Accounting for Reductions:

The Carbon Footprint of a Zero Waste Grocery Store

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Abstract

The food sector is responsible for 20-30% of all global greenhouse gas emissions (GHG). These emissions are a driving factor of climate change, leading some in the industry to seek opportunities for reduction. Emissions from the food system are found throughout the supply chain, from the growing practices at the farm level, transportation of products, storage, preservation and protection, and disposal. A large fraction of these GHGs are emitted after they leave the farm, as products make their way to the consumer. Grocery retailers can have a large impact on emissions, even before they leave the farm. Grocery stores are in a unique position as the intermediary between the producer and consumer. With a growing population and a strained food system in need of change, a growing number of stores are investigating their practices to seek ways to reduce their overall carbon footprint. Nada Grocery is a Vancouver, BC based grocery store that offers sustainably sourced foods, zero waste lifestyle products, and a package-free shopping experience. What sets Nada apart is their drive to not only understand their carbon emissions as a business, but also those along their supply chain. This project quantified the carbon footprint of Nada Grocery for 2019 and 2020. We identified areas of success and areas of improvement along their supply chain, as well as the carbon savings through their food waste diversion programs. With these areas identified we were able to develop a high-level framework for food retailers to use as a guide to implement initiatives that will reduce carbon emissions.

Key Words

GHG inventory
Carbon footprint
Emission reduction strategies
Food systems
Food retail
Food waste
Waste
Input-Output LCA
Supply chain emissions
Climate change
Zero waste

Executive Summary

Background, Objectives, and Significance

The science is clear: anthropogenic emissions are leading to unprecedented climate changes that are impacting both human and natural ecosystems (IPCC, 2018). The last 2 decades have had 18 of the 20 hottest years since 1850, when record-keeping began, and the IPCC reports that the 30 year time period from 1983 to 2012 was likely the warmest 30 year period in the Northern Hemisphere in over 1400 years (IPCC, 2018). Emissions must be cut across all sectors to avoid future catastrophic damage. One important sector is the food sector, which contributes somewhere between 21% to 37% of global anthropogenic emissions and presents a key challenge going forward (Mbow et al., 2019). As the global population continues to grow, we must find a way to feed a projected 9 billion people by 2050, while at the same time reducing emissions from the food sector (Buttriss & Riley 2013). This will not be easy, and will likely require a combination of agricultural intensification and yield improvements, a grid shift to renewable energy, dietary shifts, reduced food waste, and changes throughout the food supply chain, beginning with food retailers. Grocery stores play a unique role in connecting consumers to their food, and can have a large impact in influencing the entire food supply chain, as they lie at the interface of consumers, producers, and distributors (Naidoo & Gasparatos, 2018). One such store, Nada, has their sights set on revolutionizing the way we eat and connecting consumers with their food to create a more sustainable and just food system.

Nada is a zero waste grocery store, based in Vancouver, BC, and offers sustainably sourced foods, zero waste lifestyle products, and a package-free shopping experience. The business is also committed to environmental and social justice and is a certified B Corporation. One of the ways Nada is working to further reduce their environmental impact is by quantifying the carbon footprint of their business model and looking for areas they can reduce their emissions. Our team, “NadaTrace” helped them achieve this goal by calculating their carbon footprint for 2019 and 2020, with the following two objectives:

1. Establish an annual carbon footprint baseline
2. Identify and evaluate options for emissions mitigation

The results from this study will help inform Nada of their emission hotspots and where they can feasibly reduce emissions. Additionally, this study will shed light on how Nada’s business model compares to that of a conventional grocery store in terms of emissions.

Scoping and data sources

In this study, we calculated Nada's carbon footprint for both 2019 and 2020, including emissions from refrigerant leakage, emissions from purchased electricity, and emissions from upstream transportation and purchased goods & services. Appliance information to calculate refrigerant leakage was acquired from equipment SPEC sheets and charge capacity information was provided by the manufacturer. Monthly utility bills were used to quantify Nada's electricity consumption. All the data used to calculate upstream transportation and purchased goods & services emissions were extracted from Nada's purchase invoices from 2019 and 2020. To calculate the emission savings from Nada's food waste diversion program, discounted food item data was acquired from Nada.

Results

Nada's total carbon footprint in 2019 was 320,000 kg CO_2e, while in 2020 it was 252,000 kg CO_2e. Emissions from refrigerant leakage were less than 700 kg CO_2e in both years, and emissions from purchased electricity were less than 1000 kg CO_2e in both years. The majority of Nada's emissions were from upstream transportation and purchased goods & services, which together represented more than 99% of their entire carbon footprint in both 2019 and 2020. Specifically, for both years, upstream transportation represented about 17-20% of their total carbon footprint, while purchased goods and services represented about 79-83%. Emission savings from Nada's food waste diversion program varied depending on certain assumptions, but for both years fell between 4,000 and 35,000 kg CO_2e, enough to offset emissions from refrigerant leakage and purchased electricity combined.

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Introduction

Since the mid-20th century, global temperature has increased at an unprecedented rate (IPCC, 2018). This warming trend has been the result of human activities that lead to greenhouse gas emissions. Greenhouse gases trap heat and affect the transfer of infrared energy through the atmosphere (Kweku et al., 2017). This warming effect leads to the rise in global temperature. Global warming has a plethora of long-term effects that are devastating and even irreversible. Some examples include: more frequent extreme weather events, sea level rise, changes in precipitation pattern, longer growing seasons, and ocean acidification (IPCC, 2018).

To slow the rise in global temperature, intergovernmental collaboration has emerged to take action on climate change. The most notable is the Paris Agreement, which aims to limit global warming to well below 2 degrees Celsius, compared to pre-industrial levels (UNFCCC, 2021). Currently 195 countries have signed the Paris Agreement, and 190 have submitted their Nationally Determined Contributions (NDCs), which are plans for national climate actions.

In addition to efforts at the national level, the private sector also has a crucial role to play. Corporations have arguably the most power to reduce greenhouse gas emissions, as they produce almost everything that people buy, use, and throw away. Emissions are produced during almost every part of supply chains. Therefore, the opportunities for emission reductions in supply chains are huge. Many multinational corporations have committed to climate mitigation actions. For example, Volvo has announced to completely phase out internal combustion engines by 2030, including hybrids while Amazon announced that it will achieve carbon neutrality by 2040 across its business (Volvo Cars 2021; Amazon Sustainability 2020).

In order to effectively reduce greenhouse gas emissions globally, it is important to understand where emissions are coming from. When broken down by economic sectors, about 21% to 37% of annual anthropogenic greenhouse gas emissions can be traced to the food system (Mbow et al., 2019). Emissions are a byproduct of food production, and they occur at every stage in the food supply chain. At the farm stage, greenhouse gases (GHGs) are released through land use change, application of nitrogen fertilizers, soil and livestock processes, and fossil fuel combustion to power machinery (Garnett, 2011). After food leaves the farm, emissions are largely the result of transportation, refrigerant leakage, and waste (Garnett, 2011; Mbow et al., 2019; Scholz et al., 2015).

Because of the significant contribution to global emissions by the food system, businesses that are part of the food system also have important roles to play in reducing carbon emissions. Grocery stores are in a unique position to promote change in the food system, because they are the point of contact between consumers and producers of food, and have influence on both the behaviors of customers and the practices of food suppliers. They can reduce supply chain emissions by choosing suppliers based on location and food production practices, being selective of the products they sell, and reducing food waste within the store.

This study aims to quantify the carbon footprint of a zero waste grocery store and identify opportunities for emission reductions. Specifically, emissions from food waste and the supply chain, including upstream transportation, product mix, and different growing practices, are analyzed to demonstrate how the overall emissions of a grocery store may vary depending on these factors. How a grocery store approaches each one of these levers, and what practices they employ can have large implications on their overall carbon footprint. This report first summarizes existing knowledge on how the supply chain and food waste can impact overall emissions of a grocery store, then breaks down the emissions from a zero waste grocery store in both of these areas and compares them to a conventional grocery retailer. Our findings suggest that implementing best practices in each of these areas can significantly reduce the carbon footprint of a grocery store, and although there are some barriers to adoption, there is potential for conventional grocery stores to adopt these practices.

Background

Being the place where consumers and food producers cross paths, grocery stores have a lot of potential to reduce the carbon footprint of the food system. Grocery stores have control over which suppliers to source from, the products they sell, and the amount of food waste that the store generates. Because their influence covers both suppliers and consumers to varying degrees, multiple sources of carbon emissions can be mitigated, directly or indirectly, by grocery stores.

There are at least four levers that a grocery store can pull to reduce the carbon footprint of its supply chain: sourcing from local suppliers, choosing less carbon intensive food products to sell, sourcing from suppliers with low-carbon growing practices, and minimizing food waste within the storefront. Sourcing local means less distance for transporting food. However, the impact of the distance traveled by food between its production and consumption depends on multiple factors. Being selective of the product a grocery sells is also important, because food production emits greenhouse gases, and some food items have lower carbon footprints than others. Additionally, the production of the same food item can also differ in emissions, depending on the growing practices. Certain food production activities and processes lead to large emissions. Last but not least, food waste also contributes significantly to global GHG emissions, and grocery stores are responsible for a sizable portion of that waste.

In order to minimize emissions from grocery stores, one innovative business model has emerged in recent years: zero waste grocery stores. These stores offer the customers a plastic-free, bring-your-own-container shopping experience, bringing customers organically grown products from local suppliers, while minimizing food waste within the store.

Nada Grocery

One company that is catalyzing change in the food space is Nada Grocery, otherwise known as “Nada”, a package-free, zero waste grocery store. In 2018, Nada opened in Vancouver, Canada with the goal to reconnect people to their food and provide an environmentally friendly and health conscious option for consumers. Nada offers sustainably sourced foods, zero waste lifestyle products, and a package-free shopping experience. The business model also eliminates all food waste through thoughtfully designed food handling protocols.

Nada strives to minimize food and packaging waste, and is a leader among an emerging category of zero waste grocery stores. Nada has a “BYOC” (bring your own container) policy and gives nearly-expired products a new life as ready-to-eat meals served in the on-site Café. To keep prices low, Nada purchases surplus and imperfect produce directly from farmers. In addition, the procurement strategy at Nada emphasizes local, transparent, and ethical sourcing.

Despite the innovation at Nada and other zero waste stores, there are elements of the global food system that are out of store owners’ control. The complexity and inertia of the food system complicates the mission of achieving a truly waste-free supply chain. In addition, customer expectations and habits are often not aligned with the requirements of zero waste shopping. Now, in the midst of the global COVID-19 pandemic, concerns about hygiene and an increased demand for online ordering and home delivery have driven Nada to make sweeping changes to its business activities.

With the knowledge of the food system's contribution to climate change, Nada wanted to take action and discover ways they could reduce their own carbon emissions and potentially be a model for other grocery stores. However, Nada was unaware of the magnitude and distribution of their own emissions. They needed to understand what areas of their business were the most carbon intensive in order to make data-driven decisions of where to mitigate emissions. With its newer, more agile business model and commitment to environmental and social justice, Nada created a vision to understand their own carbon emissions and implement strategies that not only lower their own emissions, but educate and inspire their customers and other grocery retailers to do the same.

Nada strives to remain at the forefront of sustainability and to be a leader in their community, using their business for good and paving the way to a more just and regenerative food system. Many of Nada's efforts are focused around reducing plastic and food waste, and sourcing from local, socially and environmentally responsible farmers and suppliers who use best practices to produce their products or grow their crops. Over 100 of Nada's suppliers are located within the Lower Mainland and Vancouver Island, however with thoughts on expansion, their impact and influence are set to grow. Through our analyses, we considered four areas in which Nada has the ability to effect change. Outlined below are details about food waste and supply chain emissions including local sourcing, product mix, and growing practices. All of these explain where there is space to reduce emissions and how Nada has already reduced or can reduce emissions in the given area.

Supply Chain Practices

Local Sourcing

"Food miles", or the distance food travels between its production and consumption, is one aspect to consider when analyzing the life cycle emissions of food products. In the US it is estimated that food travels over 2000km before it reaches the consumer. Though this may be shocking to some, the actual impact food miles have on a product's total life cycle emissions vary depending on a variety of factors. Some key points to consider are what type of food is being shipped, how the food is grown, the electric grid mix where it was grown, what types of energy inputs the farmers are using, how far the food travels, and what type of vehicles the food is being transported on (Avetisyan et al., 2014). Ruminants, for example, are highly emission intensive in the production phase, so the transportation and distribution stage of red meat contributes a very low amount to the overall life cycle emissions, typically around 1 percent (Clune et al., 2017; Weber & Matthews, 2008). Fruits and vegetables, on the other hand, are less emission intensive during production, leading to a greater proportion of their emissions coming from their associated food miles (Weber & Matthews, 2008). The energy efficiency in the production of the same product is also not equal everywhere and can vary spatially. For example, some producers may use 100% renewable energy in their farm operations, while others may depend heavily on fossil fuels. To illustrate this point, a life cycle assessment (LCA) study comparing the emissions associated with lamb production in New Zealand (NZ) and the United Kingdom (UK), found that importing lamb from NZ resulted in less overall emissions in comparison to local UK lamb production, despite the long distance it had to travel (Saunders et al., 2006). This was largely due to the high energy and emission intensity of lamb production in the UK from its high reliance on fossil fuels (Saunders et al., 2006). The type of transportation food is being shipped on will also impact the relative contribution of food miles to a product's overall emissions. For example, shipping products by air is typically much more emissions intensive than shipping products by rail or by water. Average airfreight emission factors (CO_2e/tonne-km) are typically 10 to 100 times larger than rail and water transport (Cefic, 2011).

Given the complexities in assessing the overall impact of food miles on a product's life cycle emissions, it can be difficult to quantify the impact of local sourcing on emissions without knowing other attributes of the retailer, such as who they're sourcing from, how much food is going to waste, and what types of food they are sourcing. In this case of Nada, fortunately, most of these are known. Though they have yet to implement any strict tracking methods, Nada does their best to source their food from responsible farmers with sustainable, low impact growing practices. They also produce zero food waste, diverting 100% of any food waste from the landfill through discounting, donating, and composting any food items they cannot sell or donate for whatever reason. Nada also carefully curates the food products they have stocked in store, maintaining a food portfolio of largely fresh produce and very little red meat. Lastly, Nada strives to support their local community as much as possible, with over 75% of their suppliers in 2020 within 150km of their storefront. Because Nada is mindful of the environmental impact of every part of their operation, the impact of food miles and sourcing local has a larger overall effect on emissions than it may have in a traditional grocery store.

Product Mix

Food production of any kind will emit some amount of greenhouse gases, however literature shows that different foods can have a wide range of carbon emissions associated with them (Tilman & Clark, 2015). The three main contributors to GHG emissions from agriculture are methane from ruminant livestock, nitrous oxide from fertilizer use, and land clearing (Tilman & Clark, 2015). This research indicates that certain diets that prioritize low carbon-intense food (e.g., vegetables) and limit the consumption of high carbon-intense foods, can lower the amount of greenhouse gases emitted by the food system.

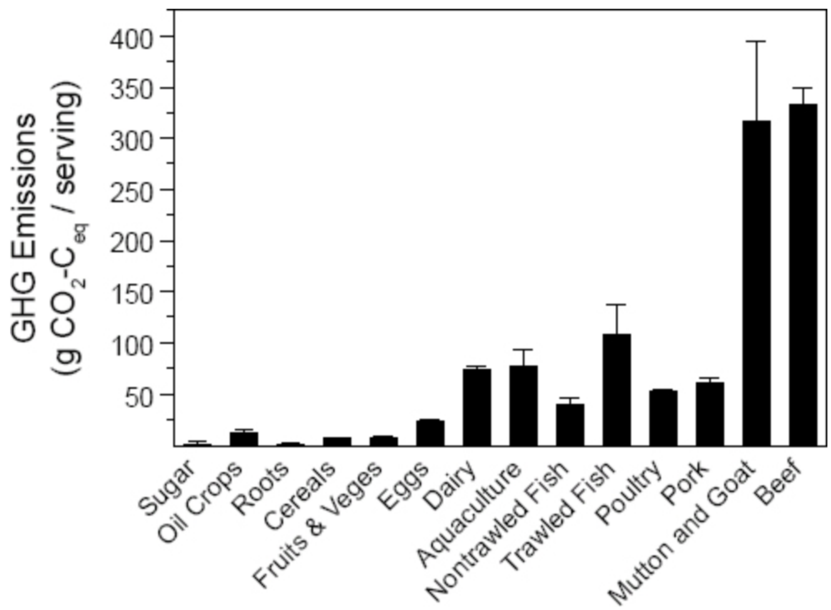

Figure 1. Greenhouse gas emissions associated with different foods. Source: (Tilman & Clark, 2015)

When broken down further taking the entire life cycle of food into account, we see that the largest impact in terms of reducing emissions can be made by specifically choosing what foods are eaten as well as the growing practices used to grow the food or raise the livestock (Figure 2).

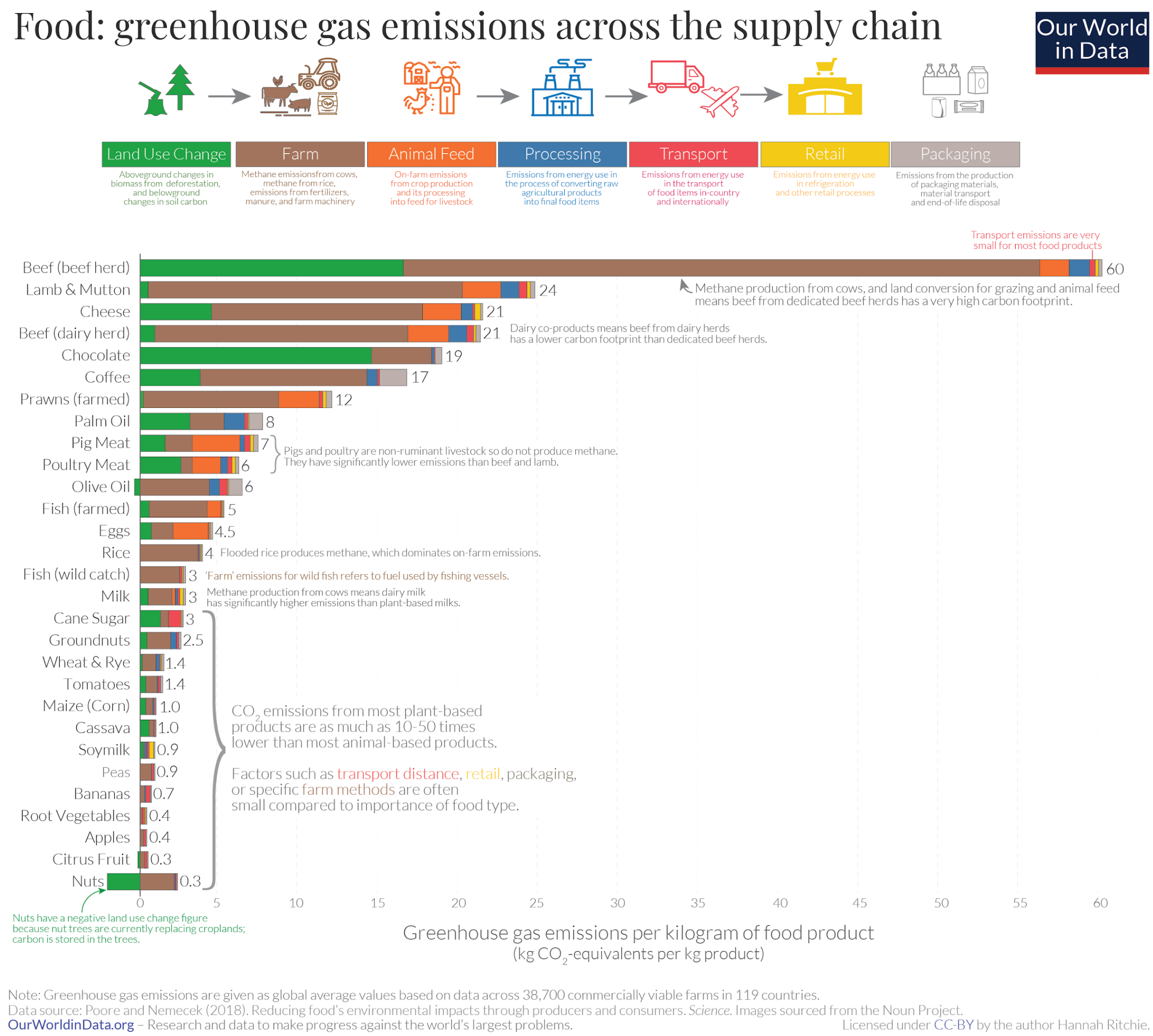

Figure 2. Greenhouse gas emissions of different foods broken down by supply chain phases. Source: (Ritchie, 2020)

Therefore, the most impactful role that grocery stores can play in the climate crisis is to source a product mix that has lower greenhouse gas emissions associated with them and source these products from farmers who use practices that regenerate the ecosystem (no-till, crop diversity, and cover cropping) (Montgomery, 2020). Nada does their best to both limit the amount of carbon-intensive products in their store and source from farmers who use climate smart farming practices. On the consumer side, large differences in emission intensities of different foods means that dietary shift is one of the most effective ways to reduce your individual carbon footprint. Long-term dietary change requires sustained contact with a similar community. Evidence suggests that identity- or role-based decision-making (i.e., "I am the type of person who lives a sustainable lifestyle") may cascade into other, positive environmental behaviors (Truelove et al., 2014; Elf et al., 2019). Association with a like-minded group also contributes to behavior change (Elf et al., 2019). Pro-environmental behaviors are affirming when they lead to positive feelings, instead of guilt or shame (Elf et al., 2019). The presence of a trusted, reputable source of information may also be associated with positive, long-term behavior change (Elf et al., 2019).

Growing Practices

Another area where grocery stores can reduce their carbon footprint is sourcing from farms that use carbon smart growing practices. By sourcing from less carbon intensive suppliers, grocery stores can reduce the greenhouse gases generated from their supply chain. Although different food items have inherently different carbon footprints, the same food item can also have varying levels of emissions depending on the growing practice. Certain activities during the production of food crops lead to large amounts of greenhouse gas emissions. The most notable is the use of nitrogen fertilizers. In one study that examined the carbon footprint of growing different food crops through different farming practices (conventional, integrated, and organic), researchers found that nitrogen fertilizers account for over 75% of the total emissions. Additionally, once nitrogen fertilizer use is accounted for, there is no significant difference between conventional, integrated, and organic farming practices (Hillier et al., 2009). This presents a lever for grocery stores to reduce their carbon footprint, because it is largely within a grocery store's control to be selective of the supplier they source from. However, it is often challenging for grocery stores to use this lever, as it requires data about the carbon footprint of the potential suppliers.

Food Waste

Food waste is responsible for 8% of all global greenhouse gas emissions (Quest, 2021). Grocery stores and supermarkets are responsible for 12% of that waste, while an additional 5% does not even make it from the supplier to the store (Quest, 2021; Feeding America, 2021). Food waste is typically generated in storefronts through damaged, expired, or imperfect products, and includes food that spoils, expires, or is otherwise left uneaten between the point of sale (the grocery store) and the point of intended consumption (e.g., a place of residence) (Ranganathan et al., 2016). These items are normally destined for the landfill, where they generate additional emissions during decomposition (Quest, 2021).

Food waste reduction has two implications for the climate and food system: avoided emissions and increased efficiency (Garnett, 2011; Ranganathan et al., 2016). Because the production of food itself generates greenhouse gases, saving food from disposal increases the efficiency of the food system (Garnett, 2011). In addition, in the landfill, uneaten food releases greenhouse gases (Sisto et al., 2017).These emissions are referred to as ''empty emissions'' as the products are not used for the intended purpose. ''Empty'' emissions include all the emissions released in production, transportation upstream, transportation to landfill, and landfill decomposition (Porter & Raey, 2014). The impact of food waste is so costly — and the potential benefits of minimization so high — that the UN Sustainable Development Goals includes the target of reducing food waste at the retail and consumer levels by 50% globally (UN, 2015).

Nada has tried to minimize both storefront and supply chain food waste losses through their in-store Café, sale of imperfect foods, discounting of imperfect or expiring foods to both employees and customers, and donation. Through these programs, Nada has eliminated all food waste since opening their storefront. Our analysis looks at the carbon savings Nada's programs provide and how Nada can be an example to other grocery stores.

Although packaging waste is out of the scope of this project, it remains a consideration for grocery retailers and consumers when making purchasing decisions. Packaging waste has become a mainstream environmental issue in North America in recent years. In 2020, the British Columbia provincial government announced plans for sweeping bans of single-use items, such as straws, following several municipalities in the province (Hernandez, 2020). Packaging waste includes a range of materials — including glass, aluminum, cardboard, paper, and plastic — that are disposed by end users (US EPA, 2017). Packaging is the most common use for plastic; nearly half of all primary production of plastic was devoted to packaging in 2015 (Geyer et al., 2017). Most of this plastic is discarded after a single use, remaining in circulation for less than one year (Geyer et al., 2017). After disposal, most plastic waste accumulates in landfills; as of 2015, most (79%) of the plastic ever made had either been landfilled or leaked into the environment (Geyer et al., 2017). In Canada, only 9% of plastic waste is recycled, and the primary contributor (43%) to plastic waste is packaging (Lee-Anderson, 2019). However, only 3% of the carbon emissions across the supply chain of food come from packaging. Additionally, there is debate about whether in some cases packaging reduces carbon emissions through avoiding food wasted from being damaged because of a lack of protection from packaging.

Food System and Equity

Food waste not only contributes to climate change, it also represents inequity within the food system. Waste represents resource depletion and environmental degradation without providing utility to society. The issues of resource depletion, environmental degradation, and climate change do not impact global communities equally. Climate change impacts reinforce existing patterns of inequity; they exacerbate transnational and intergenerational inequality (Füssel, 2010; Hartmann-Boyce et al., 2018). Environmental burdens are disproportionately borne by the poor and marginalized; with climate change, it is the same (Füssel, 2010). Because patterns of consumption drive environmental degradation, resource depletion, and climate change, the highest spenders contribute most to climate change. Meanwhile, the victims are those who are least culpable — and least equipped to adapt (Füssel, 2010).

Although these trends exist at local levels and within national borders, they are most extreme at the global level. High-income countries consume more and produce more emissions and waste — while the most countries vulnerable to climate change generally have the lowest environmental impact. (Füssel, 2010). The food we consume is one example of how consumption patterns are exacerbating the environmental inequities around the world. Diets in urbanized, high-income economies have changed, with beef, dairy, and ultra-processed foods becoming daily staples in the average diet (Füssel, 2010). These foods typically have high environmental impacts, and are highly energy and emission intensive (Tilman, 2014). Additionally, in these high-income countries, obesity rates are highest in poor and marginalized communities (Füssel, 2010). Meanwhile, in countries with minimal environmental impact, low food security, and low income, obesity prevalence is low (Füssel, 2010).

These findings suggest that the most culpable and the least vulnerable to climate change are high-income groups and countries, and those who are privileged by their race, gender, sexuality, or ability status (Füssel, 2010; Reckien et al., 2017; Hartmann-Boyce et al., 2018). The social threat of climate change is the expectation that climate change impacts would reasonably vary by income, age, race, and gender, among other marginalized identities (Hartmann-Boyce et al., 2018). Food insecurity is experienced by individuals in these groups at higher rates, and climate change is expected to worsen the disparity (Hartmann-Boyce et al., 2018). Furthermore, these groups are commonly excluded from decision-making processes at loci of power (Füssel, 2010).

Significance

Since its inception, sustainability has been at the forefront of Nada's mission. Nada has made local headlines for its commitment to the zero waste movement and its ingenuity in reducing in-store waste. Up until this point, however, Nada's focus had been on reducing waste, while it's carbon footprint and emissions had not been addressed. This project serves as the first step for Nada to begin thinking about their contributions to climate change and how they can play a role in reducing emissions. By establishing a baseline greenhouse gas inventory, Nada can pinpoint the emission hotspots within the store's operations and value chain and start addressing the areas where they can reduce their carbon footprint. Additionally, the retail sector has more influence over their supply chain than ever, and can use their unique position connecting manufacturers, producers, and consumers to shift us towards more sustainable patterns of consumption (European Commission, 2013; Naidoo & Gasparatos, 2018).

As a proven leader in sustainability, this project can help Nada leverage their position and expand their influence to educate and inform their stakeholders about climate change, and inspire them to look at their own carbon footprints and reduce their emissions. As climate change continues to become a more mainstream topic, there is increasing pressure from stakeholders for retailers to disclose their emissions, however with no consistent and standard methodology in calculating the carbon footprint of a retail store, this can often be difficult (Naidoo & Gasparatos, 2018). This project can be used as a baseline to establish a consistent and effective methodology of measuring grocery store emissions that can be replicated by others in the future. Nada can also use the information gained in this study to push other grocery stores to begin measuring, reporting, and reducing their own carbon footprints, taking their entire value chain of emissions into account. This will be one more step towards achieving their goal of creating a more just food system that builds up local communities, connects people with their food, and is resilient to climate change.

Our team, "NadaTrace", working alongside Nada, has helped bring us closer to this vision. We conducted a carbon footprint analysis of Nada's operations and supply chain, analyzed the climate impact of its waste savings, and recommended viable options for emissions reduction.

Objectives

The goal of this project is to establish a baseline carbon footprint for Nada so that they can identify strategies to reduce their emissions and continue to lead their community as an impact-driven grocery store. Though they already have many systems in-store to reduce their waste, their emissions are unknown. This project will address this knowledge gap and help Nada to continue championing sustainability in grocery stores. Specifically, this project has two objectives:

1. Establish an annual carbon footprint baseline
2. Identify and evaluate options for emissions mitigation

Methodology

Life Cycle Assessment

The process of tracing and estimating the impact of each stage in production, use, and end-of-life outcomes is called life cycle assessment (LCA). Numerous life cycle assessments of individual food products underscore the importance of transportation and product type (Sim, 2007; Craig et al. 2012). Meat and dairy products and air-freighted foods are usually associated with the highest emissions (Sim, 2007). LCAs focused on packaging tend to find that its most important role is the prevention of food waste (Russell, 2014; Humbert et al., 2009; Wikström et al., 2014). That is to say, if packaging aids in the reduction of food spoilage or waste, the presence of packaging may reduce emissions (Williams et al., 2012). Packaging itself is rarely the primary contributor to emissions (Russell, 2014).

Carbon Accounting

This analysis followed the Greenhouse Gas Protocol's reporting standards (WRI, 2004). These standards include Scope 1, 'direct' emissions and Scope 2, 'indirect' emissions. Additionally, 2 categories were included from Scope 3 'indirect value chain' emissions, Upstream Transportation and Purchased Goods and Services. Scope 1 and 2 are required however, Scope 3 is optional. Scope 3 includes 15 different categories, but it is most valuable to focus on only the top greenhouse gas generating activities (WRI, 2004).

Although this is a well-established methodology of conducting a carbon footprint, there have been criticisms around the problem of "framing" that arises in all carbon footprint accounting studies. When deciding whether certain emissions fall within or outside of a reporting entity's boundary, judgements have to be made about ownership, control, and responsibility (Haslem et al., 2014). In other words, the setting of an entity's operational boundaries can be arbitrary and malleable to some extent. It is possible to manipulate the scope in which certain emissions fall. For example, a reporting entity could sell assets and lease them back. In this way, those assets would be outside of the reporting entity's boundaries, thus moving from direct emissions to value chain emissions. Haslem et al. (2014) suggested a new approach of framing carbon accounting disclosure. This approach looks at each reporting entity's business model holistically, and dissects it into mutually-exclusive stakeholder relations that involve carbon emissions. Using this approach, reporting entities would disclose the emissions from each stakeholder relation. They argued that this business model approach would increase the visibility of carbon generating relations, and avoid arbitrariness.

Although this criticism for the framing problem is valid and should be further investigated and debated, it does not particularly concern this carbon accounting analysis for Nada. The problem with arbitrariness in setting operational boundaries is that reporting entities could take advantage of the fact that Scope 3 emissions are optional to report, and find loopholes to move certain emissions from Scope 1 to Scope 3. However, this study looks at the two Scope 3 categories that typically represent the majority of a grocery store's carbon footprint, in addition to Scope 1 and 2. Ultimately, Nada's goal through this study is to increase visibility on which supplier relations and products contribute the most carbon emissions, thus taking the first step to reduce emissions throughout the supply chain by leveraging supplier relations. In this sense, the study is aiming for the same goal as Haslem et al. (2014), who suggested the business model framing approach. Below describes each Scope's methodology and assumptions.

Scope 1: Direct Emissions

Scope 1, or 'direct' emissions include on-site emissions and emissions produced by owned property (Allwood et al., 2014). This category also includes unintentional gas leaks, which are termed fugitive emissions (Bajpai, 2018). Many of these fugitive gases are potent greenhouse gases (US EPA, 2014). Environmental policymakers are increasingly turning their attention to fugitive emission mitigation (Bajpai, 2018). Through an inventory of the store's equipment, we determined that Nada's only Scope 1 emissions are fugitive refrigerant gases.

Refrigerators and freezers are known to leak over their operational lifetime (US EPA, 2014). Historically, ozone-depleting substances (ODS) were used as refrigerants (US EPA, 2014). However, these refrigerants were phased out beginning in the late 1980s, as a result of the Montreal Protocol of 1987 (Hu et al., 2017). As ozone-depleting substances were phased out, they were largely replaced by hydrofluorocarbons (HFCs), which act as powerful greenhouse gases in the atmosphere (US EPA, 2014). Other common contemporary refrigerants include perfluorocarbons, ammonia, carbon dioxide, propane, and isobutane (US EPA, 2014). Although leakage quantities each year are small, these substances may have very high 100-year global warming potentials—making them up to 1000s of times more powerful than CO_2 at warming the planet.

There are eight on-site sources of refrigerant leaks (Table R1). Data about appliances were acquired from equipment SPEC sheets and charge capacity information was provided by the manufacturer. The refrigerants include R290, R134A, and R404A. The age of all but two freezers were known with certainty. The estimated range for the remaining two freezers was five to ten years. Five years of age was assumed to avoid biasing results to the lower end of uncertainty, although the relative impact on total Scope 1 emissions was insignificant in a sensitivity test for age.

To quantify the global warming impact of fugitive emissions on owned property, our team performed a mass balance of equations according to technical guidelines (IPCC, 2004). In the absence of data, we assumed the average annual loss rate. In accordance with guidelines for stand-alone commercial applications, a 15% annual loss rate was applied for each year since the appliance was manufactured. The estimated quantity of each refrigerant leaked in each year was converted to CO2 equivalents using global warming potentials on a 100-year time scale.

Scope 2: Indirect Emissions (Purchased Electricity)

Scope 2 is a category of emissions including those that result from the generation of purchased electricity (Electricity facts, 2020). Both Scope 1 and 2 are required reporting categories for carbon footprints according to the Greenhouse Gas Protocol (US EPA, 2020). Our team identified purchased electricity as the sole source of Scope 2 emissions for Nada. Purchased emissions tend to vary with local characteristics, such as building efficiency and grid mix (BC Hydro, 2021).

In Vancouver, BC, the local electricity grid is supplied largely (92%) by hydroelectricity generation. Hydropower is a renewable, low-carbon energy source. The utility company, BC Hydro, reports a market-based emission factor of 11 tonnes CO_2e per gigawatt-hour (BC Hydro, 2015). In addition, the store is located in a LEED Gold Certified building, which meets high performance standards for energy efficiency.

To calculate annual purchased electricity emissions, our team acquired Nada's monthly utility bills through 2019 and 2020. Using this data, we determined the annual energy consumption of the store. Then, in accordance with carbon footprinting guidelines, applied the market-based emission factor to calculate carbon equivalency (WRI, 2004).

Sources of uncertainty in this methodology include: (1) measurement error, associated with ineffective metering and (2) error associated with the consistency and reliability of the electricity emissions factor. However, because this analysis is rooted in measured data, it is an area of high confidence within the overall carbon footprint.

Scope 3: Value Chain Emissions

Scope 3, or 'value chain' emissions include any source of emissions that are pertinent to the business, but do not fall within the company's direct control. This is not a required reporting category for carbon footprints, but Scope 3 accounting provides insight into the life cycle impacts of the company's value chain. There are 15 categories within Scope 3, all of which are elective under the Greenhouse Gas Protocol (WRI, 2004). This analysis of Nada included two categories: Upstream Transportation and Distribution and Purchased Goods and Services.

Upstream Transportation and Distribution

Upstream transportation & distribution emissions were defined as greenhouse gases that result from the distribution of purchased goods between Tier 1 suppliers and Nada. Tier 1 suppliers, under our definition, include food distributors. Emissions in this category include those released through transportation-related activities, such as fossil fuel combustion in the engine of a distribution vehicle. Emissions vary depending on the mode of transportation; air transport is generally the most carbon intensive, while marine transport is typically the least carbon intensive option. Other sources of variation include vehicle characteristics and product weight.

In the absence of data about supplier vehicles, shipping weights, and shipping distance, the team relied on a simplified, but consistent, model of upstream transportation. Supplier location data was acquired in part through Nada records, online research, and approximation. When a shipping address was not available, the center of the local township or city was used as a substitute. In the absence of data relating to supplier distribution, shipping distance was estimated in kilometers using Google Maps to route an efficient path between the supplier and Nada. We assumed each purchase order by a supplier on Nada's purchase invoice to be one trip. We then found the total distance traveled per year for each supplier by multiplying the number of trips by the supplier distance. The total product weight for each supplier was calculated by looking at the top product by spend for each supplier, and using that product as a proxy for the weight of all of the products for that supplier. To do so, we found the weight per dollar spent of the top product by spend, and multiplied that ratio by the total spend on that supplier to get a final weight approximation per supplier. Mode of transportation was also unknown, so we applied the same emission factor for all suppliers, using a fleet average 3.5t – 16t lorry from Ecoinvent (0.33 kg CO_2e/tonne-kilometer).

Finally, to actually calculate the emissions for upstream transportation & distribution, we multiplied the distance each supplier traveled per year, by the approximated product weight, to get a total tonne-kilometers for each supplier. We then multiplied each supplier's tonne-kilometers by the chosen emission factor from Ecoinvent to get emissions per supplier. Finally we summed the emissions across all suppliers to get a total for upstream transportation and distribution. A summarized example for calculating emissions per supplier is illustrated below (Figure 3).

Figure 3. Example calculation for upstream transportation.

Purchased Goods and Services

The official name of this GHG Protocol emissions category is "Purchased Goods and Services", which we refer to as Purchased Goods. This category includes the supply chain emissions released into the environment by every process in the production of consumer goods. This includes, for instance, on-farm combustion of fossil fuels or methane released by ruminants.

Order quantities and total expenditures on purchased goods were acquired through the compilation of purchase order invoices for 2019 and 2020. Each of Nada's products was sorted into a CEDA (Comprehensive Environmental Data Archive) industry category. CEDA is an economic input-output tool that quantifies the life cycle environmental impacts of different economic sectors and reports the impacts on a per dollar basis (Suh, 2005). The sorting process was informed by CEDA meta data descriptions and additional product research. Once all products were categorized into CEDA categories, the total spend in each category was multiplied by the associated emission factor given in CEDA to approximate the amount of emissions, in kg CO_2e.

Because CEDA provides emission factors based on 2014 producer prices given in USD, three price conversions were performed before multiplying the total spend in each category by the associated emission factor. Expenditures in Canadian dollars (CAD) were first converted to US dollars (USD), using average conversion rates for the appropriate year. The expenditure in USD was then deflated to 2014 prices, as this was the base year for CEDA emission factors. Expenditures for 2019 and 2020 were both deflated using the 2014/2019 deflation ratio provided by the CEDA 5.06 Price Indices table. The 2014 wholesale price was then converted to producer price with a CEDA industry-specific conversion rate.

Finally, after converting the expenditure of all products to 2014 producer prices (USD), life cycle product emissions were calculated by multiplying the new expenditure by the CEDA emissions factors which were given in kilograms of carbon dioxide equivalents per US dollar (2014 producer cost), using 100-year global warming potentials. Lastly, the total kg CO_2e was summed across all categories to get the total emissions.

Food Waste Diversion

Food waste diversion — the practice of preventing food from decomposing in a landfill — is associated with efficient use of resources and avoided emissions. Food waste is not specifically included in the carbon accounting methodology, but is a large source of emissions in the food system. Although Scope 3 has a waste category, waste diversion is not addressed. The methodology we chose to represent diverted emissions follows the LCA avoided burden method (Porter and Reay, 2015). We adopted an adaptive methodology for comparing different food outcomes at Nada with disposal in landfill. Two food outcomes were observed: (1) incorporation into Café products and (2) composting. Composting is the practice of repurposing food waste through natural decomposition and nutrient recycling.

To calculate the diverted emissions two analyses were performed, one for Café and one for compost. For Café diversion emissions, the total kg of food that was used by the Café was multiplied by 3 different landfill diversion emission factors, a high, medium and low estimate. Due to the high uncertainty of food waste emissions, we chose to provide 3 different types of scenarios from North American studies (Porter & Reay, 2015). The low estimate emission factor only accounts for food diverted from landfill, but not other external factors such as transport or avoided burden (Hall et al., 2009). The medium emission factor accounts for landfill diversion and all embedded emissions, which was provided by “To Good to Go” (Truelove et al., 2014). The high emissions factor takes an avoided burden approach, accounting for all embedded emissions, diverted from landfill emissions and all emissions from avoided food purchases (Cuéllar & Webber, 2010). These 3 scenarios will provide a range of potential carbon offsets from Nada’s food waste diversion Café program.

To calculate the carbon savings of compost, the total kg of compost from both Nada and the Café was added together and multiplied by EPA emission factors for compost; one for CH_4 emitted by compost and one for the carbon savings. The final food diversion emissions were added together to get Nada’s food waste emissions savings in a single year. Due to data management changes over the course of the study period, we were unable to calculate the impact of imperfect and blemished food sales over 2019 and 2020.

Results

Nada’s total carbon footprint for 2019 was 320,300 kg of CO_2e. Scope 1 and 2 emissions (emissions from refrigerant leakage and purchased electricity) were very small relative to their total carbon footprint, and combined made up less than 1% of their total emissions in that year. Scope 1 emissions were 666 kg of CO_2e while Scope 2 emissions were 978 kg CO_2e. Scope 3 emissions made up over 99% of their total emissions in 2019, with about 54,000 kg of CO_2e (~17%) coming from upstream transportation and 265,000 kg of CO_2e (~83%) coming from purchased goods & services, for a combined total of about 319,000 kg of CO_2e.

For 2020, their total emissions were 252,000 kg of CO_2e. This 21% reduction was likely due to the decrease in product sales as a result of the temporary closure due to COVID-19. Although there was an overall reduction in emissions, the distribution of emissions was very much the same as 2019, with Scope 1 and 2 emissions making up less than 1% of their total emissions combined and contributing 567 kg CO_2e and 875 kg CO_2e respectively. Scope 3 emissions in 2020 once again made up over 99% of their total carbon footprint, with upstream transportation emitting 50,490 kg CO_2e and contributing to about 20% of their overall emissions, while purchased goods & services emitted about 200,000 kg CO_2e, making up about 79% of their total carbon footprint.

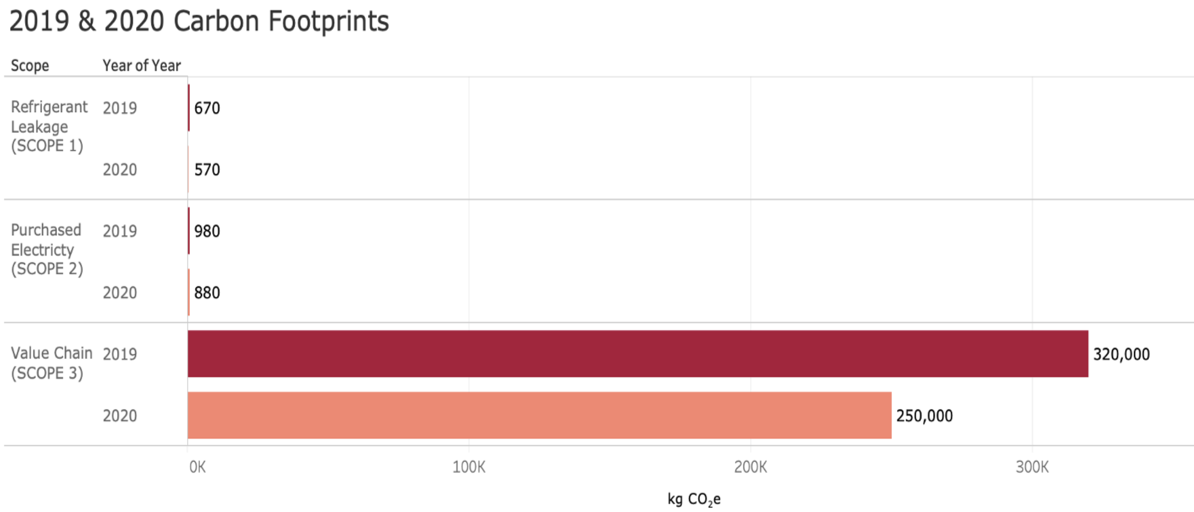

Figure 4. Nada's 2019 and 2020 carbon footprint (kg CO_2e), broken down into Scope 1, 2, and 3 emissions. Scope 3 emissions are rounded to the nearest thousandth. Total emissions were 320,300 kg CO_2e in 2019, and 252,000 kg CO_2e in 2020.

Outlined below are more detailed analyses of the emissions from Scope 1, 2, and 3, as well as the results of our analysis of Nada's food waste diversion program.

Scope 1: Direct Emissions

In the baseline year, 2019, fugitive emissions totaled to 666 kg CO_2e. Because of R290's low global warming potential, its relative impact on overall Scope 1 emissions was less than 0.1% in 2019 (Table R1). Most of the impact (86%) was the result of R404A leakage, which contributed 570 kg CO_2e to the footprint in 2019. The relative impact of R134A leakage was lower (14%), at 96 kg CO_2e.

Table R1. *Scope 1 Emissions at Nada Grocery (2019): Three refrigerants were identified as contributors to Scope 1 emissions: R290, R134A, and R404A. The majority of appliances (6) use R290 as a refrigerant. Despite contributing a relatively low quantity toward the overall leakage mass, R134A and R404A contributed 14% and 86%, respectively, to the overall climate impact of Scope 1 emissions.*

Refrigerant	No. of Appliances	100-Year Global warming Potential (GWP 100)	Emissions (kg CO_2e)	% Contribution
R290	6	3(Hoornweg et al., 2018)	0.21	< 0.1 %
R134A	1	1,300 (Sisto et al., 2017)	96	14 %
R404A	1	3,922 (Russell, 2014)	570	86 %
TOTAL	*8*	*n/a*	*666*	*100 %*

In 2020, fugitive emissions decreased by 15% (an artifact of the 15% annual loss rate assumption) to 567 kg CO_2e. As the appliances age, their carbon footprint continues to decrease.

Scope 2: Indirect Emissions (Purchased Electricity)

In 2019, purchased electricity emissions totaled 978 kg CO_2e and accounted for 0.29% of the total annual footprint. In 2020, Nada's emissions from purchased electricity decreased by 10.6% from 978 kg to 875 kg CO_2e (Table R2). This decrease could be attributed to closure of the store in 2020 as a result of the COVID-19 pandemic. Even when the store reopened in July 2020, the store only operated during limited store hours and transitioned to a delivery model which lowered their in-store energy consumption. Both of these factors could have led to the lower emissions from purchased electricity in 2020 compared to 2019.

Table R2*. Scope 2 Emissions from Nada Grocery in (2019 & 2020). From 2019 to 2020, Nada's scope 2 emissions from purchased electricity decreased by 10.6% from 978 kg* CO_2e *to 875 kg* CO_2*e.*

Purchased Electricity	Emissions (kg CO_2e)	% change
2019	978	-
2020	875	-10.6%

Scope 3: Value Chain Emissions

In 2019, Scope 3's total emissions were ~319,000 kg CO_2e accounting for over 99% of all GHG emissions. Purchased goods and services accounted for over 80% of the emissions, with ~265,000 kg CO_2e. Transportation emissions were approximately ~54,000 kg CO_2e. The total Scope 3 emission broken down by top 5 contributing subcategories per category are shown in Figure 5.

In 2020, Scope 3's total emissions were ~ 250,000 kg CO_2e, which was a 27% decrease from 2019. Although Scope 3 emissions decreased from 2019 to 2020, the emission distribution stayed relatively the same. Scope 3 still accounted for 99% of all carbon emissions in 2020. The emission breakdown for 2020 can be found in Figure 6.

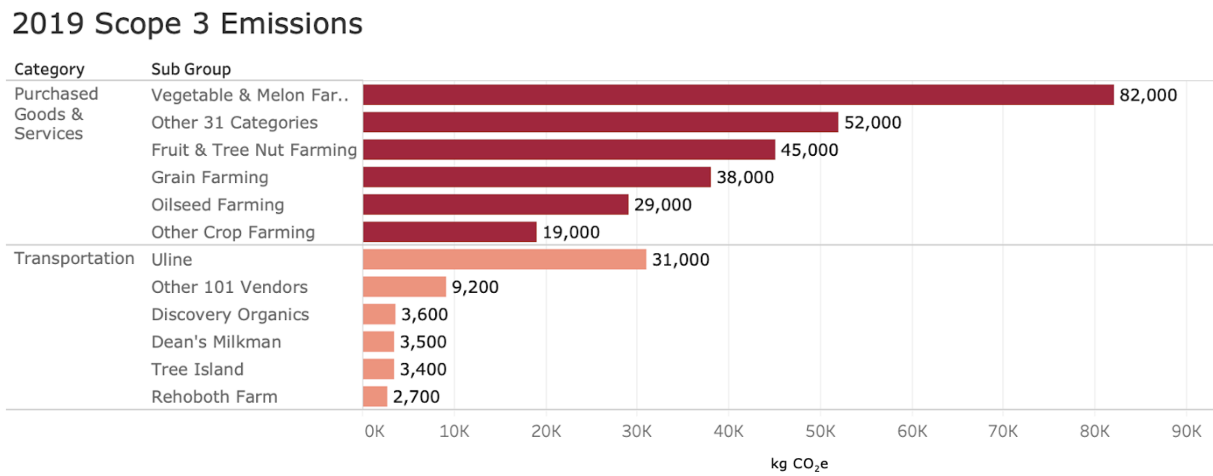

Figure 5. 2019's Scope 3 emissions broken down by the top 5 contributing subgroups per category.

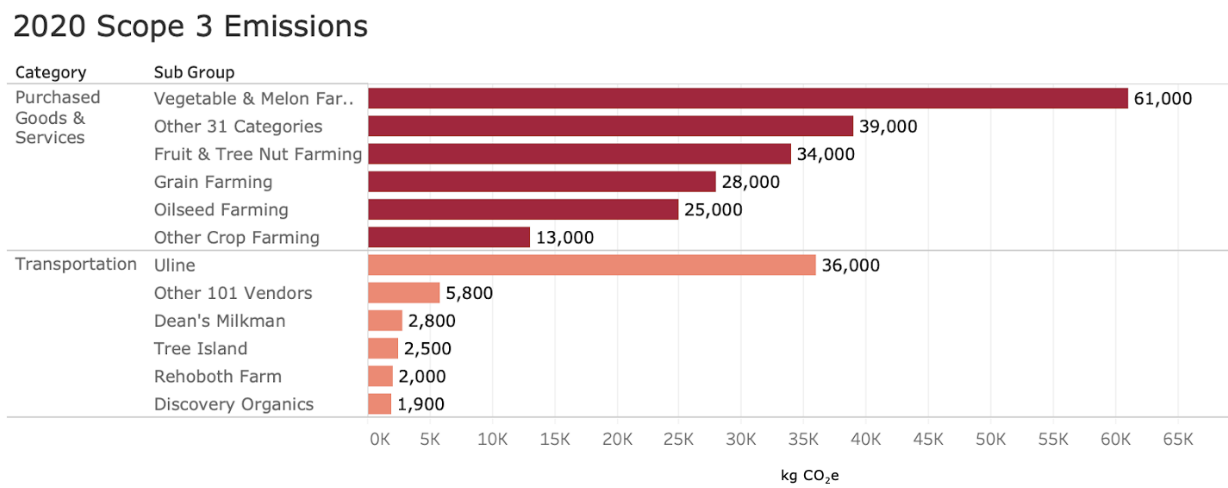

Figure 6. 2020's Scope 3 emissions broken down by the top 5 contributing subgroups per category.

Upstream Transportation

In 2019, Nada purchased products from 106 different vendors, though the emissions from the majority of these vendors were an extremely small percent (<1%) of Nada's upstream transportation & distribution emissions. For 2019, the total emissions from the Scope 3 category, upstream transportation & distribution were 53,570 kg CO_2e. The vendor that contributed the most to Nada's emissions in this category was ULINE, emitting 31,228 kg CO_2e in 2019, and making up about 58% of the total emissions in the upstream transportation & distribution category. The top 5 emitters made up over 80% of the emissions within this category, while the top 10 emitters made up over 90% of the emissions. The top 10 emitters for 2019, ranked in order of emissions were ULINE, Discovery Organics, Dean's Milkman, Tree Island Gourmet Yogurt, Rehoboth Farm, Left Coast Naturals, Klippers Organics, Nelson Naturals, Brush Naked, and Giddy Yo (Table R4). When normalized to emissions per dollar, ULINE stands alone at 3.54 kgCO_2e/CAD, with Tree Island Gourmet Yogurt the next closest at 0.61 kgCO_2e/CAD (Table R3).

In 2020, Nada purchased products from 102 different vendors, again, with the majority of the emissions in upstream transportation & distribution concentrated in the top 10 vendors. In 2020, the total emissions from upstream transportation & distribution were 50,490 kg CO_2e. This was about a 6% reduction from the year 2019. The vendor that contributed the most to Nada's emissions in this category in 2020 was ULINE, the same as in 2019. In 2020, however, ULINE's emissions in this category actually increased from 31.2 metric tons of CO_2e, to 35.5 metric tons of CO_2e, about a 12% increase. Their overall percent contribution to this category also increased to just over 70% of the emissions. The top 10 emitters combined for 2020 made up just over 95% of Nada's total upstream transportation & distribution emissions, while the top 5 made up over 88%. Ranked in order of emissions, the top 10 emitters in this category for 2020 were ULINE, Dean's Milkman, Tree Island Gourmet Yogurt, Rehoboth Farm, Discovery Organics, Factory Direct Vinegar, Left Coast Naturals, Giddy Yo, A Bread Affair, and Klippers Organics (Table R5). Again, ULINE is by far the most emission intensive supplier when emissions are normalized per CAD, at 2.75 kgCO_2e/CAD, while Tree Island Gourmet Yogurt comes in at second again with the same emission intensity from 2019 of 0.61 kgCO_2e/CAD (Table R3).

Table R3. Top 5 vendors by emission intensity (kgCO_2e/CAD) in 2019 and 2020.

2019		**2020**	
Vendor	**kg CO_2e/CAD**	**Vendor**	**kg CO_2e/CAD**
1. ULINE	3.54	**1. ULINE**	2.75
2. Tree Island Gourmet Yogurt	0.61	**2. Tree Island Gourmet Yogurt**	0.61
3. Giddy Yo	0.38	**3. Factory Direct Vinegar**	0.37
4. Dean's Milkman	0.27	**4. Dean's Milkman**	0.28
5. Rehoboth Farm	0.18	**5. Giddy Yo**	0.26

In both 2019 and 2020 the top 5 highest CO_2e emitting suppliers remained the same, with only slight changes in order after ULINE at the top. The top 10 emitters of CO_2e for both years were also nearly the same with only two changes. In 2020, Factory Direct Vinegar, a vendor Nada did not purchase from in 2019, was the 6th largest contributor to the upstream transportation & distribution emissions, while A Bread Affair came in at 9th, after ranking 22nd in the previous year. The 8th and 9th top emitters in 2019, Nelson's Naturals and Brush Naked, fell to 16th and 22nd respectively, in 2020.

Table R4. *Top 10 contributors to Upstream Transportation & Distribution emissions in 2019.*

Vendor	Metric Tons CO_2e	% Contribution
1. ULINE	31.2	58
2. Discovery Organics	3.6	7
3. Dean's Milkman	3.5	6
4. Tree Island Gourmet Yogurt	3.4	6
5. Rehoboth Farm	2.7	5
6. Left Coast Naturals	1.8	3
7. Klippers Organics	1.2	2
8. Nelson's Naturals	0.9	2
9. Brush Naked	0.6	1
10. Giddy Yo	0.6	1

Table R5. *Top 10 contributors to Upstream Transportation & Distribution emissions in 2020.*

Vendor	Metric Tons CO_2e	% Contribution
1. ULINE	35.5	70
2. Dean's Milkman	2.8	5
3. Tree Island Gourmet Yogurt	2.5	5
4. Rehoboth Farm	2.0	4
5. Discovery Organics	1.9	4
6. Factory Direct Vinegar	1.3	3
7. Left Coast Naturals	0.8	2
8. Giddy Yo	0.5	1
9. A Bread Affair	0.4	1
10. Klippers Organics	0.4	1

Purchased Goods and Services

In 2019, Nada's carbon footprint from purchased goods and services was 265,000 kg CO_2e, which accounted for 83% of the total carbon footprint. Among the 36 CEDA categories used, the top five by contribution to total purchased goods and services emissions were:

- Vegetable and melon farming
- Fruit and tree nut farming
- Grain farming
- Oilseed farming
- Other crop farming.

The respective emissions for these categories are listed in Table R7. The biggest contributor by far is vegetable and melon farming, which accounted for 31% of the total purchased goods and services emissions in 2019.

In terms of emissions per Canadian dollar, the top five categories were (Table R6):

- Floriculture
- Grain farming
- Vegetable & melon farming
- Other crop farming
- Fruit & tree nut farming

Except for floriculture, the other four categories were also among the top five by actual amount of carbon emitted.

Table R6. Top 5 Product Categories by emission intensity (kgCO_2e/CAD) in 2019 and 2020.

2019		2020	
Product Category	**kg CO2e/CAD**	**Product Category**	**kg CO2e/CAD**
1. Floriculture	1.14	**1. Floriculture**	1.14
2. Grain Farming	1.11	**2. Grain Farming**	1.11
3. Vegetable & Melon Farming	1.06	**3. Vegetable & Melon Farming**	1.06
4. Other Crop Farming	0.99	**4. Other Crop Farming**	0.99
5. Fruit & Tree Nut Farming	0.82	**5. Fruit & Tree Nut Farming**	0.82

In 2020, Nada's carbon footprint from purchased goods and services dropped to 200,000 kg CO_2e, which is 79% of the total carbon footprint. When compared to 2019 purchased goods and services emissions, the 2020 emissions were smaller, but the percentage to the total carbon did not change significantly. Among the 36 CEDA categories used, the top five by contribution to total purchased goods and services emissions remained the same as in 2019. The respective emissions for these categories are listed in Table R8. In 2020, the largest emitting category, vegetable and melon farming, contributed to 30% of the total purchased goods and services emissions. In terms of emissions per Canadian dollar, the top five categories in 2020 were the same as 2019.

Table R7. *Scope 3 Purchased Goods & Services (2019): Top 5 product categories in terms of contribution to total footprint.*

Product Category	Category Emissions (kg CO_2e)	% Contribution
1. Vegetable & Melon Farming	82,000	31%
2. Fruit & Tree Nut Farming	45,000	17%
3. Grain Farming	38,000	14%

4. Oilseed Farming	29,000	11%
5. Other Crop Farming	19,000	7%
All Other Categories	52,000	20%
Total Purchased Goods & Services Emissions	**265,000**	

Table R8. *Scope 3 Purchased Goods & Services (2020): Top 5 product categories in terms of contribution to total footprint.*

Product Category	Category Emissions (kg CO_2e)	% Contribution
1. Vegetable & Melon Farming	61,000	30%
2. Fruit & Tree Nut Farming	34,000	17%
3. Grain Farming	28,000	14%
4. Oilseed Farming	25,000	13%
5. Other Crop Farming	13,000	6%
All Other Categories	39,000	20%
Total Purchased Goods & Services Emissions	**200,000**	

Food Waste Diversion

In 2019, Nada diverted between 4,100 to 12,000 kg CO_2e from going to the landfill. Compost emission savings were 750 kg CO_2e, while Café emission savings ranged from 3,300 to 11,000 kg CO_2e (Table R9). While food waste diversion offset less than 3% of Nada's total 2019 carbon footprint, food waste diversion completely offset Scope 1 and 2 emissions in all 3 scenarios. Food waste diversion offsets were 2.7 times more than Scope 1 and 2 emissions. Although food waste diversion is small when compared to the carbon footprint as a whole, offsetting Scope 1 and 2 is a great start for food waste diversion programs.

Table R9. *Food waste diversion High, Medium, Low estimates (2019).*

Estimate	Café (kg CO_2e)	Compost (kg CO_2e)	Emission Savings (kg CO_2e)
High	11,000	750	11,750
Medium	5,300	750	6,050
Low	3,300	750	4,050

In 2020, Nada diverted 11,500 to 36,000 kg CO_2e from the landfill. Compost diverted 1,500 kgCO_2e from landfill, while the Café ranged from 10,000 to 35,000 kg CO_2e diverted (Table R10). 2020 diverted emissions were over 3 times that of 2019 emissions and 5-18 times that of 2020's Scope 1 and 2 emissions. While there was a large increase in diverted emissions, compared to the entire footprint, food waste offset about 4-14% of emissions. Although not as large of an offset as predicted, these are still extremely valuable savings when looking at the store as a whole. Compared to 2019, there was a large increase in both Café and compost diversion. This increase leads us to believe that more food was being composted or used in the Café in 2020 due to the limitations of the shopping due to COVID-19 safety protocols. Other food waste programs, like discounted damaged goods also stopped due to a shift to online delivery service, which may have led to more imperfect food being used in the Café. All of these could have led to a large increase in compost and Café emission savings.

Table R10. *Food waste diversion High, Medium, Low estimates (2020).*

Estimate	Café (kg CO_2e)	Compost (kg CO_2e)	Emission Savings (kg CO_2e)
High	35,000	1,500	36,500
Medium	16,000	1,500	17,500
Low	10,000	1,500	11,500

Overall food waste diversion programs, although small compared to Nada's overall carbon footprint, offset more than Scope 1 and 2 emissions in both years. Food waste diversion programs are a viable way to offset Scope 1 and 2 emissions, as well as some Scope 3 emissions.

Discussion and Recommendations

Our results show that the majority of Nada's carbon footprint comes from supply chain emissions, which in both years made up over 99% of the entire carbon footprint. Specifically, upstream transportation represented about 17% in 2019, and 20% in 2020, while purchased goods and services represented about 83% and 79% in 2019 and 2020, respectively. Having identified Scope 3 as the largest source of emissions, we then honed in on Scope 3 emissions to identify hotspots and potential mitigation recommendations.

The hotspot for upstream transportation is the supplier ULINE, who supplies Nada with reusable glass jars, contributing to 58% and 70% of the total upstream transportation emissions in 2019 and 2020, respectively, and is by far the most emission intensive supplier on a per dollar basis. Given the high emission intensity of shipping ULINE's products, and the relative ease of finding a substitute product for the glass jars they supply, it is recommended that Nada find a more local supplier to source their glass jars from.

There are, however, a few sources of uncertainty in our methodology for calculating upstream transportation emissions. First, product weights were not always available, so product weights were calculated for each supplier by using the weight of the product that Nada spent the most on as an approximation for all of a given supplier's products. Second, the type of vehicles used by each supplier is unknown; therefore, the emission factors are unknown. We assumed that all transportation trips used the same vehicle (3.5t – 16t lorry, Ecoinvent).

In the other Scope 3 category analyzed, purchased goods & services, emissions were broken down by product category as opposed to by supplier. The hotspots were the following product categories:

- Vegetable and melon farming
- Fruit and tree nut farming
- Grain farming
- Oilseed farming
- Other crop farming

However, our results did not reveal top contributing suppliers for purchased goods and services. This is because our methodology uses the CEDA database, which has information on the average carbon emissions of certain food producing and processing industries, but does not differentiate between suppliers within the same industry. In other words, by using the CEDA database, our study sacrificed the granularity of differentiating low-carbon suppliers from high-carbon suppliers from the same industry. Nevertheless, CEDA allowed us to quantify all of the value chain emissions that stem from the production of the food products purchased by Nada.

Despite a lack of granularity, general comparisons to other retailers can still be made. Some of the areas that set Nada apart from conventional grocery retailers are their supply chain practices, including sourcing locally and stocking foods with low emission intensities, and diverting all food waste. Described below are more detailed analyses of how each of these areas can affect overall carbon emissions and how Nada's emissions compare to a conventional grocery store.

Implications of Supply Chain Practices

Impacts of Product Mix & Sourcing

Foods have varying carbon emissions associated with them (Tilman, 2014). Therefore, the product mix that a grocery store carries can have a range of effects on their carbon footprint. Nada carries a product mix where a majority of their products come from vegetable and melon farming, fruit and tree nut farming, oilseed farming and grain farming. Nada is a unique grocery store that already carries a product mix in their store that promotes a plant-based, low carbon-intense diet and doesn't carry many animal products.

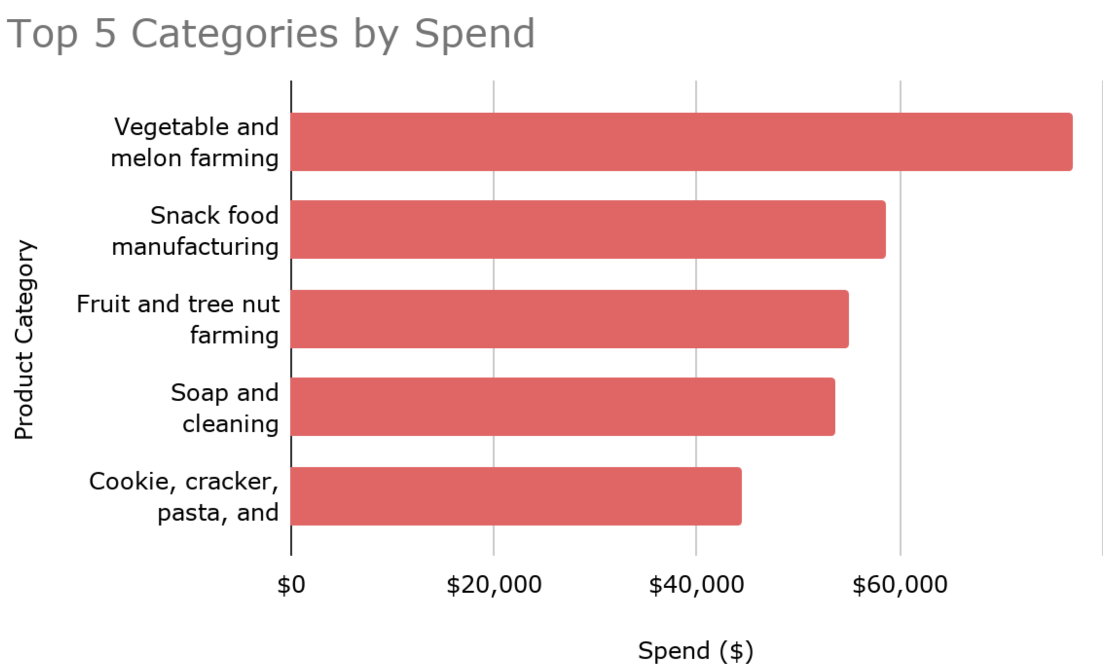

Figure 7. Nada sources and carries a selection of foods that are lower in greenhouse gas emissions. A majority of their spend goes to produce, snack foods, and nuts.

To understand how the emissions from Nada's product mix compares to that of a conventional grocery store, we estimated the emissions of a conventional grocery store's product mix using data from a report by FMI (2020) that shows the product mix breakdown of a conventional grocery store. This study gives percentages for the breakdown of products a conventional grocery store carries (i.e. the percent of meat, dairy, produce), which we recategorized into 12 CEDA categories to estimate the emissions of a conventional grocery store's product mix. To make a fair comparison, we then recategorized Nada's products into the same 12 CEDA categories used for the conventional grocery store, and recalculated Nada's Purchased Goods & Services emissions. In this comparison we are using the assumption that customers only buy products that the grocery store offers.

Nada's carbon footprint from products carried was 8% lower than the carbon footprint of a conventional grocery store. This implies that Nada's efforts to source and sell an intentional product mix has been effective in lowering their carbon footprint.

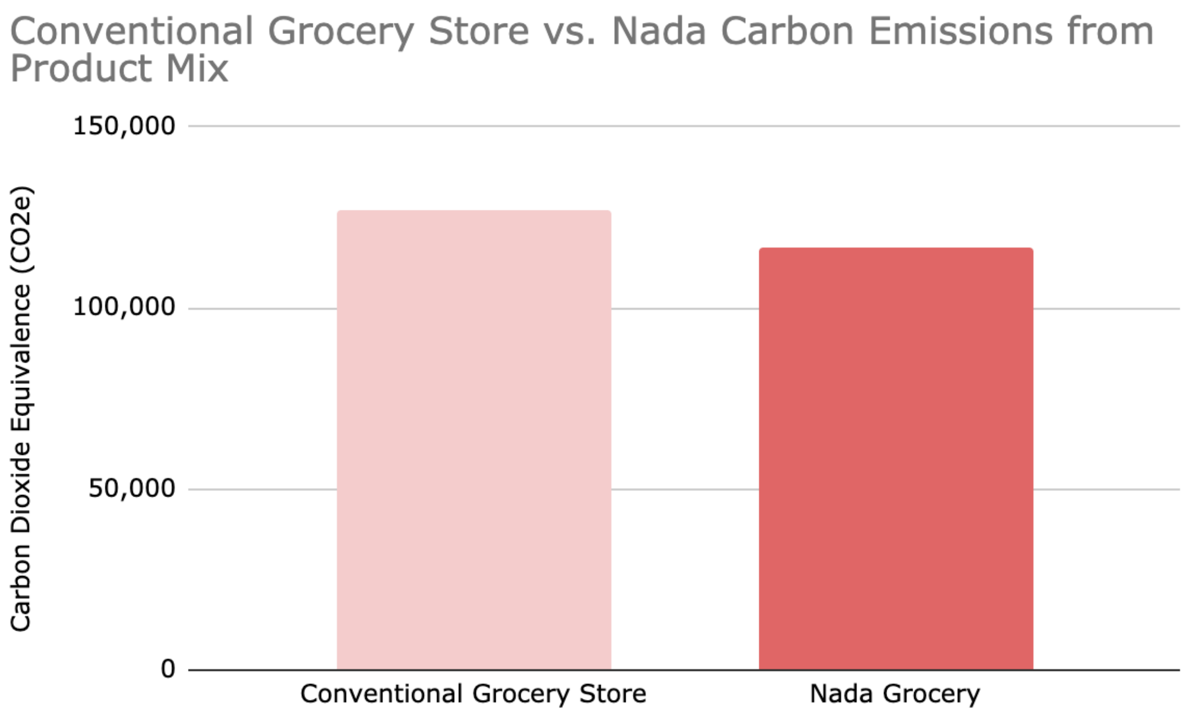

Figure 8. Nada Grocery releases 8% less carbon emissions to the atmosphere than a conventional grocery store when comparing the product mix that each store carries and offers to their customers. This only represents the carbon emissions associated with the percent of food categories that each store carries.

We recommend that Nada continue to source and offer an intentional product mix to consumers. This can be one way to lower carbon emissions involved in food consumption. We recommend that Nada influence upstream suppliers through buying specific products from them as well as influence downstream consumers through offering a specific product mix and education around why eating this diet is important. There are opportunities for Nada to improve their communication to consumers about the "why" behind their sourcing decisions. With eco-labels on products and marketing channels that educate consumers about the carbon emissions associated with various foods, Nada can change consumer behavior to make purchasing decisions with the environmental impacts of foods in mind.

These reductions lead to more efficient and streamlined operations, cost-savings, and can help them stay ahead of policy. This comparison between Nada and a conventional grocery's store product mix is also useful for informing other grocery stores. It shows them the emission reduction potential of changing the product mix that they offer. Although doing an exact comparison between Nada and a conventional grocery store poses issues because of the differences in the business model, supply chain, and operations, the product mix that Nada sources can be used as a high level framework for conventional grocery stores. With this hypothetical comparison we can imagine the potential reductions in carbon emissions that could occur as a result of conventional grocery stores offering a product mix to consumers that focuses on foods with lower carbon footprints.

Impacts of Supplier Selection & Growing Practices

In addition to choosing to sell foods with lower carbon footprints, emission reductions can also be achieved through choosing to source from suppliers with good growing practices. Regenerative growing practices that minimize the use of nitrogen fertilizers will have lower footprints than conventional practices. However, currently this is outside the scope of this study, as the methodology uses industry average emission factors. As a result, there is no information on the growing practices of each supplier and the resulting emissions from their food production. Therefore, the next logical step in reducing the carbon footprint of Nada's purchased goods and services is to engage with suppliers and acquire supplier-specific data. This is a challenging task for Nada, because in the past suppliers have been reluctant to respond to surveys. This could be caused by a number of reasons. Suppliers might fear that Nada will no longer source from them if they disclose carbon footprint information; or suppliers could simply lack the know-how to quantify their carbon footprint. Although it is unknown what caused the reluctance, Nada should take precautions when engaging suppliers, minimizing any conceivable difficulty or fear of the suppliers.

As a general strategy, we recommend Nada work with the current suppliers and encourage them to adopt farming practices that minimize the use of nitrogen fertilizers and make it convenient for suppliers to quantify their own carbon footprint by only asking for specific, easy to acquire information, such as the quantity/type of fertilizers used and the acreage of land fertilized.

Impacts of Local Sourcing

Sourcing locally can also have a significant impact on upstream transportation emissions and when applied in unison with good practices in other areas, can play a significant role in reducing the overall carbon footprint of a company. Because Nada rigorously uses best practices throughout all areas of their operations, their efforts to source locally likely have a larger impact on their carbon footprint than that of a conventional grocery store. This comparison, however, is difficult to make because our study only looks one tier up at the upstream transportation from the distributor to Nada, so any comparison to the overall food miles of a traditional grocery store would not be fair. We do know, however, that the majority of Nada's suppliers are local, which is typically not the case with most large traditional retailers (Wells, 2016).

To approximate the impact of sourcing locally, we used average food miles from a study that estimated and compared the distance traveled of locally sourced food and conventionally sourced food (Pirog et al., 2003). In this study, Pirog et al., looked at 16 different types of produce and calculated each item's food miles based on if it was locally or conventionally sourced. For comparison purposes, we used the farthest distance of a locally grown product to define "local", which in this case was 75 miles. By this definition, 70% of Nada's suppliers are local, while 30% are not. To model a store that sources locally, we applied the average local distance (56 miles) from the Pirog et al. study, to all of Nada's local suppliers, and the average conventional distance (1,494 miles) to all of Nada's non-local suppliers, and recalculated upstream transportation emissions. To model a conventional grocery store we used the average conventional distance for all of Nada's suppliers and recalculated the upstream transportation emissions again.

When comparing Nada to a conventional grocery store under these assumptions, we found that there was a 94% reduction in upstream transportation emissions (Figure 9). Although this is a very rough approximation with many assumptions, it shows that under certain circumstances, food miles and local sourcing can have a very large impact on a store's upstream transportation emissions, with its overall impact dependent on the various other factors mentioned previously.

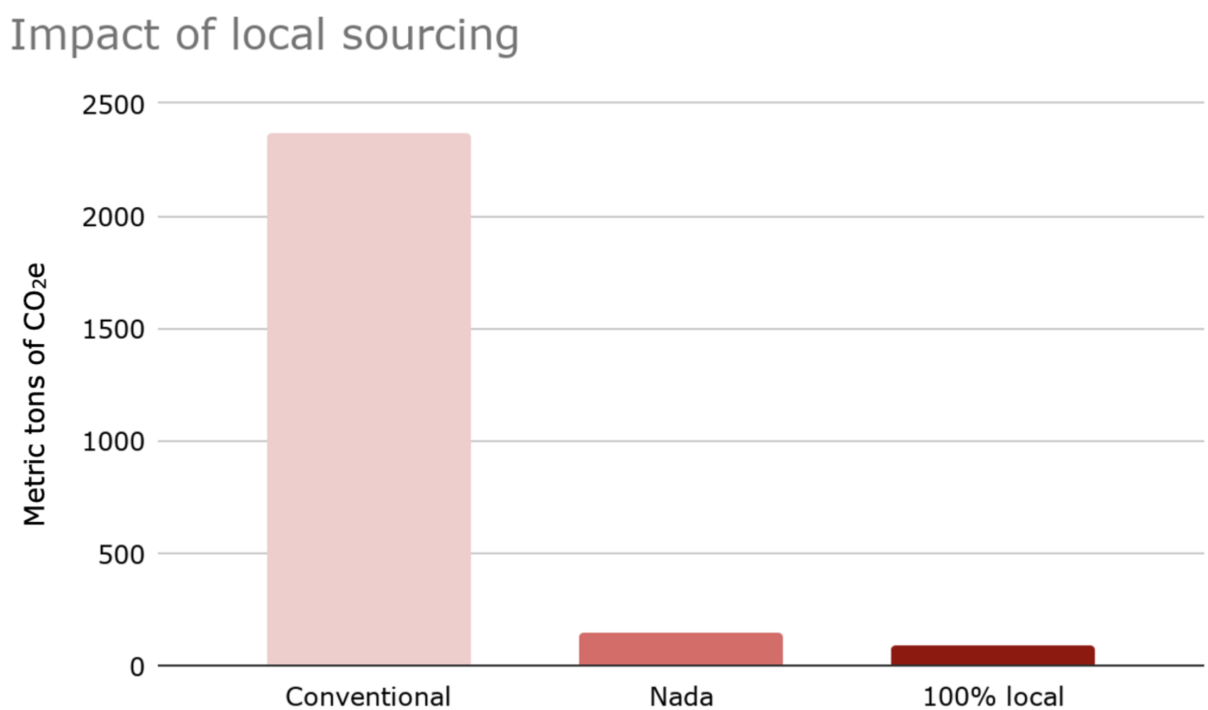

Figure 9. Comparing the upstream transportation emissions using a standardized distance for local and non-local suppliers. Suppliers are considered 'local' if they are within 120km of the store. All suppliers who fit this definition were assigned the same distance of 90km. All suppliers who did not were assigned a distance of 2404km. Conventional stores are assumed to be 100% non-local and Nada's suppliers are 70% local.

For Nada, we recommend they continue their efforts to source as locally as possible. Given that Nada sources from farmers with sustainable practices and environmentally conscious suppliers, stock relatively few meat items in store, and generate zero food waste, the emissions from the upstream transportation of their products likely contribute a larger overall percentage to their total carbon footprint than it would in a conventional grocery store. It is thus important that Nada continue to source locally, as well as try to find substitutes for those few suppliers who are located farther away, particularly ULINE. For certain products like avocados and bananas, it will be impossible to source locally, so for these products it is important for Nada to source these from responsible farms with sustainable, regenerative practices, and try when possible to have them shipped by ocean freight or rail as opposed to airfreight.

Implications of Food Waste Diversion

Nada has diverted upwards of ~47,000 kg of CO_2e between 2019 and 2020 through their Café and compost efforts. Our results show that through these food waste diversion programs, they were able to offset ~7% of their overall emissions. Nada is successfully executing the top 3 favorable diversion strategies from the European Commission of Sustainable Food. These strategies include reduction, reuse, recycling, and recovery for energy and disposal (Papargyropoulou et al., 2014). Programs like Nada's Café and composting have the highest potential for emissions savings, compared to traditional disposal (Moult et al., 2018).

The Café is a great example of how grocery stores can incorporate imperfect foods, damaged items, and other food waste products into their emission reductions efforts. The Café diverts over 75% of potential food waste in the store, while also creating a viable product for purchase. All of the raw material for the Café come solely from products that were destined for landfill. Nada is able to recapture these products, provide a good at a fraction of the cost to them, and avoid food waste in their store. Most grocery stores sell products that are made in house and could potentially adopt a version of Nada's Café program. By following Nada's Café model, grocery stores could greatly reduce their food waste, while also providing in house items at a lower cost of production.

While compost was a small portion of Nada's food waste, it is a viable program that other stores can adopt to divert greenhouse gas emissions produced by food waste. Nada's compost program has a smaller impact than other grocery stores should expect because the Café diverts as much food waste as it can before going to compost. Nada has demonstrated that composting can be done effectively at a grocery store level. Overall, Nada's food waste diversion programs are a great blueprint for other grocery stores to follow.

We recommend that Nada continue their food waste diversion programs, as well as promote the carbon savings from them. In addition, Nada should track all food waste consistently across all programs. We suggest tracking the weight of all items and giving them a code for which program they are going to. This would allow Nada to more accurately calculate all of their emissions savings from their food waste programs.

By promoting the benefits of the food waste diversion programs, Nada could inspire customers and suppliers to implement similar programs. The European Commission has reported that retailers like Nada have a growing influence both up and downstream of the supply chain (European Commission, 2013). Nada has the unique opportunity to influence how suppliers and consumers deal with food waste through education and sharing of their different food waste diversion programs. Nada has proven that their food waste programs are a viable way to divert emissions and has a great opportunity to expand its influence beyond the building doors.

Conclusion

With climate change looming, as the global population continues to grow, and the demand for food continues to rise, it is crucial that we find ways to reduce the emissions associated with the food system. For most people, grocery stores are the vehicle that connects them to their food. Grocery stores thus play a critical role in transforming the food system and have a unique opportunity to better connect people to their food and help them make more sustainable food choices.

This study quantified the carbon footprint of Nada in 2019 and 2020. Specifically, Nada’s emissions from refrigerant leakage, purchased electricity, upstream transportation, and purchased goods and services, are reported. The emission reduction through Nada’s food waste diversion program is also quantified. This study found that upstream transportation and purchased goods and services contributed the majority of the entire carbon footprint and that the emission reductions from food waste diversion was larger than Nada’s emissions from refrigerant leakage and purchased electricity combined, in both 2019 and 2020. From the analysis, hotspots of carbon emissions were uncovered and specific areas for Nada to mitigate emissions were identified.

Recommendations

1. **Acquire supplier specific data** on emission factors and work with suppliers to implement data tracking practices and low carbon growing practices. Suppliers differ in their growing practices, leading to vastly different food production emissions. Nitrogen fertilizer use accounts for 75% of the total emissions of growing food crops. By nudging suppliers to minimize fertilizer use, the emissions from food crop production could drastically reduce.

2. Continue to **prioritize local sourcing**; there is potential for a 96% reduction in upstream transportation emissions when comparing conventional to 100% local sourcing. When not feasible, ship via ocean freight or rail as opposed to airfreight. Prioritize finding local substitutes for heavier products as transportation emissions will be higher due to their weight.

3. **Offer a product mix of low carbon intense foods**; emissions can be reduced up to 36% with this strategy. Additionally, include education to customers about carbon emissions associated with various food groups.

4. **Promote emissions savings from food waste diversion (~7%).** Create more knowledge flow and disseminate best practices and impacts to customers, suppliers, and other grocery retailers through educational material and social media posts. In addition, implement a consistent data tracking system across all food waste diversion programs.

Through our analysis on Nada's operations and initiatives, we found that Nada has a lower carbon footprint because of programs they have in place such as food waste diversion strategies and sourcing specific, low-carbon products from local suppliers. When compared to a conventional grocery store, Nada has reduced their upstream transportation emissions by an estimated 94% by sourcing most of their products locally, while their product mix releases 36% less carbon emissions than a conventional grocery store's product mix. Nada's food waste diversion program in both 2019 and 2020 was able to completely offset their emissions from refrigerant leakage and purchased electricity combined, and saved as much as 47,000 kg CO_2e from being emitted. Emission reduction strategies like the ones Nada has used will be critical for all grocery stores to implement moving forward to meet an increasing food demand without compromising the future of the planet.

Nada has been successful in influencing and educating upstream suppliers as well as downstream consumers on environmental and social issues. As a B Corporation and mission-driven company, Nada has made it part of their business model to prioritize these issues and created a business where these areas can be prioritized. Nada can continue to improve on their mission through supplier engagement and the acquisition of supplier specific information from their top suppliers. This will give them a better understanding of their carbon footprint and allow for them to collaborate with suppliers to implement best farming practices that promote the best environmental and social outcomes.

However the successes and recommendations for Nada can have larger implications than just improving Nada's own carbon footprint. Although there are fundamental differences between Nada and conventional grocery stores, the strategies developed in this report can be applied as a framework for other grocery stores to inform decision making and potential goals to reduce the magnitude of impact the food system has on climate change. Food retailers can pull these levers to lessen the environmental impact of their operations, reduce unnecessary waste, and lower their overall carbon emissions. Through this study we have seen how Nada significantly reduced their carbon emissions through the implementation of this framework. With collective action from grocery retailers and the food sector at large, meaningful and critical change can be achieved to reduce carbon emissions, combat climate change, and equitably feed the world.

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