofficial English translations.

[14] https://atlas.foodbanking.org/

Country	Law	Year	Main Substance
	Agriculture Act (Official Gazette No. 118/18)	2018	Defines donors, non-profit persons, and charity organizations that can receive donations and their responsibility, as well as the final recipients of donated food. It also forbids the selling of donated food.
	Income Tax Ordinance (Official Gazette No. 79/03) and Profit Tax Act		Excludes donated food from VAT within the limit of 2% of the donor´s income. Also, under certain conditions, donations are tax deductible.
France	Anti-food Waste Law	2016	National law to reduce food waste by 50% by 2025. Utilized the food waste hierarchy as a framework for food waste prevention, incentivized food donations, prohibited the destruction and mandated donation of unsold food products. Initial law targeted the retail sector and penalized them for violations, which was later extended to catering and food distribution. The law also provides tax credits for donated food.
	Circular Economy Law	2016	Distinguishes between “best before” and “longest use by.” Requires labels to indicate that some foods can be consumed after “best before date.”
	Circular Economy and Anti-waste Act	2020	Increases the number of penalties for waste food. Prohibits businesses along the supply chain from destroying unsold non-food products.
Italy	Good Samaritan Law	2003	Exempts food donors from liability.
	Anti Food Waste Law Law No. 166/2016	2016	National law that aims to reduce food, pharmaceuticals, and other products’ waste across the supply chain. It covers donation of safe food for human consumption and sale of food not fit for human as animal feed or sending it for composting. It promotes expanding range of food donors and provides tax benefits to donors. It also allows reusing confiscated food products that are fit for human or animal consumption.
	Article 2 of Law No. 166	2016	Distinguishes between “best before” and “expiration date.”
Norway	Agreement to Reduce Food Waste	2017	This is a voluntary agreement led by the private sector and signed by industry representatives together with five ministries that aims for 50% food waste reduction by 2030. There has been discussion at Parliament on need for Food Waste Law.
Singapore	Zero Waste Masterplan	2019	The plan aims for a 70% recycling rate and a 30% per capita reduction in landfill waste by 2030, with a 20% reduction by 2026, focusing on e-waste, packaging, and food waste.
	Resource Sustainability Act	2019	Starting 2021, mandates on-site food waste treatment space in new large developments of hotels, shopping malls, and industrial premises above certain thresholds, and requires waste segregation for treatment by 2024.
South Korea	Volume-based Waste Fee policy	1995	Policy based on the “pay as you go” principle. In 1995 the Food Waste Council was formed.
	Comprehensive Food Waste Masterplan	1996	Introduced to prevent wet food waste from entering landfills, as it constituted 30% of landfill waste.
	Food Waste Resource Utilization	1998	Aimed to set governing structure for recycling food waste.

Country	Law	Year	Main Substance
	Revision of Waste Management Act	2005	Outlawed sending food waste to landfills.
	Master Plan for Reducing Food Wastes	2010	Introduced to facilitate the implementation of a comprehensive Weight-based Food Wastes Fee system.
	Weight-based Food Waste Fee Policy	2016	Residents must dispose of waste properly and pay for the food waste they generated per weight.
	Natural Circulation Framework Act	2016	The "recycling of food waste" policy aimed to valorize discarded food waste for composting, animal feed, and biogas production.
	Revision of Waste Management Act	2019	Established Food Waste Control Plan.
	Act to Produce and Use Biogas from Organic Waste	2022	Defines mandatory scope for private biogas producers, sets biogas production targets, and outlines financial support goals.
Spain	Royal Decree 271/2014	2014	Quality standard for yoghurt eliminating requirement for sell by date.
	Code of Good Business Practices in Food Contracting	2015	A commitment by businesses to reduce waste across all phases of the food chain and develop protocols for better food handling.
	Anti Food Waste Law	2020	Mandates stakeholders along the food supply chain to actively reduce food waste and train their employees on correct handling, storing, and transporting to prevent damage. It includes a hierarchy of priority destinations for unused food, and hefty fines for non-compliance.
	Prevention of Food Loss and Waste (Draft Bill)	2024	Commitment to further reduce FLW, and the use of the FLW hierarchy to reduce FLW.
United Kingdom	The Waste (England and Wales) Regulations 2011, Part 5, Regulation 12	2011	The Law presents UK's FLW hierarchy adopted by the UK government, which advises entities to prevent food waste and redistribute unavoidable waste to feed people or animals. Remaining food waste must by law be treated (through anaerobic digestion and composting, recovering waste by land spreading, or recovering energy from waste, and as a last option disposed of by sending it to the sewer or landfill).
United States	Bill Emerson Good Samaritan Food Donation Act	1996	Encourage food donation by addressing the issue of liability pertaining to the "donor" of food, the "donee" who uses donated food, and the "owners" of the property from where donations are collected or gleaned.
	Federal Food Donation Act	2008	Introduced to further maximize food donation by requiring all federal contracts above $25,000 that involve food to include a provision that "encourages the donation of excess wholesome food to food-insecure people." It also exempts the cost of donation in addition to the exemption from liability.
	USDA Regulations	2017	Requires standardization of labels using "best is used by" for egg, meat, and dairy products.
	State-level policies	Various	Six US states have enacted policies to prevent organic waste from going to landfills: - California: Mandatory Commercial Organics Recycling Bill (2014)

Country	Law	Year	Main Substance
			- Connecticut: Public Act 11-217 (2011) and Public Act 13-285 (2013) - Maryland: Organics Recycling and Waste Diversion of Food Residuals Bill - Massachusetts: Food waste ban under the Solid Waste Facility Regulations (2014) - Rhode Island: Food waste ban under its Refuse Disposal laws - Vermont: Act 148, under the Universal Recycling law (2019)
Sources: Kim, S., 2022; Shen et al., 2023; Lee et al. 2024; Platt, B. 2024; Zero Waste Europe (n.d.); DEFRA. 2011; FAO. n.d.e.			

3. Fiscal Measures Establishing Financial Incentives for Food Loss and Waste Reduction

As highlighted in the previous BP, having an enabling policy and regulatory environment that supports FLW prevention and reduction is critical. Essential tools within a supportive regulatory framework are financial incentives and de-risking facilities that encourage investments in waste reduction technologies, methods, infrastructure, and improved waste management practice. Various fiscal measures such as tax breaks, subsidies, and grants can be utilized to create favorable conditions for businesses to **operate a**nd utilize technologies and practices that prevent FLW or recover and valorize food products that would otherwise go to waste. Identifying the most effective fiscal measures should be done based on the local economic, social, and environmental context, in collaboration with businesses and solution providers. Following is an overview of some primary fiscal tools' governments can consider:

Tax Incentives: these include tax reductions or credits to companies implementing FLW reduction practices. Landfill taxes that penalize the disposal of waste in landfills, incineration taxes that discourage burning waste, and carbon taxes on high greenhouse gas emitters, which indirectly impact waste management practices in sectors like food production and retail, are examples of environmental taxes to prevent and reduce FLW. On the other hand, offering tax credits or rebates to companies that adopt sustainable measures such as waste reduction systems, energy-efficient equipment, dynamic pricing systems,[15] and donating food to charities can incentivize companies to change their practices.

Weight-based Food Waste Fee: South Korea identified FLW as an issue, with food waste amounting to an average of 130 kilograms per capita annually and staple foods constituting the leading contributors to the country's food waste. The Wastes Control Act adopted in 1986 and amended in 2007 specifies the responsibilities and roles of producers and consumers in waste management. It required the Ministry of Environment to write a waste management plan for the country every decade.

As part of its food waste program South Korea introduced a pay-as-you-throw system, which requires residents to use special bags for their discarded food. These bags are priced according to volume or weight, thus encouraging waste reduction at source. Additionally, the country embraced high-tech solutions like automated bins with scales and ID scanners to bill residents based on the precise amount of their food waste. This system encourages citizens to be more mindful of their food waste and ensures a cleaner and more efficient waste collection process. Concurrently, the country invested in state-of-the-art recycling facilities that convert food waste into valuable resources such as animal feed, biofuels, and compost, fostering economic growth within the green technology sector (Kim, S., 2022).

Subsidies: providing subsidies for purchasing equipment or technology that helps reduce FLW, such as composting systems, refrigeration units, or inventory management software can ease the financial burden on companies seeking to invest in these solutions. Subsidies can also be in the form of discounted loans (below-market rates) for projects demonstrating positive environmental impact (e.g., purchasing harvesting equipment, cold storage facilities and refrigerated transportation, adoption of AI and automated systems). It can also include the installation of composting and anaerobic digesters to process organic waste.

Increase Small Businesses' Access to Credit: improving access to credit is particularly important for small farmers, producers, and businesses who often struggle to secure financial resources to improve their

[15] Dynamic pricing systems automatically adjust product prices based on remaining shelf life, inventory levels, and demand, providing a financial incentive for retailers to sell products nearing their sell-by dates by making them more attractive to consumers at reduced prices.

operations, increase quality, and minimize wastage. It is important for credit access mechanisms to be culturally appropriate. For example, in the Muslim faith, interest rates are discouraged, so many Muslim farmers and small producers avoid traditional bank loans. To address this, the Global Resilience Partnership, USAID, Mercy Corps, and local credit institutions developed a Shari'a-compliant loan system in Uganda. Instead of paying interest, this system allows smallholder pastoralists and livestock traders to access finance by sharing profits and losses with the financier (Tufts University Friedman School for Nutrition Science and Policy, 2022).

Grant Funding and Green Bonds: green bonds issued by national governments, municipalities, or corporations can raise capital to support investments in infrastructure (e.g., waste treatment, recycling, cold storage, etc.) and upgrading production systems. Research grant funding can support projects that aim to innovate or improve waste management practices and valorization through improved techniques and technologies. Grant funding can also be used to lower the cost of compliance and expand markets for surplus goods, which make it financially viable for companies to participate in food waste reduction efforts.

ReFED Catalytic Grant Fund: this fund was created to accelerate the development and implementation of solutions that cut down food waste across the food system. It targets nonprofit and for-profit organizations to develop and execute effective food waste solutions. The Fund offers different grant types, post-grant support, and strategic partnerships in focus areas that prioritize projects preventing food waste, rescuing surplus food, and recycling waste into valuable products. It supports a range of projects, from small scale solutions ready for testing to those that can be scaled rapidly with a focus on impactful initiatives that can make a significant difference (ReFED, n.d.).

Public-Private Partnerships (PPPs): these partnerships involve financial agreements where private entities finance, build, or manage public service facilities in exchange for long-term contracts based on performance metrics such as waste management services. The partnerships are further discussed under the BP "Integrated Collaboration."

Feed-in Tariffs: these tariffs guarantee a fixed, premium price for energy fed back into the grid from sustainable sources and can be used to encourage the production of energy from organic waste, such as in Germany.

Turning Waste into Energy: facing significant challenges with organic waste and greenhouse gas emissions, Germany introduced feed-in tariffs (FITs) that offered fixed, premium prices for electricity generated from renewable sources, including biogas from organic waste. Germany's FIT scheme ensured that energy producers received a set price for the electricity they fed into the national grid (higher than the market rate), which compensated for the higher costs of renewable energy production. The tariffs were designed to gradually decrease over time, encouraging cost reductions and technological improvements.

This provided financial incentives for farmers and waste management companies to invest in biogas technology by guaranteeing a stable return on investment, which led to the development of numerous biogas plants across the country. For instance, the biogas plant operated by Bioenergie Taufkirchen processes agricultural residues and food waste to produce biogas[16]. This biogas is converted into electricity and fed into the grid under the FIT scheme. It also led to significant investments in biogas technology (European Commission, n.d.a).

[16] Food waste sent for energy recovery is accounted as food waste as per the FLW Standard. It is at the bottom of the FLW hierarchy presented later and should be a lower priority intervention than maintaining the waste food in the food system.

Regulatory Penalties: financial penalties such as fines for not meeting waste management standards or not accurately reporting food waste data serve as a financial incentive for businesses to improve their practices to avoid fines.

China's Anti-Food Waste Law: China has long faced challenges with food waste, especially in urban catering, where about 18 billion kilograms of food is wasted annually, threatening food security and degrading the environment. Previous campaigns like the "Clear Your Plate" had limited success without legal backing (FAO, n.d.b). To address this, China introduced a comprehensive Anti-Food Waste Law in 2021. This law aims to promote resource-conserving practices by imposing stringent measures, especially in the catering sector. Measures include banning competitive eating videos that lead to excessive wastage and allowing restaurants to charge customers extra for leftover uneaten food.

Carbon Credits: the use of carbon credits allows initiatives that aim to prevent and reduce FLW to be certified as carbon credits. These credits can then be sold to countries, companies, organizations, or individuals to offset their GHG emissions to meet emission reduction goals. This process allows FLW initiatives to generate financial gains, making them more viable and sustainable.

The Mexican Foodbanking Network[17]***:*** In Mexico, around 39 tonnes of food is wasted every minute. BAMX (Banco de Alimentos de México), a nonprofit organization, has taken significant measures to combat this issue. By partnering with Zero Waste Company (formerly CoreZero), BAMX has turned food waste into an asset—carbon credits that can be traded on the voluntary carbon market. This provides a new revenue stream for BAMX, enabling it to continue and expand its mission of serving vulnerable communities.

BAMX operates a nationwide network of over 50 food banks across the country that work with producers and retailers to rescue food and other consumer items from being discarded. Rescued food is distributed to those in need. Each year, BAMX rescues around 150,000 tonnes of food, nourishing more than 1.9 million Mexicans facing food insecurity. This effort not only addresses hunger but also reduces the environmental footprint associated with food waste—when discarded food waste decomposes in landfills, it produces methane, a greenhouse gas with 80 times the warming potential of carbon dioxide over a 20-year period. It is estimated the food waste is responsible for 8-10% of all global emissions. Therefore, addressing food waste is not only a social imperative but also a critical environmental necessity.

Zero Waste Company quantifies the amount of GHG emissions that BAMX prevents from entering the atmosphere through its food rescue efforts. Between 2021 and 2023, BAMX's efforts generated over 365,000 carbon credits. This achievement marks the first time carbon credits have been serialized from food rescue initiatives globally, and offers a replicable solution for other organizations and countries grappling with food waste challenges.

Regulatory Adjustments

Although not a direct financial incentive, adjustments in regulations that make it easier to sell "ugly" produce or near-expiration products remove obstacles to selling food typically discarded. Regulatory adjustments can also facilitate collaboration with third-party tools, apps, and platforms that provide financial gains to the retail and food service sectors to adopt waste-reducing practices. Some examples of tools, apps, and platforms that can reduce FLW and generate financial benefits to businesses:

[17] This case study has been prepared by Nicolas Dobler, VP of Sustainability and Carbon Solutions of Zero Waste Company.

- "Assisted Distressed Sales" utilizes third-party companies or apps to sell salvaged, off-spec, overstocked, and out-of-date food at discounted rates. Manufacturers, distributors, and retailers can recover part of their investment, avoid losses from unsold stock, and minimize waste disposal costs.
- "Decreasing Minimum Order Quantities" allows businesses to order only what they need, reducing the risk of excess inventory that can lead to waste. This practice ties financial incentives directly to waste reduction by aligning purchases with actual demand, ensuring businesses spend less on unnecessary stock.
- "Increasing Delivery Frequency" enables businesses to order smaller quantities more often, minimizing stock levels and reducing spoilage. This incentivizes businesses to maintain just enough inventory to meet demand, thereby lowering both waste and holding costs.

Business Case

Presenting a business case for cutting FLW can also serve as a critical financial motivator, especially when supported by evidence and tailored to local circumstances. This approach involves showing businesses that investing in FLW reduction strategies can result in financial gains and align with company values. Examples drawn from local contexts provide data showcasing how businesses have directly benefited from lower waste disposal expenses and improved resource efficiency. Additionally, adopting sustainable practices can improve a company's reputation among environmentally conscious consumers, potentially boosting sales and customer loyalty.

Champions 12.3 Advocacy Campaigns Targeting the Hospitality Industry: Champions 12.3—a coalition working towards achievement of SDG 12.3—have developed several business cases to demonstrate to the private sector the viability of investing in food waste reduction action. Below are two case studies developed under their campaign:

Business case for restaurants to reduce FLW: this study shows that across 114 restaurants in 12 countries, the average restaurant achieved a $7 saving for every $1 invested in food waste reduction measures. Measures included regular food waste measurement, staff training, customer engagement, and kitchen process improvements. Within one year, participating restaurants reduced food waste by 26% on average, leading to substantial cost savings and enhanced sustainability (Champions 12.3, 2019).

Business case for hospitality to reduce FLW: this case study shows how 42 hotels across 15 countries (spanning the budget to luxury segments) reported an average saving of $7 for every $1 invested in reducing kitchen food waste. Within the first year, hotels achieved a 21% reduction in kitchen food waste by weight, with over 70% recouping their investment. By the second year, 95% of hotels had recouped their costs. Key actions include measuring food waste to identify hotspots, engaging staff with clear guidance, rethinking buffet strategies, reducing overproduction, and repurposing excess food. For example, cooking à la carte towards the end of mealtimes and having a plan for safely repurposing leftovers, such as using unsold meats from breakfast in lunch or dinner dishes, significantly reduced waste. Hotels were able to keep their total investment below $20,000, typically less than 1% of their sales. The study encourages hotel owners and managers to "target, measure, and act" to reduce food waste (Champions 12.3, 2018).

4. Measurement According to International Standards and Methodologies

Despite numerous data points on FLW, a significant gap in comprehensive quantification persists, largely due to non-compliance with standardized methods complicating result comparisons, which is compounded by the rare use of direct measurement in postharvest loss studies. A meta-analysis spanning 2006 to 2017 revealed a heavy reliance on surveys and mixed methods, with a mere fraction using direct measurement exclusively. Another analysis indicated that only 20% of the studies reviewed relied on empirical field data (Flanagan, Robertson and Hanson, 2019). There is an urgent need for a concerted

effort to accurately quantify FLW and make this data widely available, categorized by country, food category, and within the private sector, including supply chains by embracing and applying the established FLW Accounting and Reporting Standard and the published FLI and FWI methodologies.

SDG target 12.3 requiring nations to halve per capita food waste and reduce food losses by addressing both the edible and inedible parts, includes two sub-indicators, the SDG 12.3.1(a) Food Loss Index and the 12.3.1(b) FWI (UNEP, 2024). Each Index developed a methodology to guide countries on measurement and both are based on the FLW Protocol and Standard. In addressing the complexities of FLW, it is essential to rely on structured, standardized methodologies that provide accurate, actionable data. International standards such as the FLI, FWI, and the FLW serve as critical tools in this endeavor, each contributing unique insights and methodologies to tackle different aspects of FLW along the supply chain.

SDG 12.3.1(a): Food Loss Index

International Food Policy Research Institute Food Loss Methodology: to address the scarcity of data on FLW, particularly in developing counties, in 2017 the International Food Policy Research Institute developed a methodology to measure food losses across the value chain, including farmers, intermediaries, and processors. This survey-based methodology aimed to identify the hotspots of food loss that occur along the supply value chain due to poor storage, inefficient supply chains, inadequate infrastructure, and consumer behavior, including preharvest losses. It measures both quantitative and qualitative economic losses (Delgado, Schuster and Torero, 2017).

FAO Food Loss Index Methodology: the FAO developed the methodology of the FLI and is its custodian (FAO, 2018). This methodology lays out the process to measure losses from post-harvest up to, but excluding, the retail level. It focuses on key agricultural commodities within a country and tracks losses that occur during storage, transportation, and processing. “Wholesale” food falls under FLI but is sometimes reported under different sectors in the FWI. The FLI is crucial for identifying critical loss points within the production and supply chains that can be targeted to improve overall food security and efficiency (UNEP, 2024).

The methodology gives countries flexibility to choose the implementing strategies that best suit their context to collect data. The suggested approaches include rapid value chain appraisals using case studies, conducting surveys based on representative sampling techniques, and ad hoc estimates derived from field trials. Countries have the option and flexibility to exceed the requirements set out by the FLI, if they have data for a greater number of commodities than required. On the other hand, if data is available for fewer commodities, then the data can still be aggregated and used to report food loss to the FAO.

In addition to quantitative measures, the entity implementing measurements for the FLI can estimate other types of losses or impacts through various methods. Qualitative food losses can be indirectly estimated by identifying the causes of quantitative losses and tracking the quantities and prices of different quality grades of the commodities. Economic losses can be assessed by monitoring quantities and prices for different uses, such as the quantities redirected to feed or compost, and the quality grades of the food products. Environmental impacts related to food losses can be estimated using environmental impact factors within national accounting systems. Nutritional losses, related to the quantity of lost food, can be estimated using nutritional content factors. This comprehensive approach ensures a robust framework for understanding and mitigating food loss, supporting the overarching goal of SDG 12.3 and enhancing food security.

FAO Food Loss App (FLAPP): on April 25, 2024, the FAO Food Loss App (FLAPP) was introduced to a global audience via a webinar attended by over 150 participants from 41 countries. This webinar provided a comprehensive overview of the rationale behind the development of FLAPP, as well as its potential benefits and win-win outcomes (FAO, n.d.c).

FLAPP is designed to offer accessible information on food loss through video advisories, thereby enhancing the capacities of farmers, companies, producer associations, and cooperatives. By leveraging this tool, stakeholders can make informed decisions and apply evidence-based solutions to reduce food loss. Furthermore, the app significantly improves FAO's ability to analyze the origins and causes of food losses at the farm level by utilizing crowd-sourced information from farmers. This contributes directly to global efforts and commitments towards achieving SDG 12.3, particularly the indicator focused on reducing food losses (SDG 12.3.1).

Currently, FLAPP reports on food loss data from 10 countries and 7 commodities. As the user base grows, the app will continue to expand its coverage, both in terms of geographic reach and the variety of commodities it tracks, becoming increasingly specific and comprehensive. While it presently focuses on on-farm losses, future updates will extend its scope to cover the entire value chain up to the retail level.

SDG 12.3.1(b): Food Waste Index

The UNEP developed the methodology for the FWI and manages this indicator, which measures food waste at the retail and consumer levels, including households and food services. This index not only measures total food waste in terms of volume but also incorporates the inedible parts of food that are discarded. By capturing inefficiencies at the consumer end of the FSC, the FWI provides a comprehensive measure of waste that needs to be addressed to enhance sustainability in food systems (UNEP, 2024).

The FWI provides a consistent methodology to measure food waste at the retail, food service provider, and consumer stages of the FSC. The FWI also allows countries to report on food loss in manufacturing that is not captured by the FLI (e.g., when more than one commodity is combined to produce a more complex food product). In some countries, the guidelines for measuring food waste generally follow the same methods as the FWI, however, there are some differences in what is included for certain sectors. For example, in the "retail" and "processing and manufacturing" sectors, some data that is usually reported in the FLI (like wholesale data) is included in these measurements (UNEP, 2024).

Countries are encouraged to use the most appropriate methodology to collect food waste data for SDG 12.3 reporting. Recommended methodologies include waste compositional analysis, direct measurement, and mass balance for households; and waste compositional analysis or direct measurement, counting/scanning, interviews and surveys, or mass balance for the retail sector. These approaches ensure that collected data is comprehensive and reliable, providing a solid foundation for developing effective food waste reduction strategies.

The United Nations Statistics Division (UNSD) and UNEP, as the custodian agency for the FWI, collate the data through the Environment Statistics Waste Questionnaire (UNSD/UNEP, 2022). The questionnaire is filled in by the designated national authorities and statistical offices in the respective member states and submitted to UNSD and UNEP for further analysis and inclusion in global databases (UNSD, n.d.).

Food Loss and Waste Accounting and Reporting Standard (FLW Standard)

The FLI and FWI methodologies are both based on the Food Loss and Waste Accounting and Reporting Standard (FLW Standard) quantification and reporting methods. The FLW Standard (Hanson et al., 2016) serves as a comprehensive global framework designed to guide entities in quantifying and reporting the weight of food, and its associated inedible parts, removed from the FSC, collectively defined as "food loss and waste." By adhering to this standard, countries, cities, companies, and various organizations are empowered to create detailed inventories that measure the extent of FLW within their operations. The primary aim of these inventories is to provide a starting point and solid foundation upon which effective FLW strategies can be developed.

This framework is designed for practical application and enables entities to accurately quantify FLW by clarifying what should be measured and how it should be measured to develop an inventory for their

specific objectives. It also emphasizes the importance of consistency, transparency, and comparability of data, which is essential to monitor progress towards achieving a specific goal such as SDG Target 12.3. The framework is also used to establish reliable baseline data for entities as well as governments.

Synthesis of FLW Measurement Frameworks

To effectively tackle the global challenge of FLW, a coordinated approach that integrates the FLI, FWI, and the principles of the FLW Standard is essential. This integrated methodology ensures that all points of the supply chain—from initial production to final consumption—are adequately monitored and managed. The benefit of this approach is that it provides comprehensive coverage of the entire value chain, including food loss and food waste, and provides data on FLW hotspots that can be used by all stakeholders to establish targeted interventions. This approach also supplies comparable data that can be used to benchmark progress with others or towards a local or international commitment.

5. Identifying the Causes and Underlying Drivers of Food Loss and Waste

Understanding the distinction between causes and drivers of FLW is a prerequisite to developing effective regulations and strategies to mitigate these issues. In the simplest form, a cause of FLW is an immediate and specific factor that directly results in FLW at different stages of the FSC. The direct causes leading to the exclusion of food from the FSC often relate to concerns over the safety or suitability of food for consumption, lack of perceived utility or market, deterioration, suboptimal quality, issues tied to the food's appearance, excessive supply, and fluctuations in seasonal production (Flanagan, Robertson and Hanson, 2019). However, these immediate reasons are underpinned by deeper, underlying drivers that can be technological, managerial, behavioral, or structural, as elaborated in the section “Drivers of Food Loss and Waste.”

Drivers are systemic and complex; one driver can occur at different stages of the supply chain and affect more than one stakeholder. Underlying drivers are usually interrelated. For example, food loss due to poor storage containers (inadequate storage equipment) can be caused by the producer not having access to financing to purchase better storage containers (access to financing). Not all drivers are relevant to all countries and regions. For instance, poor infrastructure may be a driver in rural areas in developing countries but not in developed countries. Social and cultural norms also differ depending on region. Finally, in the complex system of the FSC, underlying drivers at one stage can result in FLW at different stages. Actions or conditions affecting food at one point in the chain often have ripple effects that impact subsequent stages. For example, inadequate food management practices, such as rough handling of fruit during the production or handling stages, can significantly reduce the fruit’s shelf life at the market or consumption stage. This not only diminishes the quality of the fruit but also increases the likelihood of it being wasted by consumers or retailers (Flanagan, Robertson and Hanson, 2019).

These systemic causes include inadequacies in institutional, policy, and regulatory frameworks that are necessary to facilitate the coordination of actors, enable investments, and support the adoption of improved practices along the FSC (HLPE, 2014). For instance, FLW can result from inadequate policies that lead to unstable prices, causing producers to leave produce unharvested in fields. Excessively stringent food quality regulations can pose barriers against food producers and processors accessing markets for their products.

Understanding these interdependencies is crucial for designing effective interventions. By addressing the root causes at each stage and considering their broader impacts, stakeholders can implement more comprehensive and sustainable solutions. This is why identifying the underlying causes and drivers of FLW requires a systemic approach. The causes arise because of the actions of multiple actors across the supply chain and the behavior of millions of people in their homes or restaurants (World Bank, 2019). Once the case for FLW reduction has been made, it is necessary to use a multi-faceted methodology to determine

the scale of the problem and the hotspots, as this will identify the direct causes and underlying drivers. This can be done through data collection, stakeholder engagement and systemic analysis.

1- **Review of existing studies:** data regarding in-depth analysis of FLW drivers and causes may already exist in the form of academic and organizational reports. These could include stage-specific FLW insights that show where waste is prevalent. The analysis of existing studies will also reveal data gaps. The information available at each stage of the value chain may vary in quantity, quality, and accuracy and may have been gathered for a different purpose. FLW measurement related data may not exist entirely or may not have a common framework throughout the FSC.

2- **Data collection and measurements:** as mentioned in several international best practices and frameworks, accurate FLW measurement is crucial to identify the causes and drivers of FLW. There is a need to use standardized methods to collect data across the FSC to pinpoint where and why waste and loss occur. Data collection and measurements is a necessary step in identifying hotspots within the FSC, but alone will not be able to identify the causes and the drivers. Further information on data collection and measurement can be found in the "Measurement According to International Standards and Methodologies" section of this report.

3- **Stakeholder Engagement:** collaboration with various stakeholders, including farmers, businesses, and policymakers, helps in understanding the specific contexts and challenges that lead to FLW. Platforms like the EU FUSIONS project facilitate multi-stakeholder engagement, bringing together diverse perspectives to identify and address the root causes of food waste. The complexity of the FSC means that FLW issues cannot be effectively addressed in isolation. Each stakeholder in the FSC has unique perspectives and knowledge about where and why FLW occurs. By leveraging these insights, stakeholders can collaboratively identify critical points of intervention and develop targeted strategies to mitigate FLW. Further information about stakeholder engagement can be found in the "Integrated Collaboration" section of this report.

By combining these methods—data-driven analysis, stakeholder collaboration, academic research, and supportive policies—organizations can systematically identify the underlying drivers of FLW and consequently develop effective evidence-based solutions and interventions that result in significant reductions in FLW.

Conceptual Framework for a National Strategy for FLW in Mexico: the World Bank, building on its prior work on FLW in Mexico, developed a comprehensive conceptual framework for a national strategy for FLW at the request of the Mexican government. This initiative aimed to address the significant FLW identified in a key report that focused on 79 critical products in the country. The framework aimed to pinpoint "hotspots" along the FSC where losses and waste are most prevalent. It also provided an actionable roadmap of solutions for short-, medium-, and long-term implementation to mitigate these issues (WB, 2019).

Key components of the framework included:

- Understanding challenges: it built on existing knowledge of the FLW challenges specific to Mexico.
- Identifying hotspots: the framework mapped out the main sources of FLW and their underlying causes.
- Solution mapping: it identified potential solutions and created a phased action plan for implementation.

The development process involved extensive consultations with a wide array of stakeholders from both the public and private sectors, as well as international organizations and trade associations. This collaborative approach ensured a comprehensive understanding of the food system in Mexico and facilitated the creation of the country's first national estimate of FLW. The findings revealed a significant

challenge, with at least 20 million tons of FLW annually from farm gate to retail, and an estimated additional 11 million tons from households and small businesses. The framework emphasized the importance of enhancing national data collection and proposed a voluntary agreement between the government and businesses to address the issue effectively.

6. Shape Environments for Waste Reduction

This BP revolves around designing the physical and social settings in the environment where individuals interact with food, with the objective of rearranging food facilities and introducing tools and information that makes it easier for consumers and workers at consumption points to engage in waste-reducing behaviors. There are several innovative strategies to shape consumer environments that have been effectively implemented across various settings, demonstrating significant impact on reducing FLW, such as:

- **Optimizing portion control to minimize food waste:** applicable in both buffet settings and packaged food services to reduce waste. It includes adopting trayless dining and providing smaller plates in buffets to encourage diners to take only what they can consume. Research from university dining halls supports this method, showing reductions in food waste by as much as 30-32% when trays are removed (REFED, 2021; Compass Group, 2023). Offering a variety of portion sizes at a price differential can cater to different appetites and further reduce food plate leftovers. Strategic placement of educational signage at the point of decision outlining the environmental impacts of food choices and promoting sustainable habits has also been shown to affect decisions. Another direct deterrent of over-portioning in buffet environments is charging a fee for leftover uneaten food, as is done at Jan's Noodles, a restaurant in Dubai (see highlight below). In the retail sector, redesigning food packaging to align with typical consumption patterns can increase the likelihood of all content being used. Integrating digital feedback systems at consumption points that allow customers to comment on portion sizes and food quality can also provide valuable insights on desired portion sizes.

  Pay for Your Leftovers—Jan's Noodles' Innovative Policy: recognizing the significant environmental impact of food waste, Jan's Noodles, a popular restaurant in Dubai, has implemented an innovative policy to combat this issue by charging diners double for uneaten food left on their plates. This measure, prominently displayed on the restaurant's menu, aims to encourage patrons to take only what they can consume, thereby minimizing food waste. The policy has generated considerable attention both online and within the community, promoting a culture of mindful consumption among customers and reducing the amount of food that ends up in landfills. This initiative aligns with broader sustainability goals by addressing food waste at the consumer level.

  Jan's Noodles demonstrates how restaurants can play a pivotal role in reducing food waste through creative policies and customer engagement. By holding diners accountable, the restaurant sets an example for other establishments, contributing to environmental conservation and fostering a more responsible dining culture. This initiative benefits both the business and the community (Curly Tales, n.d.).

- **Advanced labeling techniques to enhance food safety and reduce waste:** standardizing date labeling and integrating sensory-based expiry indicators can significantly reduce food waste. By clearly distinguishing between safety-based and quality-based expiration dates, consumers are less likely to discard still-edible food due to label confusion. Technologies such as digital tags or QR codes provide further clarity by offering detailed information about storage and expiration

directly via smartphone scans. Time-temperature indicators and color-changing freshness indicators that react to specific spoilage-related changes in the food offer a dynamic and reliable method to gauge food safety beyond printed dates. To maximize their effectiveness, these initiatives should be supported by public educational programs to ensure consumers understand and trust these innovative labeling methods.

Zero Hunger, Zero Waste Vision – Kroger's Standardized Date Labels: in early 2020, Kroger began transitioning to a standardized and simplified date labeling system for its "Our Brands" products as part of its Zero Hunger | Zero Waste commitment. The labels include "Use By" for food safety and "Best if Used By" for quality and freshness on various product categories, such as dairy, deli, bakery, and fresh and frozen grocery items. It aimed to help consumers better understand date labels.

Kroger's initiative was driven by its belief that much food waste occurs in customers' kitchens due to unclear date labels and that by providing clearer guidance through standardized labels, it will reduce food waste across its business and communities and be a cost-effective solution to support food banks (The Kroger Co., 2019).

- **Strategic retail layouts and incentives for waste reduction:** retail stores can reduce food waste by adopting strategic layouts and shelf stocking practices that prioritize the sale of older inventory. Incorporating dynamic pricing strategies, which adjust prices based on approaching expiry dates, improves this approach. Stores can also implement visible freshness indicators, such as the "first-in, first-out" inventory system, which organizes inventory by purchase date and positions older items in a convenient access point or at the front of the shelves. This is a popular system used by big retail stores such as Walmart. Additionally, grocery stores can nudge positive consumer behavior by offering discounts on future purchases when consumers buy near-expiration items, or by introducing digital labels such as those discussed above that provide real-time updates on product freshness.

First-Expired-First-Out, Tesco's Strategy to Reduce Food Waste: Tesco, one of the UK's largest retailers, has effectively implemented the "first expired, first out" (FEFO) system to manage inventory and reduce food waste. This method prioritizes the sale of products with the earliest expiration dates, minimizing spoilage and waste and reporting a substantial decrease in expired products, lower waste disposal costs, and improved product turnover.

Food waste in retail often results from inefficient inventory management, where newer stock is placed in front of older stock, leading to expired products. By integrating the FEFO system into its operations, Tesco labeled products with clear expiration dates using barcodes and RFID technology, [18] facilitating easy identification and management, as this software enabled prioritizing the dispatch of items nearing expiration. Staff were trained to implement the FEFO system effectively, ensuring compliance and consistency. Regular audits and real-time data analytics ensured adherence to FEFO practices and identified areas for improvement. Concurrently, Tesco's ordering system helped improve forecasting and stock management. Store data matched appropriate ranges and product sizes with different types of Tesco stores. For example, larger packs of Tesco "Finest Pork Chipolata Sausages" are stocked in larger Extra stores for weekly shoppers, while smaller packs are stocked in Express stores (Tesco, 2024).

- **Interactive meal planning and ordering:** implementing pre-order options in food service settings such as corporate cafeterias and school lunch programs allows kitchen staff to prepare more

[18] Radio Frequency Identification (RFID) technology uses electromagnetic fields to automatically identify and track tags attached to objects. An RFID system comprises RFID tags, which can be passive, active, or semi-passive, and RFID readers that send and receive signals to and from these tags, enabling the identification and tracking of the tagged objects.

accurate meal quantities, directly reducing overproduction and food waste. Collaborative meal planning further enhances this strategy in settings like schools and nursing homes. Moreover, individuals are more likely to consume meals they have personally selected or contributed to planning, which can increase meal satisfaction and decrease waste. This approach can be strengthened by educational campaigns that encourage more conscious meal choices.

Reduce Waste and Eat the Food You Like: school cafeterias often face significant food waste due to inefficient meal planning and ordering processes, resulting in financial losses and increased food waste. MealManage—a software solution designed to streamline school meal programs by enabling parents to pre-order meals for their children—can ensure food is prepared based on actual demand. Moreover, the system tracks consumption patterns, allowing schools to adjust menus according to student preferences, further minimizing waste.

Schools using MealManage have reported substantial reductions in food waste. For example, the Randolph Township School District in New Jersey noted the platform's ability to monitor frequently wasted items, enabling menu adjustments that reduce waste and costs. The Challenge Charter School highlighted the system's efficient tracking and reporting features, which cut down on paper use and reduced the administrative burden on staff (MealManage, n.d.).

- **Creating secondary and waste-to-value markets for food redistribution and upcycling:** these markets provide retailers and food service providers with an alternative destination to landfills to send their unwanted food. Secondary markets can offer surplus food and near-expiration items that are still within their safe consumption period but may not be visually perfect at discounted rates to consumers or charities. Meanwhile, waste-to-value markets focus on transforming food scraps and expired items into new products, such as turning stale bread into croutons or breadcrumbs.

Tomato Isn't Red Enough: the food processing industry often rejects produce that does not meet specific aesthetic standards, leading to substantial food waste. In the case of tomato processing, tomatoes that are not "red enough" are typically discarded, contributing to millions of tomatoes wasted annually. To address this issue, Unilever's Hellmann's Red and Green Tomato Ketchup incorporates perfectly good tomatoes of various colors that would otherwise be discarded for not meeting traditional "red" color standards. This initiative has saved an estimated 2.5 million tomatoes each year, highlighting the potential for using produce that is perceived as imperfect in food production (Unilever, 2018).

- **Segregation of waste, at the source:** effective waste management, crucial for sustainable resource recovery, remains elusive without proper segregation practices. When done properly, waste segregation at source can play a critical role in facilitating effective waste reduction behaviors across various sectors, from households to large-scale food production facilities. It can also improve collection and disposal efficiency by easing handling and processing, enhancing resource recovery, and fostering reuse and recycling (Kihila, Wernsted and Kaseva, 2021). Harnessing segregation potential could reduce operational costs, generate income, and improve environmental cleanliness and urban aesthetics. Main factors hindering effective waste segregation are negative attitudes towards segregation, perceived high costs of segregation facilities, and a lack of awareness about the benefits and methods of waste segregation. Governance challenges including insufficient policy framework, ineffective strategies, and inadequate enforcement mechanisms further exacerbate these issues.

Sorting Waste at the Source—Indore's Success Story: Indore, a rapidly growing city in India, faced severe waste management issues, generating approximately 1,100 metric tons of waste

daily. Before 2016, mixed waste disposal led to unhygienic conditions, pollution, and health hazards. The Swachh Bharat (Clean India) campaign motivated the Indore Municipal Corporation (IMC) to overhaul its waste management practices, focusing on source segregation and community involvement.

The IMC implemented a mandatory waste segregation policy requiring households to separate waste into wet (biodegradable) and dry (recyclable), enabling efficient waste collection and processing. Over 600 GPS-enabled vehicles were deployed to collect segregated waste daily from households and commercial establishments. A waste processing facility with a 15-megawatt (MW) waste-to-energy plant and a 200-ton-per-day (TPD) composting plant were established. Public awareness campaigns about waste segregation, coupled with regular inspections, fines, and incentives, ensured compliance with segregation rules.

As a result, over 90% of households now segregate their waste and the city's waste processing facility manages 1,000 metric tons of waste daily with a 95% recovery rate. This has significantly reduced landfill burden and environmental impact. Since 2017, Indore has consistently ranked as the cleanest city in India, with significant reductions in vector-borne diseases and improved air quality (Earth5R, n.d.).

7. Food Loss and Waste Hierarchy

The FLW hierarchy prioritizes food waste management methods based on their environmental impact from the most to the least environmentally friendly, focusing on source reduction and diverting organic waste from sewers and landfills. The hierarchy provides a structured approach to guide governments in evaluating and prioritizing FLW reduction interventions by prioritizing waste prevention, followed by reuse of surplus food, then recycling and recovery processes, with disposal being the last resort. This systematic method helps create comprehensive and sustainable waste management policies that seek to minimize environmental harm, optimize resource use, and enhance food security. Utilizing the hierarchy should be in line with the specific needs and conditions of each country. Following is the evolution of the hierarchy over the last two decades and the prioritization framework of different entities and countries.

In the United Kingdom, the hierarchy was first introduced under regulation 15(1) of the Waste (England and Wales) Regulations 2011 (DEFRA, 2011), which presented a general waste hierarchy as well as an adaptation specifically for food waste. It prioritized prevention followed by anaerobic digestion, then by composting and other energy recovery technologies, with disposal ranked as the least favorable option.

FAO's "Toolkit: Reducing the Food Wastage Footprint" (FAO, 2013) included the inverted "food waste pyramid." It classified reducing food wastage as the most environmentally friendly option, as it minimizes the use of natural resources by balancing supply and demand, thereby avoiding unnecessary production and resource pressure. The next priority is reusing surplus food within the human food chain through secondary markets or donations to vulnerable populations. The pyramid prioritizes diverting it to livestock feed to conserve resources, and if not possible, for commercial feed. The last stage of the pyramid classifies the least priority interventions as recycling and recovery such as by-product recycling, anaerobic digestion, composting and incineration with energy recovery, and finally landfilling. Landfilling is considered the least desirable option, as it emits harmful gases like methane and pollutes soil and water resources. The FAO pyramid was later expanded, and "Reduce" was classified to include food redistribution, with animal feed having a higher priority within this category. Additionally, recycling and recovery were split in two activities, with recycling having a higher priority (FAO, 2017).

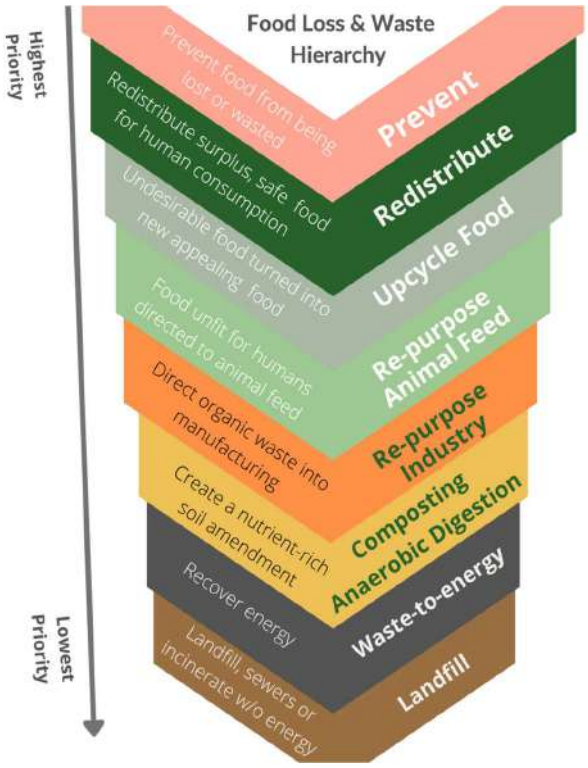
In May 2018, the European Commission adopted the revised "Waste Framework Directive" that required Member States to "reduce food waste at each stage of the FSC, monitor food waste levels and report back regarding progress made," providing incentives for the application of the adapted waste hierarchy (EC, 2018). In 2023, the United States Environmental Protection Agency (EPA, 2023) presented an updated the

"Wasted Food Scale" of its "Food Recovery Hierarchy" of the 1990s. The revised scale includes six levels that prioritize prevention of wasting food, followed by donating or upcycling surplus food, then feeding animals or leaving crops unharvested. Composting or anaerobic digestion utilizing digestate/biosolids comes in fourth place, followed by anaerobic digestion without utilizing digestate and/or biosolids, or applying to the land. The last (to be avoided) stage is sending food waste down the drain, to the landfill, or incinerating it with or without energy recovery.

Table 8 exhibits how different FLW hierarchy pyramids prioritize interventions. Interventions highlighted in the green spectrum colors are interventions that maintain the food in the food system, be it for human or animal use. Interventions highlighted in blue recover food waste and valorize it to produce commodities, thus maintaining the waste in the economy. Interventions highlighted in the orange spectrum of colors are those that regenerate soil, while those highlighted in the spectrum of brown colors are the interventions at the lower end of the spectrum that involve recovering energy. Incineration without energy recovery and disposal in landfill or sewers falls at the bottom of the pyramid and are highlighted in dark grey. Only the EPA 2023 food scale includes upcycling wasted food into new food products for human consumption. With the increase in upcycling of edible and inedible food discards into food products, it is essential that upcycling for human food should be an integral part of the FLW hierarchy.

Figure 3 depicts the authors' recommendation for the FLW Pyramid, which integrates "Upcycling Food" as a priority that is higher than animal feed but lower than donations.

Figure 3: Food Loss and Waste Hierarchy



Source: Adapted by Thriving solutions 2024

The FLW standard complements the prioritization of the food waste pyramid. Moreover, the standard requires that food exiting the food system that is sent for disposal, recycling, or recovery, which includes waste directed to landfill, thermal treatment (with or without energy recovery), anaerobic digestion, advanced thermal treatment, rendering, and composting, be accounted as wasted food. On the other hand, food that remains within the human FSC through reuse interventions (e.g., that redistribute surplus food for human consumption or upcycle it into food products) and food that is legally diverted to animal feed is not considered food waste.

Within the framework of the FLW standard, interventions in **Table 8** highlighted in green that keep the surplus food in the FSC are accounted for as FLW reduction and considered high priority, while the interventions highlighted in blue, orange, brown, and grey are accounted in FLW measurement studies as food loss or food waste. Measures highlighted in blue, orange, and brown pertaining to repurposing food waste for industrial uses, composting, anaerobic combustion, and incineration with energy recovery contribute to a circular economy. Sending food waste to landfills, sewers, or incineration without energy recovery is the practice under the current linear economy.

Table 8: Evolution of the Food Loss and Waste Hierarchy

	Priority 1	Priority 2	Priority 3	Priority 4	Priority 5	Priority 6	Priority 7	Priority 8
EPA 1990s	Prevent	Donation	Animal Feed	Industrial Uses	Composting	Landfill	Incineration	
UK 2011	Prevent	Anaerobic digestion	Composting Energy Recovery	Disposal				
FAO 2013	Prevent / Reduce	Redistribute *(human use)* Animal Feed	Anaerobic Digestion Composting Incineration *Energy Recovery* Rendering					
UK 2014	Prevent	Redistribute *(human use)*	Animal Feed	Process surplus food make biomaterials	Anaerobic Digestion Composting	Recover Waste land spreading	Recover Energy	Dispose *(sewer/landfill)*
FAO 2017	Prevent ***(Source Reduction)***	Redistribute *(human use)*	Animal Feed	Composting	Bioenergy Recovery	Landfill Incineration		
EU 2018	Prevent	Reuse *(human use)*	Animal Feed	Reuse Valorize by products Recycle Valorize food waste	Composting Anaerobic Digestion *utilize digestate/biosolids*	Incineration *energy recovery*	Disposal *Sewer/landfill* incineration *w/o energy recovery*	
EPA 2023	Prevent	Donation Upcycling *Produce food*	Animal feed Leaving Unharvested	Composting Anaerobic Digestion *utilize digestate biosolids*	anaerobic digestion *utilize digestate/biosolids* Applying to the Land	Disposal *Sewer/landfill* Incineration *energy recovery* Incineration *w/o energy recovery*		

Sources: DEFRA, 2011; FAO, 2013; FAO, 2017; EU, 2018; EPA, 2023.

Legislation and fiscal measures can promote and even mandate the state to manage FLW according to a hierarchy that prioritizes different material streams, making it a responsibility for both the state and FSC actors, especially food business operators. For example, Colombia's Law No. 1990/2019 prioritizes diverting food waste first to human consumption and secondarily to animal consumption (Pasarín and Viinikainen, 2022). However, it is important to highlight that although the hierarchy provides overall structured guidance on prioritizing FLW interventions, it is critical to evaluate the appropriateness, efficacy, and efficiency of selected interventions based on the local context. The food-energy-water-climate dynamics differ from country to country, and even within regions of the same country, and these elements are not adequately captured within the FLW hierarchy framework (Parsa et al., 2023). Parsa et al. (2023) simulated two sets of scenarios to compare the food-energy-water-climate impacts of the food waste hierarchy for the city of Bristol and found that for Bristol, food waste reduction should be prioritized at the consumer level, while within the supply chain, it is more advantageous to prioritize food surplus redistribution.

Prevention

Prevention of FLW, or source reduction, which is the highest priority in the pyramid, refers to measures and actions taken to reduce overproduction and prevent food produced for human consumption from being lost or wasted. This method prioritizes preventing waste before it occurs, distinguishing it from other waste management pathways by ensuring no waste is generated (DEFRA, 2011; FAO, 2013; FAO, 2017; EU, 2018; EPA, 2023). By preventing FLW from occurring, we save the raw materials, ingredients, and labor used to produce that food (Caldeira, De Laurentiis, Sala, 2019). Strategies for source reduction can be specific to sectors, like improved harvesting techniques, or applicable across the entire FSC (EPA, 2023).

To prevent FLW from occurring in the first place, we need to address the technological, managerial, behavioral, or structural drivers that are compromising food quality, appearance, and/or leading to market mismatch. Many of the best practices presented in this section include key approaches to prevent FLW from occurring. These approaches include identifying hotspots and drivers, aligning food supply with demand, improving the different dimensions of infrastructure, adopting better handling technique, enhancing packaging, optimizing distribution, finding secondary markets for surplus produce, increasing education, and supporting behavioral change.

FLW poses a critical threat to global food security and nutrition by directly reducing food availability and negatively impacting access to food. Not only is there a reduction in food volume, but the loss of quality and nutrients can lower the nutritional value of food, destabilizing food systems. Climate change further exacerbates these issues, increasing vulnerability, hunger, and malnutrition, with its impacts compounding those of FLW. This creates significant challenges for food systems to provide sufficient, nutritious food for growing populations. Additionally, FLW undermines adaptation, risk reduction, and resilience efforts, especially in vulnerable regions.

For producers, FLW leads to decreased income, wasted labor, and capital and reduces the return on investment. For consumers, it causes higher food prices, making food expenses a larger share of household budgets. These socio-economic impacts are particularly severe for poor and marginalized populations, who are most susceptible to climate change and experience the highest levels of food insecurity (FAO, 2017).

Preventing food waste at the source conserves essential resources like energy, water, and land, reducing the need for increased production and thus minimizing environmental impacts such as greenhouse gas emissions. Preventing FLW supports climate action by addressing adaptation and mitigation objectives, enhancing food system resilience, and reducing emissions. Additionally, preventing FLW through climate-smart practices contributes to sustainable development and poverty alleviation, making it essential for achieving global food security and environmental sustainability (FAO, 2017).

In 2019, the European Commission published an evaluation framework that aims to provide a clear methodology to assess the performance and efficacy of food waste prevention actions to enable evidence-based scientific support to the European policymaking process along the FSC to prevent food waste (Caldeira, De Laurentiis, Sala, 2019). In developing the Assessment Framework, a total of 99 preventative actions pertaining to food redistribution for human consumption, food valorization into value-added products (e.g., animal feed), consumer behavior change, improving supply chain efficiency, and cross cutting action that enhance the governance environment were collected and assessed. Criteria used to evaluate the actions include the quality of the action design, its effectiveness and efficiency in producing the desired action, its sustainability over time, its transferability and scalability, and its utilization of inter-sectorial cooperation. Consequently, a calculator was developed and tested to assess the net economic benefits and net environmental savings of food waste prevention actions.

Improved Smoke Ovens to Reduce Fish Losses During Drying: to reduce post-harvest losses and enhance the livelihoods of fish processors in Cameroon, FAO introduced improved fish smoking ovens to replace traditional smoking methods that generate substantial losses due to inefficiency and contamination. The new ovens provide a controlled setting, ensuring even smoking and better preservation, increasing production efficiency, and allowing processors to smoke more fish in less time and with better quality. This improvement led to higher market prices and economic stability for fish processors. Additionally, the new ovens are more fuel-efficient, reducing firewood use and deforestation, while addressing health concerns from harmful smoke exposure. This initiative demonstrates the significant impact that simple and suitable technological advancements can have in developing regions (FAO, n.d.e).

SAVEFRUIT® and Mi Fruta, Mi Pueblo—Champions of the #SinDesperdicio Contest in Mexico: SAVEFRUIT® emerged as a winner in the #SinDesperdicio contest held in Mexico with its non-hazardous chemical solution designed to extend the shelf life of fruits. This treatment effectively slows down the ripening process, preserves the color, and provides protection against diseases. As a result, it significantly reduced FLW during storage, transportation, and retail (IDB, 2022a).

In second place was Mi Fruta, Mi Pueblo, which introduced a community cooperative approach to aid farmers in converting seasonal fruits into novel products. By working with the Zapotec communities in Oaxaca, this initiative has led to the creation of several value-added product concepts for excess citrus fruits, facilitated their market entry, and fostered the development of producer cooperatives in regions affected by food scarcity and economic hardship.

Redistribution

When food waste cannot be prevented, the food waste hierarchy ranks recovery and redistribution of surplus food for human consumption as the next best strategy. Redistribution involves storing, processing, and distributing food to those in need while complying with safety and quality regulations. Key actors include donors/suppliers of surplus food, recipient and food distribution organizations, end users, and facilitators who streamline the process using information and communications technology (ICT) networks (FAO, n.d.a.). Having food waste recovery and donation policies and legislation governing foodstuff donation is crucial for facilitating the redistribution of surplus food from households, businesses, restaurants, and events to those in need. This contributes to reducing food waste and diverting food from landfills, as well as combating food poverty, as local food donation initiatives support vulnerable communities. Establishing structured programs and partnerships for food recovery, which prioritize providing culturally appropriate and suitable foods in ways that clients perceive as dignified, can contribute to creating a more efficient and equitable food system.

Borusiak & Knežević (2024), identify four main types of food redistribution organizations that operate under three different models: “sharing for money,” “sharing for charity,” and “sharing for community.” These organizations are:

1. **Food banks:** humanitarian aid organizations that collect, organize, and distribute food to nonprofit agencies and individuals to alleviate hunger and reduce food insecurity among those in need. Operating as a nonprofit entity, food banks often work with intermediaries like food pantries and soup kitchens. They receive food donations from producers, retailers, and individuals, and sometimes purchase additional supplies. In addition to ensuring that the donated food is safe, nutritious, and meets dietary requirements, food banks also strive to provide culturally appropriate and dignifying food options to overcome the stigma that some cultures associate with food banks.

   Global Food Bank Movement: the food bank movement began in 1967 with John Van Hengel's St. Mary's Food Bank in Arizona, which initially gathered surplus food for a soup kitchen and later distributed to other organizations. The idea spread rapidly, leading to the opening of food banks in the US, Canada, and Europe (European Federation of Food Banks, n.d.).

   In Europe, the European Federation of Food Banks (FEBA) was established in 1986, coordinating 351 food banks across 30 countries. As of 2024, FEBA has distributed 876,316 tonnes of food to over 12.4 million people, working with 44,884 charitable organizations to prevent food waste and feed those in need (European Federation of Food Banks, n.d.).

   In the US, Feeding America was founded in 1960 to provide nutritious food, advocate for antihunger policies, and address food insecurity. By 2023, it supported 5.3 billion meals (Feeding America, 2023). Established in 2003, the Global FoodBanking Network now includes member food banks in 46 countries, distributed 18.4 million kilograms of food to 32 million people, with 60% comprising fruits, vegetables, grains, dairy, and animal protein (Global Foodbanking Network, n.d.).

2. **Social supermarkets:** a specific type of social enterprise and retail format designed to address poverty and material deprivation by collecting surplus food from producers, retailers, and individual donors, which would otherwise go to waste, and offering it at significantly reduced prices (or free of charge) to people on low incomes. By doing so, they help reduce food insecurity, promote social inclusion, and provide environmental benefits through waste reduction. Social supermarkets operate on volunteerism and reinvest any profits into social projects. They differ from food banks by offering food choices and social support in a dignified, retail-like environment. However, their reliance on food surplus means they normally offer a limited assortment of products with variable ability to provide healthy food, which risks exacerbating existing health disparities in vulnerable communities (Saxena and Tornaghi, 2018). Social supermarkets have been operating in Europe since the 1980s and are expanding to other regions, but remain under-researched.

   Rise of Social Supermarkets in Britain: due to stagnant wages, rising food prices, housing costs, worsening income inequalities, and rising food insecurity in Britain, the number of social supermarkets has grown since 2013, particularly in deprived areas. These markets operate under diverse models based on food source, access, pricing, workforce, and social support, with the aim of reducing food waste, providing low-cost food, and supporting communities (Saxena and Tornaghi, 2018).

   A study of two social supermarkets reliant on volunteers that used a pay-as-you-feel model to reduce stigma and served 699 households found that 70-80 households used the service weekly. Surveys and interviews revealed that members appreciated the food variety, reduced waste, and social aspects, and that most members prioritize healthy eating, although cost and time are significant barriers (Mulrooney, H. et al., 2023).

3. **Food sharing initiatives:** organized by social work institutions or individuals, they involve collecting unwanted and overproduced food from households and businesses and redistributing it to those who will consume it. Depending on how distribution is structured, it may require storage space and clear communication on acceptable food types. Community refrigerators are a common method, though they face regulatory challenges in some countries due to differing perceptions of food safety risks. For example, the European Commission's 2017 guidelines emphasize traceability and compliance with food hygiene regulations, but uncertainties remain for food sharing initiatives about the logistics and responsibility for ensuring food quality and safety.

   Surplus Food Redistribution in Bangladesh: in Bangladesh it is common among many middle-class or lower-middle-class families to share surplus food among extended family or nearby people experiencing poverty. This practice, termed "reclaimed food system," expanded in the early 2000s to include a large network of informal food markets involving chefs, caterers, hotel managers, community centers, festival organizers, collectors, suppliers, and sellers. Reclaimed food typically includes leftovers from weddings, public functions, and high-end restaurants, often due to overestimated portions or guest attendance. This food is sold at very low prices (2-5% of the normal price) in easily accessible public areas or streets. According to a 2013 visual census by the Bangladesh Youth Environmental Initiative, more than 500 community centers and 50 upscale restaurants in Dhaka collect approximately three tonnes of food daily. To fully leverage this surplus food, it is critical to upgrade the collection, hygiene maintenance, preservation, and distribution channels within a sustainable business model that enables redistribution of safe and nutritious food to those in need (UNEP, 2014).

4. **Food sharing platforms** are digital solutions that facilitate the redistribution of surplus food, promoting sustainability by reducing waste and enhancing social inclusion. These platforms operate under three models: "sharing for money," which involves selling discounted food from businesses to consumers, "sharing for charity," where nonprofits distribute donated food to those in need, and "sharing for community," which allows individuals to share food with each other for free. These platforms use apps and websites to streamline the process, making it easier for providers and consumers to connect and share resources efficiently.

   Olio, a Community Food Sharing App initially started as a WhatsApp group chat servicing a single neighborhood where members could offer surplus food. Olio has grown into the UK's top community sharing app for food and other household items that owners do not want or use anymore. As of May 2024, Olio has 7.7 million users and 111,000 volunteers rescuing unsold food from local businesses such as supermarkets, corporate organizations, and school and hospital canteens and redistributing it to their local communities via the Olio app. The app has facilitated the sharing of 164 million portions of food and 11 million household items. (Olio, 2024).

Implementing food waste recovery policies at the local level through foodstuff donation is crucial for facilitating the redistribution of surplus food. These policies can help ensure that excess food from households, restaurants, and events reach those in need, reducing food waste while simultaneously addressing hunger. By incorporating food redistribution into social protection frameworks, surplus food is redirected to those in need more effectively, as it leverages existing mechanisms that help overcome logistical and supply-demand challenges, thereby increasing the efficiency and reach of food redistribution efforts while significantly enhancing individual livelihoods, social welfare, community resilience, and environmental sustainability (Yue et al., 2023). The avoided environmental impact of food redistribution ranges from 0.5 to 2 kg CO_2 eq per kilogram of food donated (Borusiak & Knežević. 2024; FoodBanking Network, 2024).

However, several barriers limit the effectiveness and scale of foodstuff redistribution, starting with the fact that not all surplus food is edible. For example, in the UK manufacturing sector only 53% of food surplus and waste is edible, meaning a perfect redistribution system can address only half of it (Parsa et al., 2023). Other barriers include cross-sectoral complexities and insufficient cooperation among stakeholders (EU, 2019), absence of clearly defined processes and activities for food waste recovery within the food industry, undefined and unapproved food waste recovery procedures, misconceptions of liabilities, and lengthy donation processes, coupled with the additional costs, efforts, and logistical challenges associated with food donation (Borusiak & Knežević. 2024). To effectively scale and institutionalize food donations while ensuring food safety, quality, and donor liability protections, it is critical to have clear food donation policies and laws in place (Yue et al., 2023).

Upcycling Food

Upcycling or conversion of food refers to transforming wasted food—surplus edible food, unsellable produce, or food byproducts like pits, peels, and fish skins—that would otherwise be discarded into new food products for human consumption. This pathway is unique as the recovered wasted food is processed, distributed, and consumed as if it were "regular" food. Upcycling food waste into new food products is a new concept and very few studies are available to assess its prevalence and evaluate its environmental impacts. (EPA, 2023).

Salmon Skin Snacks: Goodfish, an Alaska-based company, utilizes salmon skins, a by-product of the fish processing industry that are often discarded, and turns them into a nutritious snack rich in omega-3 fatty acids and marine collagen. Importantly, its product is viable and profitable. Within 90 days after launching during the COVID-19 pandemic, the company achieved a $1 million run rate, doubling to $2 million within 6 months. Goodfish partially attributes this success to its direct-to-consumer model, which allowed it to gather immediate feedback and continuously improve their product by adjustments in seasoning and flavor to better suit its customers. (Trotter, 2021).

Date Seed—An Alternative to Coffee: in the United Arab Emirates, young entrepreneurs have managed to utilize date seeds to produce a coffee substitute. Date seeds, typically discarded during the processing of dates, are now being collected, cleaned, roasted, and ground into a fine powder to produce an eco-friendly, caffeine-free coffee alternative. Date seed coffee is also rich in antioxidants and has been researched for its potential health benefits, which include anti-inflammatory properties. The resulting drink offers a unique taste that has the essence of dates and is sometimes preferred for its health benefits compared to regular coffee. (Khaleej Times, n.d.)

ReFED (ReFED, 2021) highlights several challenges to upscaling food solutions. For example, higher costs of value-added upcycled products can restrict their market appeal. Product variability based on waste types can affect economic viability and diversion potential. Distribution challenges and regional limitations associated with sourcing scraps from diverse locations, especially for businesses with limited storage capacity, can hinder scalability. Ensuring a constant, stable waste stream is crucial for businesses to be able to maintain operations throughout the year. All these factors should be carefully assessed when identifying economically feasible projects to upcycle discarded food into novel food products. Policy and financial incentives that can improve the viability of projects should also be identified.

Repurposing Food as Animal feed

This option involves repurposing wasted food originally intended for human consumption or a byproduct of food production (e.g., corn husks) as animal feed. It offers varying nutritive and economic benefits depending on the feedstock and processing methods, especially since wasted food can be nutrient rich, containing more crude protein compared to traditional maize (EPA, 2023). In the UK, approximately 660,000 tonnes of former foodstuffs valued at £110 million are annually processed into animal feed (WRAP, 2016). This strategy has large environmental implications, as 35% of global grain production currently goes towards animal feed (Shurson G.C., 2020).

However, not all food waste is suitable for animal feed due to safety, moisture content, and nutritional variability; criteria like origin, animal tissue presence, nutritional density, and processing extent help determine suitability or alternative uses such as insect meal production (Shurson, Dierenfeld and Dou, 2023). When substituting primary agricultural feed sources like soy meal, barley, and corn with wasted food it is important to ensure that animal health is not compromised (EPA 2023). To address feed safety concerns and maximize the utilization of wasted food, it is critical to have in place well-needed thermal processing facilities to eliminate pathogens in food waste, as well as the proper legislative framework to govern repurposing food waste into animal feed (Shurson, Dierenfeld and Dou, 2023). Due to historical food safety concerns related to disease transmission caused by feeding animals uncooked and untreated animal-derived food waste, many countries have adopted restrictive regulations and have not actively encouraged recovering food waste for use as animal feed (Shurson, Dierenfeld and Dou, 2023).

To maximize the reuse of wasted food as animal feed, Japan, South Korea, and Taiwan have adopted supportive regulations and invested in the required thermal processing infrastructure to control microbial contaminants (Shurson, Dierenfeld and Dou, 2023). For example, the Japan Food Waste Recycling Law (2007) requires increasing animal feed production with maximum domestic ingredients while specifying feed processing regulations and allowable uses of animal-derived food waste. This resulted in 74% of total business food waste being converted to animal feed by 2017 (Shurson, Dierenfeld and Dou, 2023).
In the UK, the "Using Surplus Food in Animal Feed" guide developed by WRAP for food and drink producers, manufacturers, retailers, logistics providers, and wholesalers that are diverting or considering diverting food surpluses to animal feed (WRAP, 2016), assists in identifying suitable surplus food, navigating legislation, and establishing effective processes. The guide includes three sections: (1) developing the business case, (2) practical guidance for diverting surplus food to animal feed, and (3) case studies from manufacturing and retail.

Surplus Dairy Products to Animal Feed: Arla Foods' Sustainability Initiative: Arla Foods, a leading dairy company, sought to improve sustainability by finding efficient uses for surplus milk and dairy products. Previously, these products were separated from their packaging and sent to anaerobic digestion plants as waste. To reduce costs and enhance sustainability, Arla Foods explored alternatives that could prevent waste and contribute to the circular economy.

In 2014, Arla Foods collaborated with partners to redirect surplus dairy products from anaerobic digestion plants to animal feed. This initiative, part of their broader sustainability program, focused on creating a controlled and replicable process to safely divert surplus food to animal feed. As a result, Arla Foods successfully diverted 100% of the surplus food to animal feed, achieving significant cost reductions compared to expenses associated with anaerobic digestion. By repurposing surplus dairy products, Arla Foods has effectively reduced waste and supported sustainable agriculture (WRAP, n.d.b).

8. Strong Infrastructure

A strong and reliable infrastructure is essential to reduce FLW throughout the value chain, from safe and accessible roads to proper cold chain infrastructure, a reliable electricity source, and clean water (IDB, 2022a). A study conducted by the International Food Policy Research Institute (IFPRI) assessed the return on investment from infrastructure development needed to reduce post-harvest loss conditions. The results indicated that "investment in infrastructure for reductions in post-harvest losses contributes to lower food prices, higher food availability and improved food security, and has positive economic rates of return" (World Bank, 2019). Infrastructure needs should be assessed according to each individual location's needs through stakeholder engagement as well as applicable and cost-effective solutions by the relative specialists.

Infrastructure upgrades should be done in conjunction with one another, the first step being safe and accessible roads to facilitate the introduction and expansion of other aspects such as cold chain infrastructure, access to clean water, the development of a reliable electricity grid, and the establishment of a strategic emergency food reserve. Upgrading infrastructure for handling and storage is also a critical aspect to prevent spoilage and wastage. USAID's Food Loss and Waste Value Chain Selection Guide (USAID, 2022) emphasizes the need to modernize storage infrastructure to mitigate losses and improve overall supply chain efficiency.

Safe and Accessible Roads

Safe and accessible roads are essential for the transportation of people, produce, and final products. Roads that are both safe and accessible throughout the year (regardless of weather conditions) ensure that perishable goods can be transported between farms, processing centers, and markets in a manner that does not attribute to spoilage or bruising of the product. Safe roads are also imperative to maintain a healthy, willing, and constant workforce throughout the value chain (FAO, 2019).

Rural Road Upgrades: India has a large agricultural sector that suffered from significant post-harvest losses, in part due to inefficiencies in transport and logistics. The Indian government invested in road improvements, including upgrading and expanding rural roads to increase connection for the agricultural sector. The "Pradhan Mantri Gram Sadak Yojana" (PMGSY) initiative aimed at providing all-weather road connectivity to remote villages. The project improved access to rural roads and directly contributed to faster travel time, reduced transportation costs, and improved accessibility (Singh, A., 2020).

The impact of these road improvements on agricultural productivity and food preservation has been significant. Prior to the upgrades, perishable goods often spoiled during long and complicated journeys from farm to market. With the enhanced road network, travel times were drastically reduced, allowing for quicker turnover of fresh produce and reducing the opportunity for spoilage. This not only helped in preserving the quality and nutritional value of food but also reduced economic losses for farmers and traders.

Proper Storage and Cold Chain Infrastructure

Proper storage and cold chain infrastructure play a pivotal role in reducing food losses, especially for a wide range of commodities such as cereals, pulses, oilseeds, fruits, vegetables, and animal protein products. Lack of climate-controlled storage is regarded as one of the primary causes of significant food commodity losses (Food Systems for Nutrition Innovation Lab [b], 2022). Factors other than temperature that need to be considered when designing proper storage solutions are light, temperature, moisture, contaminants (microbial and non-microbial), and pest and rodent infestations (Food Systems for Nutrition Innovation Lab [b], 2022). Given that different food types experience varying degrees of loss at different stages of the supply chain—for example, grains and cereals are more prone to losses during handling and storage, while fresh produce is more susceptible during processing and packaging—it is essential to tailor storage solutions to the specific needs of each food type and the local context (Flanagan, Robertson and Hanson, 2019). This approach ensures that interventions are both effective and efficient in minimizing food loss. Cold/thermal chain packaging (e.g., insulated boxes and mailers, gel packs, ice bricks, palette blankets) to control temperature and safeguard food commodities from when they leave storage until consumed is another important aspect to consider when evaluating storage capabilities and infrastructure.

According to the UC Davis, Horticulture Innovation Lab, another approach that is critical to the preservation of agricultural products and post-harvest handling are dry chain and dry storage (Feed the Future Innovation Lab for Horticulture, n.d.). **Dry chain** involves maintaining a continuous process of drying and keeping produce at safe moisture levels to prevent spoilage and contamination. This is particularly crucial for grains, seeds, and other perishable commodities that are highly susceptible to fungal growth,

mycotoxin contamination, and quality degradation when exposed to moisture. **Dry storage** refers to the methods and facilities used to store these dried products in a controlled environment, ensuring they remain dry and safe until they reach the consumer. Proper dry storage solutions include the use of airtight containers, moisture-proof packaging, and climate-controlled storage facilities that protect the stored goods from humidity, pests, and other environmental factors that could compromise their quality and safety (Food Systems for Nutrition Innovation Lab, 2022a).

Mobile Units Slash Food Loss in Sinaloa: in Culiacán, Sinaloa, Mexico, technology has significantly reduced post-harvest losses during the handling and transportation of eggplant, tomato, and chili pepper. In 1985, the region lost 70,000 tons of eggplant due to inefficient handling and transportation. The largest producer in the area identified this issue and introduced mobile factories and packaging units to the harvest sites. These mobile units, equipped with technology to wash, sort, and package eggplants directly from the field, transferred the produce to attached refrigerated trucks for distribution. This shift minimized physical damage, reduced food losses, and offered significant cost savings (e.g., elimination of static packaging facilities cut down on electricity usage for cold storage). The producer reported annual savings of US$70 million following the adoption of this technology.

Following its success, the mobile packaging model was rapidly adopted across Sinaloa for other crops such as tomatoes and chili peppers during their immediate post-harvest stages (World Bank, 2019).

Purdue Improved Crop Storage (PICS) bag: Purdue University developed the Purdue Improved Crop Storage (PICS) bag to provide an effective, affordable, and scalable storage solution for smallholder farmers, significantly reducing FLW. In many developing regions, traditional storage methods fail to protect crops from pests, mold, and moisture, leading to substantial post-harvest losses. PICS bags create an airtight storage environment with three layers: two inner liners made of high-density polyethylene and an outer woven layer for strength. This hermetic seal prevents pests and limits oxygen levels, inhibiting insect and mold growth without chemical treatments (PICS Network, n.d.).

Studies show that PICS bags significantly reduce post-harvest losses. For example, in Nigeria, cowpea storage losses dropped from over 50% to less than 5% with PICS bags. Similar results have been reported in Kenya, Uganda, and Burkina Faso, with dramatic reductions in losses of maize, sorghum, and other grains.

The simplicity and affordability of PICS bags have led to widespread adoption, with over 5 million farmers in more than 30 countries using this technology, demonstrating its scalability.

Constant and Reliable Electricity

A reliable and constant electricity supply is essential for the operation of irrigation systems, climate-controlled processing and storage facilities, manufacturing facilities, and more. In areas where electricity outages are common, food loss rates are higher due to suboptimal storage conditions and the need to process food faster. Rural areas that cannot be connected to a reliable and stable power grid can use renewable energy sources to include in their local power grid, such as solar-powered cold storage units. Implementing low cost, off-grid facilities such as solar-powered cold storage units offer a viable solution for maintaining a constant energy supply (World Bank, 2019).

Solar Cold Storage—a Game-changer in Agriculture: Kenya, located on a solar belt, receives year-round sunshine, making solar energy a viable option for the country's economic and social needs. Many rural areas lack access to the national electricity grid, and solar energy offers decentralized, off-grid, or mini-grid systems to provide electricity to these remote communities. This not only enhances quality of life but also supports rural development by powering schools, healthcare facilities, and businesses (Nwokolo et al., 2024).

The introduction of solar-powered cold storage facilities in Kenya marks a significant advancement in the country's agricultural and renewable energy sectors. These facilities address food loss and the

scarcity of reliable electricity in rural areas, where most agricultural activities take place. By harnessing the solar energy, these cold storage units provide a reliable and sustainable method to preserve perishable agricultural products such as fruits and vegetables. The optimal temperatures extend their shelf life, reducing waste and increasing food availability.

Clean and Reliable Water Source

Clean and reliable water sources are essential not only for the production of food, but also for its processing, preservation, and preparation. Access to clean water directly impacts several areas within the FSC, reducing overall FLW. In the production stage, clean water is vital in crop irrigation, reducing the risk of crop disease, crop failure, reduced produce quality, and harvest loss. In the processing stage, clean water is required to process raw materials in ways that maintain hygiene standards, reduce bacterial count, and ensure that food products are safe for consumption, thereby reducing overall loss due to spoilage and contamination. Clean water is also required during food preservation to maintain freshness and extend shelf life (FAO, 2019). Finally, hygiene is a requirement throughout the FSC to reduce spoilage and foodborne diseases, thus reducing waste.

Empowering Women Farmers in Senegal Through Solar-powered Water Pumps: the rural town of Potou, located in an arid region of Senegal, faces challenges with water access due to short wet seasons, long dry seasons, and the high costs of diesel-powered water pumps. This inconsistency in water availability has adversely affected the crop yields and livelihoods of smallholder farmers (USAID, 2023).

Through a USAID project, 132 women from the Cooperative of Women Producers of Potou have received 18 solar-powered water pumps, significantly empowering women in agriculture. The broader program has installed 247 solar pumps across Feed the Future zones, covering 520 hectares and benefiting numerous small producers. The initiative emphasizes affordability and sustainability by offsetting the cost of pumps by 30-40% and ensuring proper design, installation, and maintenance through partnerships with solar energy providers. The project provided an innovative approach to addressing water scarcity and agricultural productivity while reducing GHG emissions. These technologies improved access to clean water, positively affecting crop health and yields.

Strategic Emergency Food Reserves Linked to Social Protection Programmes

Emergencies such as natural disasters, pandemics and conflicts can disrupt food systems and generate a substantial level of FLW. In collaboration with relief agencies, development organizations, and other relevant partners and stakeholders, governments should take measures to reduce FLW in the preparedness, response, recovery, and rehabilitation phases of emergencies. Measures taken should align with the “Sendai Framework for Disaster Risk Reduction 2015–2030” (FAO, 2022). Establishing a strategic emergency food reserve is critical for mitigating FLW, especially in times of crisis. When linked to social protection programs, these reserves can enhance food security and provide a safety net for vulnerable populations.

Strategic food reserves are large scale storage systems managed by governments or international organizations, activated to distribute food to designated areas that experience food shortages. When the food reserves are linked to social protection programs, they create a more resilient and responsive food system. The social programs have existing mechanisms to identify and reach vulnerable populations that can be used during emergencies, and they are also able to ensure surplus food is stored for later use instead of going to waste (FAO, 2022).

Establishing strategic emergency food reserves that are effectively linked with social protection programs offers a robust mechanism to reduce FLW while enhancing food security. This integrated approach ensures that during times of crisis, vulnerable populations have access to the food they need, thereby mitigating the impacts of food insecurity and stabilizing food supplies (FAO, 2022).

9. Integrated Collaboration

The global food system is an interconnected entity that involves an integrated network of stakeholders from the FSC. The activities vary and span from production, processing, distribution, consumption, and disposal of food and food-related products. There is a need for collaboration and a systemic approach when tackling FLW as a regional or global issue (HLPE, 2017).

Because of this, it is recommended to engage a broad spectrum of stakeholders throughout the process in preventing, reducing, and redistributing FLW. The stakeholders involved should represent the entire sector, which includes all actors from the food production stage (including farmers and all entities that provide the inputs required to produce food) to consumption and food disposal points (UNEP, 2024). These stakeholders include government decision-makers, producers (crop, animal, and aquaculture farmers, fishers, hunters, foragers), food processors and manufacturers (primary producers, packaging houses, storage, transportation, and logistics service providers, slaughter houses, processors, manufacturers), wholesale markets, formal and informal retailers, food services (restaurants, caterers, hotels, hospitals, schools, cafeterias, charities, food banks), social enterprises in the food business, and households.

Once the stakeholders have been mapped and identified, it is crucial to facilitate the coordination and collaboration between the actors within the FSCs. Strengthening commodity, sector, location, and industry associations and promoting public-private partnerships (PPPs) can significantly enhance research and development, infrastructure investments, access to finance, and value chain development (UNEP, 2024). Additionally, fostering collaboration between national and local governments and bolstering multi-stakeholder platforms for awareness-raising, advocacy, and the exchange of experiences, knowledge, and information also contribute to mitigating secondary causes of FLW.

Inclusive Value Chain Development

Inclusive value chain development is crucial to addressing FLW by promoting collaboration among the stakeholders in the FSC. Collaborative working groups play a vital role in sharing lessons learned and best practices, participating in demonstration projects, and developing solutions to collective challenges. These groups facilitate the exchange of knowledge and innovations, which are essential for tackling FLW effectively. FAO's "Guidelines for Action on Food Loss and Waste Reduction in the Near East and North Africa" emphasize the importance of such collaborative efforts in achieving sustainable FLW reduction (FAO, 2021).

USAID's "Food Loss and Waste Value Chain Selection Guide" (USAID, 2022) provides a practical decision support process for projects to integrate FLW in the value chain development process. It recognizes the importance of collaboration and mentions that specific working groups (involving stakeholders such as local agricultural experts to community leaders) are formed for different parts of the value chain based on a common objective.

This guide provides a framework for selecting and prioritizing value chains based on FLW criteria such as economic outcomes, food security, and environmental impact. By helping organizations plan and mobilize resources effectively, the guide aids in the systematic reduction of FLW (USAID, 2022).

VC Development for Food Security: in Egypt, the "Food Loss and Waste Reduction and Value Chain Development for Food Security in Egypt and Tunisia" project focused on several critical points along the FSC, particularly during the production, handling, processing, and distribution stages, where roughly two-thirds of food loss occurs. The project aimed to enhance the efficiency of these value chains by incorporating smallholders and marginalized groups, thereby promoting more inclusive economic opportunities and improving food security. The initiatives included training programs, capacity-building

activities, and the introduction of innovative technologies and practices to reduce FLW along the value chain (FAO, n.d.).

Key components of the project involved improving post-harvest practices, promoting better storage solutions, and enhancing marketing and processing activities. By addressing these areas, the project sought to reduce food loss during the production and distribution stages, ensuring that more food reaches consumers in good condition. Additionally, the project emphasized the importance of creating rural off-farm and agro-industry employment opportunities, thereby fostering economic growth and resilience in rural communities (FAO, n.d.).

The project's value chain development approach was crucial in achieving its objectives. By focusing on improving various stages of the value chain, from production to market, the project ensured that interventions were holistic and addressed the root causes of food loss. This comprehensive strategy not only reduced FLW but also built capacity among stakeholders, ensuring the sustainability of the interventions. The value chain development approach enabled the project to integrate smallholders into the market, improve their livelihoods, and enhance food security in the region (FAO, n.d.).

Stakeholder Mapping

When approaching integrated collaboration, including coordination between FSC actors, deployment of PPP models, and sharing resources and best practices amongst stakeholders, it is important to identify and map the connections of all actors within the FSC. A mixed methodology approach is suggested when identifying stakeholders (Surucu-Balci and Tuna, 2022). The roles and powers to implement change within each sector of the FSC should be identified when conducting the mapping exercise; toolkits and guidelines to follow for this activity is widely available (UNEP, FAO and UNDP, 2023). Various methodologies are available for mapping stakeholders, each tailored to accommodate different country-specific contexts. The consensus on the steps to conduct stakeholder mapping involves several key phases (World Bank, 2016), mainly:

1. **Clearly identify the aim of the exercise**: determine the goal of the stakeholder mapping process and understand why it is necessary. This clarity of purpose ensures that the mapping exercise is focused and effective. Next, conduct a comprehensive mapping of stakeholders. This should include as many stakeholders as possible, informed by a combination of literature reviews, insights from government policy and climate experts, and interviews. This comprehensive approach ensures a broad and inclusive identification of relevant stakeholders.

2. **Categorize stakeholders**: categorization helps in organizing the stakeholders and understanding their roles and influences within the FSC and FLW reduction initiatives. Stakeholders can be categorized into three main groups: governments, businesses, and civil society organizations (CSOs). For a more detailed analysis, these categories can be further broken down according to the different stages within the FSC. In the production stage, stakeholders include farmers, agricultural cooperatives, and agribusiness companies involved in the cultivation of crops and livestock. The handling and storage stage encompasses entities responsible for post-harvest handling, storage facilities, and logistics companies. Processing and packaging involve food processing companies, packaging manufacturers, and technology providers for food preservation. Distribution and marketing consist of wholesalers, retailers, supermarkets, and marketing organizations that facilitate the distribution and sale of food products. Finally, the consumption stage covers consumers, consumer advocacy groups, restaurants, food service providers, and waste management services. By breaking down the stakeholder categories in this manner, we can achieve a more comprehensive understanding of the roles and influences of different entities within the FSC, facilitating targeted strategies for FLW reduction (Flanagan, Robertson and Hanson, 2019).

3. **Analysis of the interconnectedness of all actors**: once stakeholders are identified and mapped it is important to understand the social network structures, actor positions, and their influence within the FSC to identify the decisions and actions required to drive the desired changes. To begin with, identifying how stakeholders are connected, what the nature of their relationship is and how the flow of information and resources between them occur is essential to recognize the collaborative potential between them. Each actor within the FSC has a different role and position that can influence change, for example, government agencies may hold regulatory power, businesses may have economic leverage, and CSOs may possess social capital and community trust.
4. **Influence mapping**: this phase involves assessing the power dynamics among stakeholders, considering both formal authority and informal networks, reputation, and access to critical resources. For example, a local farmers' cooperative might wield significant influence within its community due to grassroots connections, even if it lacks formal regulatory power (Mitchell, Agle, & Wood, 1997).

Stakeholder mapping is an essential step in understanding the interconnectedness of all actors in the FSC, and changes in one area can have a ripple effect throughout the system (UNEP, FAO and UNDP, 2023). Recognizing this interconnectedness of all actors ensures that strategies are comprehensive and inclusive, ultimately driving more effective and sustainable outcomes. By following a structured and systematic approach to stakeholder mapping, key players in the agri-food sector can be effectively identified and engaged (HLPE, 2017). An example of the stakeholders within the FCS is depicted in **Figure 4**.

This process not only enhances the understanding of the complex network of stakeholders but also provides insights into their roles, influences, and interactions. These insights are crucial for developing targeted strategies for reducing FLW, promoting a circular economy, and implementing regenerative agricultural practices. A thorough stakeholder analysis examines social network structures, actor positions, and their influence. It identifies collaborative potential and key influencers who can drive systemic change (World Bank, 2016).

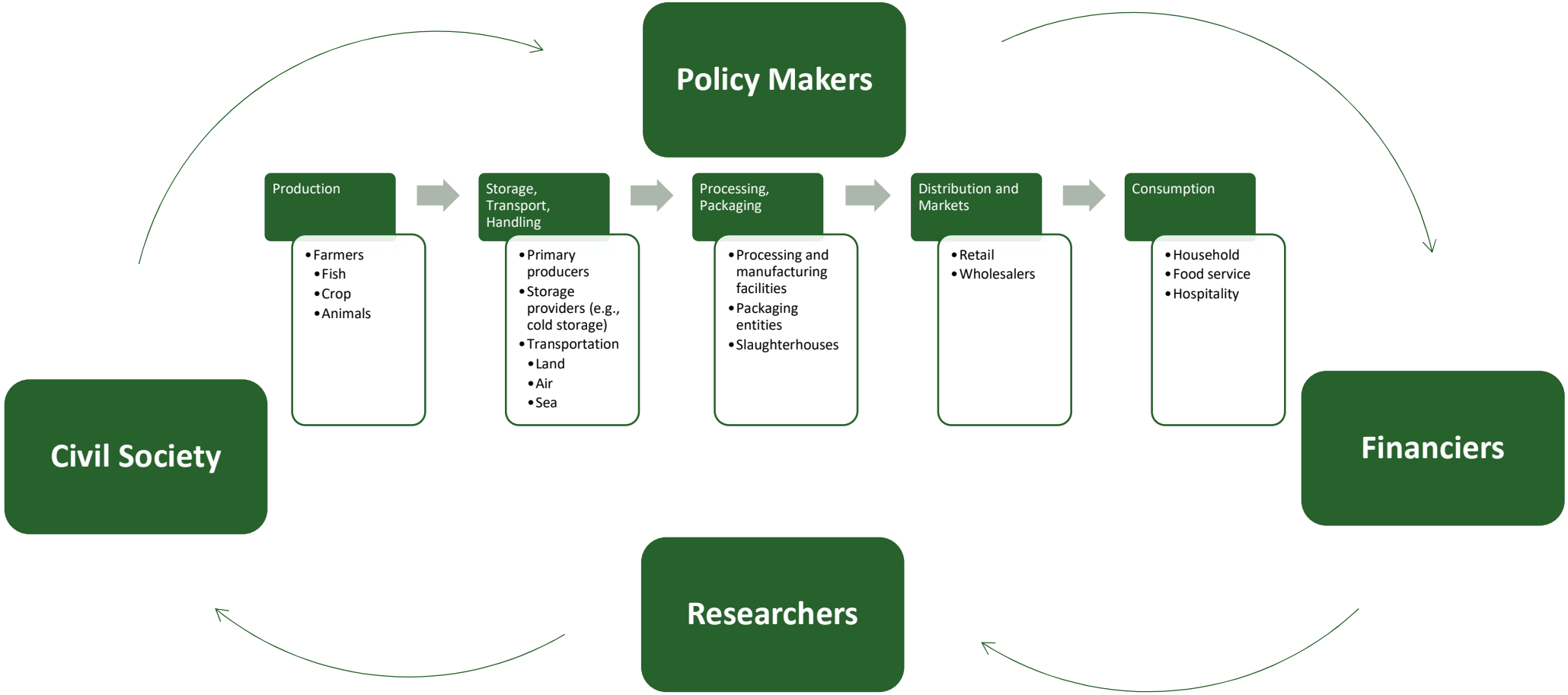
Effective stakeholder mapping facilitates the development of comprehensive and inclusive strategies, enhancing sustainability in the agri-food sector by recognizing the complex interplay of actors and their respective impacts on the system (UNEP, FAO and UNDP, 2023).

Multi-stakeholder Platforms

A multiple stakeholder platform (MSP) for FLW brings together various stakeholders from government, the private sector, civil society organizations, and academia to address FLW. The primary function of an MSP is to create a structured and inclusive framework to reduce FLW by facilitating cooperation, sharing best practices and developing coordinated strategies and policies. By fostering the exchange of strategies and best practices, MSPs provide a vital space for stakeholders facing similar challenges to collaborate. This pre-competitive exchange of knowledge and collaborative problem-solving enhances the speed and efficiency of FLW reduction initiatives. It is not merely sharing information, but also pooling resources and insights to tackle common problems more effectively (Netherlands Food Partnership, 2021).

Such cooperative approaches hasten the adoption of innovative solutions and improve their cost-effectiveness. Through such synergistic collaboration, stakeholders can leverage collective expertise and experiences, driving more impactful and economically viable FLW reduction strategies. This method turns individual challenges into shared opportunities for advancement, demonstrating the power of unity in addressing complex issues. MSPs are not mandatory but provide a structured and inclusive approach to reduce FLW by sharing best practices, developing coordinated policies and strategies, and facilitating cooperation (including monitoring, evaluation, and accountability mechanisms) (Netherlands Food Partnership, 2021).

Figure 4: Stakeholder Mapping: Actors in the Food Value Chain



EU FUSIONS Multi-stakeholder Platform: EU FUSIONS (Food Use for Social Innovation by Optimizing Waste Prevention Strategies) was a European project aimed at reducing food waste through social innovation. Running from August 2012 to July 2016 and funded by the European Commission's Framework Program 7, it involved 21 partners from 13 countries. The project aimed to harmonize food waste monitoring across the EU, determine social innovation's role in reducing food waste, develop guidelines for a common EU food waste policy, and contribute to the European Commission's target of a 50% reduction in food waste by 2020.

A central feature of FUSIONS was the multi-stakeholder platform, which facilitated collaboration among over 200 leading European organizations, including universities, research institutes, consumer organizations, and businesses. The project was divided into five work packages focusing on reliable data sources, stakeholder collaboration, policy recommendations, feasibility studies, and dissemination. FUSIONS achieved significant milestones, such as developing standardized methodologies for food waste reporting, organizing platform meetings, analyzing existing legislation, and launching feasibility studies to test social innovation solutions. The project has played a crucial role in raising awareness and providing actionable strategies for reducing food waste in Europe, fostering collaboration across sectors and countries to create a sustainable food system.

Working Together for Change: in 2018, Argentina (IDB, 2022a) took a significant legislative step by passing Law 27.454, establishing a comprehensive national strategy aimed at diminishing FLW and aligning with the objectives of SDG 12.3. This pivotal legislation empowered the Ministry of Food and Bioeconomy with the responsibility to craft and implement public policies and initiatives designed to curb FLW across the nation. To bolster private sector engagement in these efforts, the Argentine government amended Law 25.989 to enhance legal protections for food donors and intermediaries against potential litigation related to food donations.

Further solidifying its commitment to FLW reduction, the Argentine government initiated a national FLW network in 2016, which, as reported, includes over 150 entities spanning private sector companies, non-profit organizations, and civic groups. This network convenes regularly to exchange best practices, discuss policy updates, confront shared challenges, and explore collective actions to combat FLW. These collaborations have been instrumental in setting national FLW priorities, such as improving food donation systems, standardizing FLW metrics and reporting processes, and addressing critical loss points, particularly in the fresh produce sector.

To tackle these challenges, Argentina has forged strategic partnerships, including with the Inter-American Development Bank, IBM Argentina, and the Argentine Network of Food Banks. One notable initiative is the #SinDesperdicioHortícola contest, designed to fund and mentor projects with innovative solutions to reduce on-farm and post-harvest losses. Organized into various working groups (WGs), the network systematically addresses FLW causes across different sectors. Notably, the industry and retail WG includes leading food, beverage, and retail companies committed to measuring FLW and exchanging effective practices. The universities WG focuses on raising awareness and fostering research, while the newly formed municipalities and local governments WG aims to encourage local FLW policies. Additionally, the Ministry of Agriculture, Livestock, and Fisheries is actively working to promote FLW reduction among small and medium enterprises (SMEs), within a broader initiative to enhance competitiveness and add value in this sector.

Public-Private Partnership

Engaging public and private stakeholders to drive food waste reduction through PPPs across the entire supply chain is another key strategy. Known as "voluntary agreements," PPPs foster collaborative efforts to achieve shared goals, specifically targeting waste generated at various stages of the food system (UNEP,

2024). By uniting stakeholders from different segments of the supply chain, these partnerships address the system's fragmentation. Establishing a PPP highlights the collective responsibility of international organizations, national governments, businesses, and consumers in tackling FLW. Globally, this approach has proven impactful, significantly reducing food waste, combating food insecurity, and lowering costs.

The suggested PPP model that addresses food surplus, loss, and waste as outlined in the FWI Report (UNEP,2024) leverages the "Target-Measure-Act" approach to drive impactful and measurable reductions in FLW. This approach ensures that participants (from private and public sectors) set clear measurable targets, use a standardized measurement and reporting methodology, and take collective action to mitigate these issues. The framework is adaptable to local contexts and consists of four key components:

1- **Strategy and commitment**: the stakeholder is involved in the PPP and required to have a vision or aim for FLW reduction. This in turn is complemented by a set of agreed upon collective targets, and an overall delivery road map to ensure the targets can be achieved.

2- **Collective activity**: the road map will detail the interventions required to achieve the targets through collaborative efforts, such as working groups, pilot projects, campaigns, and reporting.

3- **Outputs**: in line with the PPP vision, outputs to support the delivery of the targets may include guidance documents and reports, developed approaches based on pilot studies within local context, and some industry-based recommendations.

4- **Impact**: the impacts include measurement reporting and progress tracking documents as well as action taken by members based on findings of the outputs.

This framework is designed to continuously report feedback and refine the targets and road map to ensure that the impact is maximized, with the delivery through a governance structure guided by representatives across the food system or sectors relevant to the PPP.

Effective stakeholder engagement is paramount to the success of PPPs in addressing FLW. Strategic stakeholder mapping is essential to identify and engage the right signatories aligned with the collective targets of the PPP. Private sector organizations across the entire FSC, including manufacturers, retailers, wholesalers, food service organizations, waste management companies, trade bodies, agricultural businesses, and farmers should be strategically recruited to ensure comprehensive representation and effective collaboration, facilitating a holistic approach to FLW reduction.

PPPs play a crucial role in leveraging funding for FLW reduction by combining resources and expertise from the public and private sectors, ensuring sustainable and scalable solutions. PPPs enable the pooling of financial resources from various stakeholders, including government, private sector, non-governmental organizations (NGOs), and international organizations, increasing the overall funding available for FLW reduction projects (OECD, 2008). PPPs provide different financial mechanisms for innovative solutions. These funding types include seed funding, long-term funding, and bridge funding, each playing a distinct role in addressing different stages of project development and implementation (UNEP, 2024). The more detailed PPP funding mechanisms such as build-operate-transfer, joint venture, and concessions depend on the specific project, the funding available, and the local context. These need to be assessed on a project by project basis and will not be further discussed in this section.

Seed funding is the financing required in the initiation or setup phase to establish a strong value-added proposition to possible funders. It provides financial resources to develop exploratory studies, implementation plans, and recruitment strategies, and is usually provided by the government to leverage the private sector resources (UNEP, 2024). However, reliance on government funding may expose PPPs to risks from competing policy priorities or changes in government (OECD, 2008). International organizations and development aid can be sources of seed funding, particularly for projects focused on food

redistribution or alleviating food insecurity. Trusts and foundations can also offer seed funding. This usually occurs when the goals of the PPP align with their entity objectives. In some cases, the private sector can provide seed funding, especially if the PPP's objectives align with their business goals (UNEP, 2024).

Bridge funding ensures a seamless transition from the initiation phase to full-scale operations. After the seed funding phase of project startup, the project is required to be financially sustainable during the operation phase. Governments and businesses, the primary stakeholders, are likely to provide this bridge funding due to the significant benefits they stand to gain in terms of savings, operational sustainability, and food security (OECD, 2008). The benefits include socioeconomic elements such as job security and development, food availability, and better living conditions due to less waste and reduction of greenhouse gas emissions (UNEP, 2024). Businesses involved in PPPs, referred to as signatories, contribute to the long-term financial stability of these initiatives. Establishing the concept of business contributions early is crucial to avoid resistance from business participants later in the process. These contributions should be fair and proportional to the size of the business. For instance, they may be based on sales turnover in the relevant market. Businesses benefit from reducing their own operational costs, gaining insights from the collective experience of other PPP members, and enhancing their image and reputation. Thus, for businesses, funding and participating in PPPs is an investment in their sustainability (OECD, 2008; UNEP, 2024).

Long-term funding will build upon the foundation established by bridge funding. Having a large and committed base of signatories will be crucial for ensuring long-term stability, along with diversified funding sources such as national and municipal governments and international financing. A diversified funding model is the most resilient, as it mitigates risks associated with reliance on a single funding source, such as changes in government (UNEP, 2024).

PPP success requires sustainable funding. The required level of financial support varies based on local circumstances and the PPP's scope and ambition. PPPs in larger countries or those with substantial agri-food industries, such as major exporters, or PPPs addressing multiple issues across the entire supply chain will need more funding. In contrast, smaller, lower-income countries or PPPs with a narrower focus will require less financial support. This tailored approach ensures that each PPP can effectively meet its objectives and deliver meaningful reductions in food waste (UNEP, 2024).

Continuous and stable funding is crucial for the sustainability of PPPs. Signatories can contribute through membership fees as part of a mixed funding model. This approach not only ensures a steady financial base but also aligns the interests of the members towards achieving the PPP's goals. Research shows a significant return on investment, with every $1 invested in FLW reduction yielding a $14 return, underscoring the financial viability and benefit of these initiatives (REFRESH, 2021).

Third parties, including non-governmental organizations, trade associations, and research institutions, play a critical role in enhancing the credibility and effectiveness of PPPs. These entities can be specifically established to deliver PPP objectives, providing neutral and independent advice while avoiding conflicts of interest. Researchers and academia significantly contribute by participating in working groups or committees and supporting negotiation, implementation, and administrative processes.

The REFRESH (Resource Efficient Food and Drink for the Entire Supply Chain) PPP model suggests a collaborative approach to cutting food waste. This model can be used to set up new legislation and provide competitive space for companies to work together (REFRESH, 2021). There are five key steps in setting up the PPP:

1- **Initiation and setup**: gather data to understand local context, identify current policies, and map key stakeholders. During this phase the vision and purpose of the PPP should be defined, the types of agreements required by and between the signatories identified, a timeline of key deliverables set, and the baseline established.

2- **Ambitions, goals, and targets**: when discussing FLW, it is easy to set a target that aligns with UN SDG 12.3, with PPPs contributing to this target. Targets should complement existing national initiatives and plans to set a long-term goal. Collective measures to reduce FLW are required, and businesses should set measurable targets to contribute to the overall goal. They can also assist and influence businesses upstream or downstream to reduce FLW.

3- **Governance and funding**: Stakeholder engagement and a robust governance structure (including a steering committee and an independent secretariat that oversees and coordinates the PPP's activities) ensuring progress towards targets is critical to a successful PPP model. Funding is required to help manage the group. This funding can originate from the government, members, or both. It is also recommended that the group communicate a strong business case to reduce FLW, with a high return on investment. This type of investment can pay dividends to the funders.

4- **Establishing actions**: PPPs should carry out a gap analysis by exploring the existing food waste initiatives. Are the initiatives enough to meet the FLW reduction goals? If not, where within the FSC does more action need to be taken? Finally, actions need to be agreed upon within each subsector. When actions are decided collaboratively by a group of members, they are more likely to achieve these goals than if the actions are imposed on them.

5- **Measurement and evaluation**: when working towards a goal for FLW reduction, it is important to establish a baseline to work from, establish a data collection process, and use a recognized reporting standard. This is the basis of the "Target-Measure-Act" approach as outlined by WRAP in the "Food Waste Reduction Roadmap, 2023."

REFRESH Netherlands Voluntary Agreement to address FLW: the REFRESH project aimed to tackle FLW across Europe through voluntary agreements and collaborative efforts among diverse stakeholders. One notable implementation of this voluntary agreement that exemplifies how multi-stakeholder collaboration can effectively address FLW at various levels of the FSC was in the Netherlands, where the Samen Tegen Voedselverspilling (Foundation Together Against Food Waste) was established.

The primary objective of Samen Tegen Voedselverspilling was to reduce food waste by 50% by 2030, in line with SDG target 12.3. The foundation sought to achieve this by coordinating efforts across companies, knowledge institutions, governments, and citizens, focusing on the food service sector, retail, and households.

The foundation employed a comprehensive methodology that included stakeholder engagement, data collection and analysis, targeted interventions, and regular monitoring and reporting. Key actions included consumer education campaigns, collaborations with supermarkets and restaurants for better inventory management and food donation, and the development of apps to track and reduce food waste.

The Samen Tegen Voedselverspilling initiative achieved significant reductions in food waste, increased consumer awareness and behavioral change, and enhanced collaboration among stakeholders. Consumer surveys indicated a higher awareness of food waste issues and a greater willingness to adopt waste-reducing behaviors, while educational programs in schools helped instill these values in younger generations. Additionally, the initiative fostered stronger partnerships among stakeholders, creating a cohesive network focused on sustainable food practices.

Several key lessons emerged from the initiative, including the importance of a holistic approach, data-driven decision-making, consumer engagement, and adaptability. Addressing food waste requires a comprehensive strategy that engages stakeholders across the entire supply chain, while accurate data collection and analysis are crucial for identifying waste hotspots and measuring the impact of interventions. Educating and empowering consumers is essential for reducing food waste at the

household level, and the ability to adapt strategies based on monitoring and feedback is critical for ongoing success.

In conclusion, the Samen Tegen Voedselverspilling initiative demonstrates the effectiveness of voluntary agreements and multi-stakeholder collaboration in reducing FLW. By coordinating efforts across companies, knowledge institutions, governments, and citizens, the foundation made significant strides toward achieving its waste reduction goals. (REFRESH, 2021).

10. Research for Innovation

Innovation is the process of creating, proposing, and initiating new ideas, processes, methods, products, services, or solutions. It can also involve improving existing ideas, products, and services to deliver outcomes that boost efficiency and effectiveness or address unmet needs (Dodgson et. al. 2013). Useful innovations are long lasting and create significant positive impact and value (Salter and Alexy, 2014). For innovation to arise, an enabling environment that consists of a particular socio-economic, political, and institutional context is required (IICA, 2014).

Role of Research for innovation in FLW: research and development (R&D) play a critical role in building and promoting innovations that address the challenge of FLW. The TMA approach benefits from innovation throughout its process and requires the gathering and analysis of large data sets, developing innovative solutions for data analytics to identify patterns and trends, and advanced monitoring tools that rely on sensors and blockchain technology. These tools provide accurate, real-time data to measure progress against set targets and drive the development of tools that are needed to address any identified hotspots within the FSC.

Research is needed to develop technologies and practices that improve food production, handling, and storage to prevent FLW throughout the food value chain (FVC), especially effective storage and cold chain infrastructure (FAO, 2011). Innovation in precision agriculture, such as internet of things (IoT) devices and drones, provide real-time data on crop health and allow for timely interventions to prevent losses due to pests, diseases, or unfavorable weather conditions. R&D ensures that these innovations are adapted to local situations. Research into advanced storage solutions such as hermetic storage bags and controlled atmosphere storage has proven effective in extending the shelf life of various commodities. Similarly, cold chain innovations, including solar-powered refrigeration and thermal insulation materials, keep perishable foods at optimal temperatures throughout the supply chain. This infrastructure reduces food spoilage and maintains food quality from farm to fork. Research provides the methodologies and tools needed for monitoring systems such as remote sensing and satellite imagery that can monitor crop conditions and post-harvest handling practices. Additionally, machine learning algorithms can analyze data to predict potential FLW hotspots and suggest preventive measures. Regular evaluation of these systems helps refine practices and technologies, ensuring they remain effective and adaptable to changing conditions.

Research is needed to enhance nutritional databases, develop prediction equations, conduct risk assessments, and establish biosecurity protocols for converting food waste into animal feed (Shurson G.C., 2020). As mentioned earlier, there are health risks that need to be addressed to ensure animal safety when using wasted food as animal feed, and research can support in this area. Research for innovation in how various food by-products can be upcycled into nutritional food products will not only reduce FLW, but also generate economic opportunities.

Black Soldier Fly and Its Role in Agricultural Waste Management: in an innovative move to address agricultural waste management, the Australian government provided a $2.5 million grant to support the development of Black Soldier Fly (BSF) technology. This initiative, led by the University of Western

Australia in collaboration with Australian Pork Limited, aims to transform agricultural waste into valuable by-products, such as protein-rich feed for livestock and high-quality compost.

This project is expected to significantly reduce greenhouse gas emissions and align with Australia's broader environmental goals. The grant also facilitates research and development efforts to optimize the BSF processes, ensuring scalability and effectiveness across different agricultural settings (University of Western Australia, 2020).

Innovation Ecosystems: successful innovation ecosystems are marked by interactive networks spanning multiple levels, comprising a diverse and intricate network of stakeholders from both the public and private sectors (Fukuda and Watanabe, 2012). This collaboration accelerates the development and dissemination of new technologies critical for reducing FLW (UNEP, 2024). Multi-stakeholder platforms bring together various actors, including governments, private companies, research institutions, non-governmental organizations and farmer groups, to collaborate on reduction efforts, leading to more holistic and context-specific solutions for different segments of the FSC (Global Food Loss and Waste Research Platform, n.d). These platforms provide a space for capacity building, knowledge exchange, and dissemination of research findings and innovations through conferences, workshops, and trainings. PPPs leverage the strengths and resources of diverse stakeholders to drive innovative solutions across the FSC, pooling funding, technical support, and human resources, sharing risks, and aligning to common goals (UNEP, 2024). Private sector partners contribute technological expertise and innovation capacity, while public entities provide regulatory support and infrastructure. Financial backing can come from either or both.

Dodgson et. al (2013) highlight that in addition to the involvement of a diverse range of contributors, successful innovation requires the ability to integrate various technical inputs throughout the process. They identify six broad innovation processes that institutions use to coordinate resources to create, deliver, and capture innovations:

1. **Research- and technology-led process**: utilizing science as a stimulus for innovation
2. **Market-facing approach**: responding to market demand and engaging users in the development process
3. **Internal coupling**: cross-departmental and inter-departmental teams with multidisciplinary skills
4. **External collaboration**: involving the private sector, universities, research institutes, customers, and suppliers
5. **Strategic integration**: supporting overall objectives and addressing actual needs
6. **Future readiness**: increasing adaptive capacity for disruptions

Role of Governments: government organizations promote innovation by creating a well-connected innovation ecosystem through shaping effective policies, providing the required infrastructure, and funding research and development (Fukuda and Watanabe. 2012). By supporting firms in transforming research into market solutions and collaborating with universities and research institutes, governments can enhance both the ecosystem's performance and the performance of individual stakeholders (Fukuda & Watanabe. 2012). Salter and Alexy (2014) point out that the level of investment in research and development is an indicator of the level of innovation.

Innovations for the Future: the Foundation for Food & Agriculture Research (FFAR, n.d.) is a leading organization dedicated to advancing research and innovation in food and agriculture. FFAR builds partnerships to leverage combined resources and expertise for impactful research that tackles critical challenges, including a wide range of research projects that address different aspects of FLW. The Food Waste Challenge, launched in collaboration with The Kroger Co. Zero Hunger | Zero Waste Foundation, seeks to develop innovative methodologies for measuring household food waste in the US. This project

emphasizes the importance of accurate data in designing effective interventions to reduce FLW at the consumer level.

The Consortium for Innovation in Post-Harvest Loss & Food Waste Reduction brings together global experts to develop solutions that preserve food quality, enhance nutrition, and improve livelihoods by improving post-harvest storage technologies, and developing new food processing and packaging methods. The Health-Agriculture Nexus Challenge Area supports pioneering research to decrease FLW while improving food and nutrition security by taking a systems-level approach. Projects under this initiative evaluate the interactions within food systems to identify actionable solutions that increase access to nutritious foods and reduce waste.

By fostering PPPs, funding diverse research initiatives, and focusing on innovative technologies, FFAR enables the development and implementation of best management practices to address the immediate challenges of FLW.

11. Utilizing Technological Innovations

Embracing technological innovations offers a vital path to transforming operations within the food industry into more sustainable and efficient systems. By integrating advanced technologies and applications, businesses can significantly improve their management of FLW across multiple sectors. Innovations utilizing low-cost, environmentally sustainable methods hold the greatest potential in developing countries (Feed the Future Innovation Food Lab, 2022b). This section explores how such innovations enhance operational efficiency and reduce waste, leading to improved profitability and reduced environmental impact.

Lack of real-time, reliable information is mainly a problem for smallholder farmers, where access to information regarding pricing impacts decision-making processes and in turn will contribute to on-farm FLW. When pricing information is unavailable, this hinders decisions for optimal harvest timings and post-harvest handling. For example, if farmers delay harvest due to hopes of better prices, this leads to an increase in overripe produce and spoilage. Alternatively, farmers may harvest prematurely, leading to lower quality products and ultimately, spoilage. Without proper information, farmers may be less likely to invest in improved storage facilities with regulated temperatures and humidity controls that will reduce post-harvest losses if the farmers are required to store their produce after harvest while waiting for better prices or higher produce demand.

Real-time information regarding anticipated weather patterns can also help farmers prepare for adverse weather conditions. Access to timely and accurate weather forecasts allows farmers to make informed decisions about the timing of planting, harvesting, and the application of inputs like water and fertilizers. For instance, if heavy rainfall is anticipated, farmers can choose to harvest crops early to avoid crop loss due to flooding. Conversely, in the case of an impending drought, they can adjust their irrigation schedules to conserve water or decide to plant drought-resistant crop varieties. This preparation is vital for minimizing the potential damage to crops and infrastructure, thereby reducing the risk of FLW.

AI Food Inspectors: AgShift, a cutting-edge technology company, uses artificial intelligence (AI) and computer vision to automate the quality inspection of agricultural commodities such as grains, fruits, and vegetables. Traditional quality inspection in agriculture relies heavily on manual processes, which are time-consuming and prone to inconsistencies due to human error and subjectivity. These inconsistencies often lead to the rejection of good produce or the acceptance of substandard items, resulting in significant food waste and financial losses (Jha, 2018).

The technology involved during the inspection phase captures high-resolution images of produce and analyzes them using advanced AI algorithms to detect defects such as bruises, discoloration, and mold. High-resolution cameras capture detailed images of the produce from multiple angles, which are then processed using AgShift's AI algorithms, trained on extensive datasets to recognize various defects. The system provides quick, real-time analysis that categorizes produce based on quality standards, identifying defects and enabling quick decision-making.

The automated system ensures consistent and accurate inspections, eliminating the subjectivity associated with human inspectors, leading to more reliable quality assessments and reducing the rejection of good produce. By accurately identifying defects, AgShift minimizes the unnecessary disposal of consumable produce, reducing overall food waste and enhancing the efficiency of the supply chain. Automation speeds up the inspection process, reducing the time required for quality checks and enabling faster processing and distribution of produce. Improved accuracy and reduced waste translate into cost savings for producers and distributors, enhancing profitability and sustainability.

The use of AI for tacking FLW has gained traction in the last few years and increases by the day. AI technology can be used throughout the FSC to identify and quantify waste, ultimately reducing it. In the field, AI smart farming techniques and precision agriculture have been used as a predictive analysis tool for harvesting to minimize pre-harvest losses by picking crops at their peak condition, reducing the risk of premature or delayed harvest times. This reduces food loss due to spoilage and ensures optimal quality. AI-enhanced platforms that predict market trends have also been used to optimize crop yields and minimize overall environmental impact. The use of GPS tractors and drones, coupled with AI models and IoT have enabled farmers to conduct more efficient land management and crop pest control, leading to less crop damage and increasing production (Nwokolo et al., 2024). Monitoring tools that provide real-time data on soil conditions, weather patterns, and crop health allow farmers to apply the exact resources needed in specific areas, such as water and fertilizers. This precision reduces unnecessary resource expenditure and minimizes waste at the source. Sensors that monitor food contaminants during processing, packaging, and storing can ensure food safety and quality throughout the supply chain.

Technological innovations have also allowed for the optimization of FSC efficiency, which is critical for minimizing the time perishables spend in transit and storage, thus reducing spoilage and waste before foods reach consumers. In processing facilities, AI-enabled optical sorting machines automatically assess fruits and vegetables by their size, ripeness, and quality. This ensures that only the best produce reaches the market, while items not meeting standards are rerouted to uses like animal feed or composting, reducing waste. AI-driven technologies in refrigerators, mobile apps, and inventory systems can monitor food storage conditions, track expiration dates, and analyze consumption patterns. This can help retailers better predict demand and adjust their stock accordingly, preventing overstocking, reducing the need to discard unsold goods, and decreasing the environmental footprint of excess production. Integrating sophisticated tracking systems, including real-time temperature controls and GPS tracking, optimizes delivery routes and schedules (Nwokolo et al., 2024). This adjustment to supply chain logistics reduces the time perishables spend in transit, minimizing spoilage and effectively cutting down waste before it reaches consumers.

AI Drives and Efficient Supply Chain: Coricelli, an Italian olive oil producer, faced challenges in optimizing their production process and minimizing FLW. In partnership with IBM, Coricelli implemented AI-driven solutions to enhance their operational efficiency and sustainability.

Through the integration of AI technology into Coricelli's operations for quality control, predictive maintenance, and supply chain optimization, Coricelli achieved significant improvements in efficiency, sustainability, and cost-effectiveness. The AI-driven quality control and predictive maintenance systems minimized waste by ensuring that only high-quality olives were used and by preventing equipment failures that could lead to production losses. By analyzing historical and real-time supply and demand

data, the AI system optimized Coricelli's inventory management and distribution logistics, ensuring timely and fresh deliveries. This enhanced supply chain efficiency reduced spoilage and waste, and consistently improved the production of high-quality olive oil. The reduction in waste and improved efficiency translated into substantial cost savings. Moreover, predictive maintenance reduced the costs associated with unexpected equipment breakdowns and production halts (IBM, 2021).

Within the retail and food services sectors, intelligent packaging that monitors changes in temperature, moisture, and pH informs retailers of the freshness of their produce, while dynamic pricing systems empowered by machine learning proactively adjusts the prices of products based on their shelf life. This helps in selling products that are nearing their expiration faster, thus reducing the amount of discarded goods. Similarly, distressed sales platforms that connect businesses with networks to sell off-spec, overstocked, or nearly expired products at discounted rates prevents perfectly edible food from being discarded, while providing an economical option for buyers looking for cheaper alternatives. AI-driven technologies in refrigerators and mobile apps can monitor food storage conditions, track expiration dates, and analyze consumption patterns. This technology suggests recipes to utilize available ingredients effectively and sends reminders about products nearing their expiration, significantly reducing household food waste. AI-driven technologies in refrigerators and mobile apps can monitor food storage conditions, track expiration dates, and analyze past consumption patterns, allowing retailers to order the appropriate quantity of produce as well as providing real-time alerts about products nearing their expiration. Some applications even suggest recipes to utilize available ingredients effectively. Moreover, sophisticated inventory management systems allow retailers and food service outlets to optimize their order quantities, significantly cutting down on excess stock and associated waste. Active and intelligent packaging technologies, such as ethylene absorption and moisture control materials, enhance product longevity and provide vital freshness indicators, which further support waste reduction. Improving logistics through increased delivery frequency ensures products remain fresh by minimizing the time they spend in storage or transit, complemented by intelligent packaging solutions that actively manage the product environment to extend shelf life (ReFED, 2021).

Reducing Food Waste through Dynamic Pricing: Meijer, a leading grocery chain, partnered with Flashfood, a digital marketplace, to address food waste by offering discounts on items nearing expiration. This initiative diverted millions of pounds of food from landfills, showcasing a sustainable approach in retail.

In 2020, Meijer integrated Flashfood's app to implement dynamic pricing, adjusting prices in real-time based on shelf life. Customers could easily browse and purchase discounted items through Flashfood's app, preventing potential waste. The app listed various categories, including fresh produce, dairy, and meats, with prices dropping as expiration dates approached. The closer an item was to its expiration date, the greater the discount offered to incentivize quick sales. Meijer promoted the app via in-store signage, social media, and email marketing.

Since the partnership began, Meijer has diverted over 10 million pounds of food from landfills. This initiative reduced disposal costs, generated additional revenue, and provided customers with significant savings, enhancing customer satisfaction and loyalty (The Food Institute, n.d.).

Pioneering Food Waste Reduction in Hospitality through the power of AI: the hospitality industry, particularly due to buffet-style breakfasts, faces significant challenges in managing food waste. To tackle this, Hilton collaborated with Ne'ma (the United Arab Emirates' [UAE's] national food waste initiative), UNEP West Asia, and Winnow (a UK-based food waste company that has developed an AI tool for commercial kitchens to track, measure, and monitor their food waste). This collaboration launched the Hilton's Green Breakfast initiative, which aimed to enhance sustainability by addressing food waste in Hilton hotels during breakfast services. It targeted three main barriers: lack of awareness among staff and guests, prevailing social norms contributing to waste, and misaligned incentives. Interventions included:

- Data-Driven Decision Making: utilizing Winnow in plate waste measurement technology across 13 UAE-based hotels, serving a combined total of 1.8 million breakfasts annually. This provided baseline data on food waste, enabling the identification and implementation of effective waste reduction strategies in food production, optimization of buffet layouts, and reduction in portion sizes.
- Staff Engagement and Training: focusing on sustainable food preparation practices and waste awareness.
- Consumer Engagement: encouraging guests to reduce waste through communication strategies and offering options like doggy bags for leftover pastries

The initiative achieved a 62% reduction in food waste, leading to substantial savings in meals and CO_2 emissions. Pre-consumer waste was reduced by 76% and post-consumer waste by 55%. This significantly impacted Hilton's food waste footprint. The initiative also highlighted the significance of collaborative efforts in achieving sustainable goals within the hospitality industry (Winnow Solutions, n.d.).

At the consumer end, AI-driven applications in smart refrigerators and apps can track food inventory, expiry dates, and consumption patterns, significantly enhancing household food management. These technologies not only suggest recipes to use up food before it spoils but also remind consumers about items nearing expiry. Additionally, consumer apps that provide tailored recipes and portion size suggestions based on the user's needs complement these efforts by ensuring ingredients are fully utilized. Moreover, community sharing platforms can be integrated with these applications, allowing users to share or give away food they will not use, thus reducing waste. Applications providing insights into the sourcing and sustainability practices of food products encourage informed purchasing decisions that support FLW reduction efforts. AI has also played a pivotal role in waste tracking and reporting, offering valuable data that stakeholders can use to devise targeted strategies for reducing FLW. These integrated technologies and platforms collectively form a robust system to minimize food waste at the consumer level.

The integration of these advanced technologies and systems that optimize operations not only contribute to environmental sustainability by reducing FLW, but also offer significant financial advantages. By minimizing waste, businesses can optimize their cost structures and improve profitability. For instance, dynamic pricing can increase sales of near-expiration products, while temperature monitoring reduces the economic impact of product loss due to spoilage.

Despite the clear benefits, the adoption of these technologies comes with various challenges that hinder their widespread implementation, particularly in developing countries. Initial capital investment and the cost of comprehensive training are substantial barriers. Moreover, the integration of new systems with existing operations requires careful planning and change management. In regions where IT infrastructure may be limited or absent, the challenges extend beyond financial constraints, complicating the full utilization and benefits of these technological innovations. Ensuring data privacy and security, especially in systems that handle sensitive information, is another critical aspect that businesses must address. These challenges require tailored strategies to support technology adoption in different economic contexts.

Government interventions, such as regulatory adjustments to support the widespread adoption of these technologies such as easing regulations that impede the efficient resale of food products, coupled with financial incentives like tax breaks or grants for technology adopters, can be highly effective. Moreover, stakeholders across the board, including private investors and philanthropic funders play a crucial role in providing the necessary capital and support for innovative solutions.

12. Cultivating Knowledge and Skills to Reduce FLW

Addressing FLW effectively requires a comprehensive approach that encompasses both an informed public and a skilled workforce across the entire FSC. Educating and equipping those involved in the agri-food

sector—from smallholder farmers to consumers—with the necessary knowledge and skills enables better decision-making that can significantly reduce waste. By increasing awareness and understanding of market dynamics and production costs, stakeholders can implement strategies that minimize waste effectively. The following section outlines why improving skills and increasing public awareness are effective practices in optimizing food production and consumption processes and improving the overall environmental and socio-economic impact.

Importance of having an informed public: a general lack of information, awareness, and skill plays a significant role in FLW at local, regional, and national level (WB, 2019). The objective is for FLW to no longer be considered acceptable, whether by producers, handlers, processors, distributors, retailers, service providers, or households. Accurate and timely information is crucial for making informed decisions that prevent wasteful practices and enhance food security. Without proper information across the value chain, decisions on optimal harvest timings, post-harvest handling, and investments in improved storage facilities are compromised, increasing the likelihood of spoilage and waste. Similarly, educating consumers about their personal impact on FLW is vital for changing behaviors and reducing waste effectively, as most consumers often do not realize their personal impact on FLW and what they can do about it. Consumer education should integrate objectives and messages from various campaigns (e.g., sustainable diets and health, food waste prevention, climate action) to maximize impact and efficiency. Moreover, effective communication campaigns should last at least 3 years to allow for the launch and sustained promotion of national awareness efforts, the establishment and nurturing of key partnerships, and the development of long-term consumer guidance (UNEP, 2016). Consistent messaging and collaborative partnerships are crucial to ensure impactful and enduring behavior change (UNEP, 2014).

Save the Food Campaign: according to the latest FWI Report (UNEP, 2024) the majority of wasted food is generated at consumption points, including the household level. Public campaigns such as "Save the Food," launched by the Natural Resources Defense Council (NRDC) and the Ad Council in the US, aim to raise awareness and motivate customers to take actionable steps to reduce food waste at home (NRDC, n.d.). The campaign consisted of different types of public engagement strategies that included public service announcements across television, digital platforms, print, and social media. The messaging informed the public of practical tips on meal planning, food storage, and creative ways to use leftovers. The campaign website (savethefood.com) focuses on consumer education and behavior change while providing information about the environmental, economic, and social benefits of reducing food waste.

War on Waste: Grupo Bimbo, headquartered in Mexico and known for its bakery products, has integrated food waste education into its six key environmental strategy actions, targeting a 50% reduction in food waste by 2025. It initiated a "War on Waste" (WOW) campaign across its production sites and supply chain to spread effective waste management practices, and developed a digital dashboard for monitoring food waste metrics in real-time from sales and commercial activities.

In collaboration with the Too Good To Go app, Grupo Bimbo now offers nearly expired products at reduced prices through a secondary market. These initiatives have led to a significant decrease in operational food waste, with reductions reported as 32% in Central America, 16% in Mexico, 7% in Canada and South America, and 5% in the Ricolino brand since 2019 (Grupo Bimbo 2021).

The importance of having skilled personnel across the entire food value chain cannot be overstated when it comes to effectively reducing FLW. Improper post-harvesting practices are considered one of the primary causes of significant food commodity losses (Food Systems for Nutrition Innovation Lab, 2022b). Each segment of the value chain—from agricultural production and harvesting to processing, distribution, retail, and consumption—presents unique challenges and opportunities for waste reduction. Skilled personnel are critical in navigating these complexities, as they bring specialized knowledge and competencies that optimize operations, innovate processes, and implement sustainable practices

effectively. For instance, farmers trained in precision agriculture techniques can significantly reduce pre-harvest losses, while processors with expertise in food science can enhance preservation methods to extend shelf life. Increased knowledge among smallholder farmers is essential for negotiating fair market prices and navigating market dynamics as well as exploring valorization opportunities. It is also crucial for them to develop marketing strategies that highlight the quality and uniqueness of their products (WB, 2021).

In logistics, skills in supply chain management ensure that foods are transported and stored under optimal conditions, minimizing spoilage. This includes proper fumigation treatments and optimal handling and storage practices that reduce damage. Retail workers adept in inventory management and dynamic pricing strategies can adjust stock levels and pricing in real time to avoid overstocking perishable goods, employing strategies such as proper stock rotation and maintaining ideal storage conditions. Additionally, workers across the supply chain need training in best practices for handling, such as using gentle techniques that minimize damage and reduce risks of contamination during harvesting, loading, and unloading. Government should find ways to encourage companies to prioritize food waste prevention, measure, set clear KPIs, and ensure they provide their staff with adequate training to build the necessary skills.

Moreover, the development and strengthening of skills related to FLW strategies, measurement, regulatory and financial frameworks, and effective implementation and monitoring of these strategies is crucial. It enables professionals to identify key areas of waste, apply targeted interventions, and evaluate the effectiveness of those interventions, ensuring continual improvement in FLW management. Training should be tailored to meet the specific needs of actors across the FSC, ensuring that both direct and indirect factors of FLW are addressed.

Building the Capacity of Women Farmers on Reducing FLW: The food loss analyses (FLA) conducted on maize, sorghum, and cowpea value chains in Burkina Faso identified critical loss points at various stages, including harvest, threshing, shelling, winnowing, sorting, drying, storage, and milling. Key causes of losses were poor harvesting practices, gender inequalities, inappropriate drying techniques, inadequate storage facilities, and poor transport conditions. To address these issues, capacity-building activities were implemented with eleven farmers' organizations, agricultural extension service providers, NGO staff, and equipment providers.

These activities included awareness-raising on post-harvest losses and their causes, hands-on training on good harvesting and post-harvest practices, and the promotion of improved storage and transport practices. The introduction of clean cemented drying yards, tarpaulins, hermetic bags, pallets, metal silos, and mechanized shellers significantly reduced losses by 67% to 72%. These initiatives directly benefited around 2,600 households, resulting in an estimated increase of 8,535 tonnes of maize and 103,252 tonnes of cowpea in the pilot communities (Totobesola et al., 2022).

Leveraging digital platforms, AI, and machine learning applications: as covered previously, AI is pivotal in transforming the FSC, as it can provide critical data-driven insights and automation that enhance decision-making and operational efficiency from production through consumption. The successful deployment of these sophisticated technologies requires not only awareness of their existence but also specific skills to implement and manage them effectively. Tailored training programs are essential for all stakeholders involved, ensuring they are equipped with the necessary technical knowledge to utilize these innovations. By fostering a well-informed public and skilled workforce, these digital solutions can be fully leveraged to drive significant reductions in FLW across the entire food environment (Onyeaka et al., 2023).

Impact of Commodity Pricing Policies and Information Dissemination on Smallholder Farmers in Low- and Middle-Income Countries: FAO conducted an analysis on the impact of commodity pricing policies on the livelihoods and investment decisions of smallholder farmers in low- and middle-income

countries, drawing from over 40 studies across various nations including Ghana, Côte d'Ivoire, India, Senegal, Kenya, and Vietnam. The aim of the study was to assess the effectiveness of several mechanisms such as government price support and pricing policies on the economic and social wellbeing of the smallholder farmers. The findings concluded that information played a role in enabling smallholder farmers to take decisions that reduced their overall FLW.

In Northern Ghana, information was disseminated using short message service (SMS) that was based on the Market Information Systems Program. As a result of this service, farmers were able to receive an average of 9% increase on prices. Having this information on hand put them in a stronger position when bargaining for commodity prices. In Colombia, it was found in a survey that information related to weather (disseminated via SMS) was useful in reducing the probability of weather-related crop loss (FAO and IPA, 2022).

Developing comprehensive training programs is essential for capacity building across the food value chain. These programs should be multifaceted, incorporating open access guidelines and best management practices guides that are readily available to all stakeholders. Such resources provide a foundation for understanding and implementing the most effective strategies in FLW management. Periodic trainings and ongoing professional development programs ensure that personnel remain updated on the latest techniques and technologies. This continual learning process not only enhances the skills and knowledge of individuals involved in the food industry, but also fosters a culture of continuous improvement and adaptation to new challenges and innovations. By investing in these educational tools and opportunities, organizations can empower their workforce, enhance operational efficiency, and drive significant reductions in FLW, thereby contributing to the SDGs and economic resilience (FAO, 2019).

Tanzania Horticultural Association (TAHA): under the work of USAID and USDA, a training program was rolled out to improve the food value chain in Tanzania's horticulture sector. The objective of the program was to build capacity by training farmers to reduce post-harvest losses, develop infrastructure in terms of cold storage and transportation systems, and to improve market access for smallholder farmers so that they could reach customers efficiently and reduce FLW caused by lack of access and information. The program reduced post-harvest losses by 50% and increased earnings by 25% (Climatelinks, (2021).

Role of Collectives and Cooperatives: globally, farmer collectives and cooperatives have empowered smallholder farmers and assisted in advancing food security and rural development in developing countries in Africa (Chambo, S. A. 2009). Through the sharing of resources (transportation, equipment, etc.) and collective marketing, training, and exchange of knowledge, farm operations and access to market can be improved, which in turn can reduce FLW due to their collective action. Lessons drawn from South Africa show the importance of building capacity and developing internal communication mechanisms to empower these cooperatives to support technology dissemination (Carney and Van Rooyen, 1996). Thus, effective policies and legislation are necessary to support the formation and operation of these networks and should include funding mechanisms specifically designed to enhance education and awareness around FLW reduction, valorization of by-products, and accurate FLW measurements for government reporting.

13. Monitoring and Evaluation Coupled with Transparent Reporting

Monitoring and Evaluation (M&E) provides a better understanding of the effectiveness of reduction schemes. It can also communicate why they have succeeded or failed, and monitoring progress against objectives and targets will indicate how close you are to your target.

Importance of Monitoring and Evaluation: M&E frameworks are central to assessing the effectiveness and efficiency of FLW reduction actions. They help identify successful elements and obstacles, aiding in

the development and implementation of future actions. Comprehensive monitoring systems are essential for tracking progress towards stated goals and evaluating the impact on food security, nutrition, socio-economic, and environmental benefits (WRI, 2019).

The publication "Improving the Performance of Waste Diversion Schemes: A Good Practice Guide to Monitoring and Evaluation" (WRAP, 2010) suggests that key performance indicators (KPIs) are an effective mechanism for measuring achievements. Six criteria are recommended for evaluating food waste prevention actions: quality of action design, efficiency, effectiveness, sustainability over time, transferability and scalability, and intersectoral cooperation. These KPI criteria may be adjusted based on the type of action being assessed.

For a thorough evaluation of any FLW reduction action, KPIs should be measured before and after implementation to establish a baseline and assessment of the action's effectiveness. A significant challenge in FLW reduction is the lack of accurate and comprehensive data. Overcoming this data deficit is crucial for refining hotspot identification, reduction strategies, and progress monitoring. According to the World Resources Institute (WRI), without proper data, efforts to reduce FLW may be hindered, making it difficult to assess whether targets such as SDG 12.3 are being met (WRI, 2019).

Monitoring Systems for FLW: comprehensive monitoring systems are inclusive, participatory, gender-sensitive, cost-effective, and sustainable. Harmonized FLW monitoring systems across agencies and organizations ensure consistency and comparability of data. Periodic measurement enables the monitoring of progress over time, identifying the impact of interventions and the need for corrective measures (FAO, 2018). Several internationally recognized monitoring systems are widely used and accepted for their contributions to FLW reduction efforts.

The rollout of the FLI and FWI at the country level is essential for providing a harmonized baseline, mid-period check-ins, and end-of-period assessments. This standardized approach enables global and national monitoring to determine progress towards FLW reduction targets. The FAO's FLI, for example, aggregates country-level indices to provide relevant data for international monitoring, while also offering detailed insights at the sub-national level (FAO, 2018).

The Food Waste Atlas, a collaborative platform developed by WRAP and UNEP, serves as a global repository of FLW data. This platform allows users to access, share, track progress, and benchmark against other entities. Both corporations and governments use the Food Waste Atlas (Food Waste Atlas, n.d.) to report and compare their FLW metrics, fostering a culture of transparency and continuous improvement.

Transparent Reporting and Public Access: transparent reporting is vital for accountability and knowledge sharing. Countries and companies should make their FLW measurement results publicly available and easily accessible to create a culture of transparency that can drive progress and innovation. Transparency in reporting ensures that all parties are held accountable for their actions and creates a system of checks and balances that encourages entities to adhere to commitments and continue to improve.

Platforms like the Food Waste Atlas facilitate consistent and transparent reporting, allowing organizations to upload and access FLW data. Public access to this data facilitates benchmarking, identification of success stories, and improved supply chain management (WRAP, 2020). By comparing their FLW data with that of other organizations, companies can identify areas needing improvement and set realistic targets. This comparative analysis helps organizations understand their relative performance, motivating them to adopt more efficient practices and technologies. Benchmarking also fosters a competitive environment where companies strive to outperform their peers, driving overall progress in FLW reduction (FAO, 2019).

Access to comprehensive FLW data enhances supply chain management by providing detailed insights into where losses and waste occur. Companies can use this information to identify inefficiencies and implement

targeted interventions. For example, transparent reporting can reveal specific stages in the FSC where FLW is most prevalent, allowing companies to focus their efforts on these critical points. Improved supply chain management leads to reduced waste, cost savings, and increased efficiency, contributing to overall sustainability goals (WRI, 2019).

Food Waste Atlas: developed by the WRI and WRAP, the Food Atlas is an online platform designed to monitor FLW and promote transparent reporting. By consolidating data from various sectors, geographies, and food types, the Atlas serves stakeholders aiming to understand and reduce FLW. It compiles data from over 150,000 global data points, enabling users to track FLW across different stages of the FSC. This comprehensive monitoring system helps organizations identify critical loss points and implement targeted interventions to mitigate FLW.

The Food Waste Atlas provides an open access, centralized repository of FLW data. Users can report data on FLW either anonymously or publicly. Researchers, policymakers, businesses, and the general public can benefit from the wealth of data available. The Atlas aims to promote widespread awareness, build trust among stakeholders, and facilitate collaborative action towards reducing waste and improving food security. It also aids in monitoring and reporting and supports the development of evidence-based policies and strategies (The Food Waste Atlas, n.d.).

Corporate Reporting: a large-scale participatory action to measure FLW within large food companies internationally can mainstream measurement practices in the private sector. Transparent reporting of completed inventories enables benchmarking, identification of success stories, and a better understanding of supply chains. Incentivizing measurement through financial and technical support can significantly increase participation, especially in low-income countries (WRI, 2019). A great starting point for corporate reporting is the FLW standard, it serves as a comprehensive global framework designed to guide entities in quantifying and reporting the weight of food and its associated inedible parts removed from the FSC, collectively defined as "food loss and waste." By adhering to this standard, countries, cities, companies, and various organizations are empowered to create detailed inventories that measure the extent of FLW within their operations. The information from these inventories can provide a starting point and solid foundation upon which effective FLW strategies can be developed. This framework is used by companies like Tesco to report data consistently, ensuring transparency and comparability across the sector for monitoring and evaluation (WRI, 2019).

Corporate reporting can include (but is not limited to) sustainability reports, corporate social responsibility reports, environmental reports, annual reports, carbon disclosure reports, specific FLW reports, global reporting initiative reports, and more. All of these can report on some aspect of the FLW measurement and management practices, commitment, and efforts on a regular basis.

Unilever Halving FLW Along the Production Lines: as part of its Unilever Compass and Climate Transition Action Plan, Unilever has committed to eliminating food waste sent to landfills and ensuring that no good food is wasted. Recognizing that food production often results in excess and debris that is typically discarded, Unilever has adopted creative solutions to transform food waste into valuable products (GAIN, n.d.).

An example is Unilever's ice cream production. During the manufacturing process of Magnum ice cream, excess ice cream is generated. This excess used to be discarded. However, by incorporating chocolate sauce and white chocolate chips, Unilever repurposed the leftover ice cream into a marketable new offering called Cremissimo.

This example demonstrates the potential for companies to turn food waste into profitable products, reducing environmental impact while creating new revenue streams.

14. Context Specific

Addressing FLW effectively requires tailored interventions that consider the unique characteristics and challenges of each region and country, including context-specific policies, legislations, technologies, and innovations that account for the targeted geographic area, physical and agro-climatic conditions, and the specific part of the supply chain. The *Code of Conduct for FLW Reduction* (FAO, 2022) reinforces the need for governments to develop FLW reduction strategies tailored to their country's unique circumstances, considering factors such as:

- The status of agri-food systems, including food import dependency and/or production sufficiency
- Social and cultural dimensions, including population growth, demographic changes, urbanization, consumer preferences, and nutritional needs
- Natural resource constraints
- Climate change and vulnerability to disasters
- Trade-offs among stakeholders
- National priorities, with an emphasis on food losses versus food waste, increasing local production, etc.

Context-specific interventions ensure that policies are relevant and effective, addressing the specific needs and circumstances of different communities to maximize impact and achieve sustainable FLW reduction. Technological solutions need to be adapted to local situations based on the existing infrastructure and socio-economic resources, as well as the operating conditions of the rest of the FSC (IICA, 2014). For example, high-tech and expensive technologies may not be suitable in areas lacking reliable electricity or technical capacity, or where local market conditions cannot support high capital and running costs. Interventions must also consider the unique requirements of targeted food commodities, as different commodities have varying temperature, moisture, and light needs to preserve their quality, maintain safety, and reflect their economic value (Feed the Future Food Innovation Lab, 2022b).

Tailored Interventions to Prevent Food Loss in Qatar's Food Security Strategy: Qatar's reliance on imported food, including fresh fruits, vegetables, and animal protein from distant countries, combined with its hot and humid climate, significantly increases the risk of food spoilage. Given this unique local context, Qatar's Food Security Strategy (State of Qatar, 2020) presents an approach targeting customs to minimize food spoilage and prevent food loss. To optimize food clearance processes, the strategy aims to reduce clearance times by establishing a legal maximum of less than 6 hours and utilizing technological solutions to increase the adoption of pre-arrival registration and speed up on-site inspections without compromising food safety. The country also plans to invest in infrastructure facilities such as advanced laboratories and cold storage facilities where required to support efficient food handling, storage, and clearance.

Avoiding "White Elephants" in FLW Interventions: when planning FLW reduction interventions in low- and middle-income countries, it is necessary to avoid creating "white elephants," or expensive solutions that cannot be effectively utilized and often burden recipients with maintenance and upkeep costs (Soethoudt et. al. 2021). These situations arise when communities are not involved in the implementation process and when "alien" technologies incompatible with the local context are introduced, leading to low adoption rates, particularly when external economic and knowledge support ceases (Soethoudt et. al. 2021).

To ensure the effectiveness of FLW reduction strategies, it is critical to involve the local community and thoroughly consider all environmental, infrastructural, biological, and social factors that may encourage or hinder the adoption of interventions. By integrating community involvement and ensuring compatibility

with local contexts, development interventions can be more effective and sustainable (Soethoudt et. al. 2021).

The Power of Bundling Solutions for Effective FLW Reduction: recognizing that a single solution is unlikely to be effective, combining different solutions and interventions is advisable. However, it is critical to identify the right bundle mix relative to the time and place being targeted. Barrett et al. (2020) demonstrate how bundling technological advances with sociocultural and policy changes can transform agri-food systems to tackle climate, economic, environmental, health, and social challenges. This approach of bundling context-specific innovations tailored to the unique economic, social, and environmental conditions of different regions within a country should also be applicable to addressing the complex challenge of FLW.

Assessment **Framework of the Regulatory Enabling Environment for FLW Prevention:** to support governments in developing the right bundle of context-specific interventions, the assessment framework presented as an addendum to this report provides a comprehensive checklist that both governments and researchers can use to assess the enabling governance environment for FLW prevention. This framework is designed to assist government institutions in conducting a thorough self-assessment of their policies, regulatory frameworks, supportive infrastructure, resources, and past and ongoing programs. Structured around the Target-Measure-Act approach, it offers guiding questions that delve into each aspect of government efforts to manage food loss and food waste and prevent it from exiting the food chain and ending up in landfills. Researchers and academics can also utilize this framework to analyze and evaluate the effectiveness of various FLW reduction strategies, identify gaps, and provide evidence-based recommendations.

By completing this self-assessment, decision-makers will gain valuable insights into the effectiveness of existing strategies, identifying appropriate solutions, and enhancing the effectiveness of bundled solutions. This process provides a solid foundation for developing a robust action plan that creates an enabling environment for innovation and collaboration, ultimately enhancing national FLW reduction efforts and aligning with SDG Target 12.3.

Conclusions

Policies and regulations play a dual role in the context of FLW: they can both accelerate, improve or imped its mitigation. Because of this, there is a vital need for the comprehension of regulatory and policy frameworks to effectively harness their potential for positive change. The aim of this study was to identify internationally recognized BPs to be used as a guiding framework for policy makers when developing or improving strategies aimed at reducing FLW.

Throughout the study, a mixed-methods approach was used to analyze policies and regulations affecting FLW and identify BPs for mitigation. A thorough desk study reviewed key reports, publications, and case studies on FLW policies and regulations, including academic literature, international guidelines, major FLW reduction strategies, and reports from non-governmental and governmental organizations and industry associations. This review aimed to map out existing knowledge, identify main drivers of FLW, highlight successful prevention and reduction approaches, and assess trends in policy effectiveness. This targeted review ensures that the recommended BPs are actionable and consistent with proven practices that have successfully addressed FLW challenges. These practices were then shared with a select group of stakeholders for feedback.

The presented 14 best practices provide a solid foundation for large-scale, meaningful change in curbing FLW. By adopting these BPs, governments can effectively plan, implement, and advocate for measures that significantly decrease FLW, creating an enabling environment for FLW prevention and reduction, promoting sustainable development, and enhancing food security globally. They all have common themes that include establishing clear targets, measuring baselines and progress, and taking targeted effective action based on evidence gathered systematically. International measurement standards and methodologies need to be utilized to ensure consistent and comparable data, meeting international reporting requirements. Understanding the causes and underlying drivers of FLW is important for developing targeted interventions and avoiding inappropriate actions.

Implementing supportive policies and regulations tailored to the local conditions, along with supportive fiscal measures that discourage waste and incentivize investments in necessary infrastructure and processes that create an enabling environment for action across the FSC are all fundamental. Adopting the FLW hierarchy, which prioritizes prevention and safe redistribution, upcycling food products, and recovering food waste for animal feed provides a solid guiding foundation for encouraging food to remain within the FSC.

Investing in robust infrastructure to support efficient food distribution, storage, and safe processing of food commodities optimizes efficiency to reduce spoilage and enable redistribution and recovery, while leveraging technology can greatly improve FLW monitoring, management, and reduction efforts.

Tactics that help minimize waste include shaping physical environments in ways that facilitate waste reduction and support better consumer choices, encouraging collaboration among stakeholders across the supply chain (which enhances the effectiveness of all FLW reduction strategies), supporting research initiatives to drive innovations that address these challenges, raising public awareness of the problem, and cultivating knowledge and skills across the FSC among all stakeholders.

Finally, continuous monitoring, evaluation, and transparent reporting of FLW data ensure accountability and inform policy adjustments. All these strategies need to be tailored to the specific cultural, economic, and environmental contexts of the targeted country to enhance their relevance and effectiveness.

The authors have endeavored to identify and summarize the best practices for FLW reduction from various frameworks and historical experiences, but this collection is not exhaustive. Additionally, action plans and

interventions will differ, as each country must adapt these recommendations to their local contexts to achieve the most effective outcomes.

The “Assessment Framework of the Regulatory Enabling Environment for Food Loss and Waste Prevention,” presented as a separate addendum to this guideline, provides a comprehensive checklist for governments and researchers to conduct a multisectoral situational analysis of the existing enabling environment for FLW prevention. This framework can support identifying effective, context-specific interventions that assist in creating an enabling environment. The action plans and mix of interventions adopted by countries will differ, as each must adapt these BPs to their local contexts.

While the strategies discussed may also benefit private sector entities, the emphasis is on the public sector, underscoring the government's essential role in leading the charge towards sustainability, economic efficiency, and food security. Recognizing the dynamic nature of FLW challenges, this document may be further improved and updated over time.

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About the Authors

Seta Tutundjian, Chief Executive Officer at Thriving Solution LLC and co-lead of the global coalition Food is Never Waste. Tutundjian is an avid advocate for transitioning to circular food systems and regenerative economies in water-scarce regions. Contact: seta@thrivingsolutions.earth

Dima Maroun, Chief Sustainability Officer and Partner at Thriving Solutions LLC. Maroun is an environmental scientist that is specialized in environmental auditing, impact assessments, and food system transformations. Contact: dima@thrivingsolutions.earth

Robin Shrestha, Associate Director at the Feed the Future Food Systems for Nutrition Innovation Lab. Dr. Shrestha is a medical doctor and specialized in food systems assessment, evaluation, capacity strengthening, and policy engagement.

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About Thriving Solutions LLC

Thriving Solutions is a social enterprise established by two Arab women dedicated to decarbonizing our economy, safeguarding biodiversity, advancing food-nutrition-water security, and supporting SDG 2030 and ESG priorities, with a focus on the Arab region. Our services help companies and municipalities implement nature-based solutions and adopt innovations that eliminate waste and pollution, regenerate ecosystems, transition to circular food systems, and sequester carbon.

About the Feed the Future Food Systems for Nutrition Innovation Lab

The Feed the Future Food Systems for Nutrition Innovation Lab (FSN-IL) was a United States Agency for International Development (USAID) supported initiative as part of Feed the Future and is implemented by the Friedman School of Nutrition Science and Policy at Tufts University, Boston. The objectives of FSN-IL are to support research for development (R4D), build human and institutional capacity, and ensure stakeholder engagement to support the scale-up of innovations across the food system. FSN-IL aims to reduce food loss and waste, improve access to nutrient-rich foods, and enhance food safety to support improved diets and nutrition in vulnerable populations. FSN-IL's consortium of US academic partners,

global development institutions, and food value chain and business collaborators work across the three core integrated activities in its initial focus countries of Nepal, Bangladesh, Malawi, and Mozambique. To learn more about FSN-IL visit our website at https://foodsystemsnutrition.org/ and follow us on Twitter (@FoodSysNutrLab), Facebook (@FoodSysNutrLab) and LinkedIn (Feed the Future Food Systems for Nutrition Innovation Lab).

Best Practices for Food Loss and Waste Regulatory Enabling Environment – Guideline for Government

This report was developed by Thriving Solutions and the Feed the Future Food Systems for Nutrition Innovation Lab (FSN-IL) at Tufts University. The report provides a comprehensive guide for policymakers to create effective regulatory and policy frameworks that curb FLW. Grounded in global best practices and the Target-Measure-Act approach, it outlines 14 proven strategies and offers a practical assessment framework to help governments analyze, strengthen, and optimize their national FLW strategies. By promoting evidence-based, context-specific, and actionable solutions, this report aims to support policymakers in building more efficient, equitable, and sustainable food systems worldwide.

Thriving Solutions LLC
www.thrivingsolutions.earth
info@thrivingsolutions.earth

Developed in collaboration with
Feed the Future Food Systems for Nutrition Innovation Lab (FSN-IL) at Tufts University

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