DILLON CONSULTING

75 YEARS

OUR FOOD FUTURE

Food and Food Waste Flow Study

Work Package 1

METABOLIC

June 2021 – 19-1326

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Acronyms, Abbreviations, Definitions

– A –

Avoidable Food Loss & Waste: Food product that is designated to waste streams that could have been reasonably considered edible at some point in its lifespan in the food system.

– C –

CAD: Canadian Dollar
CO_2eq: Carbon Dioxide Equivalents
Collection: Activities involving the collection of food waste by public and private actors.

– D –

Distribution: Activities involving the transport, storage and wholesale of food products.

– E –

End-of-Life: Activities involving the treatment and disposal of food waste.
EOL: End-of-life
Eq.: Equation

– F –

FCM: Federation of Canadian Municipalities
Food Loss: Refers to food that is intended for human consumption but, through poor functioning of the food production and supply system, is reduced in quantity or quality.[1,2]
Food Waste: Refers to food for human consumption that is discarded (both edible and inedible parts) due to intentional behaviors. "Food waste" often refers to what occurs along the food chain from the retail store through to the point of intended consumption.[1,2]

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[1] Commission for Environmental Cooperation. (2017). Characterization and Management of Food Loss and Waste in North America – White Paper. http://www3.cec.org/islandora/en/item/11772-characterization-and-management-food-loss-and-waste-in-north-america-en.pdf

[2] The report conforms to the standard definitions posed by the Commission for Environmental Cooperation (CEC) but recognizes, as does the CEC, that there exists a diversity of definitions of food waste and food loss. We also express caution around using the term "loss" to describe what happens at the business level while "waste" is used to describe what happens at the consumer level. Optically this may present an issue in the future so it is this report's recommendation to discuss these concepts with caution and in equal terms and together whenever possible.

– H –

Household: Consumption of food in private households.
HRI: Hotels-Restaurants-Institutions. Refers to consumption of food in hotels, restaurants, and Institutions.

– K –

ktons: Kilotonnes

– M –

Manufacturing: Activities of secondary processing into finished food products.
MFA: Material Flow Analysis

– O –

OMAFRA: Ontario Ministry of Agriculture, Food and Rural Affairs

– P –

Processing: Activities of primary processing of raw food into semi-finished food products.
Production: Activities spanning from field work and barns to farm gates, including raising livestock, growing crops, and fishing.

– R –

Retail: Retail sales of food in grocery stores and specialized food stores.

– S –

Stimulants: Coffee and tea

– U –

Unavoidable Food Loss & Waste: Food product or components of food products that is designated to waste streams because it cannot reasonably considered to be edible at any point in its lifespan in the food system.

– W –

WP: Work Package

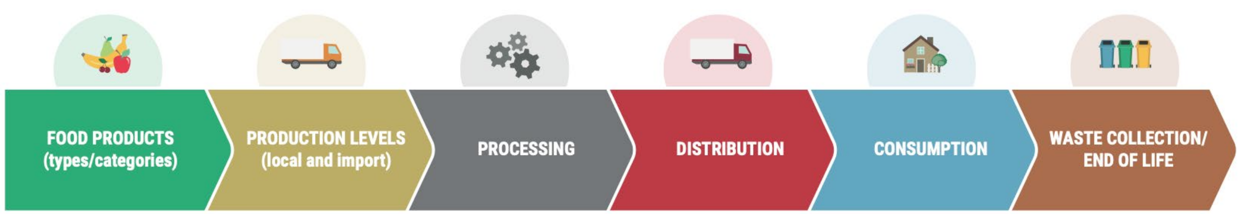
Executive Summary

The City of Guelph and the County of Wellington (Guelph-Wellington, study area) have embarked on an ambitious journey to create a local circular food economy through their successful application to Canada's Smart Cities Challenge. The funding, received through Infrastructure Canada, will be used to implement Guelph-Wellington's vision of creating Canada's first circular food economy (Our Food Future). The vision of this project is to:

- Increased access to affordable, nutritious food by 50%, where "waste" becomes a resource;
- Create 50 new circular businesses and collaborations; and
- Produce a 50% increase in circular economic benefit by unlocking the value of waste.

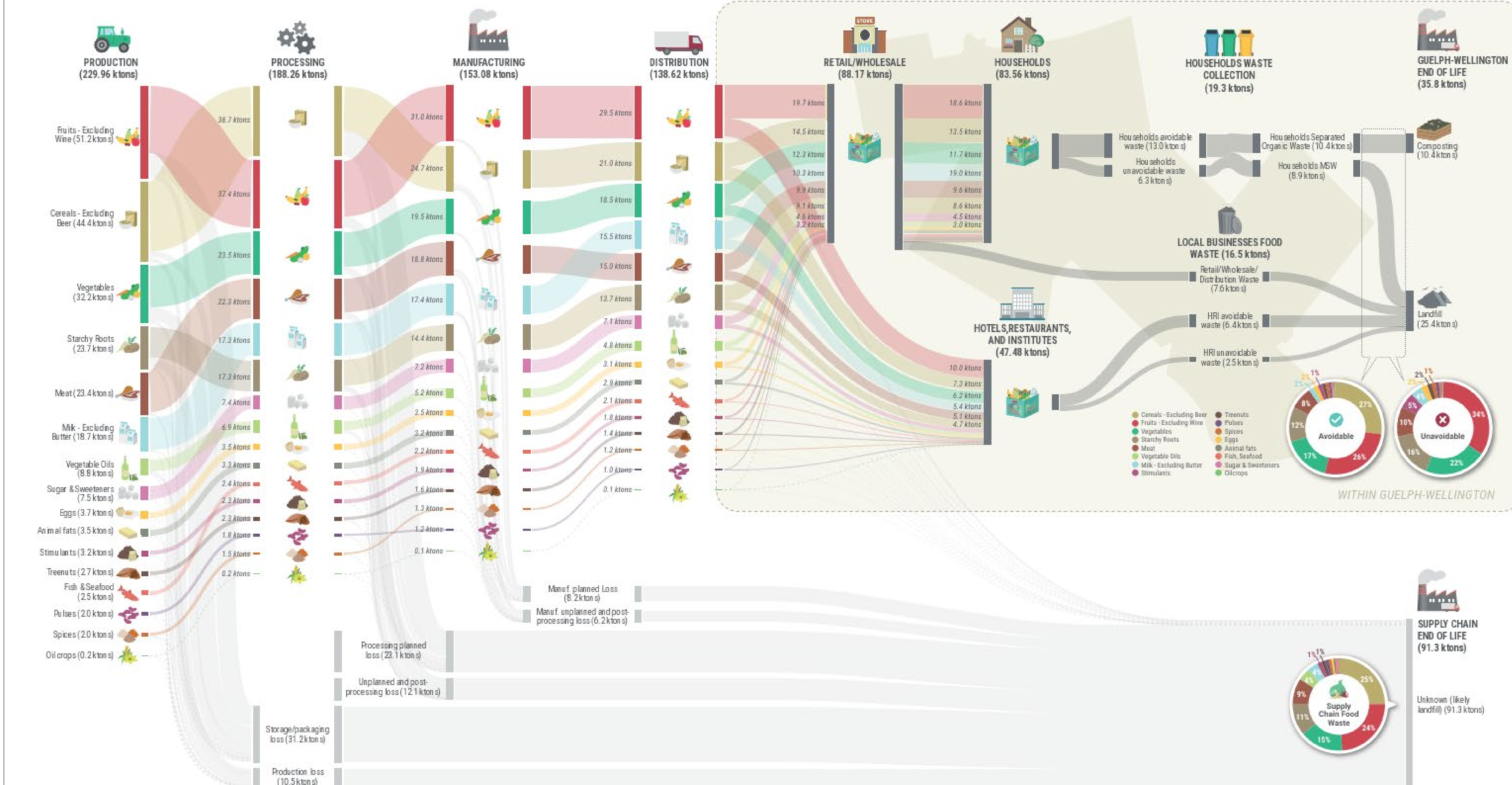
The study area that includes the City of Guelph and the County of Wellington has a combined population of close to 223,000 residents. The majority of that population resides within the City of Guelph with close to 60% of the population. The City of Guelph (City) also has a large transient population with the University of Guelph providing approximately 28,000 students to the City's population count. The County of Wellington (County) is largely rural with most of the local food production evaluated for this work coming from the County. The primary cash crops include corn, wheat, and soybeans. For animal production, the main cash contributors are dairy, beef, poultry, and swine.

To assess the current status of organic 'waste' flows in the area and to identify strategies to close these loops, Guelph-Wellington sought support to develop a baseline understanding of their circularity through a Material Flow Analysis (MFA) and subsequent circular strategy/roadmap as a starting point to this journey. For this analysis, data was collected from each point along the food supply chain, as depicted below, and an understanding of the flow of consumed, lost, and wasted food products was developed.



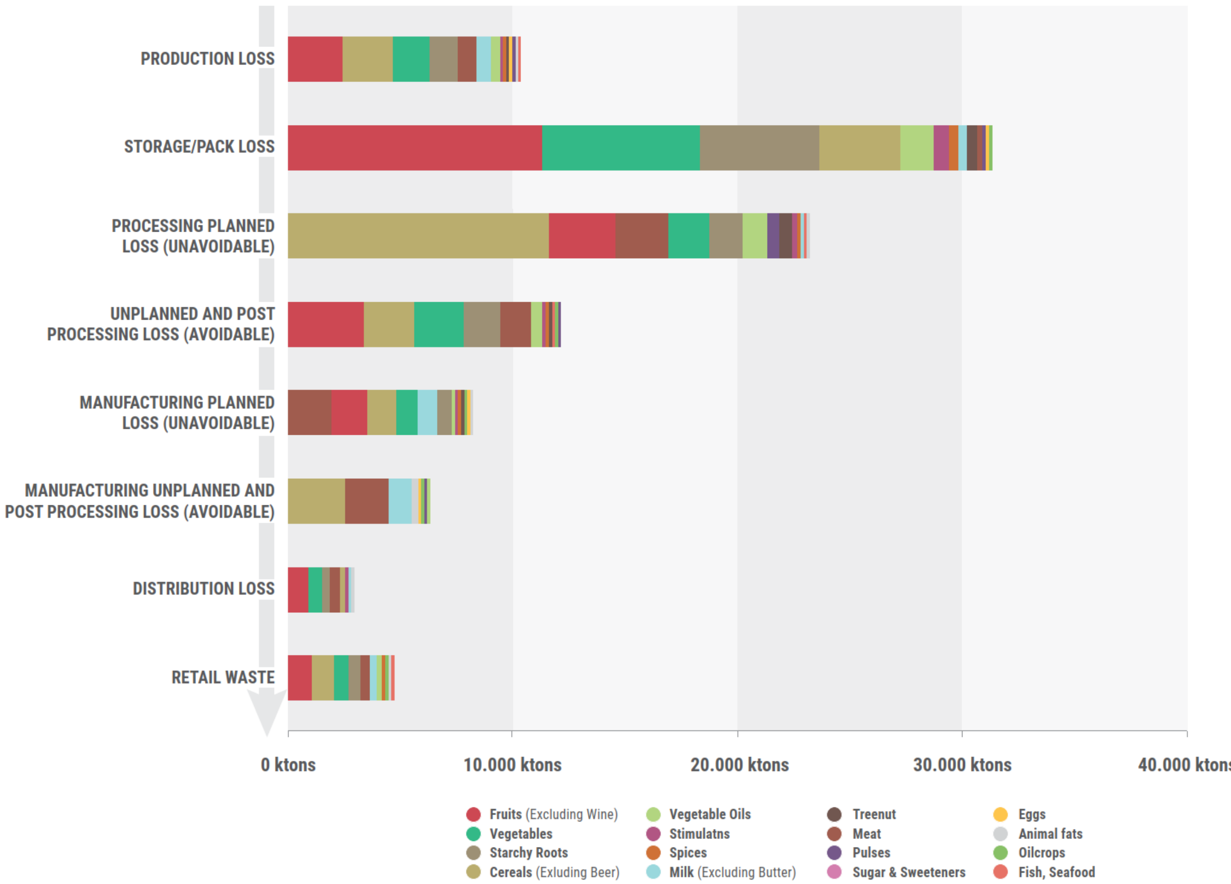
Generalized Depiction of a Food Supply Chain in Guelph-Wellington

Data was collected from a variety of different publicly available sources as well using purchased, private company data to strengthen and verify the findings. Analysis of both publically available and purchased private company data revealed that, at least in the Guelph-Wellington area, publically available data mapped closely to purchased food system data. A Sankey diagram, shown below, takes the data received and graphically depicts the flow of food products from production to consumption, as well as waste streams. This analysis revealed that some specific food categories warrant deeper investigation such as farm fruit losses before manufacturing or losses of cereals at the processing stage. Finally, some results, although interesting, did not provide novel insights such as the findings that food products originating from animal sources represent a large environmental impact on the food system.



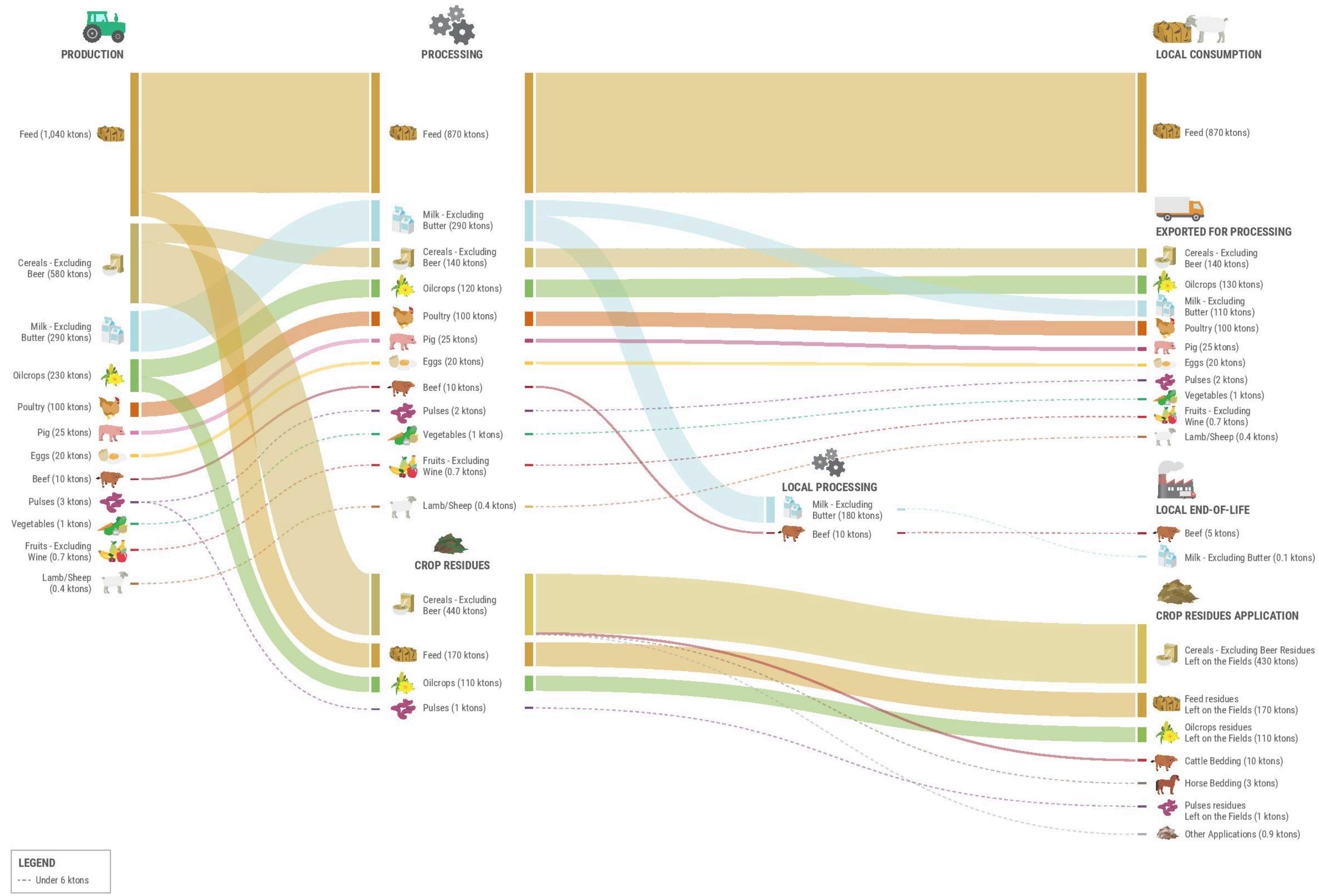
Sankey Diagram of Guelph-Wellington's Consumption-based Food Flows

The volumes of food loss & waste by product varied, as was expected, but storage and packaging represented the largest area of loss. This was particularly true for fruit and vegetables, likely due to their vulnerability to damage when handled as well as their relatively short shelf-life. This area of the supply chain provides opportunity for further investigations through targeted case studies, to identifying mechanisms for food loss reduction that would provide a larger impact compared to other points of intervention in the supply chain.



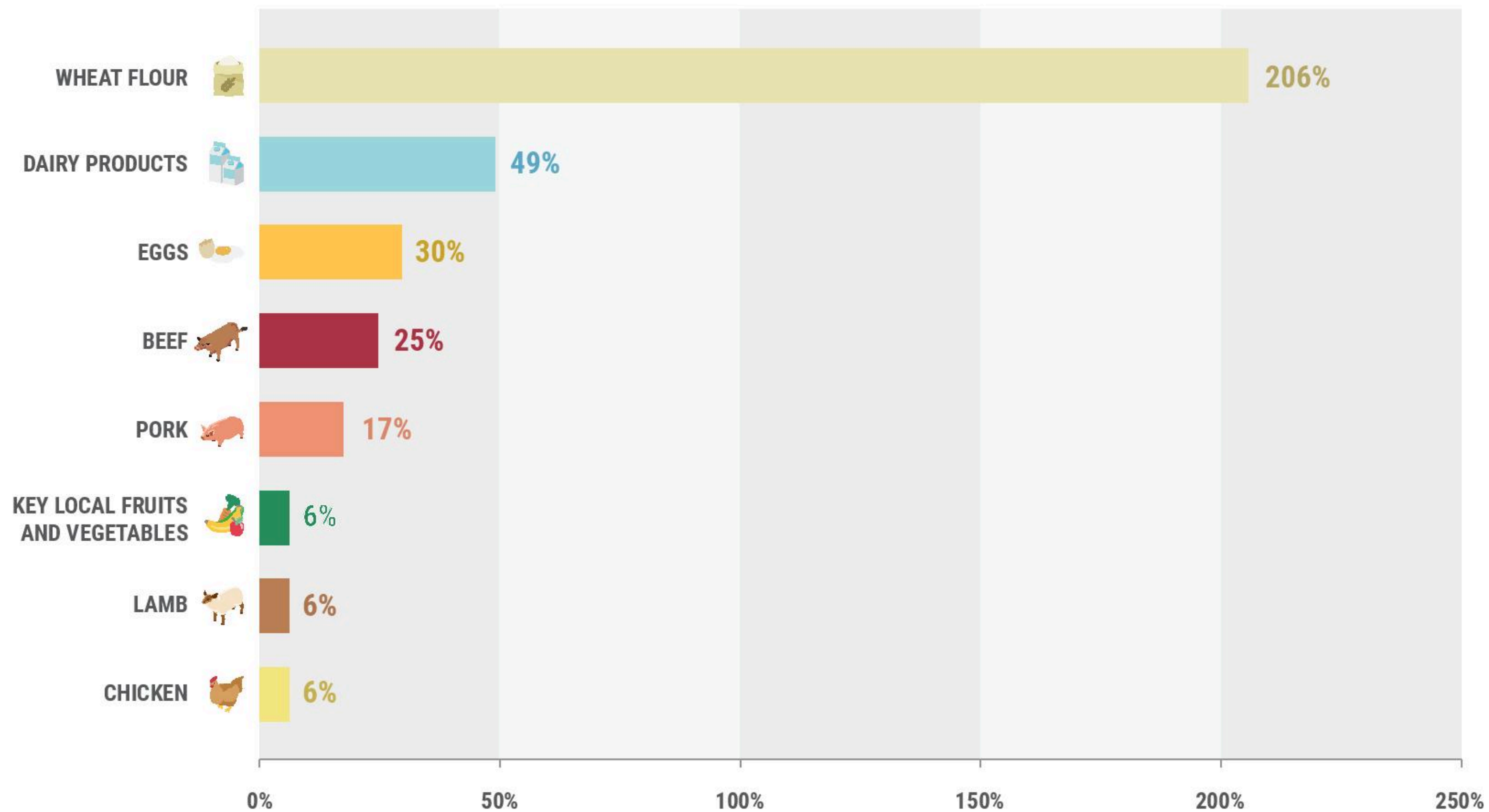
Graphical Depiction of Food Loss & Waste at Different Areas in the Food Supply Chain

In order to provide more context for this information a Sankey diagram (below) depicting the flow of food produced in the Guelph-Wellington region can be used. This diagram shows that a majority of the product produced in Guelph-Wellington is transported out of the region for additional processing.



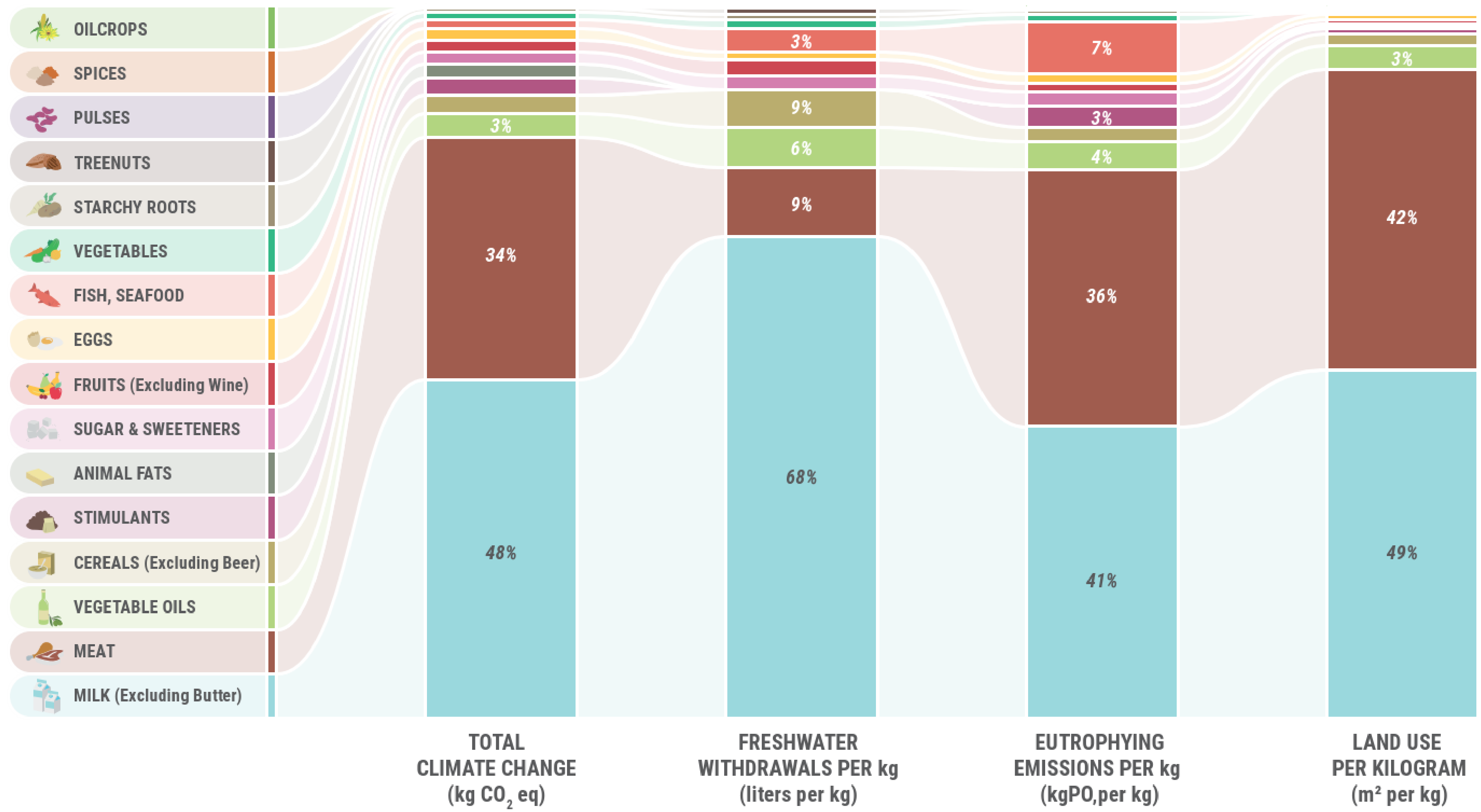
Sankey Diagram of Guelph-Wellington’s Production-Based Food Flows

Additionally, Guelph-Wellington only produces enough surplus wheat to feed its local population while still having enough to export for external consumption (as shown below). All other products evaluated indicated the need to import product produced in other regions to feed the local population.



Graphical Depiction, by Product, of the Level of Production & Self-Sufficiency in Guelph-Wellington

Finally, an assessment of the environmental impacts of the consumption patterns associated with the Guelph-Wellington food system was completed and results indicate that in general, animal products such as meat and dairy represent the largest environmental impacts in terms of CO_2 equivalents, liters of water used, eutrophying emissions (e.g. leaching of nitrogen into the environment), and land use.



Graphical Depiction of Several Environmental Impacts Associated with the Consumption of Specific Food Types in the Guelph-Wellington Area

It is important to note that the environmental impacts represent global average factors and not localized data. There are of course local variations in terms of impacts driven by local agricultural and farming practices. Nonetheless, as Guelph-Wellington's food system is deeply integrated in global food value chains, these factors represent the best estimates of environmental impacts. What we do know is that when high impact foods are wasted, so are the emissions and other impacts they produced. In the next phase of this project researchers will be working with regional producers and processors to support and scale their work on climate-friendly solutions that have promise for reducing this impact.

An advisory panel was convened to review the findings of this work and to collect feedback to direct the future steps of the analysis. The advisory panel included subject matter experts from across Canada and the world. These organizations logos are presented below. Feedback from this panel was incorporated into the larger report for this work as well as into the planning for the next stage of work.

The results found in this early analysis will be used to hone in on specific elements of the food system in the Guelph-Wellington allowing for the development of key interventions in future work. The process and data summarized here are key to informing this future work that will occur on this project as it takes stock of available food system data and summarizes the current state of the food system.

1.0 Overview of the Project - Work Package 1

The City of Guelph and the County of Wellington (Guelph-Wellington) have embarked on an ambitious journey to create a local circular food economy through their successful application to Canada's Smart Cities Challenge. The funding, received through Infrastructure Canada, will be used to implement Guelph-Wellington's vision of creating Canada's first circular food economy (Our Food Future).

The study area that includes the City of Guelph and the County of Wellington has a combined population close to 223,000 residents. The majority of that population resides within the City of Guelph with close to 60% of the population. The City of Guelph (City) also has a large transient population with the University of Guelph providing approximately 28,000 students to the City's population count. The County of Wellington (County) is largely rural with most of the local food production evaluated for this work coming from the County. The primary cash crops include corn, wheat, and soybeans. For animal production, the main cash contributors are dairy, beef, poultry, and swine.

To assess the current status of organic 'waste' flows in the area and to identify strategies to close these loops, Guelph-Wellington sought support to develop a baseline understanding of their circularity through a Material Flow Analysis (MFA) and subsequent circular strategy/roadmap as a starting point to this journey.

Dillon Consulting Limited (Dillon), in collaboration with Metabolic B.V. (Metabolic), and Dr. Michael von Massow from the University of Guelph (Consulting Team) were retained to support Our Food Future. The proposed full scope of work was broken down into the following three Work Packages (WP):

- **Work Package #1** – Create a snapshot of the flow of food through the food system in Guelph-Wellington by acquiring, analysing, and interpreting several data sources to map the flow of food and food waste using a MFA.
- **Work Package #2** – Use the knowledge gathered from the MFA to engage with key stakeholders to create a vision for the food system in Guelph-Wellington as well as identify hotspots for intervention to reduce inefficiencies and waste in the food system.
- **Work Package #3** – Apply the learning from each WP to present key environmental, economic, and social benefits of interventions as well as create a workbook to be distributed to other regions to enable replication of the project across Canada.

The information summarized in this report represents the work completed in the first Work Package which began in March 2020 with a kick-off meeting that involved key members of the team within the Our Food Future office, the City of Guelph, the County of Wellington, and the consulting team. Work Package 1 (WP1) involved aggregating data that was collected by the Our Food Future's team and supplementing it with existing data sources the consulting team had access to. As data were identified and aggregated, the consulting team organized and cleaned data to feed into the model developed by Metabolic to complete the draft Sankey diagram.

The collection of data is a foundational step to the overall success of the project. The subsequent WPs require an accurate picture of the food and food waste flows within the region in order to understand the impact of interventions. The key to this WP was collecting and analyzing accurate, representative, and comprehensive data to create a good understanding of the current picture of food flows within the Guelph-Wellington region. From the picture that is created by this data, WP2 and WP3 will be completed and involve identifying interventions to redirect and revalorize waste and alleviate hotspots. This work will contribute to the Our Food Future goals of:

- Increased access to affordable, nutritious food by 50%, where “waste” becomes a resource;
- The creation of 50 new circular businesses and collaborations; and
- A 50% increase in circular economic benefit by unlocking the value of waste.

Additionally, in line with the goal of creating a world-class project that leads the way for other regions in Canada, an Advisory Panel (AP) was created and consulted with. The AP group gathered is made up of subject matter experts and renowned specialists in the fields of circular economics, food, and health. The AP provided valuable perspectives and guidance with respect to the data gathering process and potential areas of focus in the future. This input has been key to completing WP1 and we have requested their continued input for WP2 and WP3.

2.0 Project Goals and Objectives

The overall goal of WP1 was to create an understanding and visual depiction of the flow of food products in Guelph-Wellington. Work Package 1 involved three phases, each with its own deliverables.

Phase one of WP1, was the Project Initiation. It involved the kickoff meeting with the Our Food Future team as well as timeline refinement, an update on the status of the working streams and a discussion of data availability for the team to review and process.

Phase two of WP1, included a scoping of the project for WPs 1, 2, and 3 by reviewing the data and information available to Our Food Future and the Consulting Team. To complete phase two, a summary of the data aggregated by the team was provided to the Our Food Future Team and gaps were identified. The Consulting Team worked to fill the gaps with additional sources of information that was readily available to them. Limitations and opportunities for results of the final work were discussed.

Phase three of WP1 involved an analysis of the data collected and aggregated. A MFA was completed of the flow of food products in Guelph-Wellington through the use of Metabolic's model. The results of this process produced a Sankey diagram depicting the flow of food and food waste in the study area. The findings from WP1 are documented in this report as well as the next steps for WP2.

An overarching goal of this project has been to engage widely with key stakeholders and knowledge leaders to vet the approach as well as communicate the findings. To meet this goal, an Advisory Panel of experts was created and met with to communicate the work done to date, collect and integrate feedback, as necessary, and establish a rapport with key stakeholders. This effort is discussed in more detail in **Section 5.0.**

3.0 Work Package Methodology

3.1 Introduction

The methodology was developed and applied to build a model of the flow of food in Guelph-Wellington. The scope of the Material Flow Analysis (MFA) was to map the current food flows meeting Guelph-Wellington residents' food demand. The boundaries chosen are based on the consumption of food within the geographic boundaries of the City of Guelph and Wellington County (referred to as Guelph-Wellington or the 'study area'). The model created, however, expands this analysis to include the upstream and downstream flows that represent, respectively, the food value chain that meets the study area's food demand (i.e., production, processing, manufacturing, distribution), and the end-of-life flows of food waste as they exit the study area. These upstream and some end-of-life downstream flows are therefore modelled beyond the geographic boundaries of Guelph-Wellington. Additionally, the flows stemming from the local production of food (e.g., meat, dairy, crops, fruits and vegetables) were also quantified and their processing routes (within the study area or exported elsewhere) modelled.

What is a material flow analysis?
A Material Flow Analysis (MFA) is a systematic assessment of material flows and stocks of (raw) materials within a system, with a defined scope in terms of space and time.

Why use an MFA?
This data-driven methodology for mapping out and quantifying resource flows is a crucial first step of any systems analysis, as it forms the baseline for finding effective leverage points and prioritizing possible interventions.

The MFA in this project combines top-down and bottom-up approaches, representing a snapshot of Guelph-Wellington food flows for the year 2018. The top-down approach relies on the use of the latest food availability data from Statistics Canada (StatsCan, 2018). Food availability, provided in kg/person/year, is scaled up to the Guelph-Wellington population. This starting point functions as the structural basis of the MFA. The bottom-up approach is specifically utilized to adjust Canadian averages to the specific characteristics of the region, especially regarding the food waste flows from households, their collection and treatment by the local waste management system. Additionally, the model uses study area-level production data derived mostly from the database of Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA).

Building a Material Flow Analysis: A step by step guide
The guiding principles of an MFA is that all the inputs and the outputs of a system must be accounted for and result in a correct mass balance. The mass balance must be equal to: Input = Output + Stock and this

concept is represented in a simple graphic (**Figure 1**). The setting of the system boundary is an important first step in the process as it defines where the inputs and outputs of inventories start and end.

To map the flows of food that go through Guelph-Wellington on a yearly basis, we first mapped the entire value chain of the industry – from production, till the end-of-life (EOL) processes (i.e., waste processing, disposal), and included every critical step in between: processing, manufacturing, distribution, retail, consumption in households and hotels-restaurants-institutions (HRI), and collection of food waste by the municipality and private waste management actors.

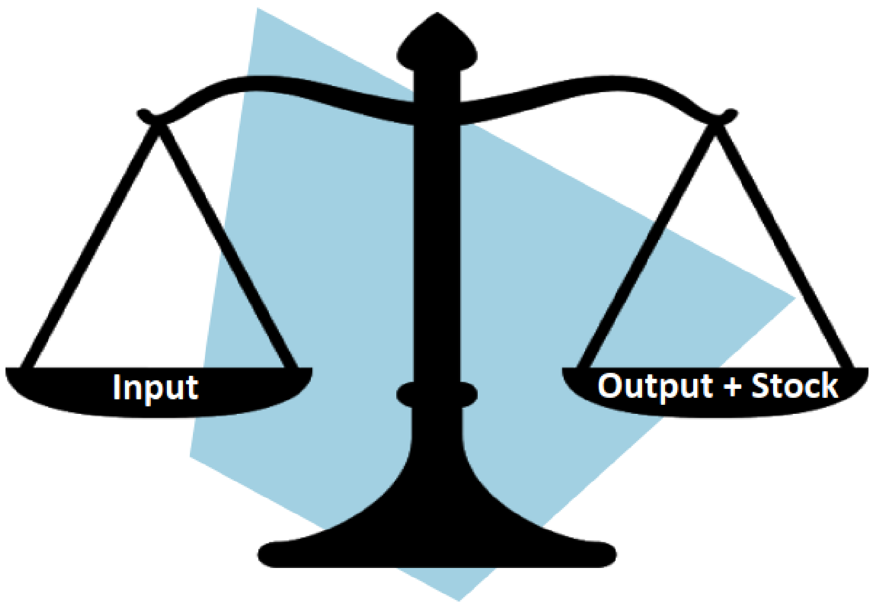


Figure 1: Mass Balance Illustration

3.2 Data Collection

Data was collected primarily by the Our Food Future team. The Consulting Team reviewed the data as it became available, organized and analyzed it, and supplemented with additional data that they had access to in order to fill any apparent holes or gaps.

Data collection can be a very long process but quality data feeding into any analysis is key to ensure a quality final output. For this work a longer timeline to collect data was exacerbated, in part, by the arrival of pandemic restrictions and shutdowns in Canada starting at the project kick-off in March 2020.

In addition to using the data collected by the Our Food Future team and supplemental data gathered by the Consulting Team, an Advisory Panel (AP) was established with knowledgeable stakeholders. The AP members were asked for their input on data sources in the early contact phases of establishing the AP as well as during the first AP meeting held in October 2020. The relevant information on data sources was incorporated into the analysis for WP1.

3.3 Data Selection and Organization

Selecting the right data is a crucial step in the process. To determine which datasets to use for the analysis of those provided by the Our Food Future team and also identified by the Consulting Team and AP members, a document register was created that identified the geographical scope and what area of the value chain it provided information on for each dataset. An initial material flow diagram was then sketched out. The datasets from the document register were mapped to this diagram to identify gaps and determine where data overlapped. The datasets were selected based on scope, level of detail, availability, and publishing year. In total ±70 datasets were used in the model (see references) out of the approximately 125 datasets received and reviewed. Most primary datasets are derivatives of national open data sources to maximize scalability and applicability in other regions.

The datasets were processed and analysed to develop the material flow diagram shown in **Section 6.0**. An extensive description of the process of data analysis and the assumptions behind the initial modelling process is provided in **Appendix A: Data Analysis & Assumptions**.

4.0 Overview of Guelph-Wellington's Food Economy

The study area, that includes the City of Guelph (City) and the County of Wellington (County), has a combined population of close to 223,000 residents. The majority of that population resides within the City with close to 60% of the population. The City also has a large transient population with the University of Guelph providing approximately 28,000 students to the City's population count. Many of these students leave the City for the summer and return for the fall and winter.

The University of Guelph is an important element of the study area. It is home to the oldest agricultural school and veterinary school in the province of Ontario and its researchers produce valuable information that flows directly to local food producers or indirectly through producer and producer adjacent groups such as OMAFRA, the Ontario Federation of Agriculture (OFA), AgriCorp, and other essential supports for Ontario food producers. This strong and well-established network of organizations has a large influence on the study area.

The County is largely rural with most of the food production evaluated for this work coming from this area. The primary cash crops include corn, wheat, and soybeans. For animal production, the main cash contributors are dairy, beef, poultry, and swine.

Because of the strong ties to food and agriculture in the study area, a large amount of food-related activities occur. Refer to **Figure 2** to see an overview of the food value chain in the study area and how the parts link.

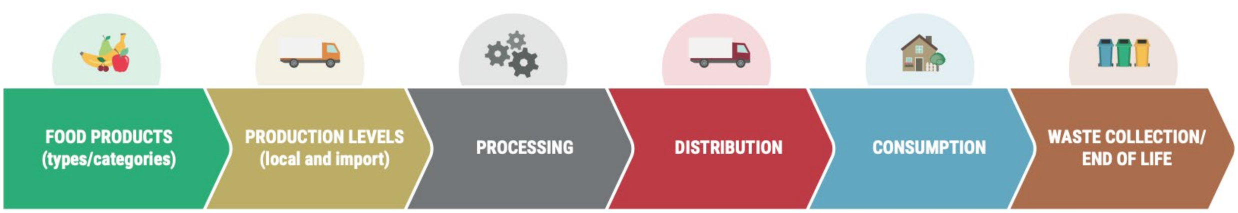


Figure 2: Simplified View of the Food Value Chain

Guelph-Wellington is also home to a large beef processor, a large dairy processor, as well as several small and medium-sized processors of animal products (including on-farm) as well as crop processors. Some specialty and niche processors that handle organic certified foods are also present, although they represent a smaller, but growing segment of the market in the study area.

There is also one large and several medium and small food distributors. These businesses are responsible for moving some of the locally produced food out of Guelph-Wellington as well as bringing in products produced across Canada and in other parts of the world.

The study area is also home to a variety of retail food outlets including a majority of conventional grocery stores as well as fewer organic and natural retail outlets. There are direct to consumer, farm-based sales as well, representing a small proportion of the retail sales in the study area. Several large commercial foodservice chains sell prepared food options while many independent food service establishments also operate.

Waste is handled differently depending on where it is produced as well as the type of establishment it is produced at. In general, the City has an established source-separated organics management program that requires residents to sort their food waste at home into a separate green cart. The contents of the green carts are collected weekly and the material is composted at the City-owned organic waste processing facility located at the Waste Resource Innovation Center. The County instituted a residential source separated organics collection program in July 2020.

In the HRI sector, organic waste separation is not required and represents a significant opportunity for improvement within Guelph-Wellington.

5.0 Advisory Panel Meeting

5.1 Introduction

The formation of an Advisory Panel (AP) was deemed to be a key component of the work associated with this project given the complexity and innovativeness of the project. The members selected for the panel are representative of a thorough depth of understanding of the subject matter and/or the food system in Ontario. For WP1, a list of potential participants was generated and was reviewed and input was given by the Our Food Future team. Participants were asked to meet virtually on October 2, 2020 to provide feedback on the work completed to-date for WP1 as well as provide feedback on the direction of the work moving into WP2 and WP3. A presentation was provided to the AP and an interactive virtual engagement tool, Mural™, was used to capture feedback directly from participants.

A sampling of the organizations that attended the session are represented in **Figure 3** which provides logos of organizations.

The objectives of the first AP meeting were to:
1. Onboard the AP to the purpose and focus of the work being done;
2. Collect feedback on data sources used and potential missing data sources;
3. Review draft consumption Sankey diagram;
4. Obtain commentary on methodology to allow for evolution as appropriate; and
5. Identify initial potential hotspots, interventions, and key performance indicators (KPI) for review in WP2 and WP3.

Figure 3: Logos of organizations in attendance at the first Advisory Panel meeting

5.2 What We Heard

The majority of the effort for the first AP meeting was spent onboarding AP participants to the purpose of the project and what had been done to date. Participants were onboarded through a virtual PowerPoint presentation that was led by Dillon, with contributions from Our Food Future's Executive Director, explaining how the project fits in the larger context of their work, as well as by Dr. Michael von Massow who outlined the food system in Guelph-Wellington, and Metabolic, who explained the results of their MFA analysis.

After the presentation of this information, participants were asked for their feedback during the interactive Mural™ session. The results of that session, as well as including several emails sent directly to the Consulting Team, are summarized in **Appendix B: Advisory Panel Feedback**.

The main changes had to do with providing additional information in the form of charts and additional explanatory text. Added figures show, for instance, a breakdown of the types of food wasted along the value chain, and the share of avoidable/unavoidable food loss & waste. Additionally, as a direct response to the feedback, we created the local production-based material flow analysis (**Figure 4**). We also revisited the impact assessment and created additional visualisations.

5.3 Moving Forward

The feedback provided by the AP participants was reviewed as a part of WP1. Thus our analysis was updated to reflect some of the feedback, as appropriate. Prior to the commencement of WP2, the feedback indicated in column 4 of **Table 1** will be reviewed again and the work plan will be adjusted to incorporate elements that are within the budgetary boundaries of the WP. Elements will also be assigned to WP3, again, as they fit within budgetary boundaries.

It is worth noting that some of the feedback provided, although with very interesting and exciting ideas, are far outside the scope of this project and would require significant time and financial efforts to complete. The ideas will be incorporated into our final reports for posterity and later review by the Our Food Future team and the City of Guelph and County of Wellington staff to consider when proceeding with future work.

6.0 Results

The results of the data analysis and processing was creating an understanding of the food and food waste flows within the study area. This information has been presented visually as part of this analysis in the form of a Sankey diagram. A Sankey diagram is an excellent tool to visualize the results of a MFA. In addition to this, other figures have been produced later in this Section to drill down and visually describe more of the nuances of the analysis.

6.1 Sankey Diagram - Consumption

Figure 4 presented below shows a visual depiction of Guelph-Wellington's consumption-based food and food waste flows. The flows that are displayed in this figure represent the data on an aggregated level. There are a total of 366 commodities underlying these 16 aggregated food flows. Using the database created for this study, we are able to zoom in on specific commodities and waste streams in order to design interventions, which will be outlined in WP2. **Appendix A** contains a short description of the processing categories. A description on how to interpret the Sankey diagram is provided following the illustration.

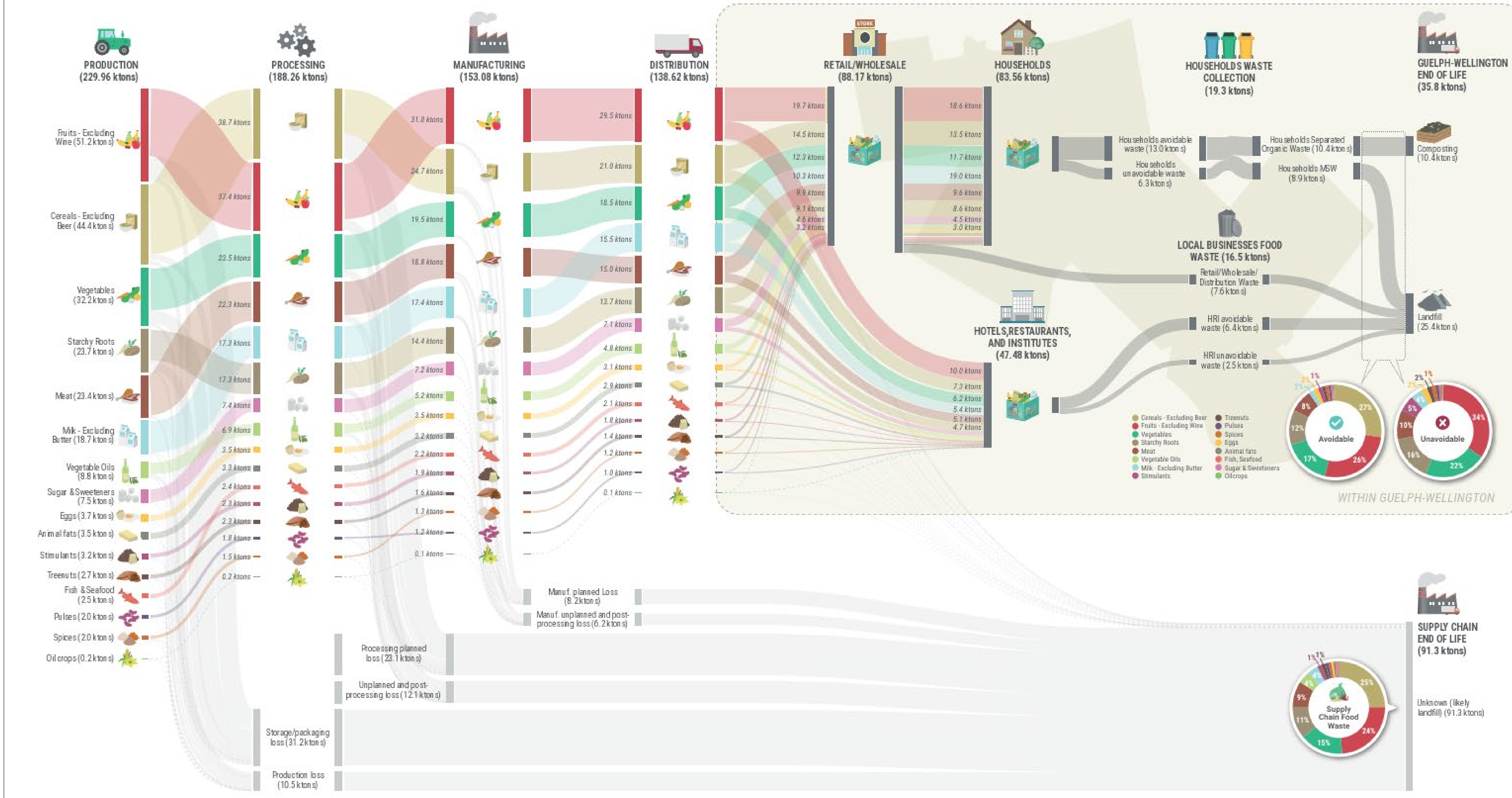


Figure 4: Sankey Diagram of Guelph-Wellington's Consumption-based Food Flows

How to interpret a Material Flow Analysis (MFA)?
The outcome of the analysis is visualized in a Sankey diagram. A Sankey diagram shows from which sources a 'flow' comes (on the left), how it is used or transformed within the area (center), and how the 'flow' eventually leaves the system and becomes processed (on the right).

How to Interpret the Sankey Diagram
This Sankey diagram (**Figure 4**) represents the entire value chain that supplies the food consumed in Guelph-Wellington. Therefore, the production shown on the left end of the Sankey represents food produced in different regional, national, and international value chains. While some of the food consumed may be produced within the study area boundaries, our findings suggest that ***most of the food produced in Guelph-Wellington is exported to the rest of Ontario, Canada, and the US*** for further processing and consumption. Although, some of these food products are subsequently re-imported to Guelph-Wellington. To understand Guelph-Wellington's local production food flows, a separate Sankey was developed, shown in **Figure 6**.
Figure 4 shows that the ***most consumed foods by mass are fruits, cereals, and vegetables***. Fruits represent the highest volume of consumption. However, based on literature we had expected fruits to be the 3rd largest flow (after cereals and vegetables). The difference might be due to food category aggregations or inconsistencies between dried, canned or fresh fruit. In addition to the high fruit consumption, fruit production is also the highest. This high volume of fruit production is likely further amplified by the significant amount of fruit losses in production, storage, and packaging.
The ***relatively large losses during production, processing, and manufacturing for all food types*** (shown in grey at the bottom of the figure) represent both avoidable and unavoidable food loss fractions. While their exact end of life treatment is unknown, we expect they mainly end up in the landfill as separate food waste pick-up from production, processing or manufacturing sites.
Distribution losses in **Figure 4** are allocated to losses occurring locally. **Figure 4** shows a more detailed breakdown of the quantities of food waste along the value chain per food category. ***Most food loss along the value chain occurs during storage/packaging*** (31.5%) and unavoidable processing loss (23.4%). This is seen especially with cereals (24.9%) and fruits - excluding wine (24.0%) that are wasted along the value chain. Since unavoidable processing loss is a planned and relatively uniform byproduct stream, it should provide strong opportunities for circular business models or symbiosis.
The analysis shows that ***about one third of all household food waste is unavoidable*** – yet even this amount provides ample opportunity for energy and nutrient recovery. The remaining avoidable household food waste could provide additional opportunities for food rescue or peer-to-peer food sharing.
A significant share of the food waste originating from households is diverted to municipal composting programs. This is attributed to the green cart program in Guelph which effectively diverted 90% of household food waste to composting. Since the data used in this study covers 2018/2019, it excludes the effect of the green bin program in Wellington County which began in mid-2020. As the green bin program in Wellington ramps up, we expect that the amount of food waste sent to landfill will decrease in favour of composting over the next 1-2 years.

How to Interpret the Sankey Diagram

Despite the many initiatives to reduce food waste in ***Guelph-Wellington's HRI sector, businesses generally don't separate their food waste, so it ends up in landfill, contributing significantly to methane emissions***. This is anticipated to be a focus group of stakeholders for reducing food waste.

Data from the analysis showed which products were lost in the largest quantities at different stages of the food system in the study area. This information is depicted in **Figure 4** but because of the level of detail presented in that figure it can be difficult to see a clear pattern. Because of this, the information has also been shown in **Figure 5**. Storage and processing are the biggest contributors to food waste, particularly for fruit and cereals. This information provides excellent early insight into possible intervention areas for WP2.

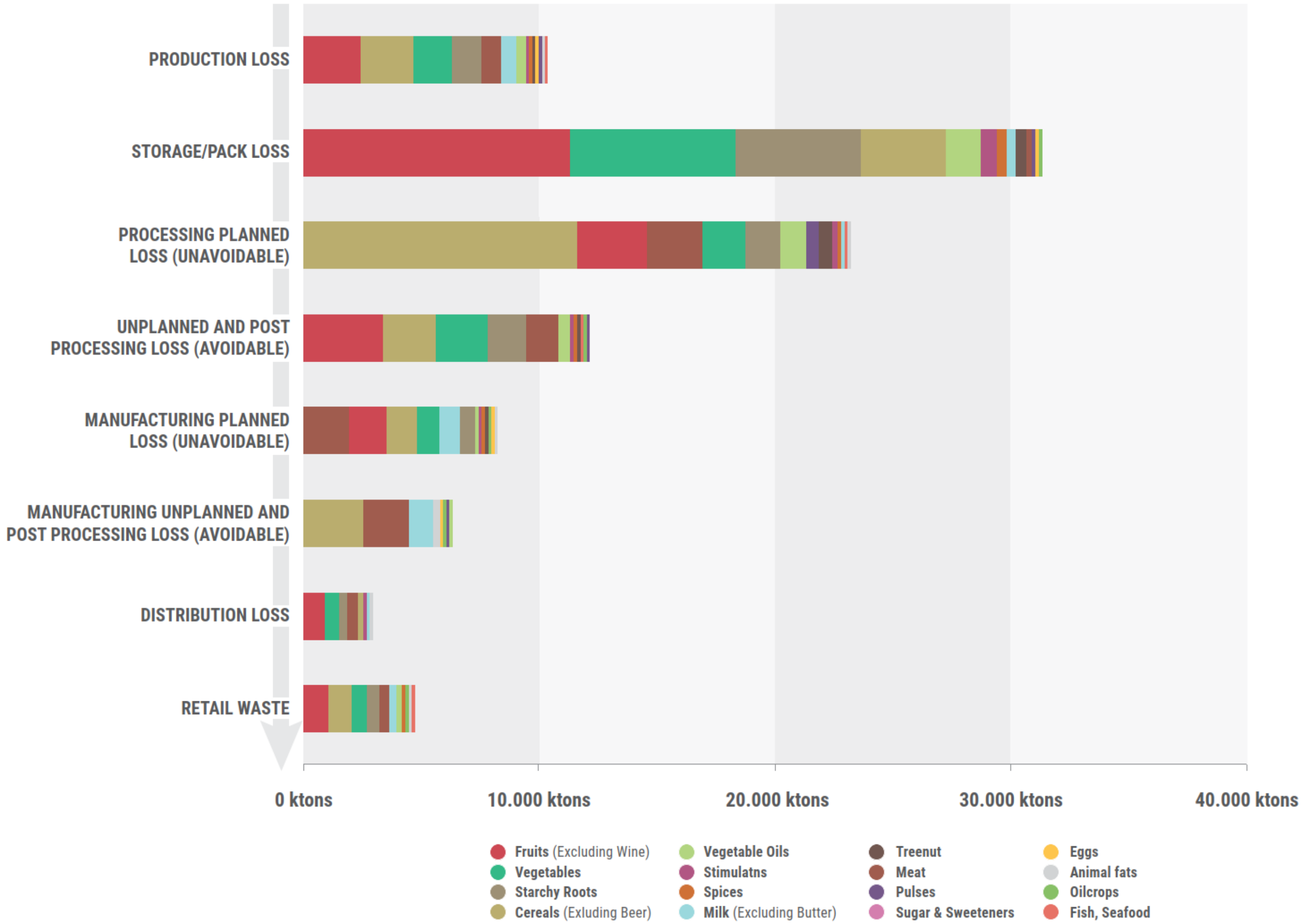


Figure 5: Food Wasted Along the Value Chain per Food Category

6.2 Local Production

Figure 6 shows the diagram of Guelph-Wellington's food production flows. To put these flows into context it is important to consider them in relation to the consumption material flow analysis (**Figure 4**). While the consumption material flow analysis revolves around the amount of food consumed in Guelph-Wellington, and the production necessary to facilitate that consumption, it does not differentiate *where production occurs*. The production material flow analysis partially fixes this problem by showing local production in the study area. However, what happens with the produced food products is largely unknown. We expect most food products to not be consumed locally, but rather exported for processing. It is of course possible that products are reimported after processing.

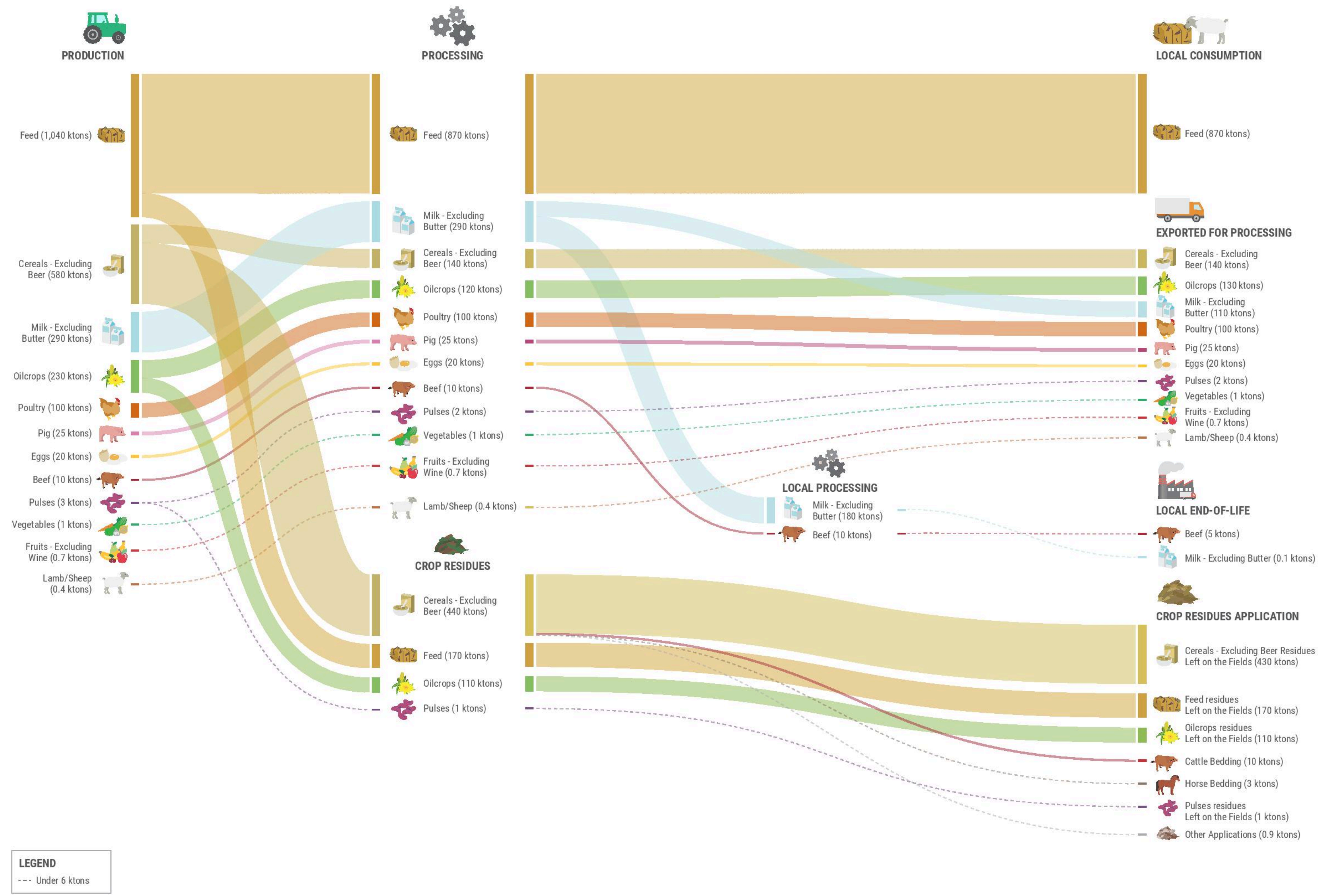


Figure 6: Diagram of Guelph-Wellington's Food Production Flows

In an ideal situation we would be able to connect the production and consumption material flow analyses. However, due to a lack of data on inter-county imports and exports, as well as on the origins of food used by local processors, we were unable to make reasonable estimations. Some key elements of the analysis on local production are listed here:

- ***The largest flow in terms of mass in Guelph-Wellington is the production of animal feed.*** Most feed is consumed locally.
- Guelph-Wellington has ***large-scale production of cereals, milk, oil crops, and poultry*** (<100 ktons/year).
- ***Guelph-Wellington produces about twice as much wheat flour as it consumes*** (~206% of local consumption) (**Figure 7**).
- Guelph-Wellington is about ***49% self-sufficient when it comes to dairy products, 30% self-sufficient for eggs and 25% self-sufficient for beef***.
- ***Fruit and vegetables need to be imported in large quantities*** to meet Guelph-Wellington's consumption demands. We also see this dynamic mirrored when we look at import/export in Ontario **(Figure 6**).
- ***Grain products have the largest monetary value*** for export products.
- Fruits and nuts, and vegetables are the largest imports in terms of monetary value (**Figure 8**) with ***exports mainly to Europe, while import is mainly from Oceania and Africa*** (**Figure 9**).
- ***Ontario is a net consumer of food*** as more food is imported than exported in the province. Compared to the other counties in Ontario, Guelph-Wellington produces relatively more poultry and eggs.
- ***Most crop residues, originating from feed, cereals, oil crops, and pulses are left on the field.***

Specific details on the estimated level of self-sufficiency, or the ability of the study area to produce enough of one product to feed the local population, is presented in **Figure 7.** This figure shows that the only product produced in surplus is wheat flour while all other products are not produced in quantities sufficient to sustain the local population.

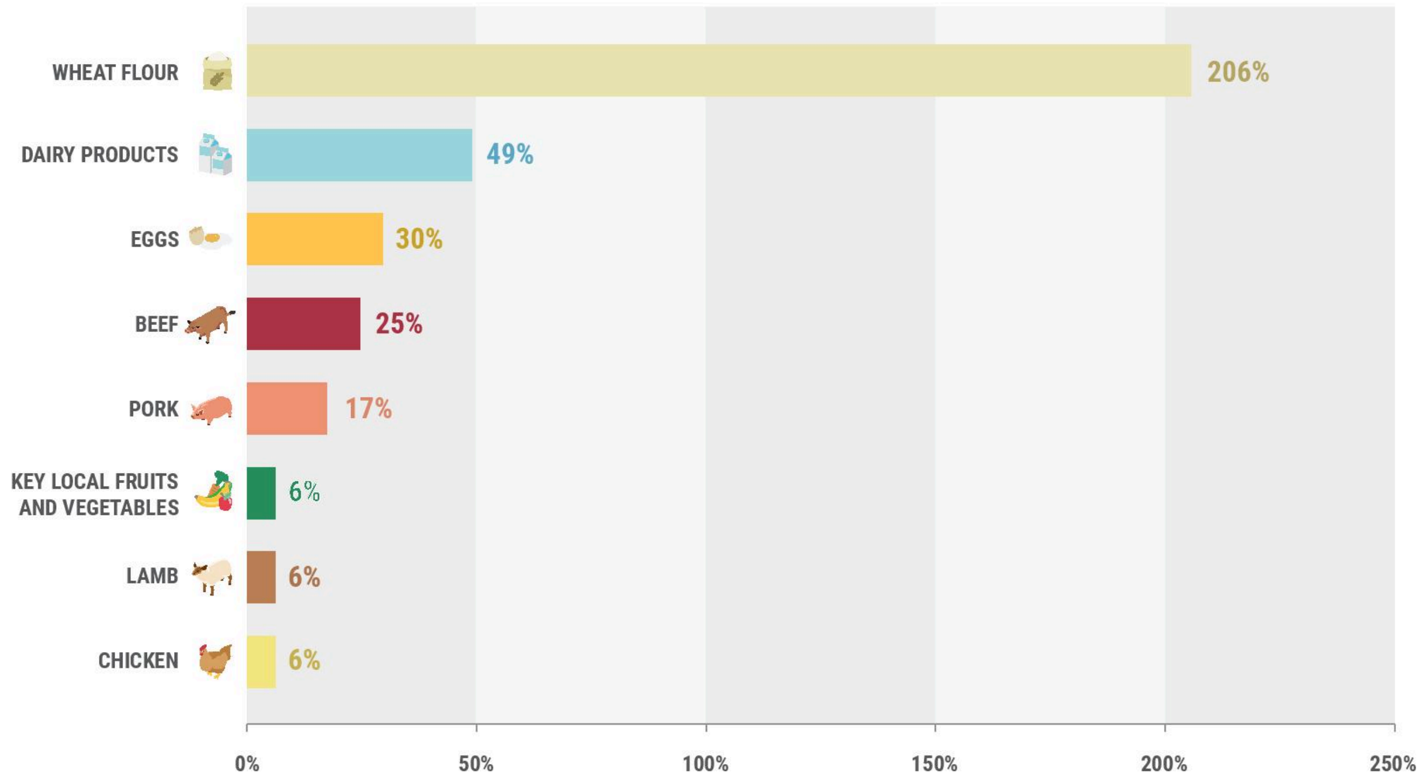


Figure 7: Self-Sufficiency of Guelph-Wellington. Based on: World Council on City Data Project.

Related to the level of self-sufficienty of the study area is the level of imports and exports. The high levels of wheat flour production make it an obvious item for export. This is shown in **Figure 8** with a high level of grain products going to export markets. Most other products are net imports with a few exceptions such as oilseeds.

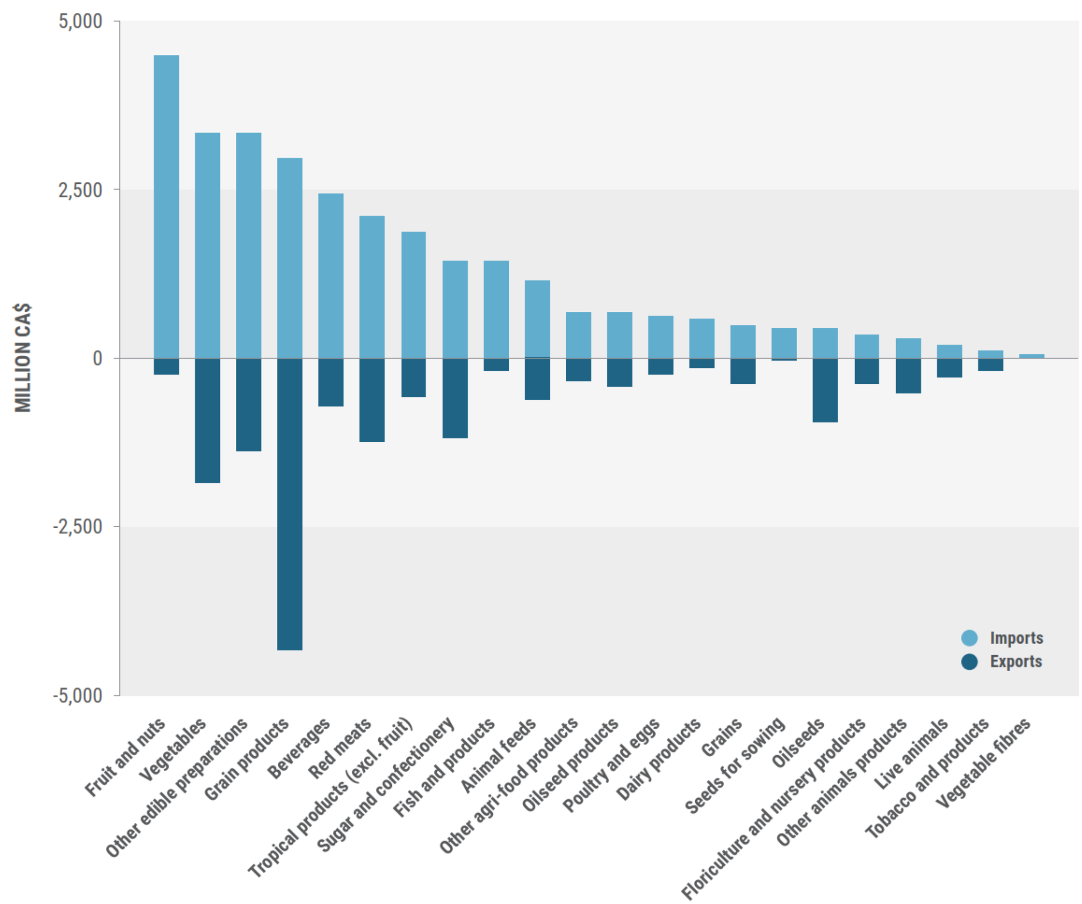


Figure 8: Monetary Imports and Exports of Food Products in Ontario (2019)

The monetary value of imports and exports in the study area provides valuable data on where money is flowing to and from the region. **Figure 9** shows that most export funds flow into the region from Latin America while most import funds leave the region to Oceania.

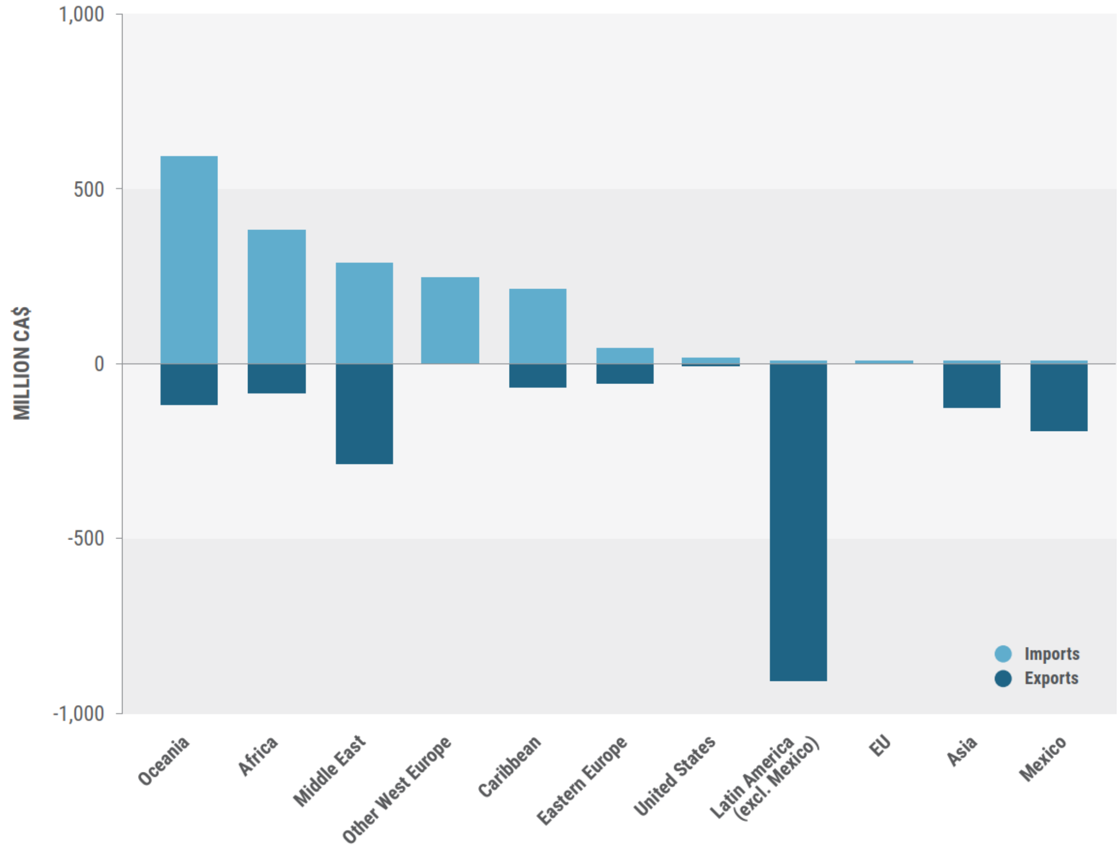


Figure 9: Monetary Imports and Exports of Food per Region in Ontario (2019)

6.3 Consumption-based Environmental Impacts

The consumption-based material flow analysis (**Figure 6**) provides a high-level overview and an indication of the relative size of food flows in Guelph-Wellington. Although this analysis does provide insight into the system's behaviour, it should mainly be considered as a *starting point* for further conversation. In the next phases of the project (WP2 and WP3), we also need to consider the environmental impacts, stakeholders, and regulations involved in these food flows as well as the feasibility of various interventions designed to make the system more circular, sustainable, and resilient.

In this section, the environmental impacts of food flows will be highlighted which can help identify both impact hotspots and opportunities for interventions. The environmental impacts of food production are mainly based on "Reducing food's environmental impacts through producers and consumers." as described in Poore, J., & Nemecek, T. (2018).

Figure 10 shows the cumulative environmental impacts as CO_2eq for the top 25 commodities to facilitate Guelph-Wellington's consumption. The top 25 commodities (out of a total of 366) represent a total of ±90% of the CO_2eq-impacts, as well as ±45% of the volume, ±88% of water consumption, ±85% of nutrient runoff, and ±95% of land-use. The top commodities associated with the largest environmental impact mainly consist of different types of meat and dairy products. Reducing the consumption and/or wastage of these food products will greatly reduce the embedded emissions and environmental impacts of Guelph-Wellington's food system. It is important to note that figure 10, 11, and 12 shows the environmental impacts due to food consumption in Guelph-Wellington, and not so much the food production impacts in the County. A large portion of food is imported from Countries with less sustainable farm management practices compared to Guelph-Wellington[3]. Therefore, these emissions are "imported". The figures do however, capture the difference in emissions between commodities. Regardless of where meat and dairy are produced, its production is responsible for a large share of production-based emission.

The top commodities associated with the **largest environmental impact mainly consist of different types of meat and dairy products**. Reducing the wastage of these food products will greatly reduce the embedded emissions and environmental impacts of Guelph-Wellington's food system.

[3] The environmental impacts factors developed by Poore & Nemecek represent global average factors that do not capture the local context of Guelph-Wellington agriculture and farming practices. It is therefore not to be understood as a comprehensive environmental impact assessment, but rather as an indication of the scale of impacts caused by the different food products consumed within the County's boundaries.

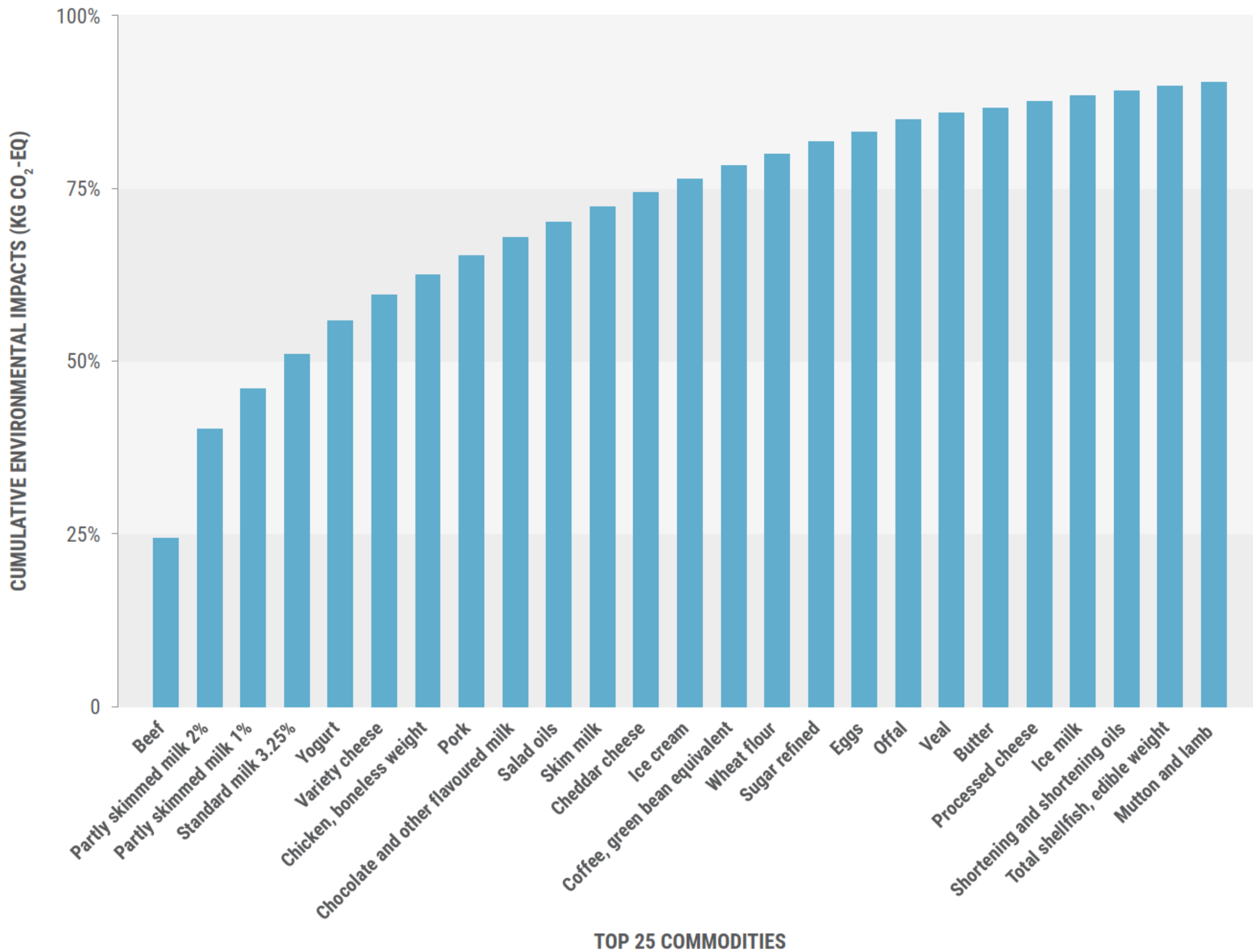


Figure 10: Cumulative Environmental Impacts of Top 25 Commodities

Figure 11 shows the relative distribution of CO_2-emissions of food consumption of Guelph-Wellington, regardless whether the food is produced in the study area. In absolute terms, most impacts derive from land use change associated with meat production (21%) and from activities on farms (58%). Meat and dairy products are responsible for the vast majority of these emissions.

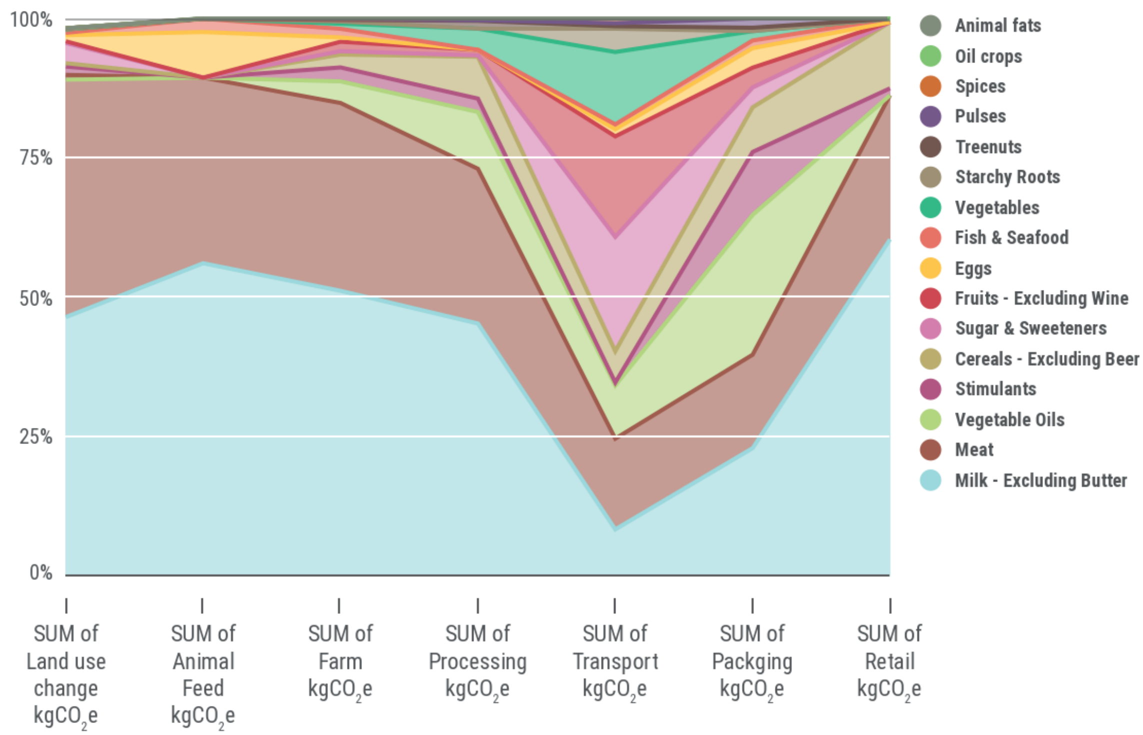


Figure 11: Relative Environmental Impacts Along the Value Chain per Food Category[4]

[4] The environmental impacts factors developed by Poore & Nemecek represent global average factors that do not capture the local context of Guelph-Wellington agriculture and farming practices. It is therefore not to be understood as a comprehensive environmental impact assessment, but rather as an indication of the scale of impacts caused by the different food products consumed within the County's boundaries.

Figure 12 shows the relative environmental impacts per food category for several impact categories. Again, meat and dairy represent the vast majority of environmental impacts, not only in terms of $kgCO_2eq$, but also in relation to freshwater depletion, eutrophying emissions (Nitrogen and Phosphorus), and land-use (change).

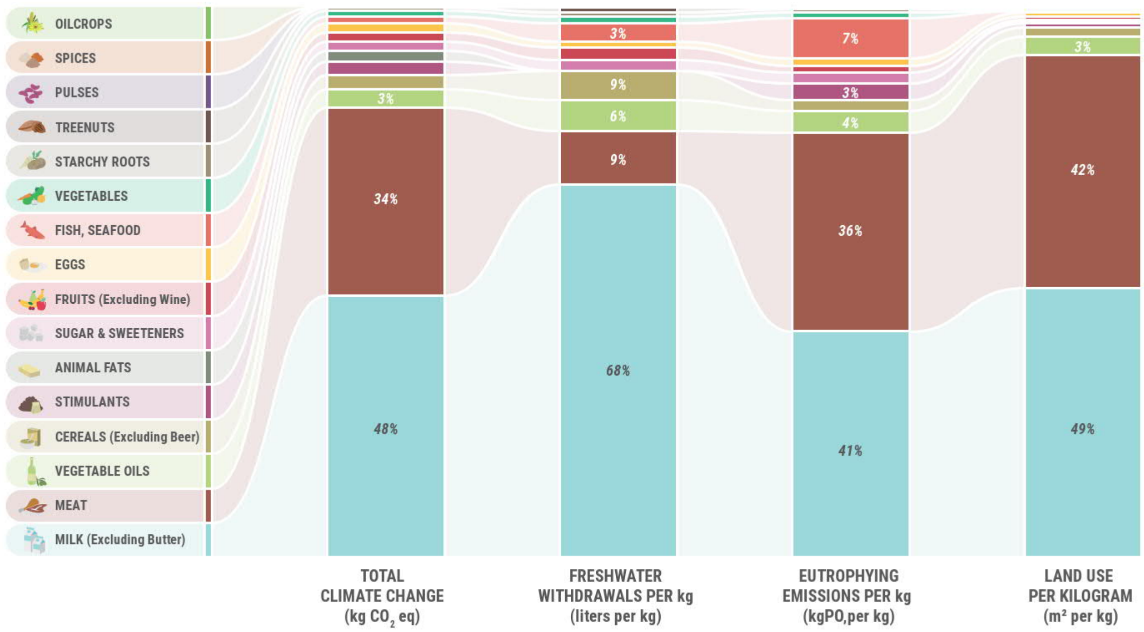


Figure 12: Relative Environmental Impacts per Food Category for Multiple Impact Categories[5]

It is important to note that the environmental impacts represent global average factors and not localized data. There are of course local variations in terms of impacts driven by local agricultural and farming practices. Nonetheless, as Guelph-Wellington's food system is deeply integrated in global food value chains, these factors represent the best estimates of environmental impacts. What we do know is that when high impact foods are wasted, so are the emissions and other impacts they produced. In the next phase of this project researchers will be working with regional producers and processors to support and scale their work on climate-friendly solutions that have promise for reducing this impact.

[5] The environmental impacts factors developed by Poore & Nemecek represent global average factors that do not capture the local context of Guelph-Wellington agriculture and farming practices. It is therefore not to be understood as a comprehensive environmental impact assessment, but rather as an indication of the scale of impacts caused by the different food products consumed within the County's boundaries.

6.4 Production-based Environmental Impacts

Figure 13 shows the relative environmental impacts per food category as a function of their nutritional content in terms of protein and food calorie (kcal). Meat has the highest emissions per 100 g of protein, while fruits - excluding wine, narrowly have the highest emission per 1,000 kcal. Pulses and oil crops perform exceptionally well.

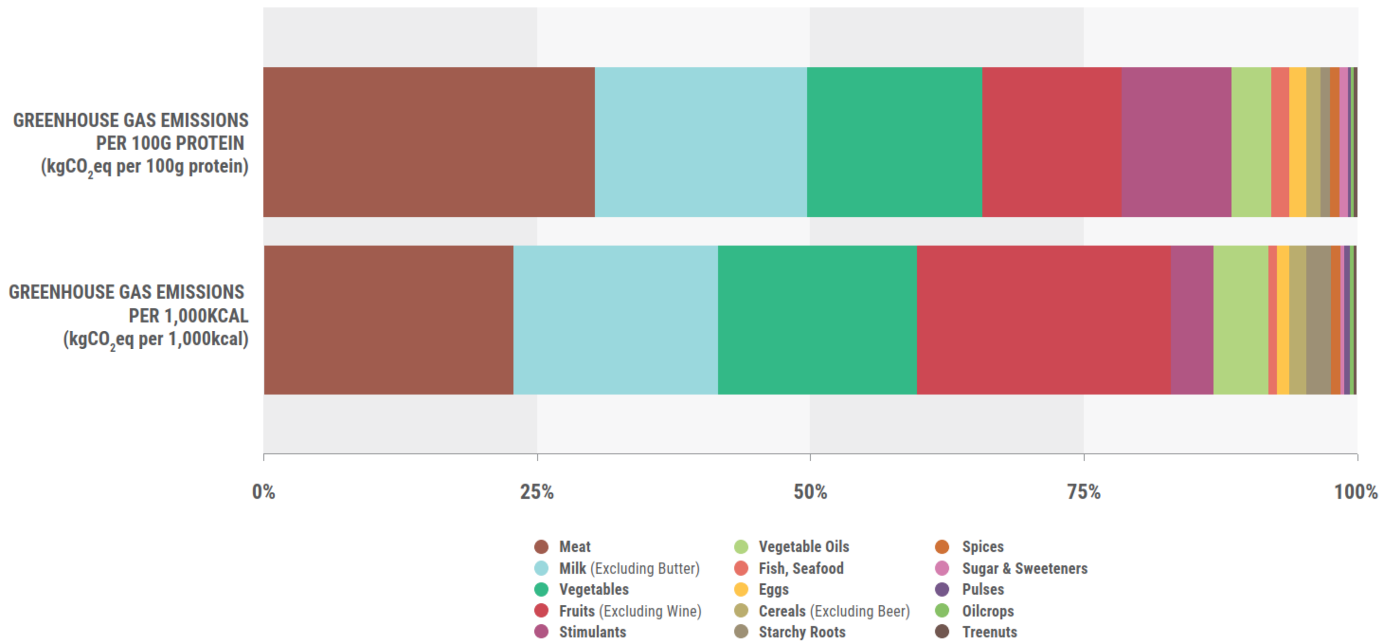


Figure 13: Relative Environmental Impacts per Food Category as a Function of their Nutritional Content[6]

[6] The environmental impacts factors developed by Poore & Nemecek represent global average factors that do not capture the local context of Guelph-Wellington agriculture and farming practices. It is therefore not to be understood as a comprehensive environmental impact assessment, but rather as an indication of the scale of impacts caused by the different food products consumed within the County's boundaries.

Figure 14 shows the environmental impacts of production occurring within the Guelph-Wellington region. The total greenhouse gas emissions correspond to approximately 1,300 ktCO_2eq. The production of feed, beef, and oil crops together represent ±70% of the total impacts.

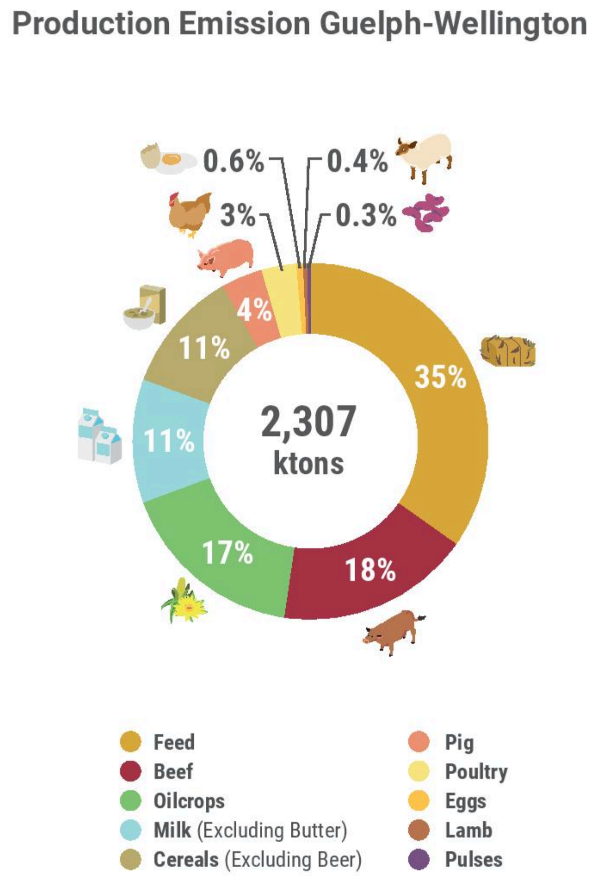


Figure 14: Environmental Impacts of Production in Guelph-Wellington (2018) [7]

[7] The environmental impacts factors developed by Poore & Nemecek represent global average factors that do not capture the local context of Guelph-Wellington agriculture and farming practices. It is therefore not to be understood as a comprehensive environmental impact assessment, but rather as an indication of the scale of impacts caused by the different food products consumed within the County's boundaries.

7.0 Additional Analysis and Impacts

7.1 Integration of New Data

After the primary analysis was complete Nielsen and a grocery chain provided additional local purchasing data.

The objective of the new data was to further improve the material flow analysis and implement changes in an updated, version of the Sankey diagram if necessary. Additionally, the 'bottom-up' local purchasing data provided by Nielsen and the grocery chain enables us to validate the 'top-down' modelling results on which the second version of the Sankey is based. However, before we incorporated the new local purchasing data in our material flow analysis, it was necessary to first validate whether the data is actually usable/comparable. To assess this, the new data was converted to match the basic unit of measurement as used in the material flow analysis, and then a comparison is made (standard deviation, absolute, relative difference). **Figure 15** is a schematic diagram of the methodological steps to process the local purchasing data from Nielsen and a grocery chain to improve the material flow analysis. The dotted lines show the use of Nielsen and the grocery chain's data to improve the top-down modelling results. After careful consideration of both top-down and bottom-up modelling results, it was decided not to incorporate the information into the Sankey diagram. Additional context on this decision is presented below.

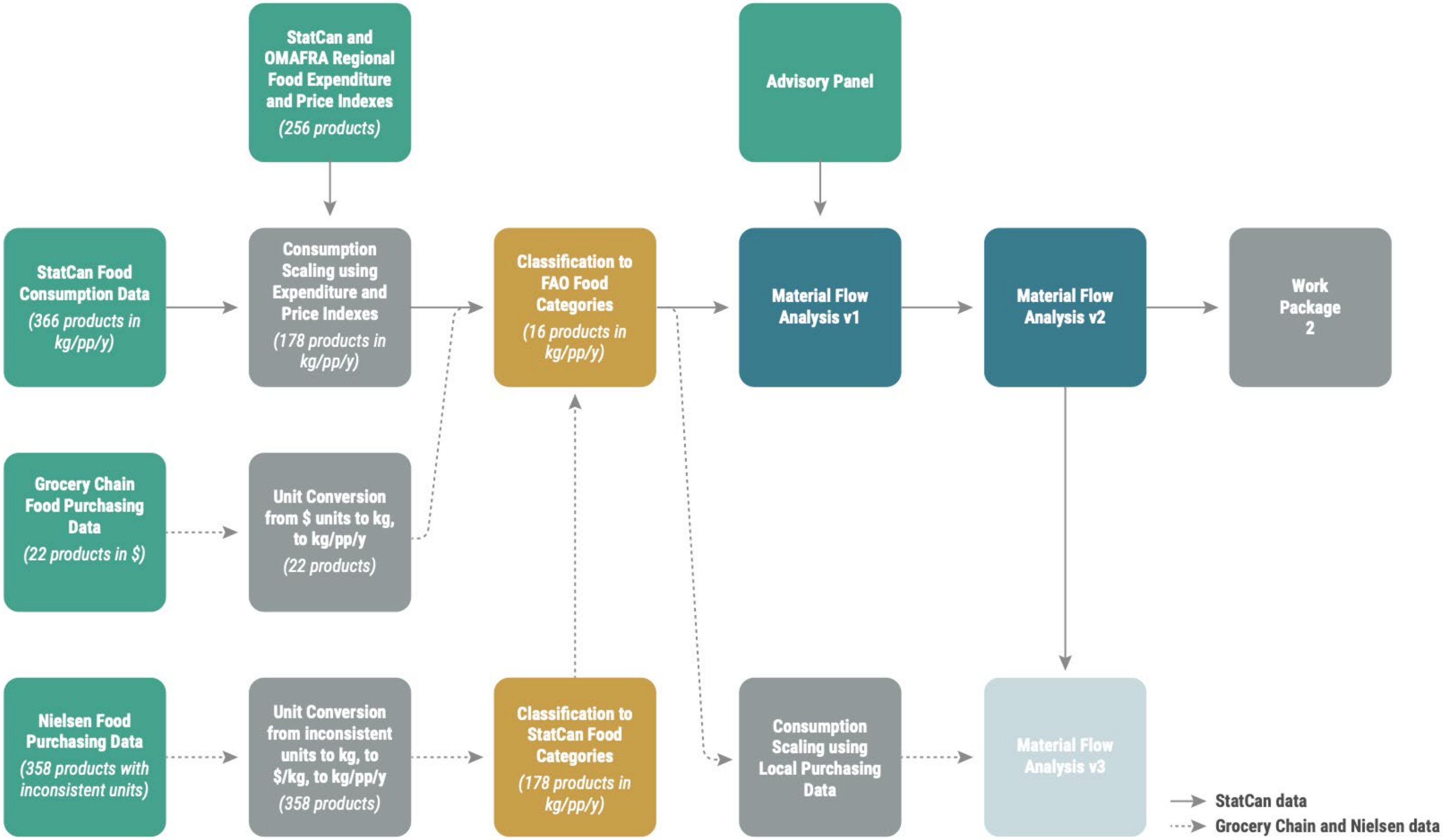


Figure 15: Simplified Diagram of Purchasing Data

7.1.1 Methodology

Nielsen Data

Nielsen provided two local purchasing datasets. The first dataset contains sales units, volume, and monetary value of 358 commodities sold between December 2018 and October 2020 per month in Guelph-Wellington. The second dataset indicated whether the sales unit from the first dataset were in kilograms, liters, or a quantity (for instance: the number of eggs). To use the data, conversion to the same basic unit of measurement (kg/commodity/inhabitant) as used in the material flow analysis was necessary.

Since there was no direct relationship between the two datasets Nielsen provided, and commodity names were incongruent, the datasets had to be matched manually to derive the unit for every commodity in the first dataset. After matching the datasets, desk research helped find conversion factors for all the commodities with quantity as their unit. These conversion factors were used to calculate the amount of kilograms per commodity (kg/commodity). Using the kilograms per commodity, the price per kilogram per commodity was calculated (CAD$/kg/commodity). The amount of dollars spent on food per inhabitant in Guelph is known (EMF, 2019), which was used to derive the basic unit of measurement underlying the Sankey (kg/commodity/inhabitant). The next step was to manually match Nielsen's 358 commodities to the 178 food products in the database. These 178 food products were subsequently aggregated to the 16 food groups that are used in the Sankey.

Grocery Chain Data

The grocery chain provided a huge dataset with 4,664,274 rows with unique transactions. The dataset contains 42 categories of which around half are related to food. However, the data only includes Sales (CAD), but no volumes, weights or impacts making it necessary to use multiple conversion factors to go from CAD to kg/commodity/inhabitant. These conversion factors were partially derived from Nielsen as they provided data on CAD/kg/commodity, as well as additional desk research. To utilize the grocery chain's data, the conversion factors per specific commodity had to be averaged to derive an indicative value for the grocery chain's food categories. Using the final conversion factors the kg/commodity/inhabitant was calculated. Subsequently, the grocery chain's food categories were manually matched to the 16 food groups used in the Sankey.

After processing the new datasets to derive the basic unit of measurement underlying the Sankey (kg/commodity/inhabitant) the results were compared to the original MFA and Sankey.

7.1.2 Results

The consumption data from the grocery chain showed a huge deviation from the original MFA and Sankey data. Vegetables (-142%) and fish (+80%) in particular, seem unrealistic for a normal balanced diet. The uncertainty and error propagation due to multiple unit conversions, commodity aggregation, and matching of several datasets with different scopes, results in unusable data to scale and validate the

Sankey. There may also be an impact of the unique market represented by the grocery store chain that provided the data. We considered this as a sufficient reason to discontinue further analysis with the grocery chain's data.

For Nielsen however, the results show the same order of magnitude. This can probably be attributed to Nielsen's large number of food categories (358 total), which allowed for detailed matching to food categories used in the Sankey (178 total).

Figure 16 shows Nielsen's data (yellow) relative to the current data in the food flow diagram (blue).

- The red line represents the original Statistics Canada consumption data.
- The blue line shows the data currently used in the Sankey derived by scaling the original Statistics Canada data using local expenditure and price indexes.
- The yellow line represents Nielsen's consumption data.

Despite the relatively close match, there are still some outliers for fish (+27.5%), oil crops (+21%), and fruits (-17%).

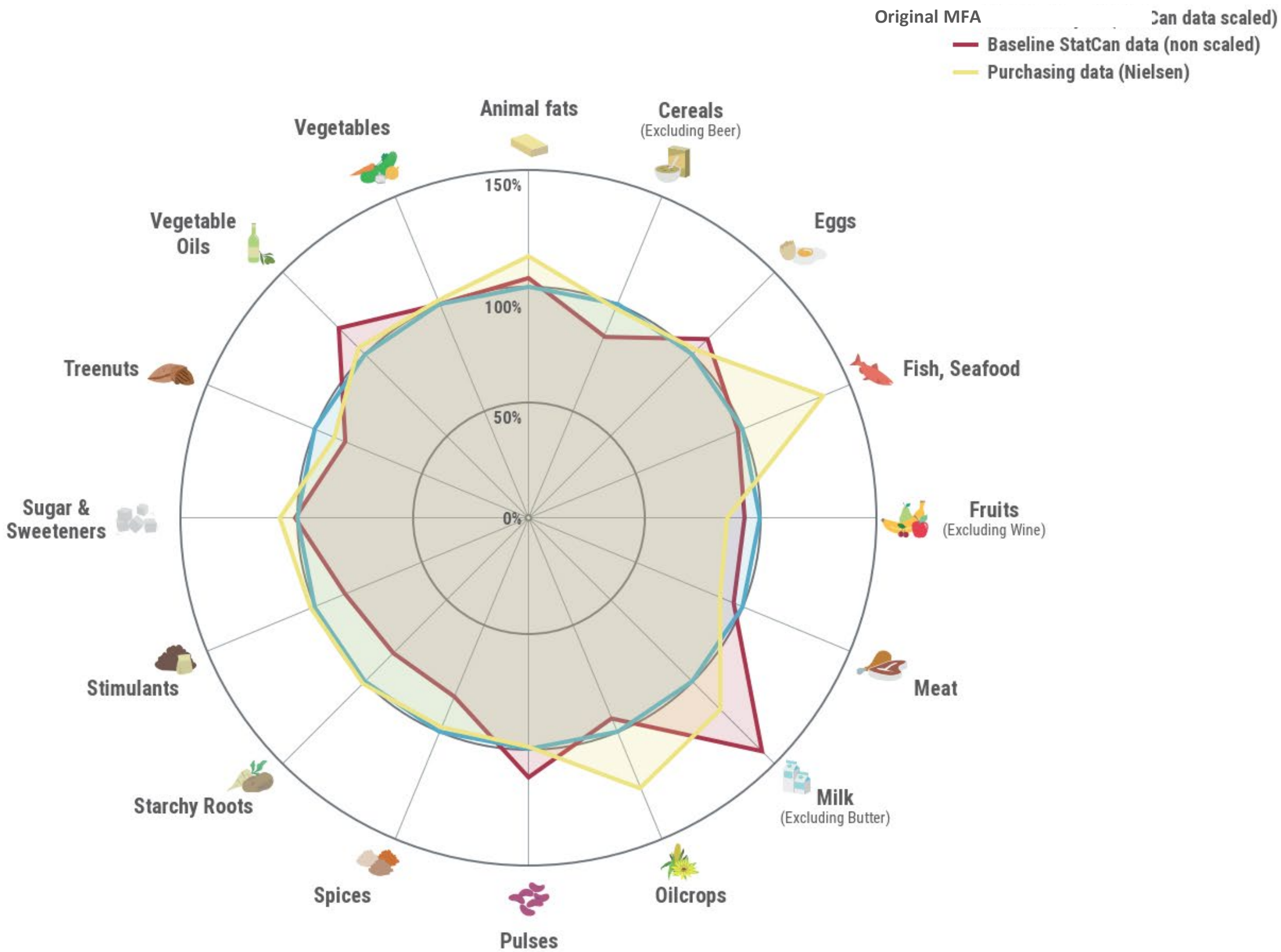


Figure 16: Comparison of Data Collected

The relative comparison of the main food groups between freely available Statistics Canada data (not scaled), MFA data (scaled), and Nielsen's purchasing data shows that although there are some deviations, the freely available data used to inform the original MFA produced results that are similar to an analysis using purchased Nielsen's data. This is a very positive finding of this work as it means one of the key goals of the project, the replicability of the analysis by other regions, should be possible without purchasing expensive datasets.

We can also show the results from **Figure 16** in absolute terms. **Figure 17** shows the total amount of ktons consumed in Guelph-Wellington per year for each food group. The figure shows the scaled/modelled data used the original MFA and Sankey (blue), and Nielsen's purchasing data (yellow). For each of the food groups, the difference between the blue and yellow bars can be considered the uncertainty range between the modelled results and the purchasing data. The food groups with the largest absolute difference and thus uncertainty are Fruits and Milk.

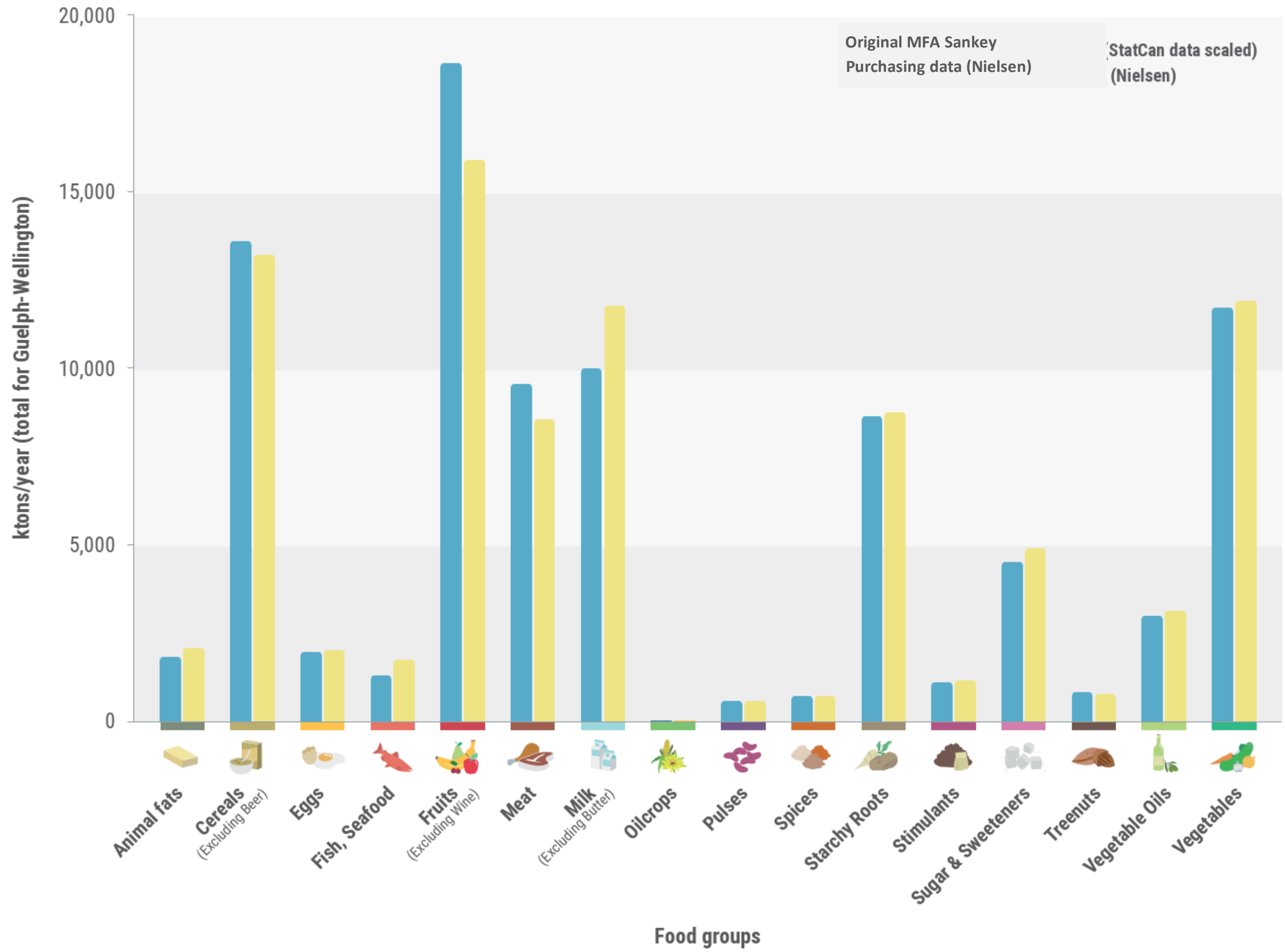


Figure 17: Absolute Comparison of Datasets

Figure 18 shows how the total consumption distribution per food group in Guelph-Wellington would look if the Sankey would be completely based on Nielsen's purchasing data. Interestingly, although a bit lower than the modelled results, fruits still represent the largest fraction of consumed food.

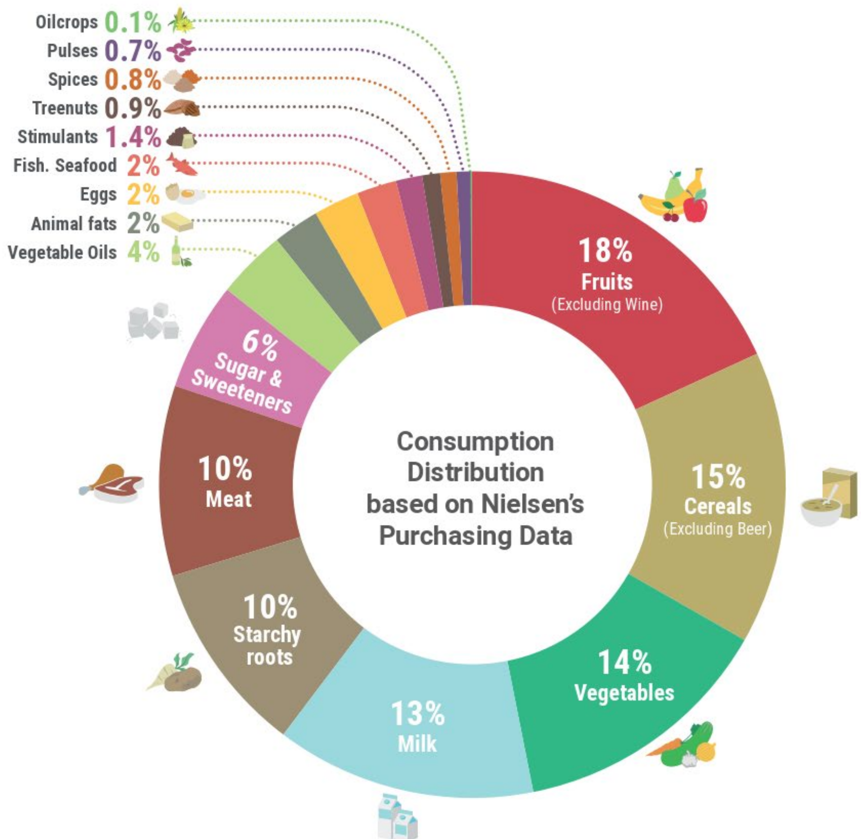


Figure 18: Total Consumption Distribution per Food Group

Conclusion

Our analysis demonstrates that uncertainty and error propagation due to multiple unit conversions, commodity aggregation, and matching of several datasets results in high variations between the data used for the MFA and the additional datasets. This makes accurate scaling of the Sankey data based on the 'bottom-up' purchasing data challenging.

In terms of the grocery chain's dataset, the error propagation due to data processing results in unrealistic food quantities for a normal balanced diet. Therefore, the data was not scaled to the MFA.

Nielsen's purchasing data, however, is in the same order of magnitude of the data used for our initial MFA. However, due to error propagation it is impossible to conclude whether Nielsen's data actually provides more accurate results. Therefore, the data was not scaled to the MFA. However, even with the methodological limitations, Nielsen's data was still considered very useful as a quality control measure. This data provides an uncertainty range to our modelled results. In WP2, the modelled results and the uncertainty range from Nielsen's data will be used to do the impact assessment. Further, the Nielsen's data was helpful to strengthen our confidence in the publicly available data.

7.2 Impact of COVID-19 Pandemic on Findings

An important consideration to this research is the impact of the global pandemic on analysis produced here. Because the data available came from years prior to the pandemic, and food flow data from 2020 will not be available until after this project completes, we are not able to provide a quantitative assessment of the impact the pandemic has had on food flows in the study area. Despite this limitation we are able to provide some general commentary based on the information that has become available during the 2020 year about the impact of the pandemic on the food flows in the region.

When the businesses shut down and stay-at-home measures were put into place there was a shift of demand from distributors to grocery stores. Because the shift was rapid, and compounded by fear-inspired over-purchasing, many grocery stores experienced large shortages of supplies, possibly further compounding the fear-motivated purchases as consumers purchased further excess when possible to safeguard against anticipated future shortages. Although the food value chains are relatively resilient, the pandemic revealed some cracks: specifically the inability to respond quickly to changes in demand patterns and the deep dependency on international imports of food products.

Many members of the food community are now reassessing our food value chains and looking at ways to increase local supply of food products. This will impact where waste is generated as well as by how much. In theory, locally produced food should be related to decreased food waste as it will have shorter transport distances meaning a longer shelf life once in retail or in the consumer's home. Although this is a strong possibility, there is also a factor of the level of development of infrastructure involved in the food value chain. Larger, established chains, often with food coming from international locations, have very good infrastructure and standard operating procedures for maximizing food lifespan. New and less developed local food value chains will likely lack this level of investment and organization which may impact waste generation. Because these chains are small they are able to respond quickly so government policy and intervention may be useful in this respect.

An additional change since the onset of the global pandemic is where food is consumed and subsequently, where food waste is generated. Health measures required the closure or limited the service in restaurants and at conference venues. This pushed food consumption primarily into the home, either through home cooked meals or delivery and take-out options. This change likely caused a larger volume of organic waste to be generated at the household level while less is generated in the HRI sector. For Guelph-Wellington this is a positive for waste handling as the compost systems that are in place are aimed at the household level. Because overall food consumption has likely not changed but more is being consumed at home, we expect this to be a positive for the regional GHG production as more waste will be diverted from landfill and be composted.

Further analysis of the impact of the global pandemic on food flows will be required in the years to come as more data becomes available. The information provided here should be used as a guide to direct thinking while reviewing new data as it becomes available.

8.0 Next Steps

8.1 Work Package 2

The analysis, findings and engagement work conducted as part of Work Package 1 served as a baseline and foundation which will be the starting point for WP2. Funding is anticipated to be received from Federation of Canadian Municipalities (FCM) to complete this second WP. As per the application requirements, the deliverable from WP1 is referred to as Milestone 1 of the project and WP2 will consist of three new milestones (Milestones 2, 3, and 4) and has been set up in this manner to facilitate reporting requirements of FCM. The second work package will include the following:

***Milestone 2:* Data Processing, Vision Integration, Indicator Framework & Plan Creation**

1. Map key stakeholders in the food system.
2. Complete a hotspot analysis.
3. Engage with key stakeholders to complete a visioning and objectives workshop and integrate feedback into final project goals.
4. Develop Key Performance Indicators for the project (social/economic/environmental) and use to monitor the circularity of the food supply chain.

***Milestone 3:* Plan & Business Case Development**

1. Create a roadmap that identifies key hotspots for food waste and loss.
2. Evaluate interventions that may be useful to apply to key hotspots for food waste and loss.
3. Develop business cases that explore hotspots and interventions further.

***Milestone 4:* Project Communication**

1. Summarize and present findings to the Our Food Future team.
2. Adjust summary based on feedback.
3. Submit to Our Food Future team for dissemination.

8.2 Work Package 3

Work Package 3 will be refined further based on the results of WP2 and in conjunction with the additional feedback from the AP meeting(s). That said, the work in WP2 has been framed to ensure key elements are elucidated to ease an application for further funding to FCM to complete the tasks in WP3. In general, the key deliverables of WP3 are anticipated to include:

- Refining this work by incorporating additional spatial analyses.
  - A spatial analysis will add a practical element showing the city where certain interventions or infrastructure is needed. This work would again be done with Jude Keefe, based on her research project which supports the use of spatial analysis to determine sites of importance in the study area, as well as in collaboration with Metabolic.
- Feasibility studies and implementation of business cases.
  - Detailed feasibility studies will answer more granular information about setting up the circular interventions recommended in the roadmap.
  - Additional support in implementation can include stakeholder convening, connections to innovative technology partners, and circular product design.
- Empowering other cities to complete the said work through distribution of the refined workbook and useful data.
  - A half-day functional design workshop is included towards the end of Work Package 2. This workshop will help determine which will be the most useful, shareable format for the resource, IP considerations, data limitations, and identify any other conditions or ambitions that we should account for.
  - The resulting resource will need to accurately reflect the reality of each jurisdiction's specific food system in a format that is universally applicable.

We recommend that detailed discussions about what this resource should be and how it will work take place at the end of Work Package 2, when we will have a clear idea of what information is available, how labour intensive it is for a jurisdiction to collect the relevant data and what the funding requirements will be.

8.3 Funding Options for Further Work

The Our Food Future team and the Consulting Team were awaiting the finalization of the contract with the Federation of Canadian Municipalities (FCM) at the time this report was written. Verbal approval of the funding for WP2 has been provided (for a feasibility study) and the structure of WP2 has been such that future funding from FCM (for a pilot project) is anticipated. Dillon tracks grants and other funding opportunities for work related to food security and food waste reduction and may be able to support an alternative or additional funding stream application if needed.

9.0 Closure

The Consulting Team is very excited to be part of this journey, embarked on by the City of Guelph, the County of Wellington, and other community stakeholders, to create Canada's first circular economy for food. We anticipate that the ambitious plan set forth by the Our Food Future team, and the work being done by the Consulting Team, will help lay the groundwork for other regions in Canada to follow. In this way, our collective efforts will not only impact and improve the food system in Guelph-Wellington, but also food systems across the country.

10.0 References

Stage	Sources used to develop the MFA broken down per stage
Production	Gooch, M., Bucknell, D., LaPlain, D., Dent, B., Whitehead, P., Felfel, A., Nikkel, L., Maguire, M. (2019). The Avoidable Crisis of Food Waste: Technical Report; Value Chain Management International and Second Harvest; Ontario, Canada
Production	Area, Yield, Production and Farm Value of Specified Field Crops (Imperial and Metric Units): 2015-2020 by year (retrieved from: http://www.omafra.gov.on.ca/)
Production	Barley (retrieved from: http://www.omafra.gov.on.ca/)
Production	Broccoli: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Cabbage: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Canola (retrieved from: http://www.omafra.gov.on.ca/)
Production	Carrots: 2002-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Cattle Supply and Disposition: 2010-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Cauliflower: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Chicken Supply and Disposition: 2004-2018 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Coloured Beans (retrieved from: http://www.omafra.gov.on.ca/)
Production	Dry Onions: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Egg Production and Value: 1998-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Egg Supply and Disposition: 2004-2018 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Fodder Corn (retrieved from: http://www.omafra.gov.on.ca/)
Production	Grain Corn (retrieved from: http://www.omafra.gov.on.ca/)
Production	Grapes: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Green and Wax beans: 2003-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Hay (retrieved from: http://www.omafra.gov.on.ca/)
Production	Milk production by county 2007-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Mixed Grain (retrieved from: http://www.omafra.gov.on.ca/)
Production	Oats (retrieved from: http://www.omafra.gov.on.ca/)
Production	Peaches: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Pears: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Peppers: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Pigs Supply and Disposition: 2010-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Plums & prunes: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Potatoes: 2007-2012 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Poultry Production and Value: 1998-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Radishes 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Raspberry: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Rutabagas: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Sheep Supply and Disposition: 2010-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Sour Cherry: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)

Stage	Sources used to develop the MFA broken down per stage
Production	Soybeans (retrieved from: http://www.omafra.gov.on.ca/)
Production	Spring wheat (retrieved from: http://www.omafra.gov.on.ca/)
Production	Strawberries: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Sweet Cherry: 1995-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Sweet Corn: 2003-2019 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Tobacco (retrieved from: http://www.omafra.gov.on.ca/)
Production	Turkey Supply and Disposition: 2004-2018 (retrieved from: http://www.omafra.gov.on.ca/)
Production	Wellington livestock (retrieved from: http://www.omafra.gov.on.ca/)
Production	White Beans (retrieved from: http://www.omafra.gov.on.ca/)
Production	Winter Wheat (retrieved from: http://www.omafra.gov.on.ca/)
Production	Ontario Agri-food Trade by Commodity Group, 2009 - 2019 (million $) (retrieved from: http://www.omafra.gov.on.ca/)
Production	Ontario Agri-food Trade by Region, 2009-2019 (million Cdn $) (retrieved from: http://www.omafra.gov.on.ca/)
Processing	Geometrix. Final Report for the Study of Food-Based Inputs for Biogas Systems in Ontario (2008). Provision Coalition.
Processing	Gooch, M., Bucknell, D., LaPlain, D., Dent, B., Whitehead, P., Felfel, A., Nikkel, L., Maguire, M. (2019). The Avoidable Crisis of Food Waste: Technical Report; Value Chain Management International and Second Harvest; Ontario, Canada
Distribution	Gooch, M., Bucknell, D., LaPlain, D., Dent, B., Whitehead, P., Felfel, A., Nikkel, L., Maguire, M. (2019). The Avoidable Crisis of Food Waste: Technical Report; Value Chain Management International and Second Harvest; Ontario, Canada
Consumption	Gooch, M., Bucknell, D., LaPlain, D., Dent, B., Whitehead, P., Felfel, A., Nikkel, L., Maguire, M. (2019). The Avoidable Crisis of Food Waste: Technical Report; Value Chain Management International and Second Harvest; Ontario, Canada
Consumption	Food available for consumption in Canada (retrieved from StatCan)
Consumption	County Profile Expenditure (retrieved from: http://www.omafra.gov.on.ca/)
Consumption	Canada Consumption Expenditure (retrieved from StatCan)
Consumption	Price Indexes (retrieved from StatCan)
Consumption	Geometrix. Final Report for the Study of Food-Based Inputs for Biogas Systems in Ontario (2008). Provision Coalition.
Consumption	Agriculture, Food and Business Employment Profile (2016 Census) (retrieved from: http://www.omafra.gov.on.ca/)
Consumption	Mapping the Circular Food Economy in Guelph-Wellington (received data)
Consumption	Wellington region data (2006-2016).xlsx - Business Profile (received data)
Consumption	2019_Chamber Directory_Agri & FoodBev (received data)
Consumption	2019_InfoCanada_Agri & FoodBev (received data)
Consumption	Wellington employee data.xlsx (received data)
Collection	Gooch, M., Bucknell, D., LaPlain, D., Dent, B., Whitehead, P., Felfel, A., Nikkel, L., Maguire, M. (2019). The Avoidable Crisis of Food Waste: Technical Report; Value Chain Management International and Second Harvest; Ontario, Canada

Stage	Sources used to develop the MFA broken down per stage
Collection	Single Family and Multi-Residential Waste Generation Projections - From City of Guelph Solid Waste Management Master Plan Review Final Report (p9)
End-of-life	Gooch, M., Bucknell, D., LaPlain, D., Dent, B., Whitehead, P., Felfel, A., Nikkel, L., Maguire, M. (2019). The Avoidable Crisis of Food Waste: Technical Report; Value Chain Management International and Second Harvest; Ontario, Canada
End-of-life	City of Guelph - Solid Waste Resources (2020). What happens to Guelph's waste?
End-of-life	Population data - Census 2016 (retrieved from StatsCan)
End-of-life	FR_ca - Guelph Region Impact Report - Dillon Consulting
End-of-life	Discussion paper: addressing food and organic waste in Ontario. OMAFRA (2016)
End-of-life	Diverted and buried materials 2017 - 2019 (received data)
End-of-life	Wellington County Residential Self Haul Curbside Waste Audit 2019 (received data)
End-of-life	Walmart Report on Averages and Distributions of Household Waste - Includes ANOVA and Regression Output Summaries (received data)
Impacts	Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. Science, 360(6392), 987-992.
Impacts	Gooch, M., Bucknell, D., LaPlain, D., Dent, B., Whitehead, P., Felfel, A., Nikkel, L., Maguire, M. (2019). The Avoidable Crisis of Food Waste: Technical Report; Value Chain Management International and Second Harvest; Ontario, Canada
Impacts	CEC. 2017. Characterization and Management of Food Loss and Waste in North America. Montreal, Canada: Commission for Environmental Cooperation. 48 pp.
Impacts	RIVM (2019). Life-cycle impacts of Food Products.
Impacts	von Massow, M., Parizeau, K., Gallant, M., Wickson, M., Haines, J., Ma, D., ... & Duncan, A. (2019). Valuing the multiple impacts of household food waste. Frontiers in nutrition, 6, 143.

Appendix A

Methodology

Methodology - Data Analysis & Assumptions

1. **Top-down approach: building the skeleton**

   1.1. **Food availability for Guelph-Wellington Residents**

      1.1.1. **Retrieving Canadian averages of food availability**

The amounts of food available per person in Canada for the year 2018 was retrieved from StatCan (StatCan, 2018- *Food Availability* dataset #32-10-0054-01). This database lists 366 food commodities available for consumption. As described by StatCan, the dataset represents the average amount of food available for a Canadian *prior* to food waste occurring at the retail stage, and the HRI and household consumption stages. It, therefore, does not represent the actual food consumed by an average Canadian. Although StatCan provides some estimate of actual food consumption (versus food availability) by subtracting the potential food waste, it does not differentiate where the wasting of food occurs (retail, HRI, or households). The food availability values were therefore chosen over the estimate of actual food consumed provided by StatCan.

From an MFA perspective, the values from the dataset, therefore represent the amounts of food available at the *Distribution* stage of the value chain, *after* accounting for Distribution losses and *prior* food commodities are being divided in terms of supply channels between Retail and HRI sales channels.

To quantify the total amounts of food available in Guelph-Wellington, the dataset values were scaled up by multiplying the amounts (per person) by the total population of Guelph-Wellington (222,726 inhabitants), thanks to the 2016 census from StatCan, such as:

$$F_{av}\ (commodity\ \ A)_{Guelph-Wellington\ (Canadian\ average)} = F_{av}\ (commodity\ A)_{average\ Canadian} * Pop_{Guelph-Wellington}$$

Equation 1

F_{av} representing the amount of a given food commodity A, available in kg and Pop representing the numbers of inhabitants in Guelph-Wellington.

Missing Food Commodity Value

The StatCan dataset presented several missing values. For key food commodities, such as rice, the FAOSTAT dataset Food Balance Sheet for Canada was used to complete the dataset (FAOSTAT, 2017). For food commodities representing marginal amounts of food, their values were not included.

      1.1.2. **Obtaining Ontario and Guelph-Wellington-specific averages of food availability**

To obtain the amount of food available to Guelph-Wellington residents, Ontarian consumer spending habits and the prices of food products sold in Ontario were integrated into the model. It is important to include this provincial specificity for two reasons. First, there is variability in the amount Canadians spend on different food products across Canada. Second, food products are priced differently depending on geography. These two factors therefore influence the final quantities of food products bought in Ontario.

In practice, we interpolated three different datasets together to adjust consumption patterns to Ontario (base year 2018). We use StatCan's *Canada Consumption Expenditure* and *Price Indexes*, and OMAFRA's *County Profile Expenditure*. A reclassification process had to be performed to match the commodity names listed in the two StatCan datasets to OMAFRA and subsequently to the food product classification used in the *Food Availability* dataset. These datasets offer different classification structures for food products therefore this harmonization step is required to aggregate their data points.

Once we finalized this classification process, the difference (expressed in percentage) in average spending for more than 260 food products is quantified as follows:

$$\begin{gathered} Spending\ Difference\ (Commodity\ A) = \\ Amount\ spent\ (Commodity\ A)_{Ontario}\ /\ Amount\ spent\ (Commodity\ A)_{Canada} \end{gathered}$$

Equation 2

Next, the difference in price indexes (expressed in percentage) between the Canadian averages and Ontario is calculated:

$$Price\ (Commodity\ A)_{Ontario}\ /\ Price\ (Commodity\ A)_{Canada} = Price\ Difference\ (Commodity\ A)$$

Equation 3

The final food availability adjustment factors use **Equation 2** and **Equation 3** results to quantify:

$$\begin{gathered} Availability\ Adjustment\ factor\ (Commodity\ A) = \\ Spending\ Difference\ (Commodity\ A) * (1 + (1 - Price\ Difference\ (Commodity\ A)) \end{gathered}$$

Equation 4

In simpler terms, the adjustment (**Equation 4**) enables accounting of the quantity of food bought relative to the local prices and local spending patterns.

To give an example: if an average Canadian spends $10 on apples every year, and an Ontarian spends $11 - an Ontarian spends 10% more. But considering the apple costs $5/kg in Canada, and only $4/kg in Ontario, the real quantities bought by an Ontario are 37.5% higher.

Additionally, the intention was to integrate the difference in food spending between Ontario and Guelph-Wellington into the adjustment factors calculation (Equation 4) - to tailor even further the newly obtained Ontarian adjustment factors to Guelph-Wellington specificities. However, the food product

> The City of Guelph and the Country of Wellington have food spending behaviours very similar to the rest of the province of Ontario.

classification used by OMAFRA *County Profile Expenditure* dataset was too aggregated, resulting in a coarse matching of food products, and therefore adding uncertainties and inconsistencies, once integrated into the calculations. Therefore, the decision made was to include this dataset in **Equation 4**. Nonetheless, the differences in spending at the Ontario-level and Guelph-Wellington were still analyzed as a reference point and to determine if Guelph-Wellington residents exhibited any peculiar food spending habits. By and large, it was concluded that Ontario and Guelph-Wellington spending behaviour was very similar.

The adjustment factors for each food product are then multiplied with their respective quantities at the *Distribution* stage (post-losses) to determine their *adjusted* availability for Guelph-Wellington residents.

$$F_{av}\,(commodity\ \ A)_{Guelph-Wellington\ (Ontario\ average)} = Availability\ Adjustment\ factor(Commodity\ A) * F_{av}\,(commodity\ \ A)_{Guelph-Wellington}$$

Equation 5

1.2. Food Waste factors to build upstream and downstream flows

The technical report of *The Avoidable Crisis of Food Waste* by Gooch et al., (2019) provided key data points to model the upstream flows (production, processing, manufacturing, and distribution). This report has been selected as it is the most up-to-date report on Canada's food waste occurrence along the food value chain. It is based on an extensive literature review, as well as numerous interviews and surveys with key actors along the Canadian food value chain. The technical report provided food waste

Avoidable Food Loss & Waste and Unavoidable Food Loss & Waste

Understanding what is avoidable and unavoidable food loss & waste is not clear cut. Different groups define it differently based on what's needed for their system and/or cultural preferences. For example, one group may determine that discarded kiwi peels are unavoidable food loss & waste while another would consider it an edible product and therefore a form of avoidable food loss & waste.

For this report, the definitions used by the data sources analyzed were used but in WP2 and WP3 a more nuanced approach will be proposed to be adopted by the region moving forward.

factors at every step of the value chain for the following aggregated food groups: *Field Crops, Produce, Meat/Poultry, Marine, Sugar/Syrup, and Dairy/Egg.* The waste factors are expressed as a percentage of the total amount of food available at a given stage in the value chain for a given food group that is discarded (*Unavoidable*) or wasted (*Avoidable*).

For two food groups, namely *Dairy/Egg and Meat Poultry*, food loss factors at the Production stage were either missing or deemed incomplete (e.g., not taking into account mortality rates of animals), therefore food loss factors from the *Global Food Waste Estimates* developed by FAO (2011) were used for these 2 food groups. These factors were specifically developed for the North-American context. A similar process was performed for the Marine food group at the manufacturing stage.

$$WF(Food\ Group)_{\ Stage\ A} = total\ F_{waste}(Food\ Group\ X)_{stage\ A} \,/\, total\ F_{av}(Food\ Group\ X)_{\ stage\ A}$$

Equation 6

As the food commodities from StatCan are very disaggregated, a classification process was performed to classify each commodity to one of the six food groups. The technical report provided more detailed information about the food commodities present in each food group, thus helping to guide the classification and data harmonization process. Once classified, each commodity had an assigned food waste factor at each step of the value chain (as shown in **Equation 6**). Starting with the values for the *Distribution* stage, we used these factors to unravel the upstream food flows. As mentioned previously, the food availability data from StatCan represents the amount of food available prior to being distributed to *Retail* and *HRI* but exclusive of the losses occurring at this stage. As a result, the amount of food available at the beginning of the *Distribution* stage is higher (it includes the share of food that will be wasted at this stage). To calculate the food available (*pre-losses)*, we use the following relation:

$$F_{av}\ (commodity\ A)_{Distribution} = F_{av}\ (commodity\ \ A)_{\ Guelph-Wellington} \,/\, (1 -\ WF(Food\ Group\ X)_{\ Distribution}\ )$$

Equation 7

Where $F_{av}\ ()_{Distribution}$ is the amounts in kg of a given commodity A at the *Distribution* stage and $WF()_{Distribution}$ is the waste factor for the given food group, to which *commodity A* belongs to (e.g., Field Crops).

The total amount of food wasted at the Distribution stage can be calculated with the following equation:

$$F_{waste}(commodity\ A)_{Distribution} = F_{av}(commodity\ A)_{Distribution} * WF(Food\ Group\ X)_{Distribution}$$

Equation 8

The same calculations are repeated to populate the data alongside the value chain: from Distribution to Manufacturing to Processing to Production. The generic equation may be expressed as:

$$F_{av}\,(commodity\ A)_{stage\ n-1} = F_{\ av}\,(commodity\ \ A)_{\ stage\ n} \,/\, (1 - \ WF(Food\ Group\ X)_{\ stage\ n-1}\,)$$

Equation 9

For the stages, upstream and downstream from Distribution, two waste factors are given by Gooch et al. report: a waste factor for “planned” food loss, which are defined as unavoidable for the report and “unplanned” defined as avoidable food waste. The differentiation between unavoidable and avoidable food waste. The total waste factor for a given stage is therefore:

$$WF(Food\ Group\ X) = \ WF_{\ unavoidable}(Food\ Group\ X) + \ WF_{\ avoidable}(Food\ Group\ X)$$

Equation 10

Therefore, the amount of avoidable and unavoidable food waste can be calculated for a given stage, once the food availability (pre-losses) has been calculated (**Equation 9**).

$$F_{\ AV\,waste\ \ _{stage\ n-1}} = F_{\ \ av}\ \ (commodity)_{stage\ n-1} * \ WF_{\ avoidablee_{stage\ n-1}}$$

Equation 11

and;

$$F_{\ UA\ waste\ \ _{stage\ n-1}} = F_{\ \ av}\ \ (commodity)_{stage\ n-1} * \ WF_{\ unavoidablee_{stage\ n-1}}$$

Equation 12

The amount of food available, avoidable and unavoidable waste may therefore be computed for all of the upstream stages.

Regarding the downstream stages, namely Retail, Households, and HRI, a different approach was developed. First, using insights provided by Gooch et al., who determined that 65% of the total amount of food sold for consumption was supplied by the retail sector and 35% by the HRI sector. Therefore, the food available at the Distribution, once the food waste at this stage has been accounted for and removed from the available total may be distributed to the these two stages in the value chain, such as:

$$F_{av}(commodity\ A)_{Distribution} - F_{waste}(commodity\ A)_{Distribution} = F_{av}(commodity\ A)_{Retail} + F_{ac}(commodity\ A)_{HRI}$$

Equation 13

The food available at the Retail and HRI stage can be calculated following the equation:

$$F_{av}(commodity\ A)_{Retail} = (F_{av}(commodity\ A)_{Distribution} - F_{waste}(commodity\ A)_{Distribution}) * 0.65$$

Equation 14

and;

$$F_{av}(commodity\ A)_{HRI} = (F_{av}(commodity\ A)_{Distribution} - F_{waste}(commodity\ A)_{Distribution}) * 0.35$$

Equation 15

The food wasted at Retail (exclusively avoidable), $F_{AVwaste}$ *(commodity A)*$_{Retail}$, and at the *HRI* stage, $F_{AVwaste}$*(commodity A)*$_{HRI}$ and $F_{UA\ waste}$*(commodity A)*$_{HRI}$, can also be calculated with **Equation 14** and **Equation 15**.

Finally, as the households received 100% of the Retail stage food supply, the amounts of food available at the Households stage can be calculated based on the following relation:

$$F_{av}(commodity\ A)_{Household} = F_{av}(commodity\ A)_{Retail} - F_{AV\ waste}(commodity\ A)_{Retail}$$

Equation 16

The amounts of avoidable F_{AV}*waste (commodity A)*$_{Household}$ and unavoidable $F_{UA\ waste}$*(commodity A)*$_{Household}$ are calculated using local (ground-truth) data further explained in the *Bottom-Up Approach* section.

The waste generated at the *Retail, HRI, and Households* (and to some extent the *Distribution* stage) is collected by the municipality and private waste collection companies in Guelph-Wellington, and subsequently treated. Although regional data exists to determine the most likely fate of organic waste streams in Ontario, bottom-up data stemming from Guelph-Wellington municipal waste datasets and local studies will enable a more granular understanding of Guelph-Wellington food waste flows. The bottom-up approach is therefore the next phase to refine the skeleton of the food metabolism of Guelph-Wellington.

2. Bottom-up approach: filling in the details

The goal of the bottom-up approach is to provide greater granularity and local insights into Guelph-Wellington food flows.

2.1. Local Food Waste Streams

2.1.1. Households Food Waste

For households, local food loss estimates from von Massow et al. (2019) were used to quantify the unavoidable and avoidable food waste. Von Massow et al. (2019) surveyed households in Guelph-Wellington, and quantified the amount of food loss/waste.

First, the shares of avoidable ($WF_{avoidable}$) and unavoidable food waste ($WF_{unavoidable}$) were calculated based on von Massow et al.'s (2019) data. This data englobes five aggregated food categories that were reclassified and harmonized with Gooch et al.'s (2019) food classification. To retrieve the quantities of unavoidable food waste, and quantify the total amount of food waste produced by the local households, the following calculations were run:

$$F_{total\ food\ waste}(food\ group\ X)_{Study\ Household} = F_{AV\ waste}(food\ group\ X)_{Household} / WF_{avoidable}(food\ group\ X)$$

Equation 17: Total food waste

$$F_{UA\ waste}(food\ group\ X)_{Study\ Household} = F_{total\ food\ waste}(food\ group\ X)_{Study\ Household} * WF_{UNavoidable}(food\ group\ X)$$

Equation 18: Unavoidable food waste

Total, avoidable, and unavoidable food waste are subsequently converted into kg/capita/year, using Guelph-Wellington's mean household size.

To integrate this local data into the model, the total amount of food reaching Guelph-Wellington on a per capita basis is first computed following Gooch et al.'s (2019) classification. The final household food waste factors for the model are then computed in **Equation 19**.

$$WF_{avoidable-Household}(food\ group\ X) = F_{AV\ waste}(food\ group\ X)_{Household} / F_{av}(food\ group\ X)_{Household}$$

Equation 19: Avoidable food waste factor

$$WF_{unavoidable-Household}(food\ group\ X) = F_{UNav\ waste}(food\ group\ X)_{Household}/F_{av}(food\ group\ X)_{Household}$$

Equation 20: Unavoidable food waste factor

These factors are then used to quantify the total unavoidable and avoidable food waste flows from Guelph-Wellington residents. Each of the food commodities are multiplied with the avoidable and unavoidable waste factors for the given food group X, to which *commodity A* belongs to.

$$F_{AV\ waste}(commodity\ A)_{Household} = F_{av}(CommodityA)_{Household} * WF_{avoidable-Household}(food\ group\ X)$$

Equation 21: Avoidable food waste for Household in the model

$$F_{UNAv\ waste}(commodity\ A)_{Household} = F_{av}(CommodityA)_{Household} * WF_{unavoidable-Household}(food\ group\ X)$$

Equation 22: Unavoidable food waste for Household in the model

2.1.2. HRI Food Waste

Concerning the HRI sector, a hybrid approach was used using both local data from von Massow et al. (2019) and top-down data from Gooch et al. (2019). This hybrid approach was developed due to the fact that the local data on HRI food waste was sparse and available to a level of granularity too low to be integrated into the model.

The food waste factors for the Canadian HRI sectors developed by Gooch et al. (2019) were first used to illustrate the difference in total food waste incidence (avoidable + unavoidable) between households and HRI. The difference was calculated with the following equation:

$$\begin{gathered} Food\ Waste\ incidence\ Difference\ factor\ (food\ group\ X) = \\ WF_{total\ waste\ -HRI}(food\ group\ X)/WF_{total\ waste\ -Household}(food\ group\ X) \end{gathered}$$

Equation 23

The avoidable and unavoidable food waste factor (in household) derived from van Massow et al.'s (2019) data (in Equation 17;Equation 18;and Equation 19) are then multiplied by the difference factor to obtain adjusted HRI food waste factors. As no reliable data was available for the shares of avoidable and unavoidable food waste at the HRI level, the shares derived from von Massow et al. (2019) for Guelph-Wellington's households were used as they were in an acceptable range (unavoidable-to-avoidable ratio) based on other Canadian studies.

$$WF_{avoidable\ waste}(food\ group\ X)_{HRI} = WF_{avoidable-Household}(food\ group\ X) * Food\ Waste\ incidence\ Difference\ factor\ (food\ group\ X)$$

Equation 24

$$WF_{unavoidable\ waste}(food\ group\ X)_{HRI} = WF_{unavoidable-Household}(food\ group\ X) * Food\ Waste\ incidence\ Difference\ factor\ (food\ group\ X)$$

Equation 25

These factors are then used to quantify the total unavoidable and avoidable food waste flows from Guelph-Wellington's HRI sectors. Each of the food commodities are multiplied with the avoidable and unavoidable waste factors for the given food group X, to which *commodity A* belongs to.

$$F_{AV\ waste}(commodity\ A)_{HRI} = F_{av}(Commodity A)_{HRI} * WF_{avoidable}(food\ group\ X)_{HRI}$$

Equation 26: Avoidable food waste for HRI in the model

$$F_{UNav\ waste}(commodity\ A)_{HRI} = F_{av}(Commodity A)_{HRI} * WF_{unavoidable}(food\ group\ X)_{HRI}$$

Equation 27: Unavoidable food waste for HRI in the model

2.1.3. Waste collection and treatment

In the base year 2018, only the City of Guelph had an extensive green cart program for households. The rest of the inhabitants of Wellington County discarded a majority of their food waste into the residual waste stream – although a small portion of their food waste may go to backyard composting.

Thus, the amount of household food waste collected in the organic waste stream (green cart) was quantified for the City of Guelph's residents. The share of food waste was attributed to the City of Guelph's residents, by using Guelph population share (**Equation 28**). Additionally, the efficiency of food waste separation into the green cart was taken into account. In 2018, the Ellen MacArthur Foundation performed a study on circular food systems and used the City of Guelph as a case study - the report estimated a waste separation efficiency rate of 91% for food waste produced in households. This factor is therefore used to quantify the total amount of food waste captured in the organic waste stream (**Equation 29**).

$$Guelph\ population\ factor = Population\ (Guelph)/Population(Guelph\ Wellington)$$

Equation 28

The quantities of food waste in organic waste from the residents of the City of Guelph can therefore be calculated with the following relation:

$$Organic\ waste_{food\ waste}\ (Guelph) = \\ Total\ food\ waste(Guelph\ Wellington) * Guelph\ population\ factor * Waste\ separation\ efficiency$$

Equation 29

According to waste reports from the City of Guelph, the organic waste stream is then composted, therefore the organic waste containing the food waste quantified by the model is treated in composting facilities. The 9% remaining that are not placed into the green cart are then allocated to the residual waste stream, and follow the municipal solid waste route that is mostly landfilled according to the waste audits and reports from Guelph-Wellington.

For the inhabitants of the County of Wellington, in 2018 the green bin program was not yet deployed, most of the food waste entered the residual waste and were managed as municipal mixed waste, which is subsequently landfilled.

$$Residual\ waste_{food\ waste}\ (rest\ of\ Guelph\ Wellington) = \\ Total\ food\ waste(Guelph\ Wellington) * Rest\ of\ Guelph\ Wellington\ population\ factor$$

Equation 30

In addition to information on the potential waste routes and waste treatment type for food waste, the curbside and self-haul audits by the County of Wellington also provided insights in the overall quantities of food waste produced per household. These numbers, obtained through household and waste surveys were used to ground-truth the results of the food waste flows calculated by the model. According to these reports, it was estimated that, on a per capita basis, 78 kg of food waste was produced by the households of the County of Wellington. At the County level, this amounts to approximately 17.4 ktons of food waste recovered that would reach either the landfills or composting facilities of the county. Our model suggests that a total of 19.2 ktons of food waste (unavoidable and avoidable) is produced by Guelph-Wellington households. The model offers slightly higher numbers (~9% higher), which can be explained partly due to the fact that the model does not include backyard composting. This household waste management practice has not been covered by any major study, offering too little data to be included into the model. The inhabitants of Guelph that do practice backyard composting are not insignificant according to City reports. Therefore these quantities of food waste that are composted in households' backyard would not be quantified in any waste stream, whether organic or residual. The overall food waste production from households would therefore likely be higher than 17.4 kton.

Food loss occurring in the HRI and Retail sectors is not subject to a waste separation scheme at the City-level or County-level. Member of the Consulting Team and local food expert from the University of

Guelph, Dr. Michael von Massow, provided additional context that indicated that most of the waste produced by these sectors were collected in the residual waste, treated as mixed municipal solid waste, and therefore landfilled. Some waste separation initiatives within these sectors do exist, albeit at a smaller scale.

2.2. Local Production and Processing

2.2.1. Local Agricultural Production

The *Production* of food described earlier in the Top-Down Approach illustrates the production of food that occurs throughout the Canadian and international value chains that supply food products to Guelph-Wellington's residents - irrespective of where the food was originally grown. To develop a comprehensive understanding of Guelph-Wellington food system, local food *production*, occurring within the county boundaries, was also quantified.

The flows of food produced locally (crops, fruits and vegetables, and animal products) were quantified based on 43 datasets compiled for the County of Wellington by OMAFRA that have been aggregated into a normalised database. The yearly production of specific food crops, vegetables and fruits, are recorded up to 2019 (OMAFRA, 2019).

For meat products, the amounts were quantified in live-weight based on the composition of the animal stocks present in Guelph-Wellington, the types of cattle (e.g., heifer, steer, veal etc.), poultry (turkey, broiler chicken), and sheep (sheep and lamb) based on OMAFRA statistics.

To quantify the numbers of animals slaughtered in 2018, we compared the share of animals "disposed" annually to the total stock from OMAFRA's livestock inventory database. The "disposition" routes quantified by OMAFRA are: *international export (live animals), interprovincial export, Condemnation/Death,* and *Slaughter.* It can be noted that OMAFRA also accounts for the import of live animals, which was also accounted for in the model. For each animal type (cattle, sheep, chicken, turkey, pork), the number of animals slaughtered in Guelph-Wellington used these Ontario-based averages.

$$Number\ of\ Animal\ slaughtered_{\ animal\ type\ A}(Guelph - Wellington) = \\ Livestock_{animal\ type\ A}\ (Guelph - Wellington) *\ Slaughtered\ Share_{\ animal\ type\ A}\ (Ontario)$$

Equation 31

Finally to determine the amount of ktons of meat produced (in live-weight), we had to determine the weight of the different animals sent to the slaughterhouse. The live-weight for each subtype of animal had to be determined- as for example, the weight of a veal and a steer, both part of the "cattle'' animal type are very different. Similarly, it was important to determine in the “Sheep” animal type, the average weight of lambs and sheep as they are both included under this category. The weight information for an individual animal was retrieved from OMAFRA.

To determine which animal subtypes were sent for slaughter and in which relative quantities, slaughter data compiled by OMAFRA from the provincial abattoirs was retrieved. The shares per animal subtype within the same animal type were calculated. For example, from the cattle headcounts sent for slaughter in Ontario abattoir, 35% were steer. For the sheep slaughter headcounts, 77% were lambs. These Ontario animal subtype factors were therefore used to further determine the animal subtypes sent to slaughter in Guelph-Wellington. The amount of meat (live-weight) was therefore calculated with the following relationship:

$$\begin{gathered} Meat\ produced_{\ live\ weight}(animal\ subtype\ A_1) = \\ Number\ of\ Animal\ slaughtered_{\ animal\ type\ A}(Guelph - Wellington) * \\ Slaughtered\ Share\ (animal\ subtype\ A1)\ *\ live\ weight\ (animal\ subtype\ A1) \end{gathered}$$

Equation 32

2.2.2. Local Processing

Once the food products are harvested or collected by farmers, they are sent for processing or wholesaling. It is therefore key to determine the most likely processing routes for these products. In this stage, the local expertise from Dr. von Massow was used to understand the type of food processing and manufacturing activities taking place within the county’s boundaries and establish the most probable processing routes for the model. Through multiple interviews, the processing route was determined for the following products: vegetables, fruits, crops, feed, beef, sheep, lamb, poultry, industrial milk, and fluid milk.

The Guelph-Wellington region contains one major beef slaughterhouse and one major dairy processing plant, as well as smaller scale slaughterhouses and food manufacturers. Including detailed data on the food manufacturers in the county’s boundaries can help improve the accuracy of the metabolism analysis of the city, and increase the detail of specific interventions to create a local circular food system.

The different food products were either allocated to “export” outside of the county’s boundaries for further processing, or wholesaling, or sent to local processing plants. Most beef, industrial milk (meant for butter, yogurt, and cheese), and animal feed were assumed to stay within the county’s boundaries to be processed or consumed by animals, while fluid milk, vegetable, fruits, other livestock, and crops were sent outside of the county to be processed/manufactured. A part of the exported food products can be reimported. However, data on inter-county import/export was unavailable.

2.2.3. Production of crop, animal, and processing

During the production of crops, crop residues are produced during the harvesting process. Similarly, during the slaughtering process of animals, animal residues are produced. Dairy residues are also produced during dairy processing.

The production of crop residues was calculated based on the existing crop residue model developed in Ontario. The research group *Western Sarnia-Lambton Research Park* performed in 2012 a study to estimate crop residues yield per hectare of specific crops for the Ontario Federation of Agriculture. Therefore, the surface area of each type of crop produced in Wellington can be used to estimate the production of crop residues in the County of Wellington. By combining Wellington's crop surface areas, retrieved from OMAFRA and their specific crop residue yield factors, it was possible to accurately quantify the yearly production of crop residues harvestable for use (apart from agricultural soil enrichment) in the Region.

$$Crop\ residues\ (crop\ A)_{Guelph-Wellington} = Crop\ surface\ area\ (Crop\ A)_{Guelph-Wellington} * Crop\ residue\ yield\ (Crops\ A)$$

Equation 33

Most of the crop residues are left on the field in Ontario. A small proportion of winter wheat crop residues are used as cattle and horse bedding.

In terms of meat residues, OMAFRA provides the carcass weight and live-to-carcass weight ratio for the animal subtype considered in the model. As most beef gets slaughtered within the county's boundaries, the amount of residues produced by the slaughtering process of the beef raised in Guelph-Wellington was calculated with OMAFRA factors. However, it is important to note that the main beef slaughtering and processing plant in Guelph-Wellington receive cattle from across Ontario and Canada, therefore the amount of animal residues produced from the cattle *raised and slaughtered* in Guelph-Wellington represent a very small proportion of the amount of residues produced by the local slaughterhouse.

For dairy residues, it is very difficult to estimate the quantities of residues produced as it depends on the type of processing activities taking place in Guelph-Wellington. Furthermore, similarly to the beef slaughterhouse, the main dairy plant receives milk not only from Guelph-Wellington but also surrounding counties across Ontario. Therefore, we were unable to accurately estimate dairy residues production from processing based on the quantities of milk produced.

To estimate the quantities of food residues produced from local processing and manufacturing, the engagement of these local economic actors will be needed.

3. Environmental impacts of Guelph-Wellington food flows

A key step for the current state analysis is to quantify and analyze the environmental impacts associated with the food being consumed and wasted in Guelph-Wellington. Therefore the flows are not only analyzed from a metabolism point-of-view (quantity over time), but also from a value chain impact point-of-view. This additional layer of analysis is necessary because, to only focus on the food flows by mass - that is the total mass present within the City boundaries - excludes an understanding of any associated, and often hidden, upstream flows and their impacts (e.g. flows and impacts associated with, production processes, processing and manufacturing, distribution and transport throughout the value chain) (Kalmykova & Rosado, 2016). A holistic understanding of the environmental impacts is essential for adequately prioritizing management strategies for the food flows.

3.1. Environmental Impact Profile of Guelph-Wellington Food Value Chain

To create an environmental impact profile of the food metabolism of Guelph-Wellington, two main datasets are used. First, the dataset from Poore and Nemecek (2018) provides the environmental impacts for a wide range of food products for following environmental impact categories: greenhouse gases (GHG) emission, land use, water use, and eutrophication impacts. These categories have been selected because they represent the most important impacts caused by the global food system on our planet (Poore & Nemecek, 2018). The dataset provides different impacts (f.e., CO_2-eq) per kg of a given food commodity. The environmental impacts of a commodity at the consumption stage (*HRI* or *Households*) can be computed with the following equation:

$$\begin{gathered} Env\ impact\ (commodity\ A)_{\ impact\ category\ I} = \\ (F_{av}(commodity\ A)_{Households} + F_{av}(commodity\ A)_{HRI}) * Impact\ factor\ (commodity\ A)_{impact\ category\ I} \end{gathered}$$

Equation 34

The environmental impacts may also be computed only for the amount of food waste for a given commodity.

A classification and harmonization process had to be performed to match the commodity names from StatCan with the food products name from Poore & Nemecek's dataset. As Poore & Nemecek's dataset did not cover all the food commodities present in StatCan food availability dataset, another dataset, developed by RIVM (Dutch National Institute of Public Health and the Environment), was used for the remaining commodities (RIVM, 2019). Although RIVM's dataset was developed for the Dutch context, the order of magnitudes in terms of environmental impacts are similar for food products consumed in western countries. The RIVM dataset's impact factors are applied the same way described in **Equation 34**.

It is important to note that the environmental impacts factors developed by Poore & Nemecek represent global average factors meant to inform about the scale and order of magnitude of the impacts of different food products. There are of course local variations in terms of impacts driven by local agricultural and farming practices. Nonetheless, as Guelph-Wellington's food system is deeply integrated in global food value chains, these factors represent the best estimates of environmental impacts. Local life-cycle analysis of specific food products would be necessary to improve the impact factors.

3.2. Environmental Impact Profile of Guelph-Wellington Local Food Production

A similar environment impact profile was developed for the crops, fruit and vegetable, and animal products produced within the county's boundaries.

First, a classification process had to be performed to match the classification used in our model to quantify local food production in our model with the classification from Poore & Nemecek's dataset. The environmental impacts factors from Poore & Nemecek were then multiplied by the quantities of food produced in the county, such as:

$$Env\ impact\ (crop\ or\ animal\ product\ A)_{impact\ category\ I} = \\ Impact\ factor\ (crop\ A)_{impact\ category\ I} * Production\ quantity\ (crop\ A)$$

Equation 35

Again, it is important to note that the environmental impacts factors developed by Poore & Nemecek represent global average factors that do not capture the local context of Guelph-Wellington agriculture and farming practices. It is therefore not to be understood as a comprehensive environmental impact assessment, but rather as an indication of the scale of impacts caused by the different food products produced within the county's boundaries.

Appendix B

Advisory Panel Feedback

Table 1: Summary of feedback by category from the first AP meeting

Topics	Notes
Data	No new sources indicated that were within scope for this project
Draft Consumption Sankey Diagram	• Request for a more explicit depiction of direct consumer to producer relationships • Tabular breakdown of data the fed into the Sankey diagram • Identify industry sources of food production and waste/legend on the diagram that indicates this as well as potential nutritional value • Show clear net imports into the region on the Sankey to make intervention suggestions easier for the AP • Mapping capital flows alongside the material flows • Clearly identified distribution associated waste • Include a representation of imports and exports (provincially or internationally) • Indicate if planned and unplanned losses in the value chain are equivalent to avoidable and unavoidable waste produced by the consumer
Environmental Impact: $kgCO_2eq$ by Food Product graph	• Place an emphasis on net sum $kgCO_2eq$ to assess the carbon footprint of animal agriculture (crops grown to feed animals sequesters carbon) • Inclusion of by-products and a discussion of what food stuffs have the greatest potential for circularity • Label if graph is consumption or production based
Future Work: WP2 and WP3	• Highlight emerging examples of food redistribution businesses • Integration of carbon impacts for hauling (collaboration with FreshSpoke) • Identification of institutions that the City or County purchase food for as potential leverage points or easy wins • Intervention focusing on restaurants using other global programs as a model • Include environmental hotspots in the $kgCO_2eq$ graph for different food products • Include more granular data in the $kgCO_2eq$ graph and discussion (e.g. around types of meats) • Waste exchange and prototyping workshops • Look at nutritional equity and the nexus of food, nutrition, poverty, health, environment, etc. • Empower stakeholders • Provide cost-benefit analysis and job creation metrics • Share positive stories to build community action • Set "self-sufficiency" as a KPI • Monitor that impact is felt equally across residents • Consider calories saved, embedded energy, labour costs, water, and GHG for products that are redirected back into the value chain
Other	Compare Guelph- Wellington to a "sister" region (potentially the City of Toronto)

Appendix C

High Resolution Figures