Food Loss + Waste PROTOCOL

GUIDANCE ON FLW QUANTIFICATION METHODS

Supplement to the *Food Loss and Waste (FLW) Accounting and Reporting Standard, Version 1.0*

The Consumer Goods FORUM

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Introduction

The *Food Loss and Waste Accounting and Reporting Standard (FLW Standard)*, the parent document to this guidance, offers an internationally accepted standard to account for and report on food and/or associated inedible parts removed from the food supply chain—commonly referred to as "food loss and waste" (FLW). This guidance document serves as a companion to the *FLW Standard* and offers entities practical guidance on methods for quantifying FLW.

Please refer to the *FLW Standard* for requirements and guidance related to FLW accounting and reporting. The *FLW Standard* also contains a glossary with definitions and commentary for important terms used throughout this document.

About this Document and the Quantification Methods

The quantification methods detailed in this document represent those commonly used to quantify FLW; however, an entity may use methods not described in the *FLW Standard* if those methods are relevant to the goals of the inventory.[1] For some entities, data on the amount of FLW will need to be gathered from multiple sources. An entity's goals, scope, and resources will also influence whether it uses a combination of methods to quantify FLW data. Users of the *FLW Standard* are required to describe the quantification method(s) used in quantifying FLW and, if any existing studies or data were used, to describe their source and scope.

The *FLW Standard* does not require that an entity use a particular quantification method because the entity's choice of quantification method(s) will be influenced by its particular goals, the scope selected for its FLW inventory, the availability of resources (human, financial), and whether it has direct access to the FLW.[2]

However, in order to help an entity select the methods that may be more or less appropriate under different scenarios, an FLW Quantification Method Ranking Tool is available at www.flwprotocol.org. This tool offers suggestions and helps guide decisions regarding the most appropriate methods, based on a set of questions related to the circumstances under which the entity is quantifying FLW. These circumstances include important criteria such as the desired level of accuracy and access to the physical FLW being quantified.

Some quantification methods, such as direct weighing, are straightforward while others, such as a waste composition analysis where FLW must be separated from other material in order to be measured, can be complex. Similarly, entities will gather FLW data in different ways. They may collect data in paper form, or enter the data into an electronic spreadsheet or database. If an entity is gathering more comprehensive information, it may use technology-enabled monitoring systems (e.g., a smart scale or meter) to routinely capture detailed information such as the daily weight, volume, and count of FLW—along with information on why it is generated—and the variation of FLW across multiple dimensions such as "time of day served" or type of food.

This document provides guidance on 10 quantification methods. Each chapter covers one quantification method and provides:

- An overview
- Advantages and disadvantages
- Level of expertise required
- Cost
- Guidance on implementing the method

Seven of the 10 methods are based on the measurement or approximation of FLW. These are:

- **Direct weighing** (Chapter 1)—using a measuring device to determine the weight of FLW.
- **Counting** (Chapter 2)—assessing the number of items that make up FLW and using the result to determine the weight; includes using scanner data and "visual scales."[3]
- **Assessing volume** (Chapter 3)—assessing the physical space occupied by FLW, and using the result to determine the weight.
- **Waste composition analysis** (Chapter 4)—physically separating FLW from other material in order to determine its weight and composition.
- **Records** (Chapter 5)—using individual pieces of data that have been written down or saved, and that are often routinely collected for reasons other than quantifying FLW (e.g., waste transfer receipts or warehouse record books).
- **Diaries** (Chapter 6)—maintaining a daily log of FLW and other information.
- **Surveys** (Chapter 7)—gathering data on FLW quantities or other information (e.g., attitudes, beliefs, self-reported behaviors) from a large number of individuals or entities through a set of structured questions.

The other three methods are based on inferring the amount of FLW through calculation. These are:

- **Mass balance** (Chapter 8)—measuring inputs (e.g., ingredients at a factory site, grain going into a silo) and outputs (e.g., products made, grain shipped to market) alongside changes in levels of stock and changes to the weight of food during processing.
- **Modeling** (Chapter 9)—using a mathematical approach based on the interaction of multiple factors that influence the generation of FLW.
- **Proxy data** (Chapter 10)—using FLW data that are outside the scope of an entity's FLW inventory (e.g., older data, FLW data from another country or company) to infer quantities of FLW within the scope of the entity's inventory.

Appendix A of this document provides guidance on quantifying FLW in the specific case where water is added to FLW, for example, to dilute FLW, or to wash down an FLW storage area.

The methods described in this guide involve different types of skills and expertise. Using some methods may require the advice of a statistician, market researcher, or other professional with experience using these methods to quantify FLW. The guidance provided in this standard should not be regarded as a substitute for input from experienced professionals.

1. Direct Weighing

1.1 Overview of the Method

Weighing is a well-established approach to measuring the weight[4] of an object and involves using a weighing device (e.g., a set of scales) to quantify amounts of FLW. Weighing may be used as a stand-alone method or in combination with other methods (e.g., waste composition analysis).

ADVANTAGES AND DISADVANTAGES

The main advantage of weighing is its accuracy, provided that the weighing device is calibrated and used properly. In addition, because an FLW inventory is required to be reported in units of weight, no inaccuracy will be introduced by making conversions from other units to weight. As a result, there will be very little uncertainty about inventory data when weighing is used.

The main disadvantages of weighing are the effort and costs involved, especially when measurement is required at more than one location. A weighing device must be purchased (or rented) and transported, and FLW must be sampled and moved to the device. From a practical perspective, weighing is often not feasible, despite its being the most accurate method for quantifying FLW.

LEVEL OF EXPERTISE REQUIRED

Although care and attention to detail are required, no particular expertise is needed to operate a weighing device and record the results. Similarly, any sampling of FLW should be done carefully but, if the standard's guidance is followed, no particular expertise is needed beyond the physical ability to move the samples. An entity should ensure that the team involved receives proper standardized instruction.

COSTS

Weighing can be costly if an entity is weighing FLW from more than one location. In addition to the initial purchase or rental of a weighing device, transport of the device and personnel can be cost-prohibitive, particularly in areas with poor vehicular access. The main constraints on weighing, however, are logistics and feasibility rather than cost.

Weighing may be used as a stand-alone method or in combination with other methods (e.g., waste composition analysis).

1.2 Guidance on Implementing the Method

An entity that chooses to weigh FLW will need to follow a series of steps.

1. SCOPE THE STUDY

As Chapter 6 of the *FLW Standard* explains, a well-defined scope, aligned with the five accounting principles and an entity's goals, is important to ensure that an FLW inventory meets an entity's needs. The scope of an entity's inventory—defined by the timeframe, material type, destination, and boundary—will dictate to a large extent the scope of the weighing exercise. Chapter 6 also describes how the scope chosen by an entity for its FLW inventory should be aligned with its underlying goals for addressing FLW.

2. SELECT THE MEASUREMENT DEVICE

A device for measuring weight, also referred to as a weighing machine, weighing apparatus, or set of scales, may be manual or electronic and will use one of various mechanisms including springs, strain gauges, and balance beams. The choice of weighing device is typically related to the range of weights expected, availability, cost, and practicalities of transport and operation (e.g., an electronic device requires a power source so, where power is likely to be a problem, a manual device should be used).

Weighing devices come in a range of sizes, from small portable scales to weighbridges designed for large vehicles. It is important to have access to scales that are appropriate to the weight range being measured.

3. DEVELOP A SAMPLING STRATEGY AND TAKE THE SAMPLE

In many instances it will be impractical to weigh all the FLW, in which case a sample of FLW should be taken and weighed. Guidance on sampling is provided in Appendix A of the *FLW Standard*.

4. TAKE THE MEASUREMENT

Before each weighing, it is important to ensure that the scale is properly set to zero (i.e., zeroed). This may occur automatically or the scale may need to be zeroed manually. The sample should then be carefully loaded on the weighing device, a little at a time if necessary, and the weight read off and recorded.

If weighing FLW in a container, the weight of the empty container (i.e., the tare weight) must be deducted from the recorded weight. This can be done by placing the empty container on the scales, resetting the scales to zero and then placing the FLW inside the container. Many electronic scales have a "tare feature" which resets the display value to zero when a container is placed on the load-receiving element. When the container is filled, the weight displayed will be that of the contents alone (i.e., the net weight). Another option is to weigh the empty container separately and deduct this weight from the recorded weight of the FLW in the container. This option is less preferable because it introduces additional handling as well as the risk of calculation error.

An entity should recalibrate its weighing devices regularly to ensure their accuracy. It should make sure that any calibration adjustment complies with laws and best practice (some countries may require weighing devices to be adjusted by an official government agency). It is good practice to use an object of known weight to regularly check whether the weighing device is working correctly.

There are many situations in which an entity can measure or approximate FLW through weighing. The three examples that follow cover different scenarios. Box 1.1 provides an example of a business weighing its own FLW.

The second example (Box 1.2) is focused on measuring FLW at the agricultural production stage. This example would be applicable to an assessment of FLW at harvest time, across a wide range of fruits and vegetables, using a series of repeated observations and a consistent framework. The aim of this type of study is to determine the weight of a crop left behind in the field after the harvest, taking into account seasonal variability.

Box 1.3 provides guidance about an approach in which FLW is weighed and analyzed across a number of stages in the food supply chain.

5. SCALE UP THE DATA

Where data have been produced from a physical sample of FLW or from a sample of FLW-producing units, they will require scaling up. Guidance on scaling is provided in Appendix A of the *FLW Standard*.

Box 1.1 | A Business Weighs Its Own FLW

SCENARIO: A business sets an FLW reduction target focused on the amount of FLW it sends to landfill.

ACTIONS: A set of large beam scales is used to weigh the business's waste container once a week, prior to its collection by a waste management company. Each week the 1.1 cubic meter wheeled container is pushed onto the scales and the weight read off and recorded. The weight of the empty container is deducted from the recorded amount and the amount is tracked week on week to determine progress against the target.

Box 1.2 | Measuring Fruit and Vegetable FLW at Harvest Using Longitudinal Observations

SCENARIO: A postharvest loss expert is interested in quantifying the amount of FLW associated with a fruit or vegetable crop at harvest. The approach involves taking repeated observations to account for temporal differences. It is adaptable to a wide variety of crops (e.g., cucumbers, pears, sweet potatoes) regardless of whether the harvesting is done by hand or by machine. Over time, standards of block size can be developed for individual crops or groupings like tree fruit, berry crops, and bush crops.

ACTIONS: One way to determine the amount of a crop left behind after the harvest is through a longitudinal observational study, which determines the weight of the FLW per area during harvest. The approach requires participation from the growers, and the use of equipment and labor.

Preparing for sampling

Several replications of field or orchard blocks of the same size are evaluated over the entire season. It is important to begin with the first harvest of a field or cultivar in a season so that the data are not confounded by FLW created during prior harvests. In addition, the first harvest is usually the highest yielding. Because harvesting styles vary by region and by grower, one day of active harvest in a non-study area could be observed in preparation for measurement, in order to be certain that the approach is appropriate to the specific crop. This is also a good time to mark off blocks in the field being harvested the next day.

Blocks should be for a single cultivar, their size and number selected such that they will all be harvested in one day. Blocks should be of a certain area, as opposed to a certain number of plants, due to differences in plant spacing. Fruit and vegetable crops tend to have several harvests over time for single cultivars and may overlap with additional cultivars in some cases. Regular harvesting crews should treat the block like the rest of the field; they should be given no additional instruction or training. The location and farm name should be recorded, as well as the cultivar, date, and weather. Sampling should take place immediately after the grower's regular harvesting crew passes through the blocks. The harvesting crew will have collected what they understand to be marketable according to their training in the standards required by the buyer.

Collecting the total mature crop

After the grower's crew collects the crop to be sold, sampling should begin of the crop left behind. Skilled labor should be employed in this specialized type of collection. Only physiologically mature crops that are not too small to be removed in subsequent harvests should be collected and evaluated. However, some crops are normally harvested immature and, in this case, the collection should focus on the immature physiological stage being harvested normally, and anything beyond that.

The entirety of the crop that meets the maturity requirements should be collected, including anything overripe or on the ground. Machine-harvested crops will necessitate hand harvesting to accomplish this. The sampling time for each block and the number of people involved should be recorded in order to determine the extra time it would take to collect the total mature crop, over and above the average harvest time.

Weighing and capturing the data

The amount of the crop that has been sampled from each block should be labeled and evaluated separately. The samples should be evaluated in the packing house or in a lab. Experienced inspectors will be useful, but may not be necessary. Instructions should be provided related to the inspection of samples (e.g., determining what is insect or disease damage and what "overripe" looks like, according to each crop). The aim of sorting is to differentiate what could still have been eaten from what was no longer suitable for consumption.

Data should be collected on:

- total weight of the crop left behind in the block;
- weight of the portion displaying incidence of minimal and significant pest and disease damage;

Box 1.2 | Measuring Fruit and Vegetable FLW at Harvest Using Longitudinal Observations (continued)

- weight of the portion that is overripe; and
- weight of the portion of the crop suitable for consumption, but not meeting size and shape standards possibly imposed by the buyer.

These data will indicate the underlying reasons for the particular fruit or vegetable being considered unmarketable by the harvesting crew.

If weighing devices are not available, estimation methods based on number of items or volume collected may be employed. These can be used to approximate the weight. Guidance on count-based and volume-based methods is provided in Chapters 2 and 3, respectively.

Box 1.3 | "Load Tracking" FLW across a Food Supply Chain

SCENARIO: A national authority is interested in tracking the amount of FLW associated with a particular crop across the supply chain. Load tracking is a common approach to use along part or all of the food supply chain. The approach results in data with a high degree of accuracy but is expensive and time-consuming. It would most likely be used when an entity wants to gain in-depth knowledge of FLW in a particular location and for a particular crop.

ACTIONS: The method relies on evaluating the quality and/or weight of a well-defined sample of the crop as it moves through a supply chain under conditions that are as near as possible to "normal" practice. To quantify FLW across multiple stages, the first step is to create the baseline (i.e., the weight of the specific sample that will be followed) so that it can be used for comparison as the crop moves along the supply chain.

This baseline is generally created by harvesting part of the crop from selected sample areas (see Box 1.2 for guidance on selecting sample areas) then scaling up the quantity produced from those sample areas in order to produce an estimate of the actual yield of the entire cropped area.

The researcher then physically follows the sample along the whole food supply chain as it journeys from the field to the processor, the trader, reseller, and eventually the consumer. He or she records the weight and quality of the sample at each point in the chain and compares it with the original weight. The resulting measurements will show changes in weight of the sample at every stage: transport from the field to the storage facility, loading into and out of the storage facility, processing operations and so on.

The process of load tracking requires the use of weighing equipment (in the field as well as at the farm, the storage site, processing or retailing facilities etc.), so skilled personnel and reliable equipment are a prerequisite. Load tracking will be easier if the crop is packaged in individual containers (such as boxes or barrels, or even a truck) that can be labeled and followed.

An example of how load tracking has been used is provided in the Food and Agriculture Organization of the United Nations' (FAO's) report Post-Harvest Fish Loss Assessment in Small-Scale Fisheries at http://www.fao.org/docrep/014/i2241e/i2241e.pdf.

2. Counting

2.1 Overview of the Method

Counting involves assessing the number of items that make up FLW and using the result to determine the weight. The items may be a single product (e.g., a banana, a can of soup) or a number of products in various types of containers (e.g., a bag of grain, a pallet of product).

Several approaches incorporate counting as a means to calculate the amount of FLW. The three approaches described in this chapter are basic counting, scanning, and using visual scales. The latter two approaches do not rely solely on counting FLW but are included because they utilize counting as a foundational step.

Counting-based methods involve the following steps:

- Determine the unit to be counted (e.g., individual item, container, bag, truck)
- If the weight is not already known, weigh one—or a representative sample—of these units
- Count the units
- Multiply a unit's weight (or average sample weight) by the count

ADVANTAGES AND DISADVANTAGES

Counting methods are generally low cost and may result in data with a high degree of accuracy, as long as the counting is carried out consistently and the assumptions used to convert counts to weight (e.g., weight per item or percent weight loss factors) are correct.

An entity may also use a scanning-based approach to gather more detailed information about the FLW and, potentially, its causes because the data are collected from bar codes, which provide other useful contextual information (e.g., an item's food category, brand, and price).

One disadvantage of counting is that inaccuracies may be introduced in the assumptions or calculations used to convert the count to a weight. This method is not well suited to quantifying FLW when there is a mix of multiple items in the FLW, when the items in the FLW vary considerably in size, or when the FLW is mixed with other non-FLW waste.

LEVEL OF EXPERTISE REQUIRED

The level of expertise required for counting varies greatly depending on the approach selected. At the very simplest level, no expertise is required beyond an ability to count and multiply data. A scanning approach requires an understanding of how the underlying database is accessed and structured to allow calculations to be made. Only basic skills are required to use visual scales (or picture cards) and associated tools (after appropriately detailed training). Developing visual scales requires a higher degree of expertise, including knowledge about the commodity of interest as well as about the type of FLW and how to measure it.

COSTS

The cost of counting-based methods is likely to be minimal unless the purchase of equipment is required (e.g., new scanning devices). Using visual scales is inexpensive although developing a visual scale and training people in its use requires an investment in human resources.

2.2 Guidance on Implementing the Method

An entity that uses counting, scanning, or visual scales to estimate FLW will need to undertake a series of steps.

1. SCOPE THE STUDY

As Chapter 6 of the *FLW Standard* explains, a well-defined scope, aligned with the five accounting principles and an entity's goals, is important for ensuring that an FLW inventory meets an entity's needs. The scope of an entity's inventory, defined by the timeframe, material type, destination, and boundary, will largely dictate the scope of the counting exercise. Chapter 6 also describes how the scope chosen by an entity for its FLW inventory should be aligned with its underlying goals for addressing FLW.

2. DEVELOP A SAMPLING STRATEGY AND TAKE THE SAMPLE

If there are too many items to count, sampling may be required. Guidance on sampling is provided in Appendix A of the *FLW Standard*.

3. COUNT, SCAN THE ITEMS, OR USE VISUAL SCALES, AND CONVERT TO WEIGHT

Guidance is provided for three approaches that are based on counting:

- Basic counting
- Scanning
- Visual scales

Basic Counting

Counting can be a straightforward way for an entity to quantify FLW where the weight of the items being counted is known. An example might be a retailer for whom tomatoes in cans have become FLW. If the net weight (i.e., excluding the can) of each can is 450 g and there are 100 cans, it can simply multiply the numbers (450 g x 100 cans) together and report 45 kg in its FLW inventory.

If the weight of an item is not known in advance or varies, an entity can derive an average weight by weighing a representative sample of items. Guidance on sampling is provided in Appendix A of the *FLW Standard*.

In an agricultural setting, an entity might take a sample consisting of several hundred grains, count the number of grains damaged, for example, by insects or rodents, and then apply "rule of thumb" conversion factors (see examples in Table 2.1) to derive an estimated percentage of the weight loss due to damage. This "percent weight loss" would then be applied to the weight of the sample to estimate the total weight of the FLW.

Table 2.1 | Conversion Factors between Grain Damage and Grain Weight Loss

CROP	CONVERSION FACTORS (DIVIDE % OF DAMAGED GRAIN BY THIS FACTOR TO OBTAIN % WEIGHT LOSS)[a]
Maize (stored as shelled grain or as cobs without husk)	8
Maize (stored as cobs with husk)	4.5
Wheat	2
Sorghum	4
Paddy rice	2

[a] Using maize as an example: insect damage is expected to remove, on average, ⅛ of the weight of each infested grain. Therefore, if the proportion of grain with insect damage is known, dividing it by eight will give an estimate of the weight loss due to infestation.

Sources: Adams and Schulten. 1978. "Losses Caused by Insects, Mites, and Microorganisms." Washington, D.C.: USAID; Hodges R., M. Bernard, and F. Rembold. 2014. "APHLIS—Postharvest Cereal Losses in Sub-Saharan Africa, their Estimation, Assessment and Reduction." Table 10.1. Joint Research Centre (JRC) Technical Report EUR 26897. Brussels, Belgium: European Commission.

Scanning

A scanning approach makes use of scanning technology linked to printed or digital bar codes to count and record instances of FLW, and therefore is most often applicable in settings where the entire product is being discarded. An entity that uses a scanning approach will undertake the following steps. Where these are automated, an entity can use appropriate scanning technology and software.

- Scan the bar codes of individual items, cases, or pallets of product that are considered FLW. This is frequently done using a mobile scanning device connected to a database. In some cases, an entity may be able to extract data manually from the inventory database.
- Convert the number of units scanned to weight using standard product weight data linked to the bar code. Scanning technology typically links the data electronically though it is also possible to look up bar code numbers manually in the underlying database.

If desired, an entity can roll up the data from the individual product level (e.g., tilapia) to the broader food category (e.g., seafood). Moreover, the information may then be combined with data on annual turnover for each product group to understand the economic implications.

Where an entity (e.g., a retailer) is also including in its FLW inventory items *without* standard product weights (commonly referred to as "loose products"), it will need to estimate the weight of these loose products separately.

At the point of scanning, an entity may also record the reason for FLW (e.g., "damaged" or "past sell-by date") as part of its FLW quantification.

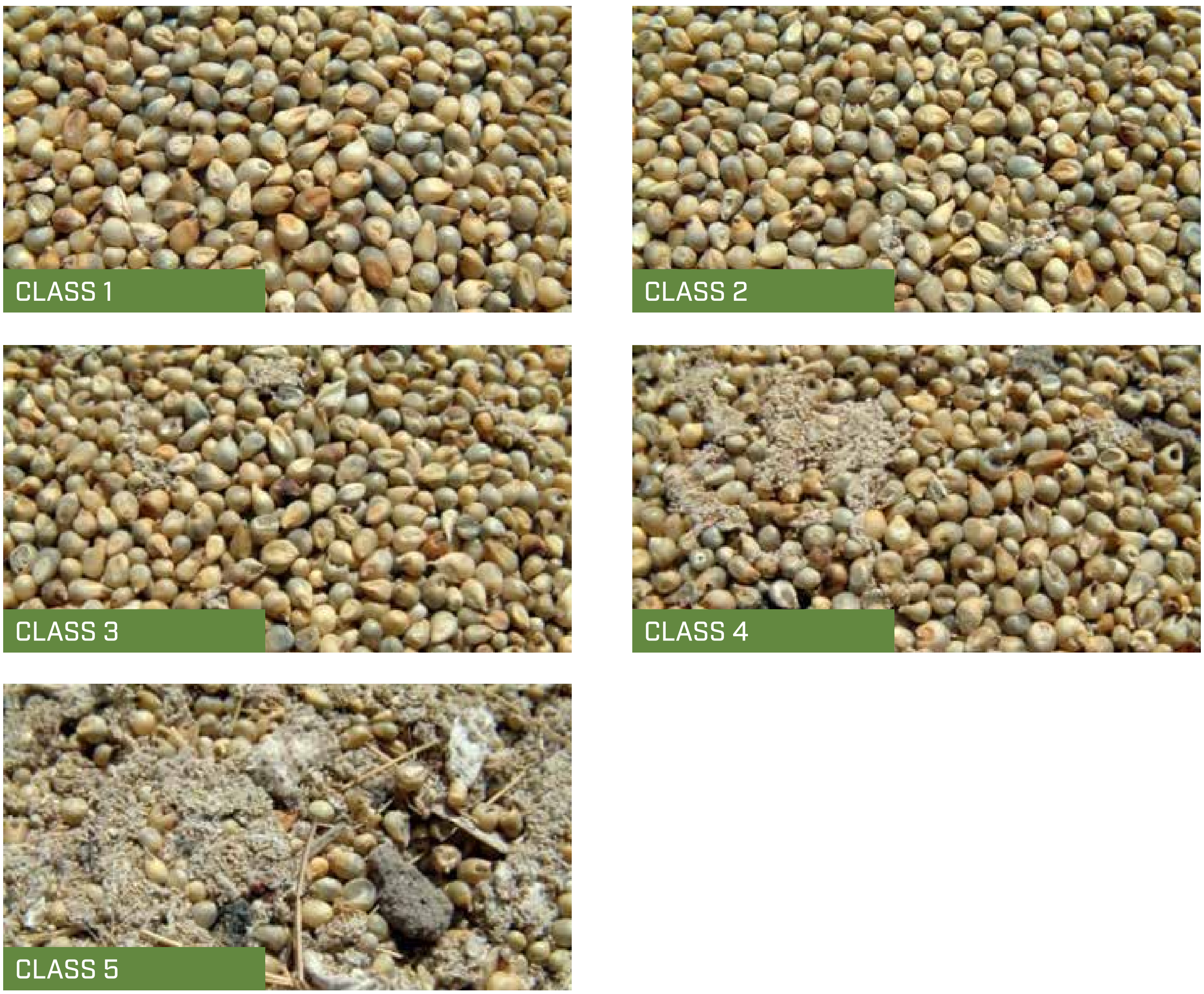
Visual scales

In agricultural contexts, picture cards and visual scales are useful aids in evaluating the condition of perishable as well as durable crops. They are a relatively quick and low-cost method of evaluating and quantifying FLW, typically to assess damage by pests to stored crops.

The visual scales developed to date for cereal grains are based on a "count and weigh" technique. If used exclusively to estimate weight loss, the "pest damaged" and "undamaged" grain from samples is first counted and then weighed. The number and weight of the grains are used to calculate the "percentage weight loss" associated with each class shown on the scale, with the more badly damaged classes losing more weight per unit than the less badly damaged classes. Reference samples, or pictures of reference samples of the full range of quality expected, are then produced and used in the field to estimate FLW. A sample visual scale for millet is shown in Figure 2.1.

The weight loss factor also corresponds to various commercial quality grades because visual scales are more generally used to ascertain the quality of the grain in terms of its market value. In this case, the reference samples, or the pictures, will include all types of grains of low quality, whether they correspond to a particular level of weight loss or not.

Figure 2.1 | Example of a Visual Damage Scale for Millet



Source: Hodges R., M. Bernard, and F. Rembold. 2014. "APHLIS – Postharvest Cereal Losses in Sub-Saharan Africa, their Estimation, Assessment and Reduction." *Joint Research Centre (JRC) Technical Report* EUR 26897. Brussels, Belgium: European Commission.

> *Several approaches incorporate counting as a means to calculate the amount of FLW. The three approaches described in this chapter are basic counting, scanning, and using visual scales.*

An entity using visual scales in the field takes samples and then assesses each sample, using the visual scales, for insect damage and quality, recording the results along with the total quantity of grain. As part of its sampling and calculations, an entity may also apply other quantification approaches and methods (e.g., it may use sampling spears—see Appendix A of the *FLW Standard*—and/or may measure the volume of stored grain and then convert the volume to weight—see Chapter 3 of this document).

The data collected from a visual scale will represent quality grade scores. The "percentage weight loss" for each of the scores will have been determined when developing the scale, and thus the scores are converted into percentage weight loss figures. From the sampling regime chosen, a mean percentage weight loss is calculated.

Detailed guidance on developing and using visual scales for cereal grains under a range of different scenarios, as well as additional detail on using percentage weight loss figures, is provided in a report produced for the European Commission.[5] (See source note to Table 2.1. and Figure 2.1.)

4. SCALE UP THE DATA

If the data were produced from a sample, they will require scaling up. Guidance on scaling is provided in Appendix A of the *FLW Standard*.

3. Assessing Volume

3.1 Overview of the Method

Assessing volume is the process of measuring or approximating the space occupied by FLW. To meet the requirements of the *FLW Standard*, the volume of FLW must then be converted to a weight. The method is ideal for liquid FLW, but can also be applied to solid and semi-solid material, including solid FLW suspended in liquid.

An entity may use devices such as calibrated containers to measure the volume precisely, or may use other techniques including water displacement or visual assessment. The international standard measurement unit[6] of volume is cubic meter (m^3) but gallons or liters are also commonly used in relation to FLW.

ADVANTAGES AND DISADVANTAGES

If FLW is in a container, it is easier and cheaper to assess its volume than to weigh it. It can be impractical to carry out the sampling and physical moving that is required for weighing if the FLW needs to be removed from the container.

The principal disadvantage of assessing volume is that it requires the application of density factors to convert the volume to weight, which may introduce inaccuracies into the data.

LEVEL OF EXPERTISE REQUIRED

The level of expertise required will depend on the approach chosen for assessing the volume of FLW. A laboratory-based water displacement method will require basic laboratory skills and equipment, whereas a measurement-based approach in which an entity reads pre-calibrated containers will require no special skills.

COSTS

Because assessing volume requires physical access to the FLW, costs will be related to ease of access. If multiple sites are included in the scope, then visiting them will add to costs, as will purchasing or renting relevant measuring devices.

3.2 Guidance on Implementing the Method

An entity that assesses volume to estimate FLW will need to undertake a series of steps.

1. SCOPE THE STUDY

As Chapter 6 of the *FLW Standard* explains, a well-defined scope, aligned with the five accounting principles and an entity's goals, is important for ensuring a FLW inventory meets an entity's needs. The scope of an entity's inventory, defined by the timeframe, material type, destination, and boundary, will influence the approach taken to assess volume. Chapter 6 also describes how the scope chosen by an entity for its FLW inventory should be aligned with its underlying goals for addressing FLW.

2. DEVELOP A SAMPLING STRATEGY AND TAKE THE SAMPLE

In some instances it will be impractical to assess the volume of all the FLW, in which case a sample of FLW should be taken and the volume of the sample assessed. Guidance on sampling is provided in Appendix A of the *FLW Standard*.

3. TAKE MEASUREMENTS OR MAKE APPROXIMATIONS

There are five basic approaches to assessing the volume of FLW:

- Reading from pre-calibrated containers (e.g., a measuring jug)
- Measuring dimensions (e.g., using a measuring tape)
- Using a water displacement technique
- Using a visual assessment
- Using a flow meter (e.g., where liquid is disposed of through a pipe)

Box 3.1 | Examples of Pre-Calibrated Containers

Example 1.
A study in the United Kingdom supplied a sample of households with three different sizes of measuring jugs. The participants used them to record the amounts and types of liquids thrown away during a one-week period. This allowed for a relatively accurate measurement of volume to be obtained for certain commonly wasted items that could be measured using jugs.

Example 2.
In the United States, the “Take the Challenge Initiative” instructed households to tape a printed “measurement” label on bags of a specified size with the one-eighth-volume measure at a uniform distance from the bottom of the bags. At the end of each week, households measured and recorded the volume of FLW (excluding liquids) in the bag, using the fractions on the printed label. Households were encouraged, if they had a kitchen scale at home, to weigh the FLW as well for a more accurate measurement.

Sources:
WRAP (2013a).
West Coast Climate Forum. 2015. “Take the Measurement Challenge Instructions.”
Accessible at: <http://westcoastclimateforum.com/food/wasteless>

Reading from pre-calibrated containers

An entity typically uses pre-calibrated containers to quantify liquids, semi-solid material, and some granular solids. However, a variation of this approach can also be applied to quantifying solid FLW (see Box 3.1).

Measurements from pre-calibrated containers will be most accurate if the containers come from a reputable source and have been calibrated in a way that links back to weights and measures standards. In order for the reading to be made to an acceptable degree of precision, it is important that the container is an appropriate size for the amount of FLW being measured. For example, measuring less than 1 liter of liquid in a jug that has 1 liter as its first marked increment will result in the amount having to be approximated.

Box 3.1 provides two examples of using pre-calibrated containers as part of a diary exercise to collect information on household FLW. In the first example, households were provided with pre-calibrated measuring jugs, which enabled measurements of liquid FLW to be taken with a high degree of accuracy. In the second example, households created a “pre-calibrated” container using a printed “measurement” label that participants taped to a paper bag with known dimensions (in this case: 5⅛” x 3⅛” x 10⅝”). Since participants affixed the label to a bag themselves, the degree of accuracy may have been compromised; however, this approach to labeling is likely inexpensive to implement.

Measuring dimensions

A simple approach to measuring the volume of a solid object, a reasonably uniform pile of FLW, or a full container of FLW is to measure its dimensions (e.g., with a measuring tape) and use standard formulas to convert them to a volume (see Table 3.1). To help with calculating volumes from dimensions, many online tools allow an entity to enter dimensions and calculate the result automatically.

An entity should ensure that it uses the same units for all the dimensions.

Table 3.1 | Common Formulas for Converting Dimensions to Volumes

ITEM	FORMULA
Cube	Area of side, cubed
Cuboid/block	Width x length x depth
Cylinder	*pi* (3.141592) x radius squared x height
Cone	*pi* (3.141592) x radius squared x (height/3)
Pyramid	(Length x width x height)/3

Using dimensions to measure volume may result in an approximation rather than a measurement if the FLW is an irregular shape, if a pile of FLW is not of uniform height, or if a container is not completely full (see "using visual assessment" below). An entity should declare such sources of uncertainty in its inventory report.

Using water displacement

The technique of water displacement involves submerging FLW in a known quantity of water and measuring the water that is displaced as a result. It may be appropriate for items that cannot easily be measured (e.g., because they are irregular in shape) and which are insoluble, such as items in packaging.

When using this technique an entity must ensure that the container into which the item is submerged is first filled with water, and that the item is submerged slowly to allow the water to seep into any air pockets. The amount of water displaced should be captured and carefully measured using a pre-calibrated container. One way of using water displacement, though focused on "street litter," is described in *Analysis of Birmingham Street Litter and Litter Bin Waste* by M·E·L Research (2002) (unpublished; available on request from info@m-e-l.co.uk).

Using visual assessment

A visual assessment may be used to provide an approximation if more precise measurements cannot be made. For example, if FLW is in a container, the capacity of the container may be known (e.g., from a waste management company) or the dimensions may have been measured. An entity would visually assess the proportion of the known or measured volume that is occupied by the FLW (e.g., half full, three-quarters full) and then derive an estimated volume.

Using a flow meter

If FLW is disposed of through pipes (e.g., to the sewer), a flow meter can be installed to measure the total volume of liquid discharged. An entity can use the volume measured to estimate FLW. In some cases, the liquid flow of FLW will be diluted with another liquid, typically wastewater. One method of dealing with this is to measure the organic compounds within the total liquid waste stream, then derive the FLW liquid waste volume by using a known conversion factor for the organic compounds/FLW product of interest.

Box 3.2 describes how this approach might be used in the case of raw milk, which has a high level of "chemical oxygen demand" (COD).

4. CONVERT VOLUME TO WEIGHT

To complete the inventory and report the weight of FLW quantified, an entity will need to convert the measured or approximated volume to weight. This conversion involves the use of density factors.

If there is no void or empty space in the FLW (e.g., for a liquid measured in a container), an entity can use the standard conversion formula of "volume x density factor = weight."

However, because FLW will normally consist of a number of disparate component parts (e.g., peel, pits, portions of uneaten food), there will often be void space within the measured volume. Because this void space does not weigh anything, including it will overestimate the weight of the FLW. For this reason, if void space is included in the measurement or approximation of the volume (e.g., FLW from a waste collection container), an entity should instead use what is referred to as a "bulk density" factor. The conversion formula is "volume x bulk density factor = weight."

The bulk density of any particular amount of FLW will be determined by the type of FLW, the way in which it is stored, and the degree of compaction. In the case of agricultural crops, it may also vary by variety, by plumpness (e.g., how well grain is filled during growth) and by moisture content. It is therefore difficult to generalize about the appropriate factor to use.

To obtain the most reliable bulk density factor, an entity may take a sample of the FLW, measure the weight and the volume, and then divide the weight by the volume, ensuring that the "volume units" are matched with the "weight units" (e.g., cubic meters with metric tons, liters with kilograms). International standards for this matching are available from ISO.

If an entity does not develop a customized bulk density factor from the FLW it is quantifying, it may use a bulk density factor from another source. The Food and Agriculture Organization of the United Nations (FAO) provides a comprehensive list of densities of specific foods,[7] which are expressed as grams/milliliter (g/ml) and may be used to convert volume to weight. If an entity uses these factors, it would apply the formula "volume x FAO density factor = weight" while ensuring that units match. For example, if the volume of the FLW has been measured in liters it should be converted to milliliters before applying the FAO factor, and the result of the calculation transformed from grams to kilograms—or whichever unit of quantification an entity is using for its FLW inventory report.

An entity should understand how these factors were developed in order to be sure that they are applicable and take into account the standard deviation. The factor used should be relevant to the unit of volume and state the result in the appropriate unit of weight. For example, a factor labeled "t/m^3" will convert cubic meters to metric tons while one labeled "kg/l" will convert liters to kilograms.

Box 3.2 | Illustrative Example: Using Chemical Oxygen Demand to Calculate Raw Milk FLW

Many dairies measure the total Chemical Oxygen Demand (COD) in their liquid waste streams and use it to calculate the corresponding amount of raw milk that is disposed of as part of that waste stream. This allows them to obtain a single, meaningful estimate of FLW from a range of liquid dairy products (e.g., milk, yoghurt, cream).

Description of COD approach

This approach applies an average measure of COD to estimate the quantity of FLW. COD is expressed as milligrams per liter (mg/l); it indicates the mass of oxygen that is needed to fully oxidize the organic compounds in the effluent using a strong chemical oxidant.[a]

Reference values are available for a range of undiluted foods and drinks. The reference values can be compared against measured values in a waste stream to infer the amount of lost product contained in the effluent.[b] This approach is difficult to apply, however, if there is a range of items in the liquid waste stream with different COD conversion factors.

COD should be measured for both water coming into a process and water going out of a process.[c] The difference can be attributed to the effluent from the process. It is important that the monitoring point is prior to any on-site effluent treatment, and does not include effluent discharged from any ancillary sources (e.g., toilets) that could affect the result.

The case of raw milk

A dairy could estimate FLW by dividing the total COD in its wastewater (for example, over the course of a year) by the average COD for milk (a standard value of 180,000 mg COD per liter of milk, or 0.18 metric tons COD per metric ton of milk).

A calculation using this example would involve:

- First, calculating COD in the wastewater. If the COD per liter of a milk-based item is 2,000 mg per liter of wastewater and the dairy produces 100,000 m^3 of wastewater a year, then there are 200 metric tons of COD a year in that wastewater. *The calculation converts the COD of the item [2,000 mg/liter] to metric tons COD/liter by dividing by 1,000,000 [which gives 2×10^{-6} metric tons/liter] and then multiplying this by the amount of wastewater in liters [100,000 m^3 is equivalent to 100,000,000 liters].*
- Second, converting COD to a weight. The 200 metric tons of COD that is calculated in the first step is equivalent to 1,100 metric tons of raw milk going down the sewer each year. *The calculation divides the 200 metric tons COD by the standard value of 0.18 metric ton COD per metric ton of milk.*

[a] COD may also be measured in parts per million (ppm).
[b] For examples, see the BREF for Food Drink and Milk Industries. http://eippcb.jrc.ec.europa.eu/reference/. Reference values are also available for biological oxygen demand (BOD)(e.g., Carawan, R.E. 1979. "Water and Wastewater Management in Food Processing." Raleigh, NC: North Carolina State University.
[c] COD monitoring devices are available for sale around the world, from online automatic monitors to smaller equipment suitable for assessing samples.

Box 3.3 | Example of Converting Volume of Grain to Weight

This example is based on grain stored in a container with parallel sides. The volume of grain in cubic meters (m^3) is calculated very simply by multiplying container length x width x depth of grain in the container. For example, if the container is 1.8 m long, 1.0 m wide and is filled to a depth of 2.1 m with sorghum grain, then the volume of grain is: 1.8 m x 1.0 m x 2.1 m = 3.78m^3.

The weight of grain is then determined by multiplying this volume by the bulk density of sorghum. Bulk densities of various common cereal grains are shown in the table below. In our example, the weight of sorghum grain would be: 3.78 x 730 = 2,759 kg.

GRAIN	BULK DENSITY (KG/M^3)
Barley (bulk)	605–703
Maize (shelled, bagged)	613
Maize shelled (bulk)	718–745
Millet (bagged)	640
Millet (bulk)	853
Paddy rice (bagged)	526
Paddy rice (bulk)	576
Rice (bagged)	690
Rice (bulk)	579–864
Sorghum (bulk)	730
Wheat (bagged)	680
Wheat (bulk)	768–805

Sources: Hodges R., M. Bernard, and F. Rembold. 2014. "APHLIS – Postharvest Cereal Losses in Sub-Saharan Africa, their Estimation, Assessment and Reduction." *Joint Research Centre (JRC) Technical Report* EUR 26897: 99. Brussels, Belgium: European Commission; Golob, P., G. Farrell, and J. Orchard. 2002. Crop Post-harvest: *Science and Technology.* Hoboken, NJ: John Wiley & Sons.

Box 3.3 provides a sample calculation using a bulk density factor to convert the volume of grain in cubic meters to kilograms.

Table 3.2 summarizes several bulk density factors that have been used for quantifying FLW. However, it should be kept in mind that, if an entity does not calculate its own density factors and uses factors from another study, those factors may not precisely reflect the entity's own circumstances. Before using external density factors, an entity should refer to the original source to understand how these factors were derived and the standard deviation.

5. SCALE UP THE DATA

Where data have been produced from a physical sample of FLW or from a sample of FLW-producing units, they will require scaling up. Guidance on scaling is provided in Appendix A of the *FLW Standard*.

Table 3.2 | Selected Bulk Density Factors Used in Previous FLW Studies (kg per liter)

TYPE OF FLW[A]	SECTOR	SMALL CONTAINER (E.G., CADDY, HOUSEHOLD BIN)	LARGE CONTAINER (E.G., SKIP/DUMPSTER)
Animal and vegetable wastes[b]	Commerce and industry	0.29	
Animal waste from food preparation and products[b]	Commerce and industry	0.29	
Vegetation and/or vegetable waste[b]	Commerce and industry	0.34	
Waste food—animal or mixed[c]	Commerce and industry		0.20
Whole and/or part animals[c]	Commerce and industry		0.83
Animal fats, oils, waxes and/or grease[c]	Commerce and industry		0.61
Food waste[d]	Household	0.29	0.50
Mixed food and garden waste[d]	Household	0.16	
Mixed food, cardboard, and garden waste[d]	Household		0.50
Food scraps[e]	Households, commercial establishments, institutional and industrial sources	0.89	

[a] Definitions of food categories listed are taken directly from source material noted in this table and may not conform to definitions used in the *FLW Standard.*
[b] Jacobs Engineering UK Ltd. 2010. *Survey of Commercial and Industrial Waste Arisings 2010.*
[c] Debenham, J.M.P., A.P. Harker. 2002. "Volume to Weight Conversion Factors for Industrial and Commercial Wastes." *Proceedings of the Waste 2002 Conference:* 250–258. September 24–26, Stratford upon Avon, UK.
[d] WRAP (The Waste and Resources Action Programme). 2010. *Material Bulk Density: Summary Report.* Banbury, UK: WRAP.
[e] USEPA (Environmental Protection Agency). 1997. *Measuring Recycling: A Guide for State and Local Governments.* Washington, D.C.: EPA. Conversion factor of 0.89 is calculated based on the following: 55 gal = 208l; 412 pounds = 186kg; 186/208 = 0.89 kg/l.

4. Waste Composition Analysis

4.1 Overview of the Method

Waste composition analysis (WCA) is a method used to physically separate, weigh, and categorize FLW. An entity may use this method to separate FLW from a "waste" stream that includes other material that is not FLW (e.g., packaging, yard waste, other solid waste items). Waste composition analysis may also be used to understand the different components that make up FLW (e.g., types of food categories, amounts of food versus associated inedible parts). A WCA may also be referred to as a "waste characterization study," or "waste sort."

A WCA provides an opportunity to collect very detailed information about FLW, where such information is useful for the decision-making needs of the entity using the FLW inventory. The FLW could, for example, be sorted into specific food categories (e.g., apples, cake, chicken). Moreover, items still in their original packaging could be sorted separately and information recorded about whether the item, when removed from the food supply chain, was opened or unopened, or how much was eaten. In the case of packaged products, if the details about which products became FLW are important to an entity's goals, then, as part of a WCA, the entity could also record information from the packaging such as the item's brand, or flavor, enabling it to understand more precisely which items were removed from the food supply chain.

In some countries, there is national or regional guidance on how to carry out a WCA. For example, Scotland has published *Guidance on the Methodology for Waste Composition Analysis: For local authorities commissioning waste composition analysis of municipal waste*.[8]

ADVANTAGES AND DISADVANTAGES

An advantage of using a WCA is that its use of weighing overcomes many of the under-reporting problems of methods such as surveys and diaries, and the inaccuracies of methods that rely on an approximation of FLW such as those based on assessing volume. When combined with other methods, such as surveys or diaries, the results of a WCA are useful not only for quantifying FLW but also for understanding why it might have been produced.

The main disadvantage of WCA is its cost. Other disadvantages include:

- A high level of expertise is needed to plan, carry out, and analyze the results
- The method is not appropriate for some waste streams (e.g., material poured down the drain)
- Depending on the climate, FLW may need to be dealt with very quickly, before it degrades and
- Given the costs involved in implementing a WCA, it may be possible to study only a small sample size, which will increase the uncertainty associated with the results

LEVEL OF EXPERTISE REQUIRED

WCA requires considerable expertise including:

- Knowledge of sampling theory and statistics to ensure that resulting data can adequately answer an entity's research questions. (This is particularly important because it is unlikely that an entity will have the resources to undertake a study of the total population it seeks to quantify, and representative sampling will be required. This may also increase cost, if the entity needs to hire a consultant with these skills.)
- Skills in collecting and sorting samples, including waste handling, managing health and safety processes (e.g., conducting risk assessments for sorting sites), and organizing the logistics.
- Suitable equipment—notably vehicles, scales, screens and boxes—in sufficient quantity to conduct a study appropriate to an entity's needs.
- An understanding of problems that can arise (e.g., material being collected by the normal collection vehicle instead of the vehicle designated for FLW) and ways to overcome them.

COSTS

The cost of a WCA will depend on the scale of the project, particularly how geographically clustered the sampling points are (advice on clustered sampling is given in Appendix A of the *FLW Standard*). The more the sorting team has to travel from place to place, the more cost will be incurred for staff time, vehicle fuel, and accommodation costs. Other items that may incur cost include:

- equipment rental, construction, or purchase (e.g., vehicles, screens, scales, boxes, brooms);
- electronic data-entry devices (e.g., tablet computers, smart phones);
- collection container purchase or rental for storing material pre- and post-sorting;
- disposal/recycling charges;
- sorting site rental;
- permit or license for carrying out the sorting.

4.2 Guidance on Implementing the Method

A WCA can be used at any of the stages in the food supply chain (from production to consumption). An entity implementing a WCA will need to undertake a series of steps.

1. SCOPE THE STUDY

As Chapter 6 of the *FLW Standard* explains, a well-defined scope, aligned with the five accounting principles and an entity's goals, is important for ensuring that an FLW inventory meets an entity's needs. The scope of an entity's inventory—defined by the timeframe, material type, destination, and boundary—will dictate to a large extent the scope of the WCA, although additional questions may be incorporated to meet wider goals. Chapter 6 also describes how the scope chosen by an entity for its FLW inventory should be aligned with its underlying goals for addressing FLW.

2. DETERMINE A SAMPLING STRATEGY

If an entity is undertaking a WCA for all the FLW that is within the scope of its FLW inventory, this step is not applicable, nor is Step 3 (gathering samples). Steps 4–10 will apply, however, except for certain aspects that relate back to sampling.

If an entity does not have the ability or resources to collect and sort the FLW of the whole population it is studying, a sample should be taken. Similarly, if an entity does not have the resources to sample all the FLW produced by an FLW-producing unit, a sample should be taken. General guidance on sampling is provided in Appendix A of the *FLW Standard*. There are several aspects of a WCA that need to be taken into account when designing a sampling strategy. Each is discussed below.

Table 4.1 | Contextual Factors that May Influence Composition of FLW

FACTORS	HOUSEHOLDS	BUSINESSES
Physical	Location of container	Location of container
Collection-related	▸ Type of collection container ▸ Frequency of collection ▸ Type of collections available (e.g., separate FLW collection) ▸ Whether collection fees are charged on the basis of volume or weight ▸ Quality of communications about accepted materials ▸ Availability of recycling or alternative disposal methods	▸ Type of collection container ▸ Frequency of collection ▸ Type of collections available (e.g., separate FLW collection) ▸ Whether collection fees are charged on the basis of volume or weight ▸ Quality of communication with staff about accepted materials ▸ Availability of recycling or alternative disposal methods ▸ Guidance from waste contractor on accepted materials
Temporal	▸ Festival periods ▸ School holiday periods	▸ Peaks or troughs in business ▸ Staff holiday periods
Socio-demographic	▸ Household size ▸ Age ▸ Urban/rural ▸ Ethnicity ▸ Presence of children ▸ Level of income ▸ Single- or dual-income ▸ Frequency of cooking/shopping	▸ Economic sector ▸ Types of food and drink processed or sold ▸ Level of mechanization ▸ Degree of engagement with FLW-prevention initiatives ▸ Level of education of staff

Contextual factors influencing the composition of FLW

Table 4.1 lists some of the contextual factors that should be taken into account when devising a strategy to select a representative sample for a WCA. The list is focused on households and businesses but most of these considerations apply to other entities as well.

Practicalities related to sampling FLW

The practicalities of taking samples can rule in or rule out certain sampling strategies, so it is sensible to consider them at this stage rather than later in the process. The issues to consider will vary, depending on how an entity's FLW is collected, but they include:

- **Collection body.** Who normally collects the "waste" material? Is it a government body or a private waste management company? How feasible will it be to engage with them? Are lots of different players involved? How feasible will it be to sample the material collected by many waste companies as opposed to one? Will some types of arrangement need to be excluded?

- **Collection cycle.** Is the collection organized into "rounds" or "routes" serviced by one vehicle? Is it feasible to sample all the material in a round or route? How representative of the whole population being studied is the round/route?

- **Location of FLW.** Where are the containers located? Are they accessible? Will businesses with inaccessible containers need to be excluded? Will some sources of FLW need to be excluded (e.g., if FLW is kept in locked areas which cannot be accessed)? How will communal systems where quantities might be large and the precise source of the FLW is unidentifiable be dealt with?
- **Mixing of material.** How do the crews normally collect the material? Do they go ahead of the vehicle and group it all together so that material from individual FLW-producing units cannot be distinguished? Will these areas need to be excluded from the WCA?
- **Bulky collections.** How will very large containers that cannot be manually tipped or emptied be dealt with? Can arrangements be made for them, or will this type of container need to be excluded from the WCA?

Once the various considerations have been evaluated, a strategy should be decided upon and a sampling frame drawn up. In the simplest case the strategy will involve randomly selecting units from a pre-prepared list of all units (i.e., the sampling frame). More likely, cluster sampling will be required due to the cost of gathering data from geographically dispersed sites. An element of stratification of the sampling frame may be needed to ensure key characteristics of importance are covered. Additional guidance about these different sampling strategies is provided in Appendix A of the *FLW Standard*.

3. SELECT APPROACH FOR GATHERING FLW SAMPLES

There are three possible ways for an entity to collect samples of FLW: bulk sampling, small-area sampling, or sampling from individual FLW-producing units. In the case of the first two, the sampling unit is not the FLW-producing unit (see "bulk sampling" and "small area-based sampling" below). Which of these three options an entity selects will determine the nature of the sampling unit, which in turn impacts how the data are scaled up in a WCA (see Step 10 in this section).

Bulk sampling

This approach involves intercepting FLW after it has been collected by the normal collection vehicle. The vehicle will typically collect material from many FLW-producing units and take it somewhere to be tipped, either straight into the disposal facility, or to a transfer site where it will be consolidated and then sent to the disposal facility.

It may be possible to sort and weigh the FLW at the disposal or transfer site, or it may be possible to ask the vehicle to divert to a special site where the sorting and weighing will take place. See Step 7 in this section for issues to consider in relation to the site. The benefit of a bulk sampling approach is that an entity can sample large quantities of FLW at relatively low cost because it is relying on the normal vehicle delivering it.

The FLW being analyzed in this scenario is one step removed from the units that produced it because it has been collected by a third party. As such, the sampling unit will be the transfer site, the vehicle from which the FLW is taken, or possibly the area from which the intercepted vehicle has collected the FLW. The definition of the unit will depend on which of these (transfer site, vehicle, area) the sampled FLW is considered to be representative of. The data will then require scaling up to all transfer sites, all vehicles, or all areas within the inventory scope. An entity shall nonetheless describe in its inventory report as much as is known about the FLW-producing units that generated the FLW (see guidance related to describing "boundary" in Section 6.6 of the *FLW Standard*).

Small area-based sampling

This involves choosing a specific physical area from which to sample (e.g., a street, a neighborhood, a business cluster). This chosen physical area becomes the sampling unit. The material from all the FLW-producing units in that area is collected and combined into one larger sample.

The advantage of this approach is that an entity can closely control the type of area included in the study (e.g., only affluent areas, areas with low levels of car ownership) without going to the additional expense of collecting from each FLW-producing unit separately. The FLW will then need to be taken to the sorting and weighing site for analysis.

In this approach to sampling, the sampling unit will be the street, neighborhood, or business cluster. The data will require scaling up to all streets, all neighborhoods, or all business clusters within the inventory scope. As with bulk sampling, an entity shall nonetheless describe in its inventory report as much as is known about the FLW-producing units that generated the FLW (see guidance related to describing "boundary" in Section 6.6 of the *FLW Standard*).

Individual sampling of FLW-producing units

This approach keeps material from individual households or other entities separate when sampling and sorting the FLW. If there are multiple FLW-producing units, FLW is often placed in separate bags—either by the FLW-producing unit or by the WCA study team—which are tagged with a unique identifier that refers to the FLW-producing unit. This identification allows the FLW to be anonymous to all but those who know which code corresponds with which unit, yet allows it to be linked to survey responses and other information about the FLW-producing unit during the analysis phase.

The information derived from this approach is particularly useful when combined with questionnaire responses from those specific FLW-producing units because it enables an entity to link FLW to characteristics of the people or entities producing it. The entity can then draw conclusions about any correlations. However, individual sampling can be expensive due to the added costs of collecting the FLW and keeping it separate, analyzing it separately, and entering data for every FLW-producing unit separately. In some cases, individual sampling will also require informed consent from the parties being sampled, rather than use of a simple "opt out" arrangement. This is because of the direct links being made between FLW and the people or entity that produced it (see Step 4 in this section about issues of consent).

In this approach to sampling, the FLW-producing unit will be the household or other entity that generates the FLW and the data will require scaling up to all the FLW-producing units within the inventory scope.

At the end of this process, an entity will have determined whether FLW-producing units or some other sampling unit (e.g., streets, neighborhoods, individual households, individual businesses, whole waste collection rounds) are to be sampled.

4. CONSIDER ISSUES OF CONSENT

If the entity undertaking a WCA is also the entity that has ownership of the FLW, then this issue will not arise. However, where the entity undertaking the study does not have ownership, it needs to consider the following issues related to obtaining consent to sort through another entity's FLW.

An advantage of using a WCA is that its use of weighing overcomes many of the under-reporting problems of methods such as surveys and diaries, and the inaccuracies of methods that rely on an approximation of FLW such as those based on assessing volume.

An entity should investigate the relevant legal framework to ensure that it does not inadvertently break the law. For example, in many countries, in order to transport waste material from its source to a sorting site, an entity will need a waste carrier's license. In some countries, it is illegal to sort through "waste" generated by a household without the household's consent. If undertaking a WCA for a business, an entity that takes away the material for WCA analysis without obtaining prior consent from the business may be breaking the terms of the company's contract with its waste contractor. An entity should also consider what is culturally acceptable. In some cultures, sorting through "waste" without consent is ethically unacceptable.

Obtaining consent is a particular issue with WCA because of the sensitive nature of sorting through someone else's FLW, particularly from households where personal items might be encountered. Whether or not consent of the entity producing or owning the FLW is required will depend in part on where the FLW is intercepted. For example, it is not usually contentious to analyze bulk loads of FLW at a transfer site (bulk sampling) because the source of the FLW will not be known. However, sometimes an entity may want to be able to link the FLW to those generating the FLW (e.g., to link the FLW to household socio-demographics or to a particular business sector), in which case the FLW may need to be collected at its source. In this case, the process might be more sensitive and the issue of obtaining consent should be carefully considered.

Obtaining consent may, however, affect the accuracy of results. This is because the effect of alerting the participants to the study can lead to participants changing their behavior and generating fewer or different items of FLW. One approach to avoiding this is to plan a waiting period of several weeks between seeking consent and carrying out the WCA so that behavior has a chance to revert to normal, and not to inform participants of the timeframe in which the WCA will be conducted.

If consent is required, two main approaches are possible—offer an "opt out" or require "opting in." Each is discussed below.

Opt-out approach

Allowing potential participants to opt out of the WCA is the simpler and arguably more effective approach from a research perspective. The entity undertaking the study should alert those FLW-producing units selected for sampling to the forthcoming WCA, describe its purpose, and encourage them to take part. To reassure the sampled units, there should be controls in place to ensure that personal information is kept confidential (see Section 8.5 of the *FLW Standard*).

Opt-in approach

In this approach, the FLW-producing units being studied should be contacted in advance and asked to participate. Where possible, consent should be "informed consent," that is, the representative of the FLW-producing unit should be given full and honest information about the process. Where a record of the consent is required (e.g., a signature of the participant against a statement of consent), an effective way to obtain the consent is in combination with a survey. The entity should be very clear about the benefits of participating to persuade as many units to take part as possible. This is particularly important where a probability sampling strategy has been adopted (see Appendix A of the *FLW Standard*), because sample size can quickly be eroded by non-participation. Incentives can be provided to increase the level of opting in (see Chapter 7 in this document for ideas).

In general, in line with good research practice, the people or entity whose FLW is being collected should be able to make a telephone call to a place of authority (e.g., the police, the local community council) to check that the work is genuine research. This means that the relevant local authorities should be pre-briefed. In some countries, identity theft from discarded documents has made the news and people may be concerned that someone is trying to "steal" their waste for gain. Reiterating that only the FLW will be analyzed and that all other material will be disposed of in the usual way (whatever that may be for the local authority or municipality in question) could allay many of these fears. In addition, it is good practice to have prepared frequently asked questions (FAQs) and responses in case of interest. Responding promptly and openly to expressions of interest by the media may also deflect what might otherwise become a hostile story about "snooping."

5. DETERMINE THE FLW CATEGORIES TO BE ANALYZED

The scope of the FLW inventory and an entity's quantification goals will dictate the categories into which the FLW must be sorted and weighed. In order to maximize the value of the WCA, an entity may also record information for categories beyond the scope of the inventory, provided their inclusion does not compromise the main objectives of the study. A list of categories should be prepared at this stage.

6. CONSIDER HEALTH AND SAFETY RISKS

The health and safety of those handling waste material is an important consideration for WCA. This standard does not provide detailed health and safety guidance. Whether an entity is carrying out the WCA itself or contracting with a specialist company, it shall ensure that safe systems of work are employed; that staff are given appropriate levels of training, personal protective equipment and vaccinations; and that detailed health and safety policies and procedures are produced and followed. In particular, the entity shall comply with relevant health and safety law and best practice guidance.

Policies should be drawn up, before commencement of the study, on the procedure to be followed if workers find hazardous material (e.g., asbestos, syringes), illegal material, or items suggesting that a crime may have been committed.

7. OBTAIN SAMPLES OF FLW, OR MIXED MATERIAL CONTAINING FLW, AND SELECT SITE FOR SORTING

The approach taken to obtain the samples of FLW, or the mixed material containing the FLW, will be dictated as much by practical access issues as by technical sampling considerations. It is possible that sampling will need to be conducted in two stages: obtaining the sample, and then sub-sampling from that sample to generate a quantity that can be sorted and weighed manageably. General guidance on physically sampling FLW is provided in Appendix A of the *FLW Standard*.

If a waste management company routinely collects FLW on a certain day, the sample should be collected on that same day, and as close to the usual time of waste collection as possible. This is because the timeframe over which the sample has been produced will normally be known only in relation to the normal collection schedule; this is essential information for scaling up the data. If the sample is collected on a different timeframe, it may not be representative of the whole period. This means that, in advance of collecting the sample, an entity will need to:

- Find out the normal day and time of collection
- Liaise with the organization that would normally collect the waste and ask it not to collect during the period of sampling. It is risky to rely on the sampled FLW-producing unit to make these arrangements. An entity should take on this responsibility

It is a common pitfall of WCA that the waste management company responsible for routine collections mistakenly picks up the intended samples of FLW, despite requests not to do so. Therefore, in order to ensure that routine waste collection does not accidentally collect the FLW, the following is recommended:

- The day before routine collection, the normal waste collector should be reminded that the entity will be collecting a sample
- The entity should aim to collect the FLW at least one hour ahead of the normal collection time to avoid the samples being collected accidentally by the normal vehicle
- If possible, the entity should liaise with the actual driver of the vehicle rather than management to communicate the importance of not collecting the FLW intended for the study

Prior to the sample being taken, an entity should also collect any other required background information such as where to locate the container that is to be sampled.

An entity will need to decide whether the sample is to be sorted on the FLW-producing unit's site or elsewhere. Where the sampling unit is a waste transfer site, it may be feasible to sort and weigh the sampled FLW at that site. Businesses are unlikely to have space for sub-sampling, sorting, and weighing FLW, and this is even less likely for households. In these cases, a separate site at which the FLW can be sorted (the "sort site") must be secured.

An entity should consider the following variables in selecting a site for sorting the FLW for weighing:

- Lighting may be required, especially in the winter months
- Where electricity is not available, a generator may be needed
- The needs of the individuals undertaking the sorting must be taken into account (e.g., toilet and washing facilities, area for eating)

- Cover may be needed in windy or rainy climates (sorting under temporary cover such as tents is possible but not ideal)
- Local laws may be in place related to storage and processing of waste. In some countries, analysis of waste may be permitted only at sites licensed for waste management activities (e.g., an entity may need to apply for a temporary license, which may take some time)

If the sample is to be removed from the location from which it was taken, an entity will need to consider how this will be achieved. In particular:

- Can the whole container be removed from the sample location? If so, what arrangements will be made for temporary replacement containers, and how will the original container be returned? And what type of vehicle will be required to lift and move it?
- If the container cannot be removed, how will the sample be physically moved in a safe manner from the container in which it is normally stored? What temporary container will be used to store the FLW? And how will the FLW be transported?
- Is it feasible to request that the normal waste collection company delivers the FLW to the sort site?

Any vehicles used must be non-compacting to ensure that material can be sorted and separated and large enough to carry what can be substantial volumes and weights of FLW without spilling and mixing samples. In some countries, for example, a vehicle that transports waste must be authorized, which means that it must be owned or hired by a "Public Service Company (PSC)." In other countries, organizations that move waste around must be registered.

If an entity is taking a large sample, careful consideration should be given to how it will be stored because it may take several days to sort and weigh it. During this time it will need to be kept secure, avoiding unpleasant smells for neighbors and staff, windblown litter issues, and pollution due to leaching. An entity may need to supply containers at the sort site for the FLW while it is waiting to be sorted.

8. SORT AND WEIGH THE FLW

Sorting stations are normally set up allowing sorters to have their own areas. Normal practice is to use screens made of wire mesh, which allow FLW that is too small to sort to fall through onto a plastic sheet below. The mesh size can vary, but 10mm is thought to be reasonable for FLW analysis. The small particles (or "fines") can be collected and weighed as one category. The screens should be set at a height that is comfortable for the individuals sorting the material. Boxes are placed around the screen, one for each category into which the sample will be sorted. Typically, individual sorters will tip a small sub-sample of material onto their screens, pick out items of the various categories, and put them into the correct box. Some agitation of the material may be required to allow small particles to go through the screen, although squashing it through is not acceptable.

The categories into which the sample will be sorted need to be very clearly defined so that, if multiple individuals are sorting, the placement of the FLW will nonetheless be consistent. Staff training will be crucial to ensure that all individuals involved follow the agreed method of categorization. This is particularly important when categorizing the FLW as "food" or "associated inedible parts" since what is considered inedible varies based on a number of factors, including cultural norms. Additional guidance on categorizing FLW by these material types is provided in Section 6.4 of the *FLW Standard*.

Meals are especially hard to classify because they consist of many different components, which are nearly impossible to separate given that thick gloves are typically worn for protection by those undertaking the sorting. A method of deciding how to assign meals to categories will be required to avoid sorters making their own decisions and introducing inconsistency. One possible option is to assign the meal according to the main ingredient/component.

Even with the best classification method there will always be some material that is impossible to identify. In the United Kingdom this has been referred to as "composite gunge" or "semi-solid mixed food." A category for this material should be included in the list and clear instruction given to sorters on when it can be used. An entity must be realistic about the level of sorting that can be achieved.

An entity should give guidance to sorters on how to handle items in packaging. The *FLW Standard* stipulates that the weight of packaging is excluded from estimates of FLW. Ideally, packaging should be removed from items before weighing. Emptying packaging will lead to a more accurate estimate of FLW, but will slow the sort down and require tools, adding to the cost of the exercise. (See Section 8.3 of *the FLW Standard* for additional guidance on how to deal with packaging when quantifying FLW.)

Once the sample is sorted into categories, the weight of each category should be determined. Guidance on weighing and assessing volume of FLW is provided in Chapter 1 and Chapter 3, respectively, of this document. An entity should also determine the weight of the material that is not FLW so it can carry out a simple mass-balance calculation at the end of the process, in which the sum of the weighed sub-samples is compared to the weight of the whole sample, to make sure that no sub-samples have gone astray.

Records must be kept of each weight, and pre-coded datasheets should be prepared for this task. The datasheets can be electronic or manual, depending on the technology available at the site and the preferences of the team.

An entity will need to provide a location for the sorted and weighed material to be stored prior to recycling or disposal. If the sort site is not a waste management site, arrangements for recycling and disposal will need to be made.

9. MANAGE THE DATA

If an entity has manually recorded the data, it will need to enter it into a spreadsheet or database. In order to check the quality of the data entry, it is good practice to check one in 10 records by making a comparison between the paper-based form and the database. If significant errors are uncovered then all the data should be checked and may need to be re-entered. If the data have been recorded electronically on site, they should be transferred to data analysis software.

If an entity took samples, it should compare the sum of the weighed samples with the weight of the whole sample that it took before sorting commenced. A degree of loss is to be expected in the sorting process because FLW adheres to boxes and screens, but if the loss is more than 10 percent then the data may contain errors.

> *When combined with other methods, such as surveys or diaries, the results of a WCA are useful not only for quantifying FLW but also for understanding why it might have been produced.*

10. ANALYZE THE DATA

If data were produced from a physical sample of FLW or from a sample of FLW-producing units, they will require scaling up. Guidance on scaling up the data is provided in Appendix A of the *FLW Standard*.

For bulk and small-area samples, analysis may involve only summing the samples and scaling up to the population of interest. One disadvantage of bulk sampling and small-area sampling is that no conclusions can be drawn about variation in FLW produced by individual FLW-producing units contributing to the sample. Confidence intervals, which indicate levels of data accuracy, will need to be calculated based on variability between the sampled units instead (e.g., neighborhoods, vehicles, areas). Guidance about using confidence intervals is provided in Section 9.3 of the *FLW Standard*.

For a WCA that has taken a small area-based sampling approach and used several areas to represent a larger area (e.g., three streets of 50 households with different levels of affluence to represent one council area), the data must be weighted in proportion to the prevalence of each subarea within the greater population area.

An entity will need to consider at the data analysis stage how to deal with incomplete data records. For example, sampled households and businesses may not have set out their waste on some occasions during the sampling period. It is normal statistical practice to delete incomplete records, but there may be specific occasions when leaving them in the dataset is advisable (e.g., where it might offset over-representation of other households or businesses).

Once the weight of FLW is obtained from a WCA, an entity may use it to calculate the percentage of a mixed waste stream that is FLW. Where an entity intends to combine the WCA results with survey or diary data to investigate possible causes of FLW, the FLW data for each category of food should first be normalized by conversion to an amount per household or per person (or another suitable metric). Guidance related to normalization is available in Appendix C of the *FLW Standard*.

5. Records

5.1 Overview of the Method

Records are individual pieces of data that have been written down or saved. They are often routinely collected (e.g., waste transfer receipts or warehouse record books) and, while often created for reasons other than quantifying FLW, they can also be used for this purpose.

ADVANTAGES AND DISADVANTAGES

Using records to generate the data for an FLW inventory often costs less than undertaking a new study to measure or approximate FLW. If records are based on actual measurements, the data may also be more accurate than data collected through a new study that relies on a number of calculations and assumptions.

One disadvantage of using existing data from records is that the method used to generate the data may not be clear. An entity should understand how the records were created because some methods result in more accurate quantification than others. For example, if the records are based on weighing, they are likely to be very accurate, whereas if they are based on an approximation of volume they may be less accurate.

LEVEL OF EXPERTISE REQUIRED

Although care and attention to detail are required, no particular expertise is needed to use records.

COSTS

The cost of using records to quantify FLW is principally associated with the time spent to obtain and analyze the records. Where data are available and already in a standard unit of measurement, the process can be very quick and inexpensive. The time requirements and cost increase if data must be converted from one set of units to another.

5.2 Guidance on Obtaining and Using Records

Using records is more straightforward for an entity that has ownership of the FLW. The process typically involves finding, collating, and analyzing the records. If records are in paper form, the data should ideally be entered into a spreadsheet or database. If the quantities are in volume form (or other units), they should be converted to weight (see Chapter 3 in this document). Once the data have been collated in this way, they can be analyzed to generate data for the FLW inventory. For example, if an entity's FLW is collected by a waste management company and that company provides invoices with a record of the weight of each load, then the entity can collate the invoices for the time period and site in question, enter the weights into a spreadsheet, and simply sum them. However, this will be possible only if the FLW was separated from the other material.

An entity that does not have ownership of the FLW (e.g., a national government) may also use records to develop an FLW inventory. The process for obtaining records from others will vary depending on the number of entities from which records are to be collected and the likelihood of these entities providing the information.

The series of steps below provides guidance on using records to develop an FLW inventory, with Step 3 focused on entities that need to obtain records from others.

1. CONFIRM RELEVANCE OF SCOPE

It is important that an entity review whether the records it proposes to use are in line with the scope of its FLW inventory (i.e., in line with the timeframe, material types, destinations, and boundary).

2. DETERMINE WHETHER THE RECORDS ARE SUFFICIENTLY ACCURATE

An entity should also assess the likely accuracy of the records. This includes considering the reliability of:

- the method used to compile the records (e.g., direct weighing, assessing volume, counting);
- the measurement device(s), if relevant;
- the transcription of the measurement or approximation into the record; and
- any assumptions or conversion factors used (e.g., to convert volume to weight).

It is likely that a series of tradeoffs will need to be made. Using records is often a less resource-intensive way of obtaining data for the inventory than carrying out a study using measurement or approximation. However, sources of uncertainty and error may be more significant.

If records are used, users of the *FLW Standard* are required to identify the source of the records and their scope. Where information is available about the quantification methods used to create the records, this should also be described. This aligns with the general requirements in Chapter 7 of the *FLW Standard* for reporting on how FLW was quantified.

3. OBTAIN RECORDS

If the entity creating the FLW inventory does not have direct access to the records, there are various ways to obtain them. The approach selected will depend on whether the entity can require that records be provided or can only request that they be provided on a voluntary basis, and whether the entity is prepared to collect and combine the records itself or can ask the "record holder" to do so.

Requesting records

If the entity preparing an inventory is in a position to require that records be provided, it may simply go ahead and do so. If the entity is likely to request records on a regular basis, it should consider establishing rules, processes, and guidance for the record holders to ensure a consistent approach to collecting records over time. It should also devise and implement a quality assurance process.

If the entity preparing an inventory is relying on the voluntary co-operation of record holders, a different approach will likely be more effective. The percentage of record holders that actually provide records is known as the "response rate." The greater the response rate, the more reliable the data generated from the records will be (see Chapter 9 of the *FLW Standard*). An entity can try to ensure an adequate response rate in the following ways:

- Explain how the records will be used and the societal benefits that will result from their use
- Make arrangements for assurance of confidentiality, taking into account local data protection laws
- Offer an incentive to respond (e.g., vouchers, a prize draw for an item of value, some other kind of recognition)
- Offer financial compensation for the work required to find and deliver the records, and/or
- Make it as easy as possible for the record holder to respond, by being clear about which records are needed and providing a simple way for them to be delivered (e.g., a prepaid envelope if hard copy records are being sent by mail)

If an entity is gathering records from many record holders, it is good practice to set up a tracking system to monitor responses. It is especially important to track responses if a sample of record holders has been taken. It is essential if a quota sampling approach is used and a certain number of responses per "quota" is required. Guidance on using a quota sampling approach is provided in Appendix A of the *FLW Standard*.

When requesting records, it is important to give a realistic deadline. At least two reminders will probably be required to get a reasonable level of response and should be factored into the timeframe. To avoid annoyance, reminders should be sent only to those who have not replied, which underscores the importance of tracking responses.

Collecting and combining records

One way to improve the response rate is to ensure that it is as easy as possible for the record holder to provide its records. From the record holders' point of view, the simplest option is for the entity preparing the inventory to accept records in whatever form they are available. This means, however, that the entity must devote time to extracting the required information and putting it into a standard format.

Another option is to provide a standardized form and request that the record holder enter the data from its records. The standardized request might be a form or a data table, and could be provided online (e.g., a data entry portal), electronically (e.g., attached to an email), or in hard copy (e.g., mailed or hand delivered). This requires some effort on the part of the record holder.

If asking the record holder to fill out a form, the entity requesting the records should undertake simple validation checks (e.g., checking that numbers sum as expected). An entity should, if possible, follow up with the record holder if there are missing or invalid data to check whether this was an oversight and to determine whether the correct data are available. It is a good idea, therefore, to request contact details and permission to re-contact at the time of the initial request.

The entity preparing the inventory could also ask for the data from record holders by means of an interview, by telephone, or a face-to-face visit. Additional guidance on conducting interviews is provided in Chapter 7 of this document.

The most appropriate and effective option for a particular entity is determined by a number of factors, including:

- resources available, to both the entity preparing the inventory and the record holder;
- likely extent of cooperation from the record holder without added incentives;
- required response rate (if the rate is high then minimizing the effort required by the record holder is important);
- expected quality and comprehensiveness of the records;
- access to technology (e.g., internet and email); and
- literacy and numeracy levels of the record holder.

4. PROCESS THE RECORDS

An entity should enter data in consistent units of quantification. Spreadsheets and databases are excellent at converting from one unit to another, and the best approach is to allow data to be entered in the units in which they were provided (e.g., using different columns for different units and then creating calculation formulas to convert them to the desired unit). This approach involves less risk of error when future adjustments or corrections need to be made.

An entity should take care to enter data consistently against the scope. For example, if one record holder's records relate to the summer and another's to the winter, the data entry system must be designed to take account of this. Once the data have been extracted from the records, it will be much harder to identify inconsistencies such as this that may affect the results.

Planning the data analysis in advance will help to ensure that the structure of the database is appropriate. For example, if the records are in volume, the entity should include the bulk density conversion factors in the relevant spreadsheet or database so the volume can be converted to weight. This allows data to be entered in volumetric units while enabling automatic conversion to weight.

Guidance on scaling the data, if required, is provided in Appendix A of the *FLW Standard*.

6. Diaries

6.1 Overview of the Method

Diaries involve an individual or group of individuals maintaining a daily log of FLW and other information. The diary method is best suited for quantification of FLW where an entity does not have direct access to the FLW and where insights are needed about behaviors linked to amounts and types of food. The technique is widely used in social and market research to capture information about behaviors as they are carried out, and is well suited to habitual, routine behaviors carried out in a private setting.

Diaries can be kept by any individual or entity producing FLW (the "diarist") but are most commonly used as a means of studying FLW in households and commercial kitchens. The quantities are recorded before the FLW is "thrown away." If done well they can provide a rich description in real time not only of the types and amounts of FLW but also of the reasons why FLW occurs.

Various types of information can be recorded in diaries, including: weights of FLW captured through direct weighing (see Chapter 1); item counts (e.g., five apples—see Chapter 2); or volume-based measurements or approximations (e.g., using calibrated spoons, cups, jugs, or approximations such as handfuls—see Chapter 3). Sometimes, measurement devices are provided to research participants (e.g., a set of weighing scales). Other times, vessels are provided for volumetric assessment (e.g., a bag or small container to collect FLW).

Diaries have been used to collect information on FLW in the UK, Sweden, State of Oregon (United States), and City of Seattle (United States), often as one part of a larger study that encompasses other methods.[9]

ADVANTAGES AND DISADVANTAGES

The main advantage of using a diary-based method is that FLW is recorded in "real time" which circumvents issues of faulty recall in survey-based methods and physical degradation of FLW in methods that rely on measurement and approximation.

Diaries provide a way of recording FLW that is not collected in a formal waste collection system and so cannot otherwise be easily quantified (e.g., disposed of down the sewer, fed to pets or wild animals, composted at home). A photographic or video-based diary offers the added advantage of capturing the data but with no requirement for the diarist to write anything down. See Box 6.1 for more on photographic and video diaries.

Diaries also offer a means of capturing qualitative information such as participants' views about FLW. This qualitative information can be linked to quantities of FLW (e.g., reasons for disposal of each food item or a diarist's thoughts about FLW) to provide added insight. Reasons for FLW can also be collected through other methods such as surveys but, with surveys, the link between quantitative and qualitative information may be unclear or distorted. Because diaries collect quantitative information alongside qualitative information, they enable links to be easily made between self-reported attitudes and behaviors and the amounts of FLW.

There are, however, some significant disadvantages to the diary method, some of which can be overcome with good design and strong analysis. First, FLW data collected through a diary method are likely to be less accurate than FLW data collected using weight-based methods such as direct weighing or waste composition analysis. This is because quantities are most frequently captured through approximation (e.g., handfuls, platefuls) rather than measurement. Where measurement is used, it is carried out by non-experts, which may lead to inaccuracies.

Inaccuracies in data reported by diarists[10] may also be affected by:

- **Novelty of the exercise —** there is some evidence to suggest that, on the first day of a diary exercise, participants are more vigilant about recording FLW than on subsequent days[11]
- **Social desirability bias —** diarists complete the diary in a way perceived by them to be desirable to others—typically under-recording the amounts of FLW because wasting food is not a desirable practice. Evidence also suggests they may alter their food-consumption behavior in an attempt to do what they perceive to be desirable (e.g., prepare more healthy foods on the first day of the diary)[12]
- **Behavioral reactivity** — diarists react to the fact that they discard more food than expected by changing their behaviors in the middle of the diary collection period
- **Missed instances of FLW** — this particularly applies where units have more than one occupant and some instances of FLW are not captured by the diarist

Second, diarists are liable to drop out of the process, particularly if the demands placed on them are high. Commitment—which may have been high at the start of the process—can easily wane, leading to smaller sample sizes than expected and increased uncertainty in the results.

Third, a diary usually captures data over a short period of time and therefore does not capture variations in FLW over longer time periods. To overcome this shortcoming, repeated diary keeping is required, which increases the cost and leads to diarist fatigue and drop-out. Surveying different diarists over time, however, can help to offset the effects of fatigue. An entity could also repeat the diary study a year later to study changes over time.

LEVEL OF EXPERTISE REQUIRED

It is important that an entity implementing the diary method has a good understanding of social or market research techniques. The data need to be handled by someone who not only understands data analysis generally, but also is capable of integrating quantitative and qualitative data. This is because diaries tend to contain comments and insights in addition to data on amounts of FLW generated. Expertise is important to maximize completion rates, tackle issues of social desirability bias and behavioral reactivity, and avoid possible inaccuracies related to estimates of FLW.

Box 6.1 | Diary Using Pictures of FLW

Nestlé has been using behavioral observation approaches in different contexts to reduce social desirability bias observed in interviews and diaries and to collect quantified information on behaviors related to food experiences. It is proposing to apply a similar approach to FLW quantification.

This approach involves capturing pictures or small videos of FLW and automatic dynamic weighing. The weight of each item of FLW is captured with no specific actions required from the household members. The pictures or videos are then coded by professionals who link the visual information (e.g., type of FLW) to the FLW weights.

The method is particularly useful where there is concern about the ability of diarists to keep accurate records. Because the burden is shifted from diarists to data processing teams, drop-out rates are reduced. This approach also avoids inaccuracies caused by poor recall and minimizes the impact of social desirability bias and behavioral reactivity. The tradeoff may be in the form of higher costs for paying and training professionals who assist with analyzing the data.

The entity implementing a diary study should therefore have expertise, or access to expertise, in:

- diary design;
- sampling theory and practice;
- operationalizing the approach, including recruiting participants, briefing and motivating them, and providing a helpline;
- coding and entering data; and
- statistical analysis of the results.

COSTS

Diaries can be expensive, whether they are carried out in-house or contracted to a specialist company. One reason is that the sample size often needs to be large so that the entity can scale up the data from the sample to the population without introducing too much uncertainty into the results. The likely level of drop-out needs to be taken into account because it can be substantial, and efforts will need to be made to minimize it. Costs associated with the following phases may include:

RECRUITMENT PHASE

- Purchasing lists of people or companies to be used for sampling
- Commissioning or carrying out questionnaire surveys to recruit participants

DESIGN PHASE

- Developing online or app-based diaries
- Printing hard-copy diaries
- Mailing/postage costs
- Purchasing and delivering measuring and recording equipment, if required
- Paying for external expertise in research sampling and diary design

OPERATIONAL PHASE

- Human resources required to brief diarists, maintain contact with them to keep up motivation levels, provide a helpline, and enter data and code the diaries
- Incentive payments or gifts for participants

ANALYSIS PHASE

- Paying for external expertise on statistical analysis

6.2 Guidance on Implementing the Method

An entity that implements an FLW study based on diaries will need to undertake a series of steps.

1. SCOPE THE STUDY

As Chapter 6 of the *FLW Standard* explains, a well-defined scope, aligned with the five accounting principles and an entity's goals, is important for ensuring that an FLW inventory meets an entity's needs. The scope of an entity's inventory (defined by the timeframe, material type, destination, and boundary) will dictate to a large extent the scope of the diary, although additional questions may be incorporated to meet wider goals. Chapter 6 also describes how the scope chosen by an entity for its FLW inventory should be aligned with its underlying goals for addressing FLW.

One particularly important scoping decision is whether to include or exclude times of the year that are known to affect the amount of FLW. FLW quantities can vary significantly during holiday and festival periods, as well as on weekends—versus weekdays—when less food may be eaten at home. The nature of food waste can also vary by time of the year. For example, during summer, households in the United States tend to eat a lot of corn on the cob and watermelons, leading to a seasonal increase in the weight of FLW and an increased share of associated inedible parts in the form of corn cobs, corn husks, and watermelon rinds.

Diaries are best suited for quantifying FLW in environments that are reasonably controlled and systematic, where the same process is carried out in roughly the same way and at the same time each day (e.g., a household, a catering kitchen).

An entity should decide whether information other than quantities of FLW will be sought through the diary study. In a household study, such information might include whether shopping has been undertaken on that day, or how many people were eating meals in the home that day. Analysis of this supplementary information may provide insights into when and why FLW occurs, which might be useful in tackling the generation of FLW.

2. DEVELOP A SAMPLING STRATEGY

An important design consideration is the way in which the diarists will be sampled because poor sampling technique can affect the accuracy of the results. An entity should determine the approach to sampling (e.g., probability versus non-probability sampling).

Probability sampling involves creating a listing of all eligible sampling units, known as the sampling frame. Non-probability sampling involves identifying potential diarists through a research process, which can be more or less formal. Additional guidance on both probability and non-probability sampling is provided in Appendix A of the *FLW Standard*.

3. RECRUIT PARTICIPANTS

The way in which potential diarists are approached will depend on the contact information available in the sampling frame. For diaries, it is useful to have personal contact so that the process can be explained and potential diarists persuaded to take part. An anonymous letter or email may not be effective.

The approach to recruitment will depend on whether probability or non-probability sampling has been selected. If an entity uses probability sampling, it should make a random selection of potential recruits and seek their participation, but should not replace those who decline. One disadvantage of probability sampling is that, because no replacements are made, the sample size can rapidly shrink. This is especially likely in the case of diaries that require a high level of commitment. Additional guidance about selecting samples is provided in Appendix A of the *FLW Standard*.

An entity should consider how to maximize recruitment. An incentive could be offered to diarists. Incentives should be culturally appropriate, and may include modest cash payments, gift vouchers, or merchandise. If this is given on completion of the task, it can also minimize drop-out rates. Other ways to maximize participation at the recruitment stage include wording letters or introductory text persuasively, perhaps stressing the social benefits of the study, or offering information on the diarists' own FLW so they can reduce it (this can work well for business diarists).

An entity should avoid introducing bias in recruiting the diarists to ensure that the results are representative of the population. One risk is that only people interested in FLW issues will volunteer for the diary study. Ways to address this risk should be carefully considered because including only "interested people" will create an unrepresentative sample, leading to inaccurate results. As another example, if a researcher is based in a store recruiting diarists, and that store tends to attract only wealthy shoppers, then the sample will be biased toward more affluent people who may have very different FLW behaviors from less affluent people.

Because studies in the UK, the United States, and Australia have shown that a proportion of the diarists will not finish the research process, it is good practice for an entity using non-probability sampling to recruit extra diarists to ensure that it gets the required number of completed diaries.[13]

At the time of recruitment, an entity should ask the diarists about their preferred means of communication (e.g., telephone, email, text) during the diary process. Observing their stated communication preferences will maximize the likelihood of full participation.

4. DECIDE HOW DIARISTS WILL QUANTIFY FLW

A key aspect of design is to decide how the diarists will undertake quantification. There are several options, which may be combined:

- **Weighing** — requires weighing equipment, which should be provided to the diarist
- **Measurement of volume** — involves the provision of measuring equipment such as calibrated jugs, cups, or spoons (see Box 6.2 for examples). It works best for liquid FLW and requires conversion to weight
- **Approximation of volume** — involves diarists making estimates of the volume of FLW, in units such as handfuls and platefuls. Volumes must later be converted to weight

Experience in the UK has shown that diarists should be asked to quantify FLW in whatever way is easiest for them, and should not be asked to make complex conversions (e.g., from platefuls to grams, amounts of FLW to cost), or to make distinctions between (edible) food and associated inedible parts. Such conversions and categorizations are best carried out by those analyzing the data after the diary has been completed. Diaries have traditionally been kept in written form on paper. However, electronic media are increasingly being used to record information for the diary (e.g., using smart phones or tablet devices). Non-written forms of diary-keeping (such as photographic and video-based records) are useful where there are low levels of literacy, where there is a high population of non-native language speakers, or where it is anticipated that diarists will not report accurately on their FLW. These methods can also be less onerous for the diarists.

Where equipment is provided to diarists, it will need to be sourced and dispatched. If the diarist is permitted to keep the equipment at the end of the study, the "gift" of those items can serve as an added incentive to take part.

5. DECIDE WHETHER A PRE-/POST-DIARY QUESTIONNAIRE IS REQUIRED

For some types of research question, it may be important to issue a pre-diary questionnaire. This will be useful if an entity is interested in assessing levels of awareness of FLW-related issues before the diary exercise. A post-diary questionnaire may provide useful insight into whether or not the diarist changed his or her behavior as a result of being a study participant or became more aware of FLW as a result of the study. The benefits of pre- and post-diary questionnaires need to be weighed against the additional cost. See Chapter 7 of this document for more information.

6. DETERMINE THE LENGTH OF THE DIARY PERIOD

An entity should give careful thought to the length of the diary-keeping period. In theory, the longer the period over which the diary is kept, the more accurate the data will be. However, the longer the period, the fewer diarists will agree to take part, and the more diarists will drop out part way through. This is a tradeoff that needs to be carefully considered.

Typically, diarists have been asked to record their wastage patterns over one week, although some diaries for food consumption (rather than FLW) have recently moved to shorter recording periods to reduce the reporting burden and thereby increase accuracy.[14] The chosen time period should reflect likely differences in food consumption and likely FLW. This will be culturally determined by factors like shopping patterns, growing and harvesting patterns, and schooling and working patterns.

7. DETERMINE HOW THE DIARY WILL BE KEPT

Diaries can be online, app-based, hard copy, or visual (i.e., photographic or video). The choice will depend on the nature of an entity's sample and the extent to which diarists are able to access technology in their kitchen or normal place of food disposal. The choice may also be driven by budget, for example, the cost of supplying expensive equipment could be prohibitive.

8. DESIGN THE DIARY

Whichever format for the diary is selected, a motivating introduction, perhaps provided as a separate letter, is important. This will encourage the diarist at least to start the diary process. Details of any support that is available to diarists throughout the process should be set out here (e.g., a telephone helpline number or email address).

A well-designed, user-friendly diary plays an important role in ensuring that information obtained is as accurate as possible. The diary should be clearly written and engaging, showing which information needs to go where, and using images where possible (e.g., providing illustrations of different food groups and the way to approximate quantities). The diary must be clear about the meaning of key terms such as "waste," "losses," and "food." An entity may wish to specify which destinations of FLW the diarists are to record, and explain that it would like information to be provided about these even though some diarists may not consider the material going to them as FLW (e.g., where FLW is home-composted or fed to animals).

The required information should be very clearly set out (e.g., in a table with obvious headings, and providing space for comments by the diarists).[15] Reminders may be included throughout the diary about the importance of ensuring that all instances of FLW are captured. It is useful to emphasize that even small amounts of FLW should be recorded, given that they will be scaled to the population and therefore could be important in accurate quantification. Reminders should also stress the importance of being honest about FLW generation.

9. TEST THE DIARY

It is good practice to pilot or test a diary and other tools to ensure that users will actually record the information desired. When significant changes are made as a result of a pilot, it is good practice to run another pilot until there is certainty that the diary will be effective. Using a diary that has proven successful in another study is one way to reduce the time spent piloting, but the fact that diaries may not be transferable across cultures and languages should be kept in mind.

10. BRIEF THE DIARISTS

It is good practice to brief the diarists directly about what is required. This is typically done by telephone or in person, but could also be done using an online video. Information to share with diarists includes:

- why the diary is being undertaken;
- when to start keeping the diary;
- how to fill in the diary;
- what to include and what not to include, including how "food," "waste," and "losses" are defined (if these terms are used);
- what sources of FLW to include (should a household diary, for example, include all household members' FLW and what should be done about visitors; should a restaurant diary cover only kitchen FLW or should it also include FLW generated by customers eating on the premises);
- how to weigh or approximate quantities of FLW;
- what to do if the diarist is away from home;
- what to do if a diarist skips a day;
- when to finish the diary and where to send it when complete;
- what the diarist can expect to receive as a thank you for participating, when it will be received, and how it will be provided.

The briefing is also an opportunity to reiterate the confidentiality of responses to the diary. Box 6.2 outlines an effective means of briefing diarists.

11. PROVIDE HELP FOR THE DIARISTS

It is good practice to set up a telephone, email, or online hotline where diarists can go for help. This is an important tool for maximizing the accuracy of the diary. It can be used to motivate participants to report all FLW and not misreport anything to make their household appear less wasteful—this can be achieved by stressing (again) that the data will be aggregated and no judgments will be made about individual households.

12. ENCOURAGE THE DIARISTS TO COMPLETE THE PROCESS

Encouragement to keep filling in the diary or sending the images is very important. It is good practice to contact every diarist at least once during the diary process. This serves two purposes—to deal with any questions they may have and also to encourage them to keep going. An entity can also remind the diarists of what they need to do when they have completed the diary, including completing a post-diary questionnaire.

Box 6.2 | An Effective Diary "Pack"

In a UK study, diarists were sent a "pack" containing everything they needed to complete the diary, which arrived at least five days prior to the beginning of participation in the project. The pack contained the diary itself, which included full instructions, as well as a pen and magnet for the fridge or collection bin, printed with prompts to encourage completion of the diary. Measuring jugs and spoons were also sent to aid accurate measurement of the food and drink. Finally, a self-addressed, freepost envelope was included for the return of the completed diary.

Source: WRAP (The Waste and Resources Action Programme). 2009. *Down the Drain. Banbury*, UK: WRAP.

A diary might include encouraging words, or reminders of any incentive being offered for diaries that are fully completed. It is useful to provide items that serve as a reminder to keep filling in the diary (e.g., a magnet if refrigerators are metal-fronted, or pens printed with reminders about the diary).

13. COLLECT, COMBINE, AND ANALYZE THE DATA

The data from diaries should be collated and converted into electronic form. There are a number of possible tasks involved in data analysis. The most common tasks are set out below:

- **CATEGORIZE FLW**
  This may include determining whether material is food or inedible parts associated with food, and assigning items to the appropriate food categories. The food classification can be made at a number of levels (e.g., classifying an item as "fruit" at the highest level and then as "apple" at a more detailed level of classification). Section 6.6 of the *FLW Standard* provides guidance on classification systems that can be used to describe food categories.

- **CALCULATE ANY DERIVED INFORMATION**
  Where diarists have provided non-weight-based measures or approximations of FLW (e.g. five apples, a handful of raisins) quantities must be converted into weight. Weights can then be converted into other measures (e.g., costs or environmental impacts) as required. Guidance on converting into other measures is provided in Appendix D of the *FLW Standard*.

- **LINK DIARY DATA TO OTHER DATA**
  Socio-demographic information may have been collected when recruiting the households, or as part of pre- and post-completion surveys (e.g., information on FLW attitudes and behaviors). This information should be combined with the diary data, taking care to match data correctly, to add richness to the dataset.

- **ADJUST THE DATA THROUGH WEIGHTING, IF REQUIRED**
  Weighting may be advisable where an unrepresentative sample has been obtained. A weighted sample complicates the analysis so an entity should consider whether weighting is necessary to obtain accurate results. Where weighting is required, decisions should be taken about which variables to use to weight the data (e.g., quantities of FLW generated or socio-demographics variables). Seasonality is also a factor (e.g., if the diary is carried out in the summer, the data may need to be adjusted to allow for winter patterns of FLW).

- **SCALE UP THE DATA TO REPRESENT THE POPULATION**
  The data should be scaled up to apply to the whole population. More information about scaling up is provided in Appendix A of the *FLW Standard*.

7. Surveys

7.1 Overview of the Method

Surveys are a cost-effective way of gathering information on FLW quantities or other information (e.g., attitudes, beliefs, self-reported behaviors) from a large number of individuals or entities. One of the defining characteristics of a survey is that questioning is structured—in other words the questions are specified in advance and written down. In the context of quantifying FLW, surveys fall into three distinct categories:

- Surveys that ask respondents to provide *prior measurements or approximations* of FLW
- Surveys that ask for *other factual information* that enables the researcher to make an estimate of FLW (e.g., information about the number, size, fullness, and frequency of collection of FLW containers that can be converted into a volume of FLW, or inputs to an inference-based method)
- Surveys that ask respondents to provide *their perceptions* of the types and amounts of FLW through recall or visual approximation

Ideally the quantification of FLW would be carried out through other means in addition to the survey (e.g., weighing, diaries, or waste composition analysis) and the data from these methods combined with the information collected through the survey. A survey can be especially useful when an entity is seeking to design effective interventions to reduce FLW and is looking to gather insights about the attitudes, values, and behaviors associated with specific amounts and types of FLW.

Surveys require questionnaires, which can either be administered by an interviewer or distributed to respondents to complete themselves.

Survey data consist of individual responses (referred to as cases) and attributes by which the responses vary (referred to as variables). Data from surveys are analyzed using quantitative techniques such as frequency counts and cross-tabulations, the choice of which will depend on the nature of the variables. Qualitative data can also be collected, often in response to "open" as opposed to "closed" questions. In surveys, responses to open questions are often coded to transform them into quantitative data.

ADVANTAGES AND DISADVANTAGES

There are three main advantages of using surveys:

- **Cost and time.** Surveys are typically cheaper than carrying out measurement-based methods and require less time than other multi-step methods (e.g., waste composition analysis).
- **Participation.** Respondents may feel more involved in survey-based research than they do in a measurement program, because they are asked for their thoughts and opinions.
- **Added value information.** Surveys enable easy gathering of useful additional information. For example, data on respondents' knowledge of FLW can be gathered, and information about their attitudes and claimed behaviors can be combined with FLW data to understand the causes of FLW and devise successful intervention strategies. While approaches other than surveys can also gather views (e.g., through informal discussions during site visits), that information is not systematically recorded and so cannot be readily analyzed.

There are three main disadvantages:

- **Difficulty of conveying important concepts.** The definition of "food" (i.e., excluding the associated inedible parts) is not commonly understood so simply asking people to recall "food waste" incidents may lead to misleading results. Respondents typically pay little attention to instructions, definitions, and other parts of a survey that they find less interesting, so the risk of misunderstanding and varying interpretations across respondents is high.
- **Single respondent bias.** A survey relies on a single respondent reporting on behalf of an entire household or business. For household surveys, this assumes that the respondent is aware of, and can recall, the FLW of every household member. A diary-based approach might result in more accurate data if this is the purpose of the survey. In the case of businesses, a survey assumes that the respondent knows about the FLW of the whole business.
- **Unreliable responses.** A major disadvantage of using surveys (especially those based on recall) for the purpose of quantifying FLW is that, as with all claimed behavior methods, they are prone to error. For example, even where all FLW events are recalled and reported to a researcher, the respondent also needs to accurately approximate the amount of FLW generated. This is not a simple task and can easily introduce errors of estimation.

"Food-wasting" behaviors are not high profile in most people's lives, whether at home or in a business context, so asking questions about them may result in unreliable responses or no response at all. The routine, habitual nature of food management means FLW often goes into collection containers and gets taken away with very little thought.

When asking about attitudes, individuals' thoughts and beliefs may not be deeply held or well considered so the responses they give may not reflect reality. For example, the survey might be the first time that the respondent had given FLW any thought at all. Many people do not recognize themselves or their entities as "food-wasters" and will regularly report that they do not generate any FLW at all even where they do.

The respondent may give responses that he or she thinks are required. This may be done to please the surveyor, or out of self-interest, for example, if the respondent believes that some material benefit may be gained, such as a subsidy or assistance in improving postharvest activities.

LEVEL OF EXPERTISE REQUIRED

It takes skill and experience to design and administer a successful questionnaire, which is a core element of any survey. The robustness of the sampling framework is a key determinant of the uncertainty associated with the results and advice should be sought from someone with a good knowledge of statistics. Similarly, data should be analyzed by someone with previous experience. Ideally, experienced researchers should be used to conduct the study; at a minimum, advice should be sought from experts.

COSTS

The cost of a survey is determined by two factors:

- the mode of administration or means of distribution (i.e., face-to-face, mail/post, online, telephone); and
- the size of the sample.

Face-to-face surveys are typically the most expensive option and online surveys typically the least expensive. However, the choice has to be balanced against response rate considerations because the higher the response rate the less uncertainty will usually be associated with the results. Face-to-face surveys typically achieve higher response rates than other approaches. The cost of sending reminders to respondents must be factored in because few people will respond to the first request. The associated costs of the various possible approaches (noted in parentheses) include:

- Travel (face-to-face)
- Stationery and postage, both outgoing and for respondents to return their questionnaires (by mail/ post)
- Printing of the questionnaire (face-to-face, postal, and possibly telephone if not recorded electronically)
- Web hosting (online)
- Email address provision (email)
- Phone charges (telephone)
- Electronic scripting development (e.g., computer-assisted personal interviewing (CAPI) and computer-assisted telephone interviewing (CATI), telephone, face-to-face, and online)

7.2 Guidance on Implementing the Method

This section provides guidance on the steps an entity may undertake when carrying out a survey. As discussed in Step 3, design and implementation of surveys requires skill and expertise. The guidance provided in this standard should not be regarded as a substitute for input from an experienced professional.

1. SCOPE THE STUDY

As Chapter 6 of the *FLW Standard* explains, a well-defined scope, aligned with the five accounting principles and an entity's goals, is important for ensuring that an FLW inventory meets an entity's needs. The scope of an entity's inventory—defined by the timeframe, material type, destination, and boundary—will dictate to a large extent the scope of the survey, although additional questions may be incorporated to meet wider goals. Chapter 6 also describes how the scope chosen by an entity for its FLW inventory should be aligned with its underlying goals for addressing FLW.

2. DETERMINE THE APPROACH TO QUANTIFICATION

As discussed in Section 7.1 above, surveys can ask respondents for:

- Prior measurements (or approximations) of FLW
- Other factual information that enables the researcher to make an estimate of FLW
- Perceptions of amounts of FLW, based on recall

The accuracy of the information captured is likely to be highest where prior or simultaneous measurements are provided and lowest where recall alone is used. A good example of a simultaneous measurement would be the implementation by the survey team of a "visual scale" assessment together with a questionnaire. The provision of prior approximations and information that can be used by an entity to make an approximation are likely to be of an intermediate level of accuracy.

Table 7.1 | Comparison of Interviewer-Administered and Self-Completion Surveys

METHOD	USEFUL WHERE ...	NOT USEFUL WHERE ...
Interviewer-administered	▸ The subject is new or difficult for the respondent to comprehend ▸ Literacy levels are low ▸ Questionnaire routing is complex ▸ Rapport is required to elicit reliable responses ▸ Information must be recorded exactly as said by the respondent	▸ Interviewer presence might adversely influence the results (e.g., subject is sensitive or embarrassing) ▸ Entity cannot afford to employ interviewers ▸ Access to respondents is not possible (e.g., long travel time, limited telephone access)
Self-completion (i.e., questionnaire completed by the respondent without an interviewer present)	▸ Questions are few, short, and easy to understand ▸ Instructions are limited ▸ Questions are "closed" with limited answer options ▸ Money for quantification is limited ▸ An interviewer is not able to conduct an interview (e.g., it is hard to access potential respondents) ▸ The appropriate respondent is known	▸ Routing between questions (e.g., skipping some questions if a response is given in an earlier question) is required (in paper-based surveys) ▸ There are high levels of illiteracy ▸ Where access to information and communication technology is limited (relevant for online surveys) ▸ Respondents will require explanation of key terms

The decision to use a survey for quantifying FLW will depend on an entity's judgment about the information that respondents will be able to supply. For example, companies in developed countries may have records from waste management companies of the weight of FLW removed. Obtaining those records through a survey is likely to provide very accurate information. By contrast, some households may not have records and may not be able to provide an approximation, so recall-based survey methods may be the only option if diaries, waste composition analysis, and other more reliable approaches have already been ruled out.

3. DEVELOP A SAMPLING STRATEGY

Because robust sampling is one of the critical determinants of reliability, an entity that does not have expertise in sampling should consult a statistician or an experienced market or social science researcher to help guide the sampling design. Appendix A of the *FLW Standard* provides guidance on sampling.

Sampling for surveys is almost always a tradeoff between the desired level of certainty and the resources available for the study. For example, boosting the sample size typically reduces sampling error, one of the more measurable forms of uncertainty. However, to double confidence in the results, the number of samples must be quadrupled, so reducing uncertainty can quickly become very expensive.

Table 7.2 | Advantages and Disadvantages of the Most Common Ways of Conducting Surveys

MODE OF ADMINISTRATION/ MEANS OF DISTRIBUTION	ADVANTAGES	DISADVANTAGES
Face-to-face	▶ Can use an interviewer-administered questionnaire (see Table 7.1)	▶ Impractical where sample is very dispersed ▶ Expensive in interviewer time and travel costs
Telephone	▶ Can use an interviewer-administered questionnaire (see Table 7.1) ▶ Low cost, especially where calls are inexpensive or free	▶ No visual prompts possible ▶ Those without a telephone cannot be sampled, so sample will be biased ▶ Cannot be too lengthy
Mail/post	▶ Relatively low cost, although mailing/ postage and printing costs can accumulate	▶ Impractical where the mail/postal service is infrequent or unreliable ▶ Requires several reminders to achieve an acceptable response rate
Electronic	▶ Low cost ▶ Automated routing overcomes restrictions on question length and complexity	▶ Those without the technology cannot be sampled, so sample will be biased ▶ Likely low response rate ▶ Requires several reminders to achieve an acceptable response rate

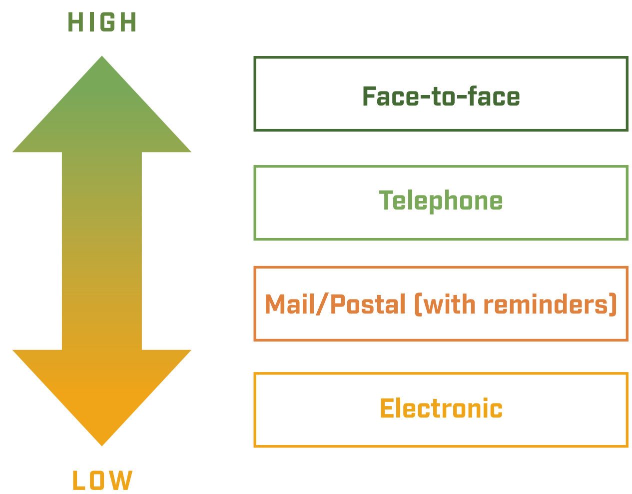
4. SELECT A MODE OF ADMINISTRATION OR MEANS OF DISTRIBUTION FOR THE QUESTIONNAIRE

Questionnaires can be administered by an interviewer and carried out either by telephone or face-to-face interview. Or, they can be distributed for respondents to complete themselves, in which case they can be either mailed or sent in some electronic form (e.g., online, email, app-based).

The choice between interviewer administration or self-completion will depend on who is being surveyed and the kinds of answers that are required. For example, where illiteracy is likely to be common, self-administration may be ruled out. Where establishing rapport is likely to be an important aspect of reliable responses, interviewer administration through a face-to-face approach may be preferred. Where open-ended questions are required to gather qualitative information, interviewer-administered modes are likely to be more effective. Choices might be different for households compared with businesses.

The key advantages and disadvantages of each mode of administration are shown in Table 7.1. Table 7.2 shows that response rates are likely to vary according to the mode of administration or means of distribution. Figure 7.1 illustrates response rates associated with different modes of administration.

Figure 7.1 | Typical Response Rates to Different Methods of Conducting Surveys



One key factor that will influence the choice of how the survey is to be administered is the type of information that is available for the sampling frame. For example, if up-to-date telephone numbers are available, then an entity can undertake a telephone survey. However, if only names are available, a telephone survey will be more difficult because additional steps will be required to obtain telephone numbers.

Many market research companies run omnibus surveys which can be a useful way to reduce costs if an entity has only a couple of questions to ask. Omnibus surveys cover a range of different topics, where multiple parties share the cost of carrying it out. They can be face-to-face, telephone, mail/ postal, or electronic. If buying into an omnibus survey, an entity should ensure that the survey will meet its needs in terms of representativeness, that appropriate socio-demographic information is collected, and that a "screener question" can be asked to ensure that only relevant people answer the questions. An entity should also find out what other subjects will be covered in the omnibus to be sure that there are no questions that could influence the results of the FLW survey.

Panel surveys are another way to reduce costs. In a panel survey, a group of respondents (the "panel") is recruited. This panel may be asked about a wide range of topics over an extended period of time, reducing costs of recruiting survey respondents. Many market research companies and government bodies operate panels. If using a panel survey, an entity should ensure that the panel is representative of its target population, and regularly refreshed to avoid respondent fatigue.

5. DEVELOP AREAS OF QUESTIONING AND SEQUENCING

Rather than jump straight into writing questions, it is good practice to prepare a table that lists the areas of questioning that must be covered in order to answer the research questions of interest. This ensures that the survey stays focused.

Asking the questions in a logical sequence considerably reduces the chances of individual questions being misunderstood. The question sequence must be clear and advance smoothly, meaning that the relation of one question to another should be readily apparent to the respondent. The easiest questions should be asked at the beginning of the survey. The first few questions are particularly important because they are likely to influence the attitude of the respondent. Relatively difficult questions should be left until near the end so that even if the respondent decides not to answer such questions, considerable information will already have been obtained.

It is important to remember that just because a question can be asked, that does not mean it can be answered. Only questions that have a realistic chance of being answered reliably should be included in a questionnaire. For example, it is possible to ask a company as part of a questionnaire how much FLW it generates, but if FLW is not routinely measured the answer will simply be "don't know" and the survey will generate no useful results.

Piloting (see Step 10 in this section) will also provide important feedback on the validity and usefulness of the questions as written.

6. PREPARE QUESTIONS TO QUANTIFY FLW

The nature of the questions aimed at quantification will differ according to the approach to quantification that has been selected (see Step 2, above, in this Chapter).

Asking for prior measurements or approximations

This approach to quantification assumes that an existing measurement or approximation exists and that the respondent simply has to look it up. This type of survey can therefore ask matter-of-fact questions. They should, however, specify *exactly* what should be provided, defining *precisely* the scope of the information being requested (e.g., the timeframe the data should cover, the material type, the destination(s), and the lifecycle stage). The "questionnaire" in this case is often more akin to a form or information request than a traditional survey questionnaire.

This kind of survey is often carried out by membership organizations asking for information from their members. If considering a survey of this nature, an entity should be realistic about what its members are capable of providing. If prior measurements or approximations are unlikely to exist, this approach to quantification is not appropriate and should not be used. Instead, efforts should be made to encourage members to make use of the guidance in this standard to make measurements or approximations, or the next approach (asking for other factual information) could be considered.

Asking for other factual information that enables the researcher to estimate FLW

This approach to quantification is useful where a respondent is unlikely to have a prior measurement or approximation, but where other information can be sought that will enable an estimate of FLW to be made.

Approximating volume. It may be possible, for example, to ask respondents to state how many containers they use for FLW, what size they are, how often they are collected, and how full they are on collection. This will enable an entity to calculate the volume of FLW generated in a specific time period (see Chapter 3 of this document on assessing volume).

Inference through calculation. Similarly, it may be possible to collect information that enables an entity to infer quantities of FLW, for example, by asking about inputs and outputs to a process to derive FLW amounts via a mass-balance technique (see Chapter 8 of this document on mass balance) or input to a model (see Chapter 9 of this document on models).

Asking for recall

Quantification of FLW through recall is challenging and prone to error, so questions must be designed to maximize the likelihood of receiving accurate information. The uncertainty associated with such data should be clearly explained. Because the accuracy of the data will be lower than that of data obtained through other types of survey, an entity should not use the data for anything more than a general understanding of FLW quantities.

To maximize the chance that useful responses will be received, the food types referred to in the questionnaire must be unambiguous and easy to understand. It is unlikely that respondents will be able to recall quantities on a weight basis. Item counts, handfuls, cupfuls, or binfuls will be easier for the respondents to comprehend. Asking respondents to make an assessment against measures such as "a lot" or "a little" should be avoided because these terms mean different things to different people. Recall is likely to rely on visualization, so using visual prompts within the questionnaire may be one way to help respondents accurately recall quantities of FLW.

7. PREPARE ADDITIONAL QUESTIONS

Writing questions that avoid bias and elicit relevant information is a skill that is acquired with experience. This section provides only a general guide and should not be regarded as a substitute for the recommendations of an experienced professional.

Types of questions

Thinking about the types of questions to be included in a survey is useful because it helps link back to the study's objectives and scope. The types of questions that are useful for an FLW quantification study include:

- Factual questions about self or own operation
- Factual questions about others or others' operations
- Questions about the respondent's attitudes
- Questions about the respondent's beliefs
- Questions about the respondent's values and standards
- Questions about the respondent's knowledge (i.e., to test knowledge)

Questions aimed at quantifying FLW are likely to fall into the "factual" categories whereas questions aimed at understanding contextual information (e.g., about the reasons food leaves the food supply chain) are likely to concern beliefs, values, and attitudes.

Closed or open questions

Questions may be either "closed," (i.e., have a set number of answer options) or "open" (i.e., have blank space for the answer to be written). The advantages of closed questions are that:

- responses are easy to provide;
- the answer options help clarify the meaning of the question;
- consistency is enhanced across respondents; and
- they do not require coding, unlike open-ended questions that must be coded in order to be analyzed quantitatively.

However, closed questions also have disadvantages. They do not enable respondents to answer spontaneously in their own words so, where such responses are important, an open-ended question is preferable. Open-ended questions are sometimes used where answer options are not known, although a more effective approach would be to pilot the survey first to determine likely answers.

Answer options for closed questions must be balanced with an equal number of top and bottom options (e.g., "very good, good, fair, poor, very poor" rather than "excellent, very good, quite good, fair, poor").

Commercial research companies will often price their services according to how many closed and open questions they will be expected to ask. An entity should be as explicit as possible about what it expects, including specifying whether the research company will be expected to code open-ended questions and "other" options.

"Don't know" options

It is worth considering whether to include a "don't know" option. This option is important when not all respondents will be able to answer the question, but can be counterproductive in situations when it allows respondents to avoid difficult questions.

Number of questions

It is very easy for questionnaires to become too long, especially where several people have input into their design, so an entity should be disciplined about including only necessary questions. Long, complicated questionnaires will not only be more expensive to conduct but may also result in respondents not taking part, dropping out before the end, or providing poor-quality responses toward the end.

Screening questions

Depending on the nature of the survey, "screening questions" may be required to ensure that only relevant respondents answer the questions. In a survey of households, for example, an entity may want to ensure that the person answering the questions has some responsibility for either household food shopping or food preparation because of the relevance of these activities to the creation and management of FLW. Therefore, an opening question would ask whether or not the respondent is responsible for buying food or cooking food in the household.

Cultural considerations

Questions should be provided in multiple languages in situations or regions where respondents may speak one of several languages. Where specific foods are mentioned in a question, consideration should be given to whether these foods are culturally relevant; for some parts of the population, substitution of food examples may be useful.

Non-leading questions

Every effort needs to be made to ensure that questions do not lead the respondent in the direction of any particular response. This can be aided by shuffling the answer options for every new respondent, ensuring that the most or least desired response is not at the top, or arranging the responses in a logical scale (e.g., in the order of "more," "the same," and "less"). In addition, it is necessary to be mindful of the question order within the survey to ensure that the presentation of certain themes (e.g., attitudes toward FLW, knowledge about environmental impact of FLW) does not influence responses to later questions (e.g., FLW quantifications, description of shopping habits).

An entity shall comply with data protection laws in its country and should abide by any codes of conduct from relevant professional organizations. It is particularly important to inform respondents about the intended use of the data, and assure them that information will not be passed to third parties for marketing purposes. If an entity intends to share the raw data it collects with others, for example, with someone who will analyze the data, this intention should be explicitly stated to the survey participants.

Unless a survey is mandatory, participants should always be given the option to opt out, even if they are part of the way through the survey. A question might be asked about whether it is acceptable to re-contact the research participants for a follow-up. Doing so may add depth to the survey by clarifying responses and enable an entity to reuse the sample without having to repeat all the socio-demographic and screening questions.

Box 7.1 provides a list of common flaws to avoid when designing questions.

Box 7.1 | What to Avoid When Designing Questions

- Ambiguity
- Jargon and technical terms
- Lengthy questions
- Double-barreled questions (e.g., are you motivated to reduce food waste in order to save money or run a more efficient household?")
- Over-generalized questions (e.g., "do you produce food waste?")
- Leading questions, where a respondent is encouraged to respond in a particular way (e.g., "do you agree that producing food waste is ethically abhorrent?")
- Questions that can be answered "not applicable"—ask a screening question instead and route the respondent around questions that are not applicable
- Questions incorporating negatives—they are easy to misunderstand (e.g., "Would you agree that you don't like people who don't recycle?")
- Questions that respondents cannot answer because they do not have the necessary knowledge

8. DESIGN THE QUESTIONNAIRE

Creating an attractive visual design for the questionnaire is important for self-completion questionnaires. An entity should also include information about why it is important for a respondent to participate in the survey and the reason for the survey. Creating a logical structure and layout together with easy-to-understand instructions and routing is critical, regardless of the mode of administration or means of distribution.

Instructions

It is important to supply sufficient information in the questions and associated instructions to ensure that all participants are responding in relation to the same scope of FLW. The attitudes of the participant about food and/or inedible parts that leave the food supply chain, and differing perceptions regarding the generation of FLW or the destinations to which it goes (e.g., to compost versus landfill), may also lead to differences in the amount or type of FLW that is reported. It may also be worthwhile to use a less value-laden term than "food waste" (e.g., discarded food, food not eaten) in the hope of minimizing social desirability bias (See Section 6.1 of this document).

Routing

Questionnaires commonly include "routing" (i.e., respondents are directed to skip questions based on their response to previous questions). Some online survey tools are unable to cope with complex routing; therefore, if an entity is planning to put its survey online, it should check whether its software can accommodate it. Modern professional methods of interviewing, such as computer-assisted personal interviewing (CAPI) and computer-assisted telephone interviewing (CATI), have routing as a standard feature.

Visual design

Box 7.2 lists tips for designing an effective paper-based self-completion questionnaire and Box 7.3 lists tips for designing an effective web-based survey.

Designing for online completion involves special considerations. Time should be devoted to improving the layout and appearance of questions because this will encourage respondents to complete the survey.

9. FORMULATE AND IMPLEMENT STRATEGIES FOR MINIMIZING AND COPING WITH NON-RESPONSE

Response rates to surveys can be very variable. They depend on a wide range of factors including the length of the survey, the topic, where and when it is being carried out, and the type of respondent. Surveys of consumers typically achieve better response rates than surveys of businesses.

Maximizing response rate is important, because higher response rates mean lower levels of uncertainty. Many of the tips given in Boxes 7.2 and 7.3 are related to maximizing response rates (e.g., keeping surveys as short as possible, making them visually appealing).

Approaches to increasing response depend on the mode of administration and type of survey selected. If an interview-based mode of administration is chosen,

Box 7.2 | Tips for Designing an Effective Paper-Based Self-Completion Questionnaire

- Make the layout attractive
- Increase the number of pages rather than cramp the text
- Think about whether to show answer options vertically or horizontally
- Make it very obvious how and where respondents should record their responses
- Be clear whether more than one answer is acceptable or whether the respondent must choose only one
- Keep questions and their answer options on the same page

Box 7.3 | Tips for Designing an Effective Web-Based Survey

- Avoid the need for scrolling up and down by presenting only a few questions on each page
- Be wary of using unnecessary graphics—they slow systems down
- Use images carefully because respondents can use them to frame the meaning of questions (e.g., a photograph of decomposing vegetables could encourage the respondent to believe the question relates only to vegetable FLW and not to other types of FLW)
- Keep questions and their answer options as simple as possible, avoiding too many matrix questions that might not display well on screens (and especially on mobile phones)
- Think carefully about the format of answers: radio buttons and drop-box options are the most common
- Make sure that free-text fields contain sufficient characters for the respondents' answers
- Think carefully about which, if any, answers to make mandatory. If respondents cannot answer a mandatory question, they are likely to provide a made-up answer or abandon the survey
- Use "error messaging," but be specific about the cause of the error
- Show progress, so respondents know how much more they have to complete
- Allow respondents to save their progress and come back later. This is especially important if factual information is requested, which the respondent may need to look up
- Make use of the electronic features where relevant (e.g., hyperlinking)
- Incorporate automatic logic checking where available in the survey software

providing good training on techniques for encouraging participation is important. Sometimes respondents will be recruited for the survey not by interviewers but by a specialist recruitment company; this can be a very effective way of boosting participation.

If a survey is being carried out by an official body, the use of local authority, government, or relevant trade association logos can help boost response. Participation can also be encouraged with well-worded text that explains the reasons for the survey, why it is important for people to take part, and provides assurances about confidentiality.

Another approach to boosting the response rate is to provide an incentive. This can take monetary forms (e.g., cash payment, voucher, or entry into a prize draw for something of value) or non-monetary forms (e.g., public recognition or individual feedback on the results of the survey). The key is finding imaginative ways to provide effective incentives that are in line with cultural norms and involve minimal cost.

For self-completion surveys, consideration should be given to operating a survey helpline. This enables respondents to clarify issues that might otherwise lead them to abandon the survey. It can also provide assurance that the survey is official.

10. PILOT THE SURVEY

It is tempting to start the survey as soon as everything is ready, but piloting the survey will avoid expensive mistakes. A pilot is simply a small-scale test of the survey. It tests the questionnaire itself alongside operational aspects of the survey such as the mode of administration or means of distribution, the way in which responses will be received, and the way in which data will be processed. If a question does not elicit the sort of response intended, it should be revised so that participants can understand it more readily.

11. ADMINISTER OR DISTRIBUTE THE QUESTIONNAIRE

General points

Throughout the survey, it is important to keep track of those who have and have not responded. This will enable effective targeting of non-respondents for reminders and enable an accurate calculation to be made of the response rate at the end of the survey.

Careful thought should be given to the timing of the survey. For example, in some surveys, data collection may need to be staggered across various days of the week (both weekdays and the weekend) to avoid bias arising from potentially different food management behaviors throughout the week. And seasonal variations must be accounted for as well as periods of unusual activities such as festivals and national holidays.

Face-to-face surveys

For face-to-face surveys, it is important that interviewers are well trained and administer the survey consistently and accurately. Interviewers should not show surprise, approval, or disapproval in reaction to a participant's answer. Interviewers will also need to be able to answer any questions the participant may have about the survey.

It is also important to consider when and where the survey will take place. This depends on the nature of the sample.

It may seem obvious that businesses can be surveyed only during working hours. If businesses are highly dispersed, it is a good idea to book the interview in advance to ensure that the right person is present. Even so, it is common for the respondent to forget about the interview or not be available at the pre-arranged time so flexibility needs to be built into the process.

A range of methods is available for interviewing householders, including in-home interviews, doorstep interviews, and interviews conducted in a public place. The choice will be influenced by several factors:

Length of questionnaire. It is unreasonable to expect respondents to answer a survey of more than 15 minutes while standing in a public place or on their doorstep. Lengthy or in-depth surveys should be carried out in-home or in a public building where seating is available. In-home surveys may need to be pre-arranged with the participant.

Privacy. If the survey contains questions that respondents could view as sensitive, shameful, or embarrassing, the survey should be carried out in a private place to maximize the chance that the respondent will be honest with the interviewer.

Likelihood of eligible participants being present. Working-age people are likely to be out of the home during working hours; relying on surveys conducted only during the day can therefore lead to a biased sample, which contains too many elderly people and stay-at-home parents. Equally, surveying in public areas can underrepresent some segments of the population. Careful thought should be given to the specific requirements of the survey and choosing the interview location that is least likely to bias the sample.

Consent. Consent of the premises owner may be required to interview in public. This applies to places that are clearly privately owned, like retail stores, but also to places such as shopping malls and some outdoor areas in towns.

Telephone surveys

Just as in face-to-face surveys, it is important for the interviewer in a telephone survey to be well trained so that the survey results will be as accurate as possible.

Telephone surveys can be more effective if the interview is booked in advance, especially with businesses. Even so, it is common for participants not to be available at the allocated time, so flexibility should be built into the process.

If surveying a business, it is important to build in extra telephone time for identifying an appropriate respondent. Small and large businesses present different challenges in this respect. In small businesses, one person often deals with many different aspects of the business and is well informed, but it may be difficult to contact and reserve time with such a person. Large businesses, on the other hand, may have staff with more narrowly defined jobs, who are well informed only about their own area.

Mail/Postal surveys

Mail/postal surveys will require several reminders to be sent to participants. An entity should monitor response rates to determine whether additional reminders are necessary.

Electronic surveys

In the case of electronic surveys, it might be tempting to simply release the URL and see who responds. But using a convenient sample (e.g., companies that happen to be local) or snowball sampling (relying on word of mouth through social media to spread the survey link) will result in a biased sample and inaccurate results.

12. PREPARE THE DATA FOR ANALYSIS

Responses need to be standardized and collated before they can be analyzed quantitatively. Electronic systems are now commonplace and this guidance assumes that electronic systems are available, although processing and analysis can of course still be carried out manually.

Where data have been recorded on paper, a process of data entry will need to be undertaken. Professional data entry companies exist in many countries and they may provide a good value option. When entering data, it is good practice to check a proportion (say 10 percent) of entries to ensure accuracy. If significant inaccuracies are found, the data may need to be re-entered.

When entering data, it is important to differentiate between blank responses where no answer was required (e.g., the respondent was instructed to skip it) and blank responses where the respondent should have provided an answer but did not. At the analysis stage, it can be decided whether to report these "missing data" or simply omit them when summarizing responses. It is common practice to report only "valid" responses but, where there are significant levels of missing data, it may start to influence the degree to which survey results are representative.

Where an entity has used open-ended questions, whether as part of paper-based or online surveys, a decision should be made about whether to "code" them or use the responses qualitatively as supportive quotes and insights. Coding is the process by which similar open-ended responses are grouped together and thereafter considered as a group. This process can be time-consuming and therefore costly and is a good reason to think carefully about the extent to which an entity includes open-ended questions (see Steps 4 and 7 in this section).

Data quantifying FLW from survey responses relying on recall are most likely to be in volumetric form. They must therefore be converted to weight using bulk density conversion factors (see Section 3.2 of this document).

13. ANALYZE THE DATA

Data analysis converts raw data from questionnaire interviews into a summary presenting the quantification of FLW and any additional qualitative information such as:

- Frequency of FLW
- Reasons for different types of FLW
- Relationship between FLW and variables (e.g. income, age group, location)
- Livelihood issues of people affected by FLW
- Coping strategies used to overcome FLW

Policymakers and planners can use the information from the analysis to make informed decisions regarding intervention strategies to reduce FLW or improve the livelihoods of those affected by FLW.

An experienced professional should analyze survey data whenever possible. The production of summary data (frequency counts and percentages) is the normal starting point followed by more complex techniques such as cross-tabulation and other tests of association.

Guidance on scaling up results from a sample to a population is provided in Appendix A of the *FLW Standard*.

8. Mass Balance

8.1 Overview of the Method

An entity can use a mass-balance method to infer FLW by measuring inputs (e.g., ingredients at a factory site, grain stored in a silo) and outputs (e.g., products made, grain removed from a silo) alongside changes in levels of stock and changes to the weight of food during processing (e.g., evaporation of water during cooking). This method can be applied at various stages in the food supply chain. Using mass balance is one of three methods described in this standard that are based on “inference by calculation.” The other two are using a model and using proxy data (see Chapters 9 and 10 of this document).

Mass-balance calculations can be used to quantify FLW where reliable measurement or approximation is not possible. Mass-balance analysis may also be referred to as “Material Flow Analysis” or “Substance Flow Analysis.”

Table 8.1 provides several examples of possible inputs, outputs, and stock in a range of circumstances. Changes in stocks may be positive (i.e., an increase in material stored) or negative (e.g., material withdrawn). A negative change in a stock will include FLW but may also include other changes, such as stolen items, which increases the uncertainty associated with this method.

Different categories of inputs, outputs, and stocks may be important. For example, an entity might wish to separately itemize food by type, or record sold outputs separately from donated outputs. At whatever level of detail the mass balance is carried out, it is essential that all parts of the equation are measured in the same units (e.g., kilograms).

Table 8.1 | Examples of Inputs, Outputs, and Stock

SUPPLY CHAIN STAGE/SECTOR	INPUTS	OUTPUTS	STOCK
Processing site/ factory	Ingredients	Final product	Levels of ingredients or final product held on site
Retail store	Food products delivered to the store	Food bought by customers	Food on shelves and in storage
Household	Food purchases entering the home	Food consumed	Food held in the home
Whole economy	Food production and imports	Food consumption and exports	Food held within the country

ADVANTAGES AND DISADVANTAGES

Mass balance is quite flexible and can be applied at either a product or substance (e.g., ingredient) level. It can allow for changes over time and changes in stocks of material held at various points in the process.

One important advantage of the mass-balance method is that there are established procedures for using it.[16] In addition, free software is available to allow calculation of a mass balance for a system or process.[17]

A further advantage is that the information required is likely to be available (e.g., national statistics, company invoices, billing information) because it has often been gathered for other purposes. This makes the data relatively inexpensive and applicable at a range of levels from a nation to a specific site.

There are several disadvantages in using the mass-balance method, however, relating to issues of data availability, unit conversions, and levels of uncertainty.

In many situations, data from a range of sources are required and some data may require conversion, increasing the cost to perform the analysis and reducing the accuracy of the results. For example, in meat supply chains, data may be recorded as live animals, live weight, and carcass weight at different points in the lifecycle, and consistent identification and conversion is required. As another example, the input in drink production (i.e., ingredients) may enter a process measured in weight (e.g., metric tons of oranges) yet leave the process as an output measured in volume (e.g., liters of orange juice concentrate). At some stages, the available data (e.g., financial data) may have little direct relation to a volume or mass and specific conversions may be required to allow recording in a consistent unit. This adds further complexity and uncertainty about the reliability of the results.

An entity should also consider changes in the weight of the food and/or associated inedible parts that are not related to FLW, in particular the loss of moisture (e.g., natural evaporation, cooking, drying) or addition of water. Similarly, there may be uncertainties about the precise materials to which the results of the mass balance apply. The end result will include FLW but it may also include other "flows" of material that are not FLW but still represent material not being used for its intended purpose. For example, it may include theft, which could be a sensitive issue for an entity to investigate.

The uncertainties in the underlying data used in the mass-balance method will affect the uncertainties in the results obtained. The uncertainties in the underlying data will propagate through the calculations (Box 8.1) but these uncertainties can be addressed by assessing the data quality and using information from more reliable data sources (e.g., where larger sample sizes were used and/or where the measurement tool was more accurate). Quantifying the degree of uncertainty in the results of the analysis is an important step for all methods. Guidance can be found in Chapter 9 of the *FLW Standard*.

> *Mass-balance calculations can be used to quantify FLW where reliable measurement or approximation is not possible.*

Box 8.1 | Subtraction and Uncertainty in the Mass-Balance Method

Subtraction is at the core of the mass-balance method and can increase the uncertainties associated with the resulting estimate of FLW, specifically when the FLW is expressed as a percentage.

The following example provides an illustration. In a mass-balance calculation, an estimate of 90 metric tons (t) (±10 t) for the outputs is subtracted from 100 t (±10 t) for the inputs. In this simple example, there is no change in level of stock or in the weight of food during processing. The resulting estimate of FLW would be 10 t (±14 t), assuming the only uncertainty emanates from that associated with the inputs and outputs. The uncertainty, expressed as a percentage in the final result, would be (±140%)[a], which is much greater than in the two original quantities (±11% and ±10%). This is often the case when one quantity is subtracted from another.

In some cases, the level of uncertainty due to the underlying data used and the propagation of uncertainties within the mass-balance calculations will render the results from a mass-balance method insufficiently accurate for the needs of the FLW quantification study. In such cases, other methods should be considered.

[a] When adding or subtracting two quantities, if the uncertainties associated with those quantities are independent of one another, one can take the square root of the sum of the values (i.e., Sqrt (10^2 + 10^2) = c. 14 metric tons (or 140% of 10 metric tons).

LEVEL OF EXPERTISE REQUIRED

Using a mass-balance method to infer the amount of FLW generated within a process requires access to data on the inputs to and outputs from the process, and on changes in levels of stock.

In a simple process where all data are available in consistent units, little experience is required beyond the ability to work with numbers, which could include using a spreadsheet and processing data.

Where data are presented in different units, contain gaps, and require additional interpretation, a higher level of numeracy and familiarity with calculation methods may be required. This is because all processes (e.g., combining of ingredients) and movement of food between processes (e.g., food product sent to animal feed) must be identified to ensure that FLW is correctly described. It is easy for someone unfamiliar with each of the processes involved to overlook flows.

COSTS

The cost of a mass-balance exercise is principally associated with the time spent by the analyst in sourcing the data and carrying out the mass-balance analysis. Where data are available and already in a standard unit of measurement, the process can be very quick and inexpensive. The time requirements and cost increase if data must be converted from one set of units to another. If any new measurement is required (e.g., of inputs, of outputs), then costs can increase dramatically.

8.2 Guidance on Implementing the Method

An entity that plans to use a mass-balance method will need to undertake a series of steps.

1. SCOPE THE STUDY

As Chapter 6 of the *FLW Standard* explains, a well-defined scope, aligned with the five accounting principles and an entity's goals, is important for ensuring that an FLW inventory meets an entity's needs. The scope of an entity's inventory—defined by the timeframe, material type, destination, and boundary—will dictate to a large extent the scope of the mass-balance study. Chapter 6 also describes how the scope chosen by an entity for its FLW inventory should be aligned with its underlying goals for addressing FLW.

2. IDENTIFY DATA SOURCES AND OBTAIN DATA

The next step is to identify data sources for the inputs, outputs, stocks, and changes. These should conform to the boundary, time period, and other components identified in the scope.

Information may come from a wide range of sources including invoices, bills, transport/distribution documentation, storage and warehouse records, and data on company management systems (e.g., quality management or inventory systems). See Chapter 5 of this document for more information about how to obtain records. If data are not available, it may be possible to initiate a measurement exercise (e.g., asking production staff to record weights of ingredients and/or products). For national or global estimates, national statistics (e.g., trade data, FLW statistics, food production, and import/export data) may also be a relevant source of data.

Box 8.2 provides an example in which the data source for inputs is sales data on household purchases and the source of data for the outputs is a national survey.

Box 8.2 | USDA's Use of a Mass-Balance Approach to Estimate Amounts of Food Available for Consumption and Food Loss

The U.S. Department of Agriculture (USDA) uses a mass-balance approach in its Loss-Adjusted Food Availability data series to estimate the amounts of 215 foods or commodities (e.g., fresh apples, canned tomatoes, beef, eggs) available for consumption in the United States. The USDA also uses the series to estimate food loss at the retail and consumer levels. USDA defines "food loss" as the amount of food after removing the inedible parts (postharvest) that is available for human consumption but is not consumed for any reason. It includes cooking loss and natural shrinkage (e.g., moisture loss); loss from mold, pests, or inadequate climate control; and food waste. To obtain the underlying consumer-level loss estimates, USDA compared purchasing data from a sales-data provider (Nielsen Homescan data) and subtracted information on consumption from a survey (National Health and Nutrition Examination Survey).

Source: USDA (2014). *The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States.* Washington, D.C.: USDA. http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib121.aspx

Box 8.3 | Methodology of FAO's Global FLW Study

The Food and Agriculture Organization of the United Nations (2011) quantified FLW on a global scale using FAOSTAT's Food Balance Sheets, presenting mass-balanced volumes of supply elements (i.e., production, imports, stock variations, exports) and utilization elements (e.g., feed, seed, processing waste, food) for different countries/regions of the world. Data from the national/regional Food Balance Sheets, together with the weight percentages of FLW, were used to quantify the amount of FLW for seven regions and seven commodity groups (cereals; roots and tubers; oilseeds and pulses; fruits and vegetables; meat; fish and seafood; and dairy products).

Data were analyzed along the food supply chain from harvest to consumption for each of the seven commodity groups. Mass flows of each commodity group were considered. Detailed descriptions of these calculations as well as detailed descriptions on how FLW was quantified for each step of the food supply chain are described in Gustavsson et al. (2013).

The study also used (for certain crops) allocation factors to determine the part of the product oriented to human consumption (and not for animal feed) and conversion factors to determine the "edible mass." Because quantifying aggregated commodity groups and regions of the world presents great challenges (e.g., finding representative data on FLW percentages, especially in some developing countries) a number of assumptions and estimates had to be made.

Sources: FAO (Food and Agriculture Organization of the United Nations). 2011. *Global Food Losses and Food Waste: Extent, Causes and Prevention.* Rome, Italy: FAO; Gustavsson, J., C. Cederberg, U. Sonesson, and A. Emanuelsson. 2013. *The Methodology of the FAO study: Global Food Losses and Food Waste: Extent, Causes and Prevention*. Rome, Italy: FAO.

In another example, the FAO study that quantified FLW at a global level applied elements of a mass-balance method, drawing from a range of data sources (e.g., national statistics); see Box 8.3.

3. IDENTIFY DATA GAPS AND FILL THEM

For a mass-balance study to be successful, all flows must be considered and quantified. For example, in a household analysis, inputs should include donated and grown food as well as purchased food. If these are omitted, then the level of FLW may be underestimated. If data are missing on some inputs or outputs, then efforts should be made to obtain the data, even through measurement if necessary.

In addition, a mass-balance study needs to take into account changes in the food that occur during processing. For instance, dried pasta absorbs water during cooking. If this additional water content is not taken into account in the mass-balance calculations, then the calculated level of FLW could be very inaccurate (a large underestimate). The impact of drying must also be taken into account in mass balances (e.g., unwrapped food left for some time may lose a significant amount of weight).

4. ENSURE THAT UNITS ARE STANDARDIZED

It is essential that all data use the same units of measure. It may be that data can be converted to a standard unit. For example, invoices and bills may not include weight data, but may include other useful information (e.g., number of units sold, financial value of units) that can be converted to a consistent unit via an appropriate conversion factor. Some common conversion factors that may be needed in a mass-balance study are described in Table 8.2.

Table 8.2 | Examples of Conversion Options for a Mass-Balance Study

RECORDED UNIT	DESIRED UNIT	CONVERSION OPTIONS	COMMENTS
Financial value/ number of units	Mass	Weigh a sample of product of a known value, and divide sample weight by value or number to derive a conversion factor Or Use trade data (e.g., Comext)[a] which record some product flows by weight, number, and value	Take particular care with co-products, which can vary in value
Liters of final product and mass of ingredients used	All in mass	Density	

[a] Comext is a statistical database including data on the trade of goods. It is managed by Eurostat. http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do

5. PERFORM MASS-BALANCE ANALYSIS

Once the data have been collected, gaps identified and filled, and the units standardized, the data can be used to infer the magnitude of the unknown flows. The unknown flows will include FLW. The calculation is based on the following equation:

FLW = Inputs – Outputs – Change in Stock + Adjustments

One example of an adjustment is to account for the change in weight during processing. The weight will increase where water content increases (e.g., a product such as rice or pasta absorbs water during cooking) and decreases where the water content decreases (e.g., products lose moisture content both through natural evaporation and drying processes).

In simple situations, calculating mass balance can be a straightforward calculation. For example, a very simple version of mass-balance is to collect or estimate total harvest data for a particular crop and subtract the amount sold. The difference is the estimated FLW.

However, where the flows are more complex, software can be used to assist in the analysis of a system or process. As shown in Box 8.4, some mass-balance studies require that a range of scenarios and data sources be considered.

Box 8.4 | Hypothetical Example: Data Considerations for a Mass-Balance Analysis of Households

It is possible to undertake a mass balance study of food (and drink) entering households within a particular geographic area. This is usually most easily performed for a country, because relevant statistics may already exist. In such a case, the equation would be:

FLW = Input (food brought into homes) – Output (food ingested) – Non-FLW outputs (e.g., donations out) + Adjustment for weight change within household (e.g., adding water) + Adjustment for changes in stock levels (e.g., change in the amount of food in the home over the relevant time period).

Sources of inputs could include food from the following sources: retailers, including grocery stores, farmer's markets, and convenience stores; home-grown (e.g., from a garden or allotment); donations (e.g., from charities or food banks); and/or gifts (e.g., from family and friends). The approach to quantifying each of these sources may be different. For some sources, it may be possible to use existing data (e.g., food purchases in a country). Others may require new measurement (e.g., using diaries or surveys for the amount of food gifted). It is also necessary to define what (if any) are the non-FLW outputs. These may include food donated out of the home (e.g., food donated to other households, collections, or charities).

It is also important to determine which types of food changed weight when in the household. Likely examples include foods that absorb water when cooking (e.g., pasta and rice) and foods that lose water to the atmosphere through evaporation during cooking (e.g., ready-to-eat meals). Many foods will lose weight during storage (e.g., fresh fruit and vegetables) unless effectively wrapped. For some of these changes, data exist on the extent of the change (e.g., some nutrition databases[a] include factors for weight change during cooking). Alternatively, measurement of weight change or mathematical models could be used to determine the relevant information.

[a] Public Health England. 2015. *McCance and Widdowson's The Composition of Foods: Seventh Summary Edition.* Cambridge, UK: Royal Society of Chemistry and London: The Food Standards Agency.

9. Modeling

9.1 Overview of the Method

Models are used to infer the amount of FLW by calculation. A model is a simplified version of the real world; it uses mathematical terminology and a mathematical approach to estimate FLW based on the interaction of multiple factors that influence the generation of FLW. These factors may be causal and directly affect the amount of FLW generated (e.g., grain storage practices), or may be contextual in that they are more indirect (e.g., weather conditions) and may amplify the effect of the causal factors. Using a model is one of three methods described in this standard that are based on "inference by calculation." The others are undertaking a mass balance and using proxy data (see Chapters 8 and 10 of this document).

There are a number of ways in which models can be used to estimate FLW. A wide range of modeling approaches may be used, drawing from various disciplines including statistics, economics, and operational research.

Models for FLW may use factors such as climatic, agricultural, or other data from which a scientific analysis has demonstrated that FLW values can be calculated. One example is the African Postharvest Losses Information System (APHLIS),[18] which uses a well-documented algorithm to express postharvest losses of grains in Africa, based on scientific literature; local data; and local factors such as rains at harvest time, agricultural practices, or storage and marketing practices (see Box 9.1).

Models that rely on previously established relationships between measurable factors (e.g., weather conditions) require two kinds of information:

- **Information about the factors that can affect the level of FLW** (e.g., timing of rain and timing of crop harvests). This information may be available from existing datasets, if they are sufficiently reliable, or it may need to be quantified.
- **Information about the nature of the relationship between these factors and FLW.** The relationships between measurable factors and FLW are described by mathematical functions (e.g., formulas) within the model. These relationships may already have been established (e.g., reported in literature) or may need to be determined through a new study. This involves understanding, for example, how harvesting a crop that is wet from recent rain may influence the likelihood of damage that results in FLW. Another example is the relationship between temperature during storage and insect damage. Higher temperatures result in faster life cycles among insects, which results in higher levels of damage by insects.

Another approach to modeling uses information on the relationship between the amounts of FLW generated and economic factors (e.g., output of a sector) to estimate levels of FLW within an economy.[19] Box 9.2 provides an example of this type of economic modeling.

Other modeling approaches simulate the system that generates FLW. For example, an estimate of FLW can be obtained by tracking food as it is bought, stored, and consumed. An example of this simulation approach is the Milk Model developed by WRAP,[20] which is described in Box 9.3.

ADVANTAGES AND DISADVANTAGES

The principal advantage of using models is their relatively low cost, especially compared with measurement- and approximation-based methods. They are especially valuable in agricultural contexts due to the need to measure or approximate FLW in different seasons and locations, and by crop type, soil type, and agricultural system. Models can be used to generate provisional data that can be improved later with measurements or approximation. This is useful when a quick estimate is required.

The main disadvantage of modeling is the risk that the resulting estimates of FLW will be inaccurate. Inaccuracies can result from the following:

- Unfounded assumptions may be included in the model. This tends to happen where there is a lack of reliable data on the factors included or where the relationships between the factors and FLW are inadequately understood or cannot be reliably quantified. This can result in a model structure that does not adequately reflect the real world.
- Data may be drawn from contexts, locations, or environments that are too dissimilar from those where the FLW arises.
- Mathematical relationships among model elements may be inappropriately applied.

LEVEL OF EXPERTISE REQUIRED

An in-depth knowledge and understanding of the information used within the model is required. This includes knowledge about the data on which the model is based and the relationships between different factors and FLW.

Some mathematical and statistical knowledge is required to understand how the model operates, which factors are included in and excluded from the model, and how to estimate uncertainty.

Simple models can be built in standard spreadsheet packages, but more complex models may require more specialized types of software, which can require training, expertise, and experience to operate.

COSTS

The cost of modeling is a function of the human resources required to develop, populate, and use the model. There may also be costs associated with purchasing datasets. Using a model to infer the amount of FLW typically costs less than undertaking a measurement or approximation of FLW.

9.2 Guidance on Implementing the Method

The type of model an entity uses will differ depending on the scope of the model and the nature of the data included within it. This section provides guidance for an entity using an existing model. It does not provide guidance on creating a new model. An entity seeking to develop a new model should consult with professionals skilled in the design of models because the process requires specialized expertise.

1. UNDERSTAND SCOPE OF THE MODEL

As Chapter 6 of the *FLW Standard* explains, a well-defined scope, aligned with the five accounting principles and an entity's goals, is important for ensuring that an FLW inventory meets an entity's needs. In using a model, an entity should confirm that the scope of the model aligns with the scope of an entity's inventory, defined by the timeframe, material type, destination, and boundary. Chapter 6 also describes how the scope chosen by an entity for its FLW inventory should be aligned with its underlying goals for addressing FLW.

2. REVIEW CHARACTERISTICS OF THE MODEL AND USE IF SUITABLE

An entity should search relevant literature and contact experts to determine whether there is an existing model that suits its purposes. This is important because it will usually be cheaper and quicker to use a model that already exists than to create a new one.

In selecting a model, an entity should understand why the model was developed, and how it has been used previously. In addition, an entity should understand how the model works—its structure and the factors included within it. If a model seems to be potentially usable, steps should be undertaken to verify and validate the model outputs for the situation the entity wishes to model.

(These considerations are also useful for an entity working with an experienced professional to develop a new model.)

Review of factors and relationships incorporated in the model

An entity should have a good understanding of the structure of any model it decides to use. This includes understanding the factors and relationships incorporated, because the accuracy of a model is critically dependent on the inclusion of all important factors affecting FLW. For instance, in agricultural settings, this requires knowledge of the crop being grown and the range of factors that could affect FLW during and after harvesting.

The owner of the model may have used several techniques for identifying the appropriate factors to include. These include literature reviews as well as workshops in which experts are consulted. These techniques typically provide a list of measurable factors that directly or indirectly influence FLW. Alternatively, an approach such as systems thinking may have been adopted to produce a qualitative diagram that reflects the understanding of how FLW is produced.

All models are simplifications of the real world. A good model is complex enough to robustly explain the generation of FLW (so that it is fit for its purpose), but no more complex than that (because the effort involved to develop the model quickly increases with complexity).

Some simplification will also be dictated by whether data are available or relationships between factors are known. Data may be sparse on the factors that influence FLW, and consideration should be given to whether there is adequate understanding of the relationship between the factors that influence FLW and its generation, including whether that relationship can be quantified. An entity should be clear on whether important factors have been excluded (e.g., because there are insufficient data to include them) and the impacts of their exclusion on the results.

Validation and verification of model

Validation and verification are important steps of model development; they define whether a model can appropriately be used under conditions specific to the entity. They may also lead to substantial improvements to the model.

An entity using a model should undertake some validation of the existing model to check that it accurately calculates the level of FLW given certain values for the factors (i.e., inputs to the model). This can be achieved by comparing the levels of FLW predicted by the model against measurements of FLW from the real world in situations where the factors (inputs) are known. Validation is difficult in situations where there are few real-world measurements, or where all the real-world measurements have been used to determine the relationships in the model (i.e., there is no new data against which to validate the model).

If possible, an entity should verify whether the model accurately represents the intended relationships between the factors and FLW. Its ability to do so will depend on the transparency of the existing model and its complexity. Verification can be achieved by checking results from the model against results that have been independently calculated in an alternative way (e.g., by hand), which might detect whether any of the relationships are described incorrectly within the model. Validation and verification are simplified when the model is clearly documented.

Using existing model

If a suitable model is identified, discussions should be initiated with the owner of the model to ensure that it will satisfy requirements (e.g., align with the scope of the FLW that the entity is quantifying) and that it can be applied to the inventory's specific case. It will also be necessary to arrange access. In some cases, intellectual property rights may preclude models being used by others although it is always worth exploring ways in which these issues could be overcome.

It is good practice for an entity to document clearly how it used a model, including values for factors used for each "run" of the model and any options or choices required.

Examples of models used to quantify FLW

Boxes 9.1–9.3 provide a series of examples of models that have been used to generate estimates of FLW.

Box 9.1 | Modeling Postharvest Losses for Cereal Grains in Africa

The African Postharvest Losses Information System (APHLIS) provides estimates of weight losses from the postharvest chain for the most important cereals grown in Sub-Saharan Africa.

To make loss estimates, APHLIS uses a model and relies on two distinct sources of data:

- **Postharvest loss (PHL) profiles** quantify the expected losses at each link in the postharvest chain. These data are derived from the scientific literature.
- **Seasonal data** quantify losses that occur on a seasonal or annual basis (e.g., because of weather-related factors). These data are submitted by African specialists in the APHLIS network.

PHL PROFILES

One problem of seeking to provide PHL profiles is that PHL data have been collected in only a few parts of Sub-Saharan Africa. It is therefore inevitable that, in the creation of the PHL profiles, many different provinces will have to share the same data. This sharing was achieved by clustering the data from provinces of various countries that are basically similar with respect to climate. The climates of Sub-Saharan Africa have been classified according to the Köppen system[a] and, for the purposes of APHLIS, are of three types: tropical savanna, arid/desert, and warm temperate.

There is a PHL profile for each crop in each climate. Thus with seven crops (maize, sorghum, millet, wheat, barley, rice, and teff) there are a total of 21 (3 x 7) profiles. Except for maize, the profiles are specific to the technologies associated with smallholder farming. For maize, there are profiles for both smallholder and large-scale farming.

In the creation of PHL profiles, it is necessary to create a generalized loss figure for each step in the postharvest chain. The basic data on which these are based came from the scientific literature and the PHL Network. These data were refined by:

- removing outliers;
- avoiding the use of information from questionnaires and "guesstimates" where there is information from a more robust (measurement) approach; and
- averaging the remaining data.

SEASONAL DATA

Several "seasonal" factors can have a substantial bearing on the actual estimate of FLW. Data on these seasonal factors include the impact of:

- damp weather during any of the harvests, which would make drying difficult;
- the proportion of grain that is marketed within the first three months, thus will not enter farm storage for any significant time;
- the length of the farm storage period; and
- in the case of maize, whether the larger grain borer *(Prostephanus truncatus)* is expected to be a significant pest.

APHLIS is entirely documented and the underlying data and sources are all available online. It also offers a downloadable calculator that uses the same underlying model and into which specific, local data can be input.

[a] APHLIS. "Understanding APHLIS." May 2014. Accessible online at http://www.aphlis.net/downloads/Understanding%20APHLIS%20ver%20%202.2%20May%2014.pdf.

Box 9.2 | Using National Economic and Trade Data to Estimate FLW

One type of model makes use of information found in national accounts of economic activity and national trade data. This information is then combined with data on waste and loss from which FLW can be calculated by applying appropriate factors and assumptions. This means that total waste generation—rather than FLW—is the starting point for this type of modeling.

This approach may require assumptions to generate an estimate (e.g., it may be assumed that the amount of FLW is related to the gross output of a sector). Examples of the approach include:

- Delahaye et al. (2011) introduced a method using national accounts tables which quantified the underlying driving forces of changes in total waste and landfilled waste.
- Reynolds et al. (2014) proposed a method using national accounts tables to estimate the types and quantities of waste generated in both industry and households, which has been applied to Australia.

Sources: Delahaye, R., R. Hoekstra, and L. Nootenboom. 2011. "Analysing the Production and Treatment of Solid Waste using a National Accounting Framework." *Waste Management & Research* 29(7); Reynolds, C., A. Geschke, J. Piantadosi, and J. Boland. 2015. "Estimating Industrial Solid Waste and Municipal Solid Waste Data at High Resolution using Economic Accounts: An Input–Output Approach with Australian Case Study." *Journal of Material Cycles and Waste Management* 3.

Box 9.3 | Using Discrete Event Simulation for Milk FLW

A "Milk Model" was developed by WRAP (The Waste Resources and Action Programme) to explore the factors that affect FLW of milk in households in the United Kingdom. The model allows activities relating to purchasing, storage, and consumption of milk to be simulated and provides an estimate of milk FLW for the modeled household. It also allows the impact of attributes of the milk (e.g., its shelf life) to be explored. The system created in the model includes many of the features that are important to household FLW. However, by modeling only one product—milk—rather than all food and drink, it allows many insights to be uncovered that are frequently obscured by the complexity involved in studying total household FLW. Many of the findings for milk, however, are relevant to other fresh food products purchased and consumed at a similar frequency (e.g., sliced bread).

The modeling technique used was discrete event simulation, which is a well-established method, but one that had not been applied previously to FLW in the home. It allows data and insights from a large range of sources to be used together within a single framework to understand the system in question. This work suggests that system-based approaches to considering FLW prevention in the home can increase understanding of the issues and estimate the approximate impact of potential changes.

Source: WRAP (The Waste Resources & Action Programme). 2013. *The Milk Model: Simulating Food Waste in the Home.* Banbury, UK: WRAP.

10. Proxy Data

10.1 Overview of the Method

This method enables an estimate of FLW to be made using proxy data (i.e., FLW data that are *outside* the scope of the FLW inventory but which can be used as part of a calculation to infer quantities of FLW within the scope of the entity's inventory).[21] An entity may decide to use proxy data if measurement or approximation are not feasible (e.g., if it does not have direct access to the FLW, or if it has a limited budget). Using proxy data is one of three methods described in this standard that are based on "inference by calculation." The others are undertaking a mass–balance approach and using models (see Chapters 8 and 9 in this document).

The proxy data might be specific (e.g., amounts of the FLW generated by individual sites or households) or meta-level (e.g., total agricultural FLW in a country). The level of detail in the proxy data will affect the nature of the calculations performed to obtain an estimate of FLW, as described in Section 10.2, Step 4.

Proxy data could include data that are older than the temporal scope of the inventory, that come from a different geographical area, or that are drawn from a sector other than the one defined in the scope. For example, if data on FLW exist for 2009 but the inventory scope is 2013, the 2009 data could be used and scaled up to account for population (or other) changes since 2009. In this case, the 2009 data are the proxy data. As another example, if an entity wishes to prepare an inventory for its country but has no data, FLW data from a neighboring country could be used based on the assumption that the two countries are very similar. In this case, the data from the neighboring country are the proxy data.

ADVANTAGES AND DISADVANTAGES

The overriding advantage of using other FLW data as proxy data to generate estimates of FLW is that it is less expensive than methods that measure or approximate the amount of FLW.

The primary disadvantage is that the results are less accurate because assumptions have to be applied. The proxy data are outside the scope of an entity's FLW inventory, and the degree of uncertainty in the FLW estimate may be relatively high. As a result, it is usually not recommended to monitor FLW reduction targets using FLW estimates derived using proxy data because the data relate to a different scope from that of the target; for example, using data from one country as a proxy for another country makes it very difficult to monitor a target in the country in which the data are being applied. Any change over time is likely to reflect changes emanating in the country from which the proxy data came.

LEVEL OF EXPERTISE REQUIRED

For very simple calculations using proxy data, a basic ability to understand and work with numbers is required. For more complex applications, an entity will need more advanced skills to undertake various calculations.

It is also essential that an entity using this method be familiar with both the proxy data and the scope of the FLW inventory for which data are being estimated. It needs to understand the limitations of the data in order to identify appropriate approaches to working with the data and performing calculations. This is important because of the potential for major errors to creep in as a result of uncertainties or assumptions in the original data. Understanding where the data come from and how they were collected can help prevent the introduction of errors. Furthermore, a familiarity with the way in which the sector generates FLW is advantageous and helps avoid errors of inference or the application of incorrect assumptions. Familiarity with the sector also helps with "back of the envelope" cross-checking of the FLW estimate once it has been produced.

COSTS

The cost to use proxy data are principally associated with the time spent by the analyst in sourcing the data, performing the calculations, and writing up the results. Where the data are available and relatively straightforward to use, the process can be very quick and inexpensive.

10.2 Guidance on Implementing the Method

This section describes the steps that an entity should undertake when estimating FLW using proxy data.

1. SCOPE THE CALCULATION

As Chapter 6 of the *FLW Standard* explains, a well-defined scope, aligned with the five accounting principles and an entity's goals, is important for ensuring that an FLW inventory meets an entity's needs. The scope of an entity's inventory—defined by the timeframe, material type, destination, and boundary—will dictate to a large extent the proxy data that may be appropriate and the way in which they should be used to generate data for the inventory. Chapter 6 also describes how the scope chosen by an entity for its FLW inventory should be aligned with its underlying goals for addressing FLW.

2. DETERMINE AVAILABLE PROXY DATA

The next step is to identify data that have the potential to be used for proxy-based calculations. Searches can be performed in the academic literature and on the worldwide web to establish relevant information that could be used.

As the data are being collected and combined, it is also important to create a "meta-data file," which contains background information about the data (e.g., how the data were generated, the timeframe and geographical scope they represent, and associated uncertainties). This information will help with deciding which data to use, which is the next step of this process.

3. SELECT PROXY DATA TO USE

An entity should compare the scope of the potential proxy data with the scope of its inventory. It is important to review the scope across all the components outlined in Chapter 6.

In some situations, there may be a large number of differences between the scope of the potential proxy data and the scope of the inventory. For example, if proxy data being considered are from a different country, a different time period, and a different crop, then an entity will need to make a number of assumptions and calculations to convert these data so that they align with the scope of its inventory. The more differences that exist between the scopes, the more inaccurate the estimate of FLW is likely to be.

Before selecting which proxy data to use, an entity should find out how they were generated. It is important to understand the quantification method used and the related level of uncertainty, along with any other biases (e.g., how the "sample" was drawn, which conversion factors were used). In addition, it is good practice to talk to the parties (e.g., consultants, researchers) who generated the data being evaluated.

In summary, the decision about which data are suitable for use as a proxy should be based on the quality of the data and the clarity of the associated documentation, the extent to which they can be converted for use with the inventory scope, and the number of assumptions that will need to be made to derive an estimate of FLW. If the level of uncertainty is higher than the level considered acceptable for an entity's particular quantification goals, then the entity should rule out using those potential proxy data. This decision will depend on why the FLW quantification is being undertaken. For instance, if two countries are very similar with respect to household food consumption habits, it may be possible to use household FLW data from one country as a proxy for the other. This may be acceptable for a general understanding of FLW levels. However, if an entity is seeking to establish FLW reduction targets and monitor changes over time, using data from another country could be very misleading.

> *...it is usually not recommended to monitor FLW reduction targets using FLW estimates derived using proxy data because the data relate to a different scope from that of the target...*

Changes in FLW in one country may not be representative of changes in the other, due to FLW reduction activities being implemented in one country but not the other.

4. CARRY OUT THE CALCULATIONS

Most calculations involving proxy data are performed in the following stages:

- **Calculate FLW expressed in a normalized form** (e.g., FLW per capita, per employee, per metric ton of food processed). In simple calculations, there may be one normalized FLW figure applied to a whole sector (e.g., FLW per metric ton of food processed for the whole food processing sector). However, there are also benefits to producing multiple FLW figures for different parts of a sector (e.g., FLW per metric ton of food processed per different type of food processing). This is important if normalized FLW estimates differ between distinct parts of a sector. In addition, if an entity has access to detailed data sources (e.g., those containing information from a number of FLW-producing units, such as households), then it could combine this information in a number of ways to create proxy factors. For example, an entity could exclude any FLW-producing units that fail to meet certain data quality criteria.

- **Scale the normalized data**. In a simple calculation, this involves multiplying the normalized data (e.g., FLW per capita) by the appropriate value for the inventory scope (e.g., the number of people in the relevant population). In more complex calculations, scaling may be carried out for each distinct sub-sector, and the results combined to create the FLW estimate.

  The data required for scaling may be obtained from national statistical sources. It is important that these “scaling data” match the inventory scope as precisely as possible to increase the accuracy of the resulting FLW estimate.

The process described above is likely to be iterative based on the availability of suitable proxy FLW data and data for scaling. Additional guidance on scaling and normalizing data is provided in Appendix A and C, respectively, of the *FLW Standard*.

The following are two examples of how proxy data may be used:

- *Northern Ireland Commercial and Industrial (C&I) Waste Estimates.*[22] This study applied FLW factors (FLW per company) from England to the number of companies in Northern Ireland based on the type of company.

- *Waste in the UK Hospitality and Food Service Sector: Full Technical Report.*[23] This study used a variety of different proxy data to scale up data collected from a program of direct measurement across different types of establishment. Direct measurements included FLW per student (schools, other educational institutions), per acute bed (hospitals), per employee (restaurants, pubs, hotels, quick-serve restaurants), and per prisoner (prisons).

Appendix A. Quantifying FLW if Water Is Added

A1. Overview

This Appendix provides guidance for an entity seeking to quantify FLW where water has been added (see related requirement in Section 6.7 of the *FLW Standard*). Water may be added to meet requirements for diluting the FLW before disposal. Water may also be used to wash a storage area or equipment in a food processing facility to meet production and safety standards, which results in FLW becoming part of the liquid waste stream.

Samples of wastewater should be collected before any biological treatment that converts the FLW is undertaken. If an entity (e.g., a food manufacturer) has screened out solids or used other separation methods to remove food (e.g., oil, small solids), these are required to be included in the analysis. Moreover, if sanitary wastewater is part of the liquid waste stream, an entity is required to subtract that amount (the volume and organics) from its calculation.

If the FLW is flushed through a pipe to the sewer or another destination, an entity should explore whether there are existing data on "effluents" (i.e., the liquid discharged) that it could use to quantify the FLW. A "drying and weighing" approach may also be used to estimate the amount of FLW, if it is insoluble (i.e., cannot be dissolved). This approach may be applied to a liquid waste stream before or after it flows through the pipes.

A2. Using Existing Data on Effluents

Existing data on effluents may be available where an environmental permit is required to discharge effluent to a sewer or watercourse. In these situations, it is common for limits to be set for total suspended solids, total dissolved solids, total organic content, chemical oxygen demand, and biological oxygen demand.[24]

"Total solids" can then potentially be calculated by summing the data on "total suspended solids" and "total dissolved solids." These limits may be periodically monitored by the organization responsible for the sewer or watercourse into which the effluent is discharged. In addition, many operations may also monitor/treat their own effluent to ensure that permit conditions are met, which may provide further data that could be used to calculate the amount of FLW.

Using existing data on effluents could reduce the cost of data collection and provide a time series against which to evaluate FLW. However, it requires an effective sampling regime to ensure that the results are not biased, for example, by changes in production rates throughout the day.

A3. Using a "Drying and Weighing" Approach

A "drying and weighing" approach involves taking a sample of the FLW along with the added water and taking steps to separate, dry, and weigh the suspended solids. It is a relatively "low-technology" way to determine the amount of FLW suspended in a liquid.

The primary advantage of this approach is that it can provide a reasonably accurate measurement of suspended solids that would otherwise be very difficult to measure. However, any soluble FLW and intrinsic water content will be evaporated during the heating process. This approach also cannot distinguish suspended solids that are not FLW (e.g., grit or soil) from the FLW.

"Drying and weighing" can be undertaken regardless of the concentration of solids in a liquid. If this approach is applied to effluent discharge, it does require an understanding of the rate of discharge in order to quantify the amount of suspended solids relative to a given quantity of processing or over a given period of time.

Implementing this approach involves taking samples of known quantities of the liquid that contain the suspended FLW solids, filtering them, and then heating the suspended material to evaporate the water. The dried material that remains at the end of the process is then weighed. The average weight of this material is then multiplied by the total volume of liquid to calculate the total amount of solid material in the liquid over a given period of time.

If the wastewater does not contain significant levels of non-food organic solids (such as soil), an entity could also burn the dried sample leaving only inorganics. From that, it could calculate the amount of FLW in the sample. Standard methods exist to carry out this type of analysis.

When calculating the amount of FLW it is important to take into account the intrinsic water content removed during the drying process (see Section 6.7 of the *FLW Standard* for details about intrinsic water content). As an example, if, over the course of a year, sample weighings indicate that 100 metric tons of suspended solids are in the liquid waste stream and the finished item is 50 percent water and 50 percent dry matter, then the equivalent of approximately 200 metric tons of FLW has been produced over that period of time (i.e., 100 metric tons divided by 50 percent).

An entity may also adjust for a known level of solubility for the items included (e.g., if half of the items were soluble and half insoluble, the entity would double the estimate calculated from the suspended solids alone). This adjustment may be difficult to apply if there is a range of items with a different solubility and water content.

Heating and weighing will need to be conducted in a laboratory. This may add to the cost of the process, and also means that only relatively small samples can be processed. Small samples may however lead to inaccuracies in the results if the sample is unrepresentative.

References

Adams, J.M. and G.G.M. Schulten. 1978. "Losses Caused by Insects, Mites, and Microorganisms." Washington, D.C.: U.S. Agency for International Development.

Andersen, F.M., and H.V. Larsen. 2012. "FRIDA: A Model for the Generation and Handling of Solid Waste in Denmark." *Resources, Conservation and Recycling* 65(0).

Andersen, F.M., H. Larsen, M. Skovgaard, S. Moll, and S. Isoard. 2007. "A European Model for Waste and Material Flows." *Resources, Conservation and Recycling* 49(4).

Brunner, P.H., and H. Rechberger. 2004. *Practical Handbook of Material Flow Analysis. Advanced Methods in Resource and Waste Management*. Boca Raton, FL: Lewis Publishers.

Cencic, O., and H. Rechberger. 2008. "Material Flow Analysis with Software STAN." *Journal of Environmental Engineering and Management* 18.

Delahaye, R., R. Hoekstra, and L. Nootenboom. 2011. "Analysing the Production and Treatment of Solid Waste using a National Accounting Framework." *Waste Management & Research* 29(7).

FAO (Food and Agriculture Organization of the United Nations). 2011. *Global Food Losses and Food Waste: Extent, Causes and Prevention*. Rome, Italy: FAO.

FAO and INFOODS (International Network of Food Data Systems). 2012. *FAO/INFOODS Density Database Version 2.0*. Rome, Italy: FAO.

FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies). 2014. *Standard Approach on Quantitative Techniques to Be Used to Estimate Food Waste Levels*. Kråkerøy, Norway: FUSIONS.

FUSIONS. 2016. *Food Waste Quantification Manual to Monitor Food Waste Amounts and Progression*. Paris, France: FUSIONS.

Golob, P., G. Farrell, and J. Orchard. 2002. *Crop Post-harvest: Science and Technology*. Hoboken, NJ: John Wiley & Sons.

Gustavsson, J., C. Cederberg, U. Sonesson, and A. Emanuelsson. 2013. *The Methodology of the FAO Study: Global Food Losses and Food Waste: Extent, Causes and Prevention*. Rome, Italy: FAO.

Hodges R., M. Bernard, and F. Rembold. 2014. "APHLIS—Postharvest Cereal Losses in Sub-Saharan Africa, their Estimation, Assessment and Reduction." *Joint Research Centre (JRC) Technical Report* EUR 26897. Brussels, Belgium: European Commission.

Joosten, L.A.J., M.P. Hekkert, E. Worrell, and W.C. Turkenburg. 1999. "STREAMS: A New Method for Analysing Material Flows through Society." *Resources, Conservation and Recycling* 30(2).

Morris, A.E., G. Geiger, and H.A. Fine. 2011. *Handbook on Material and Energy Balance Calculations in Material Processing* (3rd ed.). Hoboken, NJ: John Wiley & Sons.

Östblom, G., M.L. Söderman, and M. Sjöström. 2010. "Analysing Future Solid Waste Generation: Soft Linking a Model of Waste Management with a CGE-Model for Sweden." Stockholm, Sweden: National Institute of Economic Research.

Public Health England. 2015. *McCance and Widdowson's The Composition of Foods: Seventh Summary Edition*. Cambridge, UK: Royal Society of Chemistry and London: The Food Standards Agency.

Reynolds, C., A. Geschke, J. Piantadosi, and J. Boland. 2015. "Estimating Industrial Solid Waste and Municipal Solid Waste Data at High Resolution Using Economic Accounts: An Input–Output Approach with Australian Case Study." *Journal of Material Cycles and Waste Management* 3.

UNEP (United Nations Environment Programme). n.d. "Detailed Assessment: Waste Minimisation." Accessible at: <http://www.unep.org/resourceefficiency/Portals/24147/scp/presme/pdfs/UNEP_PRE_SME_ITH_Chapter_7.pdf>

USDA (United States Department of Agriculture). 2014. *The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States.* Washington, D.C.: USDA.

USEPA (United States Environmental Protection Agency). 1997. *Measuring Recycling: A Guide for State and Local Governments.* Washington, D.C.: USEPA.

Van Garde, S.J., and M.J. Woodburn. 1987. "Food Discard Practices of Householders." *Journal of the American Dietetic Association* 87(3).

van Graas, M.H. 2014. *Food Waste or Wasted Food: An Empirical Investigation of the Determinants of Food Waste*. Stavanger, Norway: University of Stavanger.

West Coast Climate Forum. 2015. "Take the Measurement Challenge Instructions." Accessible at: <http://westcoastclimateforum.com/food/wasteless>

WRAP (The Waste and Resources Action Programme). 2009. *Down the Drain*. Banbury, UK: WRAP.

WRAP. 2010. *Material Bulk Density: Summary Report*. Banbury, UK: WRAP.

WRAP. 2013a. *Household Food and Drink Waste in the United Kingdom 2012*. Banbury, UK: WRAP.

WRAP. 2013b. *The Milk Model: Simulating Food Waste in the Home*. Banbury, UK: WRAP.

WRAP. 2013c. *Waste in the UK Hospitality and Food Service Sector—Full Technical Report*. Banbury, UK: WRAP.

WRAP. 2014. *Household Food and Drink Waste: A Product Focus*. Banbury, UK: WRAP.

WRAP Northern Ireland. 2011. *Northern Ireland Commercial & Industrial (C&I) Waste Estimates*. Belfast, UK: WRAP Northern Ireland.

Zero Waste Scotland. 2015. *Guidance on the Methodology for Waste Composition Analysis*. Stirling, UK: Zero Waste Scotland.

Endnotes

1. Examples of additional methods used to quantify FLW are described in FUSIONS (2014).

2. FUSIONS (2016) is a useful resource for selecting and using different quantification methods. It is aimed principally at authorities in the Member States of the European Union seeking coherent methods for acquiring national food waste data covering all sectors of the food chain. The publication highlights for five sectors (primary production; processing and manufacturing; wholesale, retail, and markets; food service; and households) certain methodologies it has found to be suitable.

3. Visual scales are practical pictorial aids used in agricultural contexts, typically to help assess the different levels of damage by pests to stored crops.

4. Strictly speaking, the measurement is called "mass" and is expressed as pounds, kilograms, tons, metric tons (tonnes), etc. In colloquial terms, however, it is most often referred to as "weight" and the *FLW Standard* therefore uses the term "weight."

5. Hodges et al. (2014).

6. Based on Système Internationale (SI), the international system of specifying standard units.

7. FAO/INFOODS (2012).

8. Zero Waste Scotland (2015).

9. WRAP (2013a); WRAP (2009); Sörme et al. (2014); Van Garde and Woodburn (1987); van Graas (2014).

10. Unpublished research by WRAP found that diarists in households with multiple occupants reported just 60 percent of the amount recorded through waste composition analysis.

11. See section 2.6 of WRAP (2014).

12. See section 2.6 of WRAP (2014).

13. WRAP (2013a).

14. For example, for the UK's National Diet and Nutrition Survey: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/216486/dh_128546.pdf

15. An example of a diary can be found at: http://www.wrap.org.uk/sites/files/wrap/Kitchen-Diary-2012-Final-Low-Res.pdf

16. See Brunner and Rechberger (2004); Morris et al. (2011); UNEP (n.d.).

17. One such site where free software is available is www.stan2web.net. See also Cencic and Rechberger (2008). http://enviroinfo.eu/sites/default/files/pdfs/vol119/0440.pdf.

18. APHLIS is accessible at www.aphlis.net. For more on APHLIS, see Hodges et al. (2014).

19. One of the hurdles presented by economic-based models is the conversion of financial data to physical quantities. When undertaken incorrectly, this can lead to some unanticipated results (see Joosten et al. (1999)). Furthermore, the relationship between FLW generated and economic factors can lead to uncertainty of results in some cases (Andersen et al. 2007; Östblom et al. 2010; Andersen and Larsen 2012).

20. WRAP (2013b).

21. This approach differs from scaling up data (see Appendix A of the *FLW Standard*) where data are taken from *inside* the scope of the FLW inventory (i.e., data from inside the geographical, temporal, and material scope of the inventory).

22. WRAP Northern Ireland (2011).

23. WRAP (2013c).

24. Biological oxygen demand (BOD) is a measure of how much organic material is in the discharge liquid. If BOD is too high, it can deplete the oxygen level of the water to which it is being discharged.

ABOUT THE CONSUMER GOODS FORUM (CGF)

CGF is a global, parity-based industry network that brings together the CEOs and senior management of some 400 retailers, manufacturers, service providers, and other stakeholders across 70 countries.

ABOUT FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO)

An intergovernmental organization, FAO has 194 Member Nations, two associate members and one member organization, the European Union. Achieving food security for all is at the heart of FAO's efforts—to make sure people have regular access to enough high-quality food to lead active, healthy lives.

ABOUT EU-FUNDED FUSIONS PROJECT

FUSIONS is working towards a more resource efficient Europe by significantly reducing food waste. FUSIONS has 21 project partners from 13 countries, bringing together universities, knowledge institutes, consumer organisations and businesses.

ABOUT UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP)

UNEP sets the global environmental agenda, promotes the coherent implementation of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment.

ABOUT THE WORLD BUSINESS COUNCIL FOR SUSTAINABLE DEVELOPMENT (WBCSD)

The WBCSD is a CEO-led organization of forward-thinking companies that galvanizes the global business community to create a sustainable future for business, society and the environment.

ABOUT WRAP (THE WASTE AND RESOURCES ACTION PROGRAMME)

WRAP is a charity based in the UK. Its mission is to accelerate the move to a sustainable resource-efficient economy through re-inventing how we design, produce and sell products; rethinking how we use and consume products; and re-defining what is possible through re-use and recycling.

ABOUT WORLD RESOURCES INSTITUTE (WRI)

WRI is a global research organization that spans more than 50 countries, with offices in Brazil, China, Europe, India, Indonesia, and the United States. WRI's more than 450 experts and staff work closely with leaders to turn big ideas into action to sustain our natural resources—the foundation of economic opportunity and human well-being.

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Food
Loss + Waste
PROTOCOL

The Food Loss & Waste Protocol (FLW Protocol) is a multi-stakeholder partnership, which has developed the global *Food Loss and Waste Accounting and Reporting Standard* (or *FLW Standard*) for quantifying food and/or associated inedible parts removed from the food supply chain—commonly referred to as "food loss and waste" (FLW).

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