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Final Report

Quantification Study of Food Loss and Waste in Quebec

Analysis, Reporting and Benchmarking of Whole of Chain Food Loss and Waste and Related GHG Emissions

Québec without waste

RECYC-QUÉBEC
Québec

Acknowledgments

RECYC-QUÉBEC's mission is to lead Quebec to reduce, reuse, recycle and recover residual materials to promote a circular economy and fight against climate change.

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Glossary

This section defines key terms to ensure uniformity in the context and meaning conveyed in the English and French language versions of this report and in the terms used by the food loss and waste (FLW) researchers.

Term	Description
Associated non-edible parts (ANEP)	Referred to in the Food Loss and Waste Accounting and Reporting Standard as "inedible parts." Examples include animal bones, wheat chaff, and fruit and vegetable peelings (e.g. onions, avocado, and pineapple).
Carbon dioxide equivalent (CO_2E)	Standardized unit of measure used to convey the equivalent warming potential of any emission in relation to 1 tonne of carbon dioxide.
Households (Consumers' FLW)	Food loss and waste occurring at home (e.g. food preparation and plate wastes).
Distribution	Intermediaries who supply retail businesses and food services and who perform certain functions, such as storage, transport and product bundling (e.g. food wholesalers).
Edible food loss and waste (EFLW)	Any edible part of food intended for human consumption that is diverted, degraded, lost or discarded at any stage of the biofood system. Referred to in the Food Loss and Waste Accounting and Reporting Standard as "food that is not consumed."
Food loss and waste (FLW)	Edible food loss and waste + associated non-edible parts.
HRI	Hotels, restaurants and private or publicly owned institutions. Together they form the foodservice sector.
Greenhouse gases (GHG)	Any gas that, through the absorption of infrared radiation, contributes to the greenhouse gas warming effect of the atmosphere, including carbon dioxide, methane and nitrous oxide.

Term	Description
Manufacturing	Further processing of primary processed products into consumer foods that typically contain multiple ingredients. For example: animal carcasses into frozen entrees; flour, eggs and salt into bread; fruits, nuts, oats into granola.
Processing	The primary processing of commodities into foods purchased by consumers or food ingredients used in the further manufacturing of consumer foods. Examples of practices within this category include the grading and packaging of fruits and vegetables, and the processing of wheat into flour.
Production	Stage in which products from agriculture, fisheries, pisciculture and mariculture (cultivation of plants and marine species, mainly algae and mollusks) are grown, raised, caught, or harvested. For the purpose of this study, only those intended for human consumption were considered.
Recovery and redistribution	Process of recovering surplus edible food from across the supply chain and redistributing it to vulnerable populations who are food insecure.
Retail	Establishments that retail merchandise in small quantities, primarily to individuals or households. This activity can be carried out in-store or out-of-store (e.g. Internet).
Unavoidable	Expected to occur during the course of normal operations.
Unplanned	Not expected to occur during the course of normal operations.
Biofood system	The biofood system refers to the food supply chain, including agriculture, aquaculture, fisheries, processing and manufacturing, wholesale and retail trade, foodservices (in hotels, restaurants and institutional sectors), food recovery and redistribution, as well as consumers.

Executive Summary

The Food and Agricultural Organization of the United Nations estimates that one third of all food produced globally for human consumption is lost or wasted — the equivalent of about 1.3 billion tonnes annually. In Canada, an estimated 11.2 million tonnes of food that was edible at the time of or prior to its discarding by industry and consumers is lost and wasted annually. As part of Canada's commitment to achieving the United Nations Sustainable Development Goals (SDGs) by 2030, efforts are being made by governments and organizations across the country to prevent and reduce food loss and waste (FLW).

The Province of Quebec as a whole, along with jurisdictions like Ville de Montréal, has a history of being at the vanguard of implementing environmental initiatives, and is committed to reducing FLW and its associated environmental emissions. Understanding and measuring FLW is critical to establishing economically and environmentally sustainable biofood systems. The food industry is an important contributor to Quebec's economy. Addressing the root causes of FLW reduces food and associated wastes, resulting in improvements to the biofood industry's economic performance and lessening its impact on the environment can be achieved by establishing circular economy strategies. Such strategies prioritize the reduction of FLW at its source, followed by the donation, reuse and upcycling of foods.

The purpose of this study was not to apportion blame, nor to criticize, anyone or any organization. Its intention was rather to establish a robust detailed estimate of edible food loss and waste (EFLW) and associated non-edible parts (ANEP) in Quebec from a supply chain perspective. Policy makers can use research outcomes to guide the design and implementation of policies and programs relating to FLW reduction, environmental sustainability and social assistance programs addressing food insecurity issues. Academics and practitioners can utilize research findings in future studies. Businesses can refer to the information to make informed decisions.

The research encompassed the biofood system, from primary production through to the destination of EFLW and ANEP. The volumes and types of FLW were estimated at each discrete link in the supply chain. The CO_2E of FLW was then calculated for EFLW and ANEP at discrete levels of the chain. The impact of FLW destination on total CO_2E emissions was also quantified. With the exception of alcohol, the project included all foods and beverage ingredients (e.g. sugar in soft drinks) available for purchase by consumers in Quebec. Food exported from Quebec, including transhipments, were outside the scope of the study. The research and data limitations are presented in Section 2.1 of the report.

Using reference data for 2019, 7.5 million tonnes of commodities were estimated to enter Quebec's biofood system. Based on a population of 8.5 million, this equates to 2.43 kg per person per day. Of total inputs, 4.43 million tonnes are consumed and 3.12 million tonnes are discarded as EFLW and ANEP. EFLW represents 39 percent (1.2 million) of annual FLW. Fruits and vegetables account for 45.4 percent of EFLW. Field crops (e.g. bread, bakery and pasta) account for 24.4 percent of EFLW. The four remaining types of food together account for 30.1 percent of EFLW. Between 88 and 74.4 percent of food is purchased at retail for consumption in the home or another location; the remaining 12 to 25.6 percent of food is purchased in HRI. The effect that 88 versus 74.4 percent of food being purchased in retail has on daily per capita FLW is minor: 1.01 kg versus 1.0 kg, respectively.

The majority of industry respondents do not measure FLW. Among respondents who do monitor FLW, the gold standard for tracking FLW in distribution, retail and HRI is the scanning of barcodes to trace where loss and waste occur. This level of tracking is the exception, not the rule. Marginally, more respondents measure EFLW compared to ANEP; and marginally, more respondents are actively trying to reduce EFLW than are trying to actively reduce ANEP. These and other findings lead to two overarching insights: 1) businesses that measure FLW are largely measuring outcomes (they react to unexpected incidences versus proactively measuring operational performance); and 2) ANEP is typically viewed as a cost of doing business.

This attitude leads to there being less motivation to measure, monitor and reduce FLW. It also leads to businesses having less opportunity to improve performance by addressing operational inefficiencies as a result of imbedding FLW monitoring into their continual improvement programs. This contrasts with the financial opportunities that a large proportion of Quebec's food industry could attain by having implemented continual improvement programs and, in so doing, addressed inefficiencies associated with FLW.

Executive Summary

Given the above insights, it is perhaps not surprising that decision-centric management and human factors were identified as the most impactful of the relatively small number of drivers found to have a moderate to significant effect on the creation of FLW within the food industry. This includes retail and foodservice. Decision-centric drivers of FLW include incorrect forecasts, which were found to impact all levels of industry. Commonly associated with inaccurate forecasts are changed orders. The consequence of inaccurate forecasts and changed customer orders include increased inventory and storage losses — particularly in perishable products that cannot be frozen, such as fresh produce. Primary producers identified weather and how climate change negatively impacts their ability to control disease or pests as drivers of FLW. Other drivers associated with discrete points in the food system include the effect of hospital kitchens not being made aware of patients' allergies, treatment plans, food preferences, or discharge.

The most notable difference between the destinations of EFLW versus ANEP is the proportion of EFLW destined for landfill (47% vs 27% percent, respectively). Compared to ANEP, EFLW is almost twice as likely (81%) to be landfilled, and therefore not valorized by, for example, transforming it into animal feed or upcycling it into nutritional supplements. Sending EFLW to landfill does not require surplus edible food to be sorted or stored, onward logistics to be arranged, or employees to be paid to manage the process. Other reasons why more EFLW than ANEP is sent to landfill include: 1) businesses largely do not plan for EFLW to occur (they react to its occurrence by disposing of it in the cheapest, easiest and least risky way possible); 2) cross-contamination and non-compliance concerns do not apply to landfill; 3) food is often packaged (the de-packaging of food can be costly); and 4) there is a lack of composting and anaerobic digestion infrastructure and a lack of accessibility to collection services.

Of the 23 thousand tonnes of surplus edible food rescued for redistribution to vulnerable populations, an estimated 12 percent (2,798 tonnes) is lost. Respondents cited two overarching drivers that result in rescued food not being redistributed to vulnerable populations. The first is the lack of infrastructure and personnel required to receive, store and handle fresh and frozen products. The second driver is variability in quality and types of foods received. Establishing closer relationships with businesses would help them address these issues, though current and potential donors of surplus edible food are often reluctant to form such relationships due to the sensitivity of information pertaining to turnover and losses.

The intensity of CO_2E emissions associated with FLW differs by food type, where along the supply chain FLW is discarded, and its destination. The majority of CO_2E emissions are associated with the primary production of food that is subsequently lost or wasted. Destinations account for a relatively small proportion of FLW-related CO_2E emissions. In 2018, Quebec's total CO_2E emissions were estimated to be 80.1 million tonnes (IQEA, 2020). Excluding alcohol and exported foods, total annual CO_2E emissions associated with Quebec's biofood system – including all aspects of processing, distribution and consumption – is an estimated 20.2 million tonnes (6.5 kg per person per day). Of this, a total of 39 percent (7.9 million metric tonnes) is attributable to FLW. Of total FLW emissions, those related to EFLW and ANEP equate to 45 percent (~3.6 million tonnes) and 55 percent (~3.3 million tonnes), respectively.

The intensity of emissions associated with distinct types of food mean that meat and poultry represent a comparatively small proportion of total EFLW by volume (13.4%), though over half (56.8%) of EFLW CO_2E emissions. The effect of FLW and destination on total biofood system emissions equates to each 1 kg of food consumed, representing 4.55 kg in CO_2E emissions. The combined effects of reducing FLW (particularly that which is associated with GHG intense foods) through addressing at source, improved coordination between businesses, reductions in household FLW, donations of surplus edible food to address food insecurity, the upcycling or feeding to animals of by-products, along with not disposing of FLW in landfills or sewers, would measurably reduce CO_2E emissions associated with the biofood industry.

The report concludes by presenting two distinct opportunities to refine the quantification, enabling stakeholders to more accurately monitor and benchmark FLW and CO_2E associated emissions. The first is to quantify the volume and nature of EFLW and ANEP occurring in Quebec households. The second is to quantify the volume of FLW going to discrete destinations at an administrative region level.

1. Introduction

The Food and Agricultural Organization of the United Nations estimates that one third of all food produced globally for human consumption is lost or wasted – that is the equivalent of about 1.3 billion tonnes annually (Gustavsson et al., 2011). As part of Canada's commitment to achieving the United Nations Sustainable Development Goals (SDGs) by 2030, efforts are being made by governments and organizations across the country to prevent and reduce food loss and waste (FLW). The Province of Quebec as a whole, along with jurisdictions like Ville de Montréal, has a history of being at the vanguard of implementing environmental initiatives, and is committed to reducing FLW and its associated environmental emissions.

FLW significantly impacts the sustainability of Canada's food industry and has enormous social, economic and environmental consequences for communities, the country and the planet. Of the two forms of FLW – edible and associated non-edible parts – edible, in particular, constitutes the most inefficient use of natural resources. This report reflects RECYC-QUÉBEC's definitions of FLW:

- Edible FLW (EFLW) includes plate waste, spoiled food and food past the best before date.
- Associated non-edible parts (ANEP) includes animal bones, wheat chaff, and fruit and vegetable peelings.

"The Avoidable Crisis of Food Waste: Technical Report" (Gooch et al., 2019) analyzed the impacts of FLW and shed new light on the scale and implications of FLW in Canada. The national study estimated that 35.5 million metric tonnes (MMT) of FLW occurs annually in Canada, of which 11.2 MMT is potentially edible. Based on the cost of food at the time of the 2019 study, EFLW represented $49.5 billion or "51.8 percent of the money Canadians spent on food purchased from retail stores in 2016" (Gooch et al., 2019:5/6). The estimated carbon dioxide equivalent (CO_2E) of annual EFLW in Canada is 22.2 MMT (Gooch et al., 2019). The estimated blue water (volume of surface or groundwater used) footprint of Canada's EFLW equates to 1.4 billion metric tonnes.

The scale of these environmental impacts means that significantly reducing FLW is key to Canada meeting its commitment, by 2030, to reduce the total CO_2E emissions that occurred in 2015 by 28 percent (GC, 2018; CBC, 2018). Achieving these targets by decoupling FLW from economic development is also critical to Canada fulfilling its commitment to achieve its SDGs (Gooch et al., 2020).

As a follow-up to the national report, RECYC-QUÉBEC, in partnership with Ville de Montréal, commissioned Value Chain Management International (VCMI) to establish a robust detailed estimate of FLW from a whole of chain perspective — from production or catch to final destination (e.g. composting). The volumes, values and types of FLW occurring at each link in the biofood system (MAPAQ, 2018:95) have been estimated, along with the sources and destinations of FLW. Directing FLW to the most appropriate destination is another outcome of the project.

In addition, this evidence-based project quantified FLW and GHG emissions using an internationally recognized standardized unit of measurement – tonnes of FLW and carbon dioxide equivalent (CO_2E) – for reporting and benchmarking purposes. In using CO_2E, the framework provides a standardized means for reporting all forms of greenhouse gas (GHG) emissions (including carbon, methane and nitrous oxide) associated with food production and FLW.

The following report summarizes VCMI's analysis, reporting and benchmarking of whole of chain FLW and calculates FLW-related CO_2E emissions in Quebec.

1.1 Why Quantify FLW

The biofood industry is an important contributor to Quebec's and the wider Canadian economies. In 2019, the Quebec biofood industry generated $15.8 billion of gross domestic product (GDP). This represents just over four percent of the province's $377.8 billion GDP (MAPAQ, 2020; Statistics Canada, 2021a/b). When retail and foodservice are factored in, Quebec's total biofood-related GDP for the prior year (2018) stood at $29 billion. This is eight percent of the province's 2018 GDP (MAPAQ, 2019). Due to the concentration of production, processing and manufacturing facilities, Montreal and the region of Montérégie represent 48 percent of the province's food industry–related economic activity (Institut de la statistique du Québec, 2020). Population density in these areas result in a higher concentration of retail and foodservice – restaurants, education facilities and health care – than other regions of Quebec.

RECYC-QUÉBEC's definitions of FLW:

- Edible FLW (EFLW) includes plate waste, spoiled food and food past the best before date.
- Associated non-edible parts (ANEP) includes animal bones, wheat chaff, and inedible fruit and vegetable peelings.

Understanding and measuring FLW is critical to adopting and adapting management strategies for more productive and sustainable food production and operations. FLW represents enormous economic, environmental and social costs on individuals and society as a whole. Addressing the root causes of FLW measurably improves businesses' profitability (ENVIRO-STEWARDS, 2019a/b/c; VCMI, 2017; INCOME Consulting AK2C, 2016; Gooch & Felfel, 2014). Businesses can use outcomes described in this report to implement continual improvement programs to address inefficiencies and benefit their stakeholders.

In terms of the wider industry, RECYC-QUÉBEC and Ville de Montréal can use insights and capabilities that result from this study to design and implement tailored programs and policies targeted at motivating individual businesses to improve efficiencies. Policy makers can use the research outcomes to guide the design and implementation of policies and programs relating to FLW reduction, environmental sustainability and social assistance programs addressing food insecurity issues. Academics and practitioners can utilize the research findings in studies. Industry associations refer to the research outcomes to guide the creation of policies, programs and communications that lead to the creation of more innovative environmentally sustainable sectors than may otherwise occur.

1.2 Project Purpose and Objectives

The purpose of this study was not to apportion blame, nor to criticize, anyone or any organization. This project, conducted by VCMI, was designed to establish a robust detailed estimate of EFLW and ANEP in Quebec from a whole of chain perspective. The volumes, values and types of FLW were estimated at each link in the supply chain, as well as the sources and destinations of FLW. The CO_2E of FLW was then calculated — for overall FLW, for each level of the chain by food type, and for the impact of FLW destination on total GHG emissions. With the exception of alcohol, the project included all foods and beverage ingredients (e.g. sugar in soft drinks).

The analysis used primary and secondary data for the volume of Quebec's domestic food flows and FLW occurring in all foods at all levels of the supply chain, excluding household FLW. Household FLW was estimated by triangulating secondary provincial, national and regional data for FLW volumes. This included the characterization of waste in Quebec's municipal sector (Éco Entreprises Québec and RECYC-QUÉBEC, 2021), household food disappearance data from the national FLW study (Gooch et al., 2019), and the physical measurement of household FLW volumes for specific foods in Canada (incl. Gooch et al., 2020; Parizeau et al., 2014) and the United States (McDermott et al., 2018).

Standardized FLW metrics from a whole of chain perspective were used to produce detailed measures. Key performance indicators (KPIs) will help stakeholders benchmark FLW in Quebec, compare it to other jurisdictions, and benchmark the impact of changing FLW volumes and destinations (e.g. compost vs. landfill) on CO_2E emissions.

Total FLW and associated GHG emissions for the entire province were organized by Quebec's 17 administrative regions based on population size (see Section 6).

2. Scope and Methodology

This section concisely describes the methodology and methods used to estimate Quebec's FLW and associated GHG emissions. See appendices A and B for more details on research methodology and methods. The process of estimating FLW volumes ultimately began by quantifying the volume of food available for consumption via retail and HRI. FLW factors were subsequently applied to each level of the biofood system. The results were then used to estimate the overall CO_2E emissions that accumulate during the production, processing, manufacturing, transportation, distribution, selling, preparation, and consumption of food. The volume of food entering the Quebec food system was quantified, along with the estimated amount of CO_2E generated to produce that food, regardless of where the food was produced. Estimations of the CO_2E emissions associated with comparative volumes of FLW reaching discrete destinations were also produced. Section 5 describes results of the analysis of CO_2E emissions.

The analysis did not include food produced in Quebec for export outside of the province, and food imported into the province for onward exportation outside the province. Once food flows were established, the volume of EFLW and ANEP occurring at discrete points along the supply chain was estimated.

2.1 Research Limitations

The research described in this report was extensive, rigorous and robust. It estimated food flows and FLW in the context of Quebec, by triangulating results produced from analyzing an array of data from different sources to establish defensible estimates on 1) the volume of food flowing through the Quebec biofood system, 2) the volume of EFLW and ANEP attributable to Quebec's biofood system, 3) the destination of EFLW and ANEP that occurs in Quebec, and 4) the GHG emissions attributable to FLW.

The focus of the analysis was FLW related to food consumed in Quebec, regardless of its source. The study did not include food produced, processed or manufactured in Quebec and consumed outside of the province. This includes, for example, food that is imported as primary commodities (e.g. wheat and livestock) or as partially processed products (e.g. raw sugar and beef carcasses) before being transformed into consumer-ready products exported to another province or country.

The generality of some data sets limited the degree to which precise estimates could be produced by the research and analysis. Interprovincial trade data is inaccurate and reported in aggregated dollar values of generic commodities — not volumes of distinct products (BC Gov., 2021). In cases where provincial datasets did not exist, Canadian data (and sometimes data from elsewhere) were used to establish estimates for Quebec. This may affect the representativeness of the results for Quebec to some extent, which is difficult to assess.

Statistics Canada reports food availability as a total estimated volume, arrived at by combining USDA (2020) loss factors and assumed domestic losses to administrative Canadian production and import data. The monthly average retail prices for food, a consumer price index for food published by Statistics Canada (2021c), is national and does not take into account the actual proportions of food purchased by Canadians. Food availability estimates are not broken out by the retail versus HRI sectors. Publicly available data cannot therefore be used to precisely determine: 1) the proportion of food consumed within Quebec that is produced within the province versus elsewhere, and 2) the volume of food purchased by consumers from retail versus commercial HRI and non-commercial HRI. These limitations also forced VCMI to apply the same GHG emission factors to foods produced in Quebec and outside of the province.

The lack of accurate interprovincial trade data, and the fact that the majority of interprovincial commodity and food movement reports are in dollar value, not volumes, required the researchers to establish assumptions and test the robustness of hypotheses at key points throughout the research. Robust conclusions were arrived at by triangulating results produced by analyzing data gathered from different sources. The volume of EFLW and ANEP calculated to occur in Quebec's food industry was arrived at by applying loss factors acquired from industry surveys. Where insufficient data was provided by industry to enable robust FLW factors to be established, the researchers applied loss factors established during a national Canadian FLW study (Gooch et al., 2019). Many of the businesses that contributed to that study operate in Quebec.

As the loss factors used to estimate the volume and types of FLW occurring in Quebec were derived from self-reported surveys, it is possible that respondents underreported actual losses and waste figures. This means that the FLW volumes and associated CO_2E emissions presented in this report are likely conservative. As no definitive data exists on the comparative volume of food sold in retail versus the various forms of commercial and non-commercial foodservice that exist within the overall HRI sector, VCMI triangulated data captured from multiple sources to estimate the retail versus HRI split presented in the report. This triangulation process is described in Appendix A. The sample size used to estimate the proportion of total food volumes flowing through the commercial HRI sector was limited by the number of establishments that include food prices and weights in their online menus. Differences between the values and consequently volumes of food flowing through non-commercial HRI (e.g. hospitals and prisons) versus commercial HRI were based on assumptions derived from the analysis of secondary data and in consultation with food industry experts.

Primary research of household FLW was beyond the project's scope. The lack of an empirical study that measured household FLW in Quebec required the researchers to use research results produced outside the province. Household EFLW and ANEP were arrived at by applying loss factors captured by the measurement of household FLW completed in Oakville, Ontario (Gooch et al., 2020). Other household FLW measurement studies have been completed elsewhere in Canada and the United States; however, the Oakville research was the only North American study known to have produced empirical loss factors for both EFLW and ANEP in distinct types of food.

The distinction between EFLW and ANEP is partly subjective and determined by cultural norms. Some food parts can be considered edible by some people or in some context, while being considered non-edible by other people or in other contexts. Where industry respondents draw the line on edible versus inedible in self-reported data (including surveys) affects data and conclusions drawn from its analysis. The research's reliance on secondary household data from outside of Quebec affected the degree to which conclusions could be drawn on EFLW and ANEP occurring amongst consumers. A potential solution to this problem is to conduct a survey to establish edibility according to the cultural norm(s) in Quebec.

The estimation of GHG emissions associated with food production and FLW (reported as carbon dioxide equivalents: CO_2E) is an evolving discipline. While common standards exist for the measurement and reporting of CO_2E at an enterprise level (e.g. ISO, 2018), there can be considerable variability in the scope of analysis and assumptions that lie behind GHG estimates associated with food production, and therefore FLW (Meier et al., 2020; Helm, 2020; Peter et al., 2017; Broomfield, 2019). Every effort was made to ensure that the GHG emission factors used to calculate CO_2E volumes associated with FLW occurring at discrete level of the biofood system and its destination were sourced from studies that utilized complementary research methodologies. Wherever possible, CO_2E emission factors produced by North American meta-analysis studies were triangulated against Quebec-specific estimates. GHG emission factors associated with packaging (whether primary, secondary or tertiary) were beyond the scope of the analysis. It should also be noted that, due to data limitations, regardless of where food was produced, the intensity of CO_2E emissions associated with the production of food and used in the analysis do not differ. See Appendix B for details on the main hypothesis used to estimate CO_2E emissions.

The extent to which conclusions produced by the research results described in this report can be directly compared to conclusions produced by the analysis of FLW in the national study (Gooch et al., 2019) are limited. This is because the lack of quantitative data on interprovincial trade and the porosity of the data that does exist forced the researchers to adopt a different methodology to that used to establish the national FLW estimates. For the 2019 national FLW study, food input volume for 2016 was determined, FLW was surveyed along the supply chain, and then the amount of available food per person/day was calculated. In this study, the estimation of food flows and FLW began in reverse. An estimate of the amount of food per person flowing into retail and foodservice was established first, to which FLW factors derived from the analysis of primary survey and secondary data were applied to calculate the volumes, types and sources of EFLW and ANEP associated with Quebec's biofood system. These and other methodological differences are explained in more detail in Appendix A.

Finally, in an attempt to ensure that the surveys could be equally understood by respondents in English and French, and that the reporting reflects globally accepted FLW accounting standards, some of the results are presented differently to what respondents saw when completing the survey. For example, what was termed "post-production losses" and "production losses" in primary producer surveys, and termed "unplanned losses" and "unavoidable losses" in industry surveys, are respectively termed EFLW and ANEP in the report. In some cases, this may affect the preciseness of EFLW and ANEP volumes reported for distinct types of food at discrete points in the biofood system. It does not affect overall FLW volumes. Every effort was made to capture and analyze data from 2019 (pre-pandemic) perspectives. The enormous effect that the COVID-19 crisis has had on Quebec's biofood industry may, however, have influenced the primary data captured from the surveys and interviews.

2.2 Scope

The sources of FLW considered for this research included:

- Food in Quebec that was produced domestically or imported (within Canada or internationally), and consumed in Quebec
- All types of foods including tertiary (land based) and marine
- All levels of the food chain: production to consumer including food rescue/redistribution to vulnerable populations
- Domestic production: food that is processed, further manufactured and distributed, and consumed in Quebec
- External production: food imported into Quebec before processing and/or further manufacturing, or as finished goods that are distributed and consumed in Quebec

The sources of FLW not considered for this research included:

- Alcohol
- Food produced and/or processed in Quebec for export to other areas of Canada or internationally

Reasons alcoholic beverages were not included in the FLW calculations include the limited data available on interprovincial trade, and the fact that existing data is reported in value and not by volume. In addition:

1. Alcoholic beverages are not a significant contributor to EFLW and ANEP, and Quebec as a province is not a major producer.
2. The volume of commodities from which alcoholic beverages are produced represent a small proportion of total production. For example, approximately six percent of barley is malted and two percent of corn is distilled.
3. Losses of the end product (wine, beer, liquor) would be minimal. There may be slightly more waste in hotels, restaurants and institutions (HRI) where catering is involved, but these events would be minimal compared to the amount consumed in restaurants, bars and the home.

2.3 Methodology

Beyond the limited data available to establish food flows and volumes within a jurisdiction with opaque borders, two additional factors caused the researchers to make significant modifications to the methodology used in the national FLW study. These are: 1) the Quebec estimate reflects a subset of the Canadian food industry, and 2) the Quebec estimate includes FLW and CO_2E emissions. Considerations that informed the revision of the research methodology from that employed to complete the national 2019 study are summarized below and expanded upon in Appendix A.

2.3.1 Inputs that shaped the final methodology

Several sources guided the revision of the methodology used to estimate Canadian FLW at a national level. They included lessons learned and insights gained during the 2019 national FLW study, intellectual property and methodologies used by VCMI in prior research over the last decade in Canada and internationally, as well as guidance provided by RECYC-QUÉBEC and Ville de Montréal.

The following research methods were used.

Value chain analysis (VCA): The drivers of FLW and the FLW that results from those drivers often occur at different points along the supply chain. The VCA process begins by triangulating[1] qualitative and quantitative data captured from multiple primary and secondary sources to estimate food flows — and then developing a hypothesis regarding the comparative impact of factors influencing those flows. Estimations of FLW volumes, and the comparative effect of intra- and inter-organizational drivers on the creation of FLW occurring at specific points along the supply chain, along with the ultimate destinations of FLW, are then developed and refined as new information emerges.

Connecting commodities to foods: This approach was established in the national FLW study (see page 21 of "The Avoidable Crisis of Food Waste: Technical Report") to enable all primary foods (tertiary and marine) to be connected to consumer products.

Mass balance: This method accounts for what volumes enter and exit a system, and where. An initial landscape of food flows was established through triangulation of secondary and primary data on food volumes and values, and associated GHG footprints. FLW estimates for each food type and discrete level of the chain were established by applying loss factors deduced from the analysis of primary data captured through online surveys completed by industry respondents. Many of the same industry respondents subsequently participated in interviews, which tested the hypothesis developed during the initial analysis and informed overall conclusions drawn from the study.

GHG emissions: Representative CO_2E footprints were established for each type of food and the impact of physical factors on total emissions. The most important physical factors include food origin stages in the supply chain (production and downstream, including households), and transportation (distance and mode).

2.3.2 Connecting commodities to foods and beverages

The ability to conduct the whole of chain analysis of foods and FLW, and in so doing establish mass balance estimates for food and FLW, rests on drawing distinct relationships between commodities produced by primary industry (incl. farm, greenhouse, wild catch marine and aquaculture) and products consumed. With the exception of alcohol, for reasons presented in Section 2.1, the categorization of commodities and food/beverages products consumed matched that which was established during the national analysis of FLW and is presented in Table 2-1.

Table 2-1: Connecting Commodities to Consumer Foods and Beverages

Category	Dairy and eggs	Field crops	Produce	Meat and poultry	Marine	Sugars and syrups
Consumer products incl. (examples)	• Eggs • Liquid milk • Cream • Yogurt • Cheese • Butter	• Bread • Baked goods • Cereal • Soymilk • Vegetable oils	• Fresh fruits and vegetables (F+V) • Processed F+V • Nuts • Chocolate • Fruit juices • Coffee • Tea	• Fresh cuts • Primal cuts • Processed meats • Entrees	• Fresh fish • Processed fish • Fillets • Shellfish • Entrees	• Maple syrup • Sugar • Honey • Soft drinks
Crops/inputs (examples)	• Milk: cows, goats, sheep • Eggs: broiler hens	• Wheat • Soybeans • Barley • Durum • Oats • Canola • Flaxseed • Beans	• Root crops • Tree fruits • Berries • Greenhouse • Leafy greens • Hardy greens • Nuts • Sweetcorn	• Livestock • Poultry	• Sea fish • Freshwater fish • Seafood	• Maple trees • Sugar beet • Apiaries • Corn

Source: Modified from Gooch et al., 2019

1 The term triangulation describes the process of comparing data captured from different sources to ensure, by having established a trail of evidence, that conclusions drawn from the analysis of data are robust and not biased in favour of an incorrect hypothesis.

While the categorization of commodities and end products presented above is most convenient for products that are consumed fresh (e.g. fruits, vegetables, liquid milk) or following minimal processing (e.g. cheese, cereal, primal cuts of meat, sugar), the above categorization also works for further processed products. Knowing the comparative percentage of commodities contained in further processed foods (e.g. baked goods, frozen entrees), (Gooch et al., 2019), makes it possible to measure and monitor FLW from the primary production of commodities from which they are derived through to the destination of EFLW and ANEP.

2.3.3 Sources of primary food flow and FLW data

Information for the FLW estimate was gathered by conducting 453 surveys and subsequent 29 follow-up interviews with Quebec's food industry, including redistribution. The interviews were used to verify survey responses, test the hypotheses developed by analyzing survey responses, and gather more clarity on the causes and impact of FLW. Interviews provided additional insight into the level of FLW (for specific foods) occurring within various sectors and across the supply chain as a whole.

Table 2-2 breaks down the responses by sector. Within each sector of the food chain, responses were further segmented. For example, responses within HRI include restaurants, hospitals, schools, universities, and long-term care facilities. The depth of insight assisted the development of loss factors that were then applied to flow estimates from analyzing secondary data. Some responses relate to numerous locations (e.g. major retailers and sectoral associations).

Table 2-2: Survey Respondents by Sector

	Survey	Interviews
Production	66	7
Processing/manufacturing	44	6
Distribution	15	4
Retail	72	2
HRI	248	8
Rescue/redistribution	8	2
TOTAL RESPONSES	**453**	**29**

2.3.4 Sources of secondary food flow and household FLW data

Summarized below is the extensive list of secondary sources of data and information consulted during the research to establish 1) 2019 food flows and triangulate these against primary data during the development of FLW factors from which estimates for EFLW and ANEP were derived, and 2) the comparative volume of total FLW that reaches distinct destinations. The bibliography (Section 8) contains a detailed list of food flow and FLW literature consulted during the study.

- Public sources of data and information included the Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ), Statistics Canada, Port of Montreal, and food industry reports
- Customized data provided by Agriculture and Agri-Food Canada and MAPAQ
- Household FLW studies completed by VCMI, ReFED, Canadian and American universities, and government agencies
- Municipal waste characterization conducted by Éco Entreprises Québec and RECYC-QUÉBEC

2.3.5 Retail versus HRI food flows

The analysis of secondary data identified that between 88 and 74.4 percent of food is purchased at retail for consumption in the home or another location; for example, school or office. See Appendix A for more information. The estimate of 88 percent is based on a quantitative analysis of the value of food purchased in retail versus HRI. The 74.4 percent estimate is based on analysis of the wholesale value of food purchased by HRI and retail triangulated with total value of food available for consumption in Quebec. The latter estimate assumes food wholesale prices paid by retail and HRI operators are the same. Numerous consultations with industry experts identified this is not the case. Considerable variability exists in the prices paid between businesses operating in the retail versus HRI sectors, and within those same sectors. This and higher distribution costs result in much of the HRI industry paying higher prices. We assume that reality may lie somewhere in between.

2.3.6 Sources of secondary GHG (CO_2E) data

The means to estimate GHG emissions (reported as carbon dioxide equivalents: CO_2E) associated with food production, food consumption and FLW are evolving. With no agreed standard on how to measure, estimate and report food and FLW-related CO_2E, the primary focus of the literature review pertained to life cycle analysis, which reported CO_2E for a specific volume of food produced at distinct points in the supply chain. Literature on comparative CO_2E emissions associated with specific destinations of FLW was also consulted and expert scientific advice sought.

The bibliography (Section 8) contains a detailed list of GHG literature consulted during the study. This literature included life cycle analysis studies that encompassed an estimation of nitrous oxide emissions associated with plant and animal production, along with carbon and methane — together reported as CO_2E. The sources of such studies included Ville de Montréall, ReFED, Canadian and American universities, and government agencies.

3. Research Findings

This section describes Quebec's food flows and the estimated volumes and types of FLW at discrete points along the supply chain. The findings also describe the estimated volume quantities of surplus edible food successfully redistributed to vulnerable populations instead of going to waste. It also estimates FLW redirected to animal feed, thus preventing their recycling or disposal.

3.1 FLW Estimates: Annual Tonnage and Value

FLW factors for each sector and food type (Table 3-1) were derived by analyzing industry responses to the online survey and from interview transcripts. The null hypothesis was that the FLW percentage in the national FLW study (Gooch et al., 2019) remained unchanged unless the percentage provided by survey respondents was statically different, using a sample >5 and a 2 sample t test. An interview backed up the analysis. Quebec is more self-sufficient in certain foods; therefore, particular attention was paid to establishing the mass balance from production to consumption of dairy, eggs, poultry, pork, and produce.

3.1.1 Household FLW: triangulation of secondary data

The research estimates the average weekly FLW is 4.01 kg per household per week. This falls in the range (3.22 to 4.41 kg per household per week) of estimates provided by quantitative household FLW measurement studies conducted in Canada (e.g. Gooch et al., 2020; von Massow et al., 2019; Parizeau et al., 2014) and the United States (McDermott et al., 2018).

3.1.2 FLW estimates: annual tonnage and value (mass balance)

Mass balance is a calculation of all the food that enters Quebec's food chain and all that leaves. Based on 8.5 million residents (Institut de la statistique du Québec, 2021), the following estimations were used to calculate mass balance:

- Total food that entered the Quebec supply chain in 2019 = 7.5 million tonnes
  - Equates to 2.43 kg per capita per day
- Total volume of EFLW and ANEP that occurs annually in Quebec = 3.1 million tonnes
  - Equates to 1.01 kg per capita per day

Table 3-1 provides an estimate of the overall FLW by food type along the food supply chain from production to consumption. Within each segment of the chain, EFLW and ANEP are listed. The extensive data analysis, inference and triangulation efforts employed to produce the loss factors that enabled the estimates presented below to be calculated are described in Appendix A, Section 9.3.

7.5 million tonnes of food entered the Quebec supply chain in 2019 of which 3,1 million tonnes were discarded as EFLW and ANEP.

Table 3-1: Estimated FLW Along the Supply Chain (Metric Tonnes)

	Production		Processing		Manufacturing		Distribu-tion	Retail	Consumer (HH)		HRI		Total FLW occurring along the food value chain	Losses (%) occurring during rescue and redistribution
Food type	**EFLW**	**ANEP**	**EFLW**	**ANEP**	**EFLW**	**ANEP**	**EFLW**	**EFLW**	**EFLW**	**ANEP**	**ANEP**	**ANEP**		
Dairy and eggs	8,917	8,458	16,660	486,416	-	-	13,212	45,427	51,352	51,352	8,186	9,649	699,628	6,5%
Field crops	100,807	66,321	66,972	334,860	18,093	29,182	7,291	28,265	74,865	9,253	5,483	4,824	746,216	14,2%
Produce	62,867	67,856	73,830	25,326	6,236	7,796	77,225	153,812	137,569	320,994	32,960	32,960	999,430	22,5%
Meat and poultry	-	-	48,662	352,233	13,721	34,302	14,717	36,298	41,343	27,562	6,577	6,334	581,748	11,5%
Marine	182	1,387	5,112	5,112	81	81	3,224	4,139	3,925	2,406	692	887	27,225	8,0%
Sugars and syrups	1,376	1,383	2,711	2,711	1,107	1,107	2,662	5,033	30,145	19,273	1,233	980	69,722	6,8%
Total	174,149	145,404	213,946	1,206,657	39,238	72,468	118,330	272,975	339,198	430,839	55,131	55,634	3,123,969	
Rescue and redistribution	- 4,730					- 12,337	- 481	- 5,090	-	-	- 677		- 23,315	
Est. FLW at redistribution													2,798	
TOTAL FLW	**169,420**	**145,404**	**201,609**	**1,206,657**	**39,238**	**72,468**	**117,850**	**267,885**	**339,198**	**430,839**	**54,454**	**55,634**	**3,103,452**	

The total annual tonnage of FLW along the chain, including households though excluding food rescue and redistribution, is 3.1 MMT. By food type, the highest volume of total FLW occurs in produce (fruits, vegetables), followed by field crops (grains, corn, oilseeds, etc.), then dairy and eggs. The lowest total volume of FLW occurs in marine (fish, seafood, etc.). For each of the six food types, the remainder of Section 3.1 summarizes the percentage of total inputs that FLW represents, with the comparative composition of EFLW versus ANEP in relation to total FLW, and from where along the biofood system comparative volumes of EFLW versus ANEP emanate. For reasons detailed in Appendix A, Section 9.3, FLW data was not sought for livestock and poultry production.

Based on 88 percent of food flowing through retail and 12 percent of food flowing through HRI, on an individual basis, the estimated weekly potential EFLW occurring in households is 1.74 kg per person per week (4.01 kg/household/week). If 25.6 percent of food goes through HRI, household FLW is lower (1.47 kg/person/week, 3.39 kg/household/week).

It is worth noting that the effect of 12 percent versus 25.6 percent of food being distributed and consumed in HRI (versus distributed via retail and consumed by households) on total per person FLW is just 0.01 kg per person per day.

Table 3-2 shows that total FLW equates to 41 percent of total food inputs. The analysis of survey responses and secondary household FLW data indicates that 39 percent is EFLW.

Table 3-2: Quebec Food System Overview

	Million tonnes	Percent of food inputs	Percent of total FLW
System inputs	7.5		
Food consumed	4.4	59%	
Total FLW	**3.1**	**41%**	
EFLW	1.2	16%	39%
ANEP	1.9	25%	61%

Based on 88 percent of food flowing through retail, the percentage of total EFLW and ANEP that occurs along the chain for each of the six aggregated types of food, as a proportion of food entering Quebec's food system, is presented in Figure 3-1.

Figure 3-1: Percentage of Total FLW, EFLW and ANEP in Proportion to Foods Entering Food System

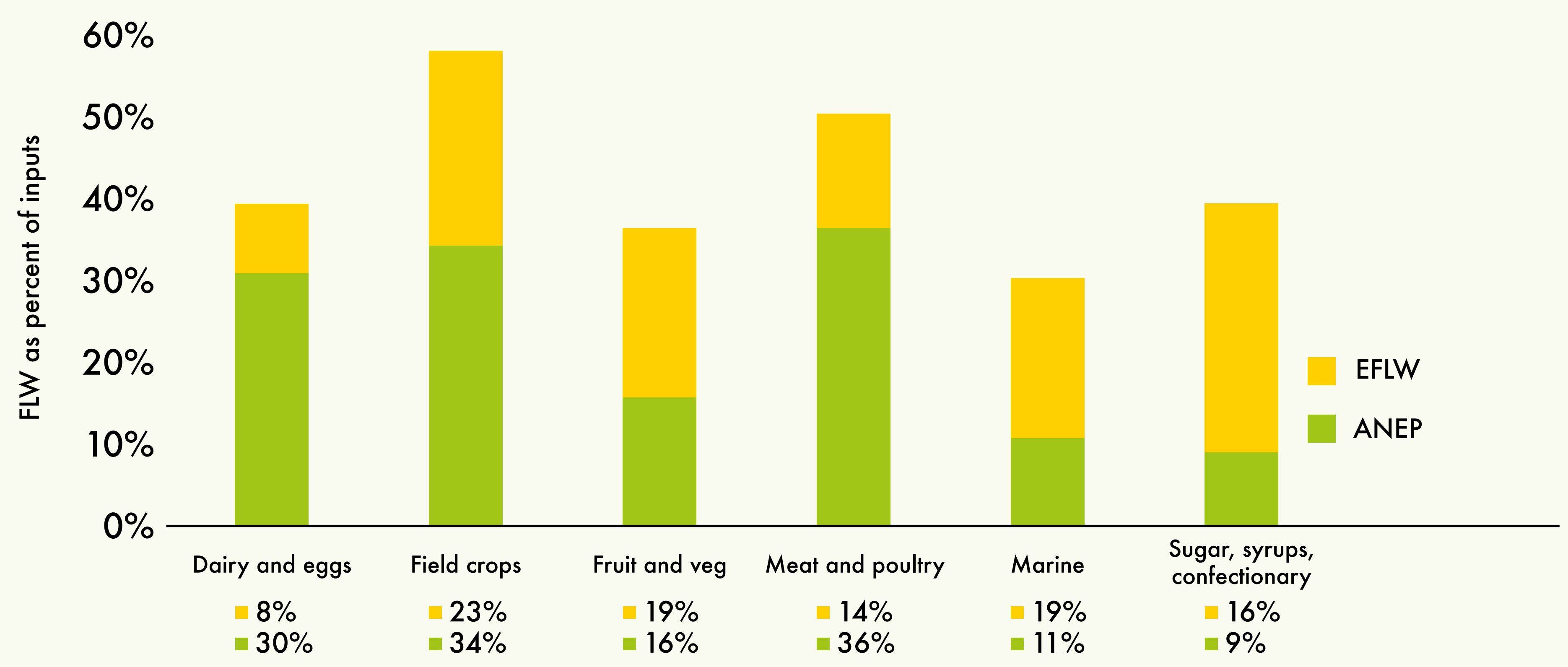
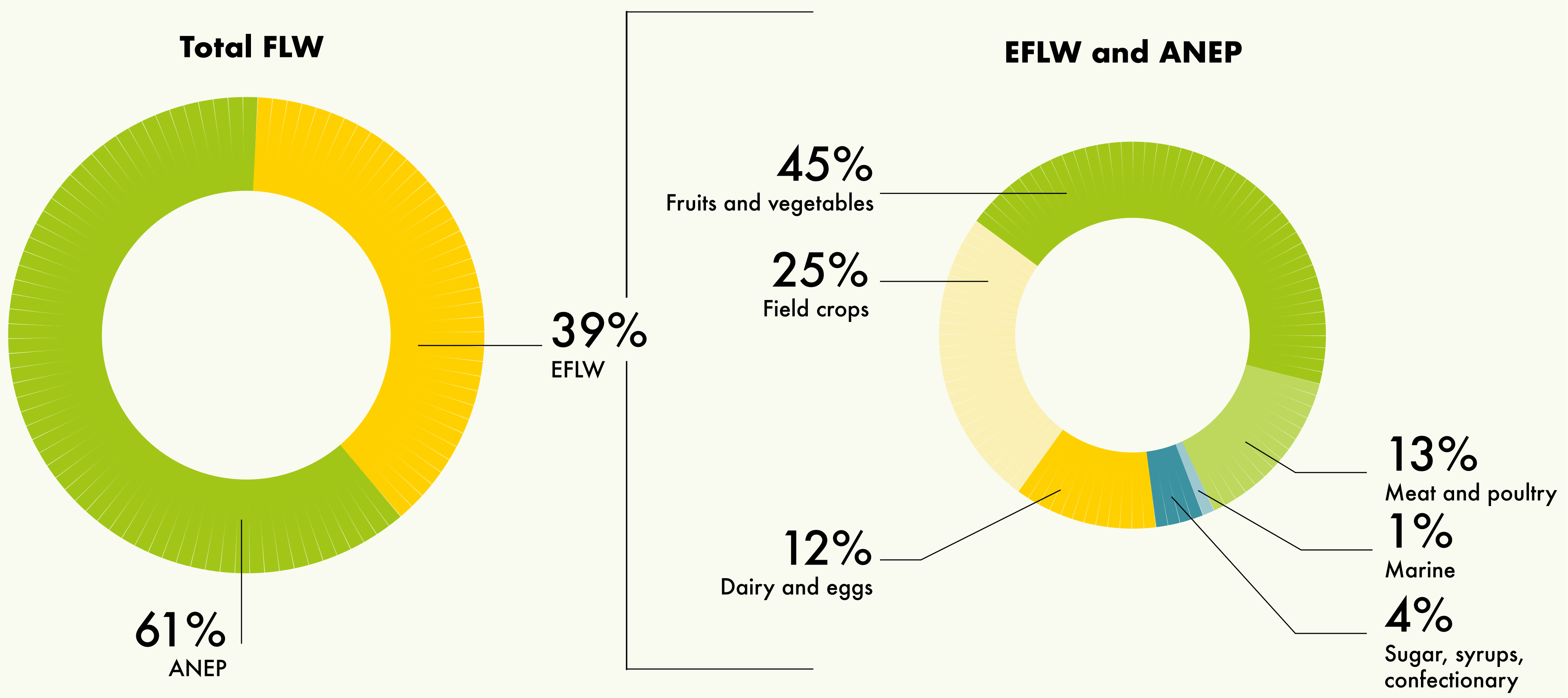


Figure 3-2: EFLW and ANEP as Proportion of Total FLW



As can be seen, the highest percentage of ANEP as a proportion of each type of food entering Quebec's food system occurs in meat and poultry, followed by field crops. The highest proportion of ANEP as a percentage of total FLW occurs in dairy and eggs. The highest proportion of EFLW as a percentage of total FLW for that food type occurs in marine, followed by sugars, syrups/confectionary, then fruits and vegetables, then field crops (bakery, pasta, rice, etc.). ANEP in meat and poultry is primarily eviscerated losses during the harvesting of livestock, along with skin and bones. The comparatively high percentage of ANEP occurring in dairy and eggs can largely be attributed to the liquid lost during the manufacture of dairy products — most notably cheese. In field crops, significant ANEP occurs during the milling of grains and crushing of oilseed.

The proportion of total FLW represented by EFLW and ANEP is shown in Figure 3-2. As shown, EFLW represents 39 percent of total FLW. Fruits and vegetables, followed by field crops (e.g. bread, bakery and pasta), represent the largest proportion of EFLW: 45.4 and 24.4 percent, respectively. The four remaining types of food together account for 30.1 percent of EFLW.

While reductions in EFLW would enable reductions in ANEP, due to fewer inputs having to be processed to meet market demands, the findings presented above emphasize why ANEP is generally considered unavoidable. It will occur during the production, processing, manufacture, and preparation of food that is consumed. Businesses therefore factor the management of ANEP into their operational plans. On the other hand, EFLW is avoidable and largely unplanned.

Shown below in figures 3-3 and 3-4 is the volume and percentage of total FLW and EFLW that occurs at discrete links along the supply chain (incl. production, processing, retail, and HRI).

3.2 Analysis of Overall FLW Findings

Businesses along the supply chain and within different sectors of the food industry actively measure EFLW and ANEP in different ways and to varying degrees. As a result, consistency of FLW data and differing attitudes towards FLW may impact the inclination and capacity of businesses to reduce FLW.

Table 3-3 shows the number of survey respondents along the supply chain (including sector/food type, where appropriate) who reported that they measure or estimate EFLW and ANEP.

Fruits and vegetables, followed by field crops (e.g. bread, bakery and pasta), represent the largest proportion of EFLW.

Figure 3-3: Tonnage and Percentage of Total FLW

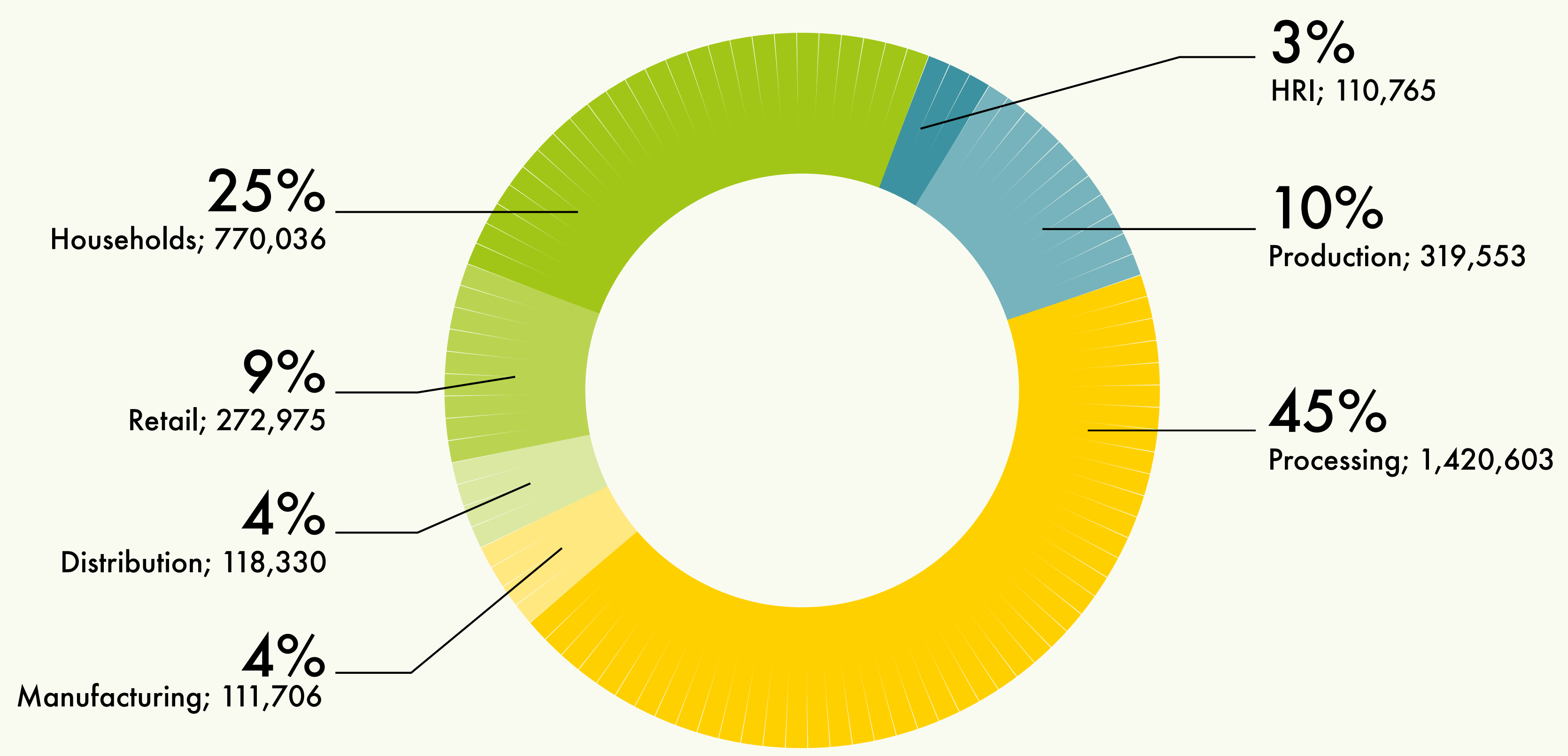


Figure 3-4: Tonnage and Percentage of EFLW

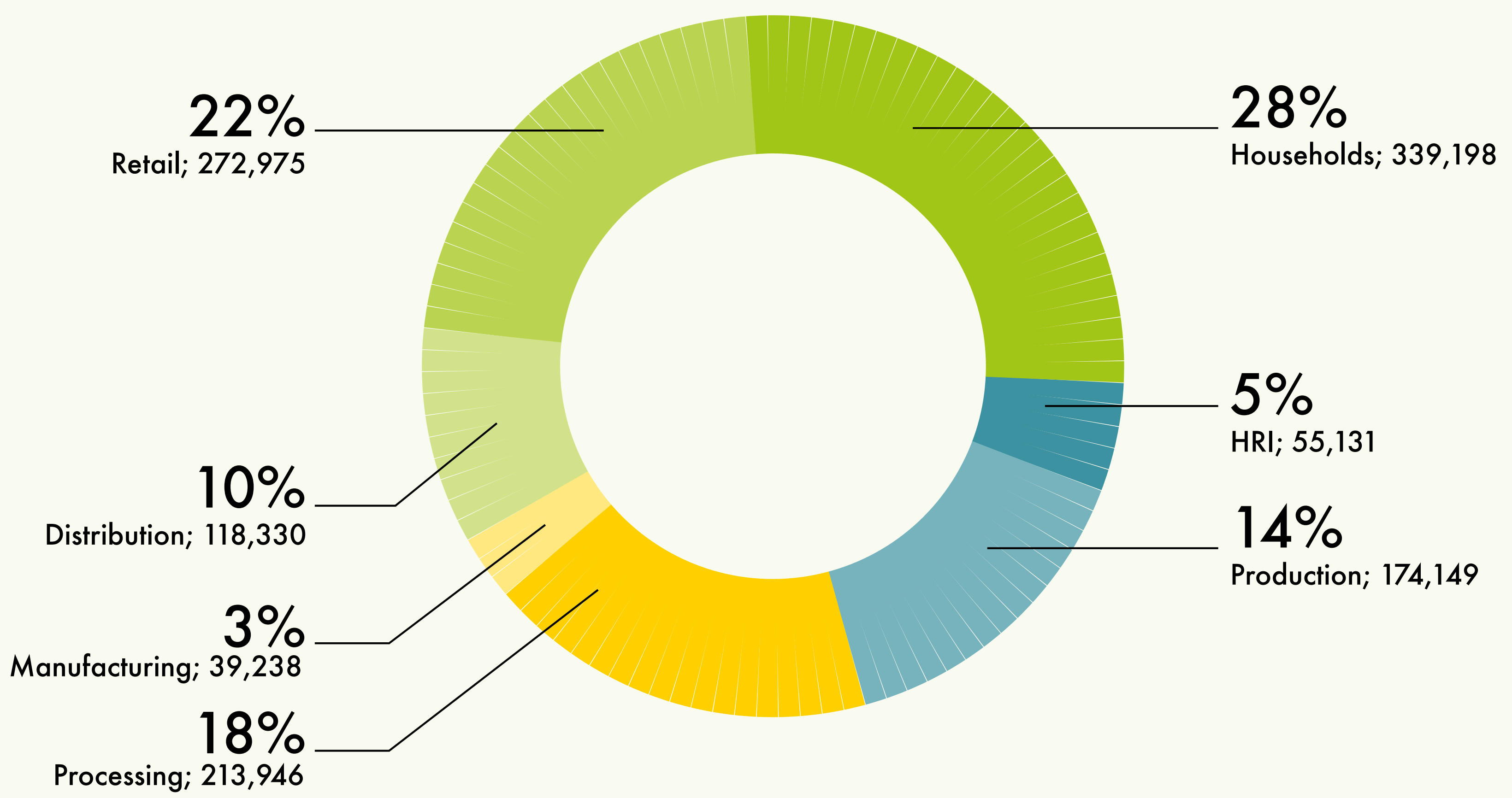


Table 3-3: Survey Respondents Who Measured or Estimated FLW

Industry sector	FLW measurement						
	EFLW (post-production*)			ANEP (production**)			Total Respondents***
	Measured	Estimated	NA	Measured	Estimated	NA	
Dairy producers*	4	9	12	3	18	4	25
Eggs for consumption*		2	1	1	1	1	3
Field crop producers*		3	2		3	2	5
Fruit and vegetable producers*	3	8	6	1	11	5	17
Marine producers*	1	3	2	1	4	1	6
Maple syrup / sugar production					1		1
Production TOTAL	**8**	**25**	**23**	**6**	**38**	**13**	**57^**
Processing		8	5		9	4	13
Manufacturing	2	25	4	4	23	4	31
Processing and manufacturing TOTAL	2	33	9	4	32	8	44
Distribution	2	9	4	0	0†	15	15
HRI	8	134	106	4	141	103	248
Retail	5	61	6	0	0†	72	72
Rescue /redistribution	3	3	2	2	5	1	8
GRAND TOTAL	**28**	**265**	**150**	**22**	**287**	**135**	**444**
% of total	6.3%	59.8%	33.9%	5.0%	64.8%	30.5%	100%

* The loss and waste of edible food typically occurs after its production/processing/manufacturing.

** The loss and waste of associated non-edible parts typically occurs during its production/processing/manufacturing.

*** Small number of respondents represented an entire sector (e.g. a segment of the processing industry or sectoral associations), while others represented one location (e.g. a farm or food distributor).

^ The nine livestock and poultry producers who responded to surveys were not asked questions regarding FLW.

† Reflecting respondents' confusion regarding the difference between EFLW and ANEP, no conclusive results could be derived from the analysis of distribution and retailer respondents' data for ANEP.

Survey results indicate that the majority of respondents do not measure FLW. Most respondents said they estimate losses, but do not have practical measurement tools. A further indication of the general lack of FLW measurement and benchmarking among respondents was the degree to which a number of post-survey interviewees appeared to rely on confirmation bias. Because they had no other point of reference for whether their estimations were correct, or whether they were measuring correctly, they asked the interviewer if their estimations appeared valid.

It is worth noting that one post-survey interviewee indicated that the act of weighing FLW had resulted in less waste, even though they did not change any practices to address FLW. The act of proving to workers that unnecessary FLW was occurring had, by itself, caused changes to occur in workers' behaviour. This in turn led to a reduction in FLW.

Among respondents, the gold standard for tracking FLW is in finished products — where distribution, retail and HRI use barcode scanning to trace where loss and waste occur. This level of tracking is, however, the exception, not the rule. It commonly occurs in professionally run logistics companies in many different sectors, but appears to be less common in the food industry.

Marginally, more respondents measure EFLW compared to ANEP; and marginally, more respondents are actively trying to reduce EFLW than are trying to actively reduce ANEP. As a percentage of respondents, the analysis showed there is no difference in the measurement nor effort to reduce FLW at discrete points along the supply chain. This is in contrast to the 2019 national study, which identified that businesses operating closer to consumption (e.g. distributors, retailers) were considerably more likely to measure and proactively seek to reduce FLW than those operating closer to production (e.g. farmers, food processors).

Two overarching insights were drawn from the analysis of survey responses and the subsequent interviews.
These are:

1. Those respondents that measure FLW are largely measuring outcomes. They react to unexpected incidences versus proactively measuring operational performance. The small number of respondents who measure FLW as part of their continual improvement initiatives are the exception, not the norm.
2. ANEP is typically viewed as a cost of doing business. This attitude leads to there being less motivation to measure, monitor and reduce. Consequently, businesses have less opportunity to improve performance by addressing operational inefficiencies.

These findings strengthen the assumption that the FLW measurement, monitoring and remedial processes that do exist are not embedded into operational systems. Instead, it is more likely that incidences of EFLW (or particularly noticeable incidents of production or processing losses perceived unavoidable) are monitored and reported ad hoc when they occur. Quebec's food industry therefore appears to be missing opportunities to improve performance by addressing the range of inefficiencies associated with FLW.

FLW measurement, monitoring and remedial processes that do exist are not embedded into operational systems. Quebec's food industry therefore appears to be missing opportunities to improve performance by addressing the range of inefficiencies associated with FLW.

4. Drivers and Destinations of FLW

The following section describes the key drivers of FLW identified by the research and the impact that certain drivers can have on the final destination of FLW. For each link in the supply chain (and sector/food type, where appropriate), the drivers (causal factors) of EFLW and ANEP loss were identified by analyzing survey and interview data. Respondents were asked to rate the impact, on a scale of 1 to 5 (1 = minor impact; 3 = moderate impact; 5 = significant impact), of specific drivers on distinct types of FLW occurring within their business. Respondents were also asked to ignore any drivers that were irrelevant to them. Specific drivers contained in the survey were based on prior research findings (Gooch et al., 2019; ReFED, 2020a; CEC, 2019; ReFED, 2016) and in consultation with representatives from Quebec's food industry.

While efforts were made to differentiate between the drivers of EFLW and ANEP, that level of analysis could not be completed for the following reasons. The analysis and early reporting of survey and interview data identified that the majority of respondents typically 1) do not explicitly differentiate the causes of EFLW and those of ANEP, and 2) view ANEP as a cost of doing business. Amongst respondents there also appears to exist a general misunderstanding of the differences between EFLW and ANEP, often termed “avoidable” and “unavoidable,” respectively.

This results in businesses having limited motivation to identify causes, and little data to enable correlations to be established between the incidence of different forms of FLW and its cause. This is particularly the case in instances where respondents deem FLW as unavoidable. This important finding highlights that, with few exceptions, respondents have not embedded continual improvement initiatives into their daily management monitoring systems, and therefore businesses have less opportunity to improve performance by addressing operational inefficiencies.

4.1 Key Drivers of FLW

The analysis of survey and interview data identified that a relatively small number of drivers are viewed by respondents as having a moderate to significant effect on the creation of FLW. Certain drivers of FLW were detected as affecting a large proportion of the food industry, whereas others as only affecting one or two of its segments. As a small number of respondents represented an entire sector (e.g. a segment of the processing industry or sectoral associations), while others represented one location (e.g. a farm or food distributor), the effect of each driver described below may not be equally representative of all organizations handling a certain type of food or operating in a specific segment of the biofood system.

The most impactful drivers of FLW were identified to be decision-centric managerial factors, the effects of which can be exacerbated by dysfunctional supplier/customer relationships (Gooch et al., 2019; Devin & Richards, 2018; ReFED, 2016; Gooch, 2010). The impact of inaccurate forecasts on driving FLW was identified by all levels of the food industry. This includes 37 percent of dairy producers, 25 percent of processors, 10 percent of manufacturers, 27 percent of distributors, 25 percent of retailers, and 21 percent of HRI respondents. As identified by multiple researchers, including Gooch et al. (2019), Barrat (2004) and Lee et al. (1997), inaccurate forecasts create supply chain imbalances that can lead to significant waste. Commonly associated with inaccurate forecasts are changed orders. Thirty percent of processors, 20 percent of manufacturers and 20 percent of distributors who responded to the survey stated changed orders as key drivers of FLW. The consequence of inaccurate forecasts and changed customer orders include increased inventory and storage losses — particularly in perishable products that cannot be frozen, such as fresh produce.

An underlying driver of both inaccurate forecasts and changed orders is the adversarial business relationships that typify much of the food industry (Gooch et al., 2019; Devin & Richards, 2018; ReFED, 2016; Gooch, 2012; Gooch, 2010). Interestingly, two food industry experts consulted during the analysis and interpretation of research results commented on how the Quebec food industry is typified by less dysfunctional relationships than other regions of Canada. The existence of more collegial and functional relationships, they said, stems in part from Quebec's food industry being comprised of smaller businesses, which are treated better by retailers due to Quebec consumers' preference for local products. These insights may partly explain why neither survey respondents nor interviewees cited inaccurate forecasts and changed orders as driving FLW to the same degree as identified in the national FLW study completed by Gooch et al. (2019) and elsewhere by, for example, Devin & Richards (2018) and ReFED (2016).

The impact of inaccurate forecasts on driving FLW was identified by all levels of the food industry. The consequence of inaccurate forecasts and changed customer orders include increased inventory and storage losses — particularly in perishable products that cannot be frozen, such as fresh produce.

Examples provided by interviewees of how incorrect forecasts and, subsequently, changed orders lead to FLW in Quebec included a processor whose customer directed them to increase production of a product that was popular and in short supply during a particular season the previous year, though the predicted trend did not transpire. Why inaccurate forecasts are particularly impactful drivers of FLW in the distribution sector include the timing of product procurement in relation to market demand, while simultaneously predicting possible shipping delays or container costs and availability. Particularly where the cycle time between orders and deliveries are long and products are perishable, distributors also have to assess quality and price considerations throughout the procurement and sale process. Another distributor stated that waste results from having purchased products ahead of a promotion by a large customer, only for demand to not meet expectations. In hospitals, FLW is increased when kitchens are unaware of changes in the number and mix of patients being treated or when specific treatments are occurring, as well as a range of factors including food allergies, or cultural and personal preferences. These are amongst the drivers of hospital FLW identified by other researchers and commentators, for example McGee (2022).

Respondents from primary production (farming and fisheries) commonly identified weather followed by disease as having a moderate to potentially significant effect on the creation of FLW. As identified in prior studies (e.g. Gooch et al., 2015), 33 percent of respondents from the marine sector stated that weather can have a particularly detrimental effect on product quality — leading to increased FLW. Forty percent of field crop producers and 35 percent of fruit and vegetable producers also identified weather as a notable driver of FLW. The need to offset potential supply and quality issues that could result from inclement weather, and the potential for a lack of supply or quality issues to cause a customer to purchase from other regions of Canada or North America, leads to producers overplanting. This too can drive increased FLW.

One interviewee, a field crop producer actively engaged with an industry association, went further, stating that climate change is leading to more weather-related events detrimental to crop quality. He also stated that climate change is challenging farmers' ability to manage diseases and pests. This leads to increased losses in the field and during storage. Forty percent of responding dairy producers also identified diseases, including mastitis, as a driver of FLW.

In terms of FLW drivers identified by one sector of primary production, 48 percent of responding fruit and vegetable producers identified product over-specification. This finding aligns with research by Gooch et al. (2019), Devin and Richards (2018), and Gunders et al. (2017), which identified the degree to which arbitrary standards set by downstream customers – combined with unrealistic consumer expectations – drive FLW at multiple points along the value chain. Approximately 20 percent of interviewees mentioned the need for programs to address the EFLW that results from fresh produce not meeting quality requirements, such as "ugly fruit and vegetable" marketing programs.

Human factors were noted by respondents from across the food industry as a common driver of FLW. Forty percent of field crop respondents and 30 percent of dairy respondents identified equipment malfunction – often due to its inappropriate operation, the lack of preventative maintenance, or ineffective training and supervision – as a notable driver of FLW in those sectors. Human factors were also noted by 35 percent of processors, 20 percent of manufacturers, 22 percent of distributors, and 18 percent of retail respondents. Human factors encompass a large range of potential actions, including incorrect inventory management, inaccurate ordering or dispatch, and the creation then sharing of inaccurate forecasts. Physical factors an interviewee gave as an example include rough handling, leading to bags of flour splitting during transport and distribution.

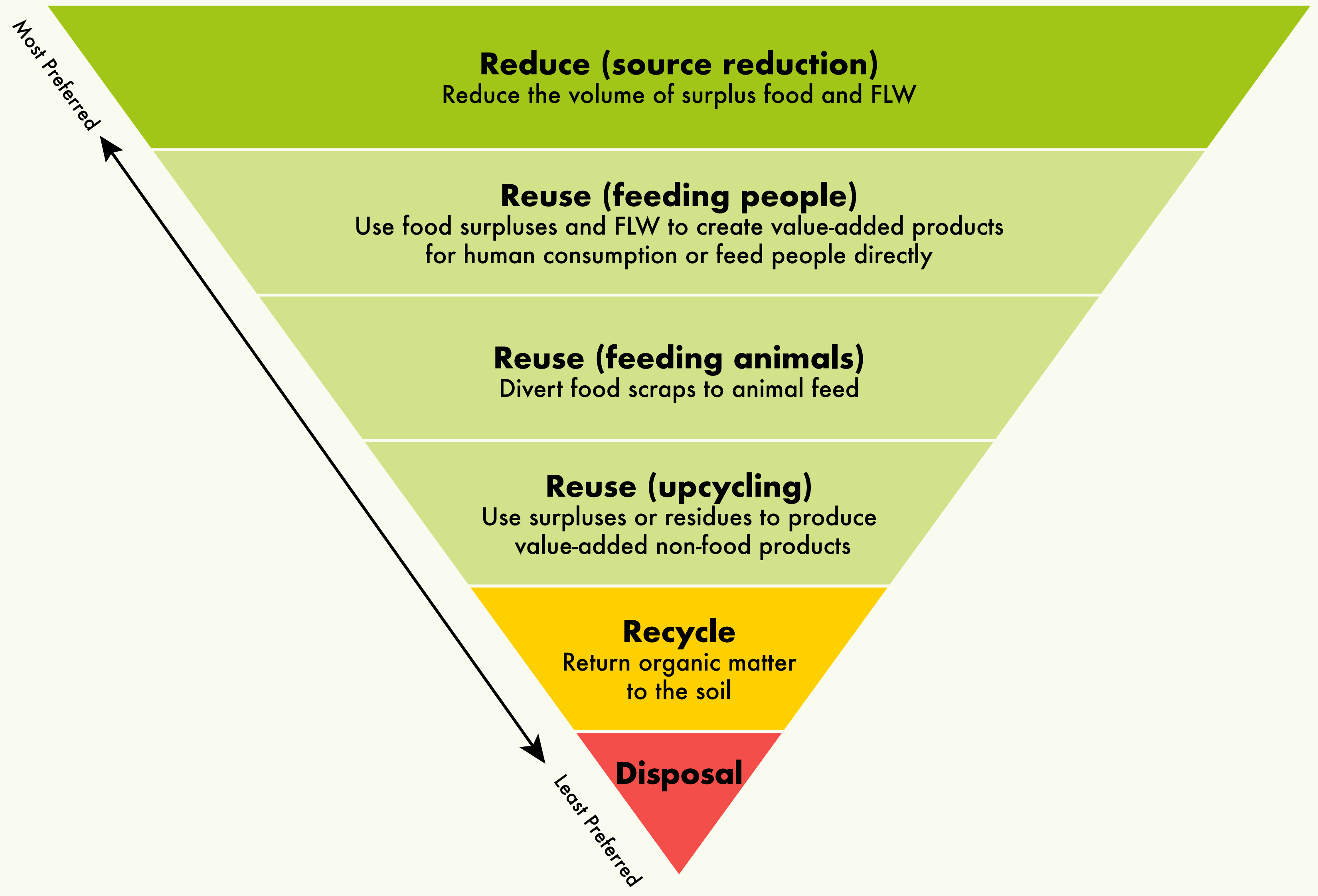
Two drivers of FLW were noted by specific sectors as occurring during distribution and transportation: contamination and weak packaging. Twenty percent of food processors and manufacturers identified food contamination during transportation. A distributor noted how weak packaging commonly leads to them experiencing increased FLW. Of respondents from the HRI sector, 15 percent stated that errors made during the preparation of meals commonly leads to increased FLW, and 20 percent cited plate waste as a notable driver of FLW.

4.2 FLW Destinations

The food recovery hierarchy, based on the 4R-D waste hierarchy, illustrates the comparative preference of distinct management options and FLW destinations from economic and environmental perspectives. As shown in Figure 4-1, and for reasons described below, the most preferred option is to reduce FLW at source. The least preferred option is to dispose of FLW in non-valorizing ways, such as landfilling or incineration.

Human factors were noted by respondents from across the food industry as a common driver of FLW. Human factors encompass a large range of potential actions, including incorrect inventory management, inaccurate ordering or dispatch, and the creation then sharing of inaccurate forecasts.

Figure 4-1: 4R-D Waste Hierarchy



EPA (2021), Flanagan et al. (2019) and CEC (2019) communicate the economic perspective of different management strategies in terms of the financial valorization of FLW, including the comparative value of financial, environmental and societal outcomes that can be achieved by reducing FLW at source, and directing food/FLW to distinct destinations. Societal benefits include redistributing edible food to vulnerable populations who are food insecure. The environmental perspective is communicated in terms of comparative GHG footprint (CO_2E emissions) associated with distinct management practices.

The preferred way to reduce CO_2E emissions is to prevent FLW at source, followed by the redistribution of surplus edible food to vulnerable populations. This is because, as the research identified, primary production accounts for 67 percent of total GHG emissions associated with Quebec's biofood system, and the intensity of emissions increases as food moves along the chain. All other potential destinations 1) enable a portion of total CO_2E emissions to be mitigated — for example by composting FLW; or 2) lead to the creation of additional CO_2E emissions — as occurs for example due to FLW being landfilled. Additional environmental benefits most associated with having reduced FLW at source, followed by the redistribution of surplus edible food to vulnerable populations, include the more efficient use of fresh water (Flanagan et al., 2019).

Section 5 presents the estimated CO_2E emissions associated with EFLW, ANEP and distinct destinations.

4.3 Effect of Unplanned Incidents on Destination of EFLW

The analysis of survey data and interview transcripts identified a correlation between the occurrence of unplanned incidents and the destination of EFLW. This finding is expanded upon in subsequent sections. Unplanned incidences include unsold products being returned to suppliers, due to them being surplus to customer requirements, and products not meeting customers' specifications. Unplanned incidences also occur when products remain unsold due to date code parameters (not to be confused with shelf life) being insufficient to meet retailers' or foodservice operators' specifications.

As identified by prior studies (Gooch et al., 2021; Gooch et al., 2019), for a range of reasons – not the least of which are legal liability concerns, best before dates and corporate policies – businesses are often reluctant to donate surplus foods that they know are edible. In such cases, EFLW may knowingly not be redistributed to vulnerable populations.

Primary production accounts for 67 percent of total GHG emissions associated with Quebec's biofood system, and the intensity of emissions increases as food moves along the chain.

The highest incidence of FLW that respondents deemed to have been edible when discarded occurs in processing, where an estimated 50 percent was deemed edible without the need for further processing. The EFLW reported by field crop producers (e.g. wheat, barley, corn, soybeans) needs to be processed prior to consumption. This means that a proportion of it will be lost due to the existence of ANEP.

Large retailers reported a higher percentage of unplanned FLW that is edible when discarded than smaller retailers. Based on prior research (e.g. Gooch et al., 2019; Gooch et al., 2017), this is partly due to larger retailers having service counters and preparing meals in store. This can lead to various forms of edible trim and meals that may exhibit a shorter shelf life than factory produced alternatives. It could also be an outcome of larger retailers possessing more extensive monitoring systems than smaller retailers.

4.3.1 Process of calculating FLW destinations

The estimation of FLW volume reaching distinct destinations used a combination of primary and secondary data.

Acknowledging that the analysis of responses suggested that a general misunderstanding exists amongst respondents regarding discrete differences between EFLW and ANEP, the estimation of industry FLW began with the circulation of the previously mentioned online survey. The survey asked respondents to indicate, separately, the percentage of total EFLW and the percentage of ANEP they sent to the top three destinations listed. In consultation with representatives from RECYC-QUÉBEC and Ville de Montréal, the nine destinations[2] included in the survey were drawn from the Food Loss and Waste Reporting and Accounting Standard (Hanson et al., 2016). Respondents were also provided the opportunity to list additional destinations. The subsequent post-survey interviews provided an opportunity to test the validity of FLW destination responses and better understand the drivers behind why food (if edible) and FLW (if edible or inedible) were directed to specific destinations.

The analysis of survey data to estimate FLW volumes per discrete destination began by establishing the range in the percentages reported by industry respondents. The frequency of response enabled the researchers to weight the proportion of EFLW and ANEP occurring at each distinct level of the supply chain going to specific destinations. These proportions were then applied to the FLW quantification.

Determining the destination of household FLW by volume began by the researchers reviewing "The Characterization of Waste in Quebec's Municipal Sector 2015-2018" (Éco Entreprises Québec and RECYC-QUÉBEC, 2021). This review was to establish the percentage of total household FLW reported by municipalities as reaching one of two destinations: 1) compost or anaerobic digestion, and 2) landfill or incineration. The study did not encompass alternative destinations, such as sewers. This produced an estimate of total household FLW, reaching each of the two destinations by volume. Considering a lack of data to specifically determine that proportion for household EFLW and household ANEP, the same estimates have been used for both and then applied to the quantification.

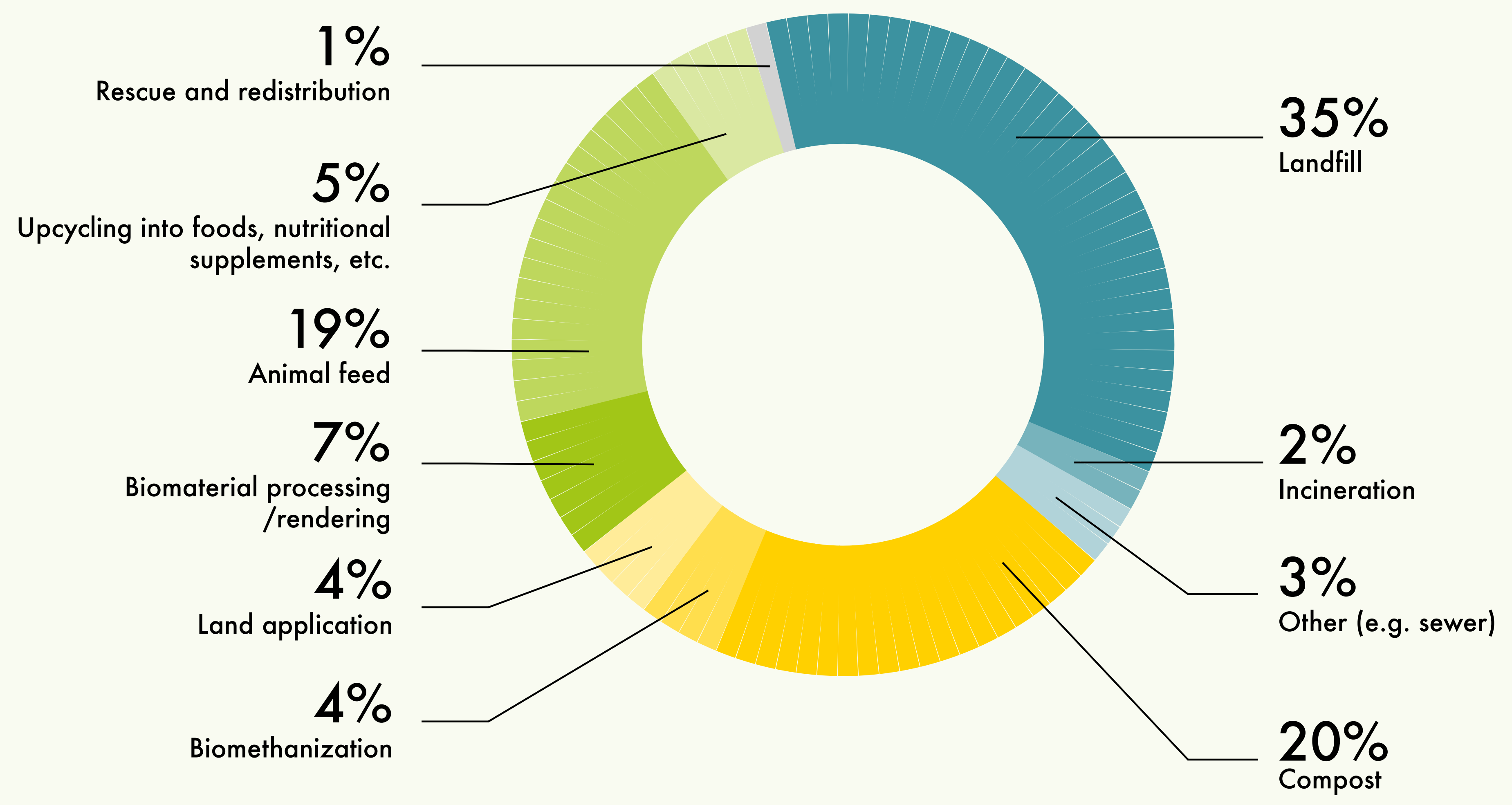
2 Rescue/redistribution for human consumption; Upcycling into foods, nutritional supplements, etc.; Animal Feed; Biomaterial processing/rendering; Biomethanization (anaerobic digestion); Compost; Land application; Incineration or controlled combustion; Landfill/burial. Source: Modified from Gooch et al., 2019

The following section presents the results of the industry and household destination analysis; firstly in terms of total FLW (Section 4.4.2), then in the form of a comparative summary of the destinations of EFLW and ANEP (Section 4.4.3).

4.3.2 Total FLW volumes by destination

In terms of total FLW, as shown in Figure 4-2, the largest destination of FLW by volume is landfill (35%), followed by compost (20%), then animal feed (19%). The least likely destination of surplus edible food is its rescue and redistribution for human consumption (1%). This is partly because households, a source of 24 percent of total FLW, are unlikely to donate surplus edible food for redistribution. Due to reasons discussed below and in Section 4.4.3, the research identified that the majority of household FLW is landfilled. As discussed in Section 5, this affects FLW-related CO_2E emissions.

Figure 4-2: Destinations by Tonnage and Percentage of Total FLW and Surplus Edible Food Volumes



Sixteen percent of industry interviewees stated they wished more FLW was being composted or going to other valorizing destinations. Two respondents declared the only viable option offered by their service providers was landfill; with one, a retail respondent, saying they would pay a moderate premium above current rates if they knew that their organic waste would not be landfilled. A respondent from a health care institution mentionned the lack of coordination between departments within their organization led to FLW being unnecessarily landfilled. Two respondents deplored that there is no effective municipal organic waste collection program in place for the HRI sector.

Thirty percent of interviewees stated that better collaboration between food rescue organizations and industry would enable considerably more edible food to be redistributed to vulnerable populations. This included over 50 percent of fruit and vegetable distributors, who stated that they could donate more fresh produce to feeding vulnerable populations; however, food rescue and redistributors were unable to handle everything offered. This was even though one of the distributors indicated that the labour costs associated with donating foods for rescue and redistribution were three times those associated with disposing of food via composting, anaerobic digester or landfill.

Sixteen percent of interviewees stated that they had achieved a modicum of success in valorizing FLW by selling their FLW for processing into animal feed and for feeding insects, which was, in turn, harvested for animal feed or for manufacture into human food. One respondent stated that, once their peers heard about their having successfully redirected FLW away from landfill, they received requests to do the same for other businesses. The use of anaerobic digesters to capture some value from FLW also appears to be increasing.

4.3.3 Comparative differences in the volume of EFLW and ANEP

The analysis of survey results identifying comparative differences in the destinations of EFLW versus ANEP is presented in figures 4-3 and 4-4.

The most notable apparent difference between the destinations of EFLW versus ANEP is the proportion of EFLW destined for landfill (47% vs 27%, respectively). Therefore, the form of FLW that industry respondents and researchers of household FLW deem as unplanned and likely edible prior to its discarding is almost twice as likely (81%) to be landfilled than inedible loss and waste. Compared to ANEP, EFLW is less likely to be valorized — for example, by transforming into animal feed or being upcycled into nutritional supplements. From a societal perspective, a valuable destination of surplus edible food is the rescue and redistribution to vulnerable populations. At the time of writing, a mere 23 thousand tonnes is destined to feed those who are food insecure.

Figure 4-3: Destinations by Tonnage and Percentage of EFLW and Surplus Edible Food

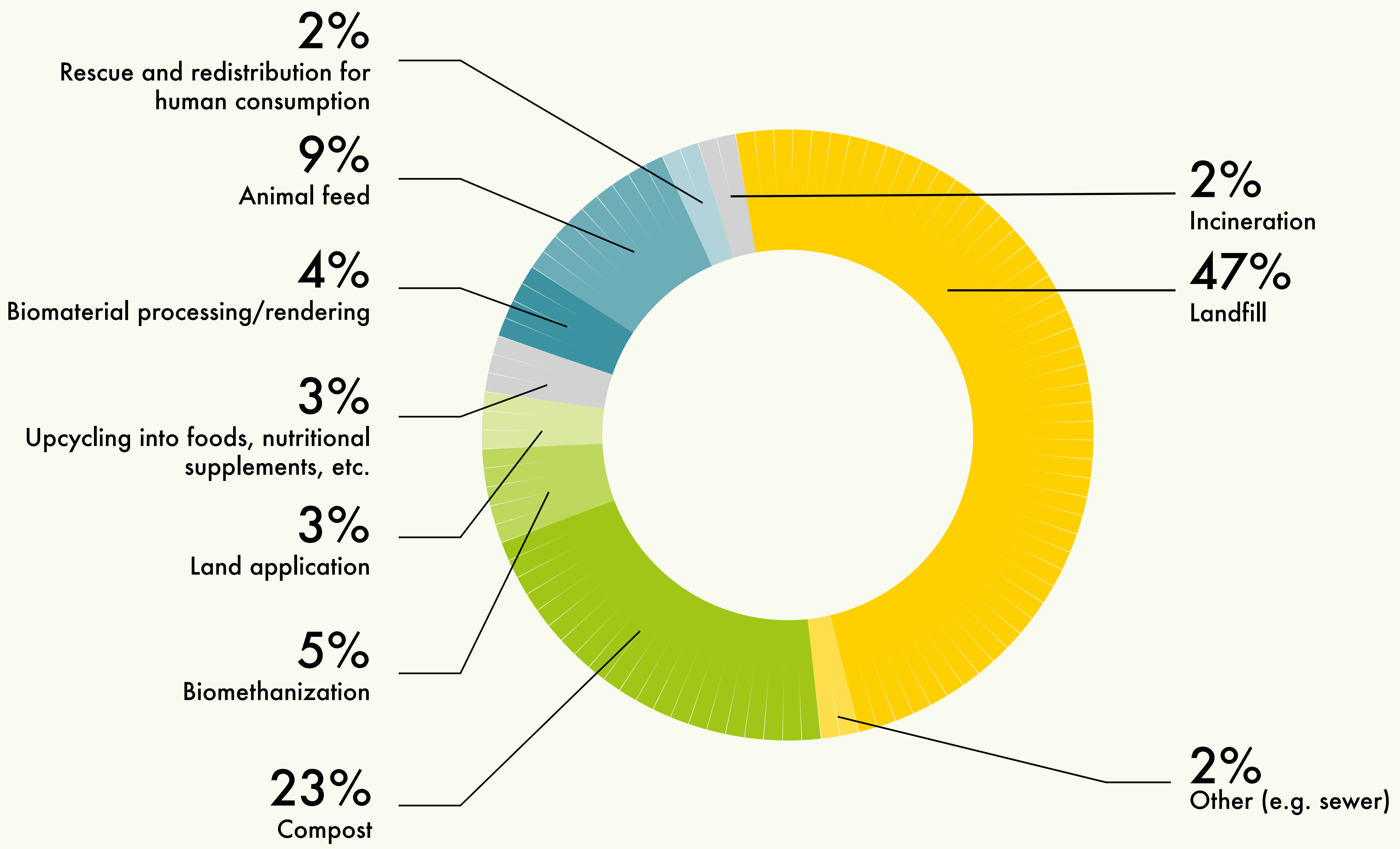
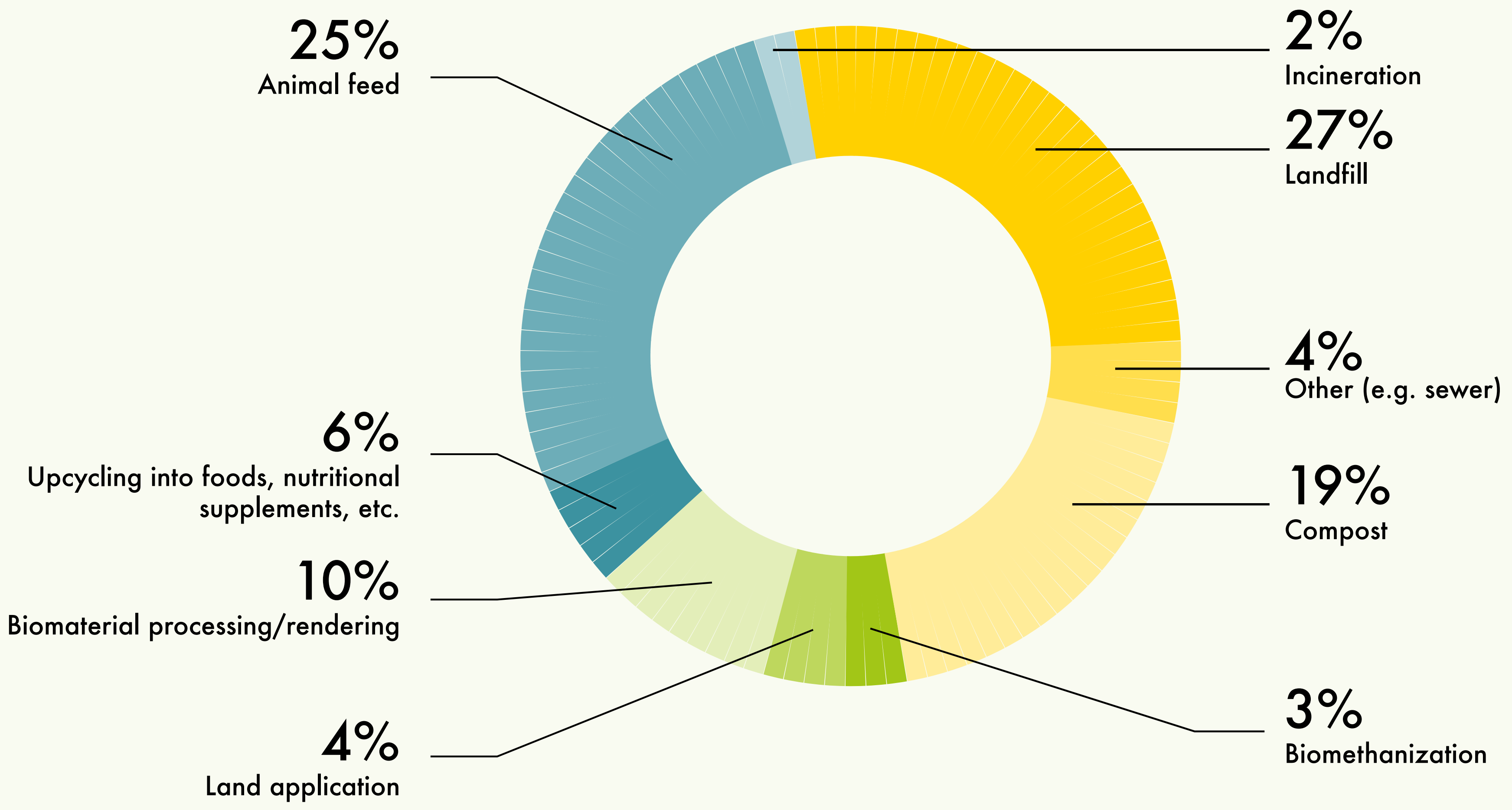


Figure 4-4: Destinations by Tonnage and Percentage of ANEP



The analysis of survey data and interview transcripts indicated a number of drivers lying behind why less EFLW than ANEP is valorized by industry, and why a higher proportion of EFLW is landfilled. A key reason cited by over 20 percent of interviewees for why the landfilling of FLW continues is that it can be the cheapest and easiest disposal option. Why a higher proportion of EFLW than ANEP is landfilled is that ANEP is planned. Therefore, businesses are prepared for its occurrence and can proactively predetermine a destination as part of their due diligence and legal compliance requirements. They also factor the cost of disposal and potential revenue, such as from selling for animal feed or processing into biofuel, into their operating costs and pricing structures. Because industry-associated ANEP predominantly occurs during the processing of specific commodities (e.g. wheat, soybeans, potatoes, milk, and chicken), there is also less risk of cross contamination — resulting in ANEP being directed to specific markets uses.

Conversely, avoidable EFLW is not planned. Therefore, individual businesses' response to its occurrence is largely reactionary. To minimize transaction costs and commercial or compliance risk, it is directed to the least costly and most easily managed destination. This often transpires to be landfill, particularly where cross contamination concerns exacerbate commercial or compliance concerns. Sending EFLW to landfill does not require surplus food to be sorted or stored, onward logistics to be arranged, or employees to be paid to manage the process. Staff turnover rates, partly due to students' temporarily working part time as and when available, also affects businesses' ability to make meaningful change. Turnover rate and part-time employment can lead to employees not being incentivized to engage in FLW reduction efforts (ReFED, 2016).

Another important driver behind why a higher proportion of EFLW is destined for landfill is because it is packaged. Packaging can prevent FLW from being valorized. This includes the composting of food or transforming FLW into biomaterials, such as fuel. The de-packaging of food can be costly — particularly in those instances where, due to the lack of specialized equipment, it is a manual process. Thirty-five percent of interviewees from the food processing, HRI and retail sectors mentioned that an unnecessarily high proportion of FLW is landfilled due to the lack of infrastructure required to recycle (composting, anaerobic digestion). Infrastructure limitations can account for why the research identified that the incidence of FLW going to landfill versus other destinations is higher in smaller non-corporate operations. Smaller businesses cannot afford to invest in infrastructure, such as biomethanization and the de-packing units, or have insufficient volumes of FLW to make the establishment of a dedicated organic waste stream a financially viable consideration.

4.3.4 Food rescue and redistribution

As identified in Figure 4-1 above, food industry respondents reported that just 23 thousand tonnes of surplus edible food is rescued for redistribution to vulnerable populations who are food insecure. To provide context, this is equivalent to approximately 40 percent of the 35,000 to 40,000 tonnes of food that Food Banks of Quebec reported as being rescued and distributed by the membership in 2019 (FBQ, 2019). As community food organizations purchase a proportion of food handled, the total volume they distribute is greater than the volume of food that businesses donate for rescue and redistribution (FBC, 2021; Gooch et al., 2021).

While the interviews conducted with representatives from organizations involved in food rescue and redistribution helped shed light on survey results, the sporadic nature of responses prevented robust conclusions being drawn on the volume of EFLW versus ANEP lost during redistribution. Table 4-1 shows the volume of aggregated FLW estimated to occur during the redistribution of edible food. The aggregated total is based on the grand average (11.6 percent) of loss factors derived from survey results for individual types of food.

Table 4-1: Losses Occurring During Rescue and Redistribution of Edible Food

Food type	Losses (%) occurring during rescue and redistribution
Dairy and eggs	6.5%
Field crops	14.2%
Produce	22.5%
Meat/poultry	11.5%
Marine	8.0%
Sugar/syrups	6.8%
Grand average	**11.6%**
Estimated food rescued/redistributed from the supply chain (tonnes)	**23,315**
Estimated FLW occurring during rescue/redistribution (tonnes)	**2,768**

Survey respondents and interviewees cited two key drivers resulting in rescued food not being successfully redistributed to vulnerable populations.

The first key driver is the lack of infrastructure (including refrigerated trucks and refrigerated storage for chilled and frozen foods), along with the personnel required to receive, store and handle fresh and frozen products. This is particularly due to the fact that: 1) there can be a considerable fluctuation in volumes and types of food received, 2) these fluctuations can occur with little to no prior notice, and 3) many of the products received are close to their best before or use-by date. Quick response is therefore essential, and supply rapidly exceeds organizations' capacity to handle. The inability to handle large fluctuating volumes of food is partly due to rescue and redistribution organizations' reliance on voluntary labour, which requires time to organize, with volunteers often not possessing the required expertise.

The second key driver is variability in the quality and types of goods received. Interviewees stated that the ability to divert food that, due to quality issues or capacity constraints, cannot be redistributed in their present state to processing and repurposing facilities would measurably reduce waste.

Interviewees mentioned that establishing closer relationships with donors would help them address both of the above issues, though donors are often reluctant to form closer relationships due to the sensitive information pertaining to turnover and losses. Businesses' desire to capture at least some return on investment leads them to not discard (or donate) food until its shelf life is minimal or expired, often without prior notice. This further impacts organizations' ability to rescue and redistribute edible food.

In terms of destination, a number of survey respondents and interviewees commented on how a lack of infrastructure and/or appropriate service providers led to a potentially significant proportion of EFLW and ANEP going to landfill. In some cases, this can be due to no municipal organic waste collection programs being in place for the HRI sector. In such cases, businesses are responsible for finding other ways to dispose of FLW, which is not always easy.

4.4 Summary of Findings

The following is a summary of the results produced by the analysis of EFLW and ANEP occurring in Quebec's food industry. Where appropriate, similarities and differences between the 2019 national FLW study and this study are noted.

In 2019, 7.5 million tonnes of commodities were estimated to enter Quebec's biofood system. This excludes commodities associated with the production of alcohol and those exported from Quebec. A total of 3.1 million tonnes of EFLW and ANEP was discarded from Quebec's biofood system. Based on a population of 8.5 million, this equates to 2.43 kg of food inputs and 1.01 kg of FLW per person per day. Of the 23 thousand tonnes of surplus edible food that is rescued for redistribution to vulnerable populations, an estimated 12 percent (2,798 tonnes) is lost during redistribution.

The most likely destination of EFLW is landfill (47%), followed by compost (23%). This compares to 27 and 19 percent of ANEP, respectively. Why a higher percentage of EFLW than ANEP is destined for landfill appears to be due to 1) a lack of composting and anaerobic digestion infrastructure and accessibility, 2) businesses not planning for EFLW to occur, and 3) contamination concerns lessening valorization opportunities. The food industry sometimes hesitates establishing the collaborative relationships that food rescue and redistribution organizations say would enable them to successfully capture a higher proportion of EFLW and, simultaneously, improve the effectiveness of their own operations.

The majority of respondents (>80%) explicitly expressed an altruistic desire to do the right thing: reduce EFLW in particular, and increase the value of all FLW in one way or another. A considerable number of respondents cited that improved forecasting would enable them to reduce FLW by establishing close supply chain relationships. While the degree of fractious relationships identified in this study, and its effect on the creation of FLW, appears to be less than that which was identified in the national study, it is still a notable driver of EFLW. The existence of more cordial business relationships in Quebec may help explain why FLW factors found to typify Quebec's biofood industry, particularly in processing and manufacturing, are lower than those identified in the national study.

Similar to the national FLW study, the research identified that the vast majority (~94%) of respondents do not measure FLW. Unlike the national study, no distinct sectors of the Quebec biofood system measure FLW more than others. The national study identified that as food gets closer to market and gains value, downstream stakeholders are more likely to measure. Those respondents who do measure FLW are more likely to be measuring EFLW than ANEP. This illustrates the degree to which most businesses have not incorporated monitoring practices into their operations. This suggests that, for the most part, respondents typically view FLW as a cost of doing business.

Through greater monitoring of their operations (resulting in increased operational effectiveness and efficiency) and greater implementation of continual improvement practices (resulting in increased quality, expanded market and increased revenue), a large proportion of Quebec's food industry could capture missed opportunities to both improve performance and, in turn, address inefficiencies associated with FLW.

4.5 Benchmarking Sustainable Development Goal Target 12.3

While the purpose of producing a robust detailed estimate of FLW volumes in Quebec aims to guide the design and implementation of policies and programs, it also enables the province to benchmark its performance in regard to international goals. As such, it is pertinent to use the present findings in relation to Target 12.3 of the United Nations' Sustainable Development Goals (SDGs) — global goals to end poverty, protect the planet, and ensure prosperity for all (United Nations, 2022a/b). Although countries have the primary responsibility for follow-up and review of progress toward these goals, the actions of all parties are necessary to achieve the SDGs.

Figure 4-5: Sustainable Development Goal Target 12.3

Source: United Nations, 2022a

Through greater monitoring of their operations and greater implementation of continual improvement practices, a large proportion of Quebec's food industry could capture missed opportunities to both improve performance and, in turn, address inefficiencies associated with FLW.

This target calls for halving per capita global food waste at the retail and consumer level and reducing food losses along production and supply chains (including post-harvest losses) by 2030.

At the moment, the recommended approach to interpreting SDG Target 12.3 includes:

- The entire food supply chain, from the point that crops and livestock are ready for harvest or slaughter through to the point that they are ready to be ingested by people.
- Both food that is intended for human consumption and its associated inedible parts (EFLW and ANEP), which leave the human food supply chain. However, entities able to measure and report on food and associated inedible parts separately can apply the 50 percent reduction target only to the food portion, although steps to reduce the amount of inedible parts as much as possible should also be taken.
- Excludes animal feed and biobased materials/biochemical processing (where material is converted into industrial products) for country-level reporting. This is coherent with Figure 4-1, which presents animal feed and upcycling into non-food value-added products as reuse.

As presented in Figure 4-6, this translates to 1,004,778 tonnes of edible food throughout the supply chain or 118 kg per capita, a volume that could be used as the starting point for measuring the achievement of Target 12.3 in Quebec. Of this quantity, it is interesting to note that 38 percent (382,875 tonnes) is recycled through composting, biomethanization and land application while 62 percent (621,903 tonnes) is still disposed through incineration, landfilling and other. The distribution of these quantities according to the different sectors of the biofood system is presented in Figure 4-7.

Figure 4-6: Breakdown by Destination of Food (Not Consumed) Covered by SDG Target 12.3 (Tonnes)

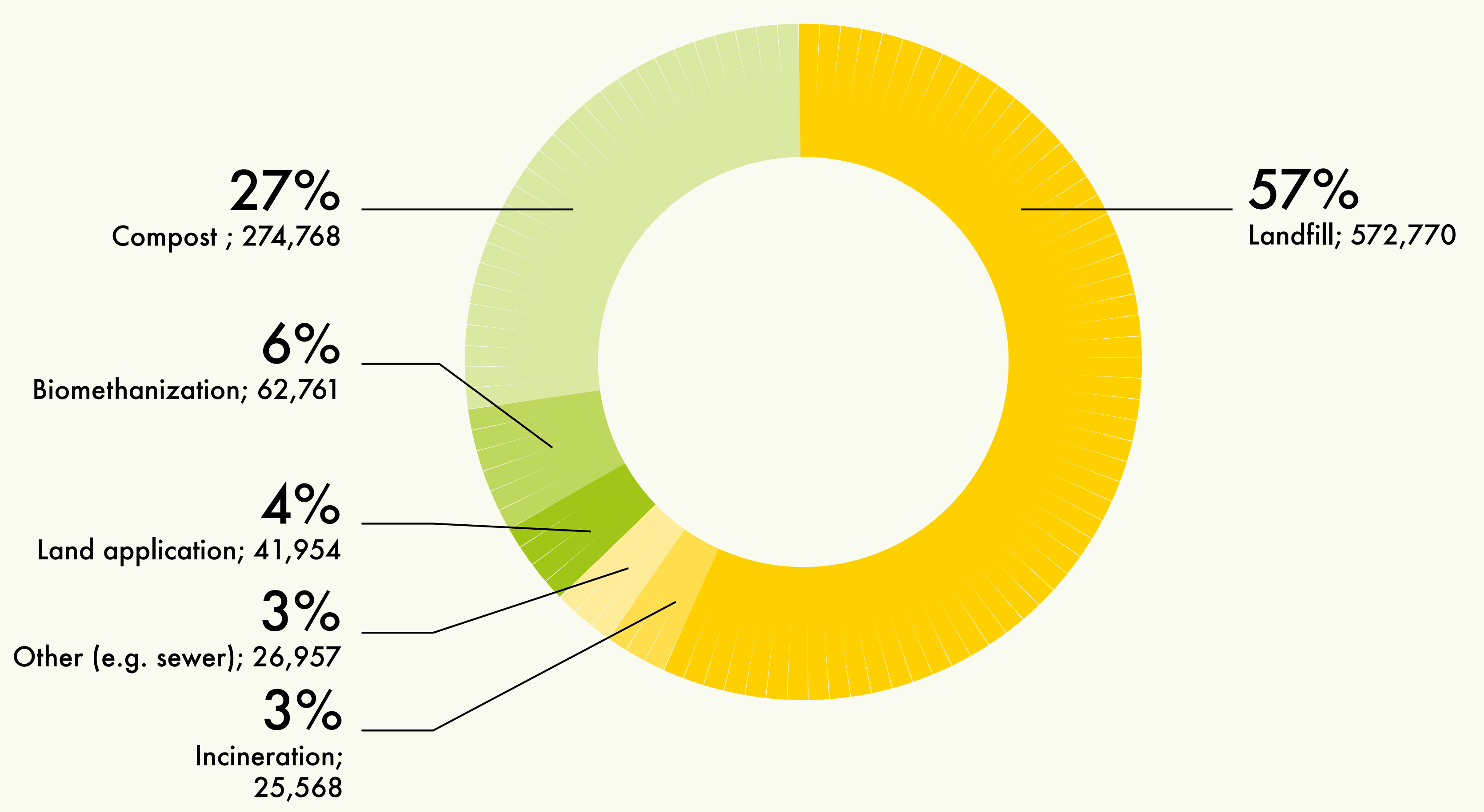
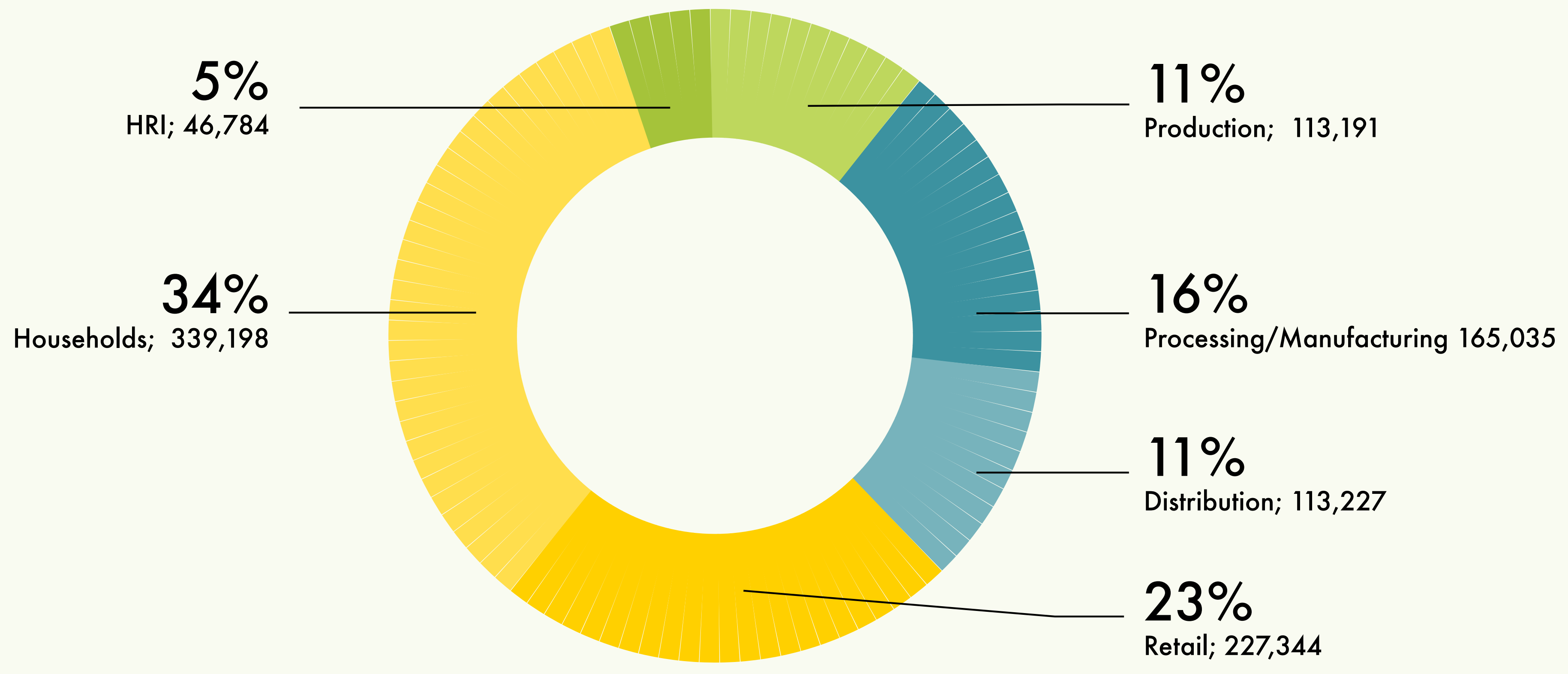


Figure 4-7: Distribution Through the Biofood System of Food (Not Consumed) Covered by SDG Target 12.3 (Tonnes)



5. CO_2E Estimates: Annual Tonnage

The following section summarizes findings from the analysis of CO_2E emissions associated with the volumes and types of FLW estimated to occur in Quebec. Appendix B contains more detailed information on the processes employed to estimate FLW-related CO_2E emissions in Quebec's context. Section 10.1 of the Appendix describes the secondary research findings, which suggest that Quebec's total food system could account for between 15.2 and 27.2 million tonnes of CO_2E emissions.

5.1 Objective

The CO_2E part of this study shows the estimated CO_2E (carbon, methane and nitrous oxide emissions) for each food category along the supply chain from production to consumption in the home or the HRI sector. The estimate also takes into account the increase or decrease in CO_2E emissions associated with the end destination of FLW. For example, while the landfilling of household FLW is estimated to increase total emissions by 204 kg CO_2E per tonne of FLW, the composting of household FLW is estimated to decrease total emissions by 230 kg CO_2E per tonne of FLW (ReFED, 2020b; Corona et al., 2020). The precise amount to which a discrete destination will increase or decrease total CO_2E depends on the type of FLW (e.g. leafy greens versus chicken) and from where in the food chain the FLW emanates (e.g. primary processing versus retail).

The most effective means to reduce FLW-related CO_2E emissions is to reduce FLW at source, due to the fact that primary production accounts for 71 percent of total emissions (Crippa and al., 2021). This is followed by upcycling or redistributing excess edible food, as this keeps the food in the biofood system for human consumption. Appendix B provides a detailed description of how CO_2E emissions related to FLW were calculated. This includes how Quebec's self-sufficiency in particular foods impacts the total CO_2E emission estimates taken into account in the GHG calculation.

5.2 GHG Calculation Details

The quantification reflects that the CO_2E footprint of food accumulates as it moves along the food chain from production to consumption. CO_2E takes into account carbon and other GHGs associated with the food system, including methane and nitrous oxide emissions. The latter occurs on farms due to the application of fertilizers during the growing and production of food. The GHG quantification considers that the total volume of food leaving the farm gate steadily decreases as it moves along the supply chain. As shown in Figure 5-1 (Section 5.5), columns containing CO_2E calculations are identified to show how cumulative numbers were derived.

5.3 Scope

The array of CO_2E data available for modelling is enormous, and often contradictory. Differences in research methodologies employed to estimate CO_2E emissions create potentially misleading results if the information is not chosen, analyzed and reported in context (Porter et al., 2016; Vermeulen et al., 2012). Clear boundaries must therefore be established when comparing the results of life cycle analysis (LCA).

This section categorizes the forms of food and FLW-related CO_2E data relevant to the analysis of the environmental emissions associated with the production of food consumed and the associated FLW within Quebec. The analysis of CO_2E data to provide emission estimates related to specific types of FLW occurring at discrete points along the supply chain included triangulating estimates produced by comparable studies completed by different researchers. As identified in Appendix B, where possible, this triangulation process involved comparing results produced by the meta-analysis of LCAs (Porter et al., 2016; Clune et al., 2016) against Quebec sources. These sources included confidential CO_2E emission data possessed by Ville de Montréal.

Given the importance of establishing distinct boundaries when interpreting CO_2E emission data, attributed data counted in the estimation of CO_2E emissions associated with FLW in Quebec included that which pertains to:

- The growing and production, primary processing and manufacturing of food consumed in Quebec
- Standard carbon footprint for a typical distribution and retailing operation
- Emissions associated with transportation between each element of the supply chain
- Estimates for emissions associated with HRI and household food preparation and cooking
- The effect of discrete source and destination of FLW on total emissions, including, for example, the offset effects achieved by replacing synthetic fertilizer with composted FLW

Attributed data excluded from the estimation of GHG emissions associated with FLW in Quebec include that which pertains to:

- The growing, primary processing, packing and transportation of food that is exported to jurisdictions outside of Quebec (i.e. Canadian and international markets)
- Animal medication and healthcare, unless accounted for in the LCA literature
- The construction of warehouses, retail stores and HRI properties
- Employee and consumer commuting
- HRI eatery footprint
- Water and wastewater pumping and treatment
- Carbon sequestration of fruit trees and grazing/pasture lands

5.4 CO_2E Emission Factors

The intensity of CO_2E emissions associated with a specific type of food varies according to the discrete point in the chain where food or inedible associated parts are discarded. For example, due to the effects of transport, processing, etc., a tonne of food discarded at the point of production will have a lower CO_2E intensity (footprint) than the same tonne of food discarded in retail stores or by households.

The following section presents the emission factors for each explicit link in the chain, and food type where attributable, and were used to estimate total CO_2E emissions associated with FLW in the province of Quebec. Details on specific data sources, along with assumptions that guided the process of analysis and inference of results across Quebec's food system, are presented in Appendix B.

5.4.1 Food production, processing and manufacturing

Shown in Table 5-1 are the CO_2E emissions per tonne of food, and consequently per tonne of FLW, that were used in relation to the primary production, processing and manufacturing activities associated with different types of food. Each category is an aggregate of distinct foods; for example, dairy encompasses liquid milk, yogurt and cheese. As data sources relate to food, not FLW, the same factors were applied to EFLW and ANEP.

While a proportion of emissions occurring in the manufacturing sector would be for an amalgam of foods – for example, dairy, eggs, field crops (flour), sugar, and poultry in the production of chicken entrees – there is insufficient data to enable this level of analysis.

Table 5-1: Tonnes of CO_2E per Tonne of Food

Food type	Production	Processing	Manufacturing
Dairy and eggs	0.92[3]	2.35[4]	Included in processing[5]
Eggs	0.35[6]	See footnote[7]	See footnote[13]
Field crops	0.500	0.041[8]	0.219[9]
Produce	0.462	0.03[10]	0.03
Pork	4.29[11]	0.148[12]	0.148[13]
Beef	23.5[14]	0.149	0.149
Lamb	15.35	0.148	0.148
Poultry	4.39	0.221	0.221
Marine	4.420	0.00[15]	0.01[16]
Sugar/syrups[17]	0.440	0.189	0.189

3 Production intensity for Quebec (Verge et al., 2013).
4 (Verge et al., 2013) Average of intensity for various products in Quebec minus the portion of on farm emissions. Approx. 1% of emissions are associated with transportation; therefore, average intensity was reduced by 1% to avoid double counting.
5 In the quantification, CO_2E emissions for dairy processing and manufacturing are captured in the processing stage of the model.
6 Calculation is based on one response from the survey that gave production CO_2E per dozen eggs.
7 Insufficient data was available to establish a CO_2E emission factor for egg processing and manufacturing. No definitive data could be sourced, and communications with representatives of the processing sector suggested that emission intensities could be negligible and are considered as such within the scope of this study.
8 Wheat milling was used as proxy (Espinoza-Orias, Stichnothe, and Azapagic 2011).
9 Bread manufacturing was used as proxy (Espinoza-Orias, Stichnothe, and Azapagic 2011).
10 Clune et al. (2016) reports an intensity of 0.06 for processing vegetables; in our model we split this 50:50 between processing and manufacturing.
11 Emission intensity data reported by Les Éleveurs de porc du Québec (2021) was converted to retail weight (the functional unit) using the AAFC red meat conversion factor for pork of 76%.
12 Slaughtering and Rendering of Pigs, Chickens and Cattle (Aan Den Toorn et al., 2017). Used average of other meats for mutton/lamb.
13 Applied the same emissions estimate for manufacturing based on cooking energy, etc., required for further processing of meat products.
14 Based on Canadian Roundtable for Sustainable Beef LCA report and Clune et al. conversion factor for carcass to boneless meat.
15 Processing of fish is conducted within the bounds of the farm or catch facility, therefore included in CO_2E emissions.
16 A minimal CO_2E was assigned for the small amount of further processing/value adding of marine products.
17 Emissions factors for sugar/syrups sourced from García et al. (2016), which is the best available estimate that could be found.

Due to the effects of transport, processing, etc., a tonne of food discarded at the point of production will have a lower CO_2E intensity (footprint) than the same tonne of food discarded in retail stores or by households.

5.4.2 Food distribution, storage and preparation

The following section summarizes how emissions associated with the distribution of food consumed in Quebec, and consequently FLW, were calculated. Appendix B contains more details of the calculation process.

Data on CO_2E emissions associated with the distribution, storage and preparation of food is limited and not reported in a manner that enables inferences to be produced for distinct types of food on a tonnage basis. In distribution, an estimation was made of transport mode and distance associated with different types of food, to which a specific CO_2E emission per km was applied. In retail, HRI and households, the CO_2E per tonne of food was calculated by first estimating the total food-related CO_2E emissions associated with each of these three discrete links in the food system. The tonnage of food previously estimated to reach each link in the chain enabled a CO_2E estimate per tonne of food, and, by definition, per tonne of FLW. Presented in Table 5-2 are the FLW emission factors that were used in this study.

Table 5-2: Emissions Factors: Tonnes of CO_2E per Tonne of FLW

Food type	Transport to distribution[18]	Retail	HRI	Households
Dairy and eggs	0.01	0.30[19]	0.72[20]	0.11[21]
Field crops	0.07			
Produce	0.21			
Meat/poultry	0.02			
Marine	0.05			
Sugar/syrups	0.01			
Average	**0.11**			

18 CN (2021a/b), BSR (2014/2015), CSL Group (2021)
19 Metro (2019), LCL (2019)
20 NRC (2021a), ECCC (2013)
21 ECCC (2013), NRC (2021b, 2020c)

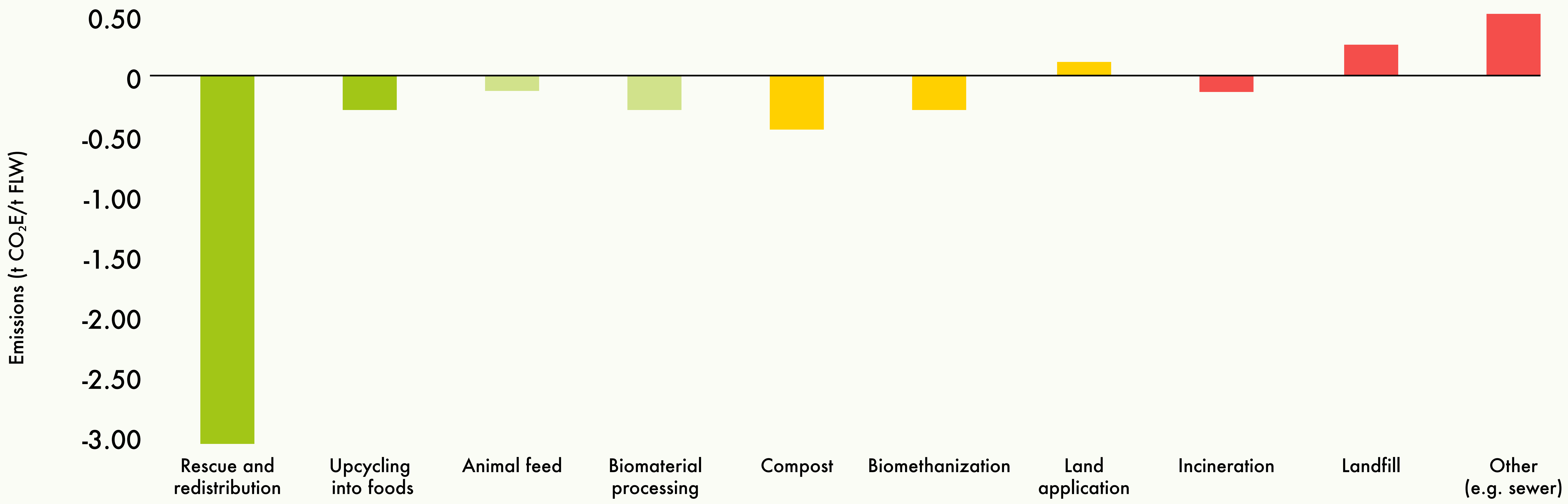
The estimation of distribution-related CO_2E emissions was based on secondary data pertaining to provincial production and quantities consumed, along with predominate trade partners from which distinct types of food are imported. This enabled assumptions to be made regarding the distance that particular food types would travel, indicative weights of different foods transported within a given unit (e.g. a truckload of leafy greens versus truckload of meat), and the mode of transportation most associated with distinct types of food. Hence, there is variation in the CO_2E associated with the transportation of food from production to processing/manufacturing, and from processing/manufacturing to retail and HRI.

The estimation of CO_2E emissions at retail, HRI and households were proportioned based on the quantity of food estimated to flow through to those three discrete points in the supply chain. Consequently, on a CO_2E emission/tonne of food basis, the emission factors are not differentiated by food type.

5.5 Effect of Destination on Total CO_2E Emissions

The analysis of survey data, interview transcripts and ReFED data enabled an estimation of the effect of FLW destinations on total CO_2E emissions associated with FLW in Quebec. As Appendix B describes in more detail, destinations such as redistributing edible food to vulnerable populations, composting, and biomethanization allow varying proportions of FLW-related CO_2E emissions to be recovered. However, as shown below in Figure 5-1, the disposal of FLW in sewers or by landfilling leads to increased CO_2E emissions. This compounds the environmental effects of FLW.

Figure 5-1: Destination Effect on CO_2E Emissions (Tonne of CO_2E -/+ per Tonne of FLW)



The greatest recovery of CO_2E emissions stems from the donation of surplus edible food to vulnerable populations, followed by the composting of FLW. The median volume of CO_2E emissions mitigated by direction to preferred destinations equates to 2.87 tonnes of CO_2E per tonne of FLW reduced by donation, and 0.24 metric tonnes of CO_2E per tonne of FLW composted. By comparison, for each tonne of FLW landfilled, CO_2E emissions increase by 0.18 tonnes. The highest additional emissions stem from disposing of FLW in sewers, 0.38 tonnes CO_2E. The effect that each distinct food type has on emissions associated with each of the destinations shown above and by where in the biofood system FLW emanates is presented in Table B4, Appendix B.

Presented next in Figure 5-2 is the mitigation or compounding (-/+) effect of each discrete destination for all FLW, along with proportion of total CO_2E emissions for each destination associated with EFLW versus ANEP. As detailed in Table 5-3, the sequestration effects of preferred destinations, such as food redistribution and composting, equate to total emissions having been reduced by 33,300 tonnes of CO_2E. Including the effect of destination, this results in total EFLW and ANEP emissions equating to 3.5 and 4.3 million tonnes of CO_2E, respectively.

The biggest single reason why the mitigation effects of preferred destinations do not reduce total CO_2E emissions by a greater degree is due to the volume of household FLW that is landfilled. Each tonne of household FLW going to landfill represents an additional 0.2 tonnes of CO_2E emissions. This compares to the average intensity of CO_2E emissions that result from each tonne of food landfilled, for the chain as a whole, being 0.185 tonnes of CO_2E.

Figure 5-2: Total -/+ CO_2E Emissions Associated with Destination (Volume of FLW, Volume of CO_2)

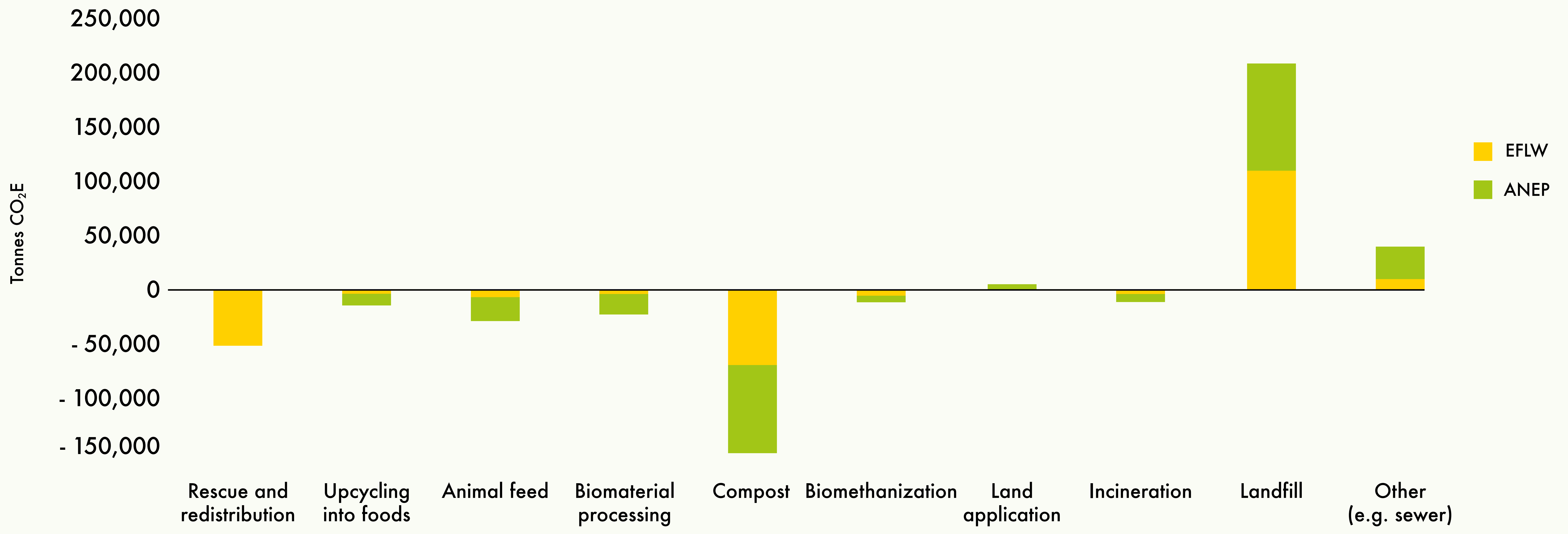
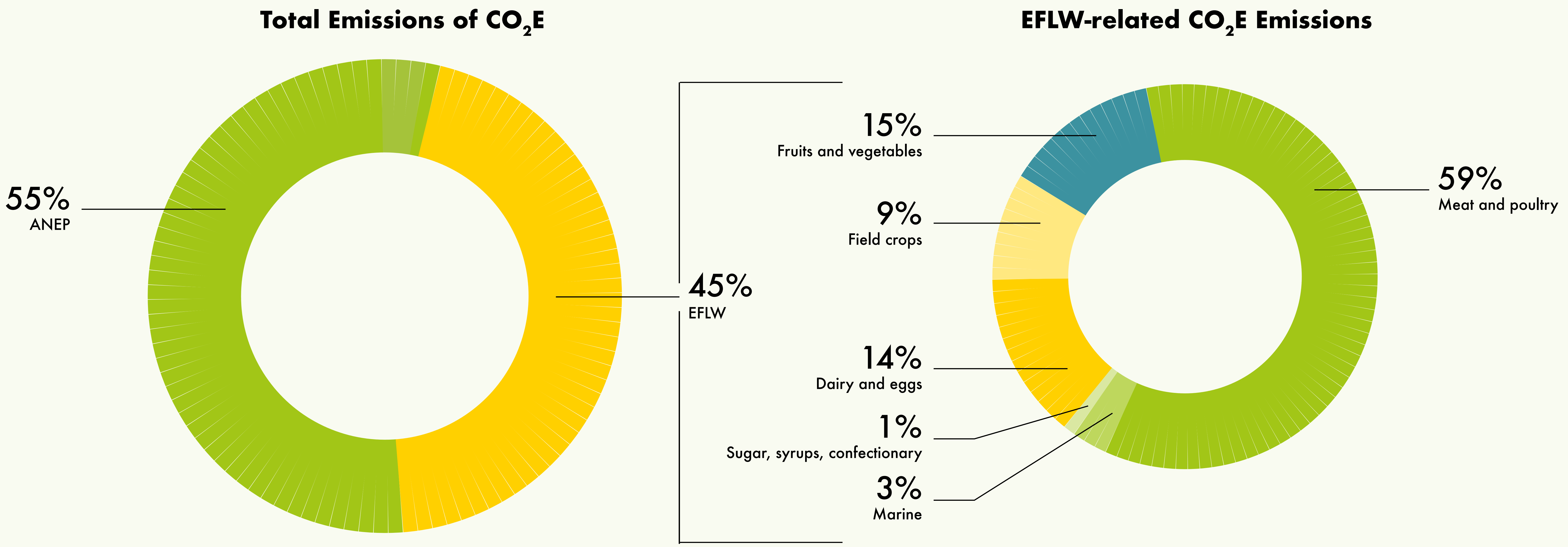


Figure 5-3: Total Emissions of CO_2E (Tonnes) Associated with EFLW and ANEP



5.5.1 CO_2E emissions associated with edible and inedible loss and waste

The analysis estimated that total emissions associated with Quebec's biofood system amount to 20.2 million tonnes of CO_2E. Of this total, 17.7 percent (3.5 million tonnes) of CO_2E emissions are attributable to EFLW and 21.6 percent (4.3 million tonnes) are attributable to ANEP. As presented in Figure 5-2, when destination effects are factored into the calculations, EFLW and ANEP represent 45 and 55 percent of FLW associated CO_2E emissions, respectively.

This significant difference in the proportion of CO_2E emissions versus FLW by volume represented by different types of food is due to the comparative intensity of CO_2E bound up in each tonne of food.

5.6 Summary of Findings

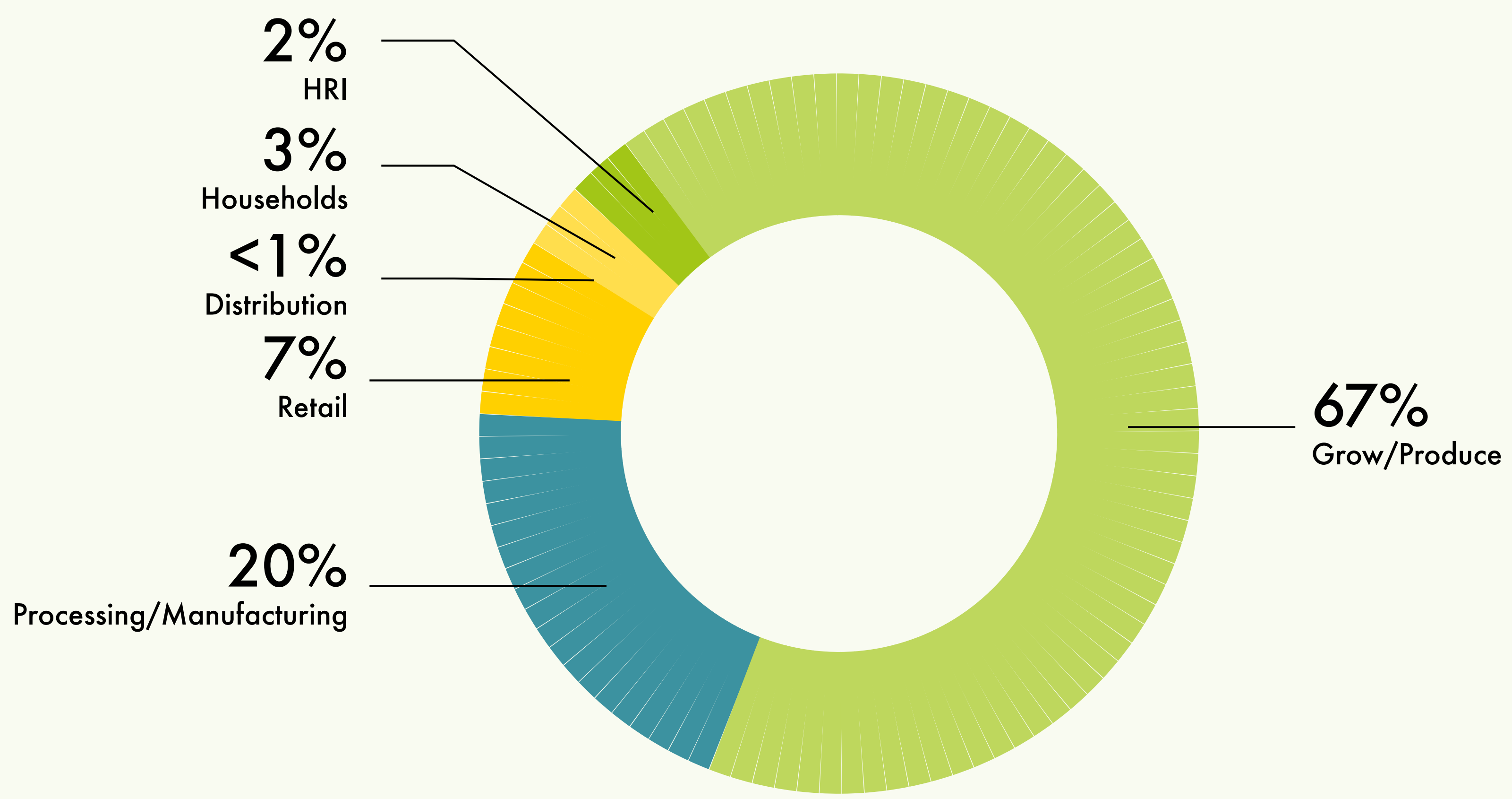
A summary of key findings from the analysis of CO_2E emissions associated with Quebec's biofood system, including the total effects of destination on FLW-related emissions (-33,000 tonnes CO_2E), is presented in Table 5-3. As survey responses provided insufficiently granular data to accurately calculate the effect of destination by EFLW versus ANEP for each food type disposed of at discrete points in the biofood system, destination effects are presented in aggregated form.

Excluding alcohol and exported foods, total annual CO_2E emissions associated with Quebec's biofood system (including all aspects of processing, distribution, consumption and disposal) is estimated to be 20.2 million tonnes. This equates to 6.5 kg per person per day. Presented in Figure 5-4 is the proportion of this 20.2 tonnes of CO_2E emissions associated with discrete points in the biofood system. The largest proportion of total CO_2E emissions is associated with primary production (67%), followed by processing and manufacturing (20%). The smallest proportion of total CO_2E emissions is associated with distribution (less than 1%), followed by HRI (2%).

Table 5-3: Biofood System and FLW-Related Emissions (Metric Tonnes CO_2E)

Food type	Biofood system	Food loss and waste		
		EFLW	ANEP	TOTAL FLW
Dairy and eggs	5,270,080	507,314	1,827,164	2,334,479
Field crops	1,206,641	309,466	311,810	621,275
Fruits and vegetables	2,948,493	519,176	497,202	1,016,377
Meat and poultry	10,001,042	2,099,495	1,657,476	3,756,971
Marine	446,545	92,194	49,586	141,780
Sugar, syrups, confectionary	333,913	50,889	28,992	79,881
Sub total	20,206,714	3,578,533	4,372,230	7,950,763
Destination effects		-14,006	-18,011	- 32,018
Grand total	20,174,696	3,564,527	4,354,218	7,918,745

Figure 5-4: Proportion (%) of CO_2E Emissions Associated with Discrete Points in Biofood System



This total of 20.2 million tonnes is close to the mid-point of the 15.2 to 27.2 million tonnes of CO_2E emissions that global estimates suggest is attributable to Quebec's biofood system (see Section 10.1 of the Appendix). The study estimates that the GHG intensity of food consumed in Quebec equates to 4.55 kg of CO_2E per kg of food.

Of total emissions, 39 percent (7.9 million metric tonnes = 2.55 kg per person per day) is cumulative CO_2E associated with FLW. This includes a reduction of 33 thousand tonnes of CO_2E, which stems from mitigation effects of destination. The CO_2E emissions associated with EFLW and ANEP equate to approximately 3.6 and 4.4 million tonnes, respectively. The effects of sending FLW to preferred destinations according to the 4R-D hierarchy (e.g. redistributing EFLW to vulnerable populations, upcycling, directing both forms of FLW to animal feed, or composting) currently only marginally offset total FLW-related emissions. A disproportionate percentage of industry EFLW and total household FLW reaches landfill. Reducing the amount of FLW sent to landfill will further reduce its environmental impact.

Reflecting the 4R-D hierarchy (Figure 4-1), the greatest reductions in CO_2E emissions would come from the establishment of circular economy strategies. These include businesses reducing FLW at source by having implemented continual improvement programs — resulting in optimized operations, donating surplus edible food, and upcycling what would have become EFLW and ANEP into new food products. For households, the implementation of circular economic strategies would include improved planning of food purchases, better storage practices, and maximizing the utilization of foods. The latter includes utilizing offcuts (e.g. broccoli stems) in innovative ways, such as in soups.

The largest proportion of total CO_2E emissions is associated with primary production (67%), followed by processing and manufacturing (20%). The effects of sending FLW to preferred destinations according to the 4R-D hierarchy only marginally offset total FLW-related emissions.

6. Administrative Regions

Results produced by the analysis of food flows, FLW and CO_2E emissions enabled the characteristics of each of the 17 administrative regions (which together comprise the province of Quebec) to be calculated. The limit of this approach is that it is based solely on population. It does not take into account industry concentration, the discrete segments of the food industry (including those producing or handling specific types of food), and any differences in consumer purchasing behaviours. The results presented in Table 6-1 were achieved by multiplying per person estimates for food consumed and FLW by the population of each region.

Not surprisingly, due to population density, the highest volume of FLW and associated CO_2E emissions occur in Montreal followed by Montérégie: 24.3 and 18.6 percent of FLW and CO_2E emissions, respectively. This result is also consistent with the high intensity of economic activity in these two regions.

Table 6-1: Consumption, FLW and CO_2E Emission Characteristics per Administrative Region

Region #	Region name	Population 2019*	Total food consumption (Est. tonnes)	FLW (Est. tonnes)	CO_2E associated with FLW (tonnes)
1	Bas-Saint-Laurent	197,480	103,017	72,023	183,939
2	Saguenay – Lac-Saint-Jean	277,985	145,013	101,384	258,924
3	Capitale-Nationale	751,345	391,945	274,024	699,826
4	Mauricie	271,181	141,464	98,903	252,586
5	Estrie	329,325	171,795	120,108	306,743
6	Montreal	2,064,991	1,077,219	753,124	1,923,396
7	Outaouais	397,004	207,100	144,792	369,782
8	Abitibi-Témiscamingue	147,625	77,100	53,840	137,502
9	Côte-Nord	90,699	47,314	33,079	84,480
10	Nord-du-Québec	45,894	23,941	16,738	42,747
11	Gaspésie – Îles-de-la-Madeleine	90,412	47,164	32,974	84,212
12	Chaudière-Appalaches	428,947	223,764	156,442	399,534
13	Laval	439,575	229,308	160,318	409,434
14	Lanaudière	515,711	269,025	188,085	480,349
15	Laurentides	620,521	323,700	226,311	577,972
16	Montérégie	1,583,554	826,073	577,539	1,474,970
17	Centre-du-Québec	249,454	130,130	90,979	232,349
TOTAL		**8,501,703**	**4,434,980**	**3,100,661**[22]	**7,918,745**

* Population Data Source : Institut de la statistique du Québec, 2021.

22 Due to a rounding error, this does not equate equally with estimate in Table 3-1.

7. Conclusions

FLW represents enormous economic, environmental and social costs on individuals and society as a whole. Using 2019 data, the purpose of the study was to establish a detailed estimate of EFLW and ANEP occurring annually in Quebec's biofood system, then calculate the CO_2E emissions associated with FLW — including GHG emissions related to the destinations to which FLW is directed.

With the exception of alcohol, the scope of the study was food available for consumption by consumers in Quebec via retail and HRI. Food produced and/or processed for export to other jurisdictions, including transshipments, was beyond the study's scope. A lack of reliable interprovincial trade data required the research team, at key points during the research, to triangulate results produced by analyzing data captured from different sources. This process of triangulation enabled VCMI to establish hypotheses that were subsequently tested, validated and refined.

The analysis concluded that 3.1 million tonnes of FLW, of which 39 percent is deemed to have been edible prior to discarding, occurs annually in Quebec. The intensity of GHG emissions associated with Quebec's biofood system equates to 4.55 kg of CO_2E per kg of food consumed. The combined effects of reducing FLW through the implementation of circular economy strategies that prioritize reduction and reuse ahead of other options would measurably reduce CO_2E emissions. This would result from less FLW occurring at source and improved coordination between businesses, reduced household FLW, the increased donation of surplus edible food, and the feeding to animals or upcycling of by-products produced by the biofood system. All of these strategies would result in markedly less FLW and less of the FLW that did occur being disposed of in landfills or sewers.

Two distinct opportunities exist to refine the FLW and GHG quantification estimates and address a number of limitations described in Section 2.1. The first is to define the notion of edibility in the cultural context of Quebec (e.g. survey) and to quantify the volume and nature of EFLW and ANEP occurring in Quebec households (e.g. kitchen diary studies). The second is to quantify the volume of FLW going to discrete destinations at an administrative regional level.

The greatest reductions in CO_2E emissions would come from the establishment of circular economy strategies. These include businesses reducing FLW at source by having implemented continual improvement programs — resulting in optimized operations, donating surplus edible food, and upcycling what would have become EFLW and ANEP into new food products. For households, the implementation of circular economic strategies would include improved planning of food purchases, better storage practices, and maximizing the utilization of foods.

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9. Appendix A: Food Loss and Waste Quantification

The following sections describe the approach used to determine the daily volume of food consumed in Quebec, how FLW volumes and types occurring were estimated and validated, and why the approach was markedly different to the national FLW study (Gooch et al., 2019).

9.1 Starting Volumes (Mass Balance Input for Quebec)

For the 2019 national FLW study, food input volume for 2016 was determined, FLW was surveyed along the supply chain, and then the amount of available food per person/day was calculated. In this study the process began in reverse, for reasons described in Section 9.2. MAPAQ data (2020a) was consulted to estimate the amount of available food per person per day, to which FLW factors were applied to calculate input volumes.

For the national FLW study, reliable data and information was available for the total national food production as well as the net food imports and exports. This enabled a starting volume of 61 million tonnes of food inputs (prior to processing/manufacturing) to be calculated. For the national study, an average per person food availability in households and HRI was estimated at 2.0 kg per per person per day. This was deemed a reasonable assumption, considering that similar estimates had been proposed for the United States and Mexico: 2.7 kg and 1.8 kg per person per day, respectively (National Geographic, 2018).

Revisiting the national study during the initial stages of the Quebec study, the total starting volume of food was lowered to approximately 48 million tonnes, based on insights unavailable in 2018 regarding grains in storage. This pertains to grains that may be exported or used in the production of beer, spirits and other non-food purposes. For reasons described in the report, alcohol was excluded from the analysis of FLW in Quebec. This modification – and the impact of industry structure and social culture on food consumption patterns in home versus foodservice – resulted in adjustments to the average per person food availability for Canada. If the scope of the Quebec analysis was applied nationally, the initial food availability estimate would reduce from 2.0 kg to 1.65 kg per person per day.

9.1.1 Provincial level analysis

Estimating the starting volume of commodities entering the food system at the provincial level was challenging. At the national level, food production, imports and exports are subject to regulation, recording and reporting. At a provincial level, the movement of commodities and food between provinces is largely unregulated, neither recorded nor reported, and is sporadic. The interprovincial data that does exist represents an inaccurate assessment of commodity and food movements within Canada (BC Gov., 2021). The use of interprovincial data for calculating domestic movements is also hampered by the unit of measure for the interprovincial trade monitored and reported in value, not volume.

These data gaps mean transshipments are also unreported. Therefore, it is not known what international food exports originate in Quebec, though exit Canada outside of the province. It is also not known what international imports, for example into the Port of Montreal, remain in Quebec. At the time of this study, one national food retailer supplied all its Quebec and Atlantic stores with food from a distribution centre in Ontario. An unknown proportion of that food originated in Quebec. Similarly, it is not known how much food is imported to the multiple retail and foodservice distribution centres located in Quebec from producers, processors and manufacturers located in other provinces.

An extensive analysis of secondary data estimated the total available food entering the Quebec food system from domestic and imported sources to be 8.9 MMT. Key sources of secondary data included Statistics Canada data (production and international trade data), AAFC (public and customized data), MAPAQ (sector profiles of Quebec's agricultural and biofood industry; e.g. grain, dairy, chicken, vegetable), as well as confidential discussions with industry. A selection of referenceable materials consulted during the study are listed in the Bibliography.

9.2 Estimation of Food Volumes in Retail and HRI

As described in the prior section, the definitive data required to establish a starting volume of food inputs for Quebec is lacking.

Given the need for the FLW estimate to be regularly updated, in conjunction with RECYC-QUÉBEC, it was decided that the mass balance input estimates would be calculated based on existing food availability data produced by MAPAQ (2020), which come from Statistics Canada data. This input establishes the volume of food available for consumers at the point of entry for the retail and HRI sectors, prior to purchase from consumers and waste occurring. FLW factors (see Section 9.3) were applied in reverse upstream (from this point of entry to primary production) to estimate input volumes in the biofood system and downstream (from the point of entry to the consumption or discarding of foods in HRI or households).

The calculation of food volume by value informed the proportion of food estimated to flow through retail and HRI. The primary source of information that guided the data analysis and triangulation processes used to determine the volume of food available per person per day in retail and foodservice was the MAPAQ publication: *Le Bottin : consommation et distribution alimentaires en chiffres* (MAPAQ, 2020a). *Le Bottin* provides considerable insight into Quebec's food industry, including consumers' purchasing behaviours. The limitation of *Le Bottin* is that, while it provides total sales, retail sales and HRI sales by value (the latter separated into commercial and non-commercial), food availability by volume is not proportioned into retail versus HRI.

Presented in Table A1 is the data extracted from *Le Bottin* regarding the value of retail and HRI sales, and the total volume of food availability. In line with the research scope, the *Le Bottin* data was adjusted by removing the sales value of alcoholic and non-alcoholic beverages.

Table A1: 2019 Retail and HRI Sales Plus Total Volume of Food Availability

Total food and beverage sales	**$50.34 billion**
Total retail food sales value	**$33.60 billion**
Total HRI food sales value*	**$15.85 billion**
· Commercial HRI*	$12.75 billion
· Non-commercial*	$3.10 billion
Total food availability	**5.58 million tonnes**

* Excluded alcoholic and non-alcoholic beverages
Source: Adapted from MAPAQ, 2020

At each step of the validation process, data from MAPAQ was triangulated against data sourced from elsewhere. These sources of data included Statistics Canada and USDA. As production and market channel data pertaining to supply-managed sectors was assumed to be more accurate compared, for example, to fruits, vegetables and grains, the analysis paid particular attention to industry data pertaining to milk, chicken, turkey, and eggs. Quebec is also most self-sufficient for these foods, meaning that imports represent less volume as a proportion of total consumption.

9.2.1 Distribution channels: retail versus HRI

The following section summarizes how sales volumes were estimated based on sales value. Statistics Canada tracks the national monthly average retail prices for food, a consumer price index, comprising about 44 items. For 2019, the overall average monthly price was $8.69/kg. Household food availability was calculated by applying $8.69/kg to total food sales from retail of $33.6 billion (2019). This produced an average of 1.25 kg per person per day purchased at retail.

The value ($) per kg of food sold at HRI was estimated by reviewing online menus to identify food portion sizes and prices for quick service restaurants (QSR) and full-service restaurants. The findings were segmented to estimate the value and volume of foodservice purchases into beverage and snacks. QSR food and beverages included Tim Hortons, McDonald's and Subway. Full-service restaurants included The Keg and St-Hubert, and prices were reviewed for Mike's Pizza. The limitation of this approach is that prices are for 2021, and may not accurately reflect pre-COVID-19 prices in 2018/19. For QSR and takeout food sales, the difference was split between Tim Hortons and McDonald's price per kg. Using this approach, the grand average for food sold in all HRI settings was calculated at $28.88/kg. This produced an average of 0.17 kg per person per day of food purchased/consumed in HRI.

The previous descriptions, along with the proportion of total food estimated to flow through retail versus HRI sales channels and which resulted from the analysis, are summarized below in Table A2.

Table A2: Comparative Channel Values and Volume

Food channel	Grand average value	Per person per day volume	Proportion of food flow
Retail	$8.69	1.25 kg	88%
HRI	$28.88	0.17 kg	12%

The estimated volume of food flowing to households, using the 88/12 spilt and the application of FLW factors described below in Section 9.3, produced an estimate of household FLW that fell within the range reported by Canadian and American studies that measured household FLW.

An alternative proportioning of food flowing through retail versus HRI was investigated. This drew on the distribution of food purchasing costs in retail and HRI sectors by triangulating information from MAPAQ (2019a) and the Association des Restaurateurs du Québec (2021), in order to estimate the percentage of purchase by each sector. These percentages related to the total of food purchasing costs and were then attributed to the quantity of food flowing through the HRI and retail sectors. This analysis resulted in an estimation of 25.6 percent of total food by volume going through the HRI channel and 74.4 percent of total food by volume going through retail. A bias of this approach is that this calculation assumed that food wholesale prices paid by retail and HRI operators are the same.

Numerous consultations with industry experts identified considerable variability in the prices paid between businesses operating in the retail versus HRI sectors, and also within the HRI sector. Industry experts also pointed out that, while there is a lack of empirical market insights relating to retail versus HRI wholesale prices, the typical price margins paid in HRI are measurably higher. They also stated that the HRI food chain is less consolidated, longer and typically composed of more players than the retail food chain. This leads to smaller volumes being distributed to individual HRI operations, at any one time and overall, negatively impacting economies of scale compared to retail and leading to HRI operators incurring higher distribution costs. Therefore, prices typically paid by the HRI sector for food are measurably higher than the retail sector.

The application of the 74.4/25.6 proportioning of total food volume reduced the estimated volume of household FLW below that was established by prior research. This included the volume of household solid waste reported by Éco Entreprises Québec and RECYC-QUEBEC (2021).

Due to reasons described previously, the estimates of food, FLW and GHG emissions therefore defaulted to the proportion of food flowing to retail versus HRI being 88 and 12 percent, respectively. Regardless of whether the total food volumes are proportioned in terms of 88/12 or 74.4/25.6, the total estimated volume of FLW is similar (1.0 kg/person per day), as are the loss factors described in the next section.

9.3 Food Loss and Waste Factors

Presented in Table A3 are the loss factors applied at each discrete level of the food system analysis for edible food loss and waste (EFLW) and associated non-edible parts (ANEP). The application of these loss factors to the mass balance quantification calculated the total tonnage of EFLW and ANEP that occurs along the supply chain.

Table A3: Food System Loss Factors: EFLW and ANEP

		Production		Processing		Manufacturing		Distribution	Retail	Households[23]		HRI		Total FLW occurring along the food value chain
		EFLW	ANEP	EFLW	ANEP	EFLW	ANEP	EFLW	EFLW	EFLW	ANEP	EFLW	ANEP	FLW
Dairy and eggs	milk	0.50%	0.50%	1.0%	1.0%		N/A[25]	1.0%	4.00%	6.9%	6.9%	5.10%	5.86%	6.5%
	milk further processed				45%[24]					3.3%	3.3%			
	eggs	0.37%	0.08%	0.5%	0.5%				3.59%	1.7%	1.7%	5.99%	8.07%	
Field crops	grains	8.00%	5.00%	6.0%	30.0%	3.1%	5.0%	1.0%	4.45%	12.3%	1.5%	6.33%	5.57%	14.2%
	all other			5.0%	25.0%									
Fruits and vegetables	hardy	2.20%	2.00%	9.0%	3.0%	4.0%	5.0%	3.0%	7.00%	5.9%	13.9%	11.0%	11.0%	22.5%
	tender	2.40%	3.00%	14.0%	5.0%					7.9%	18.5%			
Meat and poultry	pork		N/A[26]	2.0%	8.0%	4.0%	10.0%	2.0%	5.72%	5.9%	4.0%	7.60%	7.32%	11.5%
	beef			8.0%	10.0%									
	lamb									5.9%	4.0%			
	chicken			5.0%	10.0%					7.9%	5.3%			
	turkey/duck													
Marine	fish	0.20%	1.50%	7.5%	7.5%	2.0%	2.0%	4.0%	6.08%	6.1%	3.8%	7.45%	9.55%	8.0%
	shellfish													
Sugar, syrups, confectionary	sugars	0.50%	0.50%	1.0%	1.0%	0.5%	0.5%	1.0%	2.17%	13.3%	8.5%	3.90%	3.10%	6.8%

23 Household FLW factors from VCMI Oakville FLW study (Gooch et al., 2020).

24 With the standard in the dairy sector being that ~10 kg of milk is used to make 1 kg of cheese (90% loss), and that other dairy products (e.g. yogurt) can be as low as 25% loss, based on (COWI, 2000; Melilli et al., 2002; Trivino et al., 2016; Verge et al., 2013) the research team assumed 45% loss in an attempt to account for this variability. This does assume that all whey is loss; however, an unknown proportion of this may be upcycled into food supplements or animal feed, which is captured from a GHG perspective in the destination analysis. Some dairy processors would be able to capture this as a revenue source.

25 Some eggs and milk are used in manufactured food products; however, losses of these are presumed to be minimal and most loss occurs during the processing of milk and egg products.

26 The starting point for meat in the model is meat carcass; however, GHGs of production are considered. Reasons why FLW is not reported for the primary production of livestock and poultry include: 1) the most accurate production data is for eviscerated carcasses entering the biofood system; 2) though generic mortality rate data exists, reliable data is not available in terms of where in the life cycle comparative percentages of mortality occur in relation to discrete production systems; and, 3) livestock and poultry that die or are compromised during transportation/handling, etc., are forbidden from entering the biofood system.

The loss factors presented above are conservative, with the research erring on the side of caution. The conservative nature of the loss factors presented previously reflect that the majority of respondents estimated the losses they experience. As described in Section 2.1 (Research Limitations), this is amongst the reasons that may have led to underreporting. Where the Quebec industry survey did not provide sufficient data to produce robust loss factors for specific foods, the researchers consulted loss factors produced by survey data analyzed in the national FLW study (Gooch et al., 2019). The 2019 study included many businesses operating in Quebec. The only point in the biofood system where the extraction of moisture was explicitly included as a loss factor is dairy processing, as occurs in the manufacturing of cheese.

In terms of losses at the primary production (grow/produce) level of the biofood system, EFLW is primarily storage/transport and packaging-related losses. ANEP is primarily production-related losses. Examples of on-farm EFLW include fruits and vegetables that were edible though not harvested due to not meeting customer specifications or being surplus to customer requirements. In field crops, EFLW count crops left in the field or which passes through the harvester. In dairy, EFLW includes milk that cannot be collected from farms due to inclement weather or spoils due to equipment malfunction. Examples of ANEP occurring during the grow/production (on-farm) level of the biofood system include milk that cannot be consumed, because it is colostrum or from cows being treated with medications (e.g. antibiotics used to treat mastitis). The occurrence of ANEP reported in relation to the production of fruits and vegetables is less than might be expected. This could be due to respondents considering that the non-edible parts of the plants that are removed and discarded when harvesting vegetables (e.g. broccoli and cauliflower stalks and stems) were beyond the scope of the study. The EFLW and ANEP loss factors applied at the household level is based on findings produced by a study that measured household FLW in Oakville, Ontario (Gooch et al., 2020). While studies completed by Von Massow et al. (2019) and Zanolli et al. (2018), and cited by Carradini (2021), reported higher proportions of EFLW than those reported by Gooch et al. (2019), they did not provide comparable figures for EFLW and ANEP. Hence they could not be applied to Quebec's quantification. All four studies did produce comparable figures for total household FLW: 4.2 kg/week (Gooch et al., 2020); 4.41 kg/week (Von Massow et al., 2019); 4.04 kg/week (Zanolli et al., 2018); and 4.5 kg/week (cited by Carradini, 2021). On the other hand, the Oakville study qualified all prep waste (reported as ANEP) as inevitable. This might partly explain why EFLW seems underestimated as a part of the prep waste probably were EFLW (e.g. carrot peelings and broccoli stems) and not ANEP. As well, cultural norms determine whether a discrete food part is edible. The extent to which differences in Quebec versus Ontario cultural norms affect the categorization of EFLW and ANEP is unknown.

VCMI's hypothesis for why the Oakville study reported a comparably lower proportion of EFLW in relation to total FLW was due to participants being more predisposed to purposefully reduce avoidable FLW than the wider population. There is no empirical data to support this hypothesis.

10. Appendix B: Carbon Dioxide Equivalent (CO_2E) Estimate

The following sections describe the approach used to estimate and contextualize GHG emissions (reported as carbon dioxide equivalent: CO_2E) associated with Quebec's biofood system. Given that the measurement and reporting of CO_2E emissions is evolving, and therefore no standardized methodology presently exists (Helm, 2020), care was taken to ensure that emission estimates consulted during the study shared complementary boundaries of analysis. Where possible, Quebec-specific CO_2E emission estimates were used after having triangulated them against North American meta-analysis studies to test their comparability to peer-reviewed publications.

10.1 Background: Biofood-Related CO_2E Emissions

Vermeulen et al. (2012), Ritchie and Roser (2020) and Crippa et al. (2021) have all provided estimates of CO_2E emissions from the global food system. These studies estimate the global food system emits between 19 and 34 percent of total anthropogenic GHG (CO_2E) emissions. Vermeulen et al. (2012) estimate that between 80 and 86 percent of the global food system's CO_2E emissions is attributable to primary production, while Crippa et al. (2021) estimate primary production accounts for 71 percent of the food system emissions.

In 2018, Quebec's total CO_2E emissions were estimated to be 80.1 MT CO_2E (IQEA, 2020). Based on the above global estimates, Quebec's food system could represent between 15.2 and 27.2 million tonnes of total CO_2E, of which the production systems that produce that food (inside or outside of Quebec) could represent anywhere between 10.8 and 23.4 million tonnes of CO_2E. The following section describes how the CO_2E emissions associated with Quebec's food system, including the creation and destination of FLW, were calculated.

10.2 Production, Processing and Manufacturing Emissions

Using published literature on life cycle analysis (LCA) of various food types, CO_2E emission factors related to specific foods and discrete stages of the supply chain were gathered and used in the GHG quantification. Because primary production is the most significant source of food-related CO_2E emissions (Porter et al., 2016; Vermeulen et al., 2012; Crippa et al. 2021), that is where most LCAs focus their attention. Porter et al. (2016) provides a comprehensive source of production emission factors. By incorporating data pertaining to activities occurring along the entire food chain, the estimation that resulted from this study provides a more complete picture of CO_2E emissions.

Emissions factors for processing and manufacturing were acquired wherever possible. Table B1 illustrates the limited documentation on post-production CO_2E emissions. All production emissions factors (except sugar/syrups, dairy, eggs, and pork) came from Porter et al. (2016), using the North America and Oceania regional data set. The average of the products within the food types was generally used. Because the predominant field crops in Canada are wheat, corn and oilseeds, the emission average was adjusted downwards slightly for field crops. Where possible, the robustness of data was tested by triangulating it against alternative sources. For example, Porter et al. (2016) estimates were compared against data contained in a meta-analysis of LCAs completed by Clune et al. (2016).

Table B1: Emission Factors (Tonnes of CO_2E Emissions per Tonne of Food) Used in the Quantification

Food type	Production	Processing	Manufacturing
Dairy	0.92[27]	2.35[28]	Included in processing[29]
Eggs	0.35[30]	See footnote[31]	See footnote[37]
Field crops	0.500	0.041[32]	0.219[33]
Produce	0.46	0.03[34]	0.03
Pork	4.29[35]	0.148[36]	0.148[37]
Beef	23.5[38]	0.149	0.149
Lamb	15.35	0.148	0.148
Poultry	4.39	0.221	0.221
Marine	4.42	0.00[39]	0.01[40]
Sugar/syrups[41]	0.44	0.189	0.189

27 Production intensity for Quebec (Verge et al., 2013).
28 (Verge et al., 2013) Average of intensity for various products in Quebec minus the portion of on-farm emissions. Approx. 1% of emissions are associated with transportation; therefore, average intensity was reduced by 1% to avoid double counting.
29 In the quantification, CO_2E emissions for dairy processing and manufacturing are captured in the processing stage of the model.
30 Calculation is based on one response from the survey that gave production CO_2E per dozen eggs.
31 Insufficient data was available to establish a CO_2E emission factor for egg processing and manufacturing. No definitive data could be sourced, and communications with representatives of the egg processing sector suggested that emission intensities were negligible.
32 Wheat milling was used as proxy (Espinoza-Orias, Stichnothe, and Azapagic 2011).
33 Bread manufacturing was used as proxy (Espinoza-Orias, Stichnothe, and Azapagic 2011).
34 Clune et al. (2016) reports an intensity of 0.06 for processing vegetables; we split this 50:50 between processing and manufacturing.
35 Emission intensity data reported by Les Éleveurs de porc du Québec (EPQ, 2021b) was converted to retail weight (the functional unit) using the AAFC (2021d) red meat conversion factor for pork of 76%.
36 Slaughtering and Rendering of Pigs, Chickens and Cattle (Aan Den Toorn, Van Den Broek, and Worrell 2017). Used average of other meats for mutton/lamb.
37 Applied the same emissions estimate for manufacturing based on cooking energy, etc., required for further processing of meat products.
38 Based on Canadian Roundtable for Sustainable Beef LCA report and Clune et al. conversion factor for carcass to boneless meat.
39 Processing of fish is conducted within the bounds of the farm or catch facility, therefore included in CO_2E emissions.
40 A minimal CO_2E was assigned for the small amount of further processing/value adding of marine products.
41 Emissions factors for sugar/syrups sourced from García et al. (2016), which is the best available estimate that could be found.

10.3 Retail

Based on available data (Canadian Grocer, 2020; Statistics Canada, 2019), there are 6,647 food retail stores in Quebec:

- 1,887 corporate chain stores (28.4%), including franchised locations
- 4,760 independently owned stores (71.6%), varying in size from small corner stores to supermarkets

Approximately 40 percent of all food sales in Quebec are spent in independently owned and "non-traditional" stores.

The three main corporate food retailers (Metro, Sobeys and Loblaw) publish information on their number of stores, square footage and operating emissions on corporate websites and in annual reports and corporate sustainability reports. Non-food stores owned by the food retail corporations, such as Shoppers Drug Mart (Loblaw), were not included. Many large format Loblaw stores devote space to the sale of non-food items, but this may be offset by food sold in Shoppers Drug Mart stores.

CO_2E estimates are based on corporate-owned and franchised real estate for each banner and independent store numbers, and materials published by two of the three main corporate retailers — Loblaw (2019) reports 15.53 kg/ft^2 and Metro (2019) reports 22.29 kg/ft^2. Sobeys does not report emissions per square foot. For independent stores, an assumption was made, based on our experiences and expertise, that less investment in building and equipment upgrades likely results in slightly higher emissions, which are estimated at 25 kg/ft^2.

The estimate of total CO_2E for food retail operations in Quebec is 1,498,798 tonnes. This equates to an average of about 24.75 kg/ft^2 of CO_2E per store, and an average of 225 tonnes per store per year. Based on the estimated average volume of food flowing through Quebec retail stores, this equates to 0.30 tonnes of CO_2E per tonne of food.

10.4 Hotels, Restaurants, Institutions (HRI)

The HRI sector is comprised of commercial and non-commercial operations. Commercial and non-commercial entities differ in that the latter typically provides complementary services, such as providing sustenance to a cohort of clients — for example, long-term care home patients or refectory services to factory workers (MAPAQ, 2020a). The HRI sector's emissions was calculated using the Natural Recourses Canada (NRC, 2021) energy use data tables. NRC data is used to report on Canada's greenhouse gas emissions and commitments to international climate change action. The NRC reports that, in 2018, accommodation and foodservices in Quebec used 17.3 petajoules of energy. The tables separate energy usage by type and provide CO_2E emissions, though exclude electricity. Although electricity production and usage accounts for a very small amount of the overall CO_2E, calculations were made to add it to the estimated CO_2E from this sector. This was achieved by using the intensity of 1.5 kg[42] CO_2E/MWh reported by Environment Canada (2013) and a conversion rate of 1 petajoule equals 277,778 MWh.

A total of 435,000 tonnes of CO_2E has been allocated to the HRI sector. As there was no clear way to separate out accommodation from foodservice, all accommodation and foodservice were included in the calculation. The majority of energy associated with accommodation outside of foodservice was assumed to be electricity, which has an insignificant impact on the overall CO_2E intensity in the context of Quebec. The table energy use for healthcare was also consulted. NRC documentation regarding energy usage in hospitals suggested that a maximum of five percent of hospital floor space is dedicated to food preparation. A variety of energy uses are unique to healthcare, including refrigerated storage of non-food related items, such as medication; therefore, only five percent of the healthcare emissions reported by NRC were allocated to the GHG quantification. This represents food preparation and storage in the health sector. The calculation of CO_2E from healthcare, accommodation and foodservice resulted in an estimated 482,000 tonnes of CO_2E emitted from HRI. For the CO_2E emissions quantification, this was distributed proportionally across the types of food contained throughout the HRI sector.

10.5 Household Carbon Footprint

Statistics Canada (2016 census) states that there are approximately 3.7 million households in Quebec, averaging 2.3 people per household. Household CO_2E emissions associated with food storage and preparation was estimated using NRC energy use tables (2020b/c). NRC reports that 4.4 million tonnes of CO_2E emissions are produced by Quebec households. This estimate excludes emissions associated with electricity. Uses included in the NRC data are space heating, water heating, appliances, lighting, and space cooling. To calculate the proportion of the CO_2E emissions associated with food storage and preparation, the following assumptions were used.

- Ten percent of the house floor space was assumed for food storage and preparation.[43]
- Twelve percent of energy was related to lighting, due to the fact that much of the cooking occurs in the morning and evening when lighting would be required.[44]
- CO_2E from electricity has the intensity of 1.5 kg CO_2E/MWh[45] (Environment Canada, 2013); the analysis applied a ratio of 1 petajoule to 277,778 MWh.
- Food-related appliances are considered to be fridges, freezers, ranges (stoves),[46] and one third (33 percent) of other appliances.[47]

The total energy for food-related appliances was 28.03 petajoules. In addition to this, the portion of lighting and cooling allocated to food and the total food-related electricity is estimated to be 30.3 petajoules. This equates to 12,640 tonnes of CO_2E, which is only three percent of the CO_2E associated with food preparation and storage within Quebec households. The majority of CO_2E emissions is associated with heating household living space (79%). The total estimated CO_2E emitted by Quebec households that is directly associated with the storage and preparation of food is 499,923 tonnes.

42 The effect of applying Hydro-Québec's (2020, 2021) reporting of 0.5kg CO_2E/MWh was tested. This adjustment, which pertains only to the electricity generation and therefore does not present a full picture, reduced total FLW-related GHG emissions by 0.06%.
43 Emrath (2019) reports kitchens as being 11.2%; we rounded down to 10%.
44 Gifford et al. (2012) indicates that kitchens and dining rooms consume ~12% of household lighting energy.
45 The effect of applying Hydro-Québec's (2020, 2021) reporting of 0.5 kg CO2E/MWh was tested. This adjustment, which pertains only to the electricity generation and therefore does not present a full picture, reduced total FLW-related GHG emissions by 0.06%.
46 Using factors from Quebec GHG quantification protocol, (MLES, 2021) double counting of energy associated with natural gas ranges was avoided.
47 Assumption is that 1/3 energy usage would be small kitchen appliances and 2/3 would be TVs, computers, etc. Estimated energy utilization associated with this assumption is based on NRC 2020b, 2020c.

10.6 Effect of Food Type, Origin and Transport on CO_2E Emissions

The origin of food (produced inside and outside of Quebec) impacts CO_2E emissions associated with transportation and distribution. The quantification reflects that a large percentage of fresh, processed and manufactured foods in Quebec are imported from across Canada and around the globe.

This section describes how the assumptions about transport-related CO_2E emissions were determined, and the information the assumptions were based on. By identifying the primary sources of food, and the primary method of transportation as road, rail and ship, the impacts were determined on the typical distances food travels from production to consumer. Each mode of transport varies significantly in its carbon emissions.

10.6.1 Primary foods and origins

The purpose and scope of transport related to CO_2E emission analysis was to estimate the CO_2E emissions associated with food consumed within Quebec. Estimates did not include surplus food produced for export outside the province, or food imported for onward distribution across Canada.

Quebec is largely self-sufficient in the production of dairy, eggs, pork, and poultry products. The province's fishery industry satisfies most of provincial demand, plus some exports. The analysis identified that the most significant food imports are:

- Fruits and vegetables: largest volumes transported by road
- Field crops: mostly transported by ocean or lake-going ship and/or train, then road
- Beef: intermodal train and road

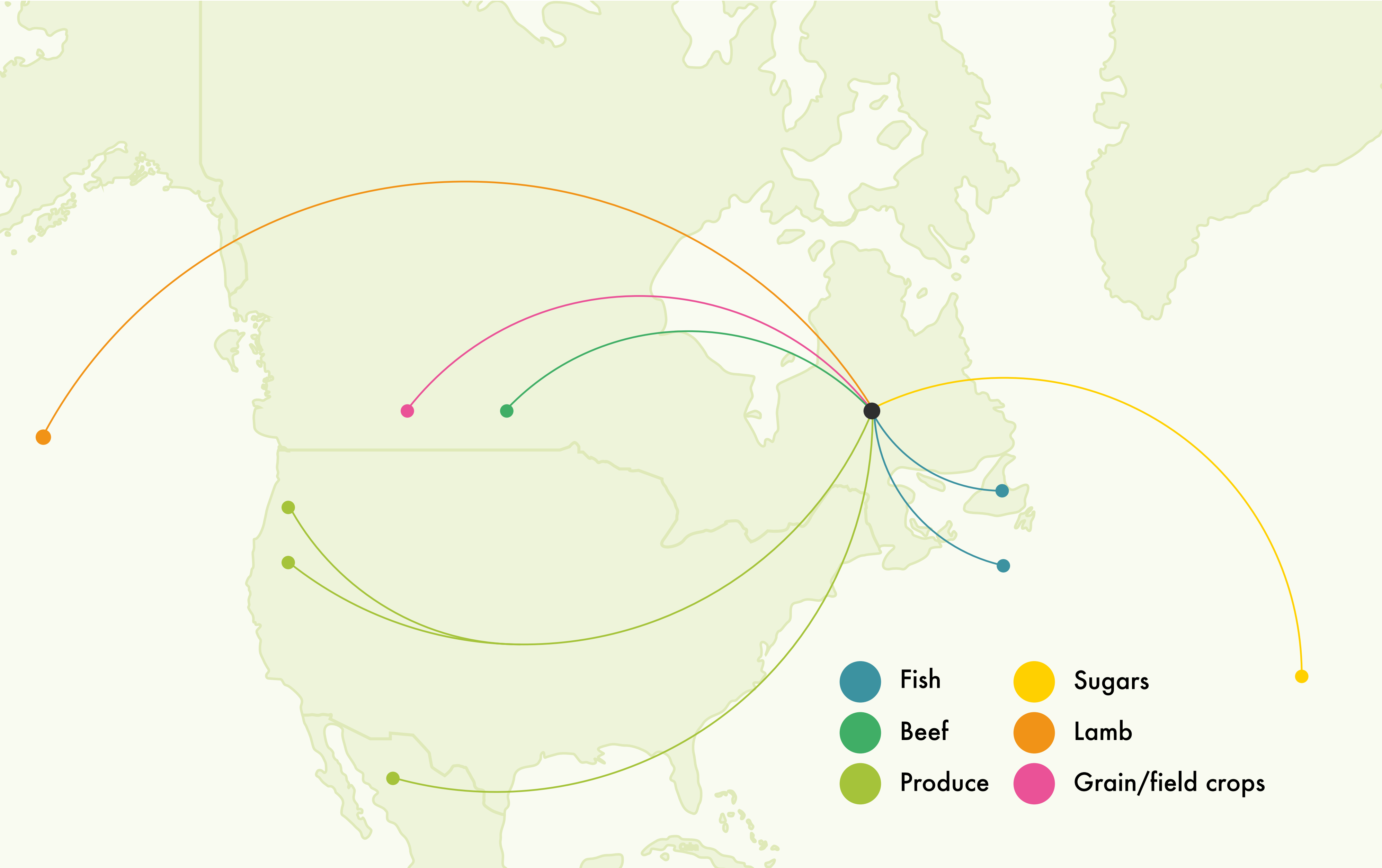
Table B2 identifies the primary production regions and transportation methods for food consumed in Quebec. Food imported into the province for onward distribution within Canada and food produced in Quebec for export outside the province/country are not included.

Table B2: Food Type, Production Region and Transport Method

Food type	Subcategory	Production regions used to estimate transportation CO_2E		Transport method for the primary regions	
		Primary origin	Secondary origin	Primary method of transport	Secondary method of transport
Fruits and vegetables	Hardy (e.g. melons, apples)	Washington	Quebec Rest of Canada	Truck	Intermodal
	Perishable (e.g. salads, stone fruit, tomatoes)	Mexico and California	Quebec Rest of Canada	Truck	Intermodal
	Citrus and tropical (e.g. bananas, oranges)	Florida, Caribbean and South America	N/A	Truck	Intermodal/multimodal
Meat and poultry primal cuts	Pork	Quebec	Rest of Canada	Truck	N/A
	Beef/veal	Alberta	Quebec	Truck	Intermodal
	Lamb	NZ, Australia and US	Quebec/Canada	Ship	Multimodal
	Chicken/turkey	Quebec	Rest of Canada	Truck	Intermodal
Field crops	Grains/seeds, flour, etc.	Western Canada	Quebec/Ontario	Rail	Laker
		North America-wide	Overseas	Truck	Intermodal
Dairy and eggs	Cheese	Quebec	Rest of Canada/EU	Truck	Intermodal
	Other dairy, eggs	Quebec	Rest of Canada	Truck	N/A
Marine	Lobster/shrimp	Quebec	Atlantic Canada	Truck	N/A
	Fish	Atlantic Canada	Quebec	Truck	N/A
Sugars	Raw sugar and molasses	Brazil, India, China and Thailand	N/A	Bulk ship	Truck
	Processed foods/beverages	Canada	International	Truck	Intermodal

The results of discussions with industry, along with the analysis of data produced by Quebec-specific and national entities (including MAPAQ and Statistics Canada regarding the primary sources and routes of food imported into Quebec), is presented below graphically in Figure B1.

Figure B1: Primary Routes for Food Imported into Quebec for Consumption in the Province



The following sections summarize how the results of the analysis regarding food types, sources and methods of transportation were translated into CO_2E emission estimates.

10.6.2 Food type, source and mode of transport

Based on the review of sectoral analysis reports and extensive consultations with industry experts, the following considerations and assumptions were used to estimate the primary sources of food consumed in Quebec, including the proportions produced domestically in Quebec versus: 1) those imported from other regions of Canada and, 2) those imported from international jurisdictions. The resulting information was subsequently used to estimate the CO_2E emissions associated with the transportation of food from other jurisdictions to an arrival terminus within Quebec, then its onward distribution within the province.

Dairy[48]

- Quebec is self-sufficient and all transportation is within province.
- Most administrative regions have production and processing, so transportation is by road and does not involve long distances.

Eggs[49]

- Quebec is self-sufficient and all transportation is within province.
- Most administrative regions have production and processing, so transportation is by road and does not involve long distances.

Field crops[50]

- Consultations with industry experts confirmed that 95 percent of grains for human consumption are imported from outside Quebec — an assumption was made that the same applies to all other field crops.
- Transportation methods for field crops are likely to include:
    - Road to elevator or storage
    - Rail to port (Thunder Bay)
    - Lake freighter to Montreal — approximately 12 MMT are moved by freighter (CSL, 2021)
    - Rail to destination terminal, then possibly by road to final destination if there is no rail spur to the mill

48 PLQ, 2020; MAPAQ, 2019e
49 FPOQ. 2021; AAFC, 2021a; MAPAQ, 2020b
50 GGC, 2021a, 2021b, 2018; AAFC, 2016; MAPAQ, 2019; AAFC, 2016

Produce[51]

- Approximately 40 percent of fruits and vegetables consumed in Quebec are produced in Quebec. Transportation would be by road.
- Approximately 60 percent of consumption is imported. Imported produce is primarily sourced from the United States and Mexico, and transported by truck.

Pork[52]

- Quebec is a large exporter of pork, within Canada and internationally.
- Quebec is self-sufficient in most pork and pork derived products.
- Hog producers are located in all 17 administrative regions.
- Most transportation is by road. As a measurable proportion of hogs produced in Quebec are processed in the United States, an adjustment to reflect an increase in distance travelled was included in the quantification for pork.

Beef and veal[53]

- Veal production is mostly sourced from the breeding of herd replacements and that required to maintain the dairy business, including male calves and female calves from less productive cows.
- There is limited domestic beef production; the majority (85 percent) of beef consumed in Quebec is imported from outside the province, arriving mostly from Alberta by road and/or rail.

Lamb[54]

- Approximately 50 percent of lamb consumed in Quebec is produced domestically.
- The remaining approximate 50 percent is mostly sourced from other parts of Canada, as well as imports from New Zealand and other jurisdictions.
- The majority of transportation is by road, followed by intermodal.

Poultry[55]

- Quebec exports a considerable volume of chicken to other parts of Canada and internationally.
- Quebec is mostly self-sufficient in chicken.
- Some processed chicken products, such as wings, are imported - namely from Brazil -, but do not account for a large percentage of total production.
- Transportation is mainly by road, with some intermodal.
- Other species of poultry (turkey, duck and goose) are a considerably smaller volume of total poultry consumed in Quebec.

Marine[56]

- Commercial fishing is an important component of Quebec's economy.
- Quebec's most valuable fisheries are located in the Gulf of Saint Lawrence for lobster, snow crab, cold water shrimp, scallops, and ground fish.
- Quebec is self-sufficient, with some exports of species (incl. lobster and shrimp), and imports of other species (incl. cod, haddock, Atlantic salmon, mackerel, sardines from Atlantic Canada, and salmon from BC).
- Transportation is mostly by road.

Sugars[57]

- Quebec is self-sufficient in maple syrup, with substantial exports within and beyond Canada.
- Grain sugars (cane or beet) are imported as finished products or for further refining. The Port of Montreal indicated that 571,000 tonnes of bulk raw sugar was imported into Quebec in 2019.
- No bulk raw sugar was exported via the Port of Montreal.

10.6.3 Carbon equivalent emission estimates by mode of transport

A set of emission factors was developed to estimate the carbon emissions for each transportation segment of the shipment, based on an examination of several sources of logistics activities. The following segments are predominantly based on data sourced from CN Rail, who have produced extensive comparisons of CO_2E/metric tonne-km emission estimates for different forms of transportation (CN 2021a/b).

Marine vessel shipping

Based on a number of technical studies, CN Rail estimated emission factors for bulk and container shipments, thereby enabling them to account for differing emissions associated with each. Emission factors for larger bulk ships were determined to be in the range of 2.5-6 g CO_2E/tonne-km. CN's calculator specifically uses 4 g CO_2E/tonne-km. The emission factor for container shipping is taken from the Clean Cargo Working Group study (BRS, 2014). Based on an average load weight of 10 tons (short) in each container/TEU, this provided an emission factor of 8.3 g CO_2E/tonne-km.

Rail transportation

Based on fuel consumption factors produced by the Railway Association of Canada's Locomotive Emissions Monitoring Program (2021) and rail diesel combustion emission factors estimated by Canada's National GHG Inventory Report 1990-2018 (ECCC, 2021), the rail emission factor used CN's GHG calculator of 14.0 g CO_2E/tonne-km.

Truck transportation

Based on industry standards of 6 to 7 miles per gallon, Natural Resources Canada's fuel efficiency benchmarking study of Canada's trucking industry (NRC, 2019), and an average shipment weight of 16 tons (14.5 tonnes), CN proposed an emission factor of 63.8 g CO_2E/tonne-km.

51 EPQ, 2021; MAPAQ, 2020c
52 PBQ, 2021; MAPAQ, 2021
53 PBQ, 2021; MAPAQ, 2021
54 LEOQ, 2021 & 2020; AAFC 2021c
55 AAFC, 2021a; EVQ, 2020; MAPAQ, 2019f
56 MAPAQ, 2019d; DIRF, 2021; DFO, 2021 & 2019; Commercial Fisheries, 2021a, 2021b, 2021c
57 CSI, 2021; QMSP, 2020; Port of Montreal, 2020a, 2020b

10.6.4 CO_2E emission estimates per tonne of food transported/distributed

Within Quebec, the majority of food is transported/distributed by road. The transport of those products in which the province of Quebec is self-sufficient, such as dairy, pork and maple syrup, is therefore likely to only occur by road. Many products imported into Quebec from other regions of Canada, or that originate from an international jurisdiction, will occur via intermodal (e.g. train then road) or multimodal (e.g. sea, train, and then road) transportation routes. It is assumed that food delivery trucks pick up another load after delivery, rather than returning empty, to be economical and avoid doubling the CO_2E of the delivery.

Examples of intermodal distribution include beef transported by train from Alberta or raw sugar transported by sea from Central and South America. After arriving at a central terminus, such as the Port of Montreal, products will then be transported by road. Multimodal transport would include lamb and fruit transported by sea from Australasia to the Port of Vancouver, then by rail to Canadian Pacific Rail's Lachine Intermodal Terminal in Montreal, after which it is distributed within the province by road. Wheat grown on the Canadian prairies is also likely to be multimodal, travelling from farm to elevator by road, elevator to the port of Thunder Bay by rail, then to Montreal by lake-going freighter, before subsequently being transported by road to mills/bakers/etc.

Examples of distances travelled by representative foods imported into Quebec from across Canada and internationally that were used by the researchers to estimate transport-related CO_2E emissions include:

- Fruits and vegetables: Sacramento to Montreal = 4,633 km by road
- Fruits and vegetables: Tepic (Mexico) to Montreal = 4,797 km by road
- Fruits and vegetables: Florida to Montreal = 2,478 km by road
- Marine: Halifax to Montreal = 1,247 km by road
- Field crops: Regina to Montreal = 2,847 km intermodal
- Beef: High River (Alberta) to Montreal = 3,595 km intermodal
- Lamb: Australasia to Vancouver, onto Montreal = 10,300 km multimodal

For all foods, the estimation of CO_2E emissions associated with transport and distribution within Quebec assumes that food will travel an average of 50 km to the primary processor or key aggregation point, such as a third-party distribution centre, before subsequently being transported an average of 100 additional km from primary processor/manufacturer/distributor to the point at which it enters the retailers' or HRI operators' internal distribution system. The corporate sustainability reports from corporate retailers (LCL, 2020; Metro, 2020) indicate that emissions include internal transportation. Therefore, CO_2E emission estimations for transport and distribution do not include emissions associated with transporting food from corporate retailers' distribution centres to stores. Estimates for the CO_2E footprint of small and independant retailers are calculated using large retailer store CO_2E footprint.

The calculation of average shipment size and transport CO_2E emission estimates for international and Canadian shipments was based on the sea and freshwater, rail, and road transportation research published by CN Rail's Carbon Calculator Emission Factors comparison (CN, 2021a/b), the Clean Cargo Working Group (BSR, 2014/2015), and CSL Group (2021) described previously in Section 10.6.4. The GHG emission estimates for one tonne of different food types – and consequently FLW – transported to Quebec, then distributed within the province, are presented below in Table B3.

Table B3: Emissions Factors: Tonnes of CO_2E per Tonne of Food Used in the Quantification

Food type	Transport to distribution[58]	Retail	HRI	Households
Dairy and eggs	0.01			
Field crops	0.07			
Produce	0.21			
Meat/poultry	0.02	0.30[59]	0.72[60]	0.11[61]
Marine	0.05			
Sugar/syrups	0.01			
Average	**0.11**			

The above estimates do not include consumer travel to retail stores or HRI settings, nor the delivery of retail/E-tail[62] or HRI-sourced food to individual households.

10.6.5 CO_2E from FLW destinations

Emission factors associated with each of the identified destinations of FLW were adapted from CO_2E factors produced by Corona et al. (2020) and Powell et al. (2020) for ReFED (2020). The emission factors presented in Table B3 purposely build on the EPA's WARM model V15 (EPA, 2020a/b) by ensuring they are associated with discrete destinations and align with the Food Loss and Waste Accounting and Reporting Standard (Hanson et al., 2016). VCMI adapted the Corona et al. (2020) and Powell et al. (2020) data for use in Canada by converting it from short tons of FLW to metric tonnes of FLW. Following the table is a concise summary of considerations that the emissions factors presented below encompass.

58 CN (2021a/b), BSR (2014/2015), CSL Group (2021)
59 Metro (2019), LCL (2019)
60 NRC (2021a), ECCC (2013)
61 ECCC (2013), NRC (2021b, 2020c)
62 For the purposes of this study, E-tailing is the sale of consumer-ready foods via the Internet by an organization that does not operate a grocery store.

Table B4: Destination-Related Emission Factors (Metric Tonne of CO_2E/Metric Tonne FLW)

	Producer	Processing/ manufacturing	Distribution (used retail factors)	Retail	HRI	Household
Destinations	Emissions (t CO_2E/t FLW)					
Rescue/redistribution for human consumption	0.077619	- 2.626171	- 2.867548	- 2.867548	- 4.695198	
Upcycling into foods, nutritional supplements, etc.	- 0.000401	- 0.125942	- 0.098888	- 0.098888	- 0.179368	
Animal feed	- 0.000401	- 0.062372	- 0.049049	- 0.049049	- 0.080703	
Biomaterial processing/rendering	- 0.000401	- 0.125942	- 0.098888	- 0.098888	- 0.179368	
Biomethanization (anaerobic digestion)	- 0.046710	- 0.107919	- 0.074776	- 0.074776	- 0.117102	
Compost	- 0.251464	- 0.232566	- 0.242799	- 0.242799	- 0.229731	- 0.235587
Land application	0.021909	0.040842	0.030588	0.030588	0.043698	0.037837
Incineration or controlled combustion	0.035690	- 0.172146	- 0.059584	- 0.059584	- 0.203492	
Landfill/burial	0.118428	0.220617	0.165282	0.165282	0.235963	0.204306
Other (e.g. sewer)	0.272906	0.508345	0.380858	0.380858	0.543680	

Utilizing United States data, the emission factors encompass surplus food, the transportation of discarded food, the processing of the food waste, and the infrastructure applicable to the destination. The emission factors also encompass off-sets applicable to these destinations. These include, for example, the reduction in GHG emissions achieved by having replaced: 1) artificial fertilizers with composted organic materials, and, 2) having replaced petroleum-based fuel and artificial fertilizer with biogas and natural fertilizer produced by biomethanization. Prior to their use, the emission factors were triangulated against confidential data pertaining to Quebec.

Analysis, Reporting and Benchmarking of Whole of Chain Food Loss and Waste and Related GHG Emissions

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