Commission for Environmental Cooperation

Why and How to Measure Food Loss and Waste

A PRACTICAL GUIDE - VERSION 2.0
APPENDIX A - METHODS

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Appendix A: Methods

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

DIARIES

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

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

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

HOW TO USE DIARIES TO QUANTIFY FLW

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

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

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

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

Step 2: Identify how the diaries will be administered

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

Step 3: Identify respondent audience

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

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

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

Source: Authors.

Step 4: Recruit participants

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

Step 5: Prepare questions to quantify FLW

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

- Food type (e.g., carrot, ham sandwich, chicken)
- Material type (i.e., food and/or inedible parts)
- How it was purchased (e.g., fresh, frozen, canned)
- How much was wasted (provide unit of measure)
- Why it was wasted (e.g., cooked badly, served too much, spoiled)
- Disposal method (e.g., compost, garbage disposal, pet food)

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

Step 6: Test the diary and revise

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

Step 7: Administer the diary

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

Step 8: Prepare and analyze the data

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

Table A2. Advantages, Disadvantages and Examples of Diary Types

Method	Advantages	Disadvantages	Example
Print	· Relatively low cost · Allows for both visual and written prompts	· Can become lost or damaged · May be inconvenient and labor-intensive for the participant	See this **sample print food waste diary** (WRAP 2018).
Electronic	· May be more convenient for the participant · Allows for data to be saved and stored electronically · Saves time on data entry	· Requires familiarity with technology and computers on the part of the participant	
Smartphone app	· Most convenient option for participant · Allows for use of photographs	· Limits respondents to smartphone owners with technological capabilities · Photographs without measurements may be difficult for the researcher to assess amounts of waste	The app "**SmartIntake**" is one example of a food waste tracking app—it allows pictures to be taken before and after a meal and then sent to the researcher

Source: Authors.

COMMON DATA CHALLENGES IN USING A DIARY

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

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

ADDITIONAL RESOURCES FOR DIARIES

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

WRAP. 2018. "Toolkit Food Waste Diary." **https://wrap.org.uk/resources/campaign-assets/toolkit-food-waste-diary**.

DIRECT MEASUREMENT

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

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

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN PRIMARY PRODUCTION

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

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

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

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

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

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN PROCESSING AND MANUFACTURING

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

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

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

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN DISTRIBUTION AND WHOLESALE

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

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

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

Source: Authors.

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

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

Source: Authors.

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

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

Source: Authors.

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN RETAIL

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

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

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

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN FOOD SERVICE AND INSTITUTIONS

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

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

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

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

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

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

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

USING DIRECT MEASUREMENT TO QUANTIFY FLW IN HOUSEHOLDS

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

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

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

Source: Authors.

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

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

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

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

Table A7. Factors to Consider when Using Smart Bins

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

Table A8. Factors to Consider when Using Plate Weighing

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

Source: Authors.

Table A9. Factors to Consider when Measuring Household FLW

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

Source: Authors.

INTERVIEWS AND SURVEYS

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

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

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

HOW TO CONDUCT A SURVEY TO QUANTIFY FLW

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

Step 1: Set hypotheses and determine the survey approach

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

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

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

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

Step 3: Identify respondent audience

In some cases, the participant audience for a survey-based study will be a discrete group. For surveys with a large number of target respondents, a random sample may need to be developed. If so, a professional statistician should be consulted, although simple random sampling can be conducted if a list of the members of a population is available and complete (Laerd 2012).

Step 4: Prepare questions to quantify FLW

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

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

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

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

Source: Authors.

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

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

Questions should be sequenced in a logical progression, with simpler or more important questions at the beginning, since respondents frequently fail to complete the entire survey (Alchemer 2020). If a survey is too long, it may be off-putting to respondents, so each question should be evaluated for its importance to the study.

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

Step 5: Test the survey and revise

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

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

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

Table A12. Advantages and Disadvantages of Methods for Conducting Surveys

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

Source: Authors.

Step 6: Administer the survey

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

Step 7: Prepare and analyze the data

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

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

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

COMMON DATA CHALLENGES IN CONDUCTING A SURVEY

LOW RESPONSE RATES. Because surveys require respondents to take time from their schedules to complete, many suffer from low response rates. For example, a survey from Food and Consumer Products of Canada in 2015 to collect FLW data from companies had just a 35 percent response rate (Food and Consumer Products of Canada 2015). Although it can be difficult to boost response rates, a common strategy is to provide respondents with a benefit for participating, such as compensation (usually quite small) or a promise of sharing the survey results (Alchemer 2020).

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

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

ADDITIONAL RESOURCES ON CONDUCTING A SURVEY

Alchemer. 2020. "10 key things to consider when designing surveys." **https://www.alchemer.com/resources/blog/designing-surveys/**

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

MASS BALANCE

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

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

HOW TO USE MASS BALANCE FOR FLW QUANTIFICATION

Step 1: Define your inputs, outputs and stocks

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

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

Step 2: Identify data sources

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

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

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

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

Step 3: Account for any variations

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

Step 4: Perform the mass balance analysis

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

FLW = Inputs - Outputs ± Changes in Stock ± Adjustments

The terms in this equation are defined as follows:

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

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

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

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

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

COMMON DATA CHALLENGES WHEN USING MASS BALANCE

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

ADDITIONAL RESOURCES ON USING MASS BALANCE

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

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

PROXY DATA

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

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

HOW TO USE PROXY DATA TO QUANTIFY FLW

Step 1: Determine what data are needed

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

Step 2: Determine available proxy data

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

Step 3: Select the data to use

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

Step 4: Prepare and Analyze the Data

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

COMMON DATA CHALLENGES IN USING PROXY DATA

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

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

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

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

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

ADDITIONAL RESOURCES FOR USING PROXY DATA

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

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

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

Source: Authors.

RECORDS

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

WHEN TO USE RECORDS

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

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

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

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

HOW TO USE RECORDS TO QUANTIFY FLW

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

Step 1: Identify the records available

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

- **PURCHASING INFORMATION:** contains data relating to the amount and types of food being brought in by the entity looking to quantify its FLW.
- **WASTE TRANSFER RECEIPTS:** contains data relating to the amount of waste being transported away from a facility. It may also contain information about where the waste is being disposed of (i.e., anaerobic digestion, landfill). In some cases, organic waste is separated from inorganic waste prior to waste transfer. If organic waste and inorganic waste are combined, the amount of organic waste will need to be estimated.
- **EXISTING WASTE-REDUCTION MEASUREMENTS:** Many larger-sized companies undertake waste reduction

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

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

or efficiency measurement methodology, such as Six Sigma (FUSIONS 2016). These records may be useful when quantifying FLW.

- **DONATION RECEIPTS:** If the facility or business in question has donated food to charities or food banks, it may retain receipts to track the types and amounts of food donated. Although this food is not considered to be FLW since it remains in the human food supply chain, many businesses still find value in tracking the amount of food being donated.
- **RECORDS OF CHEMICAL OXYGEN DEMAND (COD) IN SEWAGE:** Biochemical oxygen demand (BOD) is the amount of oxygen that bacteria take from water when they oxidize organic matter (Hach et al. 1997). Because BOD tests tend to be costly, a chemical oxygen demand (COD) test, which is the total measurement of all chemicals in the water that can be oxidized, is generally used as a proxy to measure for BOD. The sewage treatment company used by the company conducting the FLW quantification may possess COD data that can be used to estimate the amount of organic matter being sent down the drain.

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

Step 2: Assess the relevance of the records

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

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

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

Step 3: Acquire the records

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

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

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

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

Step 4: Prepare and analyze the data

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

COMMON DATA CHALLENGES WHEN USING RECORDS

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

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

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

ADDITIONAL RESOURCES FOR USING RECORDS

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

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

WASTE COMPOSITION ANALYSIS

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

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

HOW TO CONDUCT A WASTE COMPOSITION ANALYSIS TO MEASURE FLW

Step 1: Identify the sectors to be reviewed

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

Step 2: Recruit and inform participants

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

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

Collect waste samples from the FLW-generating units on their regular trash collection days to ensure that the analysis is conducted on a representative sample. If possible, take the waste sample to a separate site to be sorted, since most FLW-generating units will not have the space available to sort through large amounts of waste.[1]

Step 4: Prepare the FLW for measurement

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

1. Place the waste from each FLW-generating unit in a discrete area (e.g., a table or a marked-off section of floor) where it will not mix with other samples.
2. Remove the food from any packages and sort the packages into a separate pile.
3. Sort the FLW into categories based on the scope of the study.
4. If it is of interest to the study, sort the non-FLW material into categories, such as paper, plastic, metals, etc.

Step 5: Weigh and record the data

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

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

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

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

Step 6: Dispose of the waste samples

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

Step 7: Analyze the data

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

COMMON DATA CHALLENGES WHEN CONDUCTING A WASTE COMPOSITION ANALYSIS

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

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

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

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

ADDITIONAL RESOURCES FOR USING WASTE COMPOSITION ANALYSIS

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

Natural Resources Defense Council. 2017. *Estimating quantities and types of food waste at the city level*. **www.nrdc.org/sites/default/files/food-waste-city-level-report.pdf**.

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

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

Natural Resources Defense Council. 2017. *Estimating quantities and types of food waste at the city level: Technical appendices.* **https://assets.nrdc.org/sites/default/files/food-waste-city-level-technical-appendices.pdf**.

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FLW Protocol. 2016c. Chapter 5, "Records," in *Guidance on FLW quantification methods*. <http://flwprotocol.org/wp-content/uploads/2016/06/FLW_Guidance_Chapter5_Records.pdf>. Consulted 15 May 2018.

FLW Protocol. 2016d. Chapter 6, "Diaries," in *Guidance on FLW quantification methods*. <http://flwprotocol.org/wp-content/uploads/2016/06/FLW_Guidance_Chapter6_Diaries.pdf>. Consulted 15 May 2018.

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

FLW Protocol. 2016f. Chapter 8, "Mass balance," in *Guidance on FLW quantification methods*. <http://flwprotocol.org/wp-content/uploads/2016/06/FLW_Guidance_Chapter8_Mass_Balance.pdf>. Consulted 15 May 2018.

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WRAP. 2018. "Toolkit food waste diary." Waste and Resources Action Programme. <https://wrap.org.uk/resources/campaign-assets/toolkit-food-waste-diary>. Consulted 3 June 2018.

WRAP and WRI. 2018. Food waste atlas. Website. Washington DC: The Waste and Resources Action Programme and World Resources Institute. <https://thefoodwasteatlas.org/home>. Consulted 25 September 2018.

Zero Waste Scotland. 2015. *Guidance on the methodology for waste composition analysis: For local authorities commissioning waste composition analysis of municipal waste*. <www.zerowastescotland.org.uk/sites/default/files/WCAMethodology_Jun15.pdf>. Consulted 5 June 2018.

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