Fresh City: Impacts of local food

TECHNICAL REPORT:

Assessment of Greenhouse Gas emissions by food box distribution

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Acronyms

DEFRA	Department for Environment, Food and Rural Affairs, United Kingdom
GHG	Greenhouse Gas
TKM	Tonne Kilometre
GWP	Global Warming Potential
CO2	Carbon Dioxide
eCO2	Carbon Dioxide equivalent units
CH4	Methane
N2O	Nitrous oxide
FCF	Fresh City Farms

1. Introduction

1.1. Local food and greenhouse gas emissions – a blurry picture

According to a review by the United States Department of Agriculture (Martinez et al., 2010[1]), Greenhouse gas (GHG) emissions assessments indicate that localization can but does not necessarily reduce energy use or greenhouse gas emissions. The reasons are complex and start with too many definitions of "local" – ranging from 50 km, 100 miles, the county, the state or Province, or the nation. A second reason is that many shoppers who like farm-fresh food drive their vehicles to many small farm stores, such that any savings in transportation are offset by shopping miles. Also, many local food systems have recently redeveloped and remain in an infancy stage from an economic perspective: inefficiencies in the supply chain of local food can be so large that the overall impact with respect to GHG of "local" may be worse than those of large supermarket stores that offer one-stop-shopping and make use of economies of scales.

Many participants of the infant local food economy feel that it is not reasonable to assess the whole sector, because compromises are necessary during its establishment. Instead, case studies of regional food hubs can highlight examples of good practices such that they can serve as an example for the development of the whole local food economy.

1.2. Gases and their Global Warming Potential

Many gases contribute to global warming. However, not all gases are equally potent in their impact and some have much stronger effects than Carbon Dioxide. To make emissions from multiple gases comparable, the IPCC offers conversion factors that quantify their Global Warming Potential. By multiplying the amount of any gas with its Global Warming Potential, it is converted into Carbon Dioxide equivalents [kg eCO2], which is the quantity of Carbon Dioxide that would create the same global warming as 1 kg of the gas.

The most relevant gases are Carbon Dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), and halogenated carbons that are widely used as refrigerants. The global warming potential of refrigerants can be many thousand times stronger than carbon dioxide (see Table 1.1) and emission of such gases make strong contributions to global warming.

Gas	**Chemical formula**	**Global Warming Potential [eCO2 factor]**
Carbon Dioxide	CO_2	1
Methane	CH_4	21
Nitrous Oxide	N_2O	310
HFC-125	CHF_2CF_3	2800
CFC-11/R11	$C\,Cl_3\,F$	4750
HCFC-22/R22	$CHClF_2$	1810
Mix R409A[2]	60:25:15 blend of HCFC-22, HCFC-124 and HCFC-142b	1585

Table 1.1. Global Warming Potential of relevant greenhouse gases. Source: DEFRA 2012[3]

[1] Martinez et al., 2010 (USDA)

[2] All ingredients are also controlled under the Montreal Protocol on ozone-depleting substances.

1.3. Greenhouse gas emissions in the global food chain

1.3.1. Food Chain emissions

Food system emissions—from production to consumption—contribute 8,160 million metric tonnes of carbon dioxide equivalent (MtCO e) per year, or 14% of total human greenhouse gas (GHG) emissions. This figure includes the full supply chain (Figure 1), including fertilizer manufacture, agriculture, processing, transport, retail, household food management, and waste disposal. In addition, significant emissions are associated with the conversion of forest and wetlands into agricultural lands. Estimates for these emissions from land use change vary between 4% and 18% of global emissions[4]. Together with land use change impacts, the emissions of the food system are larger than any individual economic sector, e.g. power generation (24%), industry (14%), transport (14%), buildings (8%), or waste (3%)[5].

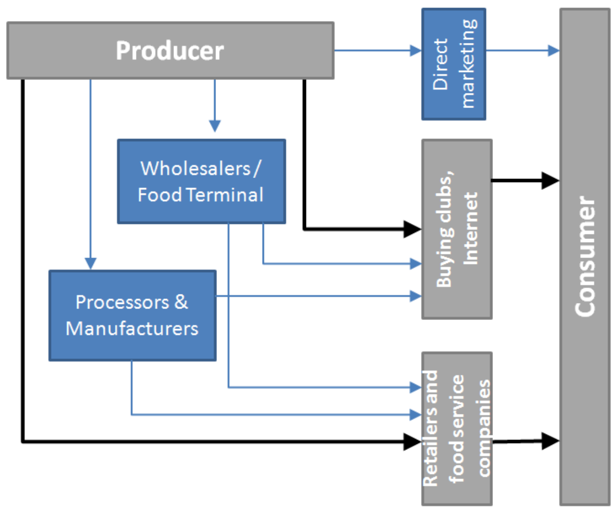

Figure 1. Components of the food chain. Adapted after GHGprotocol/WRI[6]

Generally, food system emissions are subdivided into several categories:

- *Direct emissions* from the agricultural production process, for example through activities like managing soils, crops and livestock, contribute 5,100 to 6,100 $MtCO_2e$ per year. These are 50 to 70 percent of global emissions attributed to agricultural production or 10 to 12 percent of all types of emissions.
- The *production of agricultural inputs* (fertilizers, pesticides, and energy used to produce animal feed) requires about 660 $MtCO_2e$ per year.

3 Defra 2012. This source also lists substances that were phased out of production due to the Montreal Protocol on Substances that Deplete the Ozone Layer.
4 Vermeulen et al., 2012
5 CCAFS 2012. With data from Vermeulen et al., 2012
6 GHG Protocol 2013

- The *conversion of land*, especially forest and wetlands, into agricultural production remains the most uncertain factor in the equation, and estimates range from 2,200 to 6,600 MtCO_2e per year—30 to 50 percent of agricultural emissions and 4 to 14 percent of total global emissions.

- *Post harvest emissions* can be attributed to refrigeration, storage, packaging, transport, food processing, retail activities, catering and cooking, and waste disposal. Together, these post-harvest emissions make up approximately 2,000 MtCO_2e per year —12.5 percent of total agricultural emissions and 3.5 percent of total global emissions.

In more detail (Table 1.2), post-harvest includes refrigeration (641 MtCO2e, 4% of agricultural and 1.1% of total global emissions); storage, packing, transport (480.8 MtCO2e, 3% of agricultural and 0.825% of total global emissions); retail (320.5 MtCO2e, 2% of agricultural and 0.55% of total global emissions); processing (240.4 MtCO2e, 1.5% of agricultural and 0.413% of total global emissions); catering and cooking (208.3 MtCO2e, 1.3% of agricultural and 0.358% of total global emissions); and waste disposal (96.2 MtCO2e, 0.6% of agricultural and 0.165% of total global emissions).

Description	Percentage of global emissions	Food chain emissions in relationship to direct agricultural emissions	Emissions [Million tons of CO_2e per year]
Refrigeration	1.1%	4%	641
Storage, packing, transport	0.825%	3%	480.8
Retail	0.55%	2%	320.5
Processing	0.413%	1.5%	240.4
Catering and cooking	0.358%	1.3%	208.3
Waste disposal	0.165%	0.6%	96.2

Table 1.2. Global food chain emissions. Source: CCAFS 2012

1.3.2. Agricultural production

Agricultural production emissions are not the focus of this assessment. A summary is included to highlight the most relevant sectors and also point out the methodological challenge of measuring for an analysis.

Direct agricultural activities account for 6,100 MtCO_2e per year. This includes emissions from the cropping and fertilization of fields, livestock emissions (especially enteric fermentation and feed production), use of energy for machinery, and heating of greenhouses. Only a minute part of these emissions are attributed to the direct release of the gas Carbon Dioxide by oxidation of soil organic matter. Two other gases make up the major share of direct agriculture emissions: nitrous oxide (N_2O) that is produced in soils, and methane (CH_4) emissions, mainly from rice and livestock production. Nitrous oxide is produced in soils after application of nitrogen fertilizer or manure by bacterial decomposition. Methane is created in irrigated rice fields and from digestion in ruminant animals (enteric fermentation). Unfortunately, both nitrous oxide and methane are two gases with a much stronger warming potential than carbon dioxide, which is 21 for methane and 310 for nitrous oxide. This means that 21 kg of carbon dioxide are as damaging to the climate as one kg of methane, or 310 kg CO_2 like one kg of nitrous oxide[7].

In 2005, N_2O emissions from agricultural soil management amounted to 32.5 percent of total agricultural direct emissions. Global CH_4 emissions from enteric fermentation of dairy and beef cows made up 30.5 percent of total agricultural direct emissions. This value has increased by 6 percent between 1990 and 2005 and is expected to grow further, with emerging economies increasing their meat and dairy consumption. Methane emissions from irrigated rice fields contributed 11.6 percent of total agricultural emissions in 2005. Manure management contributed another 6.4 percent of total agricultural emissions (see Table 1.3 for total values and projections).

While the intensive production of meat (especially beef), including feed based on soybean, corn, and hay, is one of the main culprits for agricultural emissions, sustainably managed grasslands also absorb atmospheric carbon dioxide and transform it into soil carbon. This not only mitigates global warming but also generates top soil. In the past, large bison herds grazing the prairies contributed to the creation of thick layers of top soils in North America[8]. Unfortunately, these areas have lost, on average, more than 25% of their topsoil, largely as a result of being used to grow monocultures of soy and corn, the main feed of industrial cattle farms[9]. However, some farmers manage to simulate the crowding effect of large migratory herds, which is key to the sequestration of carbon in top soil, with rotational pasturing[10].

Type of emission	Total emissions 1990 (MtCO2e)	Total emissions 2005 (MtCO2e)	Total emissions 2030 (projection) (MtCO2e)
Agricultural soils (N_2O)	1,804 (30.5 %)	1,984 (32.5%)	2,666 (36.5%)
Enteric fermentation (CH_4)	1,755 (29.6%)	1,864 (30.5%)	2,289 (31.3%)
Rice cultivation (CH_4)	670 (11.3%)	710 (11.6%)	739 (10.1%)
Manure management (CH_4, N_2O)	408 (6.9%)	389 (6.4%)	455 (6.2%)
Other emissions (CH_4, N_2O)	1,283 (21.7%)	1,164 (19.0%)	(1,164) (15.9%)
Total non-CO_2 emissions	5,920 (100%)	6,111 (100%)	7,313 (100%)

Table 1.3. Non-CO_2 agricultural direct emissions. Source: CCAFS 2012

1.3.3. Organic and conventional crop production

When comparing organic and conventional crop production, the first difficulty arises from a large diversity of definitions and certification rules that limit comparison. In North America, the certification standards of USDA and the Organic Products Regulation in Canada[11] dominate. In Europe, a multitude of private and governmental standards co-exist. The governmental standard sets minimum requirements

7 Global Warming Potential factors were determined by the Intergovernmental Panel on Climate Change (IPCC)'s assessment reports, for example IPCC 2007

8 Knapp et al., 1999

9 Idel 2011

10 A popular American advocate for such techniques is Joel Salatin, who runs Polyface Farm. www.polyfacefarms.com

11 See Canadian Food Inspection Agency (CFIA) Canada Organic Office, http://www.inspection.gc.ca/english/fssa/orgbio/orgbioe.shtml

while private standards must be more restrictive. The multitude of standards is reflected by international practices that export organic products to Europe. Organic standards differ in allowing certain practices and/or requiring others. At the same time, many non-certified farmers who are “conventional by default” have implemented mitigation measures and best practices, so they can be better environmental stewards than others who are certified with a minimum standard. An additional challenge stems from incoherent GHG accounting practices of primary research, the focus on individual crops, and the extent to which the studies address externalities[12]. As a consequence, the few comparative assessments of organic practices must deal with multiple baselines.

In a review of existing studies, MacRae (2009) distinguishes the conversion process and long-term effects. During the conversion process that is believed to last a decade, soils usually increase organic carbon and sequester CO2 until the soil’s carbon content stabilizes[13]. At the equilibrium state, the per-acre emissions of organic production are lower. However, because yields of organic methods are often lower than in a conventional production system, the per-yield emissions of organic production are somewhat higher. This conclusion is based on average weather conditions. Some research shows that, in untypical weather conditions, organic systems with resilient soils can significantly outperform conventional practices (MacRae 2009). Emission reductions in organic agriculture are usually attributed to the absence of synthetic pesticides and synthetic fertilizers (particularly nitrogen), and a subsequent reduction of N_20 emissions from the soils. MacRae points out the potential to improve organic yields because only a minute percentage of global agricultural research dollars are focused on organic varieties and a large research gap remains for improving cultivars and practices.

1.4. Accounting for GHG emissions within the food system

1.4.1. Approaches

Greenhouse Gases (GHGs) can be measured by recording emissions at source by continuous emissions monitoring or by estimating the amount emitted by multiplying activity data (such as the amount of fuel used) by relevant emissions conversion factors[14].

For the food & agriculture sector, two methodological approaches to carbon footprinting exist: the whole farm approach and life cycle analysis[15]. The **whole enterprise/farm approach** measures the total GHG emissions of one operation. It is useful to identify hot spots and mitigation potential within an operation and is applied in the corporate world. **Life cycle analysis** measures the total GHG emissions associated with a specific product, e.g. a kg of wheat, potatoes or processed goods. It is useful to highlight how certain steps in the food chain contribute to overall emissions, and also to compare environmental impacts of different products, . Both accounting approaches rely on enterprise/farm specific information. In addition, a database is required that offers standard emission and sequestration data for processes

12 Gomiero et al., 2008
13 Venkat 2012
14 2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting
15 Soil Association 2011

that are outside the scope of an assessment, for example for inputs or bought products. The International Panel for Climate Change (IPCC) gives recommendations for some of these data that are a widely recognized standard. Alternative database sources are discussed in Section 1.4.3.

For this study, a life cycle approach was chosen for one food box as a bundle of products. The production and pre-production emissions were excluded from this assessment and the study focuses on transportation and refrigeration. This approach focuses on the core product that Fresh City Farms offers; it is sufficiently simple within the resources of this study; and it gives a meaningful baseline to compare the Fresh City Farms operation with the conventional food chain. Assessing production practices on multiple farms is not only impossible within the resources of this project, but also has deep methodological challenges that are touched on in the next section.

1.4.2. Boundaries, Tiers, & Scope

The assessment of GHG emission of an enterprise or product relies on adequate definition of boundaries and scope.

Defining boundaries is not always easy. For example, an assessment of GHG is performed for a farm operation using the whole farm approach. If the farm also does custom work on other farms, then only the proportion of fuel that is used within the production process on the owned farm itself is accounted for, while emissions from custom work are accounted for at the other farms. Likewise, a life cycle analysis for an individual product will be difficult in mixed farming operations, where the output of one process (e.g. chicken manure from egg production) serves as the input for another process (fertilization for vegetable production). In this example, emissions from nitrous oxide from the chicken manure would partly be accounted for as egg production emissions, and partly as fertilization for the vegetable. A common way to partition emission of chicken manure would be by revenue contribution of eggs and vegetables.

Data sources are classified by their level of localization and detail. The IPCC defines a three-tier system with global, regional, and operation-specific data. For example, dairy emissions can be reported as nationally averaged emissions per litre of milk (Tier 1), as county-level emissions of the dairy sector (Tier 2), or for a specific farm taking into account specific production measures (Tier 3).

Next to boundaries and tiers, three scopes of analysis have become common practice for corporate accounting[16]:

- **Scope 1** only includes *direct emissions* from fuel combustion or other fugitive gases. Scope 1 emissions are measured with data from the operation.
- **Scope 2** includes emissions during the *generation of electricity*. Scope 2 emissions require (a) data on electricity use within an organization, and (b) standard data on how much GHG emissions

16 Carbon Trust 2013

were produced during the generation of electricity in an area, taking into account the technology mix used there.

- **Scope 3** covers all *indirect emissions*. The Carbon Trust Fund[17] outlines '**Scope 3**' as indirect emissions that are a consequence of the activities of the reporting company, but occur at sources owned or controlled by another organisation - including both upstream (inputs and input suppliers) and downstream (waste products) of companies along the value chain. This comprises those generated by all the emissions of everything a company buys, right back to raw material extraction or agriculture, as well as all the emissions that are produced from everything a company sells or disposes of, through retail, use, and end-of-life. For example, scope 3 emissions occur when purchasing goods and services, during business travel, with employee commuting, waste disposal, the use of sold products, and with transportation and distribution of inputs (upstream) and products (downstream). Finally, scope 3 includes emissions created through investments, leased assets, and franchises[18]. In most jurisdictions, additional regulations define what type of scope 3 emissions should be accounted for within a greenhouse gas assessment.

In Ontario, greenhouse gas emission reporting is regulated in Ontario Regulation 452/09 and administered by the Ministry of the Environment. This regulation lists standard quantification methods (Section 4) as well as best alternative quantification methods (Section 3). Its appendices list industrial sectors that require GHG quantification and reporting, for example petroleum refining, mining and resource production, the manufacturing of chemicals, paper and pulp, combustion, electricity generation and cogeneration. However, accounting of agricultural production and smaller food chains is not addressed in this regulation, such that a non-standard approach is required.

Globally, no general consensus has yet emerged for many aspects of the agricultural sector. Currently, the Greenhouse Gas Protocol[19] is developing an Agricultural Guidance to help companies measure their agricultural emissions. Draft versions of this guidance are available online and open for comment.

1.4.3. Data sources for GHG emission factors

A wide range of data is available publically from governmental and academic organizations, or from private consulting agencies for a fee. These databases may differ considerably and were designed for different aims and to be used in different geographical area:

- Some processes may or not be included within scope 1 and scope 3,
- The type, level/resolution (tier) of data available,

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17 The Carbon Trust is a not-for-dividend company, limited by guarantee, that helps organisations reduce their carbon emissions and become more resource efficient. Its stated mission is to accelerate the move to a sustainable, low carbon economy. It reinvests surpluses from its group commercial activities into its mission.

18 See also Corporate Value Chain (Scope 3) Accounting and Reporting Standard and the *Technical Guidance for Calculating Scope 3 Emissions*. Published by the Greenhouse Gas Protocol (a partnership between the World Resources Institute and the World Business Council for Sustainable Development) as the most widely used international accounting tool for government and business leaders to quantify and manage GHG emissions. http://www.ghgprotocol.org/

19 www.ghgprotocol.com

- Location specificity,
- Their cost and accessibility. The use of many commercial databases and software is relatively expensive, using annual or per-assessment fees.

While Canada has submitted national reporting under the Kyoto protocol, this data is currently being archived since Canada has left this protocol and has discontinued reporting under its commitment. Archived data is available from Environment Canada[20] according to standards of the Kyoto protocol established by IPCC. However, food system emissions are distributed across several sectors (industrial, manufacturing, transportation, energy, agriculture) and data is insufficient to re-calculate food system emissions from here.

For emissions from electricity generation (Scope 2), location-specific standard data is published and regularly updated by the Climate Registry[21], which is a not-for-profit collaboration between U.S. states, Canadian provinces, and Native Sovereign Nations.

Quantifying Scope 3 emissions relies on databases with standard values for industrial processes, goods, and services. In recent years, an increasing number of research institutes and consulting firms have developed such databases for academic and commercial uses. Generally, calculators are based on the IPCC guidelines and follow the IPCC tier classification. For farm operations, a comparative review of such tools is published by the Soil Association (2011) or in two recent publications[22].

The main weakness of any methodology is related to indirect land use change. In a globally closed market, the conversion of one area of crop, e.g. grain, into another such as corn will impact on the global prices of both products and send signals to other farmers to increase or decrease their production to meet global demand. An indirect impact of a conversion is that new areas are converted into farmland which is currently in pasture, wooded, or even peat wetlands, resulting in the accrual of very large amounts of indirect emissions[23,24].

[20] http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=8044859A-1
[21] Climate Registry 2013
[22] Colomb et al., 2013, Milne et al., 2013
[23] Plevin et al., 2010
[24] Searchinger et al., 2008

2. Method

2.1. Previous studies for Fresh City Farms

A number of scientific studies have attempted to compare emissions from food box programs with conventional food chains (compare Matsubuchi-Shaw 2013 [25]). These studies vary due to study parameters and the method of reporting findings so the scope for direct comparisons are very limited. Studies reviewed by Matsubuchi-Shaw indicate savings from delivery programs that substantially decrease consumer shopping emissions by up to 95%. However, this drastic reduction is based on the assumption that customers don't go shopping at all once they receive delivery, an assumption that is not supported by the consumer surveys conducted within this study. One unpublished Canadian study finds that home delivery represents a 43% savings in GHG emissions due to the elimination of consumer trips (Matsubuchi-Shaw 2013).

Matsubuchi-Shaw also offers an illustrative comparison. For transportation emissions from the farm to the retailer and to the consumer, conventional shopping is estimated to cause 4,914.0 kg eCO2 per household each year, and 2,776.8 kg eCO2 for a food box delivery scheme that Fresh City is currently running. Savings were estimated to be around 43.5% for introducing delivery, assuming that no additional shopping occurs. Matsubuchi-Shaw also lists limitations of available data, namely storage facilities, transport factors, load volumes and weights, and profiles of consumer shopping trips. In this study, all of these limitations are addressed by using standard data from publicly available databases. Another factor listed by Matsubuchi-Shaw, namely the emissions from producing and delivering farm inputs to farm operations, is not taken into account because production emissions are excluded from this study.

2.2. Boundaries and scope of this study

Within this project, a Greenhouse gas inventory is limited to emissions caused by transport from the farm to the retailer/Fresh City Farms and to the customer – both with delivery trucks and with the customer's private vehicle. The assessment takes into account storage and refrigeration. The Food box program of Fresh City Farms is compared with a simplified conventional food distribution system.

The following stages of the food chain were quantified within this assessment for both the conventional food chain and for the Fresh City system:

1. Farm to Retailer/Fresh City
    - Sea and air freight transport, if applicable
    - Road transport
    - Mobile refrigeration
2. Retail/Fresh City
    - Refrigeration per box (Scope 2 emissions)
    - Refrigerant leakage, per box
    - Other electricity use (Scope 2 emissions)

[25] Matsubuchi-Shaw 2013

3. To consumer from Retail/Fresh City
    - Delivery
    - Mobile refrigeration
4. By consumer from pickup/retail
    - Transport

Transportation emissions directly stem from the combustion of fuel, as well as from indirect emissions that are caused in the mining and refinery of that fuel, and from the manufacturing and disposal/recycling of the vehicle. DEFRA distinguishes emissions by mode of transport (air, sea, road), by the type of fuel used, by the type of vehicle, and by its loading. Emissions are accounted for by the relevant GHGs (CO2, Methane, Nitrous Oxide) and by indirect emissions.

Refrigeration emissions are mainly attributed to two sources: leakage of refrigerants (direct, Scope 1) and emissions created during the generation of the electricity that is used (Scope 2).

- Most leakage stems from refrigerants that are halogenated hydrocarbons and have very high global warming potential, between 500 to 11,000 times the warming potential as the same amount of CO2. The leakage itself depends on the amount of refrigerant in one unit, called Equipment Charge Capacity and measured in [kg].

- To measure electricity-use related emissions, refrigeration capacity and electric bills are used. The refrigeration capacity describes the cooling power of a unit and is measured in Kilowatts [kW] and heat transfer units [BTU]. Electricity use is converted into emissions using a location-specific emission factor that takes into account the energy mix (published by the Climate Registry).

During the lifecycle of a refrigeration unit, some leakage occurs at the point of installation, during operation, and at end-of-life disposal. The amount of leakage depends on the type and size of the equipment. Installation emissions range from 0% for units that are filled within the manufacturing process, 0.5% for large industrial systems, and 2% for small stationary air conditioning or centralised supermarket refrigeration systems. Annual leakage ranges from 0.3% in closed domestic fridges, 8% in industrial systems, 18% in Centralised Supermarket Refrigeration Systems, and up to 40% in marine transport refrigeration (DEFRA 2012). For mobile refrigeration during transport, leakage is the most important factor because electricity is generated within the vehicle and accounted for as fuel consumption. Experts continue to stress that mobile refrigeration is still especially hard to quantify because actual practices vary enormously, such that these numbers can only give general direction. It is important to distinguish between cooling and freezing, because different refrigerants are used.

For comparability, all calculations are based on one food box as a standard unit. Using Fresh City delivery data, the weight of one box was determined to be 4.47 kg. The following simplifications needed to be made:

- If information is available for both volumetric and weight-based freight, then both data was considered. This is the case for Fresh City Farms' delivery to consumers.

- Unless detailed information is available, the weight of a food box was used to determine transportation and refrigeration emissions. It is understood that many vegetables have large volume and low weight, which may prevent loading a truck to full weight capacity. However, companies that specialize in long-distance trucking tend to address this problem and combine light with heavy freight (e.g. lettuce and wine), in order to optimize their truck loads.

- If neither volumetric nor weight information is available, sometimes value-based data was used, especially for deriving the conventional scenario with limited information.

2.3. Data sources used

No toolkit was found that is explicitly designed for this task. Instead, several carbon calculators were reviewed. As one useful guideline, the CFF Carbon Calculator was chosen because it is (a) transparent and available free of charge, (b) it offers detailed data for growers as well as for retailers, (c) it gives data sources and an estimate of data quality. As a complement, the DEFRA Guidelines for Company Reporting from 2012 was used, which was developed for corporate reporting by the British agencies Department for Environment, Food and Rural Affairs (DEFRA) and the Department of Energy and Climate Change (DECC). For Ontario-specific emission data for energy generation (Scope 2), we used data from the Climate Registry[26]. While overall, much of the DEFRA data was determined for the British context, we believe that it provides a solid baseline also for the context of Ontario, where the government does not offer a comparable database of similar robustness, broadness, and quality.

Together, the databases offer conversion factors for converting activity information (e.g. electricity used, number of miles driven with certain load and vehicle type, tonnes of waste sent to a landfill) into kilograms of carbon dioxide equivalent, abbreviated as eCO2. The equivalent value CO2e is a universal unit of measurement that allows the global warming potential of different GHGs and any type of activity to be compared.

Also, to attempt piecing together information from scattered academic sources is believed to be unhelpful, because the studies often differ in scope, level, and focus. While these sources may improve some data, such approach bears the risk of compromising the overall consistency of the assessment. For this reason, we believe that the broad scope of the DEFRA 2012 database makes it the best available resource for this assessment. In some cases, we complement this data with more relevant sources, for example emissions from Canadian electricity generation of locally used cars.

[26] http://www.theclimateregistry.org

3. Calculation and data

This section describes the computation and data sources of each calculation step and also gives data tables with detailed assumptions, data sources, and values.

3.1. From farm to retailer/Fresh City

3.1.1. Transport from farm to the retailer and Fresh City

Emissions from transportation from farms to the Fresh City Farms packaging centre were estimated using producer interview information for travel distance, truck, and loading specification.

Over the summer of 2012 (May to October), a total of 85.2% of the weight sold by Fresh City was bought from local farms, while the rest was produced on the FC farm or from their inventory. The two largest suppliers are Zephyr Organics (Zephyr, Durham region, 15% of bought produce) and Pfennings (Waterloo Region, 64.4% of bought produce). Both farms own delivery trucks and collaborate with neighbouring farmers. These two partners supply, by weight, 72% of the products sold by Fresh City. Both farms were interviewed.

- Typical delivery vehicles are medium-sized trucks with 16t capacity (Pfennings owns several trucks of different sizes).
- When delivering, both farms state that trucks are nearly loaded to capacity, at approximately 90%. It is assumed that trucks are constructed such that volumetric and weight capacity are equally reached.
- Trips serve multiple customers, such that only a share of the total round trip emissions are attributed to Fresh City. This share was computed based on the percentage of freight destined to Fresh City, and the total length of the trip (including backhaul). The total length of round trips is around 300 km and a fifth of produce is destined to Fresh City. Using internal numbers, Zephyr Organics attributed 65 km to Fresh City, and Pfennings estimated 60 km. Using weighting, the total delivery mileage was calculated based on these figures as 61.1 km.

Standard values for road transport emissions were taken from DEFRA 2012. This database distinguishes loading capacity (t), type of fuel (Diesel or gasoline), actual loading (% of weight capacity), and the truck size. It takes into account direct emissions from combustion (CO_2, CH_4, N_2O) as well as indirect emissions for the production and disposal of the vehicle. Ultimately, emissions are given for transporting one Tonne for one kilometer [t km]. For a 16t diesel truck at nearly full capacity, the emission density is 0.91 kg eqCO_2/t/km

For supplying Fresh City, tonne kilometres (TKM) are estimated based on a sample box. One TKM is a standard unit to estimate freight emissions that accrue when transporting one tonne for 1 kilometre. The sample box was averaged from the contents of three 2012 boxes (July 18/19, August 15/16, Sept 18/19 or Boxes 59, 63, 68).

For each item, weight [kg] was determined by converting all units (quarts, pints) into bushels (see Table A.1) and then into weight equivalents (pounds, kg) using standard conversion tables (Table A.2). Results are shown in Table A.3.

As a next step, the total emissions per food box were computed for both Fresh City boxes and the conventional food chain. For each produce item, weight, the country of origin, and travel distance was estimated. Also, travel mode (sea, air, road) and vehicle type were determined and emission data per TKM were taken from the DEFRA 2012 database. Travel distance and weight was used to calculate tonne kilometres (TKM).

- For Fresh City products, transport distance is either 61.1 km (average share of transportation that is attributed to Fresh City deliveries by Pfennings and Zephyrs), or 0 km for products by Fresh City or its member farmers. Travel mode is by road and the vehicle is assumed to be a truck with 16t capacity.
- For the conventional food chain, the country of origin was determined as marked by three important Canadian retailers (Loblaw, Metro, Wal-Mart). If a product was available, then Loblaw country of origin was used. Travel distances were estimated using Google Earth. Travel mode varies by item and expert knowledge was used to distinguish road, sea, and air. For road transportation, full 40t trucks were assumed as the vehicle. For sea and air transportation, additional road transport from the airport (Pearson, Toronto, ON) and the harbour (Montreal, QB) with 40t trucks was taken into consideration. Backhaul for the conventional system is not considered, because it is not known whether trucks return empty or are filled with Ontario products.

Finally, for each item, values for TKM and emissions per TKM were multiplied and total emissions per item and per box were determined for Fresh City and for a conventional retail store (Tables A.4 and A.5, respectively*)*.

The total emissions for average boxes were determined as follows (Table 3.1.):

Fresh City: **0.20 kg eCO2 for 1 box**

Loblaw: **2.86kg eCO2 for 1 box**

		Fresh City Farms				Conventional retail			
	Weight [kg]	Average transport distance [km]	Emissions per tonne-km	Tonne * Km per item	Emissions per unit	Distance [km]	Emissions per tonne-km	Tonne * Km	Emissions per unit
AVERAGE ITEM	0.44	253.1	0.19	0.14	**0.02**	4322.6	0.14	??	??

TOTAL (1 sample box)	4.59			1.46	**0.20**			15.05	**2.86**

Table 3.1. Results for transportation emissions from farm to retail/Fresh City

For comparison, a different calculation was performed. Here, all produce is assumed to come either from Pfennings or Zephyrs (for which interview data is available), or from Fresh City. Results are very similar.

Emissions per trip = Truck capacity * Loading % * Travel distance * emission density
= 16t * 90% * 61.1 km * 0.91 kg eqCO2/t,km
=798.04 kg eqCO2

Each of such standard delivery trips contributes to the share of each box that is bought in, while no transportation is necessary for produce grown at Fresh City.

Emission per box$_{\text{Fresh City}}$ = Emissions per trip * BoughtProduceWeightPerBox / total loading
= Emissions per trip * boxWeight *shareBought / (Truck capacity * Loading%)
=798.04 kg eqCO2 * 4.45 kg * 85% / (16,000 kg * 90%)
= 0.21 kg eqCO2/box

3.1.2. Mobile refrigeration from farm to retailer/Fresh City

As summarized in Section 2.2, the main source of refrigeration emissions is leakage of refrigerants. Emissions attributed to mobile refrigeration during the above transport were estimated using IPCC and DEFRA standard data. Standard data was used regarding refrigeration capacity, equipment charge, and losses during installation, operation, and end of life disposal.

GHG emission estimates vary between the transportation from a farm to Fresh City or a conventional retailer for several reasons. First, large-scale conventional retailers tend to have larger trucks with larger refrigeration capacity [BTU] and charge capacity with the refrigerant, leading to larger emissions per vehicle. However, the transportation chain of large retailers is also optimized to make most use of the vehicle fleet, leading to a minimum of idle time, frequent trips, and long operating hours during each day. Smaller suppliers with shorter delivery distance spend more time packing and unloading the truck and also have lower usage per day, such that the operational leakage of smaller suppliers is often higher on a per- trip or a per-kilometre basis.

For the conventional food retailer, a refrigerated truck with 30 kW refrigeration capacity and 20 kg equipment charge capacity is assumed. For an average trucking distance of 3280 km, which was determined for the sample food box, each trip lasts approximately 2.5 days (80 km/h, 16 h/day on the road). Annually, 300 trips are expected for every truck, assuming that trucks are filled during their return trips and leakage emissions during the return trip could be attributed to that other customer.

For the Fresh City supplier, a refrigerated truck with 10 kW refrigeration capacity and 5 kg equipment charge capacity is assumed. Trucks are owned and managed by the farm owners (Pfennings, Zephyr

Organics). Interviews indicate that such trucks are used for two to four delivery trips each week, creating more idle time than for the conventional operators. A total of 100 trips per year and truck were assumed.

For the assumed cooling agent HFC-134a with a moderately low global warming potential of 1300, mobile emissions from refrigerant leakage, which must be accounted for in the lifecycle of Fresh City Farms food boxes, is 0.0034 kg eCO2 per box. Even though the total distance is much lower for Fresh City, this amount is only slightly lower than for a conventional system with 50-fold longer distances, estimated at 0.0047 kg eCO2 per box equivalent (Table 3.2). The main reason is better utilization of truck hours within specialized trucking and economies of scale.

Description		Unit	Fresh City Farms		Conventional Food Retailer	
Equipment specification	Type of equipment		Mobile Refrigeration			
	Refrigeration capacity	[kW]	10	IPCC	30	IPCC
	Equipment Charge Capacity	[kg]	5	IPCC	20	IPCC
Installation	Installation Emission Factor %	[%]	0%	DEFRA 2012		
Operation	Life length of cooler	[yr]	5	Assumption (following DEFRA 2012)		
	Annual Leak Rate	[%]	15%	DEFRA 2012		
End of life disposal	Capacity remaining at disposal (%)	[%]	50%	DEFRA 2012		
	Refrigerant recovered (%)	[%]	80%	DEFRA 2012		
	Refrigerant type (cooling, not freezing)		HFC-134a	IPCC (select from list from Annex 5)		
	Global Warming Potential (GWP)	[eCO2]	1300	DEFRA 2012		
	Total kg CO2 equivalent	[kg eCO2]	1105	(calc)	4420	(calc)
	Duration of trip	[days]	0.5		2.73	80 km/h average, 16 h/day,
	Trips per year	[/yr]	100	Interview with Zephyr, Pfennings	109.71	300 days annually on the road, return trip assumed to be utilized with other products
	Emission per trip		11.05	(calc)	40.29	(calc)
	Emission per box		**0.0034**	(calc)	**0.0047**	(calc)

Table 3.2. Emissions from mobile refrigeration

3.2. Emissions at the retailer and at Fresh City Farms packaging site

3.2.1. Fresh City Farms packaging site

At the box store retailer and at the packaging station from Fresh City Farms, the two main emission sources are refrigeration (Scope 2 emissions from electricity generation and direct Scope 1 emissions from leakage of refrigerant gases), and emissions from other electricity use in the office and in the packaging room (computers and other appliances, lights, air conditioning, etc). Furthermore, the consumption of natural gas was accounted for.

Emissions that are not taken into account

Emissions that were not taken into account at this point are

- Provision of city water (filtering, provision, pumping) and treatment of city water,
- Office equipment (manufacturing and disposal of retail infrastructure, especially computers and other electronic devices),
- Packaging material, especially cardboard boxes and waxed cardboard boxes,
- General material use and waste disposal,
- Savings from recycling of material.

A thorough analysis of packaging and waste is recommended. However, it requires detailed understanding of what happens with waste streams in all relevant regions and is not specific to Fresh City Farms. For example,

- Waste and recycling material can be burned for heat or electricity generation (energetic recycling), which would off-set heating emissions and Scope 2 emissions of the enterprise. Some companies (e.g. Pfennings) have begun to do so with waxed cardboard boxes, which cannot be reused due to food safety regulations, practically off-setting their heating emissions with energetic waste recycling.
- Composting of packaging material is often feasible, but especially methane emissions depend on composting practices (aerobic vs. anaerobic decomposition). Local practices are difficult to estimate and require a separate study.
- Reuse of packaging material is difficult to quantify, because reusable containers require washing, causing additional emissions for water provision and wastewater treatment, as well as an environmental burden through chemical effluents within or outside of the water treatment.
- Food safety regulations regulate packaging material and its reuse, but some farmers may find ways to improve material use efficiency within grey zones of the regs. It is unclear how to account for such practices.

Refrigeration per box (Scope 2 emissions and leakage)

Fresh City Farms uses a medium-sized stationary unit as a walk-in cooler, where all produce that requires refrigeration is stored until packaging. Technical specifications of the cooler are given in Table 3.3.

Stage in life cycle	Unit	Value	Source
Type of Equipment		**Medium stationary unit**	Fresh City
Equipment Charge Capacity	[kg]	**27**	Written onto cooler, converted from pounds
Refrigerant type		**R409**	Written onto cooler
Global Warming Potential of refrigerant	[kg eCO2/kg]	1585	DEFRA 2012, Annex 5 for medium stationary unit
Life length of cooler	[years]	10	DEFRA 2012

Table 3.3. Specifications of the walk-in cooler from Fresh City Farms

Total annual emissions for refrigeration are estimated using these specification and standard data for life cycle leakage (DEFRA 2012). Electric bills were used to estimate total annual electric use (24,500 kWh). The share of electricity that is used from refrigeration is not known and estimated to be 60%. The rest is accounted for as "other emissions from electricity usage". Refrigeration emissions per box (Scope 2 and leakage) result at 0.078 and 0.112 kg eCO2 respectively (Table 3.4).

Stage in life cycle	Item	Unit	Value	Source
Installation, total	Installation Emission Factor %	[%]	**1.0%**	DEFRA 2012
	Total kg CO2 equivalent	[kg eCO2]	427.95	(calc)
	Annual emissions (Installation)	[kg eCO2/year]	42.80	(calc)
Operation, electricity use	Energy use, over year	[kWh]	14071.1	Fresh City staff
	Ontario energy emissions	[kg eCO2/kWh]	0.18114	Climate Registry Canada
	Scope 2 emissions for electricity generation during operation	[kg eCO2/year]	2548.8	(calc)
Operation, coolant leakage	Annual Leak Rate	[%]	6%	DEFRA 2012
	Total kg CO_2 equivalent	[kg eCO2/year]	2567.7	(calc)
End of life disposal	Capacity remaining at disposal (%)		80%	DEFRA 2012
	Refrigerant recovered (%)		70%	DEFRA 2012
	Total kg CO2 equivalent	[kg eCO2/life]	10270.8	(calc)
	Annual equivalent	[kg eCO2/year]	1027.08	(calc)
Refrigeration emissions (Scope 2 only)		[kg eCO2/year]	2548.83	(calc)
Refrigeration emissions (leakage only, annually)		[kg eCO2/year]	3637.58	(calc)
Fresh City refrigeration (Scope 2 emissions), per box		[kg eCO2/box]	**0.078**	(calc)
Fresh City refrigerant leakage, per box		[kg eCO2/box]	**0.112**	(calc)

Table 3.4. Refrigeration at the Fresh City Farms packaging site

Other emissions from electricity use (Scope 2 emissions) and heating

Remaining electric use was converted into emissions using standard data. Total emissions per box are 0.052 kg eCO2. Bills for natural gas were also evaluated and total gas use was recorded from Fresh City bills and extrapolated for the full year. From Climate Registry data, emission factors for natural gas were extracted, taking into account CO2, CH4, and N2O within the usage category "residential, construction, commercial/institutional, agriculture". Total emissions per box are 0.207 kg eCO2 (Table 3.5).

Item	Unit	Value	Source
Electricity use without refrigeration, annually	[kWh/year]	9380.7	(calc)
Ontario energy emissions	[kg eCO2/kWh]	0.18114	Climate Registry
Emissions for electricity generation for other uses during operation	[kg eCO2/year]	1699.2	(calc)
(Emissions per Ca$ of perishable product)	[kg eCO2/$]		
Emissions for electrical generation, per box (Scope 2)	**[kg eCO2/box]**	**0.052**	(calc)
Annual use of natural gas	[m3]	3390	Fresh City Bills
Emission factor for natural gas	[kg eCO2/m3]	1.985	Climate Registry (CO2, N2O, CH4)
Annual emissions for natural gas	[kg eCO2/year]	6729.15	(calc)
Emissions for natural gas usage, per box	**[kg eCO2/box]**	**0.2071**	(calc)

Table 3.5. Other emissions considered from Fresh City Farms

3.2.2. The conventional retailer

For conventional retailers, standard data for emissions is not available. In order to account for retail emissions, annual reporting was reviewed from Loblaw and Sobeys. Total emissions are reported in annual sustainability reports, and annual revenue figures are available in financial reports. Furthermore, some consulting companies have published additional data, especially a report from Coriolis "*Understanding Loblaw*" from June 2005. While somewhat outdated, the report contains data on the percentage of fresh produce (including fruit, vegetable, meat, dairy) of total revenue for the year 2004 and a projection for 2010, for which no other data was found elsewhere.

With limited data, emissions are estimated by using aggregate company data, which are then converted into per-dollar emissions for perishable products, which include vegetables. Frozen products are excluded from this calculation and, for lack of more information, it is assumed that all perishable products have equal per-dollar refrigeration emissions. Due to the aggregate nature of this calculation, all emissions of the retail corporation are included, while emissions from business partners (e.g. trucking companies) would not be included within the corporate emission balance.

General information about commercial refrigeration was taken from Clodic et al (2010)[27], an update of the *Refrigerant Inventories And Emissions Previsions* (RIEP) database together with the United Nations Environmental Program (UNEP), as well as from other websites. This study estimates the refrigerant charge per m2 of sales area for supermarkets in different countries ranging between 0.26 and 0.37, with Canada/U.S. at the upper end. The refrigerant used, which determines the global warming potential, has shifted since the Montreal Protocol was adopted and is being implemented, as well as GHG emission management beginning to have an impact, led by European countries. It is estimated that in the U.S. and Canada, the Ozone-depleting and high-GWP refrigerants for refrigeration HCFC-22 (GWP 1,810 eCO2) and freezing CFC-12 (GWP 10,900 eCO2) have been phased out in the last years and substituted with others that are not ozone depleting, in particular HFC-134a for refrigeration (GWP 1,300 eCO2) and HFC-404A for freezers (GWP 3,260 eCO2).

Total GHG emissions of the Loblaw group include all stores across Canada, without T&T Supermarkets, franchised and independent stores, company-owned warehouses and distribution centres. Reported GHG emissions for the year 2012 are $E_{total} = 1{,}098{,}975{,}772$ kg eCO2, of which 52% are used for buildings (heating & electricity), 23% are refrigerant leakage, the rest is waste, transportation fuel, and others (see Figure 2).

[27] Clodic et al., 2010.

Item	Unit	Value	Source
Total annual emissions	[kg eCO2/year]	1,098,975,772	Loblaw Sustainability report 2012
Total revenue	[Ca$/year]	$ 31.250 Billion	Loblaw Financial Report 2011
Share of perishable products in revenue	[%]	32.4%	Calculated from Coriolis report on Loblaw, tables p 37 and 88
Total perishable sales	[Ca$]	$ 10.122 Billion	(calc)
Percentage of total emissions that go to Building energy (heating & electricity)	[%]	52%	Loblaw Sustainability report 2012
Percentage of building emissions that go to electricity only	[%]	50%	Loblaw Sustainability report 2012
Percentage of electricity use for refrigeration	[%]	50%	Sorbey Annual Report
Percentage of total emissions for leakage	[%]	23%	Loblaw Sustainability report 2012
Ratio of fridge area over total freezer and fridge area		69.2%	Estimate after own survey
Ratio of refrigerant GWP (fridge over freezer plus fridge)		28.5%	DEFRA 2012 data
Total annual emissions for			
Refrigeration electricity (Scope 2)	[kg eCO2/year]	98,907,819	(calc)
Refrigeration leakage (direct)	[kg eCO2/year]	49,887,716	(calc)
Other electricity (Scope 2), share for perishable products only	[kg eCO2/year]	32,035,056	(calc)
Heating emissions (Perishable share only)	[kg eCO2/year]	64,070,112	(calc)
Value of average food box	[Ca$]	$ 31.00	Fresh City data
Refrigeration emissions per box (Scope 2 only)	**[kg eCO2/box]**	**0.3029**	**(calc)**
Refrigeration emissions per box (leakage only)	**[kg eCO2/box]**	**0.1528**	**(calc)**
Other electrical emissions per box	**[kg eCO2/box]**	**0.0981**	**(calc)**
Heating emissions per box	**[kg eCO2/box]**	**0.1962**	**(calc)**
Total emissions at retail	**[kg eCO2/box]**	**0.7501**	**(calc)**

Table 3.6. Emissions by a retailer/box store. Data was constructed from reporting of Loblaw and Sorbey

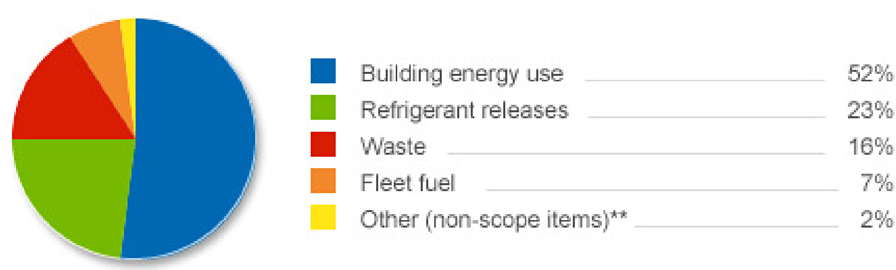

Figure 2. Global annual emissions as reported by the Loblaw Corporation

Emissions were computed for each dollar of perishable produce (including vegetable, fruit, meat, dairy, etc). The share of revenue from perishable products was derived from data given in a Coriolis report, which states the percentage of perishable products for several types of retail outlets (wholesale, fresh box, conventional, etc). It was determined that 32.4% of total revenues (or Ca$ 10.1 Billion annually) are from perishable products (Table 3.6).

Total emissions from refrigerant leakage are reported on the Loblaw website as 23% of all emissions, or

$$E_{leakage} = 23\% * E_{total}$$
$$= 252764427.6 \text{ kg eCO2/year}$$

It is assumed that all refrigeration emissions (leakage, Scope 2) are attributed to perishable produce and frozen products. The ratio is not known and was estimated from literature data. For leakage, we used the spatial ratio of area for fridges and freezers, $r_{spatial}$, as well as the ratio r_{GWP} of global warming potential between the refrigerants of fridges (HFC-134a) and freezers (HFC-404A). The total leakage attributed to refrigeration of perishable products is

$$E_{leakage}^{refrig} = E_{leakage} * r_{spatial} * r_{GWP}$$
$$= E_{leakage} * \frac{area_{fridges}}{area_{fridges} + area_{freezers}} * \frac{GWP_{fridges}}{GWP_{fridges} + GWP_{freezers}}$$
$$= 252764427.6 * \frac{9}{9+4} * \frac{1{,}300}{1{,}300 + 3{,}260} \text{ kg eCO2/year} = 49{,}887{,}716 \text{ kg eCO2/year}$$

Building energy is assumed to be equally attributable to electricity use and heating, and 50% of electricity use is attributed to refrigeration using a number published by Sobeys for their supermarket operations. Heating and other electric use are allocated to freezer and fridge area using the spatial ratio $r_{spatial}$. Altogether, emissions at retail add up to 0.75 kg eCO2 per box. About 40% of these are electricity use for refrigeration and 20% are attributed to refrigerant leakage. The rest is other electrical use (13.1%) and heating (26.2%, Table 3.6).

It should be added that retailers report considerable effort to reduce electricity costs and also refrigerant leakage. More and more retailers are switching to coolers with sliding doors, which reduce cooling losses. Some retailers have begun to substitute refrigerants with high global warming potential and use CO2 as refrigerant. This reduces leakage emissions by a factor 1000.

3.3. To consumer from Retail/Fresh City

3.3.1. Consumer shopping trips to conventional retail stores

For comparison with Fresh City, it is assumed that consumers drive regularly to a conventional box store, which is located 5 kilometers from the home so the round trip is 10 km. Equivalent scenarios would be a detour of 10 km on the way home from work. It is assumed that consumers drive average-sized cars, for which per-kilometre emissions are available by the US Environmental Protection Agency (EPA). This study bases per-km emissions on the average passenger car fleet of the United States (EPA 2008).

It is assumed further that the customer buys 10 kg at each shopping trip, including the content equivalent of one full Fresh City Farms box (4.47 kg). With 45% of the weight attributed to the Fresh City content equivalent, the same share of emissions is attributed to the box purchase. In total, from emissions of the shopping trip, 1.04 kg eCO2 are attributed to the vegetable box (Table 3.7).

Item	Unit	Value	Source
Mileage to purchase	[km]	12	Consumer survey
Vehicle type	Text	Average car	Assumption
Emission density	[kg eCO2/ km]	0.229	EPA 2008
Total purchase weight	[kg]	15	Assumption
Share of veggies in purchase/pick-up	[-]	30%	Assumption
Emissions per box	**kg eqCO2/box**	**0.68**	**(calc)**

Table 3.7. Shopping trips from consumers to retailers/box stores

3.3.2. Fresh City Farms delivery to homes and pick-up locations

Fresh City Farms packages food boxes and then delivers these directly to the homes of customers.

Per-kilometer emission data was selected for each vehicle type, using DEFRA 2012 data (Table 3.7). Total emissions were computed from adding direct and indirect emissions. These vary from 0.24 kg eCO2/km to 0.311 eCO2/km for the larger van. The maximum number of boxes was derived from Fresh City data (see Table 3.8). With freight transport, it is common to distinguish weight capacity and volumetric capacity. The former is given by the vehicle technical specifications, while volumetric capacity depends on the volume/weight ratio of the items transported. DEFRA per-kilometer emission data takes into account that most vans are not at their weight capacity even if their volume is fully utilized. The percentage of weight used once the volume is full varies between 37-50%, depending on the vehicle type. This data was derived from empirical analysis in the UK, but it is believed that it is transferable to the Ontario context.

Vehicles	Load	Number of boxes (max)	% of weight capacity if full	weight of freight if full volume	Type of van	Vehicle Reference Weight	CO_2	CH_4	N_2O	Total Indirect GHG	Total GHG
	[kg]	[box]	[%]	[kg]		[t]	[kg CO2e per vehicle km]				
Nissan	1500	78	50.00%	750	Petrol (Class I)	<1.305 t	0.198	0.000	0.001	0.040	0.240
Autoshare Van	2750	80	40.00%	1100	Petrol (Class II)	1.305-1.74 t	0.211	0.000	0.001	0.043	0.255
Savanah	4000	140	37.00%	1480	Petrol (Class III)	1.74-3.5 t	0.256	0.000	0.003	0.052	0.311

Table 3.8. Emissions for delivery vehicles used by Fresh City Farms, by vehicle km. Source: DEFRA 2012

In 2013, Fresh City Farms delivered boxes in eight trips on three days, Tuesday, Wednesday, and Thursday. Data on trip length, distance, number of boxes, and capacity usage was provided by Fresh City. Using trip length, total boxes/bags per vehicle, vehicle type, and emissions per km for that vehicle, emissions per box/bag were calculated. Per-box emissions vary between 0.24 and 0.31 kg eCO2 per box, with an average of 0.26 kg eCO2.

Day	Car Type	Capacity Used (volumetric)	Total Bags per Vehicle	Trip lengths [km]	Total emissions [kg eCO2]	Emissions per bag [kg eCO2/bag]
Wednesday	Autoshare Van	75%	60	45	11.48	0.19
Thursday	Autoshare Van	53%	42	49	12.51	0.30
Thursday	Autoshare Van	64%	51	108	27.56	0.54
Tuesday	Nissan	75%	59	87	20.85	0.35
Wednesday	Nissan	62%	49	46	11.02	0.22
Thursday	Nissan	62%	49	62	14.86	0.30
Wednesday	Savanah	100%	138	31	9.63	0.07
Thursday	Savanah	65%	82	94	29.21	0.36
TOTALS			530		137.13	

Table 3.8. Delivery routes of Fresh City Farms. Source: Fresh City 2013, own analysis

3.3.3. Consumers mobility to the pickup location

Fresh City delivery employees state that most consumers either get home delivery, or they walk to central pickup locations, or stop there after the work day on their way home. For the overall majority of customers, no additional greenhouse gas emissions from transportation to the pickup accrue. To be conservative, we assume that the average consumer drives half a km to the pickup place in an averaged-sized car, using the same reasoning as in sub section 3.3.1. In this case, no additional benefits of this trip are assumed, so the full emissions are allocated to the food box pickup. The total emissions per consumer would be 0.12 kg eCO2/box (Table 3.9).

Item	Unit	Value	Source
Mileage for purchase	[km]	0.5	Fresh City knowledge
Vehicle type	Text	Average car	Assumption
Emission density	[kg eCO2/ km]	0.229	EPA 2008[28]
Total purchase weight	[kg]	4.47	Fresh City data
Share of veggies in purchase/pick-up	[-]	100%	Assumption
Emissions per box	**kg eqCO2/box**	0.114	**(calc)**

Table 3.9. Transportation from consumers

[28] EPA 2008

4. Results

If taking all emissions together, the transportation, packaging, storage, delivery, and consumer pickup of each Fresh City food box accounts for greenhouse gas emission of 1.057 kg eCO2. If the same produce would be purchased at a regular box store or supermarket, emissions per box would be 4.246 kg eCO2. Food production itself is not considered in this calculation.

Within the conventional food distribution chain, trucking from the farm to the retailer is the most relevant source of emission. These emissions are attributed to trucking of produce from Mexico, Florida, or California. The largest per-unit emissions are those flown in from overseas, in this case herbs from Israel or South America. Even though the conventional system benefits from economies of scale, larger trucks, and better capacity utilization of trucks, transportation within the conventional system causes nearly 15 times the GHG emissions as Ontario-sourced produce through Fresh City Farms. This difference is less pronounced for refrigeration during the trip. The most relevant factor here is less idle time of trucks, which reduces refrigerant leakage.

At the retailer and at the Fresh City Farms packaging station, emissions also vary. Within the supermarket, emissions add to 0.75 kg eCO2 from refrigeration electric usage, leakage of refrigerants, other electric use, and natural gas use. The same process causes 0.45 kg eCO2 at Fresh City Farms for packaging its own produce and re-packaging wholesale produce into food boxes. Emissions at the retail level are about double in the conventional system, mostly because of longer refrigeration times and open refrigerators. Electricity use is the single most important contributor at retail stores (Table 4.1).

Nr	Stage in food chain	Fresh City	Conventional	Ratio Fresh City/conv
Farm to Retailer/Fresh City				
1	Transportation	0.193	2.863	14.8
2	Mobile refrigeration	0.003	0.005	1.3
At retail/Fresh City				
3	Refrigeration electricity	0.085	0.303	3.6
4	Refrigeration (refrigerant leakage only)	0.121	0.153	1.3
5	Other electricity use (Scope 2 emissions)	0.057	0.098	1.7
6	Emissions for natural gas usage, per box	0.224	0.196	0.9
To consumer from Fresh City/Retail:				
7	Delivery vehicle	0.259	n/a	
8	Mobile refrigeration during delivery	0.000	0.000	1.4
9	Consumer pickup/shopping	0.114	0.68	
TOTAL		**1.057**	**4.246**	**3.8**

Table 4.1. Summary of distribution emissions per Fresh City Farms food box and the equivalent box content purchased at a retailer/box store

Ultimately, delivery of multiple boxes with minivans to homes and pickup locations requires approximately 0.38 kg eCO2 per box, assuming that some customers must occasionally drive to the pickup stations (Figure 3). Fresh City Farms have chosen pickup points at offices or central locations such that these consumer miles are minimal. If regular shoppers use cars, their mileage is the second most important cause of GHG emissions. Assuming that consumers drive an additional 10 km for a shopping trip, and 30% of this trip is attributed to vegetable and fruit (4.7 kg out of 15 kg) purchases, these shopping miles account for 0.68 kg eCO2 per box. All in all, delivery is 1.8 times more efficient than consumer shopping based on assumptions outlined above.

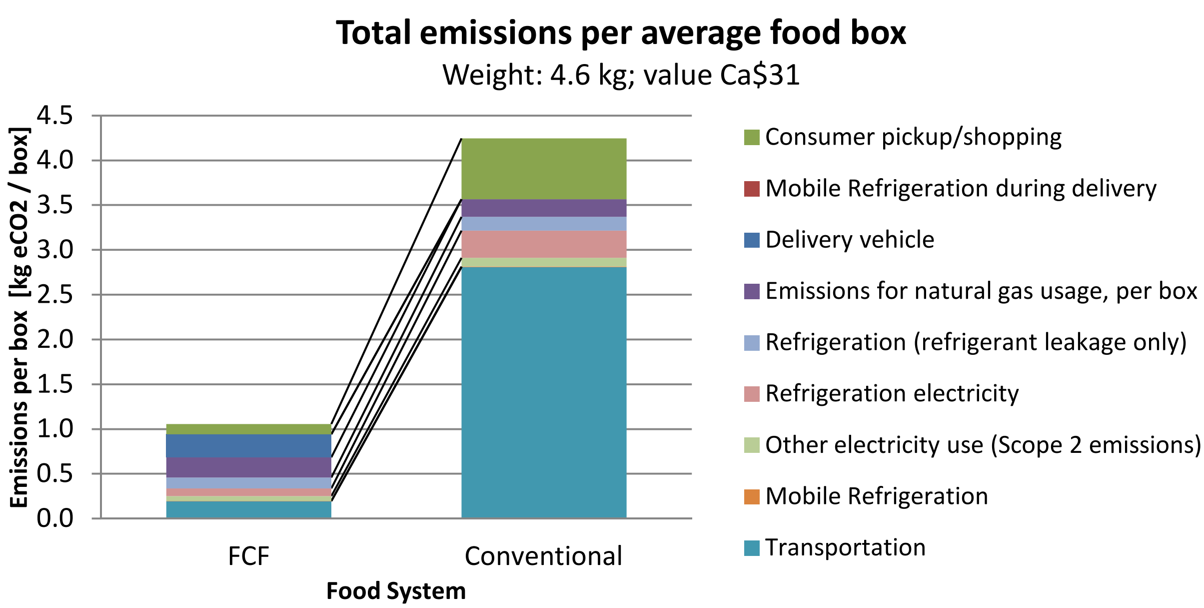

Figure 3. Total emissions per box, using data from Table 4.1

5. Insights into consumer's dietary habits and Greenhouse gas emissions

Ultimately, greenhouse gas emissions from food not only depend on how they were transported, distributed and shopped, but also on eating behavior: the nutritional composition of high-emission food (meat and poultry) and low-emission food (seasonal veggies & fruits), the frequency of going out, food waste, and cooking behavior[29].

The not-for-profit ShrinkThatFootprint has derived annual emissions for 5 types of diets (see Figure 4). Depending on dietary choices, per-capita emissions for U.S. citizens vary between 1.5 t eCO2/yr for a vegan up to 3.3 t eCO2/yr for meat lovers, or weekly emissions between 30 kg eCO2 and 65 kg eCO2 respectively. The emission footprint of each average U.S. citizen's diet contributes 2.5 t kg eCO2/year or 50 kg eCO2/week.

By subscribing to Fresh City Farms food boxes, respondents of a Fresh City Farms customer survey clearly indicate changes in their cooking skills, their frequency of cooking from scratch, and most importantly, their dietary choices. For example, 49% indicate that their cooking skills have increased since they were confronted with a stream of fresh food every week. Also, 48% of the respondents report that their consumption of meat, poultry, and fish products has decreased. With the limited data assessed within the consumer survey, it is not feasible to quantify how strong these reductions are. However, with general dietary emission data, it is feasible to provide a first estimate of the magnitude of emission savings due to behavioural change.

Each customer who started off with an average diet and, as part of complex changes that impact on their diet, has reduced his/her meat consumption, is saving Greenhouse gas emissions. It is assumed that a customer starts off with an average diet, cuts meat consumption by half, and substitutes the meat gap with a mix of vegetarian choices. Each person would save 7.8 kg eCO2 emissions each week or 0.4 tonnes annually. Compared to emissions within the food delivery system, this dietary change weighs heavily. Emissions for each box were estimated at 4.2 kg eCO2 emissions for vegetables in conventional shopping, or 1.1 kg eCO2 emissions with Fresh City Farms. The average household size of Fresh City Farms customers is 2.24. If all members of one household shift their diet as described, weekly savings would be 18.1 kg/household or box, outweighing the delivery savings six fold.

It is not clear what triggers consumers to become customers. The survey indicates that food quality and freshness is the most important reason to subscribe to regular box delivery, followed by idealism (environmental and economic benefits of local food), the convenience of delivery, and health considerations.

Out of all respondents, 60% indicated that cooking skills have increased. It is fair to assume that the rest of the respondents who know how to cook with all Fresh City foodbox ingredients are already quite sophisticated cooks.

29 Weberet al., 2008

- Out of those who still improve their cooking skills, 63% also increase how often they cook from scratch. In this group of learners, 34.7% was also confronted with 5 or more new vegetables to deal with, compared to 12% in the other group.
- Out of 140 respondents who report consuming meat, 115 have reduced their consumption of meat and 130 have reduced their consumption of chicken. This reduction is stronger with consumers who consume daily or at least several times per week, while moderate and low consumers report less reduction.

All in all, the strongest greenhouse gas impact of Fresh City Farm delivery may not be in the transportation and refrigeration. Instead, changes of consumer diets and cooking behavior are triggered when shoppers must cook regularly with whatever the foodbox provides. While greenhouse gas reductions are not the main reason for subscribing to Fresh City, the decision to eat better, more sustainably, and healthier also reduces the overall food-related footprint.

Another aspect that was not taken into account is food waste. More greenhouse gases are created from food wasted by households than by plastic packaging (WRAP, 2010), because much of this waste ends up in landfills where it composts incompletely and creates methane. Within the distribution chain, the main causes for food waste are overproduction, defects in products and equipment, unnecessary inventory, inappropriate processing, excessive transportation, waiting, and unnecessary motion (Gooch et al., 2010). However, the largest single contributing factor to food waste is consumer behavior which accounts for 51% of all food waste in Canada or a quarter of all food produced (Gooch et al., 2010).

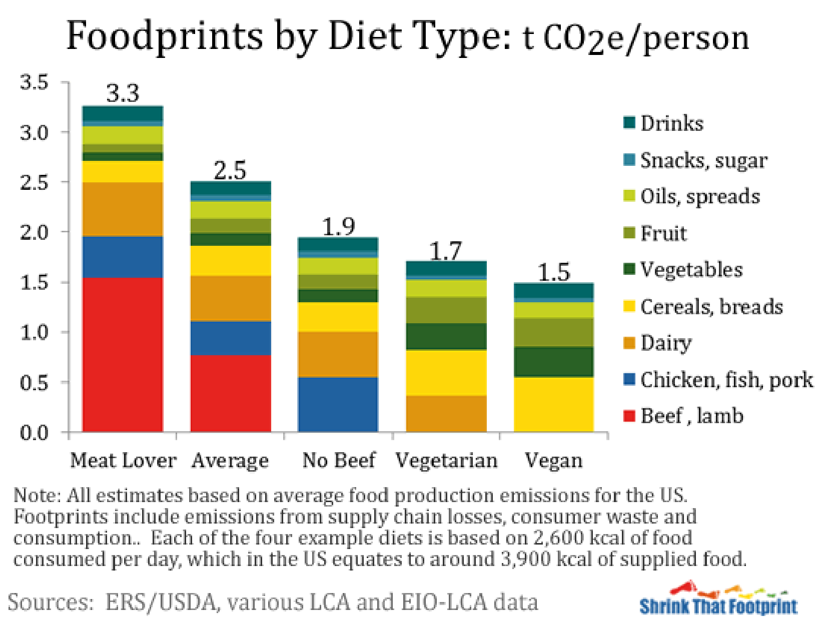

Figure 4. Footprints by diet type. Figure taken from Shrink That Footprint website[30]. Please cite the original source.

[30] www.shrinkthatfootprint.com

6. Data limitations and recommendations

The assessment presented here is based on publicly accessible data and information. Often, more specific data is available in private databases that charge access fees for each assessment (around Ca$ 1,000-2,000 per assessment) or annual user fees. Without being able to verify the claim due to access restrictions, databases promise access to location-specific and more in-depth emission factors. We refrained from purchasing such data from private companies for several reasons:

- **Funding restrictions** within this project;
- **Transparency restrictions due to intellectual property rights.** It is not allowed to distribute private data openly. Studies resulting from such proprietory data could thus not show detailed calculation steps, which undermines academic learning and misses the objective of raising public accountability.
- **Unclear data consistency.** If purchasing data from one of multiple private database providers, it is unclear how this initial decision impacts further study outcomes due to differing databases.

Especially for the conventional food chain, it is difficult to assess product life cycles from an outside perspective. Sustainability reports that follow the Corporate Standard usually give aggregate figures for large corporations, such that individual processes or products are not available publicly. While some attempts were made to re-construct this data using public information, the limits to this approach are obvious. More in-depth studies may improve how we re-construct disaggregate information from aggregate data, for example taking into account academic studies on consumer shopping behaviour, the composition of shopping baskets, average spending by product class, and product prices. Such emissions analysis of food and other shopping baskets could take into account seasonality and classification of eating habits.

Also, deriving travel distance from food labelling is not transparent. In some cases, food that is produced near a retail store is first transported to and stored at a distant centralized storage, especially in smaller centres that don't warrant a warehouse. Expert judgement had to be used to derive modes of transportation (air, sea, road) and, in the case of air and sea freight, the transportation from the port/airport to the central warehouses.

Keeping these limitations in mind, the main results of this study are considered to be robust. Using standard emission data for transportation given in tonne*km, the main source of emissions is the transportation of fresh produce from the farms to the retail locations. Due to the low emission intensity of sea freight (Defra 2011, compare data for freight transport in Defra 2012, Annex 7), imports from China or South America have emissions that are comparable with products trucked from the U.S. or Mexico. All in all, even with high efficiency in the conventional system due to economies of scale, the emission from international transport make up about 68.8% of total food distribution emissions (transport, retail, shopping).

Fresh City Farms is 15 times more efficient in moving food to their packaging location for two reasons. First, they rely on locally resourced food (low food miles). In addition, the delivery to the packaging station is efficient because their main partners operate at a fairly large scale, such that Fresh City deliveries are part of a round trip to multiple wholesale customers. This way, trucks can be filled to capacity and total delivery miles are split amongst multiple customers.

Emissions within the retail store are approximately 1.5 times larger than at Fresh City Farms packaging location, even though Fresh City's packaging facility itself may not be the most technologically advanced. We believe that the main reason is short storage times in a closed walk-in cooler, compared to longer periods of storage and display in open refrigerators at the retail store.

Finally, delivery of food boxes seems to significantly reduce shopping miles. It remains difficult to quantify saved shopping miles, partly because the consumer surveys indicate that shopping is not fully substituted with the limited product assortment that Fresh City offers, and partly because consumers are flexible in their shopping behavior, use multiple stores, and accommodates shopping within their regular commute. The consumer survey indicates that many customers have somewhat reduced their shopping frequency.

In conclusion, the Fresh City Farms foodbox delivery program is an example of how local food emissions can be significantly lower than those in a conventional food chain. The main reasons that give Fresh City Farms an advantage are

- Delivery from farms are minimized because
    - Most products are sourced locally, many of which are directly from their farm and
    - Supplying farmers are capable of optimizing their truck loads by delivering to multiple customers with full, medium-sized trucks.
- Storage and refrigeration at the packaging station is so short that inefficiencies are more than compensated, compared to regular retail.
- Consumer shopping miles are reduced because
    - Food box bundles provides access to farm-fresh, high-quality food without the necessity that consumers drive to the farm or other distant direct marketing venues.
    - Home delivery and smartly chosen pickup locations reduce shopping miles compared to conventional retailers
    - About half the customers report that they can reduce shopping time and frequency due to Fresh City boxes, because a wide range of products is offered
- Consumers who sign up for regular food boxes also commit to a diet with lower carbon footprint.

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Appendix

Data Tables

Quantity	Unit
1	Bushel
8	gallons
32	quarts
64	pints
4	pecks

Table A.1. Conversion of bushels, gallons, quarts, and pints

Abbreviation	Organization
CAES	University of Georgia, Cooperative extension
UARE	University of Arkansas, Research & Extension
ILGA	Illinois, General Assembly, Joint Comission on Adminsitrative Rules

Table A.2. Sources for weights of specific vegetable packages

Type	Weight/unit	Unit	Weight [lb per bushel]	Source	Weight (kg)
Beets	1	ct	60	CAES	0.85
Cauliflower	1	ct	24	CAES	0.34
Corn	3	ct	35	CAES	1.49
Cucumbers	1	ct	49	CAES	0.70
Eggplant	1	ct	34	CAES	0.48
Herbs [Oregano]	1	ct	22	UARE	0.31
Herbs [Thyme&Marjoram, Basil, Sage, Lavender]	1	ct	22	UARE	0.31
Kale/Chard/Collards	1	ct	18	CAES	0.26
Lettuce [Romaine]	1	ct	25	UARE	0.36
Peppers [speciality]	2	ct	28	CAES	0.80
Radish	1	ct	60	Like beets	0.85
Tomatillos	1	pint	53	like tomatoes	0.38
Tomato [Cherry Orange]	1	pint	53	CAES, like tomatoes	0.38
White Onions	1	pint	57	CAES	0.40

Table A.3. The weight per food item and its relative share in a representative food box is used to determine a relative weighting factor

		Fresh City Farms						
Vegetable item	Weight per unit [kg]	Origin	Distance [km]	Mode	Type	Emissions per tonne-km	Tonne Km	Emissions per unit
Beans	0.225	California	3500	Truck	Truck, 40t	0.10273	0.788	0.081
Beets	0.852	ON	61.1	Truck	Truck, 16t	0.42932	0.052	0.022
Brassica [Bok Choy]	0.450	ON	61.1	Truck	Truck, 16t	0.42932	0.027	0.012
Brassica [Cauliflower]	0.341	ON	61.1	Truck	Truck, 16t	0.42932	0.021	0.009
Corn	1.491	ON	61.1	Truck	Truck, 16t	0.42932	0.091	0.039
Cucumbers	0.696	Fresh City	0	None	None	0	0.000	0.000
Eggplant	0.483	Fresh City	0	None	None	0	0.000	0.000
Garlic [Fresh]	0.090	Fresh City	0	None	None	0	0.000	0.000
Ginger	0.090	ON	61.1	Truck	Truck, 16t	0.42932	0.005	0.002
Herbs [Green Onion, Parsley]	0.450	Fresh City	0	None	None	0	0.000	0.000
Herbs [Oregano]	0.313	Fresh City	0	None	None	0	0.000	0.000
Herbs [Thyme&Marjoram, Basil, Sage, Lavender]	0.313	Fresh City	0	None	None	0	0.000	0.000
Peppers [hot]	0.113	Fresh City	0	None	None	0	0.000	0.000
Brassica [Kale/Chard/Collards]	0.256	Fresh City	0	None	None	0	0.000	0.000
Lettuce [Romaine]	0.355	ON	61.1	Truck	Truck, 16t	0.42932	0.022	0.009
Mizuna/Arugula	0.113	Fresh City	0	None	None	0	0.000	0.000
Mushrooms [Button]	0.225	ON	61.1	Truck	Truck, 16t	0.42932	0.014	0.006
Okra	0.450	Fresh City	0	None	None	0	0.000	0.000
Onion [Red]	0.900	California	3500	Truck	Truck, 40t	0.10273	3.150	0.324
Peppers [speciality]	0.450	Fresh City	0	None	None	0	0.000	0.000
Peppers [speciality]	0.270	ON	61.1	Truck	Truck, 16t	0.42932	0.016	0.007
Peppers [speciality]	0.270	ON	61.1	Truck	Truck, 16t	0.42932	0.016	0.007
Peppers [speciality]	0.795	ON	61.1	Truck	Truck, 16t	0.42932	0.049	0.021
Peppers [speciality]	0.675	ON	61.1	Truck	Truck, 16t	0.42932	0.041	0.018
Radish	0.852	Fresh City	0	None	None	0	0.000	0.000
Salad Mix	0.113	Fresh City	0	None	None	0	0.000	0.000
Tomato [Cherry Orange]	0.376	ON	61.1	Truck	Truck, 16t	0.42932	0.023	0.010
Tomatoes	0.450	Fresh City	0	None	None	0	0.000	0.000
Onions [White]	0.405	Fresh City	0	None	None	0	0.000	0.000
Zucchini	0.450	Fresh City	0	None	None	0	0.000	0.000
Zucchini	0.450	ON	61.1	Truck	Truck, 16t	0.42932	0.027	0.012
AVERAGE ITEM	**0.44**		**315.63**			**0.22**	**0.24**	**0.03**
TOTAL (3 boxes used for sample)	**13.76**						**4.34**	**0.58**
TOTAL (average sample box)	**4.59**						**1.45**	**0.19**

Table A.4. Transportation emissions of a Fresh City Farms sample box. This box was generated from three actual boxes

		Conventional Retail (Loblaw example)										
Vegetable item	Weight per unit [kg]	Origin	Distance [km]	Mode	Type	Emissions per TKM [kg eCO2/t km	TKM	Emissions, main [kg eCO2]	Trucking after air/sea [km]	tkmEmissions [kg eCO2/tkm]	Emissions, Trucking after landing [kg eCO2]	Emissions, total [kg eCO2]
Beans	0.23	Canada	1000	Truck	Truck, 40t	0.103	0.225	0.023				**0.023**
Beets	0.85	Canada	1000	Truck	Truck, 40t	0.103	0.852	0.088				**0.088**
Brassica [Bok Choy]	0.45	Mexico	5000	Truck	Truck, 40t	0.103	2.250	0.231				**0.231**
Brassica [Cauliflower]	0.34	Canada	1000	Truck	Truck, 40t	0.103	0.341	0.035				**0.035**
Corn	1.49	Canada	1000	Truck	Truck, 40t	0.103	1.491	0.153				**0.153**
Cucumbers	0.70	Mexico	5000	Truck	Truck, 40t	0.103	3.480	0.358				**0.358**
Eggplant	0.48	Canada	1000	Truck	Truck, 40t	0.103	0.483	0.050				**0.050**
Garlic [Fresh]	0.09	China	20000	Sea	Refrigerated cargo, 5000-7999TEU	0.020	1.800	0.036	600	0.103	0.006	**0.041**
Ginger	0.09	Peru	15000	Sea	Refrigerated cargo, 5000-7999TEU	0.020	1.350	0.027	600	0.103	0.006	**0.032**
Herbs [Green Onion, Parsley]	0.45	USA	3500	Truck	Truck, 40t	0.103	1.575	0.162				**0.162**
Herbs [Oregano]	0.31	Colombia/Israel	10000	Air	Long-haul international	0.773	3.125	2.416	200	0.103	0.006	**2.423**
Herbs [Thyme&Marjoram, Basil, Sage, Lavender]	0.31	Colombia/Israel	10000	Air	Long-haul international	0.773	3.125	2.416	200	0.103	0.006	**2.423**
Peppers [hot]	0.11	Mexico	5000	Truck	Truck, 40t	0.103	0.563	0.058				**0.058**
Brassica [Kale/Chard/Collards]	0.26	Canada	1000	Truck	Truck, 40t	0.103	0.256	0.026				**0.026**
Lettuce [Romaine]	0.36	USA	3500	Truck	Truck, 40t	0.103	1.243	0.128				**0.128**
Mizuna/Arugula	0.11	USA	3500	Truck	Truck, 40t	0.103	0.394	0.040				**0.040**
Mushrooms [Button]	0.23	Canada	1000	Truck	Truck, 40t	0.103	0.225	0.023				**0.023**
Okra	0.45	USA	3500	Truck	Truck, 40t	0.103	1.575	0.162				**0.162**
Onion [Red]	0.90	USA	3500	Truck	Truck, 40t	0.103	3.150	0.324				**0.324**
Peppers [speciality]	0.45	Mexico	5000	Truck	Truck, 40t	0.103	2.250	0.231				**0.231**
Peppers [speciality]	0.27	Mexico	5000	Truck	Truck, 40t	0.103	1.350	0.139				**0.139**
Peppers [speciality]	0.27	Mexico	5000	Truck	Truck, 40t	0.103	1.350	0.139				**0.139**
Peppers [speciality]	0.80	Mexico	5000	Truck	Truck, 40t	0.103	3.977	0.409				**0.409**
Peppers [speciality]	0.68	Mexico	5000	Truck	Truck, 40t	0.103	3.375	0.347				**0.347**
Radish	0.85	Canada	1000	Truck	Truck, 40t	0.103	0.852	0.088				**0.088**
Salad Mix	0.11	USA	3500	Truck	Truck, 40t	0.103	0.394	0.040				**0.040**
Tomato [Cherry Orange]	0.38	USA	3500	Truck	Truck, 40t	0.103	1.317	0.135				**0.135**
Tomatoes	0.45	Canada	1000	Truck	Truck, 40t	0.103	0.450	0.046				**0.046**
Onions [White]	0.40	USA	3500	Truck	Truck, 40t	0.103	1.417	0.146				**0.146**
Zucchini	0.45	Canada	1000	Truck	Truck, 40t	0.103	0.450	0.046				**0.046**
Zucchini	0.45	Canada	1000	Truck	Truck, 40t	0.103	0.450	0.046				**0.046**
AVERAGE ITEM	**0.44**		**3279.96**			**0.13**	**1.71**	**0.27**				**0.27**
TOTAL (3 box)	**13.7**						**45.14**	**8.57**			**0.02**	**8.59**
TOTAL (1 sample box)	**4.59**						**15.05**	**2.86**			**0.01**	**2.86**

Table A.5. Emissions from transportation of a sample box in a conventional retail store.