Commission for Environmental Cooperation

Why and How to Measure Food Loss and Waste

A PRACTICAL GUIDE

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Executive Summary

This practical guide provides a step-by-step plan for how companies and governments can begin the process of measuring food loss and waste. It addresses key topics such as:

- Why to measure food loss and waste (FLW)
- How to establish a business case for food loss and waste measurement
- Addressing common barriers and obstacles
- Tracking causes of food loss and waste
- Converting measurements to other financial, environmental and social impacts
- How to select a measurement method

This guide was developed as part of the Commission for Environmental Cooperation (CEC) Operational Plan 2017-2018 and its Measuring and Mitigating Food Loss and Waste project. The goal of the project is to improve measurement of food loss and waste (FLW) across the North American supply chain and to calculate its environmental and socioeconomic impacts. Outputs of this project include this practical guide and a technical report entitled *Quantifying Food Loss and Waste and Its Impacts* (CEC 2019). Together, these publications offer practical tools, information and activities designed to help facilities, organizations and governments prevent, recover and recycle FLW.

Introduction

Across North America,[1] governments and businesses are increasingly realizing the enormous impacts of food loss and waste. Uneaten food represents social, environmental and economic costs, but also a large opportunity. Taking action to prevent food loss and waste offers a rare "triple win"—economic gains, reduction of environmental impacts and improved quality of life for those who currently lack sufficient food.

To successfully reduce and prevent food loss and waste, a government or business must first measure how much food is being lost or wasted within its boundaries. Measurement identifies the scale of the problem and the hotspots that most need to be addressed and allows for tracking progress over time. In short, what gets measured gets managed.

This practical guide walks readers through the steps for measuring food loss and waste (FLW)[2] within a home, institution, business, city, state, or country. Treat it as a quick reference for assistance and look for internal links that allow you to quickly reach the material of most interest.

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The checklist below shows seven steps to measuring FLW and the modules that address them in this guide. Use it to track progress and easily access the most appropriate module. Steps 1–6 are the same for all users, while Step 7 is divided among sectors in the food supply chain to offer sector-specific information.

✓	**Step 1: Determine *why* you want to reduce food loss and waste.** (Module: Why Measure FLW?)
✓	**Step 2: Establish your business case for reducing food loss and waste.** (Module: The Business Case for FLW Reduction)
✓	**Step 3: Prepare for the *change* of measuring and reducing food loss and waste.** (Module: Managing Change)
✓	**Step 4: Determine your *definition* of food loss and waste.** (Module: Setting Your Scope)
✓	**Step 5: Determine your *causes* of food loss and waste and identify solutions.** (Module: Determining Root Causes)
✓	**Step 6: Identify your *key performance indicators* and *impacts*.** (Module: Selecting Key Performance Indicators and Identifying Impacts)
✓	**Step 7: Select and implement a food loss and waste measurement *method* based on your sector.** (Module: Sector-Specific Guidance)

1) In this guide, North America refers to the countries of Canada, Mexico and the United States.

2) Although many definitions of food loss and waste exist in this guide, food loss and waste denotes all possible material and disposal routes that could be considered food loss and waste. For more information on defining food loss and waste in specific contexts, see the "**Setting Your Scope**" section.

Why Measure FLW?

A significant amount of food grown for human consumption is never eaten. In fact, by weight, about *one-third of all food produced in the world in 2009 was lost or wasted* (FAO 2011). In North America, approximately 168 million tonnes of FLW are generated annually: 13 million in Canada, 28 million in Mexico and 126 million in the United States. This equates to 396 kilograms per capita in Canada, 249 in Mexico and 415 in the United States (CEC 2017).

This level of inefficiency suggests three strong incentives to reduce food loss and waste: economic, environmental and social.

ECONOMIC: The huge amounts of food lost or wasted are currently considered part of the cost of doing business as usual. Rather than trying to maximize the value of food produced, companies and other organizations tend to focus on the disposal costs for the products that are lost or wasted. Companies could make significant economic gains by putting food headed for the waste stream to profitable uses.

ENVIRONMENTAL: When food is lost or wasted, all of the environmental inputs used on that food are wasted as well (FAO 2011). That means all the land, water, fertilizer, fuel and other resources that produced, processed, or transported a food item are wasted when food meant to be consumed by people is thrown away. Food waste sent to landfills creates methane—a powerful greenhouse gas. Thus, reducing FLW can reduce a company's environmental footprint.

SOCIAL: Surplus edible food can be redistributed to food banks, food rescue agencies and other charities, which can direct it to food insecure populations, making good use of the food rather than disposing of it. For many companies, food donation or redistribution is an important part of their corporate social responsibility activities. Food directed to human consumption is not considered to be lost or wasted.

The old adage that “what gets measured gets managed” holds true with FLW. Measuring food waste helps an organization understand the root causes of food waste and thus work to prevent it.

THE RISK OF NOT CHANGING

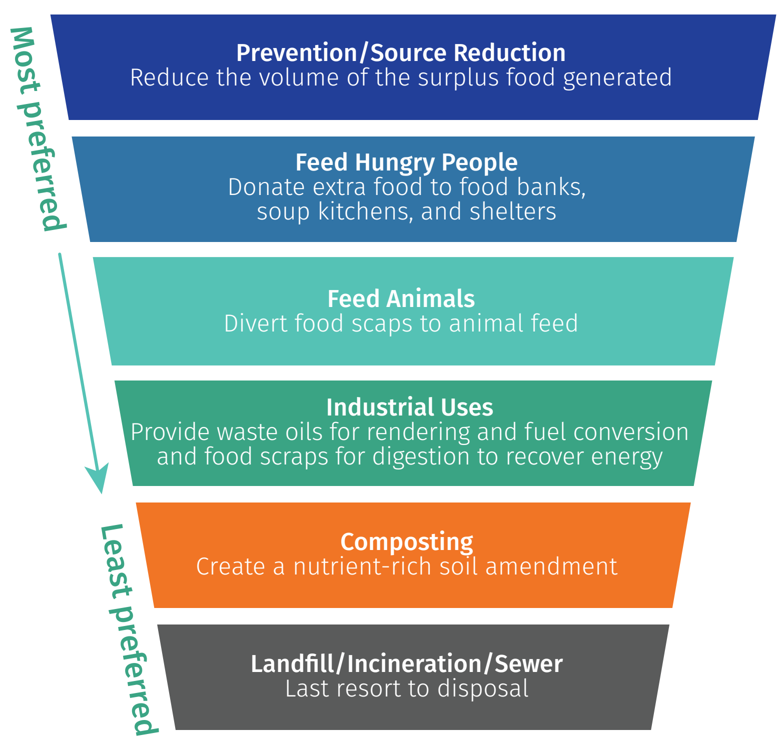
The business-as-usual path has risks. If a company continues to operate with built-in assumptions about acceptable levels of waste, it risks being surpassed by its more innovative competitors who can turn waste into profit. The business case of reducing FLW is strong and those who ignore this opportunity will continue to waste money and resources. Additionally, an increasing number of local, subnational and national governments are imposing disposal bans on food waste or requiring excess food to be donated (Sustainable America 2017; Christian Science Monitor 2018). If this trend continues, companies may face increased expenses from further regulations in the future.

THE FOOD RECOVERY HIERARCHY

When trying to reduce FLW, the first emphasis should be on *prevention*, or source reduction. Although some end-of-life destinations for FLW have fewer negative impacts than others (e.g., FLW going to animal feed is preferable to FLW going to a landfill), prevention should be the foremost goal. This principle is reflected in the Food Recovery Hierarchy (Figure 1) developed by the United States Environmental Protection Agency (US EPA).

Source reduction (i.e., preventing food waste in the first place) is the most desirable way to address FLW because it prevents the negative social, environmental and economic impacts of producing food that is wasted. Moving down the recovery hierarchy stages, less value is recovered from the FLW at each stage, until the bottom stage — landfill, incineration, or sewer disposal—where negative environmental impacts are highest. From a climate perspective, tonne for tonne, preventing wasted food is six to seven times as beneficial as composting or anaerobic digestion of the waste (US EPA 2016).

Figure 1: Food Recovery Hierarchy



Source: Adapted from US EPA n.d.

The Business Case for FLW Measurement and Reduction

Across the food industry, FLW is often buried in operational budgets, where it is accepted as the cost of doing business, or considered not worth the investment to prevent. However, more and more business leaders around the world are recognizing that reducing FLW is an opportunity to improve their bottom lines while contributing to food security and environmental goals.

Although measuring FLW may involve some upfront costs, ample evidence shows that the benefits of measuring and reducing FLW far outweigh the long-term costs of not addressing it. The upfront costs of quantifying FLW for the first time and implementing an FLW reduction program can lead to a steady stream of financial benefits for years with only minimal continued investment.

An illustrative list of costs and benefits associated with measuring FLW is shown in **Table 1**.

When starting to measure FLW, businesses often see a quick payback. In many cases, a suite of simple solutions can quickly and dramatically cut FLW and its associated costs. Enviro-Stewards, a Canadian waste-reduction consulting firm, for example, offers its clients an average payback of less than one year (Enviro-Stewards 2018). However, the business opportunity is not limited to the initial period. Financial savings and increased revenue carry on over time with minimal continued investment; especially as “best practice” behaviors and habits for reducing FLW become engrained in a business’s standard operating procedures. The positive effects of more efficient business operations compound over time.

In addition to financial benefits, reducing FLW can contribute to environmental and corporate social responsibility goals, brand recognition and improved stakeholder relationships. These impacts are discussed in greater detail in the **“Selecting Key Performance Indicators and Identifying Impacts”** module of this guide.

MAKING YOUR OWN BUSINESS CASE

Although evidence shows that reducing FLW generally results in economic gains, managers may still need to establish the benefits for their own companies. To make the case, follow two basic steps:

FIRST, DETERMINE HOW MUCH FOOD LOSS AND WASTE IS COSTING YOUR COMPANY. Tipping fees, transportation costs and the like, are only a small part of the picture. Focus on the value of the food as it moves through the supply chain.

For example, imagine a manufacturer that makes tomato paste. This manufacturer sends a tonne of tomato paste waste to the landfill each month at a cost of $100. However, that same amount of tomato paste is valued at $900 at the time it is removed from the food supply chain. So in actuality, the cost of the FLW is the $900 in lost product value in addition to the $100 in disposal fees, resulting in a total loss of $1,000 each month.

A useful tool for conducting this calculation is the Provision Coalition's **Food Loss and Waste Toolkit**, which provides a step-by-step calculator based on Enviro-Stewards' approach for determining the value of FLW as it moves through processing and manufacturing. The Provision Coalition is a Canadian food and beverage manufacturer sustainability organization with 15 member associations. Although the toolkit is intended for use by manufacturers, the principle behind it can be adapted to other sectors.

SECOND, DETERMINE THE POTENTIAL BENEFITS OF TAKING ACTION TO PREVENT FOOD LOSS AND WASTE. After assessing the cost of FLW, assess the costs associated with taking action to prevent or reduce it. For example, in the manufacturing example above, the tomato processor may discover that 2.5 tonnes per month of tomato paste, which could be used for tomato soup, is being sent to a landfill. The soup is valued at $2,000 per tonne and the cost of the equipment necessary to produce the soup is a one-time investment of $10,000. So in this case, reducing the wasted tomato paste by using it in soup would pay for itself in two months and generate $5,000 per month in profit from that point onward.

The most important concept in calculating loss is to measure the true value of the food when determining whether or not to take action. Addressing only the disposal costs provides an incomplete picture.

Table 1: Examples of Costs and Benefits Associated with Food Loss and Waste Measurement and Reduction

Costs	Benefits
• Measuring food loss and waste and identifying hotspots	• Increased operational efficiency
• Expenditures on consultants and staff training	• Lower operating costs (including purchasing costs, energy costs and even labor costs)
• Purchasing new equipment and/or repairing existing equipment	• Additional revenue via previously unsold foods
• Changing purchasing or inventory management practices	• Lower waste collection and management costs
• Changing daily business operating procedures	

Source: Authors.

Managing Change

Measuring and reducing food loss and waste is a big adjustment for many businesses, governments and other organizations. Achieving significant reductions means challenging key assumptions about how a system operates. To accomplish significant change, you must prepare for it.

Within an organization, individuals will find many reasons to resist taking action on FLW. These concerns are often legitimate and should not be disregarded. However, they generally fall into broad categories.

"We don't waste any food."

Waste is often seen as something that "someone else" does. In fact, in one survey in the United States, 76 percent of individuals believed they waste less food than the average American (NRDC 2017a). Additionally, waste is often seen as an indication that someone is doing their job poorly, so it is best not to admit to it.

Most understand that healthy food in the trashcan is food waste. Composted food or food that becomes animal feed, however, are not colloquially called "waste." While these destinations are less detrimental than the landfill, they are still food leaving the human supply chain. This food at the very least represents a missed economic opportunity and should be measured regardless of an entity's specific definition of "waste."

These views can be overcome by reframing the issue as a matter of improving efficiency, not as assigning blame.

Measurement will show that food is indeed being used inefficiently and allows for discussion of where efficiency can be improved.

"We already have too much going on to measure something else."

Many sustainability managers are already tasked with overseeing various measurements, such as greenhouse gas (GHG) emissions or water use. Measurement of FLW can seem like an added burden. However, FLW relates to many other environmental impacts and FLW reduction can help achieve broader institutional targets related to land, water and GHGs. The **"Selecting Key Performance Indicators and Identifying Impacts"** module of this guide provides more information about these related impacts.

Initial measurements may be aided by existing records to provide a cost-effective start. Inventory records and waste transfer receipts can provide an early estimate of FLW levels with minimal investment. The **"Records"** section in **Appendix A** provides more information about using such documents to estimate FLW levels.

"It's not worth the cost to measure FLW."

Although some methods of FLW measurement are expensive or time-intensive, others require only minimal investment. The **"Sector-Specific Guidance"** module in this guide offers tables displaying a range of methods for measuring FLW along with the level of resources required. Although cheaper methods are often less accurate, they can provide an initial estimate.

FLW reduction often pays for itself. The upfront costs associated with FLW measurement and reduction are frequently paid back within a relatively short time period. The module, **"The Business Case for FLW Measurement and Reduction,"** provides more information about payback periods for investments in FLW reduction.

"This is the way we've always done things."

Generating FLW is often built into the assumptions of how a business or organization operates. For example, in a restaurant that operates a buffet, a certain amount of leftover food may be expected as "the cost of doing business." However, measuring those leftovers might pinpoint an opportunity for improvement and suggest actions to reduce FLW.

The terms "food loss" and "food waste" mean different things to different people. A chef in a restaurant may think of "food waste" as food that gets thrown away from the refrigerators, but not consider waste from food preparation or plate waste. By ensuring that everyone is using the same definition and considering all potential sources, you may be able to overcome some resistance to FLW measurement and reduction. The **"Setting Your Scope"** module of this guide can help you establish a common definition.

"This isn't working."

If a change is not going smoothly and someone becomes frustrated without having a way to provide feedback, they may just give up on the change (PSU/DEQ 2018). For this reason, it is important to capture feedback (both positive and negative) and ensure that it is being considered.

In one case, the Provision Coalition worked with Ippolito Fruit & Produce in Canada to reduce FLW in its operations. For the "reinforcement" stage in the change management process, they identified key steps to help keep the change in motion (Mereweather 2018);

- Gathering feedback from employees
- Developing accountability and performance management systems
- Auditing and identifying compliance of change
- Finding root causes of FLW and taking corrective action
- Recognizing, celebrating and rewarding successes

These steps can help keep people on board with the difficult process of making a change toward FLW measurement and prevention.

Setting Your Scope

Once you've determined that it is worthwhile to measure FLW, define what FLW means in your operations and how you will communicate that information, both internally and externally. Reporting FLW data publicly has multiple benefits: it raises awareness of the issue, allows for information-sharing among businesses, provides information to policymakers and assists FLW tracking efforts over time.

Public reporting should align with the ***Food Loss and Waste Accounting and Reporting Standard***, or *FLW Standard*. The *FLW Standard* is "a global standard that provides requirements and guidance for quantifying and reporting on the weight of food and/or associated inedible parts removed from the food supply chain" (FLW Protocol 2016a). The standard clarifies definitions and shows the possible destinations of FLW when it is removed from the human food supply chain.

TRACKING PROGRESS ON PREVENTING FLW

The *FLW Standard* does not provide specific guidance on tracking progress on preventing FLW. However, prevention can be tracked by establishing a base year as a starting point and assessing prevention efforts against that baseline. If total production is increasing or decreasing, intensive measurements (tonnes per unit of production)

Table 2. Tracking Reduction in FLW by Measuring FLW Sent to Various Destinations over Time (tonnes/year)

	2016	2017	2018
Total Production	100,000 tonnes	100,000 tonnes	100,000 tonnes
Anaerobic Digestion	3,000 tonnes	4,000 tonnes	4,000 tonnes
Landfill	8,000 tonnes	6,000 tonnes	5,500 tonnes
Sewer/water treatment	4,000 tonnes	3,500 tonnes	3,500 tonnes
Total FLW	15,000 tonnes	13,500 tonnes	13,000 tonnes
Tonnes FLW per unit of production (percent)	15%	13.5%	13%
Reduction in FLW (percent relative to 2016)	0%	-10%	-13%

Source: Authors.

can better quantify how much FLW was prevented. For example, a company may set a base year of 2016 when it had 15,000 tonnes of FLW. The following year, the FLW may be 13,500 tonnes, meaning 1,500 tonnes of FLW had been prevented.

A hypothetical example of how prevention can be tracked alongside FLW amounts is shown in Table 2.

REPORTING AMOUNTS OF FLW

Reporting using the *FLW Standard* requires setting the "scope" of your FLW, as shown in Figure 2. This scope includes only food that has been removed from the human food supply chain, meaning that food donated, redistributed, or otherwise kept in the food supply chain is not included. Tracking redistribution of food may align with your objectives and can be tracked using a method similar to that outlined in the section "Tracking Progress on Preventing FLW."

The scope has four components: timeframe, material type, destination and boundary.

Timeframe

Define the period of time for which the inventory results are reported. Typically, results are reported on an annual basis.

Material Type

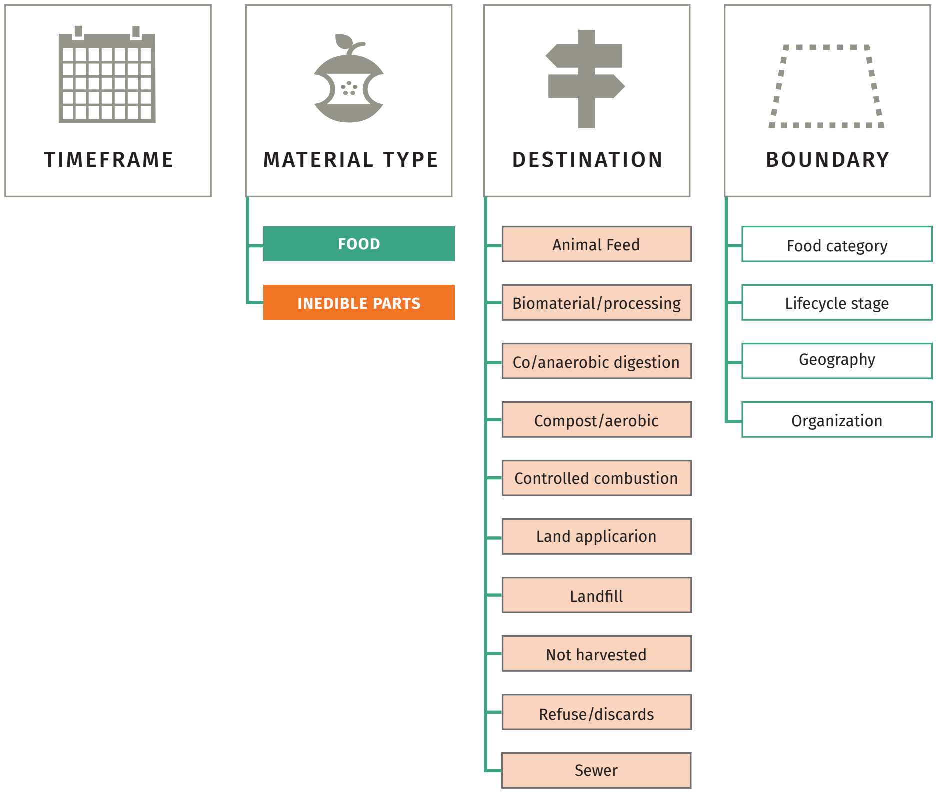
Identify the materials included in the inventory: food only, associated inedible parts only, or both. Associated inedible parts are defined as the components of a food product that are not intended for consumption, such as bones, rinds or pits.

Destination

The destination is where the FLW goes when removed from the food supply chain. The 10 categories for destinations described in the *FLW Standard* are listed and defined in **Table 3**. Again, these destinations are only for FLW that has been removed from the human food supply chain and do not include prevention or redistribution of FLW, which can be tracked as described in the section **"Tracking Progress on Preventing FLW."** Food that is distributed to humans outside the marketplace is not considered to be lost or wasted, since it is not sent to a destination.

Food that is recovered for donation to feed hungry people and that would otherwise be lost or wasted, is generally not considered to be FLW and therefore not identified as a destination in **Figure 2**. Some organizations may also exclude animal feed and bio-based materials/biochemical processing (where material is converted into industrial products) from their definition of FLW.

Figure 2. Scope of an FLW Inventory



Source: FLW Protocol 2016a.

While definitions and scope of FLW can differ, it is nonetheless important to measure all possible end destinations of recovered food and FLW to support efforts to minimize operational inefficiencies.

Boundary

The boundary has four components:

- **THE FOOD CATEGORY**, or the types of food included in the inventory;
- **THE LIFECYCLE STAGE**, or the stages of the food supply chain (e.g. processing and manufacturing, retail) included in the inventory;
- **GEOGRAPHY**, or the geographic borders within which the inventory occurs; and
- **ORGANIZATION**, or the type of unit (e.g., household or factory) within which the FLW occurs.

WHY SCOPE MATTERS

Disclosing the scope of an inventory is important because numerous definitions of “food loss and waste” exist. Some include only food but not inedible parts, while others consider only a subset of the possible destinations in the FLW Standard. By disclosing the scope of an inventory, a business or government clarifies its definition of FLW, thus allowing for more accurate comparisons and tracking of FLW over time.

ADDITIONAL RESOURCES FOR REPORTING

The ***FLW Standard*** contains a number of reporting resources. **Chapter 6** outlines the process for setting a scope and **Chapter 13** provides additional guidance on reporting. A **sample reporting template** and **customizable scope template** are available for download.

Table 3. Definition of FLW Destinations used in the *FLW Standard*

Destination	Definition
Animal feed	Diverting material from the food supply chain to animals
Bio-based materials/biochemical processing	Converting material into industrial products
Codigestion/ anaerobic digestion	Breaking down material via bacteria in the absence of oxygen
Composting/aerobic processes	Breaking down material via bacteria in oxygen-rich environments
Controlled combustion	A facility that is specifically designed for combustion in a controlled manner
Land application	Spreading, spraying, injecting or incorporating organic material onto or below the surface of the land to enhance soil quality
Landfill	An area of land or an excavated site specifically designed to receive wastes
Not harvested/plowed-in	Leaving crops that were ready for harvest in the field or tilling them into the soil
Refuse/discards/litter	Abandoning material on land or disposing of it in the sea
Sewer/wastewater treatment	Sending material down the sewer, with or without prior treatment
Other	Sending material to a destination different from the 10 listed above

Source: FLW Protocol 2016a.

Determining Root Causes

It is difficult to reduce FLW without understanding what causes it. For example, after performing a waste composition analysis, a restaurant may discover that it is discarding a large amount of tomatoes each week, but the waste data do not tell it *why* those tomatoes are being discarded. This module describes how to track causes of FLW when the information is not obvious in the quantification method.

DEFINING CAUSES AND DRIVERS

There are two layers to identifying the cause of FLW—the immediate reason why something became FLW and the underlying factor that led to the waste. The *FLW Standard* uses the terms "causes" and "drivers." A cause is defined as the proximate or immediate reason for FLW, while a driver is defined as an underlying factor that played a role in creating that reason (FLW Protocol 2016a). **Tables 4 and 5** list some possible causes and drivers by stage in the food supply chain.

If a restaurant discards a large amount of tomatoes, the immediate cause might be that the tomatoes spoiled after sitting unused in the kitchen. The underlying driver may be that the restaurant is incorrectly forecasting the amount of tomatoes it needs each week. Perhaps a previously popular dish that requires tomatoes is not selling as much as anticipated, but the restaurant is continuing to order tomatoes based on prior rather than current demand.

Table 4. Some Causes of FLW by Stage of the Food Supply Chain

Primary Production	Processing and Manufacturing	Distribution and Wholesale	Retail	Food Service/ Institutions	Household
• Spillage • Cosmetic or physical damage • Damage from pests or animals • Not harvested • Unable to sell due to quantity or size • Unable to reach market	• Spillage • Trimming during processing • Rejected from market	• Cosmetic or physical damage • Spoilage • Past sell-by date • Rejected from market • Unable to reach market	• Product recall • Food prepared improperly • Food cooked but not eaten • Cosmetic damage • Spoilage • Past sell-by date	• Product recall • Food prepared improperly • Food cooked but not eaten • Cosmetic damage • Spoilage	• Product recall • Food prepared improperly • Food cooked but not eaten • Cosmetic damage • Spoilage • Past sell-by or use-by date

Source: FLW Protocol 2016a, CEC 2017.

Table 5. Some Drivers of FLW by Stage of the Food Supply Chain

Primary Production	Processing and Manufacturing	Distribution and Wholesale	Retail	Food Service/ Institutions	Household
• Premature or delayed harvesting • Poor harvesting technique/ inadequate equipment • Lack of access to market or processing facilities • Poor access to farming equipment • Price volatility • Stringent product specifications • Overproduction • Improper storage	• Outdated or inefficient equipment and processes • Stringent product specifications • Human or mechanical error resulting in defects	• Excessive centralization of food distribution processes • Lack of effective cold-chain management • Stringent product specifications • Poor transportation infrastructure • Failure in demand forecasting • Ineffective packaging or storage conditions	• Regular replenishment of stocks to evoke abundance • Package sizes too large • Failure in demand forecasting • Too many products offered • Lack of system for food donation	• Regular replenishment of buffet or cafeteria to evoke abundance • Portion sizes too large • Failure in demand forecasting • Too many products offered • Lack of system for food donation • Improper training of food preparers	• Overpurchase • Inadequate planning before shopping • Lack of cooking knowledge • Confusion over date labels • Inadequate or improper storage of food • Desire for variety, resulting in uneaten leftovers • Overcooking

Source: FLW Protocol 2016a, CEC 2017.

In this example, simply knowing that a large amount of tomatoes was being disposed of was not enough to determine the correct course of action to reduce waste. However, once the tomato FLW was linked to a cause (e.g., spoilage after not being used) and an underlying driver (e.g., failure of demand forecasting), the restaurant is now able to take action to reduce the FLW (e.g., reduce the weekly order for tomatoes or adjust the menu to remove the dish not being ordered).

In more complicated cases, the causes and drivers may not be clear. Meeting with an outside waste-reduction consultant may be beneficial. Numerous firms make detailed sustainability audits of facilities and organizations to address root causes of inefficiencies and unsustainable practices.

INCORPORATING CAUSES INTO FLW QUANTIFICATION METHODS

The methods described in this guide differ in how well they track the causes and drivers of FLW. Table 6 provides a list of methods, whether they can track causes and how to best do so.

Table 6. Tracking Causes by Method

Method	Can it track causes?	How to track causes with the method
Direct weighing	Yes	Although direct weighing provides only numerical data, staff can be instructed to log causes while weighing the FLW. This will provide an additional data point about how the FLW occurred.
Waste composition analysis	No	A waste composition analysis will not directly provide information on causes of FLW, since the waste is being analyzed after it has been discarded. For this reason, waste composition analyses are often paired with a survey or process diary to generate qualitative data on causes and drivers assessed in tandem with the waste analysis.
Records	Not usually	Because records are kept for purposes other than FLW quantification, they are less likely to contain information relating to FLW causes and drivers. However, some records will have information that can help identify causes. (For example, a repair record for a piece of faulty equipment may help identify a cause of food waste.) Usually, a diary or survey will need to be implemented to generate qualitative data.
Diaries	Yes	A diary can be used to determine causes and drivers of FLW. The diarist can be asked to provide information on why the FLW occurred while recording it.
Interviews/Surveys	Yes	A survey can be used to determine causes and drivers of FLW. The respondent can be asked to provide information about why FLW occurs within those boundaries.
Proxy data/mass balance	No	Because inference by calculation is a mathematical operation based on material flows and proxy data, it will not provide information about causes and drivers of FLW. It provides only a quantitative estimate of the amount of FLW occurring within a given sector or commodity type. An additional analysis of the relevant sector or commodity will be necessary to understand the causes of FLW.

Source: Authors.

HOW TO TRACK CAUSES AND DRIVERS

Causes and drivers can be tracked simply by capturing information on causes while numerical estimates of FLW are being logged. In most cases, only the immediate cause will be available at first and additional research may be needed to detect the driver. Table 7 shows an example of how causes and drivers can be tracked alongside numerical estimates of FLW.

Table 7. Tracking Causes and Drivers

Food Type	Amount	Stage of the Supply Chain	Cause	Driver
Wheat	1000 kg	Primary production	Eaten by pests	Improper storage on the farm
Apples	10 kg	Processing	Trimmings	Inefficient equipment trims more than necessary
Strawberries	40 kg	Distribution and wholesale	Spoilage / Damage during transport	Lack of effective cold-chain management / Improper packaging / Excessive centralization of distribution processes
Beef	100 kg	Retail	Spoilage	Improper refrigeration
Fish	34 kg	Food service/ institution	Spoilage	Failure in demand forecasting
Milk	500 g	Household	Past sell-by date (but not spoiled)	Confusion over meaning of date labels

Note: the information in this table is illustrative.
Source: Authors.

Selecting Key Performance Indicators and Identifying Impacts

Measuring FLW should go beyond simply measuring the amount of food that leaves the food supply chain. This measurement fails to capture the impacts and benefits of reducing and preventing FLW. Preventing FLW has far-reaching economic, environmental and social benefits that can also be tracked.

WHICH IMPACTS SHOULD I TRACK?

Key performance indicators can determine an organization's success in achieving an objective or evaluating activities. Using a well-chosen suite of metrics, organizations can find out if they are achieving FLW prevention, redistribution or diversion. These metrics can also evaluate progress and tailor future interventions. Possible impacts fall into three broad categories:

- environmental impacts;
- financial impacts; and
- social impacts.

Organizations can monitor progress (and communicate success) more effectively if they use a range of appropriate metrics and consider reporting results in all three categories.

ENVIRONMENTAL IMPACTS

Food production and all its associated processes (including processing, manufacturing, packaging, distribution, refrigeration and cooking) require resources, such as arable and pasture land, fresh water, fuel and chemical inputs (e.g., fertilizer, herbicides and pesticides) and cause environmental impacts, such as air and water pollution, soil erosion, emissions of greenhouse gases and biodiversity loss.

Depending on its management, FLW can cause additional environmental impacts that would not have occurred had the food been consumed. Some of these are associated with transportation of waste, land uses for landfills and methane emissions from landfills. While less important than impacts associated with production, these impacts can still be significant.

Examples of environmental impacts that an entity could track alongside FLW data are: greenhouse gas emissions, use of water, land, fertilizers, energy and biodiversity loss.

Greenhouse Gas Emissions

Greenhouse gas (GHG) emissions are the most commonly tracked environmental impact related to FLW. For most food products, the GHGs can be determined by a lifecycle analysis (LCA), which provides a full picture of the GHGs associated with the production of a food item from the point of production to the point at which it is lost or wasted. Each food item has a unique set of GHG factors depending on the land and resources needed to produce it. The GHG impact factors increase the further along the supply chain FLW is generated.

Much LCA data are publicly available. The sources below provide GHG impact factors.

- Individual product LCA studies, found via search engine
- Commercial databases such as Ecoinvent, GaBi, FoodCarbonScopeData, World Food LCA Database (Quantis) and Agri-Footprint (Blonk Consultants)
- **US Department of Agriculture (USDA) Life Cycle Assessment Commons**

The US EPA **Waste Reduction Model** (WARM) can help to assess the GHGs associated with FLW. WARM provides estimates of GHG emissions associated with baseline and alternative waste management practices, including source reduction, recycling, anaerobic digestion, combustion, composting and landfilling.

Water Use

Water is used throughout the food supply chain, including to water crops, in manufacturing processes and to wash food waste down the drain to a sewer. Three types of water can be considered when assessing environmental impacts (Hoekstra et al. 2011):

- Blue water—water withdrawn from ground or surface water sources (e.g., irrigation water)
- Grey water—the water required to dilute polluted water for it to be safely returned into the environment
- Green water—water evaporated from soil moisture (e.g., rainfall)

Most estimates of environmental impacts include only blue water and grey water, although green water is relevant in water-scarce regions.

The largest database of water impacts is from the **Water Footprint Network**, with the Water Footprint Assessment Tool being especially useful (Water Footprint Network 2018). When using the tool, select "Production Asssessment" and select the commodity of interest as well as its country of origin to access the data of interest. The

Water Footprint Network also provides country-specific blue, grey and green impact factors for crop and animal products.

Although GHGs and water are the most common environmental impacts measured in association with FLW, several others are relevant. Because these impacts are less frequently quantified, they have fewer measurement resources.

Land Use

The impact on land use is more complicated to measure than the impact on GHGs or water. Some complicating factors are multiple cropping (where multiple crops are harvested from the same land within the course of a year) and crops that have multiple-year cycles, such as sugarcane. No simple, easily available tools yet exist to calculate land use associated with FLW, but the Food and Agriculture Organization of the United Nations (FAO) **Food Wastage Footprint** provides global estimates of land used for food that is lost or wasted, as well as the relative impacts of a range of commodity types (FAO 2015).

Fertilizer Use

At the production level, fertilizer use associated with food loss or waste can be roughly estimated by multiplying the percentage of FLW by the total amount of fertilizer used. However, no simple method exists for other stages of the supply chain where the total fertilizer input may not be known. One study has estimated fertilizer loss at the country level using data from the FAO database, **FAOSTAT** (Kummu et al. 2012, FAO n.d.).

Energy Use

Most environmental impact estimates do not break out energy use from GHG estimates, but one US study found that energy embedded in wasted food represented about 2 percent of the country's annual energy use (Cuellar and Webber 2010). The Provision Coalition's **Food Loss and Waste Toolkit** based on Enviro-Stewards' approach may help companies assess energy use relating to FLW.

Biodiversity Loss

Biodiversity loss associated with FLW is an emerging topic. Food production is the leading driver of biodiversity loss through conversion of natural habitats to farmland, intensification of farming, pollution and, in the case of fish, over-exploitation (Rockstrom et al. 2009). Some of this biodiversity loss occurs to produce food that is wasted. At the time of publication, no simple resources existed to assist in assessing potential biodiversity loss. However, tools may by developed in the future.

FINANCIAL IMPACTS

Most of the financial impacts of FLW are associated with disposal, however the *total* cost of FLW includes all resource inputs wasted along with the food. Simply focusing on disposal costs overlooks the vast majority of financial opportunities and benefits of preventing FLW. Quantifying the costs of FLW might typically involve assessing the following items:

- The purchasing costs of the incoming food and/or ingredients;
- The costs added to the food within the business (e.g., relating to labor and utilities); and
- The costs associated with redistribution of surplus food or the disposal and treatment of FLW.

Financial impacts that can be tracked alongside FLW data include the following examples:

- The value of the food that was lost or wasted;
- The cost of FLW as a percentage of food sales; and
- The cost and benefits of investment in a food-waste-reduction program.

Two direct measurement tools can capture the weight of FLW and translate it into dollar values: smart scales in the food service sector (e.g., **LeanPath** or **Winnow** tools) and the Provision Coalition's **Food Loss and Waste Toolkit** for manufacturers.

SOCIAL IMPACTS

Social impacts refer to the effects of FLW on humans. Examples of trackable social impacts are the value of the donated food, the nutritional content and meals wasted.

Donation Amount

A company may wish to track the amount of food it donates to food banks and other nonprofits. Records of these donations are usually kept and just need to be collated. If a company does not maintain records, food banks may record how much food they have received from each company.

Nutritional Content of FLW

The nutritional content of FLW can be assessed in several ways, including calories, macronutrients (i.e., carbohydrates, fat and protein), fiber and other micronutrients. The most comprehensive database of food types and their associated nutrients is USDA's **National Nutrient Database for Standard Reference**, which contains information on 8,100 food items and 146 components, including vitamins, minerals, amino acids and more (USDA n.d.). By sorting FLW by food type and multiplying the amount of FLW by the nutrient of interest in the database, you can estimate the nutritional content of the FLW.

Meals Wasted

Expressing FLW in terms of meals wasted can show laypeople the impacts of FLW. Meals are generally expressed as a number of calories, usually 600–700.[3] To determine the number of meals wasted, first determine the total caloric content of the waste using the USDA **National Nutrient Database for Standard Reference,** then divide that number by the calories in a typical meal. This will provide a total number of meals, although it should be specified that these are not necessarily *healthy* or complete meals. Calories are just one measure of nutrition and depending on the type of FLW, meals may not be the best measure.

3) There is no correct number of calories to consume per day (since proper intake depends on energy expenditure), but several health organizations suggest 2,000 calories per day for an adult as a reasonable average. Therefore, assuming three meals a day, the average meal would be 600–700 calories.

Sector-Specific Guidance

The following pages contain guidance for different sectors of the food supply chain on how to measure food loss and waste. Each section contains a short description of the sector and guidance on how to select the most appropriate measurement method for it, as well as a case study of how a company in that sector measured (or could measure) FLW. You can review the most relevant sector or sectors.

The sectors are:

- **Primary Production**
- **Processing and Manufacturing**
- **Distribution**
- **Retail**
- **Food Service/Institutions**
- **Households**
- **Whole Supply Chain Approaches**

Primary Production

INTRODUCTION

The primary production stage of the supply chain encompasses agricultural activities, aquaculture, fisheries and similar processes resulting in raw food materials. This first stage in the chain includes all activities related to the harvest, handling and storage of food products before they move to either processing or distribution. Any level of processing of raw food products does *not* fall within this stage of the supply chain, but would rather be classified as processing and manufacturing.

Examples of primary production activities are: farming, fishing, livestock rearing and other production methods.

Food losses in primary production can be caused by many factors, including but not limited to: pests or adverse meteorological phenomena, damage incurred during harvest, lack of proper storage infrastructure, cosmetic or size requirements or economic or market variability (i.e., cancellation of orders, rigid contract terms, price variability, or high labor costs).

The following nonexhaustive, illustrative list shows ways to prevent FLW during primary production.

- Work with actors downstream in the food supply chain to increase the share of second-grade products that are accepted and valorized to some point.
- Improve cold-chain management and infrastructure to prevent spoilage or degradation during storage and transport.
- Work with actors downstream in the food supply chain to expand value-added processing to increase the proportion of produced food able to eventually be consumed.

METHODS USED TO MEASURE FLW

Appropriate methods for FLW measurement depend on the context of who is doing the measuring and what information is available. Start by answering the five questions below.

- **DO YOU HAVE DIRECT ACCESS TO THE FLW?** Does the method require the ability to *directly* count, handle, or weigh the FLW?
- **WHAT LEVEL OF ACCURACY DO YOU NEED?** How accurate will the data gathered with this method be?
- **WHAT AMOUNT OF TIME AND RESOURCES CAN YOU ASSIGN TO MEASURING FLW?** The relative amount of resources (time, money, equipment) needed to carry out the method.
- **DO YOU NEED A METHOD THAT CAN TRACK CAUSES OF FLW?** Some methods can track causes associated with FLW, while others cannot.
- **DO YOU WANT TO TRACK PROGRESS OVER TIME?** Some methods can assess increases or decreases in FLW across time to track progress.

Based on the answers to these questions, use **Table 8** to determine which method or methods are most appropriate. If you are addressing multiple types of FLW (for example, both solid and liquid FLW), you may need to select several methods.

For additional guidance in selecting a method, see the **FLW Quantification Method Ranking Tool** published by the Food Loss and Waste Protocol, which asks 11 questions about your circumstances and provides a ranked list of methods based on your answers.

Table 8. How Some Methods to Measure Production Sector FLW Rank according to the Five Questions

Method Name	Direct FLW Access Needed?	Level of Accuracy?	Level of Resources Required?	Tracks Causes?	Tracks Progress over Time?
Commonly used methods for gathering new data					
Direct Measurement	Yes	High	High	Yes	Yes
Interviews/Surveys	No	Low-Medium	Medium-High	Yes	Yes
Commonly used methods based on existing data					
Proxy Data	No	Low	Low	No	No
Records	No	Variable*	Low	No	Yes
Less commonly used methods at the production sector					
Diaries	No	Low-Medium	Medium	Yes	Yes
Mass Balance	No	Medium	Low	No	Yes
Waste Composition Analysis	Yes	High	High	No	Yes

*Accuracy depends on the type of record used: for example, waste transfer receipts may be highly accurate for determing FLW levels, whereas other records are less accurate.
Note: The methods named are nonexhaustive.
Source: Authors.

CASE STUDY FOR THE PRIMARY PRODUCTION SECTOR

In the US state of California, the World Wildlife Fund (WWF) collected baseline primary data and supported measurement of post-harvest losses of several crops. The data were both quantitative and qualitative, and the WWF performed subsequent analyses to identify root causes of farm-level losses. They also calculated environmental impacts to illustrate the resource intensity of various crops and the associated impacts of any related FLW. Such a holistic measurement approach and conversion into other metrics helped identify the scale of FLW, identify root causes and find opportunities for interventions.

For example, during the 2017–18 growing season, the average measured losses at harvest on the farms sampled were 40 percent of fresh tomatoes, 39 percent of fresh peaches, 2 percent of processing potatoes and 56 percent of fresh romaine lettuce. Qualitative results highlighted the difficulties farmers face when balancing large yields and fixed contracts, as well as meeting strict product quality standards. WWF recommended further research into whole-farm purchasing contracts for specialty crops, flexible quality/visual standards and further valorization of preserved products to account for overproduction (WWF 2018).

Processing and Manufacturing

INTRODUCTION

The processing and manufacturing stage of the food supply chain encompasses all processes intended to transform raw food materials into products suitable for consumption, cooking, or sale. In this guide, "food processing" and "food manufacturing" are used interchangeably. This stage in the supply chain includes the processes that turn raw agricultural products into saleable goods, which often move to retail, wholesale, distribution or food service institutions. It also includes packaging of processed goods.

Examples of organizations in this sector are: fruit and fruit juice processing plants, cereal manufacturing facilities, pastry factories, canneries, butchers, breweries, bakeries and dairy processing plants.

In processing and manufacturing, FLW can be caused by trimming for consistency, misshapen products, spillage, degradation during processing, production line changes, contamination, overproduction, order cancellation, changes in customer demand or specifications, or improper labeling, among other things.

Food processing represents 15–23 percent of the entire manufacturing industry (including nonfood manufacturing) in North America (USDA ERS 2016, Agriculture and Agri-Food Canada 2014, ProMéxico 2015).

Some approaches to preventing FLW in processing and manufacturing are listed below.

- Work with actors upstream in the food supply chain to increase the share of second-grade products that are accepted and valorized to some point.
- Improve cold-chain management and infrastructure to prevent spoilage or degradation during storage and transport.
- Work with actors across the food supply chain to expand value-added processing to increase the proportion of produced food able to be consumed.
- Standardize date labels to reduce the amount of FLW generated from confusion over food safety.
- Adjust packaging to extend the life of food products and reduce damage during storage or transport.
- Optimize manufacturing lines and production processes to increase yields and reduce inefficiencies.

METHODS USED TO MEASURE FLW

Appropriate methods for FLW measurement depend on the context of who is doing the measuring and what information is available. Start by answering the five questions below.

- **DO YOU HAVE DIRECT ACCESS TO THE FLW?** Does the method require the ability to *directly* count, handle, or weigh the FLW?
- **WHAT LEVEL OF ACCURACY DO YOU NEED?** How accurate will the data gathered with this method be?
- **WHAT AMOUNT OF TIME AND RESOURCES CAN YOU ASSIGN TO MEASURING FLW?** The relative amount of resources (time, money, equipment) needed to carry out the method.
- **DO YOU NEED A METHOD THAT CAN TRACK CAUSES OF FLW?** Some methods can track causes associated with FLW, while others cannot.
- **DO YOU WANT TO TRACK PROGRESS OVER TIME?** Some methods can assess increases or decreases in FLW across time to track progress.

Based on your answers to these questions, use Table 9 to determine which method or methods are most appropriate. If you are addressing multiple types of FLW (for example, both solid and liquid), you may need multiple types of methods.

For additional guidance, see the **FLW Quantification Method Ranking Tool** published by the Food Loss and Waste Protocol, which asks 11 questions about your circumstances and provides a ranked list of methods based on your answers.

Table 9. Methods Used to Measure FLW in the Processing and Manufacturing Sector

Method Name	Direct FLW Access Needed?	Level of Accuracy?	Level of Resources Required?	Tracks Causes?	Tracks Progress over Time?
Methods for gathering new data					
Direct Measurement	Yes	High	High	Yes	Yes
Interviews/Surveys	Yes	High	High	No	Yes
Methods based on existing data					
Proxy Data	No	Medium	Low	No	Yes
Records	No	Variable*	Low	No	Yes
Less commonly used methods at the processing and manufacturing sector					
Diaries	No	Low-Medium	Medium	Yes	Yes
Mass Balance	No	Low-Medium	Medium-High	Yes	Yes
Waste Composition Analysis	No	Low	Low	No	No

*Accuracy depends on the type of record used: for example, waste transfer receipts may be highly accurate for determing FLW levels, whereas other records are less accurate.
Note: The methods named are nonexhaustive.
Source: Authors.

SECTOR-LEVEL CASE STUDY

Byblos Bakery is the top branded pita maker in western Canada. Byblos worked with Provision Coalition and Enviro-Stewards to measure and prevent FLW generation in its manufacturing operations and saved over C$200,000 from the interventions implemented. Enviro-Stewards conducted a food waste prevention assessment of the facilities and the Provision Coalition's FLW Toolkit helped develop a set of FLW reduction strategies and solutions. By using a facility assessment along with the FLW Toolkit, Byblos could identify root causes for FLW generation and tailor interventions to its business. For example, improvements to retail inventory management helped minimize retail returns and relatively small tweaks to the production process and facility immediately reduce waste generation in the factory. In total, Byblos reduced its food waste by 29% (Provision Coalition 2017).

Distribution and Wholesale

INTRODUCTION

Food distributors and wholesalers ensure that food products make it to market and consumers. Distributors typically maintain exclusive buying agreements with producers, manufacturers and processors or provide products to a certain territory. They rarely sell goods directly to consumers but may work with wholesalers (or larger retailers) that buy in bulk. Wholesalers typically resell goods to retailers, while retailers resell goods directly to consumers.

Because they are subject to supply and demand fluctuations across the food supply chain, they must balance time sensitivity and cost in their operations. Variability within the distribution and wholesale sector can also affect FLW downstream, in the food service, retail and household stages.

In distribution and wholesale, FLW can be caused by damage and spoilage, lack of cold-chain infrastructure, delays during transport (e.g., border inspections), variable customer demands, modification or cancellation of orders, product specifications, variable cost of transport methods, inaccurate forecasting or purchasing, miscommunication with other entities further up and down the food supply chain, and many other factors.

As the specifics of this sector vary by country, so do the root causes behind the associated FLW. Thus generation and prevention of FLW differ from country to country and even from organization to organization, and interventions must be tailored to the context.

Some approaches to preventing FLW in distribution and wholesale are listed below.

- Work with actors upstream in the food supply chain to increase the share of second-grade products that are accepted and valorized to some point.
- Improve cold-chain management and infrastructure to prevent spoilage or degradation during storage and transport.
- Work with actors across the food supply chain to expand value-added processing to increase the proportion of produced food able to be consumed. This could include the creation of processes to valorize food that is damaged or deteriorates during transport and distribution.
- Adjust packaging to extend the life of food products and reduce damage during storage or transport.
- Rethink business models to maintain freshness and reduce shrink.

METHODS USED TO MEASURE FLW

Appropriate methods for FLW measurement depend on the context of who is doing the measuring and what information is available. Start by answering the five questions below.

- **DO YOU HAVE DIRECT ACCESS TO THE FLW?** Does the method require the ability to *directly* count, handle, or weigh the FLW?
- **WHAT LEVEL OF ACCURACY DO YOU NEED?** How accurate will the data gathered with this method be?
- **WHAT AMOUNT OF TIME AND RESOURCES CAN YOU ASSIGN TO MEASURING FLW?** The relative amount of resources (time, money, equipment) needed to carry out the method.
- **DO YOU NEED A METHOD THAT CAN TRACK CAUSES OF FLW?** Some methods can track causes associated with FLW, while others cannot.

- **DO YOU WANT TO TRACK PROGRESS OVER TIME?** Some methods can assess increases or decreases in FLW across time to track progress.

Based on your needs and the answers to these questions, you can use Table 10 to determine which method or methods are most appropriate. If you are addressing multiple types of FLW (for example, both solid and liquid FLW), you may need to select multiple types of methods.

If you need additional guidance in selecting a method, the **FLW Quantification Method Ranking Tool** published by the Food Loss and Waste Protocol asks a series of 11 questions and provides a ranked list of methods based on your circumstances.

Table 10. Methods Used to Measure FLW in the Distribution and Wholesale Sector

Method Name	Direct FLW Access Needed?	Level of Accuracy?	Level of Resources Required?	Tracks Causes?	Tracks Progress Over Time?
Methods for gathering new data					
Waste Composition Analysis	Yes	High	High	No	Yes
Methods based on existing data					
Mass Balance	No	Medium	Low	No	Yes
Proxy Data	No	Low	Low	No	No
Records	No	Variable*	Low	No	Yes
Less commonly used methods at the distribution and wholesale sector					
Diaries	No	Low-Medium	Medium	Yes	Yes
Direct Measurement	Yes	High	High	Yes	Yes
Interviews/Surveys	No	Low-Medium	Medium-High	Yes	Yes

*Accuracy depends on the type of record used: for example, waste transfer receipts may be highly accurate for determing FLW levels, whereas other records are less accurate.
Note: The methods named are nonexhaustive.
Source: Authors.

CASE STUDY FOR THE DISTRIBUTION AND WHOLESALE SECTOR

The Mexican Transport Institute (*Instituto Mexicano del Transporte*–IMT) developed a methodology to identify cold-chain coverage and gaps across the country. The IMT uses a database with several metrics, including origin and destination of shipments, classification of loads, ownership of transportation units and cost of transportation. It monitors the status of the distribution and transportation system across Mexico alongside relevant costs, shipment data and records. This allows IMT to identify potential FLW hotspots and regions needing cold-chain management and infrastructure (Morales 2016, CEC 2017).

Retail

INTRODUCTION

Food retailers tend to have a relatively large influence on FLW throughout the supply chain. Because of their dominant buying power, retailers can influence FLW further upstream (i.e., primary production, processing and manufacturing) and even distribution. Because of their typical place right before final consumption in the food supply chain, variability within the retail sector can lead to FLW in the food service and household stages.

FLW in retail can be caused by any number of factors, including but not limited to: damage and spoilage, lack of cold-chain infrastructure, delays during transport (e.g., border inspections), variable customer demands, modification or cancellation of orders, inaccurate customer forecasting and overstocking, reliance on inefficient stocking practices or product sizes, misinterpretation of food safety standards, and misleading or confusing date labeling.

Because the specifics of this sector vary by country, so do the root causes behind the associated FLW. Generation and prevention of FLW differ from country to country and even organization to organization, and interventions must be tailored to the context.

Some approaches to preventing FLW in retail are listed below.

- Working with actors upstream in the food supply chain to increase the share of second-grade products that are accepted and valorized to some point.
- Working with actors across the food supply chain to expand value-added processing in order to increase the proportion of produced food able to eventually be consumed.
- Standardizing date labels to reduce the amount of FLW generated from confusion over food safety.
- Implementing packaging adjustments to extend the life of food products and reduce damage during storage or transport.
- Rethinking purchasing models in order to maintain freshness and reduce shrink.

METHODS USED TO MEASURE FLW

Appropriate methods for FLW measurement depend on the context of who is doing the measuring and what information is available. Start by answering the five questions below.

- **DO YOU HAVE DIRECT ACCESS TO THE FLW?** Does the method require the ability to *directly* count, handle, or weigh the FLW?
- **WHAT LEVEL OF ACCURACY DO YOU NEED?** How accurate will the data gathered with this method be?
- **WHAT AMOUNT OF TIME AND RESOURCES CAN YOU ASSIGN TO MEASURING FLW?** The relative amount of resources (time, money, equipment) needed to carry out the method.
- **DO YOU NEED A METHOD THAT CAN TRACK CAUSES OF FLW?** Some methods can track causes associated with FLW, while others cannot.
- **DO YOU WANT TO TRACK PROGRESS OVER TIME?** Some methods can assess increases or decreases in FLW across time to track progress.

Based on your needs and the answers to these questions, you can use Table 11 to determine which method or methods are most appropriate. If you are addressing multiple types of FLW (for example, both solid and liquid FLW), you may need to select multiple types of methods.

If you need additional guidance in selecting a method, the **FLW Quantification Method Ranking Tool** published by the Food Loss and Waste Protocol asks a series of 11 questions and provides a ranked list of methods based on your circumstances.

Table 11. Methods Used to Measure FLW in the Retail Sector

Method Name	Direct FLW Access Needed?	Level of Accuracy?	Level of Resources Required?	Tracks Causes?	Tracks Progress Over Time?
Methods for gathering new data					
Direct Measurement	Yes	High	High	Yes	Yes
Waste Composition Analysis	Yes	High	High	No	Yes
Methods based on existing data					
Mass Balance	No	Medium	Low	No	Yes
Proxy Data	No	Low	Low	No	No
Records	No	Variable*	Low	No	Yes
Less commonly used methods at the retail sector					
Diaries	No	Low-Medium	Medium	Yes	Yes
Interviews/Surveys	No	Low-Medium	Medium-High	Yes	Yes

*Accuracy depends on the type of record used: for example, waste transfer receipts may be highly accurate for determing FLW levels, whereas other records are less accurate.
Note: The methods named are nonexhaustive.
Source: Authors.

CASE STUDY FOR THE RETAIL SECTOR

Delhaize America, a food retailer, implemented a food waste measurement and reduction program in its East Coast stores and distribution centers. Through direct measurement with Scanner information and waste separation, Delhaize America is able to consistently track food waste over time. Delhaize America has used this information to identify waste hotspots and to reduce FLW across its operations. For example, daily deliveries of fresh product (via computer-assisted ordering systems) has improved order accuracy and inventory management, greatly reducing the amount of produce that goes to waste. In some locations, staff noticed that more food was going to compost, which signaled a need for better coordination with local food banks to ensure that food safe for human consumption was not needlessly being composted rather than serving those in need. Such observations led to more food going to feed people and less food becoming waste.

Recently, the retailer has started to track progress every quarter based on tonnes of food waste per sales, percentage of food waste diverted from landfills and tonnes of food donated. These metrics allow Delhaize America to monitor its progress toward preventing FLW as well as donating surplus food to charities, while also diminishing the amount of FLW that goes to landfills (FLW Protocol 2017).

Food Service Sector

INTRODUCTION

The food service sector includes all institutions that serve prepared food intended for final consumption. In this sector, food products are taken from their raw, processed, or manufactured state and prepared in-house. The final product is usually sold in single portions, though certain business models serve food in larger portions.

Examples of organizations in this sector are: restaurants, caterers, hotels or venues that prepare and/or serve food, street vendors, convenience stores with prepared food, or cafeterias within facilities such as schools, hospitals and prisons.

In this sector, there is an important distinction between pre-consumer and post-consumer waste. Pre-consumer waste is any waste that occurs before the food is on the customer's plate and post-consumer waste is any waste that occurs after that point. Some in the sector refer to this as "back-of-house" and "front-of-house," respectively.

Some approaches to preventing FLW in food service are listed below.

- Working with actors upstream in the food supply chain to increase the share of second-grade products that are accepted and valorized to some point.
- Improving cold-chain management and infrastructure in order to prevent spoilage or degradation during storage and transport.
- Reducing overproduction of under-consumed products or shifting from production models that routinely overproduce food (e.g., buffets).
- Rethinking purchasing models in order to maintain freshness and reduce shrink.

METHODS USED TO MEASURE FLW

Appropriate methods for FLW measurement depend on the context of who is doing the measuring and what information is available. Start by answering the five questions below.

- **DO YOU HAVE DIRECT ACCESS TO THE FLW?** Does the method require the ability to *directly* count, handle, or weigh the FLW?
- **WHAT LEVEL OF ACCURACY DO YOU NEED?** How accurate will the data gathered with this method be?
- **WHAT AMOUNT OF TIME AND RESOURCES CAN YOU ASSIGN TO MEASURING FLW?** The relative amount of resources (time, money, equipment) needed to carry out the method.
- **DO YOU NEED A METHOD THAT CAN TRACK CAUSES OF FLW?** Some methods can track causes associated with FLW, while others cannot.
- **DO YOU WANT TO TRACK PROGRESS OVER TIME?** Some methods can assess increases or decreases in FLW across time to track progress.

Based on your needs and the answers to these questions, you can use **Table 12** to determine which method or methods are most appropriate. If you are addressing multiple types of FLW (for example, both solid and liquid FLW), you may need to select multiple types of methods.

Additional guidance can be found in the **FLW Quantification Method Ranking Tool** published by the Food Loss and Waste Protocol, which asks a series of 11 questions and provides a ranked list of methods based on your answers.

Table 12. Methods Used to Measure FLW in the Food Service Sector

Method Name	Direct FLW Access Needed?	Level of Accuracy?	Level of Resources Required?	Tracks Causes?	Tracks Progress Over Time?
Methods for gathering new data					
Direct Measurement	Yes	High	High	Yes	Yes
Waste Composition Analysis	Yes	High	High	No	Yes
Methods based on existing data					
Mass Balance	No	Medium	Low	No	Yes
Records	No	Variable*	Low	No	Yes
Less commonly used methods at the food service/institutions sector					
Diaries	No	Low-Medium	Medium	Yes	Yes
Interviews/Surveys	No	Low-Medium	Medium-High	Yes	Yes
Proxy Data	No	Low	Low	No	No

*Accuracy depends on the type of record used: for example, waste transfer receipts may be highly accurate for determing FLW levels, whereas other records are less accurate.
Note: The methods named are nonexhaustive.
Source: Authors.

CASE STUDY FOR THE FOOD SERVICE SECTOR

Sodexo has prevented FLW through its "WasteWatch powered by LeanPath" program, which reduces on site food waste by an average of 50 percent. This program uses smart scales, which categorize food waste and generate a food waste inventory that helps identify *how much* and *where* food goes to waste. These inventories and continuous direct measurement allow staff to identify hotspots, take action and monitor progress over time. Sodexo found that tailored messaging to employees improved staff engagement in the FLW prevention program and that this staff engagement was particularly impactful in the food service sector. Additionally, Sodexo identified products going to waste that could not be sold but were still safe for human consumption. In the United States, Sodexo has collaborated with Food Recovery Network, Feeding America and Campus Kitchens to connect surplus food to those in need (Clowes et al. 2018).

Household

INTRODUCTION

Within the food supply chain, the household sector encompasses all food preparation and consumption in the home. While it is uncommon for individual households to independently track their food waste, governmental or nongovernmental organizations may want to monitor household FLW. In this guide, the household sector includes only food consumed in the home. Food consumed away from home falls under the food service stage in the food supply chain.

FLW in the household can be caused by preparation mistakes, lack of proper storage infrastructure or practices, trimming for consistency, misshapen products, spillage during handling, poor portion control, contamination, overproduction, food safety concerns, or many other factors.

METHODS USED TO MEASURE FLW

Appropriate methods for FLW measurement depend on the context of who is doing the measuring and what information is available. Start by answering the five questions below.

- **DO YOU HAVE DIRECT ACCESS TO THE FLW?** Does the method require the ability to *directly* count, handle, or weigh the FLW?

- **WHAT LEVEL OF ACCURACY DO YOU NEED?** How accurate will the data gathered with this method be?

- **WHAT AMOUNT OF TIME AND RESOURCES CAN YOU ASSIGN TO MEASURING FLW?** The relative amount of resources (time, money, equipment) needed to carry out the method.

- **DO YOU NEED A METHOD THAT CAN TRACK CAUSES OF FLW?** Some methods can track causes associated with FLW, while others cannot.

- **DO YOU WANT TO TRACK PROGRESS OVER TIME?** Some methods can assess increases or decreases in FLW across time to track progress.

Based on your needs and the answers to these questions, you can use **Table 13** to determine which method or methods are most appropriate. If you are addressing multiple types of FLW (for example, both solid and liquid FLW), you may need to select multiple types of methods.

For additional guidance in selecting a method, see the **FLW Quantification Method Ranking Tool** published by the Food Loss and Waste Protocol, which asks 11 questions and provides a ranked list of methods based on your answers.

Table 13. Methods Used to Measure FLW in the Household Sector

Method Name	Direct FLW Access Needed?	Level of Accuracy?	Level of Resources Required?	Tracks Causes?	Tracks Progress Over Time?
Methods for gathering new data					
Diaries	No	Low-Medium	Medium	Yes	Yes
Direct Measurement	Yes	High	High	Yes	Yes
Interviews/Surveys	No	Low-Medium	Medium-High	Yes	Yes
Waste Composition Analysis	Yes	High	High	No	Yes
Methods based on existing data					
Proxy Data	No	Low	Low	No	No
Records	No	Variable*	Low	No	Yes
Less commonly used methods at the household sector					
Mass Balance	No	Medium	Low	No	Yes

*Accuracy depends on the type of record used: for example, waste transfer receipts may be highly accurate for determing FLW levels, whereas other records are less accurate.
Note: The methods named are nonexhaustive.
Source: Authors.

CASE STUDY FOR THE HOUSEHOLD LEVEL

A household survey in Mexico City and Jiutepec, Mexico collected demographic and behavioral information alongside a week-long FLW diary. Using these data together gives a more complete image of household FLW and allows analysis of the effects of various socioeconomic factors to identify root causes of household FLW. The results could inform local government agencies, NGOs and others about the potential effectiveness of intervention strategies. Such a community-centered approach lends itself to more tailored (and hopefully more effective) approaches to prevent FLW than broader surveys and diaries (Jean-Baptiste 2013).

Whole Supply Chain Approaches

INTRODUCTION

A whole supply chain approach encompasses all stages in the food supply chain. This includes all activities and destinations from production to final consumption or disposal. Users of this approach would be national and local governments. A useful application of this approach would be to analyze flows of specific food products or food categories across the entire food supply chain. Such an approach can provide insights into material flows, food availability, environmental impacts, food waste hotspots and opportunities for waste prevention, disposal methods, production and consumption trends and so on. Different users could vary the working definition of FLW by adjusting the scope of their analysis to focus on specific aspects of the food supply chain.

FLW can be generated for a variety of reasons throughout the supply chain and the user is recommended to review the relevant modules in this guide for details at each stage. Interventions are often tailored to a stage in the food supply chain with a sector-specific perspective because both existing data and direct measurements tend to occur at the sectoral level.

METHODS USED TO MEASURE FLW

Appropriate methods for FLW measurement depend on the context of who is doing the measuring and what information is available. Start by answering the five questions below.

- **DO YOU HAVE DIRECT ACCESS TO THE FLW?** Does the method require the ability to *directly* count, handle, or weigh the FLW?
- **WHAT LEVEL OF ACCURACY DO YOU NEED?** How accurate will the data gathered with this method be?
- **WHAT AMOUNT OF TIME AND RESOURCES CAN YOU ASSIGN TO MEASURING FLW?** The relative amount of resources (time, money, equipment) needed to carry out the method.
- **DO YOU NEED A METHOD THAT CAN TRACK CAUSES OF FLW?** Some methods can track causes associated with FLW, while others cannot.
- **DO YOU WANT TO TRACK PROGRESS OVER TIME?** Some methods can assess increases or decreases in FLW across time to track progress.

Based on your needs and the answers to these questions, you can use **Table 14** to determine which method or methods are most appropriate. If you are addressing multiple types of FLW (for example, both solid and liquid FLW), you may need to select multiple types of methods.

For additional guidance in selecting a method, see the **FLW Quantification Method Ranking Tool** published by the Food Loss and Waste Protocol, which asks 11 questions and provides a ranked list of methods based on your answers.

Table 14. Methods Used to Measure FLW across the Whole Supply Chain

Method Name	Direct FLW Access Needed?	Level of Accuracy?	Level of Resources Required?	Tracks Causes?	Tracks Progress Over Time?
Methods for gathering new data					
Interviews/Surveys	No	Low-Medium	Medium-High	Yes	Yes
Methods based on existing data					
Mass Balance	No	Medium	Low	No	Yes
Proxy Data	No	Low	Low	No	No
Records	No	Variable*	Low	No	Yes
Less commonly used methods across the whole supply chain					
Diaries	No	Low-Medium	Medium	Yes	Yes
Direct Measurement	Yes	High	High	Yes	Yes
Waste Composition Analysis	Yes	High	High	No	Yes

*Accuracy depends on the type of record used: for example, waste transfer receipts may be highly accurate for determing FLW levels, whereas other records are less accurate.
Note: The methods named are nonexhaustive.
Source: Authors.

CASE STUDY FOR MEASURING ACROSS THE WHOLE FOOD CHAIN

The US Department of Agriculture (USDA) Economic Research Service (ERS) estimates all post-harvest losses, through the entire food supply chain for over 200 agriculture product types, through its Loss-Adjusted Food Availability Data Series. This data series helps the USDA ERS produce estimates of loss-adjusted food availability as a proxy for food consumption. To create this data series, the USDA ERS developed loss coefficients, updated primary conversion factors and compared shipping and point-of-sales data. By estimating food losses in the United States with such a high level of accuracy, the USDA ERS helps US state and local governments, food industries, nongovernmental organizations and others identify opportunities to prevent FLW. These estimates allow others to identify hotspots in which to conduct more detailed research with the aim of preventing FLW (Buzby et al. 2014).

Appendix A: Methods

This appendix contains brief descriptions of several FLW measurement methods, as well as additional resources for each.

DIARIES

In the context of FLW, diaries refer to the practice of a person or group of people (e.g., the residents of a household) keeping a log of food loss and waste that occurs within their home or other unit. The diary usually calls for the participant to log the amount and type of food being lost or wasted, along with how and why the FLW was discarded.

Diaries can take many forms, such as a paper-based diary, an electronic diary, or even a photographic diary in which participants take pictures of their food waste for further analysis.

A summary of the strengths and limitations of diaries is shown in Table A1.

HOW TO USE DIARIES TO QUANTIFY FLW

This module provides an overview of the steps that should be undertaken to use diaries to gather information about FLW. Although these broad steps will apply to most cases, a professional statistician or researcher can further tailor the design of a diary to best meet the needs of a given situation.

Step 1: Decide how participants will quantify FLW and for how long

In a diary study, participants can quantify FLW by weighing, measuring the volume, or approximating FLW. Of these methods, weighing produces the most precise data, but it is also the most time-intensive for the participant and may be expensive, since participants might be given a scale.

In determining the length of the study, consider the trade-off between a longer, more intensive diary period that will produce more data and the burden that it imposes on participants, who may be more likely to drop out of the study.

Step 2: Identify how the diaries will be administered

Diaries can be administered in print by mail or electronically via a computer or smartphone app. Each method has advantages and disadvantages as shown in **Table A2**.

Step 3: Identify respondent audience

In some cases, the participants in a diary study will be a discrete group. For surveys with a larger population of target respondents, a random sample may need to be developed, in which case a professional statistician should be consulted, although simple random sampling can be conducted when a list of the members of a population is available and complete (Laerd 2012).

Step 4: Recruit participants

Participants in a diary study must be selected from the group being studied. Because keeping an FLW diary is a time-intensive commitment for participants, some sort of incentive may be necessary.

Step 5: Prepare questions to quantify FLW

An effective FLW diary will provide fields for categories of data. Some common fields are:

- Food type (e.g., carrot, ham sandwich, chicken)
- Material type (i.e., food and/or inedible parts)
- How it was purchased (e.g., fresh, frozen, canned)

Table A1. Factors to Consider When Using Diaries to Quantify FLW

Strengths	Limitations / Points to Consider
• Provides information on the types of food wasted and the reasons behind that waste • Can gather data on otherwise difficult-to-measure material flows (e.g., food waste going into the sewer or at-home composting)	• Can be relatively expensive, especially if diary participants are given an incentive • Can underestimate the amount of waste due to aspirational biases • Can be coupled with interviews or ethnographic methods to further understand why food gets wasted

Source: Authors.

- How much was wasted (provide unit of measure)
- Why it was wasted (e.g., cooked badly, served too much, spoiled)
- Disposal method (e.g., compost, garbage disposal, pet food)

It is best to include all the above information to form the most complete FLW inventory, although the diary should be tested to ensure that the burden is not too great on the participants.

Step 6: Test the diary and revise

Testing the diary with a small subset of the target audience can provide insight into which questions may be confusing, burdensome, or unclear. The survey can then be revised to address the concerns of the testers.

Step 7: Administer the diary

Once the survey has been designed and tested, it can be distributed to the intended respondents. Keep a complete list of survey recipients along with those who respond to track response rates.

Step 8: Prepare and analyze the data

Responses must be standardized and collated. The simplest method is to enter the data into a spreadsheet. If the diary contained open-ended questions, determine whether to enter the response in full or to code the responses into categories. If the diary contained measurements of volume or approximations, convert these measurements to weight using a predetermined conversion factor.

COMMON DATA CHALLENGES IN USING A DIARY

UNDERREPORTING. Both the social desirability bias and "diary fatigue" may lead participants to underreport their FLW. This can be pre-empted with clear instructions about accurate diary-keeping and a reminder that the diary process is not seeking to shame participants over their FLW amounts. Diary results can also be cross-referenced with the findings of other quantification methods (e.g., a waste composition analysis) to determine the extent of underreporting.

LOW RESPONSE RATES. Because diary studies are generally voluntary and require the respondent to take time out of their schedules to complete, many have low response rates. A common strategy to boost response rates is to provide an incentive to the respondent. In addition to a monetary incentive, participants may be permitted to keep scales or any other any equipment distributed for FLW quantification purposes.

ADDITIONAL RESOURCES FOR DIARIES

FLW Protocol. 2016. Chapter 6, "Diaries," in *Guidance on FLW quantification methods*. **http://flwprotocol.org/wp-content/uploads/2016/06/FLW_Guidance_Chapter6_Diaries.pdf**.

OpenIDEO. n.d. "Food waste challenge: Keeping a food waste diary." **https://challenges.openideo.com/content/food-waste-diary**.

WRAP. 2012a. "Your household's food and drink waste diary." **www.wrap.org.uk/sites/files/wrap/Kitchen-Diary-2012-Final-Low-Res.pdf**.

Table A2. Advantages, Disadvantages and Examples of Diary Types

Method	Advantages	Disadvantages	Example
Print	• Relatively low cost • Allows for both visual and written prompts	• Can become lost or damaged • May be inconvenient and labor-intensive for the participant	See this **sample print food waste diary** (WRAP 2012a).
Electronic	• May be more convenient for the participant • Allows for data to be saved and stored electronically • Saves time on data entry	• Requires familiarity with technology and computers on the part of the participant	See this **sample food waste tracking spreadsheet** (OpenIDEO n.d.)
Smartphone app	• Most convenient option for participant • Allows for use of photographs	• Limits respondents to smartphone owners with technological capabilities • Photographs without measurements may be difficult for the researcher to assess amounts of waste	The app "**SmartIntake**" is one example of a food waste tracking app—it allows pictures to be taken before and after a meal and then sent to the researcher

Source: Authors.

DIRECT MEASUREMENT

Direct measurement includes a variety of methods in which FLW is directly counted, weighed, or otherwise measured as it occurs. Direct measurement often produces the most accurate FLW figures but can also require the most expertise, time and cost. These methods vary based on the stage of the supply chain thus are organized here by sector.

A summary of the strengths and limitations of direct measurement is shown in Table A3.

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN PRIMARY PRODUCTION

A common direct measurement approach at the production stage is to take random samples from the crop or product being produced to determine levels of FLW.

One method for direct measurement is described in a toolkit to help farmers to assess the amount of marketable produce remaining in their fields after harvest to help prevent in-field losses of crops (Johnson 2018). The method involves a one-off assessment of the crop in a sample area of a field, involving six steps:

- Note the row spacing, number of rows and the acreage of the field. Gather equipment.
- Select and mark rows randomly.
- Harvest the rows.
- Sort samples into categories.
- Weigh and record samples in each category.
- Extrapolate the data from the selected rows to the entire field and calculate an estimate of the potential in the field.

The toolkit suggests three categories for sorting: marketable (i.e., high-quality appearance), edible (i.e., cannot meet highest buying specification but still edible) and inedible. The categories can be adapted to further sort the inedible items according to the reasons why they are inedible (e.g., insect damage, disease, decay, over-maturity). This additional stage can help farmers identify the root causes leading to items being unsuitable for harvest and suggest other markets where it might be sold.

A summary of the strengths and limitations of on-farm data collection is shown in Table A4.

Table A3. Factors to Consider When Using Direct Measurement to Quantify FLW

Strengths	Limitations / Points to Consider
• Provides highly accurate data	• Can be relatively expensive and time-intensive
• Allows progress to be tracked over time	• Requires direct access to the FLW
• Allows for tracking of causes of FLW	• Methods vary greatly across sectors

Source: Authors.

Table A4. Factors to Consider When Using Direct Measurement to Quantify FLW in Primary Production

Strengths	Limitations / Points to Consider
• Accurate estimates of amounts and types of FLW	• Requires time to implement, often at a busy time of the year for farmers (e.g., harvest)
• Adaptable to support a change program	• Financial cost associated with method
• Estimates can be used to guide financial decisions	• Access to field/farm facilities required
	• Can be used in combination with other methods to obtain reasons for FLW

Source: Authors.

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN PROCESSING AND MANUFACTURING

How to measure material flows in manufacturing and processing facilities is explained in many toolkits aimed at identifying and tackling food loss and waste. For instance, the **Provision Coalition's Food Loss and Waste Toolkit** based on Enviro-Stewards' approach offers guidance on direct measurement of FLW in manufacturing and processing facilities. The details must be tailored to the situation, but it usually involves diverting the food that is being lost or wasted into containers (e.g., buckets) where it can be weighed. Food waste is collected for a period of time (e.g., one eight-hour shift) and then scaled up to provide an approximate estimate the amount for a week, month, or year. More accurate estimates require repeated sampling to account for fluctuations over time (e.g., seasonality).

The tool was designed for Canadian users. The financial and nutritional calculations would be accurate for other users but some of the environmental information uses factors (e.g., carbon factors) specific to Canadian provinces thus would not be entirely accurate for other countries.

A summary of the strengths and limitations of direct measurement in processing and manufacturing is shown in Table A5.

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN DISTRIBUTION AND WHOLESALE

Direct measurement is frequently not possible at the distribution and wholesale stage due to the transient nature of the sector. However, most distributors and wholesalers possess information on purchases, inventory and sales. This measurement approach compares inputs (purchases) with outputs (sales) alongside changes in stock levels. It can estimate the value of lost sales and can provide a good starting point for prioritizing action to prevent food from being wasted. The **"Mass Balance"** module below gives more detail about using this approach to approximate FLW.

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN RETAIL

A common direct measurement approach at the retail sector is electronic scanning.

Most retailers use an electronic scanning system for inventory and sales. Under this method, when items leave the retailer's premises for reasons other than being sold (e.g., landfill, donation), they are scanned and this information is integrated into a database. This database can then be used to quantify the amounts and types of food going to different destinations. It can be used to estimate the value of lost sales and can provide a good starting point for prioritizing action for preventing food from being wasted. However, fresh produce, bakery and delicatessen items are often challenging to capture since they are often not consistently scanned out.

A summary of the strengths and limitations of scanning in retail is shown in **Table A6**.

Table A5. Factors to Consider When Using Direct Measurement to Quanify FLW in Processing and Manufacturing

Strengths	Limitations / Points to Consider
• High level of accuracy (for weight and other impacts that are estimated using weight — embedded energy, water, product value, etc.) • Can provide granular data to support change programs • Data can be used to estimate range of metrics (e.g., financial, environmental) to support business case development • Can be operated consistently across many sites (e.g., factories, distribution centers) and data combined	• Cost of measurement will vary, but can be relatively cost-effective • Could lead to change in behavior of staff undertaking measurement, making baseline measurement less accurate • Can be used in combination with other methods to obtain reasons for FLW

Source: Authors.

Table A6. Factors to Consider when Using Scanning for FLW Quantification in Retail

Strengths	Limitations / Points to Consider
• High level of accuracy for most products • Provides highly granular data to support change programs • Approach can be used to estimate a range of metrics (e.g., financial, environmental) to support business case development • Can be operated across many sites (e.g., stores, distribution centers) and data can be compared or combined	• Requires products to be packaged with bar codes • Additional solution may be required for unpackaged food (e.g., fruit and vegetables sold loose) • Initial cost to develop system can be expensive but can be based on existing sales data system. • Requires changes in procedures to ensure wasted, lost and surplus items are scanned

Source: Authors.

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN FOOD SERVICE AND INSTITUTIONS

Smart bins and plate weighing are commonly used to measure FLW in the food service sector.

A smart bin is a disposal container attached to a data entry system. The smart bin weighs items as they are added. It also has a terminal for the user to enter details of the type of food being wasted and the reason for it being wasted. This information is passed to a database that can be analyzed to provide information for preventing food waste (or diverting it up the waste hierarchy). It can also be linked to procurement systems to provide financial information. Smart bins can be deployed as a one-off project to facilitate change or provide on-going monitoring for continuous improvement and measurement of performance data. Numerous smart bin providers can be found through an Internet search.

A summary of the strengths and limitations of smart bins can be found in Table A7.

Plate weighing can be used to measure plate leftovers in hospitality, food service and school settings. It usually involves two direct measurements:

- a sample of trays containing the food directly after serving to establish the average amount being served; and
- a sample of trays containing the plate leftovers after the diners have eaten.

The amount of plate waste is usually expressed as a percentage of these two quantities.

A summary of the strengths and limitations of plate weighing is shown in **Table A8**.

Table A7. Factors to Consider when Using Smart Bins

Strengths	Limitations / Points to Consider
• Provides highly granular data to support change programs • Approach can be used to estimate range of metrics (e.g., financial, environmental) to support business case development • Can be operated across many kitchens and data combined	• Measurement has the potential to change behavior (e.g., stimulate FLW prevention activities), so accurate measurement of baseline may be difficult • Financial cost and staff time required for installing and using smart bins and analyzing data • Difficult to apply to FLW going down the sewer

Source: Authors.

Table A8. Factors to Consider when Using Plate Weighing

Strengths	Limitations / Points to Consider
• A well-researched and relatively accurate method • Can provide detailed information on the types of food wasted or lost (if recorded)	• Covers only plate waste; does not include preparation (i.e., back-of-house) waste • Relatively expensive • Can be used in combination with other methods to obtain reasons for wasting food

Source: Authors.

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN HOUSEHOLDS

Scales or measurement containers can be used in households to weigh or measure FLW directly. However, it is contingent on the members of the household to correctly sort the FLW, which may lead to underreporting. More information about how households can measure their own FLW can be found in the **"Diaries"** section above.

A summary of the strengths and limitations of household caddies is shown in Table A9.

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN THE WHOLE SUPPLY CHAIN APPROACH

Although measuring FLW directly across multiple sectors is challenging, it is possible to conduct direct measurements of separate sectors and then combine those sectoral measurements to reach a total across sectors. In these cases, the following concerns must be considered:

- The scope of what is considered FLW must be identical across the sectoral studies.
- Ideally, the same method of measurement is used. If this is not possible, the different methods should be reported.
- The FLW being measured must not be double-counted across sectors. This can be accomplished by delineating the sectors in advance.

INTERVIEWS AND SURVEYS

Interviews and surveys (hereafter surveys) can be a cost-effective way to develop rough quantitative estimates of FLW and to gather information about its causes. Surveys can also help collect information from a wide array of individuals or entities on attitudes toward food waste.

Table A9. Factors to Consider when Measuring Household FLW

Strengths	Limitations / Points to Consider
• Simple, relatively cheap method to implement • Approach can be adapted to obtain information in a small number of categories (e.g., wasted food, inedible parts associated with food) • Potentially can be applied to all destinations or discard routes from a home	• Likely to underestimate amounts of food wasted. • Little information on the types and reasons for wasting food (unless used in combination with other methods) • In hot conditions, moisture may be lost from food waste, thus reducing its weight and affecting FLW estimates

Source: Authors.

Surveys can be grouped into two categories: those used to collate existing data and those used to generate new FLW estimates.

A summary of the strengths and limitations of the two different types of surveys is shown in Tables A10 and A11.

HOW TO CONDUCT A SURVEY TO QUANTIFY FLW

This section describes seven steps to conduct a survey to gather information about FLW.

Step 1: Set hypotheses and determine the survey approach

Before starting a survey, have a hypothesis in mind for the results you expect from the survey. This hypothesis will help focus the research and establish goals. An example of a hypothesis is: "We expect that corn farmers will report that 30 percent of their crop is left in the field during harvest." This simple hypothesis identifies the type of crop (corn), the intended respondent (farmers) and what is being measured (crop left in field during harvest).

Next, determine which type of survey to use. If the respondents are likely to have already collected data of their own, you can use a survey focused on collating existing data. If the survey asks respondents to contribute or quantify new FLW data, a survey focused on quantifying is needed.

Step 2: Identify the method by which the survey will be administered

Surveys can be administered by mail, by telephone, electronically, or in-person. Each method has advantages and disadvantages, as seen in **Table A12**.

Step 3: Identify respondent audience

In some cases, the participant audience for a survey-based study will be a discrete group. For surveys with a large number of target respondents, a random sample may need to be developed. If so,

Table A10. Factors to Consider when Using a Survey to Collate Existing Data

Strengths	Limitations / Points to Consider
• Cost-effective method of collating information • Can standardize the information requested from each interviewee	• Relies on third parties • Can be challenging to extract the exact type of information needed and can be difficult to ensure that collated information has the same definition and scope of FLW • Questionnaire may need to be flexible to accommodate different levels of information (e.g., granularity of data) • Can be limited by commercial sensitivities and confidentiality • Unlikely to include information on root causes (i.e., the reasons why food is thrown away)

Source: Authors.

Table A11. Factors to Consider when Using a Survey to Generate New Data

Strengths	Limitations / Points to Consider
• Relatively cost-effective to administer • Can provide data by food group or preparation stage • Can provide information by demographic group and/or other characteristics • Can provide data on root causes of waste and help identify hotspots	• Respondents tend to underestimate the amount of food waste due to aspirational biases • Not yet known how this underestimation varies over time, between groups and during intervention studies

Source: Authors.

Table A12. Advantages and Disadvantages of Methods for Conducting Surveys

Method	Advantages	Disadvantages
By mail	• Relatively low cost • Allows for both visual and written prompts	• Impractical if mail service is limited • Low response rate
Telephone	• Interviewer can administer survey directly and explain any unclear questions • Reduces travel costs as compared to in-person method	• No visuals can be shared • Limits respondents to those with telephone access • Can be difficult to schedule
Electronic	• Low cost • Wide reach	• Limits respondents to those with technological capability
In-person	• Interviewer can administer survey directly and explain any unclear questions	• More costly in terms of time and expense • Interviewer can unconsciously bias responses • Can be difficult to schedule

Source: Authors.

a professional statistician should be consulted, although simple random sampling can be conducted if a list of the members of a population is available and complete (Laerd 2012).

Step 4: Prepare questions to quantify FLW

The next step is to develop the questionnaire to be distributed for the survey.

Some common topics for questions in an FLW quantification survey are (CEC 2017):

- estimates of FLW generated;
- reasons or causes for FLW;
- how FLW is managed; and
- current strategies or suggestions on how to prevent or reduce FLW.

You might also want to collect income or livelihood data on the respondents to cross reference some of the answers.

Questions should be sequenced in a logical progression, with simpler or more important questions at the beginning, since respondents frequently fail to complete the entire surveys (Statpac 2017). If a survey is too long it may be off-putting to respondents, so each question should be evaluated for its importance to the study.

A further discussion of the benefits and drawbacks of a number of types of questions can be found in section 7.2 of the "**Guidance on Surveys**" developed by the FLW Protocol.

Step 5: Test the survey and revise

If possible, test the survey with a subset of the target audience to provide insight into questions that may be confusing or unclear for the respondent. The survey can then be revised to address these concerns.

Step 6: Administer the survey

Once the survey has been designed and tested, it can be distributed to the intended audience of respondents. A complete list of the survey recipients should be kept along with those who have responded in order to track response rates.

Step 7: Prepare and analyze the data

After responses are received, they must be standardized and collated. The simplest method for doing this is to enter the data into an electronic spreadsheet.

Points to highlight in a summary of an FLW survey are:

- Frequency and amount of FLW;
- Reasons for different types of FLW;
- Relationship between FLW and variables (such as income and location); and
- Strategies used and suggestions to address or reduce FLW.

COMMON DATA CHALLENGES IN CONDUCTING A SURVEY

LOW RESPONSE RATES. Because surveys require respondents to take time from their schedules to complete, many suffer from low response rates. For example, a survey from Food and Consumer Products of Canada in 2015 to collect FLW data from companies had just a 35 percent response rate (Food and Consumer Products of Canada 2015). Although it can be difficult to boost response rates, a common strategy is to provide respondents with a benefit for participating, such as compensation (usually quite small) or a promise of sharing the survey results (Statpac 2017).

CONCERNS OVER CONFIDENTIALITY. Companies are understandably reluctant to share information that could affect their competitive advantage. This can be addressed by reporting information from an entire sector rather than identifying data from individual companies. This requires the company to trust the entity conducting the survey to keep the information confidential.

UNDERREPORTING. Respondents may underreport FLW because they don't want to appear wasteful or because they lack awareness around FLW. To counteract these biases, clear instructions should be given on the importance of accurate responses and that the survey administrators are not seeking to "shame" participants over their FLW. Survey results can also be cross-referenced with the findings of other quantification methods (such as a waste composition analysis) to determine the extent of underreporting.

ADDITIONAL RESOURCES ON CONDUCTING A SURVEY

FLW Protocol. 2016. Chapter 7. "Guidance on surveys," in *Guidance on FLW quantification methods*. **http://flwprotocol.org/wp-content/uploads/2016/06/FLW_Guidance_Chapter7_Surveys.pdf**.

David S. Walonick. 2012. "Steps in designing a survey." StatPac. **www.statpac.com/survey-design-guidelines.htm**.

MASS BALANCE

Mass balance measurement infers food loss and waste levels by comparing inputs (e.g., products entering a grocery store) with outputs (e.g., products sold to customers) along with changes in standing stock levels. At its most basic, this method estimates FLW by subtracting the outputs from the inputs, with the difference being considered the amount of FLW.

A summary of the strengths and limitations of mass balance measurement is shown in **Table A13**.

HOW TO USE MASS BALANCE FOR FLW QUANTIFICATION

Step 1: Define your inputs, outputs and stocks

Three key figures—the inputs, the outputs and the stocks—form the basis of the mass balance calculation.

In a manufacturing plant, the inputs would be the ingredients used, the outputs would be the products produced and the stocks would be whatever ingredients or products are held on site. At a state or country level, the inputs would be domestic food production and imports and the outputs would be food consumption, exports and nonfood uses such as seed, feed, fuel and pet food.

Step 2: Identify data sources

After determining the inputs, outputs and stocks, find appropriate sources of data to estimate those numbers. Data can come from sources such as product inventories, shipping and storage records, invoices and other documentation. See the **"Records"** section below for more information on gathering records.

Once the data sources have been identified, make sure that all data are in the same units. If it is not, you will need to standardize the units.

Step 3: Account for any variations

If the weight of the inputs changes during processing or cooking, you will need to adjust for it in the mass balance equation. For example, in some cooking processes (e.g., preparing a sauce), significant amounts of water will evaporate, while in others (e.g., cooking pasta), water will be added. These weight changes must be identified so they do not skew the overall waste figure.

Step 4: Perform the mass balance analysis

Once the data have been collected and standardized, conduct the mass balance analysis. The calculation is based on the following equation (FLW Protocol 2016a):

FLW = Inputs—Outputs ± Changes in Stock ± Adjustments

The terms in this equation are defined as follows:

INPUTS: the ingredients or food products that enter the facility or geographic region during the measurement timeframe.

OUTPUTS: the ingredients or food products that leave the facility or geographic region during the measurement timeframe.

CHANGES IN STOCK: any variation, positive or negative, in the amount of ingredients or food products held by the facility or geographic region during the measurement timeframe.

ADJUSTMENTS: any change in weight, positive or negative, to the ingredients or food products, most commonly due to added or removed water.

The result of this equation is an estimate of the FLW level, since the unexplained variation between inputs and outputs can be inferred to be due to loss and waste.

COMMON DATA CHALLENGES WHEN USING MASS BALANCE

INACCURACIES IN DATA. If any of the four key variables in a mass balance equation are inaccurate, the final FLW number will also be inaccurate. Therefore, it is crucial to make sure these data are accurate and to note any points of uncertainty when reporting the final FLW figure.

ADDITIONAL RESOURCES ON USING MASS BALANCE

FLW Protocol. 2016. Chapter 8. “Mass Balance.” In *Guidance on FLW quantification methods*. **http://flwprotocol.org/wp-content/uploads/2016/06/FLW_Guidance_Chapter8_Mass_Balance.pdf**.

TU Wein. n.d. Stan2Web. Vienna, Austria: Technische Universitat Wien. **http://www.stan2web.net**. (STAN [short for subSTance flow Analysis] is a free software for conducting a mass balance measurement.)

Table A13. Factors to Consider when Using Mass Balance to Quantify FLW

Strengths	Limitations / Points to Consider
• If input/output data exist, this method can be relatively cost-effective; otherwise it can be costly • Can obtain estimates of FLW where no direct data exist (e.g., estimate FLW from food supply and consumption) • Depending on how data are collected, may help identify waste hotspots (e.g., food categories)	• Can have large inaccuracies depending on the type of data available • Difficult to estimate uncertainties • Requires quantification of all major flows of food (e.g., food going to feed animals) • Difficult to apply if there is substantial addition or removal of water (e.g., evaporation of water during cooking) • May be difficult to determine root causes

Source: Authors.

PROXY DATA

Proxy data from a similar geographic area, company, facility and/or time can be used in place of data from the unit being studied if there are no resources for conducting a full study or if data gaps exist in actual data. For example, data from another company could be used to fill in gaps in an inventory, data from one factory could approximate the level of food loss and waste in another, or household data from another city could be used to assess household waste (either per person or in total). However, proxy data cannot be used to track progress over time.

A summary of the strengths and limitations of proxy data is shown in Table A14.

HOW TO USE PROXY DATA TO QUANTIFY FLW

Step 1: Determine what data are needed

Proxy data are useful for filling identified gaps in an inventory. If a company wants to quantify its food loss and waste levels but cannot conduct its own measurements, it may use public data from another company in the same sector to approximate its own. Similarly, if a country is conducting a national food loss and waste assessment, it may look to a geographically similar country that has published data to estimate its own FLW levels.

Step 2: Determine available proxy data

Proxy data can be drawn from a range of sources. Databases such as the **Food Waste Atlas** and **FAOSTAT** compile data, allowing users to search to find the most useful proxy data for their needs. A simple Internet search should also help to identify potentially relevant sources of data.

Step 3: Select the data to use

Select the proxy data that is most similar to the inventory being approximated. Variations in geography, company, facility, timeframe and other factors can introduce uncertainty and result in a final number that is less accurate. If possible, inspect the methodology used to collect the proxy data to determine how the number was derived and how reliable it is.

Step 4: Prepare and Analyze the Data

The proxy data must be transformed into a factor that can be applied to the data gap in the quantification being undertaken. Depending on the sector, this factor could be something like FLW per employee or FLW per metric tonne of food processed by a facility. This factor can then be applied to the population or facility being studied to determine the approximated FLW level.

COMMON DATA CHALLENGES IN USING PROXY DATA

INACCURATE DATA. Although proxy data can help to estimate FLW levels, using data from other contexts will rarely be as accurate as performing a direct measurement study. For this reason, proxy data should be a last resort when a lack of resources or expertise prevents use of another method.

LACK OF AVAILABLE DATA. Many public sources of FLW exist, but there may be instances where no similar data sources can be found for a given sector, geography, or food type. In these cases, consider contacting companies or researchers in the sector or geography in question to see if they can share any nonpublic data.

INABILITY TO TRACK CHANGES IN FLW OVER TIME. Since proxy data approximates FLW in a different context than your own, it cannot be used to track FLW changes over time. This is because any change in FLW levels would be reflective of a change in the other context, not in the facility or geography being studied. For this reason, proxy data should be seen as a starting point before moving into more specific measurement methods as a company or facility becomes more active in reducing FLW.

ADDITIONAL RESOURCES FOR USING PROXY DATA

FLW Protocol. 2016. Chapter 10. "Proxy Data." In *Guidance on FLW quantification methods*. **http://flwprotocol.org/wp-content/uploads/2016/06/FLW_Guidance_Chapter10_Proxy_Data.pdf**.

WRAP and World Resources Institute. 2018. *Food Loss and Waste Atlas*. **www.thefoodwasteatlas.org**.

FAOSTAT. "Food and agricultural data." Database. Food and Agriculture Organization of the United Nations. **www.fao.org/faostat/en/#home**.

Table A14. Factors to Consider when Using Proxy Data to Quantify FLW

Strengths	Limitations / Points to Consider
• Low cost • Low effort/expertise required (if adequate data exists)	• Sufficient data may not exist and existing data may be unreliable as proxy data for FLW • Data may need to be transformed into other units • Data cannot be used to track progress over time and cannot be used to identify hotspots or root causes of waste (since the data comes from an external source)

Source: Authors.

RECORDS

Records are collections of data that have been gathered and saved. There are numerous types of records, such as waste transfer receipts or warehouse records. Although these data may have been gathered for purposes other than FLW quantification, they can often be repurposed to help gain an understanding of FLW levels within a facility.

WHEN TO USE RECORDS

Records are valuable for FLW quantification where data related to FLW is routinely being collected. For this reason, records are most likely to be useful in the manufacturing, retail and food service sectors, since proprietors frequently collect and track data relating to purchasing, food inventory and waste management.

Using existing records can be more cost-effective than undertaking new measurements, since the records are already being gathered for other purposes. Additionally, because resources like the Provision Coalition **Food Loss and Waste Toolkit** allow users to input their existing records to estimate FLW levels, this can be a simple and straightforward method. However, since the data have not been gathered expressly for FLW quantification, they may be unclear or in a form not useful for the project. This can lead to less accurate data and may require additional time and effort in adjusting the data to fit the needs of the measurement exercise.

The causes of food loss and waste can be difficult to discern from records, since the factors leading to the waste are generally not recorded. For these reasons, records are often used to supplement another FLW quantification method rather than as a primary method.

A summary of the strengths and limitations of records is shown in Table A15.

HOW TO USE RECORDS TO QUANTIFY FLW

This section gives four steps to use existing records to gather information about FLW.

Step 1: Identify the records available

A variety of records may be available to assist with FLW quantification;

- **PURCHASING INFORMATION:** contains data relating to the amount and types of food being brought in by the entity looking to quantify its FLW.
- **WASTE TRANSFER RECEIPTS:** contains data relating to the amount of waste being transported away from a facility. It may also contain information about where the waste is being disposed of (i.e., anaerobic digestion, landfill). In some cases, organic waste is separated from inorganic waste prior to waste transfer. If organic waste and inorganic waste are combined, the amount of organic waste will need to be estimated.
- **EXISTING WASTE-REDUCTION MEASUREMENTS:** Many larger-sized companies undertake waste reduction or efficiency measurement methodology, such as Six Sigma (FUSIONS 2016). These records may be useful when quantifying FLW.
- **DONATION RECEIPTS:** If the facility or business in question has donated food to charities or food banks, it may retain receipts to track the types and amounts of food donated. Although this food is not considered to be FLW since it remains in the human food supply chain, many businesses still find value in tracking the amount of food being donated.

Table A15. Factors to Consider when Using Records to Quantify FLW

Strengths	Limitations / Points to Consider
• Relatively cost-effective, because records have already been gathered for other purposes • Can provide high coverage of material flow to quantify • Suitable for initial investigation into food waste to help build internal business case and can continue as supplement to other quantification methods into the future	• Accuracy depends on method used for quantification • May be hard to obtain a method for quantification depending on the type of record used • May not have the desired granularity of data (e.g., types of wasted food) • Unlikely to include information on root causes (i.e., reasons why food is thrown away)

Source: Authors.

- **RECORDS OF CHEMICAL OXYGEN DEMAND (COD) IN SEWAGE:** Biochemical oxygen demand (BOD) is the amount of oxygen that bacteria take from water when they oxidize organic matter (Hach et al. 1997). Because BOD tests tend to be costly, a chemical oxygen demand (COD) test, which is the total measurement of all chemicals in the water that can be oxidized, is generally used as a proxy to measure for BOD. The sewage treatment company used by the company conducting the FLW quantification may possess COD data that can be used to estimate the amount of organic matter being sent down the drain.

These examples are emblematic of the type of records that will be useful for an FLW quantification effort.

Step 2: Assess the relevance of the records

Assess how relevant the selected records are for the needs of the FLW quantification project being undertaken. First, determine if they are in line with the scope of the inventory, as discussed in the **"Setting Your Scope"** module. Next, consider the reliability of the records by examining the following aspects (FLW Protocol 2016):

- the method used to compile the records;
- the measurement devices used;
- the transcription of the measurement or approximation into the record; and
- any assumptions or conversion factors used.

Some or all of these items may be missing, which will contribute to a less accurate figure for FLW quantification.

Step 3: Acquire the records

Records can be grouped broadly into two categories: internal and external.

Internal records are already possessed by the entity doing the FLW measurement and therefore are easier to access. For these records the primary challenge will be identifying who is producing them and requesting the records. Inform the record-holder why the records are needed, which will help the record-holder to understand why the records are important and will build awareness about FLW measurement and reduction within the company or organization.

If the records belong to an external party, such as a waste management company, it may be more difficult to obtain the relevant data. However, the following strategies may be useful (FLW Protocol 2016);

- Explain how the records will be used and the societal and economic benefits of quantifying FLW.
- Ensure that the records will be used confidentially.
- Offer an incentive or monetary compensation for response.
- Provide clear direction for the respondent to make the process as easy as possible.

Step 4: Prepare and analyze the data

Next, the data in the records must be standardized and collated. The simplest method for doing this is by entering the data into an electronic spreadsheet. If the records contain direct FLW data, this process may be as simple as adding up the relevant values. If the records provide data on a mixed waste stream, applying an FLW factor (e.g., how much of the waste is FLW) to the data will be necessary. If the data do not directly provide this factor, it can be obtained by performing a waste composition analysis.

COMMON DATA CHALLENGES WHEN USING RECORDS

INCONSISTENCIES BETWEEN DATA SOURCES. When using records drawn from a variety of sources, it is inevitable that methodologies, terminologies and units of data will differ, leading to confusion when the data are combined. One way to avoid this problem is to provide the record-holder with the definitions being used for terms such as "food waste" to develop a common understanding.

DATA GAPS OR INSUFFICIENT INFORMATION. Records will not always provide all the data necessary for a complete FLW quantification. In these instances, a series of steps can be taken. First, determine if the records provide *enough* data to formulate a plan for FLW reduction. If they do, proceed with developing a plan but also inform the record-holder of the gaps that exist in hopes that the missing data can be collected over time. If the gaps are too significant to proceed, use another FLW quantification method. Consult the module relevant to your sector to determine which methods are most appropriate.

INSUFFICIENT INFORMATION ON CAUSES OF FLW. Most records are of numerical data and do not capture information on attitudes or activities that contributed to the waste, making it difficult to ascertain the causes of FLW. Thus, records may need to be augmented by a survey or interview process to obtain information on why FLW was being generated. Additional guidance on this can be found in the "Surveys" module.

ADDITIONAL RESOURCES FOR USING RECORDS

FLW Protocol. 2016. Chapter 5. "Records." In *Guidance on FLW quantification methods*. **http://flwprotocol.org/wp-content/uploads/2016/06/FLW_Guidance_Chapter5_Records.pdf**.

FUSIONS. 2016. *Food waste quantification manual to monitor food waste amounts and progression*. **www.eu-fusions.org/phocadownload/Publications/Food%20waste%20quantification%20manual%20to%20monitor%20food%20waste%20amounts%20and%20progression.pdf**. (See especially the sections "Identify and review existing data relating to food waste" for each sector.)

WASTE COMPOSITION ANALYSIS

Waste composition analysis is a process of physically separating, weighing and categorizing waste. It can be used both to determine total amounts of FLW and to categorize the different types of foods that have been discarded (e.g., fruits, vegetables, meat), or distinguish between food and inedible parts.

A summary of the strengths and limitations of waste composition analyses is shown in Tables A16 and A17.

HOW TO CONDUCT A WASTE COMPOSITION ANALYSIS TO MEASURE FLW

Step 1: Identify the sectors to be reviewed

If a waste composition analysis is to be performed across several sectors, start by making a list of the sectors of interest. If the waste composition analysis is taking place within a single household, business, or facility, this step can be skipped.

Step 2: Recruit and inform participants

Participants in a waste composition analysis can be identified from publicly available information, such as databases of businesses or through trade organizations (NRDC 2017a). The participants should be fully briefed about when the analysis will be performed and who will be conducting the analysis. It may be difficult to recruit participants due to confidentiality concerns, so an incentive may be useful to encourage participation.

Step 3: Obtain samples of FLW and identify a sorting site

Collect waste samples from the FLW-generating units on their regular trash collection days to ensure that the analysis is conducted on a representative sample. If possible, take the waste sample to a separate site to be sorted, since most FLW-generating units will not have the space available to sort through large amounts of waste.[4]

Step 4: Prepare the FLW for measurement

Prepare the waste samples for measurement with the following steps (WRAP 2012);

1. Place the waste from each FLW-generating unit in a discrete area (e.g., a table or a marked-off section of floor) where it will not mix with other samples.

2. Remove the food from any packages and sort the packages into a separate pile.

3. Sort the FLW into categories based on the scope of the study.

4. If it is of interest to the study, sort the non-FLW material into categories, such as paper, plastic, metals, etc.

Step 5: Weigh and record the data

Weigh each category of FLW separately. Record the weight data in a prepared spreadsheet based on the food categories identified for the study.

Table A16. Factors to Consider when Using a Food-Focused Waste Composition Analysis to Quantify FLW

Strengths	Limitations / Points to Consider
• Can provide relatively accurate data on the total amount of FLW within given waste streams	• Cannot be applied to all destinations (e.g., FLW in sewer waste)
• Can also provide detailed information on types of food wasted, whether it is packaged, whether it was a whole or part of an item, etc.	• Detailed studies are likely to be expensive because they require relatively large sample sizes
• Detailed information can be used to estimate cost, environmental impacts and nutritional content of FLW	• Does not provide much information on why food items were wasted
• Can link information to households in the study, allow demographic analysis and correlation studies with stated behaviors, attitudes, etc.	• Can be affected by moisture losses in hot conditions

Source: Authors.

4) For a detailed discussion of how to select a site for sorting FLW, see pages 32–33 of Chapter 4 **"Waste Composition Analysis"** in *Guidance on FLW Quantification Methods* by FLW Protocol.

Table A17. Factors to Consider when Using a Waste Composition Analysis on all Materials in a Waste Stream

Strengths	Limitations / points to consider
• Can provide relatively accurate data on the total amount of FLW within given waste streams • Can be relatively inexpensive where studies/ programs already exist • Can be replicated to monitor progress	• Cannot be applied to all destinations (e.g., FLW in sewer waste) • Does not include detailed information on types of food required to estimate accurate cost or impacts of FLW • Does not provide much information on why food items were wasted • Can be affected by moisture losses in hot conditions

Source: Authors.

Step 6: Dispose of the waste samples

Once the samples have been sorted, weighed and recorded, they can be disposed of. If the scale of the study is large, it may be necessary to contract a waste management company for a special waste retrieval.

Step 7: Analyze the data

Once the data from the waste composition analysis have been obtained for a single day from an FLW-generating unit, it can be extrapolated to an entire year by multiplying the data by the number of days the unit operates annually.

COMMON DATA CHALLENGES WHEN CONDUCTING A WASTE COMPOSITION ANALYSIS

RELUCTANCE TO PARTICIPATE. FLW-generating units may not see the benefit of a composition analysis of their waste stream and may even be actively opposed to participating due to confidentiality concerns. Confidentiality concerns can be addressed through signed confidentiality agreements and by working with local officials who can assure potential participants of the legitimacy of the study. Providing an incentive for taking part in the analysis may also boost participation rates.

SAMPLE COLLECTION ERRORS. If the waste management company of the FLW-generating unit is not aware of the study being undertaken, the samples may be inadvertently collected as part of routine disposal before they can be analyzed. This can be avoided by reminding the waste management company of the study and by collecting the sample at least an hour before the usual waste pickup occurs.

UNREPRESENTATIVE DATA. The results of a single waste composition analysis might not be representative of an FLW-generating unit's "typical" output. For example, if a household held a family gathering the night before the waste analysis, the analysis would show much higher levels of FLW than usual. Atypical results can be identified by performing multiple analyses of the same unit on different days. If another analysis is not feasible, comparing the results against other similar units and discarding any outliers that seem overly high or low can minimize unrepresentative data.

LACK OF INFORMATION ON CAUSES. Although a waste composition analysis provides highly granular numerical data on FLW, it provides little to no information on the causes of FLW. It may therefore be useful to simultaneously conduct a separate study using **diaries** or **surveys** to gather qualitative information on the causes of the FLW.

ADDITIONAL RESOURCES FOR USING WASTE COMPOSITION ANALYSIS

FLW Protocol. 2016. Chapter 4, "Waste Composition Analysis," in *Guidance on FLW Quantification Methods.* **http://flwprotocol.org/wp-content/uploads/2016/06/FLW_Guidance_Chapter4_Waste_Composition_Analysis.pdf** .

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The CEC was established by the governments of Canada, Mexico and the United States through the North American Agreement on Environmental Cooperation, the environmental side agreement to NAFTA. An intergovernmental organization, the CEC brings together citizens and experts from governments, nongovernmental organizations, academia and the business sector to seek solutions to protect North America's shared environment while supporting sustainable economic development. Find out more at: www.cec.org.

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