EVALUATING THE GREENHOUSE GAS EMISSIONS OF THE ONTARIO CRAFT BEER INDUSTRY: AN ASSESSMENT OF CHALLENGES AND BENEFITS OF GREENHOUSE GAS ACCOUNTING

by

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ABSTRACT

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Ontario, Canada's cap and trade program, a provincial tool for carbon regulation, came into effect January 1, 2017. While larger companies are targeted from this policy, both large and small companies have a responsibility to reduce their greenhouse gas emissions (GHGs). Craft brewing in Ontario is growing, however industry GHGs have not been comprehensively studied. The purpose of this research is to measure the GHGs of an Ontario craft brewery, investigate the challenges and benefits to calculating GHGs, and evaluate Ontario craft brewers' perceptions of carbon pricing policy. This research found that indirect sources account for the majority of GHGs, particularly from barley agriculture, malted barley transportation, and bottle production. Direct emissions account for the least GHGs. This research found that the main challenges in calculating Ontario brewery GHGs are secondary data availability, technical knowledge, and finances. The main benefits for breweries include sustainability marketing, and preserving the environment.

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1. Introduction

According to the International Panel on Climate Change (IPCC, 2014), climate change is a growing concern and has anthropogenic roots. Climate change is the long-term change of weather patterns and is caused by an increase in atmospheric greenhouse gases (GHGs) (IPCC, 2014). Climate change is evidenced by uncharacteristic temperatures, increased frequency of extreme weather events, drought, flooding, and biodiversity loss, among other impacts (IPCC, 2014). Between 1970 and 2010, industry accounted for approximately 78% of anthropogenic global GHG emissions (IPCC, 2014). Given this huge impact, industry and consumers have a responsibility and opportunity to reduce greenhouse gas emissions in the global fight against climate change.

Breweries have significant environmental impacts due to intensive resource use. Brewing is an energy intensive process (Sturm *et al.*, 2013). National and multinational beer and beverage companies have faced increasing pressure for transparency in reporting their carbon footprint, evidenced by increased integration of environmental sustainability into operations, and improved transparency (Jones *et al*., 2013). Furthermore, a survey of global breweries revealed energy and water use intensity improvements between 2011 to 2015 (Beverage Industry Environmental Roundtable, 2016). However, there is little public data on Ontario craft brewers' greenhouse gas emissions, nor much publicly-accessible information on carbon reduction programs and strategies. According to Ontario Craft Brewers (2015), craft breweries are defined as producing less than 400,000 hectolitres of beer annually, or equivalently, 400 million litres. In addition to volume guidelines, Rice (2016) states that craft breweries must be independently owned. The aforementioned production volume and ownership definitions form the working definition for this thesis research.

Carbon reduction initiatives have recently been legislated in Canada at the provincial and federal levels amid sociopolitical pressure. Although Ontario craft brewers currently do not qualify for mandatory participation, voluntary participation is an option for companies exceeding 10,000 tonnes of CO_2e/year to begin transitioning into Ontario's cap and trade program (Ont. Reg. 144/16).

Beyond legislated requirements for carbon reporting, an unprecedented international agreement between the majority of the world's nations was made to regulate climate change at the 21st Conference of Parties (COP) climate change conference in Paris in 2015 (UNFCCC, 2015). Participating nations at the 2015 climate conference developed a climate change agreement, known as the Paris Agreement (UNFCCC, 2015). As a ratified COP member, Canada's federal government committed to reducing national carbon emissions by 30% from 2005 levels by 2030 (Government of Canada, 2017a). Consumers are also becoming increasingly invested in the sustainability of products and services, which impacts the social operating license for companies (Jones *et al*., 2013). There are therefore international shifts in industry expectations, provincially legislation, and mounting social pressure that make it crucial for Ontario craft breweries to be aware of and improve GHG performance. For craft breweries to be able to decide whether they should calculate GHGs, and how to do so, research investigating a framework, challenges, and benefits to GHG accounting is necessary.

This research had two key areas of focus to meet the aforementioned need: a case study with an Ontario craft brewer, and Ontario craft brewery interviews. The case study collected primary data from the partner company, mapped their operations, collected secondary data, and calculated 2016 annual GHG emissions, and future projections of annual GHGs, by using the globally-recognized GHG Protocol Accounting and Reporting Standard (World Business Council for Sustainable Development (WBCSD) & World Resources Institute (WRI), 2004). The interviews used semi-structured, exploratory interview techniques to shape a dialogue of Ontario craft brewers' perceptions of challenges and benefits to GHG accounting, and reception to provincial carbon regulation. The goal of this research was to understand the actual and perceived environmental performance benefits of calculating Ontario craft brewers' greenhouse gas emissions, and the logistical challenges to calculating GHGs, in a provincial context. Theory was also used to investigate the connection between carbon regulation in Ontario and brewery engagement in carbon management by using data collected from the Ontario craft brewery interviews. Given these aims, the research questions for this study were:

1) What are the greenhouse emissions of an Ontario craft brewery?

2) What are the challenges of calculating greenhouse gas emissions for Ontario craft breweries?

3) What are the benefits of calculating greenhouse gas emissions for Ontario craft breweries?

4) What are Ontario craft brewers' perceptions towards provincial carbon regulation?

2. Literature Review

The review of the literature examines global climate change, industry's contribution to climate change, trends in the brewing industry, material inputs to beer and their environmental impacts, national and international approaches to carbon regulation, and previous work this study will build on.

2.1 Climate change and industry

Anthropogenic emissions, particularly in the last century, have grown exponentially and are the principal driver of climate change (IPCC, 2014). Global greenhouse gas emissions increased by 48% between 1990 and 2012 (Environment and Climate Change Canada, 2016a). Carbon dioxide from fossil fuel combustion and industrial processes accounted for 78% of all anthropogenic global GHG emission increase between 1970 and 2010, highlighting the important role industry plays in climate change (IPCC, 2014). Carbon dioxide in Earth's atmosphere reached and sustained an unprecedented 400 parts per million in 2015 and 2016 (Environmental Commissioner of Ontario, 2016).

Climate change is driven by the accumulation of greenhouse gases in the thermosphere, which is the first and lowest layer of Earth's atmosphere. Greenhouse gases absorb the Sun's re-radiated energy from Earth's surface. The accumulation of greenhouse gases in Earth's atmosphere increases the heat that is trapped in our atmosphere as it prevents its re-emittance into space. This enhanced greenhouse effect modifies Earth's climate, which drives the aforementioned impacts of climate change (Hemond & Fechner, 2015).

Greenhouse gases include water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), perflurocarbons (PFCs), and hydrocarbons (CFCs) (Hemond & Fechner, 2015). Although Canada accounted for only 1.6% of global GHGs in 2012, it has a disproportionately greater amount of GHGs relative to national population size (Environment and Climate Change Canada, 2016a). Since industry is a major contributor to climate change, it is facing more social and legal pressure now than ever before to reduce GHGs.

2.2 The rise of craft breweries in Ontario

The beer industry is growing in Canada and globally, with beer being the fifth most consumed beverage in the world (Olaijire, 2012; Beer Canada, 2015). In 2016, 1.96 billion hL of beer was produced globally (Statista, n.d.). Beer constitutes 78% of alcohol consumption globally (Gómez-Corona *et al.*, 2016). Alcoholic beverages, which includes beer, contributes 0.7% of all products to global warming when a complete product lifecycle is considered (Institute for Prospective Technological Studies (IPTS), 2005; Cimini & Moresi, 2016). When total beer production in 2016 and the percentage of beer of all alcohol consumed globally are considered, 0.55% of global greenhouse gas emissions is attributable to beer production. As a comparison, 4-12% of global warming from all products is due to meat and meat products (IPTS, 2005; Cimini & Moresi, 2016). Provincially, Ontario craft breweries produced eight million hL of beer in 2016, meaning that this market holds approximately 0.0041% of the global market for beer production (Ontario Craft Brewers (OCB), 2018b). Despite this seemingly small percentage, beer is a non-essential beverage and is being increasingly consumed, thus presenting an important opportunity for improvement.

Craft beer consumption is growing globally, particularly among younger populations with high expendable income (Gómez-Corona *et al.*, 2016). Craft brewers, in contrast to commercial brewers, produce 400,000 hectolitres (hL) or less of beer per year, and are independently owned (Ontario Craft Brewers, 2015; Rice, 2016). The major driving factors for craft beer consumption include flavour, exposure to beer-related knowledge, and alternative choices to mainstream beer (Aquilani *et al.*, 2015; Gómez-Corona *et al.*, 2016). In the 1980s, craft brewing in Ontario began to grow and gain momentum (Dawson, 2017). In 2003, the Ontario Craft Brewer's Association was formed in an effort to show the quality and local community benefits of craft beer (Dawson, 2017). As of April, 2018, the Ontario Craft Brewer's Association has 85 members (Ontario Craft Brewers (OCB), 2018a). Specifically regarding Ontario Craft Breweries, the industry has seen an increase in sales of $240 to $370 million between 2015 and 2017, which equates to a 24% increase over two years (OCB, 2018b). As of 2017, craft beer sales in Ontario represented 7.6% of the provincial market for beer (OCB, 2018b). The aforementioned trend suggests craft breweries will continue to capture a notable portion of the beer market in Ontario.

The Ontario Craft Beer industry also contributes a notable amount to the provincial economy. In 2017, craft breweries in Ontario had a $1.4 billion impact (OCB, 2018b). Furthermore, the industry employed 2,200 full-time employees in 2017, up from 1,600 in 2015 - equivalent to a 38% increase (OCB, 2018b). These figures showcase the important economic impact of Ontario craft breweries.

2.3 Material requirements for beer production

The main ingredients in beer are water, malted barley, hops, and yeast (Food and Agriculture Organization of the United Nations (FAO), 2009). There are several inputs to beer that are susceptible to climate change, and some inputs also have high associated GHG emissions. These key inputs are discussed below and guide the major inputs included in the case company greenhouse gas accounting for this study.

Table 1 Key inputs to beer production. Source: FAO, 2009; Case company primary contact, 2016, personal communication

Category	**Category inputs**
Raw materials	Malted barley Water Hops Yeast
Production	Electricity Gasoline and/or other fuels Liquid carbon dioxide Steam
Packaging	Glass Aluminum Paperboard Plastic Steel

Cordella *et al.* (2008) literature review found that 1 L of beer requires 269 g of barley, making it beer's largest raw material input aside from water. Climate change, causing temperature and precipitation changes, will impact the growth and quality of barley (Fish, 2015). Previous research found that among beer inputs, barley was a leading cause of environmental damage through land use and greenhouse gas emissions (including fertilizer use and land use change) (Cordella *et al.*, 2008). An estimated 0.57 kg of CO_2e are released to produce one kilogram of barley (Rajaniemi *et al.*, 2011).

Cordella *et al.*'s review of the literature found 1 L of beer requires 0.707 g of hops (2008). Hops are a sensitive crop susceptible to changing growing conditions (Mozny *et al*., 2009). Climate change poses a threat to the quality and quantity of hops crops, primarily by an earlier and shortened growing season (Mozny *et al*., 2009). According to research simulations in the Czech Republic using historic data, hop yield is expected to decrease by 7% to 9% between 2026 and 2050, and 7% to 11% between 2051-2100 (Mozny *et al*., 2009). Understanding how barley and hops are used among craft breweries and identifying efficiencies is important to mitigate risk exposure to barley supply impacted by climate change.

Breweries are very water-intensive (Olajire, 2012). Water intensity is a function of volume of water used per volume beer produced (Bumblauskas, 2015). Water is used in the brewing, washing, packaging, and sterilizing stages of a brewery's operations, along with general facility use (Olajire, 2012). Water security is being increasingly threatened by climate change (IPCC, 2014). Fish (2015) argues that water scarcity and temperature fluctuations from climate change have already reduced the quantity and quality of barley in Canada, a key material input. In response to this threat, global leaders in the beer industry are incorporating water usage reduction targets into operational targets (Beverage Industry Environmental Roundtable, n.d.).

Breweries are also very energy-intensive (Olajire, 2012). Energy intensity is the amount of energy used per volume of beer produced (Bumblauskas, 2015). Fuels (gasoline, diesel, and biofuel) are primarily associated with transportation along beer's value chain. Fuels have varying degrees of associated GHGs depending on fuel type and origin. For example, biofuels have comparatively lower emissions than conventional gasoline (WBCSD & WRI, 2017). Fuel use has been garnering more attention in supply chain dynamics in recent years, with research indicating that companies with global suppliers are facing increased costs because of rising costs of gasoline and carbon regulation (Gurtu *et al*., 2015). Given the federal government's requirement for all provinces and territories to implement a cap and trade or carbon tax system by 2018, according to the Pan Canadian Framework on Clean Growth and Climate Change, fuel price increases are a very relevant concern for Ontario craft breweries (Osler, 2018).

Packaging is often the largest source of GHGs for beer (Koroneos *et al*., 2005; Olajire, 2012). According to Koroneos *et al*., bottle production accounted for 85% of energy required along the beer lifecycle (2005). While estimates vary, greenhouse gas emissions from bottle production was measured to be .314 kg in CO_2e (carbon dioxide equivalents) per kg of brown or green bottle glass produced (Turner, William & Kemp, 2015). Re-use of bottles and varying bottle thicknesses and shapes influence energy required to produce each bottle, thus exact emissions from this step are unique between breweries (Koroneos *et al*., 2005).

2.4 Environmental impacts of beer

As craft breweries are becoming more popular, breweries' energy usage and associated GHGs have become a larger priority. Given this priority, in recent years research has investigated breweries' energy usage and GHG emissions. The major heat (and energy) consuming stages in the brewing process are wort boiling and mashing (Olajire, 2012). Amienyo & Azapagic found that a United Kingdom brewery (with an unspecified production volume) emits an estimated 842 g CO_2e for 1 L of bottled beer, and 575 g CO_2e for 1 L of beer in aluminum cans (2016). At an industry wide scale, all brewery emissions in Canada have not achieved consistent reductions, as evidenced by Statistics Canada data between 2004 and 2008 (Statistics Canada, 2012). Figure 1 shows that emission reductions could not be sustained past 2006, despite an improvement between 2004 and 2006 (Statistics Canada, 2012).

A survey of United States craft brewers found that small brewers recognize social and environmental sustainability as important, in part due to strong community engagement (Hoalst-Pullen *et al*., 2014). However, commercial brewers are more transparent in their environmental performance reporting as evidenced by published annual sustainability reports (Hoalst-Pullen *et al.*, 2014). Commercial brewers, including Molson Coors and New Belgium Brewing, produce annual sustainability reports and have completed life cycle assessments, respectively (Molson Coors, 2017; New Belgium Brewing, 2017). However, research investigating

Ontario craft breweries is lacking (Fillaudeau *et al*., 2006; Olajire, 2012). The aforementioned research and commercial publications suggest craft breweries are conscious of their environmental sustainability, however commercial breweries have greater resources to communicate their environmental sustainability efforts.

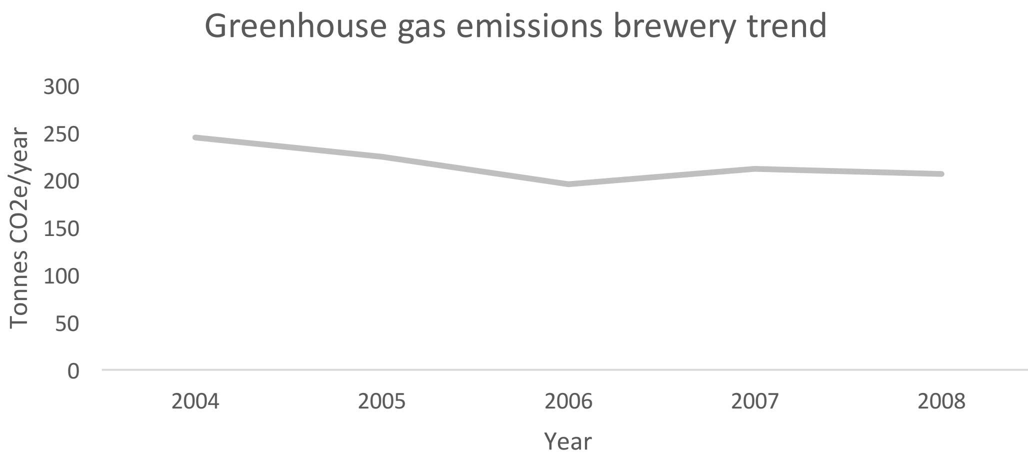

Figure 1 Canadian commercial brewery emissions in carbon dioxide equivalents reported between 2004 and 2008. Source: Statistics Canada, 2012.

2.4.1 Energy opportunities to reduce greenhouse gas emissions

Electricity produces greenhouse gas emissions during its generation, the extent to which is determined from electricity's composition of renewable and non-renewable resources. Despite extensive energy use by breweries, there has been a shift by large-scale breweries to increase their share of electricity from renewable sources (Sloane, 2012). For example, Sierra Nevada Brewing Company and New Belgium Brewing (both commercial brewers) have taken action to reduce operational GHG emissions (Sloane, 2012). Sierra Nevada Brewing Company has diversified their energy share in solar, while New Belgium Brewery has increased their energy share from wind (Sloane, 2012).

Aside from some companies using 100% renewable electricity sources, most companies must consider their regional grid composition when calculating GHGs. In Ontario, Ontario Power Generation provides electricity to industry and households. Ontario's grid composition has phased out coal, and in 2016 90% of electricity did not generate greenhouse gases (Figure 2) (IESO, 2017; Ministry of Energy, 2017). Despite this progress, the 10% of greenhouse gas emissions resulting from industry's energy use is significant and will play a role in Ontario's ability to meet provincial greenhouse gas reduction targets.

Private organizations are seeking solutions to reduce greenhouse gas emissions from energy use. Alternative options such as Bullfrog Power enable users to purchase electricity that does not create any GHG emissions to add to the Ontario grid on their behalf. Bullfrog Power generates electricity from low-impact hydro, wind, and green natural gas (Bullfrog Power, 2015). Bullfrog Power captures their natural gas from decaying organic waste at a Canadian landfill, thereby not adding additional CO_2e to the carbon cycle (Bullfrog Power, n.d.). Companies like Bullfrog Power reduce the demand for conventionally produced energy, thus reducing the GHGs associated with energy use in Ontario. Despite this, not all companies have the financial capacity to afford net-zero carbon emission sources, as there is a premium paid for the clean energy offered by Bullfrog Power. Therefore, reducing electricity consumption through process efficiencies should be a focus among Ontario craft brewers to reduce their GHGs.

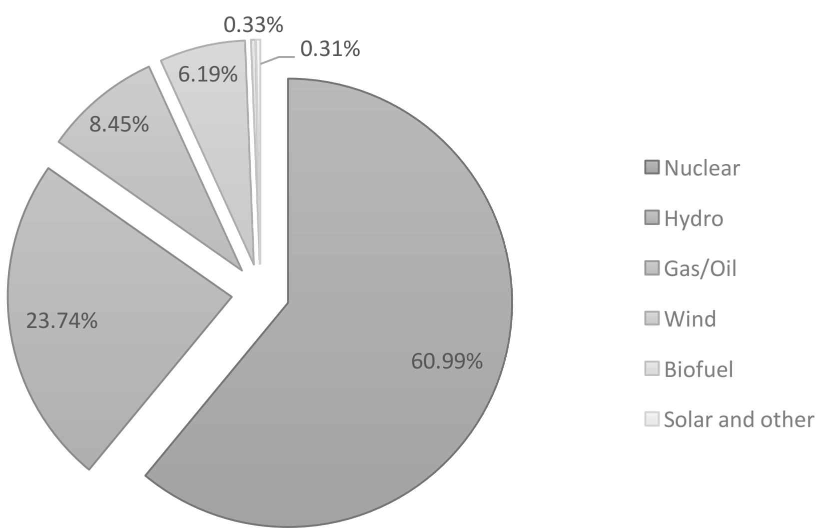

Figure 2 Ontario Power Generation electricity generation by source, 2017. Adapted from: Independent Electricity System Operator (IESO), 2017

2.4.2 Management opportunities to reduce greenhouse gas emissions

Breweries have an opportunity to reduce GHGs along their value chains by improving supply chain management. By targeting GHG reductions, companies potentially face cost savings, positive publicity, improved consumer support, and a larger market share (Sloane, 2012). Despite this, a key barrier for breweries to reduce their GHG emissions is financial cost, specifically fixed costs for new technology implementation (Sloane, 2012).

There is an opportunity for improved management to be used in combination with technology advancements to mitigate GHGs along breweries' value chains. Organizational innovation may include overhauling the business model of an organization, making changes to processes while keeping the same functions, or simply reducing inefficiencies (Wells, 2016). One way to identify opportunities is process mapping. Process mapping identifies where operational changes would be effective in improving GHG performance (Damelio, 2011). For example, the process map for a company producing product X would include raw material inputs, shipping, production of product X, as well as packaging, distribution, and disposal of product X. Essentially, process maps give a visual representation to help understand a product's stages. A complementary tool, known as a greenhouse gas inventory, accounts for activities that contribute to Scope 1, 2, and 3 GHG emissions (WBCSD & WRI, 2004). Scope 1 includes direct emissions from production, Scope 2 includes emissions from electricity purchased and used by the company, and Scope 3 includes indirect emissions (including supplier emissions, and employee commuting) (Figure 3) (WBCSD & WRI, 2004). Scope classification allows a company to understand where emissions are in their value chain, and what emissions they have direct control over, thus allowing reduction targets to be formed and performance tracked over time. Once emissions are calculated, they can overlap process maps to determine where major GHG emissions exist.

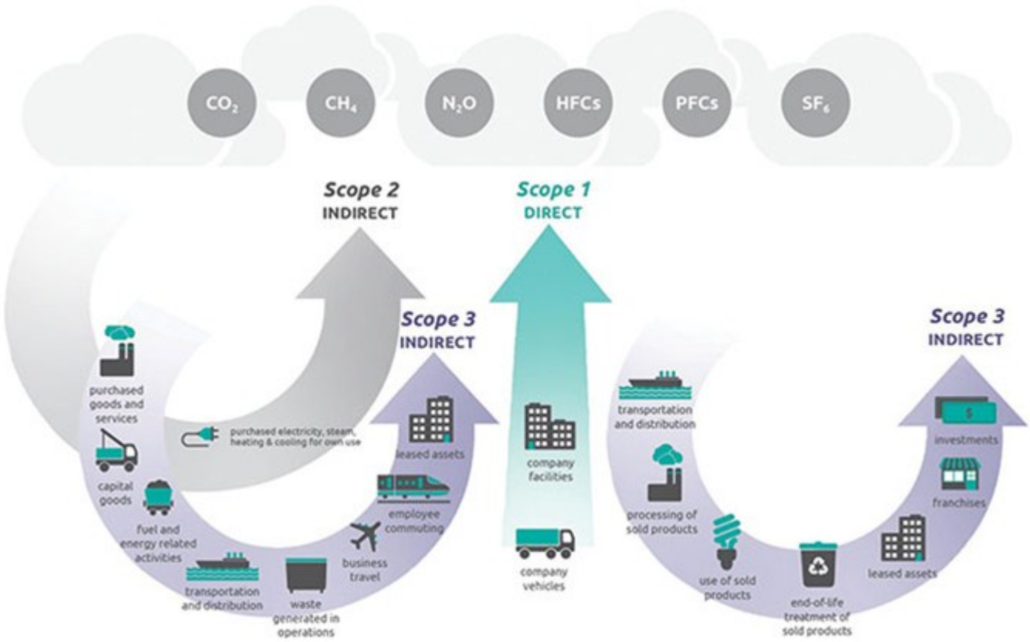

Figure 3 Hypothetical examples of scope 1, 2, and 3 sources of a company. Scope 1 refers to GHG (greenhouse gas) emissions from the company/entity. Scope 2 refers to emissions generated from electricity purchased by the entity. Scope 3 emissions are not directly from the entity, but are a by-product of their service/product, including emissions from suppliers and distributors. There are six GHGs recognized by the GHG Protocol: water vapour, carbon dioxide, methane, nitrous oxide, hexafluorocarbons, and perfluorocarbons. Source: WBCSD & WRI, 2011a

2.5 Ontario Craft Breweries and institutional theory

Institutional theory and its influencing isomorphic pressures was developed in 1983 by DiMaggio & Powell as a subset of Organizational Theory. Institutional theory holds that a company's environment influences their business actions and behaviours, and thus over time companies in shared environments behave similarly (DiMaggio & Powell, 1983; Miles, 2012). DiMaggio & Powell identified coercive, normative, and cognitive as the three isomorphic pressures that lead to similar behaviour (1983). Pishdad *et al.* (2012) expanded this model and visualized this relationship (Figure 4). Institutional theory may help explain Ontario craft breweries' action towards (or lack thereof) in reducing their GHG emissions. To better understand this theory and its connection to Ontario craft brewers, the three isomorphic pressures (Figure 4) will be explored.

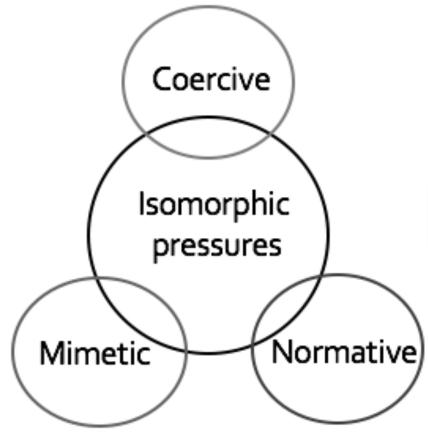

Figure 4 Institutional theory model. Adopted from Pishad *et al.*, 2012

Coercive pressure is constraining because it (can be) externally enforced on companies through laws and sanctions (DiMaggio & Powell, 1983). Coercive pressure can thus make companies' actions similar to each other (DiMaggio & Powell, 1983). For example, Ontario's cap and trade program as a method of carbon regulation is an external pressure that companies must legally meet to be compliant. As a result, qualifying companies will take similar actions to measure, document, and report their carbon emissions. Coercive pressure may also be non-legally binding, such as supplier requirements enforced by a company (Pishdad *et al.*, 2012). Although some coercive pressures, like cap and trade, do not apply directly to Ontario craft breweries, their raw material input prices are, or will be, impacted indirectly as a result of carbon regulation. Since carbon regulation adds an additional cost on producers and/or consumers, craft breweries are likely to experience a price increase from materials purchased from carbon regulated companies. This price increase from larger companies across the board may thus change breweries purchasing sources to be as inexpensive as possible, thus leading craft breweries to isomorphism in their purchasing behaviours. The indirect impacts of cap and trade on provincial craft brewers will be discussed in further detail later in the literature review.

Normative pressure is behaviourally influenced from commonly-held values and actions which can be developed through academic and professional backgrounds (DiMaggio & Powell, 1983). Normative pressure may be the largest impact of the three pressures for breweries, as their company morals and behaviours are influenced by employees, peers, suppliers, and consumers. Normative pressure is perhaps more influential among smaller organizations, such as Ontario craft breweries, because they have smaller networks, and arguably less hierarchy within companies where each employee can have a larger impact.

Finally, mimetic (cognitive) pressure influences similar companies with similar goals and communities to emulate one another as a way of benchmarking their own success (DiMaggio & Powell, 1983; Pishdad *et al.*, 2012). For example, if one company starts adopting an environmental attitude or action, similar companies may do the same when they see it is financially beneficial. Mimetic pressure leading companies to make similar decisions may also reduce uncertainty, since mimicking similar companies will (likely) yield similar outcomes (Pishdad *et al.*, 2012).

Institutional theory, influenced by isomorphic pressures, will be a useful theory in predicting and interpreting the case company and industry interview findings. The theory may help explain relationships between actors, behaviours that are not economically beneficial (i.e. inaction to reduce brewery costs, or investment in environmental programs that do not have a positive return on investment), and pace of adoption of greenhouse gas management plans and technologies.

2.6 Ontario Craft Breweries and image theory

Image theory reflects the operational and managerial choices adopted by decision-makers based on the present and future vision these decision-makers have for the company (Miles, 2012). Decision-makers continually evaluate their choices in the context of their business image for the company to make sure there are no inconsistencies (Beach & Mitchell, 1998).

Image theory is classified as a naturalistic decision theory, which is a theory to explain human decision-making based in observed behaviour and social psychology (Beach & Mitchell, 1998). Image theory describes corporate decision-makers' logic as it relates to the decision maker's values and goals for a company, rather than purely a normative analysis (Beach & Mitchell, 1998). Image theory deviates from normative decision making models, such as those based in statistics and economics, and recognizes ethics and social norms as informing a decision-makers consideration criteria (Beach & Mitchell, 1998). This subjective element explains why two decision-makers, faced with the same decision, may conclude different actions are most appropriate for their business (Beach & Mitchell, 1998). An important aspect of image theory is that while decision-makers form a course of action alone, it may be influenced and changed by group (i.e. corporate) dynamics (Beach & Mitchell, 1998).

According to image theory, there are three images which are used by the decision maker to organize the decision-making process: value image, trajectory image, and strategic image (Beach & Mitchell, 1988). Value image involves the moral soundness of prospective actions as deemed by the decision-maker (Beach & Mitchell, 1998). Trajectory image reflects the decision-makers pre-conceived (abstract or measureable) goals regarding future achievements and directions (Beach & Mitchell, 1998). Finally, the strategic image is made of plans or steps used in achieving the trajectory image, and is used to evaluate the progress towards achieving the trajectory image (i.e. the goal) (Beach & Mitchell, 1998).

One particularly relevant type of decision theory as part of image theory is progress decisions. Progress decisions seek to determine what will happen given the chosen plan in the context of the external environment. If the forecast is unacceptable (given the value, trajectory, and strategic images), then alternative actions are considered to change course (Beach & Mitchell, 1998). Image theory perhaps has a notable impact in the decision-making process of craft breweries because of the community and sustainability focus of many craft breweries reflected in these companies' values, and the relatively few decision-makers (as compared to larger corporations). Furthermore, image theory is relevant in the decision-making process of craft breweries given the subjective consideration of values, the current and future environment within which the business operated, and the reiterative evaluation of decisions. For example, following craft brewery implementation of a program, evaluation may be ongoing to determine the financial, environmental, or other intended impact of the program.

The social psychology basis of image theory makes it an appropriate framework given the craft brewery environment. Image theory may help explain the irrational decisions craft brewers make in their greenhouse gas emission management. Irrational decisions can be defined in various ways, but a common example is spending more money than is deemed necessary for the outcome (Beach & Mitchell, 1988). For example, some craft breweries in Ontario will market themselves as taking extensive measures to use cleaner fuels, improve energy efficiency, and use energy sourced from renewables when there is a lack of clear evidence that this increases their customer base. Applying image theory may clarify why branding images, and the actions that support the branding image, are so varied between craft breweries of comparable sizes and products. In line with this, image theory may help in understanding what influences craft breweries' investment decisions to greenhouse gas measurement and reduction.

2.6.1 Connecting institutional and image theory

Institutional theory and image theory are interrelated, especially in the context of their application to this thesis research. The first connection between these theories is that a company's image (image theory) is influenced from external normative pressures (institutional theory) (de Lange, personal communication, May 31, 2018). Normative pressure is the impact of a company's management and employees, developed through individual personal and professional backgrounds, that creates similar behaviours and action between companies in the same industry (DiMaggio & Powell, 1983). A company's image may be influenced by normative factors, for example managers' vision or goals for their company (Beach & Mitchell, 1988). Theory was used in this thesis to: determine craft brewers' carbon management and whether there is any connection to their value image; and analyze the perceptions of provincial carbon regulation in the craft beer industry and whether this is impacted by isomorphic pressures.

Another relationship between institutional and image theory is that coercive external pressures (i.e. taxes enforced on craft breweries) influence a company's image of themselves (de Lange, personal communication, May 31, 2018). More specifically, since coercive pressures pose constraints on craft breweries, these factors may shift craft breweries' goals for the company. This form of pressure should not be ignored, and breweries should continually revisit their goals to ensure they align with the image for their company and that they have not deviated due to coercive pressure. There are various possible examples in the context of Ontario craft breweries: in the case of taxes imposed across craft breweries in Ontario (a form of financial constraint), breweries' prioritization of carbon management may be lessened due to other competing interests such as a focus on remaining profitable, and/or being in an expansion or growth phase. The aforementioned example demonstrates the influence of an isomorphic, coercive pressure in influencing craft breweries' images. Given the theoretical framework posed here, this research will: examine how Ontario craft breweries prioritize carbon management, and identify the different forms of coercive pressures on Ontario craft breweries that shape any observed similarities in the breweries' carbon management actions.

2.7 Carbon regulation in Canada

Aside from voluntary actions, some global jurisdictions are enforcing mandatory carbon regulation to curb emissions. Carbon taxes and cap and trade are widely used today to regulate carbon emissions (Baldwin, 2008; Harrison, 2012). There are various differences in cap and trade and a carbon tax. Cap and trade puts a limit on emissions (i.e. the cap), and government allocates emission credits to participating companies (Ministry of the Environment and Climate Change, 2016). A carbon tax puts a cost on each tonne of CO_2 emitted, which usually increases in price in subsequent years (Harrison, 2012).

Already in Canada, several provinces including British Columbia and Quebec have carbon regulation programs in place. British Columbia implemented North America's first carbon tax in 2008, which received mixed support from the public, industry, and politicians (Harrison, 2012; Klinsky, 2013). Research investigating the carbon tax in British Columbia showed many large emitters treated the provincial carbon tax as a compliance cost, rather than a reason to innovate to reduce GHG emissions (Bumpus, 2015). These findings suggest there are unforeseen and/or unintended consequences to carbon regulation. See Table 2 for a summary of carbon emission reduction commitments by province/territory.

Table 2 Canadian provinces and territories with greenhouse gas reduction programs. Sources: Bumpus, 2015; Osler, 2018; Government of British Colombia (n.d.); Government of Nova Scotia (n.d.).

Jurisdiction	**Tool employed**	**Year implemented**
Canada	Carbon tax or cap and trade will be required among all provinces and territories, under the Pan-Canadian Framework on Clean Growth and Climate Change	Federal requirement for all provinces and territories to implement carbon regulation by 2018
British Columbia	Carbon tax began at \$10/tonne of CO_2e in 2008, and rose to \$35/tonne of CO2e as of April 1, 2018. The provincial government will raise the tax by \$5 per tonne of CO2e for a \$35/tonne CO2e tax by 2021	2008
Alberta	Carbon tax starting at \$20/tonne in 2017 to \$30/tonne in 2018 of CO_2e	2017
Manitoba	Emissions tax on coal and petroleum coke	2014
Ontario	Cap and trade	2017
Quebec	Cap and trade (linked to Western Climate Initiative carbon trading market)	2013
Nova Scotia	Cap and trade	2019

Ontario's cap and trade program, legislated in 2017, set a legal precedence for industries emitting more than 25,000 tonnes CO_2e/year to participate by tracking and reporting their annual operational emissions (Ont. Reg. 144/16). These companies are issued a number of carbon credits, adjusted to their baseline emissions, where each credit represents one tonne of CO_2e emissions (Ont. Reg. 144/16). Beyond the 25,000 tonne per year cap, qualifying companies are required to stay within their allocated carbon allowances, or purchase additional credits at quarterly-annual auctions (Ont. Reg. 144/16). Although Ontario's craft breweries do not currently qualify to participate in the cap and trade program, changes to program participation in the future (i.e. reduced minimum GHG emissions), and supply chain impacts, are important reasons for craft brewers to remain engaged in cap and trade developments. Furthermore, companies may voluntarily participate in the cap and trade program if they exceed 10,000 tonnes CO_2e/year (Ont. Reg. 144/16). Understanding where supply chain vulnerabilities exist due to climate change and carbon regulation costs will also assist in protecting craft brewery operations.

Ontario's recently-elected premier, Doug Ford, stated repealing Ontario's cap and trade program is a priority for his government (Jeffords, 2018). An upcoming 2018 summer parliamentary session will have Ford bring forward legislation to disband the province's cap and trade program (Jeffords, 2018). Despite the provincial government's recent plans, it is unknown how and/or if Ontario's cap and trade can be cancelled given the federal government's requirement for carbon regulation across all provinces and territories (see Table 2).

Despite Ontario's unknown carbon regulation future, Ontario's cap and trade program is a unique case study opportunity to investigate the perceptions and impacts of the program from a small-medium sized enterprise (SME), and specifically craft brewery, perspective. Perceptions of cap and trade among craft breweries will include support or opposition for the program, and the anticipated financial impacts of the program for the brewery and the craft beer industry.

Regulation of Ontario's carbon emissions through cap and trade is important for environmental and political reasons. Firstly, Ontario should adhere to its commitments to reduce our greenhouse gas emissions to prevent industry from becoming more polluting. Despite Ontario's low gross annual GHG emissions (relative to global share), in the near future it would be hard to hold incoming highly polluting companies accountable without regulation. If left unregulated, companies may pursue profit maximization while contributing to climate change. Secondly, if we do not have policy in place to regulate carbon emissions, Ontario, and more broadly Canada, may damage our relationships with other countries around the world who would think Canada is not doing enough to manage carbon emissions.

2.8 Tools for measuring greenhouse gas emissions

Ontario craft breweries may realize a cost-saving and GHG mitigation opportunity if they can establish an emission baseline and implement reduction programs. In order for a company to design effective GHG reduction programs, they must first understand their baseline emissions. Environment and Climate Change Canada (2016b) collects annual GHG data from entities exceeding 25,000 tonnes CO_2e per year to include in the National Greenhouse Gas Inventory as part of the UNFCCC. This is an international agreement, and not related to Ontario's cap and trade program. According to Environment and Climate Change Canada (2016b), the entity should take a systematic approach to their GHG emission calculations (Figure 5). As was mentioned earlier, a combination of process mapping and greenhouse gas inventory helps companies understand their baseline emissions and where these emissions are coming from. Another important tool that can be used in conjunction with these is scenario analysis.

$$Total\ Emissions = \sum_{1}^{i}\left(E_{CO_2} \times GWP_{CO_2}\right)_i + \sum_{1}^{i}\left(E_{CH_4} \times GWP_{CH_4}\right)_i + \sum_{1}^{i}\left(E_{N_2O} \times GWP_{N_2O}\right)_i + \sum_{1}^{i}\left(E_{PFC} \times GWP_{PFC}\right)_i + \sum_{1}^{i}\left(E_{HFC} \times GWP_{HFC}\right)_i + \sum_{1}^{i}\left(E_{SF_6} \times GWP_{SF_6}\right)_i$$

where:
E = total emissions of a particular gas or gas species from the facility (tonnes);
GWP = global warming potential of the same gas or gas species
i = each emission source.

Figure 5 Greenhouse gas calculation formula for Ontario companies. Companies must calculate their emissions using this formula to determine if they meet the 25,000 tonnes of CO2e/year threshold for reporting and complying to Ontario's cap and trade program. Source: Environment and Climate Change Canada, 2016b.

Scenario analysis calculates changes from projecting chosen alternatives to the business as usual scenario (Cook *et al*., 2014). Alternatives may be those that are predictable, whereby the company in question has control, or unpredictable (Cook *et al*., 2014). Factors used in a scenario analysis may be identified through interviews and feedback with the case company (Moore, 2012). Moore (2012) in his research with an electric utility case company, had staff identify investments in carbon offsets, environmental awareness and training among staff, and changes to electrical grid composition as relevant factors for a scenario analysis. Research that investigated GHG emissions associated with Darjeeling black tea also used scenario analysis for the product lifecycle (Cichorowski *et al*., 2015). This research altered electricity sources, cultivation of raw material inputs, transportation, and preparation of tea by the consumer (Cichorowski *et al*., 2015). Varying choices along the product's development, distribution, and use identified the impact these choices have on the GHG emissions associated with production (Cichorowski *et al*., 2015).

2.9 Tools for reporting greenhouse gas emissions

The GHG Protocol Initiative was designed as global, cross-sectoral independent organization that provides guidance to businesses to mitigate their environmental impacts, specifically with regards to greenhouse gases and climate change. The GHG Protocol Initiative requires emission reports to be transparent, consistent, list limitations and assumptions, and have a clear scope (WBCSD & WRI, 2004). This research chose to use this Standard because it is the globally recognized greenhouse gas emission reporting standard, thus the framework can be adopted by the case company easily should they wish to publicly report this information. Secondly, this Standard provides comprehensive, albeit generic, instructions for calculating GHG emissions that is accessible to the public.

Other organizations offer greenhouse gas measurement and reporting guidance. The Beverage Industry Environmental Roundtable (BIER) is an organization comprised of globally-leading beverage producers. The mandate of BIER is to facilitate discussion, conduct research, and share best practice particularly with regards to minimizing environmental impact (Beverage Industry Environmental Roundtable, n.d.). BIER is a globally relevant player which produces reputable guidance documents. It is also publicly accessible, which supports the accessibility and thus replicability of this research. The primary BIER document used to guide emission calculations for this research is the “Beverage Industry Sector Guidance for Greenhouse Gas Emissions Reporting (Version 3)” (2013). This document is industry-specific, which is an important complement to the broadly-applicable GHG Protocol Accounting and Reporting Standard (2004). Furthermore, BIER’s “Research on the Carbon Footprint of Beer” (2012) provides an example of how to execute a carbon footprint analysis using process mapping and data collection.

2.10 Related methods

Research studies using similar methods have made significant contributions to beer and beverage environmental impact literature. Despite this, varying methods, findings, and minimal research in an Ontario-context supports the need for this thesis. Specifically, Ontario poses a unique opportunity for research because it recently implemented a cap and trade program. This research thus explores Ontario craft breweries perceptions of cap and trade in the policy's infancy, which contributes to a better understanding for policy makers in the barriers and motivators for carbon management among small businesses. There is limited research on small and medium sized enterprises regarding their implementation and perception of carbon management, which extends beyond craft breweries and contributes to the literature in a provincial context. Keeping this research bounded to Ontario also focuses the research's evaluation of craft breweries' carbon management in the same regulatory context.

There is less published information regarding craft breweries when compared with larger breweries. Many of the methods and findings in previous research will be used for this study, but in an Ontario context. A survey of the literature indicates an Ontario-based craft brewer case study using a mixed methods approach is a valuable practical contribution to the challenges and benefits of greenhouse gas accounting, and an academic contribution to organizational theories in craft breweries. This research is both an academic and practical contribution for craft breweries wanting to measure their greenhouse gas emissions using publicly available data. Since secondary data is often more accurate when in the appropriate geographic and time scope, this research serves as a starting point for craft breweries to collect emission factor information for use in their calculations.

2.10.1 Literature informing case study and interview research methods

2.10.1.1 Process mapping

Process mapping is a technique used to visually identify the step-wise relationships in a company's value chain (Damelio 2011). Muster-Slawitsch et al. (2014) created a process mapping structure for breweries to identify key greenhouse gas emission sources. This process mapping strategy with a focus on the key emitting processes is a useful tool in combination with greenhouse gas accounting (discussed in the following section). Muster-Slawitsh et al. also used Microsoft Visio, a computer mapping software, as a tool to map brewery processes. Understanding process mapping, and Microsoft Visio, methodology and symbology lends consistency in process mapping for this thesis research study. A thesis conducted at Ryerson University worked with an electric utility company to map out their processes, calculate their carbon footprint, and determine mitigation actions to improve carbon performance (Moore, 2012). Although this research was based in a different industry, the methodology itself is transferable.

2.10.1.2 Greenhouse gas accounting

Various studies of greenhouse gas accounting, particularly with a life cycle assessment approach, were found in the literature review. Of particular focus were studies that involved brewery inputs and outputs. These studies were very useful, particularly for secondary data where approximations in calculations had to be made in the absence of primary case company data. An important note is that calculations vary depending on the geographical location, techniques employed, and technology used for the following case studies. This variation presents a challenge for finding and using secondary data that is appropriate for this research's greenhouse gas accounting. Amienyo & Azapagic (2016) produced a United Kingdom brewery company case study that calculated GHGs using process mapping, inventory data from the case company, global warming potentials of greenhouse gas emissions, and data approximations where direct measurements were not available along the value chain. The methods used in Amienyo & Azapagic (2016) contributed an important foundation to the methods developed for this research study. The key findings from this case study were that packaging comprised the majority of GHGs for beer production, with 50% of GHGs for beer in glass bottles, and 35% for steel cans (Amienyo & Azapagic, 2016). Complementing the aforementioned study is Cimini & Moresi's (2016) work on carbon footprint calculations of a lager packaged in kegs, aluminum cans, and glass bottles. Cimini & Moresi listed emission factors from their own calculations and from other sources for inputs and outputs such as glass, can, and keg packaging, recycling, hops, barley, and malted barley (2016). In Koroneos et al.'s (2005) life cycle assessment of beer at a case company based in Greece, steps along the value chain that are associated with major emissions was documented. Specifically, it was found that the bottle production, brewing, and packaging phases of the value chain were the most emission intensive (Koroneos et al., 2005). Rajaniemi et al. (2011) focused their analysis on the GHGs from barley, oats, rye, and wheat. This study found that barley emits 570g CO2e per kg of barley produced (Rajaniemi et al., 2011). This calculation for barley was used in this research's case study calculations. Finally, Olajire (2012) assessed the life cycle of beer to identify major energy inputs. They determined that the mashing and wort boiling stages are the most energy-intensive stages in the brewing process (Olajire, 2012).

The Climate Conservancy (2008) published a consultancy report that was completed for Fat Tire ale produced by New Belgium Brewery (2008). This case study included a clear written and numerical approach to GHG calculations, with explanations of where secondary data was obtained and justification for use of this data (The Climate Conservancy, 2008). The aforementioned studies introduced a starting point of where to focus analysis for this research's greenhouse gas accounting calculations, and provided useful case studies for finer-level detail for executing the calculations.

Formatting the greenhouse gas calculations is also an important planning phase that the literature informed. Amienyo & Azapagic (2016) reported greenhouse gas emissions by category, i.e. packaging, raw materials, transportation, etc. Categorizing emissions by grouping rather than lump summation allows the data to be used to identify key emitting processes and/or materials, and to focus action plans there. It also gives the user a higher-level picture to focus more in-depth analyses on highly-emitting stages.

2.10.1.3 Scenario analysis

Scenario analysis (SCA) changes present decision pathways to analyze future impacts (Cook *et al*., 2014). Scenario analysis is used to gain foresight and mitigate future risks (i.e. financial and climate change risks) (Cook *et al*., 2014). Scenario analysis is a useful tool as it allows the user to focus on data from desired pathways based on the goal of the scenario analysis, rather than be overwhelmed by an abundance of data (Schoemaker, 1995).

Schoemaker (1995) identifies ten steps in developing a scenario analysis: define temporal scope, identify stakeholders who will be impacted and who can influence outcomes, identify external trends (i.e. political, economic, etc.), identify uncertainties (i.e. political, economic, etc.), build initial scenario themes, test consistency and plausibility of scenarios (i.e. realistic given the time frame, and involves appropriate stakeholders), develop a focus to develop and test scenarios, conduct research to influence uncertainties used for scenario analyses, create a quantitative model to reflect the qualitative relationships between variables in the model, and finally evaluate the analysis and adjust as needed. While creating and adjusting a scenario analysis is procedural, it is also partly an art form and dependent on the creator's judgment (Schoemaker, 1995). When evaluating scenario analyses, the creator should consider their relevance given the purpose, their effectiveness and usefulness, reflect a range of future scenarios, and assess the long-term usability of the scenario analysis (Schoemaker, 1995).

Various studies in academia have expanded on the use of scenario analyses, and have used this tool for future projections regarding their research. Cook *et al*. discussed the various tools available for scenario analysis, and its practical usage (2014). Specifically, Cook *et al*. discussed the importance of identifying key areas for company planning that could make use of scenario planning, and highlighted various methodologies of planning such as horizon scanning, which is a complementary tool to scenario analysis for horizon planning (2014). Cichorowski *et al*. created alternative scenarios after calculating the carbon footprint of Darjeeling black tea (2015). The researchers varied energy sources, cultivation techniques, and transportation methods to evaluate these decisions' impacts on the life cycle impact of black tea (Cichorowski *et al*., 2015). Gurtu *et al*. examined the supply chain and financial impacts of fuel price fluctuations (2015). For Ontario breweries, an example of an external variable that can be manipulated in scenario analysis is a change to raw material pricing, inclusion criteria for cap and trade in Ontario, or a change of the policy tool used for provincial carbon regulation (such as a carbon tax in place of cap and trade). Examples of internal variables are supplier choices, beer packaging, and anything under the direct control of the company's decisions.

A notable application of scenario planning includes the International Panel on Climate Change (IPCC) for their climate change projected scenarios (2014). In their *2014 Climate change: Synthesis report*, the IPCC included the chapter "Future climate changes, risks, and impacts" (2014). In this chapter, the IPCC used scenario analysis to predict future greenhouse gas emissions (2014). Given the climate change projections, scientists were able to determine the level of certainty regarding measures of water scarcity, heat waves, and frequency of major precipitation events, such as flooding (IPCC, 2014).

2.10.1.4 Benefits and challenges to greenhouse gas accounting

Two of the research questions for this study are to investigate the challenges and benefits of greenhouse gas accounting, in an Ontario craft brewery context. Previous literature has investigated challenges and benefits from a practical perspective, which lends information to guide this research's methodology. Fish (2015) conducted a case study review on the environmental impact mitigation actions of selected craft breweries in Virginia. This case study highlights that there has been a recent increase in craft breweries in Virginia, which is not dissimilar to the present context for Ontario craft breweries. Fish (2015) found that reducing energy use and greenhouse gas emissions were prevalent actions taken among the case study craft breweries. These findings suggest craft brewers are cognizant of the energy and GHG emission impacts of their breweries. In a local context, Beau's, a craft brewery located in Ontario, has committed to purchasing renewable energy as part of their corporate mission to be good environmental stewards (Beau's, n.d.). Steam Whistle Brewing, also a craft brewery, has cited that efficient brewing equipment has helped the company realize cost savings (Steam Whistle Brewing, n.d.). Academic and publicly-available Ontario brewery evidence suggests benefits to brewery greenhouse gas accounting are to reduce environmental impact for cost savings and to protect the natural environment.

Beare *et al.* (2014) conducted surveys with Canadian companies to determine the relationship between sustainability reporting and provincial and federal policy regulating these companies' sustainability performance. Although this study did not involve greenhouse gas accounting and more widely encompassed sustainability reporting, it offers useful qualitative insight into the challenges around sustainability reporting for companies. Beare *et al.* (2014) found that the Canadian companies surveyed wanted greater guidance around developing sustainability reports. This suggests companies have a lack of guidance for reporting their sustainability actions and plans, which may relate to the somewhat lacking publicly available information of Ontario craft brewery websites. Furthermore, firm size has a significant positive affect on social responsibility performance disclosure, meaning larger companies disclose their performance more than smaller companies

(Tan, Benni, & Liani, 2016). The aforementioned evidence suggests small companies require more guidance around developing public sustainability reports, and are less likely to develop these reports due to size. The literature therefore suggests lack of practical knowledge is an important barrier in developing greenhouse gas accounting and sustainability reporting methodology.

2.10.1.5 Interviews and thematic analysis

Interviews are a useful data collection tool to gain context-specific information in responding to research questions (Kvale, 2007). Morali & Searcy (2013) used semi-structured interviews with corporate experts in sustainable supply chain management because the corporate reports of interest varied in the quality of information included, and to gain better context from speaking directly with the source. These interviews were used to supplement a content analysis of corporate sustainability reports, which identified keywords and content relevant to understanding sustainable supply chain management initiatives (Morali & Searcy, 2013). Morali & Searcy (2013) used content analysis of corporate sustainability reports and the interview findings relevant to their research questions, providing a mixed-methods approach combining quantitative and qualitative data collection and analysis tools.

Another study examined the motivating factors for consumers' choice between craft and commercial beer consumption (Gómez-Corona *et al.*, 2016). The researchers asked beer festival attendees in Mexico City to participate in a five-minute interview comprised of 17 questions, mixing yes/no and open-ended questions (Gómez-Corona *et al.*, 2016). Tools such as frequency tests were used to analyze findings from the yes/no answers, while open-ended questions identified terms and grouped related terms together (a coding and organization mechanism) (Gómez-Corona *et al.*, 2016). The researchers found that authenticity, better access to beer-related information, and opportunities for choice as main motivators for craft beer drinkers (Gómez-Corona *et al.*, 2016). Since the research questions were focused on consumer behaviour, interviews proved to be an efficient form of collecting this information.

3. Purpose and Research Questions

The purpose of this research is to explore GHG accounting and reporting for breweries in a provincial context. This research also aims to investigate the (indirect) impacts of carbon regulation on Ontario craft breweries. Since carbon regulation has become a legislated policy instrument in Ontario to achieve GHG emission reductions, it is important to communicate how greenhouse gas emission mapping works in practice among SMEs to identify major emission sources, and how process changes impact emissions.

Craft beer in Ontario captures 8% of the province's market share for beer, with 24% growth between 2015 to 2017 (OCB, 2018b). Ontario's craft breweries are likely to increase their impact of GHGs both because of a global population increase and market growth projections. Given provincial carbon reduction targets, it would be unwise to ignore the opportunity for carbon management among Ontario craft breweries. Furthermore, tools for carbon management are publicly available, but what is missing is time and expertise among SMEs. The practical purpose of this thesis research seeks to identify the main barriers for carbon management, clarify the carbon accounting process, and help breweries reduce costs associated with carbon management.

Given the purpose of this research, the first research question is: **What are the greenhouse gas emissions of an Ontario craft brewery?** This research question will explore the greenhouse gas emissions of an Ontario craft brewery through working directly with a case company. Understanding the greenhouse gas emissions of a craft brewery will highlight what opportunities there are for GHG reductions both with the case company and with other similar companies. The rationale for this research question is the lack of accessible methods and data for Ontario craft breweries to calculate their emissions, and the significant scope of emissions given their size.

The second research question is: **What are the challenges of calculating an Ontario craft brewer's greenhouse gas emissions?** This research question aims to identify barriers, and their impact on, calculating GHG emissions for an Ontario craft brewery. The motivation for this research question is to explore resource or other limitations of calculating GHG emissions for a small brewery to understand brewery action and/or inaction, from a behavioural perspective.

The third research question is: **What are the benefits of calculating an Ontario craft brewer's greenhouse gas emissions?** The third research question explores the financial, environmental, and other benefits of calculating GHG emissions from the perspective of Ontario craft breweries. This research question adds a behavioural understanding to the drivers for why breweries are calculating their emissions. Furthermore, the motivation of this research question is to potentially understand how to engage better with Ontario craft breweries in terms of encouraging GHG calculations.

The second purpose of this research is to determine how, or if, provincial carbon regulation is changing Ontario craft breweries' administrative and process decisions. Since carbon regulation imposes costs to GHG emitters, it is useful to understand how companies respond. Despite the Ontario government's intentions for carbon regulation tools, it is important to have qualitative research examine the perceptions and impacts of regulation at the business level. Given this research aim, the fourth research question is: **What are Ontario craft brewer perceptions towards provincial carbon regulation?** This research question will explore positive and/or negative understandings of carbon regulation in Ontario among craft breweries.

4. Methods

This research is comprised of two main components: 1) process maps, GHG calculations, and scenario analyses with the case company, and 2) interviews with company representatives from the Ontario craft beer industry. The case company portion of this research will address research questions 1, and 2: *What are the greenhouse gas emissions of an Ontario craft brewery?* and *What are the challenges of calculating an Ontario craft brewer's greenhouse gas emissions?* The brewery interviews will address research questions 2, 3, and 4: *What are the challenges of calculating an Ontario craft brewer's greenhouse gas emissions?, What are the benefits of calculating an Ontario craft brewer's greenhouse gas emissions?,* and *What are Ontario craft brewer perceptions towards provincial carbon regulation?*

Ethics approval was obtained from Ryerson's Research Ethics Board (REB) on January 17, 2017 for a one-year period (Appendix A). An annual report with request for an extension until May 1, 2018 was submitted to the REB December 21, 2017, and subsequently approved. All interviews were completed by April, 2018.

Potential risks to the case company and interview participants are minimal. Risk management procedures include a non-disclosure agreement between the case company and research team (the agreement template was created by Ryerson University), informed and voluntary consent for study participation, confidentiality for participants, and a clear project plan that was shared with the case company.

4.1 Case study

The case company is a craft brewery located in Ontario, and is independently owned and operated. The case company is a mid-sized company that employed less than 250 full or part-time employees in 2016, which is the year from which data was used for the case study. In 2016, the case company produced less than 100,000 hL (hecto litres) of beer. The case company's age was less than 20 years old as of 2016. To protect the privacy of the case company, more precise information cannot be reported.

Connection with the case company was made in late Summer/ early Fall 2016 through Dr. Oguz Morali and Dr. Cory Searcy. Upon discussion, the case company expressed their interest in working with Ryerson University to calculate their brewery's greenhouse gas emissions. The first official meeting with the case company took place in October, 2016. The meeting included the lead researcher, Dr. Cory Searcy, Dr. Oguz Morali, and the case company's sustainability manager, along with two other brewery employees. Following the meeting, a project plan was developed by the lead researcher and shared with the case company's sustainability manager, who became the primary contact in the case company. The lead researcher communicated directly with the case company's primary contact for the duration of the project. Communication with the primary contact ended in May 2018 through completion of final deliverables.

The main deliverables for the case study phase were: 1) process maps, 2) greenhouse gas (GHG) emission database, and 3) scenario analysis. Figure 6 provides an overview of the case study method.

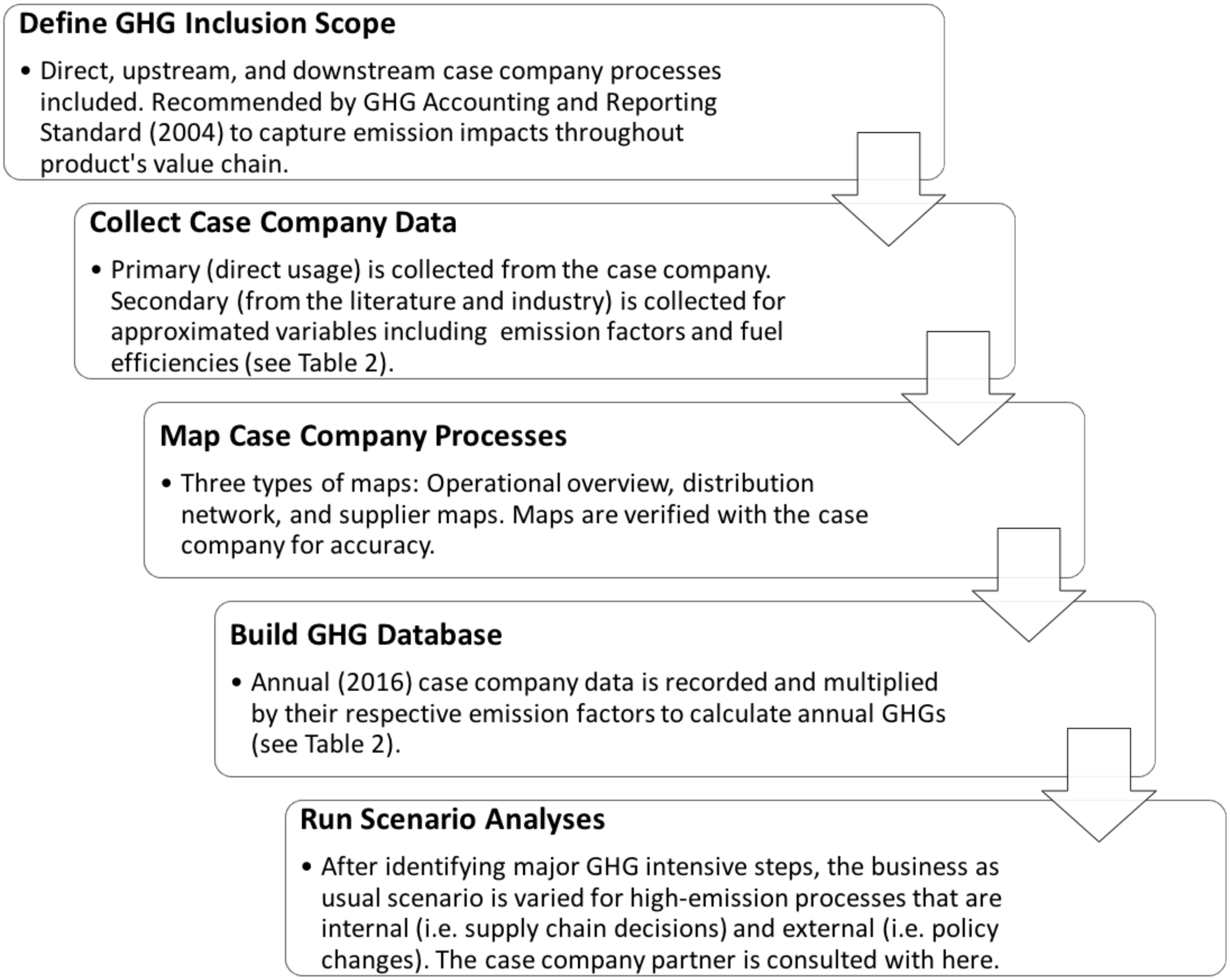

Figure 6 The five stages of the case study method

4.1.1 Greenhouse gas mapping and use of greenhouse gas accounting standards

The Basics of Process Mapping by Robert Damelio is used as the primary reference for process mapping techniques (2011). Process mapping visually breaks down the components of a process or organization (Damelio, 2011). For this research, relationship maps are created to connect supplier, case company, and distribution processes, and cross-functional maps are used to detail resource flows within stages of the case company's product value chain (Damelio, 2011). Microsoft Visio was used for mapping.

The three key standards used to calculate GHG emissions are: 1) GHG Protocol Corporate Accounting and Reporting Standard (ARS) (2004), 2) GHG Protocol Corporate Value Chain (Scope 3) Accounting and

Reporting Standard (ARS3) (2013), and 3) BIER Reporting Standard (2013). A clear distinction must be made between the intended purpose of these three standards. The GHG Protocol ARS is a cross-sectional guide that provides steps to entities calculating their scope 1 and 2 emissions (WBCSD & WRI, 2004). The ARS3 is a cross-sectional guide that provides steps to entities calculating their scope 3 emissions (which is officially not required of entities following the ARS) (WBCSD & WRI, 2013). Both the ARS and ARS3 have accompanying calculation tools and secondary data guidance documents, including the Scope 3 Technical document and Cross Sectional Emission Factors, both accessible from the GHG Protocol website (Greenhouse Gas Protocol, n.d.).

Scope 3 was chosen for inclusion for the case company's GHGs because it is anticipated to account for a large amount of total emissions based on previous reports of brewery GHG emissions (The Climate Conservancy, 2008; New Belgium Brewing, 2017). Furthermore, the WRI and WBCSD report that depending on the sector, scope 3 emissions can account for the majority of an entity's GHGs and therefore presents a huge opportunity for GHG reduction (WBCSD & WRI, 2013). Finally, the BIER Reporting Standard is a sector-specific guidance document that provides steps and examples for entities calculating their GHG emissions (BIER, 2013).

Rather than look exclusively at GHG emissions from a unit of beer, all case company operations were included in the calculations at an annual level to determine an operational overview of emissions performance and opportunities for improvement. Following the GHG Accounting and Reporting Standard (2004), emission types are reported as scope 1, scope 2, and scope 3 emissions. Scope classification is important as it indicates what GHGs are directly attributable to the case company, and what can be targeted for improvement by working with suppliers or other stakeholders downstream.

Table 3 Greenhouse gas accounting and reporting standards applied to the case company. Standards include the GHG Protocol Accounting and Reporting Standard (ARS) (WBCSD & WRI, 2004), GHG Scope 3 Accounting and Reporting Standard (ARS3) (WBCSD & WRI, 2011a), and the BIER Reporting Standard (2013).

Step description	**Standards and supplementary materials referenced**
Greenhouse gas accounting	
Meet with The case company to determine why they are interested in calculating their carbon footprint; what are their goals and intended use of this information.	Chapter 2 GHG Protocol ARS WBCSD & WRI, 2004
Set organizational and operational boundaries. Since The case company is independently owned and operated, its direct and indirect processes are included in the analysis. Operational boundaries determine whether direct (scope 1 and 2) or indirect emissions (scope 3) are to be included in calculations. Under the GHG Protocol, it is mandatory to account for scope 1 and 2 emissions, while scope 3 emissions are voluntary. Scope 3 emissions are recommended for inclusion when they are significant in magnitude, have future risk associated, and/or sociopolitical instability (source i. and ii.). Since The case company is independently owned, the control approach is used, so all calculated GHGs are applied to The case company. For companies that have split ownership, use the equity approach to greenhouse gas accounting, where emissions are calculated and reported relative to ownership structure (source ii.).	i. Chapter 3 and 4 GHG Protocol ARS WBCSD & WRI, 2004 ii. Chapter 3 GHG Protocol ARS3, WBCSD & WRI, 2011a
Set a baseline from which to calculate greenhouse gas emissions from. The greenhouse gas emissions in the baseline year will be used to inform reduction goals for the future. Data from 2016 is used for The case company.	Chapter 5 GHG Protocol ARS WBCSD & WRI, 2004
Collect primary data (provided by The case company) and identify as scope 1, 2 or 3. Use a centralized approach (primary data collected from The case company's corporate office). Collect secondary data as required (i.e. emission factors) from external sources. Scope 3 emission data collection should be prioritized by its magnitude relative to other scope 3 emission sources (source i.). Calculation approaches should be documented and consistent; purchase records (i.e. fuel, electricity, other raw materials) and activity records (i.e. kilometers travelled) are appropriate sources of The case company data (source ii.). Carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are the six GHGs included in calculations of scope 1, 2, and 3 emissions (source iii.).	i. Chapter 6 GHG Protocol ARS WBCSD & WRI, 2004 ii. Chapter 7 GHG Protocol ARS3 WBCSD & WRI, 2011a iii. Glossary GHG Protocol ARS WBCSD & WRI, 2004
Work with the primary contact at The case company to identify and collect missing data appropriate for the GHG calculations.	Supplier Engagement Guidance WBCSD & WRI, 2011b
Calculate greenhouse gas emissions from primary and secondary data. This is in line with the calculation method, with the alternative being the direct measurement method. Decisions as to whether to use primary or secondary data should be based on data availability and goals of the GHG accounting (source i.). Formula for calculation method (source ii): GHG= activity data x emission factor x greenhouse warming potential (GWP_{100})	i. Emission-factors from cross sector tools WBCSD & WRI, 2017 ii. Chapter 6, 7 & 9 GHG Protocol ARS WBCSD & WRI, 2004 iii. Chapter 7 GHG Protocol ARS3 WBCSD &WRI, 2011a

Step description (cont'd)	**Standards and supplementary materials referenced (cont'd)**
Use sector-specific or cross-sector tools for GHG calculations. The most recent greenhouse warming potentials (GWPs) produced by the IPCC should be used with a 100-year horizon (expressed as GWP_{100}) for conversion of all GHGs to carbon dioxide equivalents (CO_2e) (source iii.). Maintain a clear record of data sources, assumptions, and calculations used. These records can be used to verify GHG calculations in an internal and/or external audit (source iv.).	iv. UNFCCC Canadian 2017 submission, Government of Canada, 2017
Design the GHG database to allow The case company to add, modify, and track emissions over time.	Chapter 3 GHG Protocol AR Standard WBCSD & WRI, 2004
Greenhouse gas reporting	
When publicly reporting GHG emissions, absolute values must be reported. Ratios can also be useful to report to compare performance over time. Common ratios to report include efficiency (unit GHG produced per volume of beer), productivity (GHG produced per dollar revenue), and percentage ratios to compare performance over years.	Chapter 9 GHG Protocol ARS WBCSD & WRI, 2004
Scenario analysis	
After reviewing the GHG calculations with The case company, recommendations for scenario analysis will be made to see how GHG amounts change due to internal and external changes.	Cook *et al.*, 2014 IPCC, 2014 Schoemaker, 1995

To calculate a company's GHG emissions, according to Environment and Climate Change Canada (2016b) "monitoring and direct measurement, mass balance, emission factors, and engineering estimates" are used (p.9). Environment and Climate Change Canada indicates that there should be a focus on processes with large emissions and/or changes from previous years, and recognizes there is no one guiding GHG emission standard (2016b). This guidance is in line with the GHG Protocol Standards, which allows the use of a calculation method, in place of direct measurement, particularly in cases of limited data availability (WRI & WBCSD, 2011a). The various standards allow flexibility in companies' greenhouse gas accounting efforts, however it also fails to provide a definitive step-wise guidance to companies. To increase clarity of how this thesis approached these calculations, the greenhouse gas accounting method was developed by referencing the appropriate standard (see Table 3). Primary and secondary data sources used for case company emission calculations were carefully documented (see Table 4 and Appendix K, respectively).

Table 4 Case company primary data used for greenhouse gas emission calculations

Data Name	Data Type and/or Scope	Source
Electricity purchased	Primary data, Scope 2	Case company primary contact, 2016 and 2017
Fuel purchased	Primary data, Scope 1	
Hops purchased	Primary data, Scope 3	
Spring water purchased	Primary data, Scope 3	
Municipal water used	Primary data, Scope 3	
Waste generated	Primary data, Scope 1	
Steam purchased	Primary data, Scope 2	
Carbon dioxide purchased	Primary data, Scope 1	
Glass bottles purchased	Primary data, Scope 3	
Aluminum cans purchased	Primary data, Scope 3	
Kegs purchased	Primary data, Scope 3	
Secondary packaging purchased	Primary data, Scope 3	
Retail items purchased	Primary data, Scope 3	
Return percentage of kegs and bottles	Primary data, Scope 2 and 3	
Supplier information (location, number of shipments per year)	Primary data, Scope 3	
Shipment method for each supplier	Primary data, Scope 3	

The choice of primary data to include in the case company's GHG calculations was determined by two factors: 1) the scope of the case company GHG calculations, and 2) data availability. The scope refers to the parameters of the case company operations to include. Based on the case company's project outline and resource availabilities, emissions involved in beer production, packaging, and distribution were included, with the final output unit being identified as tonnes of carbon dioxide equivalents per year per hectolitre of beer produced (t $CO_2e_{per\ year}$/hL beer). The second factor, data availability, also influenced what primary data was used for the greenhouse gas calculations. The case company provided the research team with the data they have and continue to collect on a per month and per year basis. This data was streamlined for use by deciding what primary data provided a unit of measurement that could be used with an emission factor.

The choice of secondary data to include in the case company's greenhouse gas calculations was determined by the following factors: 1) reliability and breadth of data from each source, 2) geographic relevance, 3) technological relevance, and 4) temporal relevance. The first factor, reliability and breadth of data from secondary data sources, refers to the reputation of the publisher of the secondary data. For example, data from the "2017 Canadian National Inventory Submission to the United Nation's Framework Convention on Climate Change" and the "2017 World Resources Institute (WRI) Emission Factors from Cross Sector Tools" were used for 23 of 59 secondary data values. The WRI Emission Factors provided varying emission factors based on country (i.e. United States, United Kingdom, and other). The "other" emission factor data was primarily used for this project, followed by United States data and finally United Kingdom data when needed. Although the WRI source did not specifically provide emission factor data for Canada, the source provided data for countries with comparable levels of technology. The Canadian National Inventory Submission successfully fulfilled the reliability and breadth, geographic, and temporal relevance factors; whereas the WRI Emission Factors fulfilled the reliability and breadth, and temporal relevance factors. The data for the remaining 36 of 59 emission factors collected from secondary data sources were primarily from academic journal papers, corporate consultancy reports, the International Panel on Governmental Panel on Climate Change (2014 Synthesis Report), and databases such as BUWAL 250 and Ecoinvent (when publicly available). For a complete list of the secondary data sources used for the GHG case company calculations, see Appendix K in Section 8.11).

4.1.2 Case company: Scenario analysis

Scenario analysis for this research was developed based on the findings of the greenhouse gas emissions for the case company. Two scenarios were chosen to reflect internal (i.e. case company has control over) and external (i.e. case company does not have control over) variables using a 10-year time horizon.

The two scenario analyses used for the case study company were: 1) CO_2e emissions associated with projected growth (measured in beer sold per year) over the course of 20 years, and 2) changes to CO_2e emissions associated with packaging volume changes (i.e. hL beer packaged in aluminum cans versus beer bottles per year) over 10 years. For each scenario, two dimensions were crossed to form matrices for evaluation (Table 7). Scenario one was chosen to reflect an external variable that is not entirely controlled by the case company (i.e. case company beer sales growth) in combination with an internal variable that is controlled by the case company (i.e. GHG emissions per unit beer sold). By forecasting sales growth scenarios, the case company can plan for what is the most appropriate decrease in brewery GHG emissions to meet long-term carbon emission reduction targets. Furthermore, the uncertainty in beer sales growth may allow the case company to develop contingency plans and re-adjust as needed when continually evaluating the actual external variable change against the projected external variable change. The second scenario also uses the same forecasting for case company beer sales, but combines it with an internal variable (beer packaging in aluminum cans and glass bottles) to determine the impact on total brewery greenhouse gas emissions given sales growth. Both of these scenarios are meant to be used for planning purposes, but also to demonstrate how small changes to internal decisions can have a large impact on future craft brewery GHG emissions.

The first dimension for the first scenario was calculated using a 2015-2017 growth percentage figure published by the Ontario Craft Brewer's Association (OCB, 2018b). Primary (i.e. actual), intermediate, and advanced percentage growth estimations were created from the baseline 2015-2017 annual growth percentage reported by the OCB. The baseline annual growth percentage in craft beer revenue reported by the OCB was used as the intermediate scenario (24%), while the primary scenario was an 18% growth and the advanced scenario reflected a 30% growth. These growths were chosen given recent trends in craft beer revenue and an increasing provincial population. The primary growth percentage was set to be lower than the actual 2015-2017 industry sales growth in case of a possibility of market saturation of craft breweries, and/or a shift in consumer preferences. The second dimension varied the percentage decrease of greenhouse gas emissions by the case company (also primary, intermediate, and advanced scenarios). A decrease of greenhouse gas emissions was chosen based on evidence of the case company's environmental initiatives to lower their greenhouse gas emissions over recent years. For example, the case company's purchases of renewable energy, and packaging decisions are two areas of action to reduce GHG emissions. The primary scenario reflects a 0% change, the intermediate scenario a 10% decrease, and the advanced scenario reflects a 20% decrease in CO2e emissions per unit of beer produced). The calculated output along these two dimensions is CO_2e in tonnes, using a 10-year time horizon.

The second scenario analysis projected the use of the case company's aluminum cans and glass bottles, and the CO2e in tonnes associated with this production, over a 10-year time horizon. The first dimension for this scenario was also the OCB industry growth (same as in the first scenario) to serve as an approximation for the case company’s demand. It is important to state an assumption was made to use the same industry growth for the case company growth. The second dimension for this scenario used 2015 and 2016 case company data to calculate the percentage change of aluminum cans vs. bottles used (relative to the hL produced that year, i.e. reported as hL beer packaged in aluminum cans per year and hL beer packaged in glass bottles per year). These percentage changes were used as the primary (actual) percentage change along the first dimension, whereas intermediate and advanced scenarios were also calculated from the primary (baseline/actual) change. Both the first and second dimensions also used primary, intermediate, and advanced percentage industry growth. A 10-year time horizon was used for scenarios one and two to reflect long-term impacts, and for the scenario analysis to be a useful tool to base actions to build towards a long-term reduction target. See Table 5 for a visual representation of the scenario analysis matrices for scenarios one and two.

Table 5 Scenario analyses matrices

Scenario 1*: 10-year horizon (2018-2028) CO2e with beer production estimates x decrease in annual percentage CO2e estimates*				
		Case company beer production (hL)		
		Primary Scenario	**Intermediate Scenario**	**Advanced Scenario**
Decrease in CO2e (per hL beer)	**Primary Scenario**	CO2e emissions estimate #1	CO2e emissions estimate #2	CO2e emissions estimate #3
	Intermediate Scenario	CO2e emissions estimate #4	CO2e emissions estimate #5	CO2e emissions estimate #6
	Advanced Scenario	CO2e emissions estimate #7	CO2e emissions estimate #8	CO2e emissions estimate #9
	Scenario 2*: 10-year horizon CO2e with beer production estimates x bottle versus can production ratio*			
		Case company beer production (hL)		
		Primary Scenario	**Intermediate Scenario**	**Advanced Scenario**
Change (in hL) in beer packaged in bottles vs cans	**Primary Scenario**	CO2e emissions estimate #1	CO2e emissions estimate #2	CO2e emissions estimate #3
	Intermediate Scenario	CO2e emissions estimate #4	CO2e emissions estimate #5	CO2e emissions estimate #6
	Advanced Scenario	CO2e emissions estimate #7	CO2e emissions estimate #8	CO2e emissions estimate #9

4.2 Ontario Craft Brewer website content analysis

The website content analysis was conducted as a complementary tool to the OCB interviews. The purpose of the website content analysis was to evaluate publicly-available corporate environmental (particularly greenhouse gas emission reduction) actions, and to record descriptive data such as demographics.

4.2.1 Data collection

Prior to participant recruitment for the interviews, the Ontario Craft Brewers website members page was used as the starting point to collect information about the 85 craft breweries. A website content analysis research protocol was created to provide structure and reliability to researcher findings (Appendix D). The information collected by the researcher included:

a. Company name
b. Website URL
c. Annual production (L/year)
d. Environmental keywords
e. Environmental notes
f. Environmental quotes
g. Established date
h. Contact person (first, last names)
i. Contact person position
j. Contact email
k. Contact phone
l. Other notes (may include specific URLs for where environmental keywords were noted, may refer to best way to make contact with company, etc.)

Most of the collected information was factual (i.e. location of brewery, contact information, etc.) however some of the information was dependent on process, including environmental keywords. Only one researcher was conducting the interview research, so reproducibility and accuracy were unable to be verified (Krippendorff, 2004). However, intra-rater reliability, otherwise known as stability, was measured to ensure the researcher had the same findings upon repeated attempts (Krippendorff, 2004; Stemler, 2001). Following data collection from the OCB members' websites, 15 of 85 breweries made reference to environment and environmental sustainability. A re-test was conducted on these 15 breweries. For the re-test, environmental keywords, notes, and quotes were captured to compare the consistency of recorded findings. No re-test was required for the remaining 70 companies as their collected information was factual (i.e. brewery name, city, contact information, etc.).

4.2.2 Data analysis

Descriptive statistics were run on brewery size (production volume), and brewery age. Where information was not publicly available, the researcher asked for missing information during interviews. Missing information was a result of incomplete public information and limited participation of Ontario craft breweries in the interviews. The frequency of environmental keywords was reported, and keywords were also grouped into representative categories for analysis of brewery trends in greenhouse gas emission reduction and other environmental actions. The frequency of environmental keywords gave an indication of the depth of greenhouse gas management of Ontario craft breweries. The environmental keyword frequencies were also compared with the craft breweries who participated in the interviewees (i.e. did participants have websites with environmental keywords).

4.3 Interviews

The interviews complement the quantitative case study component of this thesis. The interviews give independent perspectives to determine knowledge of GHG accounting as a tool, use of GHG accounting, and perceived motivators and limitations of GHG accounting. The interviews will also investigate the perceived impacts of cap and trade among Ontario craft breweries. The interview questions are included in Appendix D. Table 6 provides an overview of the key stages of the interview portion of this research.

Table 6 OCB interview development and analysis process

Stage Name	Stage Description
1) Develop interview questions	Designed based on the study objectives. Refined for conciseness and focus will be modified for each interviewee for greater depth of responses (Rubin & Rubin, 2012). Interviews include main questions, probes/prompts to encourage discussion, and follow up questions to gain depth of responses (Rubin & Rubin, 2012).
2) Set interview selection criteria	Inclusion: Ontario Craft Brewers, which has 85 members (Ontario Craft Brewers, 2018). Exclusions: the case company was excluded from the interview, along with one brewery who had missing contact information, and another brewery who had the same ownership and contact information as another Ontario Craft Brewery. With these exclusions, a total of 82 companies were invited for an interview. Email-initiated survey response rate was 22% for a US-based craft brewer study (Hoalst-Pullen *et al., 2014*). Initially, approximately 10 to 20 participants were expected. Given the narrow inclusion scope and research objectives, it was anticipated that saturation would be reached with this number of participants. Saturation is achieved when the same concepts are discussed by different interviewees (Rubin & Rubin, 2012).
3) Create interview research protocol	Consistent approach to researching prospective interviewees to ensure intra-rater reliability. Depth interviewing was chosen as the interview style as it creates a dialogue and provides rich findings (Rubin & Rubin, 2012). The interview questions were reviewed and edited following the first two completed interviews for improvement purposes.
4) Recruit participants	Email contact was used as the initial means of outreach as this is the most widely available information and is the least invasive. Follow up emails and phone calls were used where possible.
5) Execute interviews	Interviewees had the choice of in-person (if based in the Greater Toronto Area), video call, or phone interviews. Interviewees signed a consent form, were reminded of their participation prior to the interview, and received a follow-up email to clarify interview notes and/or transcripts for accuracy (Rubin & Rubin, 2012). Consenting interviewees

Stage Name (cont'd)	Stage Description (cont'd)
5) Execute interviews	were audio-recorded. The interviews were planned for a maximum of 60 minutes in the interest of time, with length of interviews estimated to take 15 to 30 minute each. Confidentiality was respected, though anonymity between the researcher and participant was impossible.
6) Thematically code responses	Thematic analysis was used for the transcribed interviews. Interview material was reviewed, and code definitions were created and then applied to transcripts (Rubin & Rubin, 2012). Data was associated with generic ID numbers to protect participant confidentiality.
7) Analyze findings	Analysis of interviews was ongoing to adjust interview structure as needed (Rubin & Rubin, 2012). Coded themes were grouped to identify relationships from which to draw findings (Rubin & Rubin, 2012).

4.3.1 Interview inclusion criteria

The sampling group consisted of sustainability managers or those in similar roles in companies that are members of Ontario Craft Brewers (OCB). Ontario Craft Brewers includes 85 independent craft breweries (Ontario Craft Brewers, 2018a). The interviews focused on OCB members to keep the scope contained and within a provincial context. This group was chosen as an inclusion parameter because it allowed similarities in comparison between geography, jurisdictional legislation, and production size. Exclusion criteria included those outside of OCB, the case company, those unable or unwilling to provide consent for participation (inclusive of missing contact information), or privacy issues with potential interviewees. Interview sampling was therefore done through non-probabilistic sampling.

4.3.2 Interview: Participant recruitment

Initial contact was made via email, or phone (if no email address was available). The lead researcher asked for voluntary participation in the study (see appendix for initial contact email). If the invited participants did not respond within one week, a follow-up email was sent as a reminder (see Appendix C for follow-up contact email). Dillman (1978) suggests using a follow-up of two weeks for interview invitations with no response to improve response rate. Due to a short timeline for interview scheduling (one month) a first follow-up email was sent one week following the initial invitation. The follow-up contact should serve as a reminder, but also was used as an opportunity to frame the importance of participants for the study (Dillman, 1978). The essential components of the first follow-up email included: reference to the study and the first invitation, the importance of participants from sample, and an invitation to request any further information regarding the study with contact information (Dillman, 1978). A second (and final) email reminder was sent to participants who did not reply within a week of the first follow-up email being sent (i.e. two weeks from the initial invitation to participate). The final reminder email emphasized the importance of participation.

If the participant agreed to participate, the lead researcher sent prospective participants a consent form outlining the study and requesting voluntary consent for participation and audio-recording of the interview. The interviewee chose their preferred medium for the interview (in person if aural and visual privacy can be secured, or over the phone/Skype). Prospective participants were encouraged to ask questions regarding the study prior to and during their participation. The participants were also sent a reminder email 48 hours before their participation if the interview was schedule more than three days in advance of the interview time. Interviewees were invited to participate in groups beginning in February, 2018, so as to avoid over-scheduling. The interviews are exploratory in nature as little literature exists to form theme hypotheses/expectations a priori. The lead researcher re-evaluated the interview questions following the first two interviews so the protocol and questions could be modified.

4.3.3 Interview format

The interviews used a semi-structured approach. Semi-structured interviews are those where the interviewer has a clear list of questions that were deigned to serve the research purpose, but allows changes to the interview format for each participant (Kirby, Greaves & Reid, 2010). Semi-structured interviews allow for flexibility, and potentially unanticipated findings (Kirby, Greaves & Reid, 2010). The chosen questions were developed based on the project goals, qualitative research methodology, and preliminary research of craft breweries in Ontario. Interviews were recorded if participants' consent is given, otherwise the interviewer manually recorded notes during the interview. Interviewees were asked following the completion of the interview whether they wanted to be sent their interview transcript. These interviewees were also given the chance to make any corrections to their interview transcript.

4.3.4 Confidentiality

Due to the nature of the interviews, the lead researcher knew the identity of the participants (no anonymity). However, every effort was made to ensure confidentiality. Data was only associated with a generic participant ID number. When reporting this information, no information that is potentially identifiable was reported.

4.3.5 Interview execution

Every interview followed the same protocol:

1) The interviewer introduced self, and thanked the participant for their time and participation. The interviewer reviewed the study and consent form prior to commencing the interview, and asked if the participant had any questions from the consent form they were provided. The emphasis of the consent agreement review included the purpose of the study, potential risks, voluntary participation, and participant withdrawal.
2) The interviewer asked the interview questions, audio recorded the interview (if consent was provided), and manually took notes. The interviewer also posed follow-up questions and prompts where needed to have participants clarify and/or expand their responses.
3) Following conclusion of the interview, the researcher asked the participant if: 1) they would like to review a written transcript from the interview audio recording (to be sent over email), and 2) if the participant would like to be informed of when the researcher's thesis report is publicly available (to be sent over email). The researcher then thanked the interviewee for their time and encouraged any questions that may arise following the conclusion of the interview.

A sample of the interview script is included in Appendix E along with the interview questions. Some interviewees asked the interviewer questions during the interview. In these cases, all questions were held until the end of the interview so as to not influence the interviewee's responses.

Rubin & Rubin (2012) recommend ongoing analysis of interviews to modify the interview protocol as needed. Following the first two interviews, adjustments to follow-up questions, prompts, and elimination of a (repetitive) question was made. These adjustments improved the effectiveness and efficiency of the subsequent interviews. This involved the researcher adding follow-up questions to elaborate the interviewee responses as questions arose to the researcher in the data collection process. Question 9 ("What are (or what would be) the main motivations for tracking and reducing your company's carbon footprint?") was rolled into Question 4, which already addressed motivations for measuring brewery greenhouse gas emissions. Furthermore, a prompt for Question 4 specifically asked interviewees if marketing was a benefit of investing in greenhouse gas reductions to promote an environmentally sustainable beer (see Appendix E).

4.3.6 Interview analysis

An inductive, exploratory content analysis was developed to analyze the interview findings. An important note is that the coder reviewed and coded text manually. This decision was made due to the low volume of interview text to review, encourage a more iterative review of the interview transcripts, and to save time from the learning curve involved in learning a coding software.

Rubin and Rubin's work on Qualitative Analysis (2012) for interviews, and Krippendorff's Content Analysis book (2004) were used as resources to design the interview structure, questions, and analysis. These resources were used to guide the development of the interview content analysis process*:

1) On the first review of the transcript, the coder made notes of key points and useful quotations and recorded them as "code 2s" or "quotes". Code 2s were paraphrased material from the transcripts to succinctly represent meaning from the written transcripts, which makes code application more straight forward.
2) The coder reviewed the code 2s recorded in Step 1 (above) and assigned codes for themes, sub-themes, events, and concepts (these are "code 1s"). Code 1s were developed and/or applied following the interview execution (i.e. *a posteriori*). Code 1s reflect the meaning of the transcribed text. When a new code was developed, the coder created a clear definition and parameters for assigning the code, along with an example of text that qualifies as having the code applied. All codes, their definitions, and an example for each code was kept in a separate coding key.
3) Following coding of interview transcripts, the researcher re-read all Code 2s to look for any incorrect application of code 1s, and to add any missing information as code 1s. Following the second review, the researcher grouped similar codes and their respective texts.

4) The researcher analyzed grouped text, and reviewed the codes for consistency. Codes were combined where applicable to streamline codes to capture the same concepts, events, and themes. The coding key was updates as needed.
5) The coder repeated steps 1 and 2 above for intra-rater reliability for two transcripts once all the interviews have been completed and transcribed. An acceptable score on the re-test is Krippendorff's Alpha= 80%, meaning that the re-test should yield at least 80% of the same codes (Krippendorff, 2004).
6) Descriptive statistics were run on code frequency, and findings were qualitatively analysed from the thematic analysis of interview content.
7) Codes and their frequencies were related back to the research questions to draw conclusions (Rubin & Rubin, 2012).

* *"Code development and application" includes a more-detailed explanation of the content analysis process*

4.3.7 Code development and application

Stage 1 of the interview analysis (listed above) allowed the coder to gain an understanding of the frequency of common answers to research questions. Rubin & Rubin (2012) state that identification of common answers to interview questions is an important step in code development.

Stage 2 of the interview analysis involved the development and assignment of codes to the text from interview transcripts. The interview transcripts were analysed using a general inductive approach (Thomas, 2006). Grounded theory is an inductive approach to analyzing interviews by developing codes as the coder reviews the interview transcripts (Rubin & Rubin, 2012). This form of thematic analysis allowed more richness to emerge from the interviews, however the disadvantages are that it may have been easier to lose sight of key interview themes, and that the process takes more time (Rubin & Rubin, 2012).

Interview code development was guided by the thesis research questions and objectives. Objectives in the interview analysis include identification of key challenges and benefits of greenhouse gas management, and knowledge and perceptions of Ontario's cap and trade program among Ontario craft breweries, and the potential impact on the craft brewery industry and companies. Codes for challenges and benefits emerged after reviewing the interview transcripts. The codes were also compared with previous literature findings, mainly regarding the challenges and benefits of greenhouse gas management (Sloane, 2012). Codes mainly involved environmental and social benefits of carbon management, and financial challenges of carbon management. Understanding the perceptions of the cap and trade program among Ontario craft breweries integrates the theoretical perspectives from institutional and image theory. These theories were used to guide coding development regarding external pressures of carbon regulation on craft brewery value image development and, thus, priorities and actions regarding carbon management.

Stage 3 of the interview analysis involved grouping text between interviews with the same codes 1s. Grouping is an important step in the grounded theory approach to coding, as it allows comparison of text to determine how similarly codes are applied to texts (Rudestam & Newton, 2015). A summary was then made on the key findings from the grouped text, where emerging narratives in the context of the research questions were found (Rubin & Rubin, 2012).

Stage 4 of the interview analysis had the researcher review and combine similar code 1s together (Rubin & Rubin, 2012). This was important to reduce redundancy of code 1s and being able to see clearer patterns between interview questions, their responses, and codes. During this stage, the researcher also revised code 1s where needed to improve the codes' meanings and usefulness in better understanding the interview findings and narratives. Finally, when comparing codes and their respective texts, there was also an opportunity to see if codes were missing for pieces of text, or if more appropriate codes could be applied (Rubin & Rubin, 2012).

Stage 5 tested for intra-rater reliability, also known as stability, which was an important consideration during coding (Krippendorff, 2004). Stability ensures that the results are replicable/reproducible. The first two transcripts were re-coded to determine the degree of consistency between tests. Krippendorff's Alpha was used as a quantitative tool to determine the level of agreement between the two rounds of coding completed by the same coder (known as stability or intra-rater reliability) (Krippendorff, 2004). Krippendorff's Alpha was calculated by dividing the observed disagreement between the test and re-test by the disagreement between the tests due to chance (Figure 7) (Krippendorff, 2004). Alpha yields a value between 0 and 1, with a value of 1 representing perfect agreement between tests, and a value of 0 meaning the agreements were only due to chance (Krippendorff, 2004). A Krippendorff's Alpha equal to or higher than 0.80 was chosen for this research to indicate whether coding was considered reliable (Krippendorff, 2004). However, the level of agreement is dependent on the researcher's use of the data, and the sensitivity of any conclusions drawn from coded data (Krippendorff, 2004).

$$\alpha = 1 - \frac{D_o}{D_e}$$

Figure 7 Krippendorff's Alpha formula. D_o is the observed disagreement between tests, and D_e is the expected disagreement between tests. Source: Krippendorff, 2011.

Stage 6 in the interview analysis created descriptive statistics to understand relationships in code applications. An overview of interview findings was constructed in relation to the research objectives. Each questions' codes were isolated to determine key themes given the codes' context, and to compare between interviewees using frequency counts. This allowed the coder to understand the frequency of codes, emergence of themes, and their connection to prevalent narrative(s).

5. Results

The results section is divided into case company, OCB website content analysis, and interview results. Each section includes a summary, followed by a more detailed report of the results. The implications of this research's findings were related back to this study's research questions, and considered together in the discussion section.

5.1 Case company

5.1.1 Summary of findings

The goal of the case company portion of this research was to determine: what is the greenhouse gas (GHG) emissions of an Ontario craft brewer?, and What are the challenges associated with calculating GHG emissions? The calculations addressed the first research objective, while the practical nature of this research allowed the researcher to address both the calculation and procedural challenges of the second research objective.

The results show that the craft brewer's largest source of GHG emissions was indirect sources, with scope 3 emissions accounting for 46.43% of GHG emissions. The largest scope 3 source was barley production, which accounted for 10.73% of total (all scope) emissions. Scope 2 GHG emissions accounted for 38.70% of GHG emissions. The largest scope 2 source was steam, contributing 21.05% to total brewery emissions. Scope 1 GHGs accounted for 14.87% of GHG emissions. Gasoline was the largest scope 1 source, contributing 5.36% of total brewery emissions. The research with the case company found that GHG accounting has various associated challenges, including availability of secondary data for process mapping and calculations, and a reliance on tacit knowledge within the case company that inhibits project continuity.

5.1.2 Process mapping

Process maps were created following Damelio's process mapping guidelines (2011). The goal of the maps was to visually represent the value chain pathways of the case company in an appropriate level of detail. The process maps also allowed the researcher to check with the primary contact at the case company that their understanding of brewery processes was accurate.

Stream flow maps were used to create upstream, brewery, and downstream operations. Upstream processes included supplier production and transportation of raw materials to the brewery, brewery operations included those under direct control of the brewery, and downstream operations included transportation of waste, and returned products such as packaging. Due to the confidential nature of the process maps, most of the process maps have only been made available to the case company. An overview of the brewery operations is included in Figure 8, and a case company operational overview focusing on shipping and other transportation of goods is included in Appendix L.

The process mapping boundaries were limited to GHG calculations. Due to missing data, there was also limitations in how accurate the stream flow maps could be made. For example, the researcher had challenges with accessing upstream and downstream process information since secondary data was used. The main secondary data challenges included raw material transportation methods, shipping locations for brewery products, and exact locations for spent grain distribution. However, the purpose of the process maps was to understand the pathways of the brewery, and in this way the objective was achieved. The researcher was in contact with the primary contact at the case company for corrections to be made to the brewery maps.

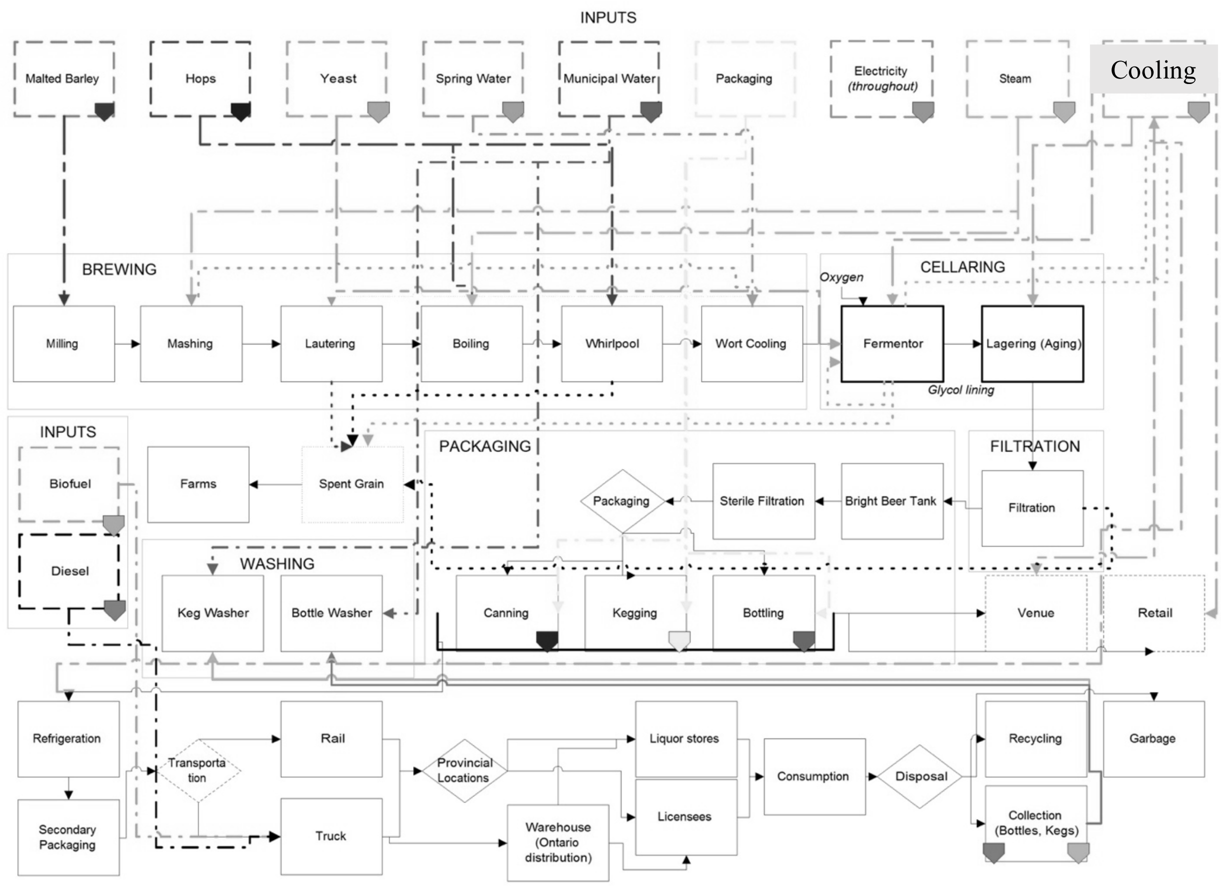

Figure 8 Process map of the case company brewery operations. Rectangle boxes encompass processes and/or products, and are colour-coded for clearer readability. Pathways of inputs through the brewery process are denoted with dashed lines. Solid lines connect the flow of processes through the brewery value chain. Data sources were obtained through the primary contact at the case company.

5.1.3 Overview of GHG emission sources

The greenhouse gas calculations found that the majority of GHGs are from indirect (scope 3) sources, followed by scope 2 sources. Scope 3 accounted for 46.43% of GHG emissions, scope 2 accounted for 38.70% of emissions, and scope 1 accounted for 14.877% of total GHG emissions (see Figure 9). A complete table of greenhouse gas emissions is included in Appendix F.

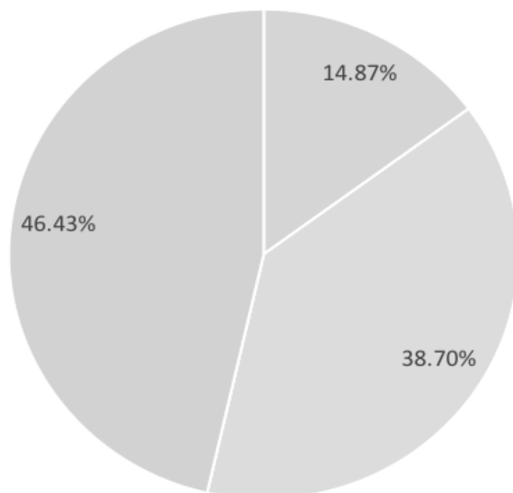

Figure 9 Breakdown of greenhouse gas emission sources by scope type. The medium-shade grey pie slice denotes scope 1 emissions, the light-shad grey pie represents scope 2 emissions, and the darkest-shad grey pie is scope 3 emissions. Data used to calculate greenhouse gas emissions is from primary (case company) and secondary sources (see Appendix K).

Within each of scope 1, 2, and 3 categories, the largest source of emissions were identified. The largest source of scope 1 emissions was the brewery's gasoline use, the largest source of scope 2 emissions was steam, and the largest source of scope 3 emissions was barley production. The relative impacts of the aforementioned sources are compared to the magnitude of GHG emissions for each scope (Figure 10). Appendix F includes a complete table of greenhouse gas calculations that was used to create Figure 10.

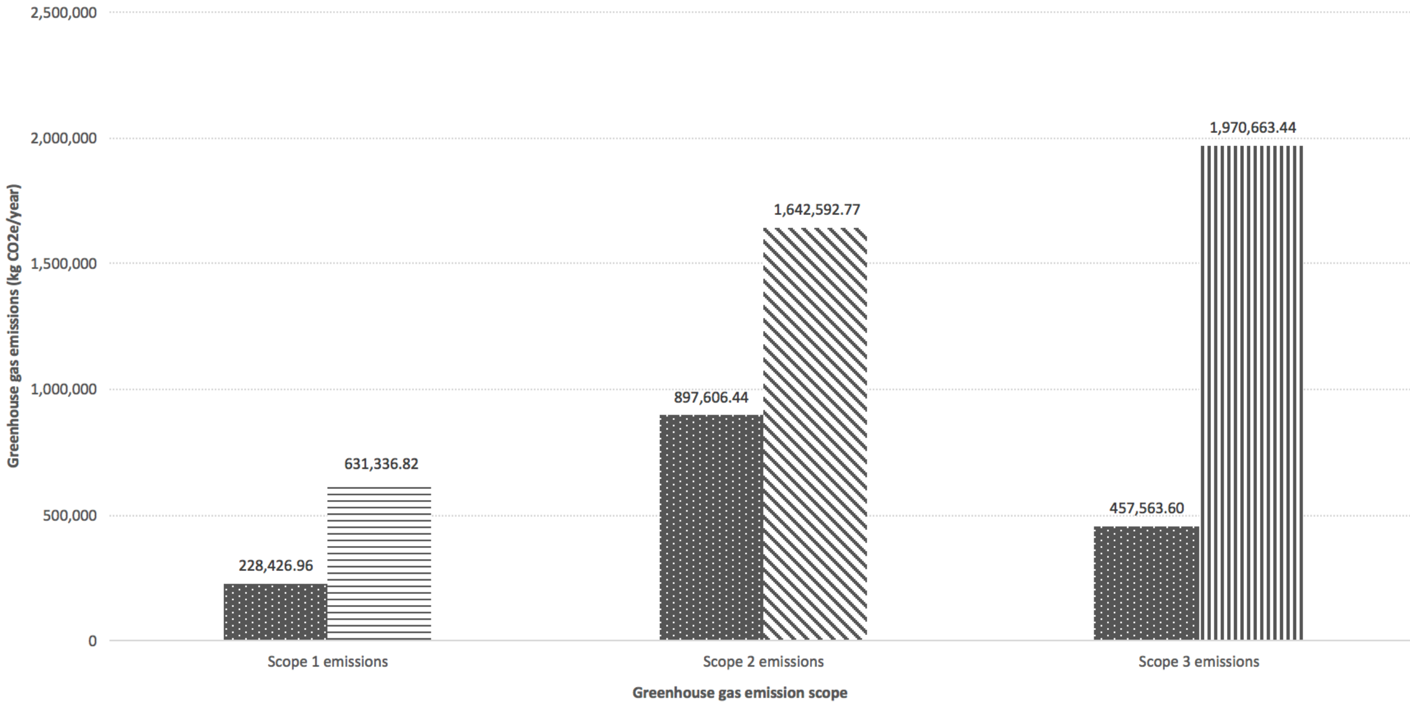

Figure 10 Greenhouse gas emissions from the case company, using 2016 data. The horizontal stripe bar is scope 1 emissions, diagonal stripe bar is scope 2, and vertical line bar is scope 3 emissions. From left to right: the first dotted bar denotes the GHGs from the brewery's gasoline use as a percentage of scope 1 emissions, the second dotted bar denotes the GHGs from steam as a percentage of scope 2 emissions, and the third dotted bar denotes the GHGs from barley production as a percentage of scope 3 emissions.

Greenhouse gas emissions were categorized in line with the suggested categories provided by the GHG Corporate Accounting Reporting Standard (WBCSD & WRI, 2004), GHG Scope 3 Guidelines (WBCSD & WRI, 2011) and the Beverage Industry Environmental Roundtable (BIER, 2013). Several standards were used for category classification as the categories from any one standard did not cover all the data from the case company calculations. The data is classified by category, scope, and relative impact to other brewery GHG sources in Table 7.

Table 7 The three largest emission sources from each GHG scope is reported by source (product/process), scope (1, 2, 3, using GHG Protocol (2004) definitions), amount of CO_2e per year, and percent of overall GHG emissions (the product/processes GHGs relative to all emissions. The "Percent of overall GHG emissions" column does not sum to 100% because only the top three sources from each GHG scope were included. See Appendix F for all sources.

Source	**Scope**	**Category**	**Tonnes CO2e/year**	**Percent (%) of overall GHG emissions**
Diesel	Scope 1	Mobile emissions	178.98	4.20%
Gasoline	Scope 1	Mobile emissions	228.43	5.36%
B20 Biofuel	Scope 1	Mobile emissions	188.79	4.43%
Steam	Scope 2	Purchased steam	897.61	21.05%
Electricity	Scope 2	Purchased electricity	406.39	9.53%
CO_2 bulk liquid	Scope 2	Beverage production and warehousing	337.14	7.91%
Barley agriculture	Scope 3	Raw material processing	457.56	10.37%
Malted barley transportation	Scope 3	Transportation and distribution	332.44	7.80%
Malting	Scope 3	Raw material processing	317.15	7.44%
Percent GHGs from top three sources from each scope				78.09%

The GHGs from each category are reported in Figure 11. Purchased steam accounts for 21% of the case company's GHGs. Steam is used as the primary heating method while brewing for wort boiling. Beverage production and warehousing accounts for 9% of all GHGs. Raw material processing also represents 18% of GHGs, which includes the process of malting barley, and all processing of packaging from raw materials (i.e. glass bottles, aluminum cans, and kegs). Mobile emissions contribute 14% of total GHGs, and include gasoline, diesel, and biofuel consumed by the brewery. Gasoline accounts for the largest in terms of emissions of these sources despite it not being the most common fuel source used, due to its high emission factor (relative to the other fuels). Purchased electricity accounts for 10% of total emissions. An important note is that the case company offsets the GHGs from their electricity use by purchasing electricity from a renewable energy source, which significantly reduces their GHGs. Transportation and distribution accounts for the 13% of total GHGs. This category includes transportation from raw material suppliers to the brewery, waste transported away from the brewery, and all transportation sources associated with parties outside of the brewery. Transportation by the brewery itself is not included in this category, and instead captured under mobile emissions (since mobile emissions was calculated using primary data for brewery fuel usage). Cultivation contributes 14% of the case company's GHGs, which is mainly from barley agriculture, followed by hops agriculture. Purchased cooling contributes 19.04 tonnes per year of GHGs, which is less than 1% of total brewery GHGs, due to a low-emission cooling source used by the brewery. Finally, end of life emissions account for just under 51 tonnes/year of CO_2e (1% of total GHGs), which accounts for waste processing of garbage, recycling, and compost. This number is particularly low due to the brewery's efforts to reduce and divert their waste production. A further breakdown of the all sources of GHGs from each category is included in Appendix F. See Appendix F for the classification of GHG sources into their categories.

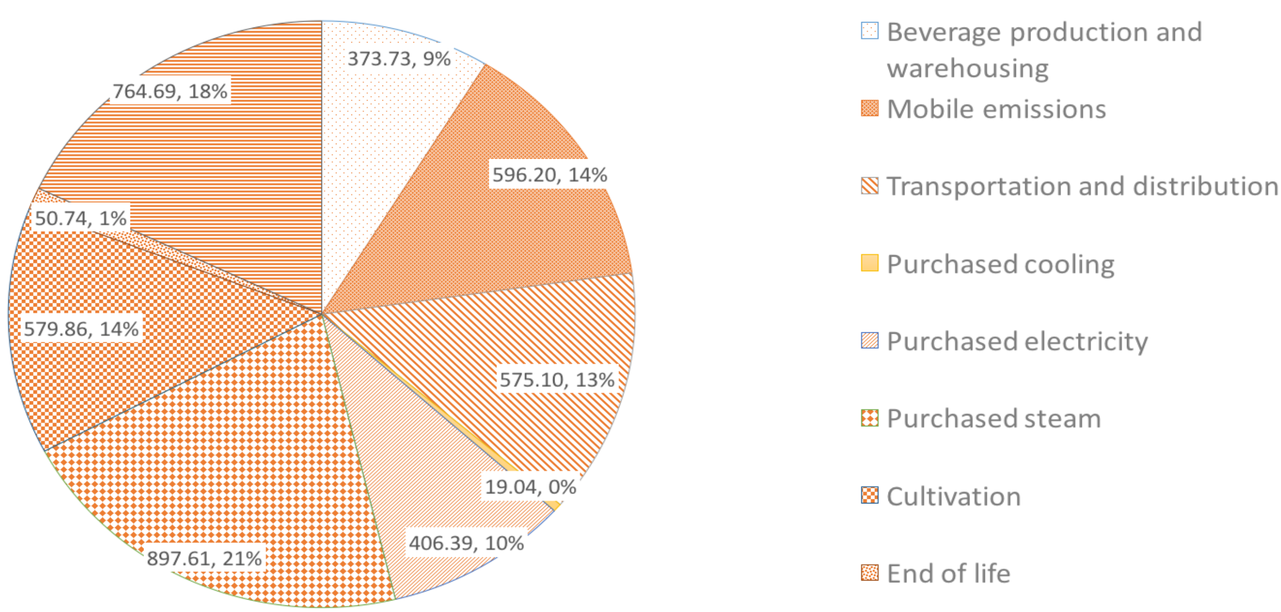

Figure 11 Greenhouse gas emissions presented by category. Both the absolute amount of GHGs by category, in tonnes per year, and by percent of all GHGs, are reported.

5.1.4 Scenario analysis findings

Two scenario analyses were run: 1) beer production growth X greenhouse gas emission percentage per hL produced reduction in GHGs, and 2) beer production growth X change in relative percentage packaging in glass bottles and aluminum cans. The beer production growth was chosen as an external variable (out of the control of the case company), while the greenhouse gas reduction and change to packaging ratios are internal variables (under control of the decision making of the case company).

Scenario 1 formula:

CO_2e_{Y2028}=2016 beer production (in hL) * (1+ (primary, intermediate, or advanced beer production growth)) * (2016 CO2 produced (tonnes CO2e/year) – ((2016 CO2 produced (tonnes CO2e/year) * (primary, intermediate, or advanced decrease in CO2e/hL beer))

Scenario 1 found that reductions in GHG reduction per hL beer produced (referred to herein as GHG intensity of beer production) can offset beer production growth between 2018 and 2028. For example, brewery GHG emissions are 1.13 times larger under a 0% beer production growth and 0% change in GHG intensity of beer production when compared with a 30% growth in beer production and 20% decrease in GHG intensity of beer production (Table 8). This GHG impact is still notable with smaller changes to GHG intensity of beer production: a 24% growth in beer production with a 0% reduction in GHG intensity for beer produced is 1.11 times larger than the same growth in beer production with a 10% reduction in GHG intensity for beer produced. This is a useful tool as the formula can be easily manipulated to suit the brewery's objective, and it allows the user to plan for GHG mitigation in the future. For example, if a brewery continues to increase production but does not know their baseline emissions, then financial cost risks may be a problem in the future. However, planning can be more effective if the brewery can determine what decrease in GHGs per hL beer produced they require to stay under a threshold total brewery GHGs target amount in the future.

Table 8 Scenario analysis findings. Case company data and secondary data were used to calculate each cell in the matrices.

Scenario 1: *10-year horizon (2018-2028): tonnes CO2e per year in 2028, with beer production estimates x decrease in annual percentage CO2e estimates*				
		Case company beer production (hL)		
		Primary Scenario (+18%)	**Intermediate Scenario (+24%)**	**Advanced Scenario (+30%)**
Decrease in CO2e (per hL beer)	**Primary Scenario (0%)**	6,559.61	6,893.15	7,226.69
	Intermediate Scenario (-10%)	5,903.65	6,203.83	6,504.02
	Advanced Scenario (-20%)	5,247.69	5,514.52	5,781.35
Scenario 2*: 10-year horizon (2028): tonnes CO2e/year in year 2028 with beer production estimates x bottle versus can production ratio*				
		Case company beer production (hL)		
		Primary Scenario (+18%)	**Intermediate Scenario (+24%)**	**Advanced Scenario (+30%)**
Change (in hL) in beer packaged in bottles vs cans	**Primary Scenario (no change)**	7,959.86	8,364.60	8,769.34
	Intermediate Scenario (+10% cans, -10% bottles)	7,463.05	7,842.53	8,222.01
	Advanced Scenario (+20% cans, -20% bottles)	6,966.25	7,320.46	7,674.68

Scenario 2 formula:

CO_2e_{Y2028} = (2016 hL packaged in bottles * 100(L/hL) / .341(L/bottle) * (10 year compound/2)‡ * % growth) * (1-decrease in bottle packaging) * weight bottle(g) / 1000(g/kg) * (% returned bottles * EF for bottle recycled + (99%returned bottles) * EF for new bottles) +

(2016 hL packaged in cans * 100(L/hL) / (.473+.355)/2 (L/can) * (10 year compound/2) ‡ * % growth) * (1+increase in can packaging) * weight can (g) / 1000(g/kg) * (% returned cans * EF for can recycling + (94%returned cans) * EF for new cans)

‡the time horizon for this calculation is 10 years (2018-2028). Since the growth in beer sales value drawn from OCB (2018) reflected their growth over two years (2015-2017), the formula reflects five compounding periods (one every two years) instead of 10 (one per year).

Other notes: two sizes of aluminum cans are reflected in the (.473+.355)/2 section of the formula to calculate the average volume of cans because the case company's primary data did not specify litres packaged in the two sizes of cans. The return rates of aluminum cans were 94%, with all other recycled material having a return rate of 99% (Teotonio, 2013).

Scenario 2 found that at a production growth increase of 24%, increasing beer can packaging by 20% while reducing bottle packaging by the same percent decreases the brewery's annual GHGs by year 2028 by 14%. Furthermore, under a period of advanced production growth (30% over 10 years), if the brewery reduces their bottles by 20% and increases cans by 20%, emissions can be lower than under a period of 18% growth over 10 years if no changes to packaging are made. These results suggest changes in beer packaging ratios can reduce total GHG emissions for the brewery under aggressive growth scenarios.

5.1.5 Challenges in execution

The primary challenge in the greenhouse gas (GHG) accounting was calculating scope 3 emissions. There were many uncertainties where primary data was not available, and secondary data was used. For example, GHGs from agricultural inputs to the case company, such as barley, hops, and yeast, were not widely available and when found in academic and industry papers, often varied with one another. This was due primarily to different geographic scope of studies, varying agricultural methods, and varying data collection methods. In these cases, there were no clear data sources to use. The most appropriate data was collected and used where possible (i.e. similar geographic scope, and year of study). Key secondary data sources included the World Resource Institute's (WRI) "Emissions factors from cross sector tools" (2017) document which contained useful data regarding greenhouse gas emissions of varying modes of transportation. This source was released in 2017, and contains data across different countries and in useful formats (particularly kg CO_2e/ kg kilometre). When no appropriate secondary data was available, the scope was adjusted to exclude certain emitting processes in the supply chain (see Exclusions section for further detail). Appendix K lists all emission factors.

A difficulty with mapping is lack of data on case company deliveries from their distribution centre and main brewery to sales outlets and customers. While total fuel usage by the case company was available, missing information made it difficult to target where these emissions were along the supply chain. Alongside this difficulty, incomplete information on shipping of case company beer via different modes of transportation (truck versus other modes) made emission factor application difficult.

5.1.6 Exclusions

Due to the challenges in execution, the inclusions and exclusion of variables was adjusted from the original scope of the calculations. Specifically, retail merchandise (all merchandise aside from beer, including items such as glassware and clothing), office and administration materials, and secondary packaging were not included in the calculations.

Including retail merchandise increased the scope of the calculations too greatly, and upon investigation there was too many variations of retail production processes. This variation made it difficult to find appropriate processes for retail merchandise production. Office and administration materials were excluded primarily due to uncertainty in emission factors and data unavailability. Furthermore, office impacts were in part included in the overall brewery impacts through factors such as the case company's total heating and cooling, electricity usage, etc. to operate the brewery. Finally, secondary packaging was not included in the scope of the greenhouse gas emission calculations. The scope of the calculations became unmanageable for the purposes of this research when all packaging for beer and transportation were evaluated (i.e. plastic wrap, cardboard boxes, etc.).

5.2 Ontario Craft Brewer website content analysis

5.2.1 Summary of findings

The goal of the Ontario Craft Brewer website content analysis was to determine whether craft breweries made environmental initiatives, stances, and progress publicly available; to investigate the age of breweries in this industry; the spread of where these breweries are located; and brewery production characteristics (i.e. hectoliters produced per year). The content analysis added qualitative findings to the research questions: what are the challenges of greenhouse gas accounting among Ontario craft breweries, and what are the benefits of greenhouse gas accounting among Ontario craft breweries? Specifically, the environmental keywords found among OCB websites address these research questions. The results found that environmental sustainability and supply chain management were the most frequent keyword categories among the 85 OCB websites reviewed.

5.2.2 Environmental keywords

Environmental keywords varied extensively between the Ontario Craft Brewery members that included environmental information on their websites. Since the range of keywords was extensive, keywords were grouped into keyword categories (Table 9). Grouping categories allowed a broader pattern to form of prevalent themes in the website content analysis. The most frequent keyword categories, after re-grouping, were: environmental sustainability (n=16), and supply chain management (n=13). Keywords included in environmental sustainability include accountability, B-Corps, carbon neutral, eco-friendly, environmental impact, environmental performance, environmental sustainability, environmentally conscious, environmentally responsible, green, sustainable, sustainable environmental best practices (Table 9). Keywords included in the supply chain management category include biodiesel, closed loop, green electricity, grown on site, ink reduction, local, locally sourced, low-emission heating and cooling, renewable energy, renewable power, responsibly sourced, and sustainably sourced energy (Table 9). These findings suggest the most popular environmental keywords reflected broader sustainability principles (i.e. eco-friendly, sustainable, green) rather than specific actions regarding how environmental sustainability is being achieved. However, supply chain management as the next most frequent keyword grouping suggests managing suppliers and inputs for breweries is the most common environmental action to improve environmental sustainability. The supply chain management keywords reflect fuel sources, office inputs, cooling and heating sources, and other energy requirements, reflecting how breweries are altering their purchasing decisions to more sustainable choices.

The remaining keyword categories were used less among craft breweries. The third most-used category environmental behaviour (n=7) reflects the learned actions of employees and management regarding reducing greenhouse gas emissions and environmental impact. This reflects social, as opposed to technical, changes and solutions to improve GHG performance. The categories input efficiency and waste reduction tie for the category with the fourth-most keywords. These categories both relate to supply chain management, but are separate from the supply chain management category in that they pertain to actions to reduce and divert inputs and outputs, rather than supply chain management which targets supplier and distributor contracting decisions. Finally, two breweries used keywords classified under responsible packaging. This suggests there is a (relatively) small focus on addressing packaging for GHG reduction and environmental performance opportunities among Ontario craft breweries, despite the academic literature's findings that packaging constitutes a large amount of brewery greenhouse gas emissions. See Table 1, Appendix G for a complete table of environmental keywords and their frequencies.

A repeat of the website content analysis was conducted for the 15 companies whose websites contained environmental keyword. The re-test showed that the 42 environmental keywords were applied for the re-test in the same frequencies (Appendix G, Table 2).

Table 9 Keyword categories and their frequencies for the content analysis of Ontario Craft Brewery websites. Frequency refers to the number of times a keyword that is included in its respective keyword category was mentioned on an Ontario craft brewer website.

Keyword Category	**Keywords included in the category**	**Frequency (# keywords included in category)**
Environmental sustainability	Accountability, B-Corps, carbon neutral, eco-friendly, environmental impact, environmental performance, environmental sustainability, environmentally conscious, environmentally responsible, green, sustainable, sustainable environmental best practices	16
Supply chain management	Biodiesel, closed loop, green electricity, grown on site, ink reduction, local, locally sourced, low-emission heating and cooling, renewable energy, renewable power, responsibly sourced, sustainably sourced energy	13
Input efficiency	Paper reduction, reduce energy usage, remove chemical usage, water conservation	4
Waste reduction	Compost, nothing goes to waste, organic waste, waste diversion	4
Responsible packaging	Reusable bottles, sustainable packaging	2
Environmental behaviour	Clean commute, employee education, re-use, recyclable, recycle, transparency	7
Total keywords		46

5.3 Interviews

5.3.1 Summary of findings

The purpose of the interviews with OCB breweries was to qualitatively investigate the key reasons why companies are or are not measuring and reducing their greenhouse gas emissions. Specifically, benefits and barriers to greenhouse gas measurement and reduction were discussed with interviewees. The goal of the interviews was to inform research questions two, three and four (respectively): what are the challenges of greenhouse gas accounting among Ontario craft breweries?, what are the benefits of greenhouse gas accounting among Ontario craft breweries?, and what are Ontario craft brewer perceptions towards, and action resulting from, provincial carbon regulation?. Eighty-two OCB companies were invited for an interview, and thirteen interviews were conducted. Six of the 13 breweries with websites containing environmental keywords agreed to participate as interviewees. The interviews found that the most common barrier to measuring and reducing GHGs (as per research question two) was financial cost (n=6), followed by human resources (n=4). The most common benefit to measuring and reducing GHGs (as per research question three) was environmental sustainability marketing (n=7), followed by a desire to preserve the natural environment (n=4). Nine of 13 interviewees have heard of, or know, what cap and trade is. Of those shared their perspectives on cap and trade brewery impacts, two participants thought cap and trade will negatively impact their brewery, while two did not think it would impact their brewery. Furthermore, additional findings such as brewery performance compared to industry performance, frequency of electricity and greenhouse gas measurement and reduction, and prioritization of other environmental sustainability programs complement the multiple purposes of the interviews.

5.3.2 Interviewee descriptive statistics

The response size was 13 OCB breweries, from a population of 82 companies (excluding the case company, and companies that had no available contact information, or were under the same management as another OCB brewery). This constitutes a 16% response rate. Other invited participants either did not respond to any of the three email requests to participate in this study, or declined to participate. The interviews ranged from 7 to 60 minutes in length, with the majority of interviews falling between 15 to 30 minutes in length. Length of interviews depended on the extent to which interviewees wished to answer the interviews questions, any extensions or asides the interviewee wanted to elaborate on, and follow-up questions posed by the interviewer given the interviewees’ responses.

There was a great range in brewery age and production volume among the brewery interviewees. The youngest brewery was established in 2017, while the oldest brewery was established in 1985. The average brewery is nine years old (founded in 2009), with the median age being four years old (established in 2014). The median age statistic, in the context of the other descriptive statistics, shows brewery age is skewed to be much younger than the average. The production volume ranges from 287 hL/year (where 1 hL= 100 L) to 67,000 hL/year. The average production volume is 19,868 hL/year, and the median production volume is 15,000 hL/year, meaning the breweries are skewed towards smaller production.

A re-test of coding for the transcripts of two of the interviews (equivalent to 15% of the sample size) was conducted. Participant notes from the transcripts (Code 2s) were re-read and Code 1s re-applied for participants three and four. Twenty-seven codes were applied to the original test, and 26 codes were applied to the re-test (Appendix J). Krippendorff's Alpha (KALPHA) was used to test the intra-rater reliability between the coder's first and second coding of the transcript material, with KALPHA= 0.925. A frequency test showed a 93.8% agreement, with n=28 agreements and n=2 disagreements, suggesting that the coding between the initial and re-coding procedure is reliable.

5.3.3 Findings from coding

The interview questions were formatted to address research questions two, three and four (relating to barriers and benefits of carbon accounting, and provincial carbon policy). See Table 10 for an explanation for the objectives of the interview questions.

Table 10 Interview questions, sub-questions, and their purposes in connection to research questions two, three, and four.

Interview question number	Interview questions	Objective of interview questions
1	A. Does your company measure its electricity usage? B. If so, does your company have plans in place to minimize electricity use? C. Are you aware of your company's electricity composition (i.e. percentage sourced from renewable vs. non-renewable energy)?	Do you measure electricity (which has a large impact on brewery greenhouse gas emissions)?
2	A. Does your company measure its greenhouse gas (GHG) emissions? B. If so, does your company have any GHG reduction programs in place? C. What is your company's process and considerations for developing GHG reduction targets? D. Do you measure direct and indirect GHG emissions?	What are your brewery's processes for managing and reducing GHGs?
3	Do you see managing electricity use and reducing GHG emissions as priorities in your business model? Why or why not?	What are the benefits of measuring greenhouse gas emissions?
4	Regardless of whether you collect baseline GHG emissions data, what do you see as the main A. challenges and B. benefits of collecting baseline GHG emissions data? Prompt: for example, do you see a marketing opportunity for promoting your beer as environmentally sustainable for reducing its carbon footprint? Is cost a consideration?	What are the benefits and challenges in measuring greenhouse gas emissions?
5	A. Does your company have any sustainability initiatives? B. What are the main challenges in implementing/maintaining these programs? C. If you do not have a program in place, what are your reasons for opting not to? D. Do you foresee development of a program(s) in the future?	What are challenges of, and prioritization of, other environmental sustainability programs compared with greenhouse gas management?
6	A. Have you heard of Ontario's cap and trade program? B. If so, what do you know of it? C. How do you think this carbon pricing scheme will impact your company?	What are your perceptions on carbon regulation in Ontario?
7	Do you have any ideas on an effective carbon pricing mechanism that should be applied in Ontario aside from cap and trade?	What are your perceptions on carbon regulation in Ontario?
8	A. Do you think the beer industry is doing enough to reduce its GHG emissions? B. How do you think your company compares to others in this industry?	What is your greenhouse gas performance in comparison to other OCB breweries?

Although evaluating code frequency in the context of the interview question is more effective for understanding meaning, it is useful to see a frequency of codes relating to the benefits and challenges of greenhouse gas measurement and reduction to evaluate any high-level commonalities between the interviewees. For example, when evaluating the interview findings as a whole, it was found that "financial capital barrier" [is a challenge to GHG accounting] (n=7), "environmental health is a motivator for brewery action" (n=4), "industry is not acting effectively on greenhouse gas emission improvements" (n=7), "sustainability marketing" [is a benefit to GHG accounting] (n=9), and "technical capital barrier" [is a challenge to GHG accounting] (n=6). These codes are commonly seen throughout the interviews, and give an indication of the key themes in relation to the research questions. The discussion section includes a review of the interview findings in relation to the research questions and previous literature, and also includes supporting interview quotes.

Electricity usage

The first interview question asked interviewees if they measured their behaviour and knowledge around electricity usage at their brewery. The coding results found that only 4 of 13 interviewees actively measure their electricity usage, and 12 of 13 do not know, approximately, what their electricity grid's renewable and non-renewable energy source composition. Four breweries currently measure their electricity usage, with the same four actively reducing their electricity usage. Three respondents stated they planned to measure their electricity use in the future, while one also said they planned to reduce their electricity use in the future.

Greenhouse gas management

The second interview question asked interviewees whether they measured their greenhouse gas emissions. Only two interviewees are currently measuring their direct greenhouse gas emissions, with none currently measuring their indirect greenhouse gas emissions. Five interviewees stated they may measure their direct greenhouse gas emissions in the future.

Business model priorities

The third interview question asked participants if managing electricity and greenhouse gas emissions is a business priority for their brewery. Seven interviewees mentioned that greenhouse gas management is a business priority, while seven interviewees indicated greenhouse gas management is not a business priority.

Benefits of and barriers to greenhouse gas management

Seven of thirteen participants agreed that financial capital was and/or is a barrier in managing their greenhouse gas emissions, with four stating that human capital (i.e. staff hours) is also a limitation. Six participants found that technical capital (technical equipment or technical knowledge) is a barrier in measuring and reducing greenhouse gas emissions, and three participants stated physical capital is a barrier.

Nine of thirteen participants stated that sustainability marketing is a benefit to greenhouse gas measurement and reduction, with four participants agreeing that environmental health is a benefit of greenhouse gas management. Five participants stated financial benefits of greenhouse gas management, and one participant found that knowing where emission sources are along the brewery value chain is a benefit. Finally, two participants were unsure of the benefits of managing GHGs.

Carbon policy

When interviewees were asked about their thoughts on carbon policy, most participants agreed about the usefulness of greenhouse gas regulation. Six participants heard of cap and trade, but do not know more about it, while four participants said they have an understanding of what cap and trade is. Of those who know of cap and trade, only one stated they were strongly opposed to the policy, calling it a government taxation whose revenue is not spent efficiently (interview transcript, 2018). Eight of thirteen interviewees were not aware of alternative carbon regulation policies (i.e. aside from cap and trade).

Brewery environmental performance

Of those who spoke of their greenhouse gas emission's performance, four interviewees felt they ranked above average compared to their peers in the OCB, and five stated they were average compared to their peers. Eight of 13 participants thought that overall, OCB brewery members are not doing enough in terms of their considerations and actions to reduce GHGs, while one interviewees thought their industry is acting effectively to reduce GHGs, and one interviewee stated the OCB industry as a whole is at least aware of their carbon emissions.

6. Discussion

6.1 Overview of research questions and study purpose

The purpose of this research was to investigate the greenhouse gas emissions of the Ontario craft beer industry, and assess the practical challenges and benefits of doing so. The research questions are:

1) What are the greenhouse gas emissions of an Ontario craft brewery?

2) What are the challenges of calculating an Ontario craft brewery's greenhouse gas emissions?

3) What are the benefits of calculating an Ontario craft brewery's greenhouse gas emissions?

4) What are Ontario craft brewer perceptions towards provincial carbon regulation?

The case study sought to directly investigate research question one. Indirectly, the second research question was also explored from the researcher's process of calculating the case company's GHGs. The second, third, and fourth research questions were addressed in the interview portion of this research. A reflection of the results in light of each of those questions is provided below.

6.2 Summary of case study findings

The case company portion of this research sought to answer research questions one and two. To approach answering these research questions, the researcher first created process maps of the case company's value chain to understand upstream, in-brewery, and downstream processes. Following completion of the process maps, the researcher collected primary and secondary data to calculate direct and indirect brewery greenhouse gas emissions. The major findings were:

1) Scope 3 sources account for the largest share of brewery GHG emissions. Scope 2 accounts for the second most GHGs, while scope 1 (direct) greenhouse gas emissions contribute the least (research question 1).
2) The process maps are difficult to extensively create without direct, and consistent, consultation with suppliers and distributors, posing large time and engagement requirements (research question 2).

3) Relevant secondary data is difficult to find (research question 2).
4) Process mapping, in combination with greenhouse gas accounting using a globally- recognized protocol, and scenario analysis, are strong visualization tools for craft breweries to create and justify a baseline plan to reduce greenhouse gas emissions (research question 3).
5) There were both similarities and differences in calculation findings when compared with previous literature
6) Challenges arise in greenhouse gas accounting from the limited human resources, employee turnover, and a reliance on tacit knowledge (research question 2)

6.3 Case study: Process mapping and greenhouse gas accounting

This section will review findings from the process mapping used for this research, discuss the greenhouse gas calculation key findings and in-context to previous research, and end with the practical challenges of executing greenhouse gas accounting calculations.

The process mapping of the case company value chain provided a visual tool to understand where important sources of greenhouse gas emissions lie, a starting point of where to look for greenhouse gas emissions, and was used as a tool to ensure the researcher understood the case company processes. Process maps were effective in visualizing the product flow of the brewery, however it is important that when developing them, the scope and detail was based on the purpose of the research, and that consultation between the researcher and the primary contact was established for check-ins. For example, process maps are often used to track the value chain of a production (where financial value is added). Process maps visualizing financial flow through the value chain will have a different focus than process maps visualizing GHG emissions. Therefore, it is important for the process maps to be at an appropriate scale for a brewery's GHGs. Process maps are a beneficial tool for all businesses, and their necessity increases depending on the complexity of a business' operations. For example, the supply chain for this case company is relatively simple due to the focus on beer and its supply chain. However, for a food manufacturing company, for example, where relationships for multiple suppliers and final products are involved, understanding the flow of inputs and outputs becomes increasing important to identify opportunities for efficiencies. Although for this thesis efficiencies were focused on greenhouse gas emissions, other corporate users of process maps may focus on opportunities for other factors such as financial and administrative efficiencies.

The largest greenhouse gas emission sources were found in the purchased inputs for brewery processes. This finding is significant as traditionally, greenhouse gas calculations have focused primarily on direct GHGs (i.e. those directly emitted by a company's operations, such as fuel usage for a company's fleet). As increasing work is being produced on life cycle assessments and carbon foot printing, this research agrees with the findings of previous work that indirect emissions account for the largest source of brewery GHGs (Amienyo & Azapagic, 2016; Koroneos et al., 2005; The Climate Conservancy, 2008). This is an important contribution as it is in the context of provincial craft breweries, and indicates to those interested in their GHG footprint that they should be focusing their calculations on their indirect emissions by looking for efficiencies in brewery energy inputs and alternative sources of energy. Furthermore, the findings from this research show the importance of connecting a brewery's GHGs to its source, through categorization and relating back to visual tools, such as process maps, to understand where the brewery's focus should be directed and determine what areas are actually feasible to reduce GHGs.

When considering feasibility of GHG reductions, first it needs to be determined whether the emission's source is under direct control of the brewery. Direct control means that the decision-making of the brewery can change the emission calculations. This includes both in-house operations, but also working with supplier and distributors for possible opportunities to reduce greenhouse gas emissions. Supply procurement standards and agreements are not uncommon among companies, so there is a possibility to work with suppliers particularly in improving their environmental performance, and reducing the greenhouse gas emissions of their products. However, it is important to note that craft breweries are small businesses, and thus may not have much influence over supplier operations. Regardless, craft breweries can decide to change suppliers based on an internal supply procurement standard to reduce indirect GHG emissions.

In certain cases, GHGs associated with a craft brewery are not under their control. For example, GHGs from electricity use depends on the government's investment decisions on how to source their regional grid in terms of its share from renewable and non-renewable energy. Although renewable energy offsets are sold by some independent companies in Ontario, and alternative sources of energy exist, depending on the brewery and the context these options are not always affordable and thus feasible. Alternatives to changing a craft brewery's energy source is evaluating areas for energy efficiencies. Efficiency opportunities will likely arise in craft brewery's process mapping stages, therefore areas for improvement are unique to each brewery. Managerial and operational decisions can also impact brewery input efficiencies, such as training for employees to conserve electricity. Craft breweries should consider where along their brewery chain there are the largest opportunities to reduce their GHGs, where low-cost opportunities exist, what actions are realistic given resource availability, and a time frame for executing these reductions.

An important finding that arose while conducting this research, and specifically looking for secondary data, is that craft breweries in Ontario vary widely in their greenhouse gas emissions. This variation is due to: geographical location, financial and spatial access to resources, corporate morals and values, marketing strategies, and economics of scale (i.e. efficiencies in production and distribution due to production volume). Major challenges in the greenhouse gas accounting process included: finding geographically, technologically, and age-appropriate secondary data for inputs and outputs of the craft brewery process. Industry and government sources were used for emission factors, along with consultant reports and academic papers. Where possible the emission factor sources were not taken from different sources for related calculations to avoid inconsistencies. Inconsistencies in emission factors from secondary data mainly arose from different methods of calculation, varying geographies, and different years (thereby influencing technology used, knowledge available, and other factors). Secondary data used for emission factors is included in Appendix K.

Previous academic and consultancy-based research has calculated the carbon footprint of breweries (Koroneos et al., 2005; The Climate Conservancy, 2008; Olajire, 2012; Amienyo, 2016; Cimini & Moresi, 2016). These studies range in their methodology and approach, and importantly, in their geographical setting.

The geographic setting of each study is an important consideration in carbon accounting because it greatly impacts scope 2 emissions, particularly the emissions associated with electricity generation in the region. Carbon accounting is also extremely variable when other factors such as method and scope are considered, along with scale of production, packaging choices, distance from suppliers, fuel sources used, and a number of other variables. This means that comparing the carbon emissions from one research study, even on a per unit basis, may not be practical. In an effort to compare studies more meaningfully, the main emission sources from this thesis research are compared with the main emission sources from previous studies.

The findings from this thesis found that steam constituted the largest source of greenhouse gas emissions (21.05%). Bottle and can production represented 11.74% of GHGs, and total packaging contributed 12.30% of brewery emissions. Electricity was another major source of brewery emissions, accounting for 9.53% of total GHGs. The literature mainly found that packaging was the largest source of GHGs for the breweries studied. Amienyo & Azapagic (in a UK-based study) found that 19%- 46% of GHGs along the value chain of beer were attributed to beer packaging, which varies largely between packaging type (2016). The Climate Conservancy found that when they calculated the carbon footprint of a 6-pack of bottled beer with the company New Belgium Brewing, electricity use contributed 28.1% of total GHGs, and glass (packaging) accounted for 21.6% of total GHGs (2008). Koroneos et al's research also suggests packaging is one of the main sources of GHGs along a brewery's supply chain (2005). The findings from this thesis research indicates packaging and electricity use account for less when compared to calculations from previous literature.

An important finding here is that when comparing previous research, there are large discrepancies in how much packaging contributes to a brewery's total GHGs. Emissions for packaging depend on the proportion of packaging used by the brewery (cans versus bottles), and the compositional differences of the packaging. Furthermore, the method used for carbon accounting influences calculation outcomes. Koroneos *et al.*'s (2005) method calculated the impact of beer's life cycle impacts by categorizing each category's impact (i.e. packaging, transportation, etc.) into carbon intensity in kg CO2e/kWh. The study, which was based in Greece, then used these scores to compute environmental scores of each category based on criteria such as global warming, photochemical smog toxicity, and human toxicity (Koroneos *et al.*, 2005). Therefore, the findings from Koroneos *et al.*'s research, while valuable, are presented in a different environmental context than focusing purely on carbon emissions.

A data availability barrier is a major consideration for this thesis's calculations. Primary data measured directly by a company is preferable, but in cases where this was not available for the case company, secondary data was used. Use of secondary data decreases the precision of the calculations because they are not specific to the company. Furthermore, while geographic and temporally-representative data was not difficult to find during data collection from secondary sources, technologically-representative data was more difficult. For example, factors such as fuel efficiency of vehicles is widely variable based on model type and size. For this case, a consistent class-size of truck and its fuel-efficiency was used for calculation purposes, but this does not capture variations in vehicle transportation sizes among suppliers. Given primary and secondary data challenges, increasing the number of products included in the GHG calculations for another SME would decrease the accuracy of the calculations.

A procedural barrier to calculating the greenhouse gas emissions is the limited human resources to dedicate to a project like this, employee turnover, and loss of project knowledge due to a reliance on tacit knowledge. Firstly, smaller companies like craft breweries typically have smaller staff sizes than larger companies because of the smaller scale of their operations. During the case study research, the researcher worked with one primary point of contact, who communicated internally with relevant staff where necessary. Although the primary contact was committed to the partnership, they had competing priorities and a full work-load to coordinate with.

Third, the case company experienced a somewhat high employee turnover over the course of this research. The primary contact changed two times, which posed issues to the depth of involvement in the project. While project material was passed on to the employees who assumed the primary contact role, they were arguably missing pieces of context in the project. Further, ongoing project engagement was difficult when relationships had to be rebuilt.

Finally, once a connection was established between the third primary contact and the researcher, the primary contact said the case company no longer had the people forming an (informal) internal sustainability committee. This committee had met with the lead researcher at the beginning stage of the project to discuss the project purpose and its use to the company. While the third primary contact still maintained connection with the researcher, the purpose and use of this research shifted once the tacit knowledge that the sustainability committee left with them. Patterson *et al*. argue that much of human knowledge is implicit, and is out of a person's conscious awareness (2010). Implicit learning is defined as gaining of knowledge without one's intention, and without being able to describe the learned knowledge (Patterson *et al.*, 2010). It was likely that the committee members had implicitly learned the inner workings of developing and implementing environmental programs. Without knowing the implicit knowledge embedded in their sustainability committee, it is possible the committee disbanded without passing on key information for current employees to continue using in environmental program planning. All three of the aforementioned issues pose a challenge to the execution of carbon accounting calculations, and also to the final usability and execution of this research.

There are various applications of greenhouse gas accounting. Since the GHG accounting method used for this thesis is aligned with the universal GHG Protocol Standards (2004, 2011a) the method can be applied to other businesses. This thesis's method is particularly geared towards craft breweries who have limited financial, time, and human resource capital because the steps have been clearly aligned with reference chapters in the GHG Protocol Standards. Furthermore, the secondary data sources used for this thesis will streamline GHG calculations for craft breweries in Ontario.

Finally, the applicability and representativeness of the GHG accounting findings for the case company is an important consideration. The case company is a large craft brewery in Ontario, so it must be noted that the final results of this thesis regarding carbon dioxide equivalent emissions per unit of beer produced may not be applicable to smaller craft breweries due to factors such as economies of scale. In terms of a geographic lens, the findings and usability of the GHG accounting results is most applicable to craft breweries in Ontario, because emission factors for electricity, as one example, are regionally-specific. Temporally, 2016 data was used for the calculations, which is fairly recent to the time of this thesis report's publication (2018).

6.4 Case study: Scenario analysis

The scenario methodology outlined in this thesis can be applied in different contexts, and is a useful tool in forecasting related to greenhouse gas emission changes. Scenario analysis can be used by those involved in operations management, and among large and small to medium-sized companies across all industries. Depending on the size, structure, industry, and priorities of a company, different scenarios can be applied. Users of scenario analyses should have a clear purpose for what they are trying to project as possible future scenarios, and research what data is available given the purpose of their scenario analysis.

Many other scenario analyses are relevant for craft breweries. For example, if a craft brewer is trying to determine financial risk exposure in the near and long term, they may decide to estimate the financial damages from climate change risks impacting their barley and hops suppliers. In this scenario, the user would have to collect data from a range of sources including, but not limited to, academia, government, private industry, and other bodies such as the Intergovernmental Panel on Climate Change to determine the sensitivity and thus potential damages of climate change to barley and hops agriculture based on region, projected droughts and floods, and other environmental changes. Another example is a craft brewery conducting a cost scenario analysis over a chosen time frame to estimate the cost savings associated with changing the company's procurement policy to prioritize local or regional raw material suppliers. Aside from greenhouse gas emission projections, a financial analysis can determine potential cost savings from transportation by including the volatility of fossil fuel prices. The financial cost with changing suppliers (i.e. time investment into relationship building, financial investment in contract development) could then be compared to the projected financial benefits in order to make an informed management decision(s). Scenario analysis can be made more complex than what was used in this thesis by involving more influencing factors on the variable of interest, which may improve accuracy of calculations.

The outcomes of the scenario analysis application for this research is discussed below.

Scenario 1

Scenario 1 results showed the drastic difference in GHG emissions when reductions of GHGs, over a long time period, can be achieved. Projecting GHGs and using the estimates as a basis for GHG management allows a brewery to plan for financial investments to reduce greenhouse gas emissions, return on investments when GHGs reductions involve cost savings, and avoidance of potential future taxation. For example, if a brewery continues to increase production but does not know their baseline emissions, then financial risk to carbon taxation may be a future problem. However, if the brewery can determine what decrease in GHGs per hL beer produced they require to stay under a threshold amount of their total GHGs, planning for where reductions in GHGs can be applied will be most effective.

Scenario 2

Scenario 2 was designed to determine what the GHG reduction potential is if packaging is changed to phase in more aluminum can packaging. Scenario 2 results suggest that increasing the share of aluminum can packaging by replacing glass bottles offers an opportunity to reduce GHGs. Under the primary growth scenario (18% in beer production by 2028), GHGs are 1.14 times larger under the 2016 beer to bottle ratio compared to the same growth scenario with a 20% increase in can use and 20% decrease in bottle use. Understanding the magnitude of changes to internal decision-making (packaging, in this case) can impact a brewery's investment planning and decision-making significantly. By knowing the impact of internal changes when compared with uncertain external variables, more informed investment decisions can be made to maximize desired changes for a brewery's GHG emissions.

6.5 Interviews: Key themes in connection to research questions

As reviewed in the results section, many themes emerged from the interviews with Ontario Craft Breweries that align with previous research findings in the literature. The following paragraphs review the interview findings in the context of previous research and the research objectives, particularly research questions two, three, and four: *What are the challenges of calculating an Ontario craft brewery's greenhouse gas emissions?*, *What are* *the benefits of calculating an Ontario craft brewery's greenhouse gas emissions?*, and *What are Ontario craft brewer perceptions towards, and actions resulting from, provincial carbon regulation?*

Barriers to greenhouse gas management

Sloane (2012) identified cost as a barrier to adopting greenhouse gas reduction management policies and equipment in California's brewing industry. The results of the interview content analysis agree with Sloane's (2012) findings. The interview results found that 7 of the 13 Ontario craft brewery interviewees viewed cost as a barrier to greenhouse gas measurement and mitigation, followed by human capital (n=5).

"...at this point in our game we have to be very conscientious of where we spend our money." (research interview transcript, P04, 2018).

"We have no time to collect data… we continue to be a small staff but we're really focused on making and selling beer, that is our business… I don't want my people involved. I'll do what I can, you know, but to me, like right now, knock on wood we're doing very well, but I need all hands on deck, you know, making beer… as we get bigger and we have more roles to play, there might be an opportunity to have an… environmental lead person in a brewery, may be in charge of our waste water and in charge of our emissions and in charge of all environmental stuff, but we're a long way away from that right now." (research interview transcript, P04, 2018).

Breweries who cited financial cost as a barrier indicated it was a large consideration in their GHG management decisions, or that it has been preventing them from measuring and reducing their GHGs. Several of the interviewees emphasized that craft breweries have competing priorities (such as growth or other environmental focuses) where money had to be focused, and that profits are thin for most breweries:

"...if we had a better cash flow we'd be willing to make some sacrifices to change the way that we do things, even if it was more costly but it's certainly an industry that has razor thin margins especially when you're starting." (research interview transcript, P15, 2018).

Since some craft breweries do not know of their greenhouse gas emissions, nor the benefits or challenges of mitigating GHGs, the interview included a question asking what the challenges were associated with sustainability initiatives not involving GHG reduction. This was useful in understanding barriers for breweries in a related field. Of the interviewees who did speak to challenges of sustainability programs, 4 of the 10 identified financial capital barrier as challenge.

Financial constraints for craft brewery GHG management are important considerations. Craft breweries in Ontario require financial and knowledge resources from government and third party groups where specialized services (including technical know-how, or having access to a consultant with the technical knowledge for GHG calculations) is accessible. Furthermore, Ontario's government should help craft breweries reduce the cost of GHG management. For example, financial rebates or incentives for equipment upgrades to reduce GHGs, or a rebate to hire a consultant who can execute carbon accounting, would be beneficial. Ultimately, cost for craft breweries was identified in the interviews as a major barrier to carbon management.

Benefits to greenhouse gas management

Sloane (2012) identified positive publicity or marketing as a benefit of an environmentally sustainable product. The interview results agree with this statement, as it was found that 9 of 13 interviewees believe environmental sustainability marketing for their beer is a benefit of greenhouse gas emission reductions.

"...lots of people talk about being socially environmentally aware and we can prove it, but we actually need to do more to…we're not promoting as much as we should..." (research interview transcript, P14, 2018).

Marketing the environmental sustainability of craft brewery products was likely appealing to most interviewed breweries because of the focus on generating a profit to stay in business as a company, and promoting a product that aligns with a company's values. Tools such as building a reputation with consumers as an environmentally sustainable company is potentially useful in establishing customer loyalty and maintaining community engagement:

"…beer in particular is a relationship commodity." (research interview transcript, P07, 2018).

A company may therefore think managing greenhouse gas emissions is an investment in market outreach and consumer retention, as well.

Four of 13 interviewees said that a benefit to managing GHGs was for environmental health. These interviewees wished to leave a positive legacy, avoid harming their community, and leaving a healthy planet for future generations. Some of these interviewees stated that the health of the natural environment took precedence to a certain degree over business operations:

"I understand that aspect of a business and you have to run it but it's like, this transcends things like selling your product. It gets to the point of you know, just being like I said, good stewards of what we have here on earth…" (research interview transcript, P06, 2018).

"…we're actually trying to make great beer but we're also trying to have a positive impact in the community, the environment and you know, and globally." (research interview transcript, P14, 2018).

Brewery resource accessibility

A novel finding from the interviews that contributes to the literature is that accessibility to guiding resources for calculating GHG emissions was not easily available. Some interviewees expanded by stating they wish provincial government bodies were more helpful in their knowledge-sharing programs, with one participant suggesting that travelling information sessions run by provincial government representatives would be helpful for craft breweries in Ontario:

"...maybe having groups or agencies that can sort of give a helping hand and educate on ways to reduce carbon emission and other sort of environmentally unfriendly things that happen at [brewery name], we are probably one of the bigger craft breweries, but there are many, many people that are smaller than us that would have even less resources than we do and honestly it's likely not a priority for a lot of businesses it's based on priorities and a lot of financial perspectives and the craft beer industry is struggling right now in general." (research interview transcript, P11, 2018).

Other interviewees stated knowledge sharing was not as strong as it could be, with mention of the Ontario Craft Brewery association's role in facilitating greenhouse gas management knowledge:

[In reference to OCB member meetings]: "I don't recall us actually talking about greenhouse gas emissions at the sessions, I mean there's lots on wastewater management and you know, quality assurance and those things, but not as much on greenhouse emissions…" (research interview transcript, P14, 2018).

In conjunction with a lack of knowledge sharing, some interviewees also had limited personal knowledge of greenhouse gas emissions, and what GHG sources are along their supply chains. Likely inspired by a knowledge barrier was also a feeling of helplessness and lack of control over an interviewee's reduction of their greenhouse gas emissions from their electricity usage:

"...I care and I wish I could control my emissions gases due to the electricity I consume. I have zero power over it, therefore as much as I care, there's nothing they can do with the monopoly that is currently in place." (research interview transcript, P03, 2018).

Carbon policy

The interviewees were mixed in their perceptions of how cap and trade will influence the OCB industry, and more specifically, how cap and trade will impact their brewery. Some interviewees stated there would be a direct negative financial impact on them, while others believed there would be an impact on industries but not them specifically, and some were unsure of the impacts:

"I'm assuming that we have to pay something for it in future and this will be like, it won't cripple us but it is a worry, an ongoing worry…" (research interview transcript, P04, 2018).

"Negatively. Absolutely. I think it was devised by those individuals who are just you know in the social elite through the political system who found a way you know, to generate more dollars for a political system. Cap and trade tax serves no purpose." (research interview transcript, P08, 2018).

"I suspect on the industry there's probably going to be some rude awakening, but I think for [brewery name] … I think for the most part it won't have a tremendous impact on us personally." (research interview transcript, P07, 2018).

This finding suggests there needs to be greater information-sharing between the Ontario government and craft breweries in the province (or, more widely, small businesses in Ontario). Despite whether the current carbon regulation policy (cap and trade) is kept, or another alternative adopted (i.e. carbon tax), the premise of this suggestion remains the same. An easy, cost-effective solution would be to publish and popularize a user-friendly guide to what cap and trade is, who it impacts, what indirect financial impacts may be experienced by small business owners (i.e. supply chain impacts), and what small businesses should be aware of concerning this policy moving forward, such as any changes scheduled for inclusion criteria. Especially given the sharing potential of having the OCB as a regulating body, and knowledge sharing between craft breweries, this would be a low-cost mechanism for clarifying what craft breweries should actually expect in terms of costs from cap and trade.

Business priorities

Business priorities were mixed among the interviewees, with seven interviewees stating greenhouse gas management is a business priority, and seven saying the same regarding electricity management. A clear barrier seen in the interviews is financial cost of implementing greenhouse gas, electricity, and other environmental programs, which suggests it influences craft breweries business priorities:

"To be honest with you, we'll do our best. I think in a small business where we're taxed quite heavily on a lot of things in Ontario and it's very difficult to survive as a manufacturing operation in Ontario because of it." (research interview transcript, P04, 2018).

However, there was evidence from the interviews that environmental sustainability is a part of brewery's core values, thus making it a business priority. Three interviewees agreed that business environmental ethics impacts their brewery actions. Further, two interviewees stated that environmental health is a motivator for environmental brewery action, and one stated sustainability is part of their brewery's business model:

"That's from top to bottom, corporate, good corporate citizenship has been a piece of [brewery name]'s branding." (research interview transcript, P07, 2018).

The interviews suggest while cost is viewed as a barrier to measuring and reducing greenhouse gas emissions, business values sometimes over-ride the cost investment to carry out these programs.

6.6 Interviews and institutional theory

6.6.1 Normative pressure

Normative pressure in institutional theory suggests that a company's morals are influenced by owners, managers, and employees, thereby influencing the managerial and operational decision-making of companies and company values (DiMaggio & Powell, 1983). The coding results suggest normative pressure is seen among Ontario craft brewery interviewees. While interviewees ranged in their employment position at their respective breweries, a common theme was that breweries have different priorities in terms of environmental action. For example, some breweries were focused on measuring and reducing greenhouse gas emissions, while others did not mainly due to competing priorities. Competing priorities included other environmental focuses (i.e. wastewater management), and a focus on growing sales and expansion alongside a tight budget:

"Really what is comes down to it's like the individuals in that place, do they care enough to you know, compost or recycle because that attitude actually kind of expands upward to you know, the overall attitude of the company…" (research interview transcript, P06, 2018).

Further evidence that value systems and beliefs permeated into managerial and operational decision-making is the interviewee's range in focus on the importance of preserving the natural environment. When asked what the benefits are to greenhouse gas measurement and reduction, breweries varied in their focus on cost savings (a common response) and environmental health. The variation of cost savings and sustainability values, and how managers have it permeate their decisions at Ontario craft breweries, is an example of normative pressure.

"There wouldn't be a brewery here if we can't be fiscally responsible but I mean yeah if we're not looking after the environment then we're not going to have a planet…" (research interview transcript, P06, 2018).

Various interviewees acknowledged and emphasized that breweries actions were important to preserving the environment for future generations, while other breweries stated the benefits were largely around cost savings and decreasing risk exposure to carbon regulation taxes in the future. A brewery also stated they do not believe that carbon emissions negatively impact the environment, which subsequently was found to guide their focus on water conservation efforts at their brewery and avoidance of greenhouse gas emission management:

"We can talk about bad chemicals, we can talk about you know, negative things in the environment, but, but carbon emissions, relative to you know, someone brewing beer have to be so inconsequential and actually probably have a beneficial side to it that we should be encouraging more of that." (research interview transcript, P08, 2018).

"...you're getting people entering the business that don't really necessarily have business experience or they're coming from a whole lot of different backgrounds where I don't think their priority is necessarily on like sustainability…" (research interview transcript, P06, 2018).

Depending on the motive of the brewery, as reflected by the interviewee respondents, the prioritization of brewery action for greenhouse gas reductions in the company values varies.

6.6.2 Mimetic pressure

Mimetic pressure is the influence of companies and their "copy-cat" tendencies which are modelled from successful companies in their industries (DiMaggio & Powell, 1983). Evidence of mimetic pressure was seen to some extent from the interviews. All interviewees were interested in being notified when the research results were available. This suggests these interviewees want to learn more about the findings from the interviews, and perhaps how their own responses compare to the rest of the sample. One interviewee noted that they were especially interested in learning what other breweries are doing in terms of environmental action as there is limited public data on environmental initiatives among OCB websites:

"...we don't necessarily see a lot of what initiatives are going on from what companies aren't publicly traded, like you know, there's not a lot of small brewers that are publishing their annual sustainability reports and so it's very hard for us to gauge and I think that you know, our industry is actually really good with sharing best practices around a lot of other things and it's still very collegial and I sense that that will also extend to sustainability and carbon management, but the fact that we haven't really heard about it to me indicates that our industry isn't there and so there's not much to share otherwise they would be more collaborative around that, in my mind." (research interview transcript, P15, 2018).

However, inconsistent evidence of brewery versus industry performance suggests mimetic pressure is not influential in brewery decision-making. When asked about the overall greenhouse gas emission performance of OCB breweries, six interviewees stated that Ontario craft breweries are not collectively doing enough to manage their greenhouse gas emissions:

"*No, they're not doing enough but I don't think they can do any more. I think, like I said is, we're small so a lot of are even smaller than us, that are even getting less funding… we do more than most, because we had some money and we invested up front…" (research interview transcript, P04, 2018).*

Further, when interviewees were asked how their brewery performed in GHG management compared to other OCB breweries (a self-assessment), the responses were nearly evenly split between average (n=5) and above average (n=4). It is interesting to note that although nearly half of the interviewed breweries believed their industry could be doing more to manage GHGs, none of these breweries believed their GHG management was below the industry average. Note that some interviewees did not comment or were unsure of their performance. This evidence suggests that there is a disconnect between the industry and OCB breweries, assuming that the interviewees are representative of all OCB breweries. However, this assumption should not be taken lightly, as it is very possible that the interviewees were skewed towards those who take more environmental action. This is especially possible in light of interviewees voluntary participation, compared to their peers who may have refused to participate with this research because of their own perceived lack of knowledge and/or action in this area.

"I think we're somewhere in the middle, I hope more towards the upper end of that. I know there are companies that do better at this. I know there's a lot that do worse" (research interview transcript, P06, 2018).

Given the research findings, mimetic pressure is somewhat evidenced by interviewees eagerness to inform or compare themselves to their peers in their environmental performance. However, the disconnect between brewery greenhouse gas performance and industry GHG performance suggests breweries are not influenced by their peers in this aspect.

6.6.3 Coercive pressure

Coercive pressure is the external influence of things, such as taxes, on a company's decision-making (DiMaggio & Powell, 1983). There was substantial evidence in the interview findings that coercive pressure is a contributing factor to financial resource constraints, which was the main barrier that interviewees cited as preventing them from measuring and reducing greenhouse gas emissions. Evidence from the interviews suggests the financial barrier is likely due to other brewery expenses and expenses from provincial and federal taxes. While most interviewees cited small monetary margins given revenue and expenses, some interviewees stood out in their detail of how forms of government taxation, and the expensive nature of electricity, constrained their operational budgets for environmental initiatives:

"We're still coming out of like trying to pay off a lot of expenses, the money is like super, super tight right now and we're still not operating like in the positive yet…our business model has to…have some sort of cost savings associated with it and to me that's a challenge..." (research interview transcript, P06, 2018).

One interviewee highlighted the increase of taxes imposed on their brewery in recent years, and the impact that an increase in taxes will have on brewery decision-making:

"*Our electricity bills are higher than ever before. Our tax bill, our liquor tax, an Ontario beer tax, that can double, triple I the last year and a half with that…Our Federal taxes are going up from beer taxes… I feel that … cap and trade or whatever it is, payment to the government. They already take so much from us. At the end of the day there will be a tipping point that we have to hold off, not because we're not making money, is that we're to make enough to survive because the government takes a big cut (research interview transcript, P04, 2018).*

6.7 Interviews and image theory

Image theory is an organizational theory describing the social influences on the behaviour and actions of companies (Beach & Mitchell, 1998). The three pillars of image theory that influence the final image of a company are values (morals), trajectory (goals), and strategy (future path of the company) (Beach & Mitchell, 1998). The results from the interviews are mixed, both suggesting that image theory is relevant and not relevant in the greenhouse gas action/inaction of craft breweries. The interviews found that there was certainly evidence of breweries acting on their environmental values. The quote below showcases how an interviewee's mindset permeates into their decision-making at their brewery:

"...leaving a better future behind...when that's your mindset, it, it translates into everything else that you do." (research interview transcript, P07, 2018).

Further evidence of how morals and values, on both ends of the environmental spectrum, is apparent from the interview findings. One interviewee stated they were willing to pay extra for a steam condenser, despite recognizing their competitors may not make that decision, because they felt it would reduce their emissions to the environment:

"*...we're okay with that extra cost because we're doing the right thing." (research interview transcript, P14, 2018).*

Another interviewee stated that they would invest more effort into environmental performance should they have more financial and technical capital available, again suggesting how values influence decision-making:

"We, being smaller, sometimes we don't have those resources, so that is definitely one of the biggest challenges but if we did or we were able to hire a company or have the resources available to measure those things, it would be much easier to see where we could make cutbacks and actually measure any progress." (research interview transcript, P11, 2018).

Another interviewee did not believe that carbon dioxide emissions has a negative impact on the environment. This interviewee went on to indicate they take water conservation very seriously, and source some of their brewery inputs locally. In speaking about greenhouse gas emission actions, the interviewee was not taking any steps to measure and/or reduce their GHGs. This example shows that despite environmental considerations in some areas (water management), one's values can influence behaviour in a related area.

The above examples of how value can influence one's mindset over rational decision-making (to make a greater profit) was not dominant in the interview sample. This reflects the realities of a competitive environment where there are many breweries competing for market share. Most interviewees cited high costs, being in an expansion phase, and limited human resources were barriers to focusing on greenhouse gas emission performance:

"...most people won't do it [invest in environmentally sustainable equipment and/or programs] if it's not a two-year payback." (research interview transcript, P02, 2018).

Overall, it is hard to agree or disagree with image theory's application to the brewery interviews since the values of interviewees would need to be explored more to determine if values influence mindset and decision-making.

7. Conclusion

The purpose of this research was to investigate the greenhouse gas emissions of the Ontario craft beer industry, and assess the practical challenges and benefits of doing so. Furthermore, this research explored the awareness, perception, and action resulting from Ontario's cap and trade program. The conclusion will include a reflection on the research findings given the four research questions, significance of this research, research implications, limitations, and finally recommendations for future work.

7.1 Collective reflection

Given the goal of this research, and how it has been built off previous work, several key learnings emerged:

1) The main sources of brewery greenhouse gases are from indirect sources, particularly emissions associated with agriculture and transportation, whereas direct GHGs from breweries contribute the least to the brewery's overall GHG emission's profile
2) Calculating greenhouse gas emissions is difficult to execute without a background in greenhouse gas accounting methods, and time-consuming particularly in the context of small businesses
3) Calculating greenhouse gas emissions accurately is challenging when secondary data has to be used
4) Calculating greenhouse gas emissions would be difficult for craft breweries, and other small businesses, to execute themselves given time and knowledge requirements
5) Craft breweries are largely too limited in their financial and human capital to engage in actively measuring and reducing their GHGs
6) Craft breweries find marketing benefits, and environmental health, as the main motivators for reducing their GHGs
7) Craft breweries are divided in whether they think cap and trade will have a negative impact on their brewery

In relation to research question 1 (*What are the greenhouse emissions of an Ontario craft brewery?*) the case study found that 0.046 tonnes of CO2e is created for 100 L of beer produced. Scope 1 (direct brewery) GHGs accounted for 14.87% of the case company's emissions; scope 2 accounted for 38.70%; and scope 3 for 46.43%. An important note, as made before, is that scope 2 emissions are very dependent on the source of the electricity used during operations, so it varies between geographies, time, and depending on any carbon offsets the brewery has purchased. Of scope 1 emissions, 36.18% are from gasoline consumed by the brewery (for transportation, delivery, and other automotive purposes), 54.65% of scope 2 emissions are from steam use, and 23.22% of scope 3 (indirect) emissions are from barley production.

An important finding beyond the quantitative calculations with the case company is that a challenge in calculating greenhouse gas emissions is data availability and establishing a point of contact when employee turnover is volatile (in relation to research question 2). The interview findings complemented the case study findings that limited finances, small staff sizes, and technical knowledge are common barriers in calculating GHG emissions. Interview findings indicated cost was the dominant challenge in GHG calculations.

The main benefits of greenhouse gas emissions were informed from the interviews (research question 3). The interviews found that marketing was the most common benefit, followed by preservation of the natural environment. The interviews also found that greenhouse gas reduction action among breweries is mixed, and is not dependent on knowledge of cap and trade, which suggests future (potential) taxation due to cap and trade is not a main motivator to reduce greenhouse gas emissions. Interviewees were also mixed in their knowing, and familiarity, with cap and trade both in theory and practice.

Research question 4 examined the perceptions among Ontario craft breweries, which was used to study the relationship between institutional and image theory. The variation among participants regarding perceptions of how cap and trade will impact Ontario craft breweries does not support the idea that values are shaped from perceptions of carbon regulation on these businesses, and that these values guide carbon management. In other words, there was not a connection between craft breweries' positive, negative, or neutral perceived brewery-impacts of cap and trade with their value image. Value image was expressed as being environmentally sustainable among positive, negative, and neutral perceptions of cap and trade impacts. Furthermore, there is not a connection between value image and decision-making regarding carbon management. This suggests that external normative pressures do not influence Ontario craft breweries' image.

7.2 Research contributions and significance

This research adds to the literature by informing GHG reporting logistical challenges, benefits, and a discussion on GHG reduction motivators and barriers in the Ontario craft beer industry. The case company will benefit directly from this study by understanding their baseline emissions and gaining a better sense of how to mitigate their emissions. The Ontario craft beer industry may also benefit from a regionally-applicable case study of how to calculate brewery GHGs and the resources used to do this. This research also highlights main emission sources which can be used as a starting point for other breweries attempting to measure their GHG emissions. Beyond the quantitative findings of this research, the qualitative findings inform an understanding of the practical challenges and benefits for craft breweries to implement GHG measurement and reduction programs. Understanding perceived challenges and benefits of Ontario craft breweries is unique in its local focus, and of significance to carbon regulation decision-makers in their consideration of indirect carbon policy impacts for Ontario craft breweries. Furthermore, the research findings provide evidence for policy makers that there is an opportunity to address concerns held by craft breweries should they develop an Ontario business-outreach plan to engage small business owners.

7.3 Research implications

This research has various academic applications. Firstly, the case study component has built on the pre-existing literature surrounding greenhouse gas accounting for breweries (Koroneos, 2005; Climate Conservancy, 2008; Olajire, 2012; Amienyo & Azapagic, 2016; Cimini & Moresi, 2016). One academic contribution of this research is greenhouse gas accounting of a craft brewery in Ontario. Geographic-specific GHG calculations improve accuracy because they better reflect local technologies, electrical grid compositions, and resulting emission factors. However, the combination of process mapping, greenhouse gas accounting, and scenario analysis for one research paper is unique among the literature. This three-tiered approach provides a useful framework for future studies, and can be applied to case study research in other industry fields. The literature is rich with guiding texts for exploratory interviews, and thematic (coding) analysis, with many academic studies using these tools. The interview methodology itself is not novel, however the population to which it is applied is unique. The interviews provide meaningful, qualitative findings from the Ontario Craft Beer industry, which may be useful for future academic work.

The practical nature of this research means there are various managerial implications of this research. Firstly, brewery managers, particularly within Ontario, have reference materials that are publicly accessible, coupled with a step-wise method, to guide them through greenhouse gas accounting. A barrier to measuring and reducing greenhouse gas emissions, as identified among interviewees, is the lack of technical knowledge (i.e. know-how) to be able to execute greenhouse gas emission measurements. Furthermore, although the scenario analysis choices may not be particularly relevant for other Ontario Craft Brewery members, the method used to execute the scenario analysis is useful to forecast greenhouse gas emissions. Scenario analysis, in this way, can be used to inform brewery actions to reduce GHGs and protect against future financial and GHG risk exposure.

Finally, the societal implications for this research is greater transparency and information-sharing among the craft beer community (including both consumers and producers). Some interviewees identified a lack of information-sharing between OCB breweries relating to GHGs as making it difficult to evaluate their GHG performance, and where they "should be". The interview findings may inform producers of where they stand in relation to other craft breweries, and draw attention to possible changes that could be made in day-to-day, and high-level, brewery operations to improve GHG performance. Consumers will also get a better idea of craft brewery environmental priorities, environmental values, and reasons for action and/or inaction regarding Ontario craft brewery GHGs.

7.4 Limitations

7.4.1 Case study limitations

Case study limitations involve secondary data quality. The largest case study limitation was the availability of geographically, temporally, and technologically-relevant emission factors for greenhouse gas calculations. Furthermore, there was variation between the estimations for emission factors among sources. Where applicable, the most appropriate and reliable data was used, to the researcher's best discretion. With more time, knowledge, and resources, it would be possible to conduct more exact measurements by working with the case company to directly measure and expand their primary data inventory. However, given the primary focus of this research is to investigate the challenges and benefits of greenhouse gas accounting for craft breweries, this was not made a priority.

If craft breweries wish to measure greenhouse gas emissions for various products, which involve different supply chains, inputs, and distribution mechanisms, a modified approach than that which was taken for this thesis would be beneficial. If this were the case, the method should include consultation with employees aside from solely the sustainability manager because more specialized, and a greater amount, of information would be required to create project maps that are reflective of the increased complexity of value chains. For example, the process maps would need to understand if the same raw material input suppliers were used for all of a brewery's beer products, or if different suppliers were used. Aside from broader consultation with others at a craft brewery, the same core tools (process mapping, greenhouse gas accounting, and scenario analysis) could be used and modified in individualized contexts.

7.4.2 Interview and coding limitations

There are a few notable limitations to the interview component of this research. Firstly, there was no secondary coder to complement the primary coder's findings. This made it impossible to ensure inter-rater reliability. However, reliability (more specifically, stability) was tested for by re-coding 15% of the interview transcripts. A second interview limitation was time. The interviewee recruitment period was a month and it is possible additional interviewees may have participated if the recruitment period stretched over a longer period of time. Another limitation is interviewer bias and preconceived notions of Ontario craft breweries. Potential interviewee anticipation of desirable interview question answers may have also influenced the interview findings. Finally, the researcher coded all of the transcripts by hand, which has both benefits and disadvantages. The primary disadvantage was a higher risk of user-made errors while coding data.

7.5 Recommendations for future work

This research study could be expanded in various ways to continue adding to the literature. Firstly, this research could be improved by using more precise measuring tools to collect more extensive greenhouse gas emission data at the case company brewery. As discussed earlier, a limitation to this research's case study was the turnover in the principal contact for the case study. This made it difficult to transfer tacit knowledge from the sustainability manager and sustainability committee to incoming employees. A recommendation for future work is to explore tacit knowledge in implementing environmental sustainability programs, or more specifically greenhouse gas management programs, among Ontario craft breweries. This future work should look to apply decision-making and cognitive sciences with the practical challenges and benefits to calculating brewery greenhouse gas emissions.

Future work may also wish to expand the target population of the interviews. Future work should look to expand the interview population to include Ontario Craft Beer and provincial government representatives to understand these governing bodies' priorities in terms of assisting craft breweries in Ontario to regulate their GHGs. This research could explore governing bodies' priorities with regards to knowledge sharing and financial resource assistance to help Ontario craft breweries manage their GHG emissions, and compare this to the actual challenges experienced by Ontario craft breweries.

Finally, another future avenue of research would be to use this research's methodology to explore related environmental issues that are common among Ontario Craft Breweries, such as brewery water consumption and waste generation. Evidence from the interviews conducted as part of this thesis suggested that waste water generation, and issues with the quality of brewery waste water in particular, is a common concern with Ontario craft breweries. This interview evidence supports the importance of this recommended future research.

Appendices

Appendix A: REB approval

Ryerson University Research Ethics Board

To: Rachel Shin
EnSciMan
Re: REB 2016-417: Evaluating the greenhouse gas emissions of the beer industry: A craft brewer case study
Date: January 17, 2017

Dear Rachel Shin,

The review of your protocol REB File REB 2016-417 is now complete. The project has been approved for a one year period. Please note that before proceeding with your project, compliance with other required University approvals/certifications, institutional requirements, or governmental authorizations may be required.

This approval may be extended after one year upon request. Please be advised that if the project is not renewed, approval will expire and no more research involving humans may take place. If this is a funded project, access to research funds may also be affected.

Please note that REB approval policies require that you adhere strictly to the protocol as last reviewed by the REB and that any modifications must be approved by the Board before they can be implemented. Adverse or unexpected events must be reported to the REB as soon as possible with an indication from the Principal Investigator as to how, in the view of the Principal Investigator, these events affect the continuation of the protocol.

Finally, if research subjects are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and approvals of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research.

Please quote your REB file number (REB 2016-417) on future correspondence.

Congratulations and best of luck in conducting your research.

Lynn Lavallée, Ph.D.
Chair, Research Ethics Board

The Following protocol attachments have been reviewed and approved.

- [redacted] - Ryerson Thesis Project 2016 NDA.pdf (submitted on: 02 Dec 2016)
- References_REB Application Attachment.pdf (submitted on: 02 Dec 2016)
- REB Application Attachments_resubmission.pdf (submitted on: 16 Jan 2017)
- REB 2016-417_Resubmission.pdf (submitted on: 16 Jan 2017)
- Associate_Membership_Morali_Apr 2016.pdf (submitted on: 16 Jan 2017)

If any changes are made to the attached document throughout the course of the research, an amendment MUST be submitted to, and subsequently approved by the REB.

Appendix B: Consent form

Ryerson University
Consent Agreement

You are being invited to participate in a research study. Please read this consent form so that you understand what your participation will involve. Before you consent to participate, please ask any questions to be sure you understand what your participation will involve.

PROJECT TITLE: Evaluating the Greenhouse Gas Emissions of the Ontario Craft Beer Industry: An Assessment of Challenges and Benefits of Greenhouse Gas Accounting

INVESTIGATORS: This research study is being conducted by Rachel Shin, and supervised by Dr. Cory Searcy, Associate Dean of Programs in the Yeates School of Graduate Studies from Ryerson University, and Dr. Oguz Morali, Professor in the School of Business at Georgian College.

If you have any questions or concerns about this research, please feel free to contact the lead researcher, Rachel Shin, at Rachel.shin@ryerson.ca.

PURPOSE OF THE STUDY:
This research project is investigating the beer industry's greenhouse gas emissions. The project consists of two primary parts: 1) a case study of a craft brewer, and 2) interviews with Ontario Craft Brewers. This research will highlight emissions-emitting processes in the beer industry, evaluate greenhouse gas reduction opportunities, and explore the beer industry's attitudes and efforts in carbon footprint reduction projects. Approximately 30 people will be interviewed. This study's results will contribute to Rachel Shin's MASc Environmental Applied Science and Management thesis, in partial fulfillment of the degree requirements.

WHAT PARTICIPATION MEANS:
If you volunteer to participate in this study, you will be asked to do the following things:

Respond to interview questions relevant to your employment. These may be technical, factual, or opinion-based questions. Before the interview begins, the lead researcher will review this consent form with you, outline what your participation entails, and review potential benefits and risks you will be exposed to. You will have the opportunity to ask questions, and will then be asked to give your signed consent agreeing to participate. If the interview is conducted in person, the lead researcher will bring a copy of the consent form for you to sign, and a copy for your records. If the interview if conducted over the phone, the researcher will require you to email a signed copy of the consent form before your interview. After an introduction to the study, the lead researcher will begin asking questions that are prepared in advance. If at any time you wish to withdraw your participation (before, during, or after the interview takes place), you may do so without consequence. Please note, however, that you must **let Rachel Shin know if you wish to withdraw your participation before the final thesis is written (April 1, 2018)**, as it is will be impossible to alter the submitted final thesis. Furthermore, you do not have to answer a question(s) if you do not wish to.

Following the interview and a short debrief by the lead researcher, the study will be concluded. The interview will take no longer than 30 minutes of your time.

POTENTIAL BENEFITS:
Direct benefits to participants may include personal reflection on their company's operations, and the beer industry as a whole. Benefits from participating in this study, however, cannot be guaranteed. Anticipated indirect benefits of this study are a contribution to the knowledge of the beer industry's carbon footprint, and information regarding how the Ontario Craft Brewing industry is engaging in carbon-reduction activities.

WHAT ARE THE POTENTIAL RISKS TO YOU AS A PARTICIPANT:
The risks associated with this study are very minimal. If you feel at any point during the study that you would like to withdraw your participation you will be free to do so, again without consequence.

CONFIDENTIALITY:
Confidentiality of the data collected will be assured by maintaining all collected data is exclusively accessible to the members of the research team. All electronic records will be kept secure in password-protected files. We will use a generic participant number (not name) in our computerized records so that the data we collect contains no identifying information. All identifying information (i.e., consent form signatures) will be kept in a locked filing cabinet. All digital records with identifying information (i.e. contact information) will be password protected and will only be accessible by the research team. No identifying data will be reported. You will not be identified in any reports or publications. The research team will store physical data in a designated locked area at Ryerson University for seven years following publication of the results (in accordance with the University's policies). Digital files will also be secured by the research team for seven years following publication of the study results. The data will be destroyed following the seven-year period.
For more information on Ryerson University's record storage policies, please see:
http://www.ryerson.ca/gcbs/records/recordsretention/research/

INCENTIVES FOR PARTICIPATION:
There is no monetary compensation or reimbursement for your participation.

COSTS TO PARTICIPATION:
There are no costs to participate.

VOLUNTARY PARTICIPATION AND WITHDRAWAL:
Participation in this study is completely voluntary. You can choose whether to be in this study or not. If any question(s) makes you uncomfortable, you can skip that question. You may stop participating at any time without consequence. If you choose to stop participating, you may also choose to not have your data included in the study. If you choose to withdraw your participation following the interview, you must let Rachel Shin know before the thesis is written (April 1, 2018), as it is will be impossible to alter the submitted final thesis. Your choice of whether or not to participate will not influence your future relations with Ryerson University and/or Georgian College, or those involved in the research (i.e. Rachel Shin, Dr. Cory Searcy, and Dr. Oguz Morali).

<u>QUESTIONS ABOUT THE STUDY</u>: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact:

Rachel Shin
Graduate Student, MASc Environmental Applied Science and Management
Ryerson University
(647) 234-4287
Rachel.shin@ryerson.ca

Dr. Cory Searcy
Environmental Applied Science and Management Program Director and
Associate Professor, Department of Mechanical and Industrial Engineering
Ryerson University
(416) 979-5000 ext. 2095
Cory.searcy@ryerson.ca

Dr. Oguz Morali
Professor, School of Business
Georgian College
(416) 731-0286
oguz.morali@gmail.com

This study has been reviewed by Ryerson University's Research Ethics Board. If you have questions regarding your rights as a participant in this study, please contact:

Research Ethics Board
c/o Office of the Vice President, Research and Innovation
Ryerson University
350 Victoria Street
Toronto, ON M5B 2K3
(416) 979-5042
rebchair@ryerson.ca

PROJECT TITLE: Evaluating the Greenhouse Gas Emissions of the Ontario Craft Beer Industry: An Assessment of Challenges and Benefits of Greenhouse Gas Accounting

CONFIRMATION OF AGREEMENT:
Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to participate in the study and have been told that you can change your mind and withdraw your consent to participate at any time. You have been given a copy of this agreement.

____
Name of Participant (please print)

____________________________________ __________________
Signature of Participant Date

OR in place of a Signature, please provide your initials (i.e. R.S. for Rachel Shin) to provide consent for voluntary participation in this study:

____________________________________ __________________
Initials of Participant Date

All interviews will be audio-recorded for the purposes of data dissemination (i.e. interpretation of the interview responses). The audio recordings will be transcribed for qualitative analysis (i.e. identifying themes in interview responses). Once transcribed, the audio records will be destroyed and there will be no identifying information linked to the transcriptions. The transcriptions will be stored at Ryerson University and kept by the research team for seven years following the research's publications (in accordance with University requirements). In other words, all responses will be kept strictly confidential.

I agree to be audio-recoded for the purposes of this study. I understand how these recordings will be stored and destroyed.

____________________________________ __________________
Signature of Participant Date

OR in place of a Signature, please provide initials (i.e. R.S. for Rachel Shin) to provide consent to be audio-recorded:

____________________________________ __________________
Initials of Participant Date

Appendix C: Interview emails

Initial email contact: Request for interview

Re: Request for participation in research regarding greenhouse gas emissions of Ontario Craft Brewers

Hello *(Name of Participant)*,

My name is Rachel Shin and I am investigating greenhouse gas emissions/ carbon footprint reduction initiatives among Ontario Craft Brewer member companies as part of my Master's thesis research at Ryerson University. I am contacting you today to ask for your participation in my study via an interview that will take 15 to 30 minutes.

My research includes interviews with individuals in sustainability/environmental/operational/management roles in companies that are members of Ontario Craft Brewers (OCB). The interviews will explore carbon footprint reduction initiatives, and opinions on related subjects, such as Ontario's carbon regulation policy of cap and trade. Participation does not require the company to be aware of carbon emissions or carbon footprint. All interviews will be kept confidential (i.e. no identifying information of the interview participants or the participants' company) will be released in any resulting research publications.

If you are interested, or have any questions regarding my study, I would be happy to further discuss details and send you the study's consent form with more information. Should you wish to participate, we will set up an interview based on your availability (which can be done over the phone, Skype, or in-person if geographically feasible).

Thank you for your consideration, and I hope to hear from you soon.

Sincerely,

Rachel Shin
Master's Student, MASc Environmental Applied Science and Management
Ryerson University
Rachel.shin@ryerson.ca
Cell: 647-234-4287

Second email contact: Request for interview

Re: Follow-up regarding request for participation in research study

Hello,

I'm following up from my first email invitation (sent one week ago) requesting your participation in my Master's thesis research.

As I mentioned previously, I'm investigating greenhouse gas emissions among Ontario Craft Brewer (OCB) companies as part of my Master's thesis research at Ryerson University. I am contacting you today to ask for your participation in my study via an interview that will only take 15 to 30 minutes of your time. Ontario Craft Brewers currently has just over 80 member companies. Since OCB is a small group to draw a sample from, I would greatly appreciate your participation.

My research includes interviews with individuals in sustainability/environmental/management roles in Ontario Craft Brewer companies. The interview content explores carbon footprint reduction initiatives, and opinions on related subjects, such as Ontario's carbon regulation policy of cap and trade. Participation does not require the company to be aware of their carbon emissions. This research has been approved by Ryerson's Research Ethics Board. All interviews will be kept confidential (i.e. no identifying information of the interview participants or the participants' company) will be released in any resulting research publications. I plan to finish all interviews by the end of this month (March, 2018).

If you are interested, or have any questions regarding my study, I would be happy to further discuss details and send you the study's consent form with more information. Should you wish to participate, we will set up an interview based on your availability (which can be done over the phone, Skype, or in-person if feasible).

Thank you for considering participation as part of my Master's thesis research.

Sincerely,

Rachel Shin

Master's Student, MASc Environmental Applied Science and Management
Ryerson University
Rachel.shin@ryerson.ca
Cell: 647-234-4287

Third email contact: Final request for interview

Re: Final follow-up regarding request for participation in research study

Hello,

I'm following up from my previous two emails (sent to requesting your participation in my Master's thesis research). This will be my last email requesting your participation.

As I mentioned previously, I'm investigating greenhouse gas emissions among Ontario Craft Brewer (OCB) companies as part of my Master's thesis research at Ryerson University. I am contacting you today to ask for your participation in my study via an interview that will only take 15 to 30 minutes of your time. Ontario Craft Brewers currently has just over 80 member companies. Since OCB is a small group to draw a sample from, I would greatly appreciate your participation.

My research includes interviews with individuals in sustainability/operations management roles in Ontario Craft Brewer companies. The interview content explores carbon footprint reduction initiatives, and opinions on related subjects, such as Ontario's carbon regulation policy of cap and trade. Participation does not require the company to be aware of their carbon emissions. This research has been approved by Ryerson's Research Ethics Board. All interviews will be kept confidential (i.e. no identifying information of the interview participants or the participants' company) will be released in any resulting research publications. I plan to finish all interviews by the end of March/beginning of April, 2018.

My research study has possible benefits for craft brewers in Ontario. Interviews with craft brewers will provide data for analysis of themes regarding the benefits and barriers (i.e. financial, human resources, etc.) of greenhouse gas/carbon accounting in the craft brewer industry. This information may highlight key commonalities and provide insight to the craft brewing community in Ontario.

If you are interested, or have any questions regarding my study, I would be happy to further discuss details and send you the study's consent form with more information. Should you wish to participate, we will set up an interview based on your availability (which can be done over the phone, Skype, or in-person if feasible).

Thank you for considering participation as part of my Master's thesis research.

Sincerely,

Rachel Shin
Master's Student, MASc Environmental Applied Science and Management
Ryerson University
Rachel.shin@ryerson.ca
Cell: 647-234-4287

Interview participation reminder

*to be sent 48 hours before study participation (or two working days, should the interview date fall on a Monday)

Re: Reminder: Participation for Evaluating the greenhouse gas emissions of the Ontario Craft Beer industry: An assessment of challenges and benefits of greenhouse gas accounting

Hello *(Name of Participant)*,

This email is a reminder that your scheduled interview time is in a few days. Please see below for your participation details:

Interview time:
Interview medium: *(Phone, Skype, In-person)*
Interview location *(if in-person):*

(*If over phone*): Please note I will call you at your provided phone number at the scheduled interview time and date.

Please let me know as soon as possible if you wish to reschedule, or if you no longer wish to participate. I will take no reply to this email as a confirmation of your participation.

Please also note that your signed consent will be required before your participation in the study (i.e. before or at the start of the interview). The consent form was sent earlier during our communication, but is also attached here for your convenience. [(*If in person*): I will bring two copies of the consent form when we meet. I will ask you to sign one copy for my records, and one copy will be for your records.]

Thank you- I look forward to speaking with you soon. Please let me know if you have any questions.

Rachel Shin
Masters Student, MASc Environmental Applied Science and Management
Ryerson University
Rachel.shin@ryerson.ca
647-234-4287

Appendix D: Website content analysis and interviewee invitation protocol

This section consists of the protocol for researching prospective participants. All prospective participants are taken from the Ontario Craft Brewer's Association (OCB) member's list (as of February, 2018). As of April, 2018 there are 85 member organizations with the OCB (OCB, 2018a).

1) Access each company's link to their website, in the order they are posted on the OCB Member's List (as of February, 2018) and:
    a. Review OCB company page information; and company website "home", "about", and "history" pages. Review any other pages that indicate environmental information, and if unclear review all pages on the website.
    b. Record information that is included in step 2 (below).
    c. Note any environmental or sustainability mandates, targets, or other environment-related reports, and record key words. Key words may include some form of: environment, sustainability, carbon, greenhouse gas emissions, etc. Quotes and other notes related to the recorded keywords should also be recorded.
    d. Record the text (as was written) from which the environmental keyword was taken. The text reference (i.e. URL) should be cited under "Other notes" (see 2. o below).
2) Complete an entry in a table that looks like the following for each company in Excel:
    a. Company name
    b. Website URL
    c. Annual production (hL/year)
    d. Environmental keywords*
    e. Environmental notes**
    f. Established date
    g. Contact person (first, last names)
    h. Contact person position
    i. Contact email
    j. Contact phone
    k. Other notes (may include specific URLs for where environmental keywords were noted, may refer to best way to make contact with company, etc.)

    * See 1) c

    ** See 1) d

    NOTE: Where information was not available, external sources were referenced for missing information

3) After steps 1 and 2 of the above protocol are completed for all the OCB companies (completed in alphabetical order, as listed on the OCB member's webpage), the protocol will be repeated for the all companies with environmental keywords to test replicability in the keyword data collection process. Companies with no keywords were not included for the re-test because the information collected apart from the keywords is either correct or incorrect (i.e. brewery contact email address, brewery headquarter location, and brewery URL).
4) All OCB companies will be invited for interviews in groups of email invitations (as to not over-book depending on the response rate of prospective participating companies). All companies were invited in alphabetical order based on the name of brewery. In terms of exclusions, one company did not have an available email or phone number, and one company owned a second brewery (so only the first brewery was contacted). Finally, the case company brewery was not included in the interviews because the research team already has a great depth of their information, and they were already exposed to a different aspect of the research protocol which may have influenced responses.

5) After the initial email invitation is sent, the researcher waits one week for a response, after which a follow-up email will be sent. If the contact does not respond to the follow-up email in an additional one week, the researcher sends out a final follow-up email. The researcher proceeds to invite the next group of new companies in one week periods. Depending on the response rate of the first round of invitations, the group size may increase for the following round of invitations. Following the execution of the first two interviews, the researcher re-visits the interview questions and edits as required.
6) Interviews will be scheduled when prospective participants respond over email with their interest. Prior to the interview (but following expressed interest in participation) the researcher will send the consent form to the participant over email and request it be signed and returned prior to the start of the interview (either by initial or full signature, as indicated on the consent form).
7) Participant response rate is expected to be between 10 to 20 participants (representing 12% and 24% of the population, respectively). All interested participants will be given a chance to participate.

Appendix E: Interview questions

Script:

"Hello, this is Rachel Shin (*if over the phone/Skype*). Thank you for agreeing to meet/talk with me today for my research study. As part of the consenting process, I will review the key elements to this study's consent form, which I sent over email to you previously, before we begin the interview. *[Will summarize purpose of the study, potential risks, and the voluntary nature of this study, thereby allowing an option to withdraw participation at any time].* Do you have any questions regarding the study, or the consenting process? (*Answer any questions*). Please let me know at any time during or after the interview if you have any questions.

(Ask interview questions- see A below)

"I am finished with the interview questions. Before we conclude the interview, would you like to receive a written transcript of this interview over email? Also, would you like to receive this study's final report (in the form of a master's thesis) when it becomes available in (estimated) June 2018? (*If yes, tell the participant it will be sent over email*). Thank you again for your participation, and please let me know if you have any questions OR if you later decide to withdraw your consent."

A) BEER INDUSTRY

Inclusion criteria for interviews external to the case company are: 1) membership with Ontario Craft Brewers, and/or 2) membership with Beer Canada. A complete protocol for interview research, recruitment, and execution is in Appendix E. Interview questions with the beer industry will include the following:

1) Does your company measure its electricity usage? If so, does your company have plans in place to minimize electricity use? Are you aware of your company's electricity composition (i.e. percentage sourced from renewable vs. non-renewable energy)?
2) Does your company measure its greenhouse gas (GHG) emissions? *If so*, does your company have any GHG reduction programs in place? What is your company's process and considerations for developing GHG reduction targets? Do you measure direct and indirect GHG emissions?
3) Do you see managing electricity use and reducing GHG emissions as priorities in your business model? Why or why not?
4) Regardless of whether you collect baseline GHG emissions data, what do you see as the main challenges and benefits of collecting baseline GHG emissions data? *Prompt:* for example, do you see a marketing opportunity for promoting your beer as environmentally sustainable for reducing its carbon footprint? Is cost a consideration?
5) Does your company have any sustainability initiatives? What are the main challenges in implementing/maintaining these programs? If you do not have a program in place, what are your reasons for opting not to? Do you foresee development of a program(s) in the future?
6) Have you heard of Ontario's cap and trade program? If so, what do you know of it? How do you think this carbon pricing scheme will impact your company?
7) Do you have any ideas on an effective carbon pricing mechanism that should be applied in Ontario aside from cap and trade?
8) Do you think the beer industry is doing enough to reduce its GHG emissions? How do you think your company compares to others in this industry?

These questions were asked when brewery information was not publicly available:

1) When was your brewery founded?
2) What is your production volume per year, in hL (or other available measurement)? A rough approximation is fine.

Appendix F: Greenhouse gas calculations

Table 1 All greenhouse gas emissions and their sources, shown in grams and tonnes of carbon dioxide equivalents (CO_2e) and as a percentage of total greenhouse gas emissions. Missing data is highlighted in yellow.

Input	Scope	Category	2016 Amount	2016 Unit	Emission factor	Emission factor units	2016 grams CO2e emissions	2016 tonnes CO2e emissions	Percent of total CO2e
Fermentation	1	Beverage production and warehousing	110,841.20	hL (hot) brewed (2016)	317.0067797	g CO2e/hL beer	35,137,411.87	35.14	0.82%
Total gasoline consumed	1	Mobile emissions	100,560.21	L/year	2.271544142	kg CO2/L gasoline	228,426,960.83	228.43	5.36%
Total diesel consumed	1	Mobile emissions	66,875.76	L/year	2.676327051	kg CO2/L diesel	178,981,413.53	178.98	4.20%
Total B20 biofuel consumed	1	Mobile emissions	88,180.50	L/year	2.140961256	kg/L biodiesel	188,791,033.99	188.79	4.43%
Spent grains transportation	1	Transportation and distribution	?	km travelled/year for spent grain transportation	2.271544142	kg CO2/L gasoline	0.00	0.00	0.00%
CO2 bulk liquid	2	Beverage production and warehousing	337,137.00	kg/year	1	grams CO2e/gram	337,137,000.00	337.14	7.91%
CO2 containers	2	Beverage production and warehousing	1,456.03	kg/year	1	grams CO2e/gram	1,456,032.00	1.46	0.03%
Refrigeration and cooling	2	Purchased cooling	477,954.00	tonne hours/year	0.03984	kgCO2e/tonne hour	19,041,687.36	19.04	0.45%
Total electricity	2	Purchased electricity	217,692.61	kWh/year	704.0024844	g CO2e/kWh	406,393,301.66	406.39	9.53%
Steam	2	Purchased steam	13,239,033.00	lbs/year	0.0678	kg CO2/lb steam	897,606,437.40	897.61	21.05%
Transportation of CO2 bulk liquid	2	Transportation and distribution	?	km/year	2.676327051	kg CO2/L diesel	0	0	0.00%
Transportation of CO2 containers	2	Transportation and distribution	?	km/year	2.676327051	kg CO2/L diesel	0.00	0.00	0.00%
Barley agriculture	3	Cultivation	1,759,860.00	kg/year	0.26	kg CO2e/kg barley produced	457,563,600.00	457.56	10.73%
Hops agriculture	3	Cultivation	10,640,760.00	L beer/year given annual hops purchase	11.492766	g CO2e/L beer	122,291,764.74	122.29	2.87%
Waste to landfill	3	End of life	9.58	tonnes waste/year	1.4	tonnes CO2e/tonne waste	13,627,221.02	13.41	0.31%
Waste incinerated	3	End of life	7.83	tonnes waste/year	0.53745	tonne CO2e/tonne waste	4,275,762.60	4.21	0.10%
Organic compost	3	End of life	34.50	kg compost/year	960.07	kg CO2e/kg compost	33,122,415.00	33.12	0.78%
Waste recycled	3	End of life	336.39	tonnes recyclables/year	?	kg CO2e saved/tonne recycled	0.00	0.00	0.00%
Malting	3	Raw material processing	451,011.59	kWh/1,759,860,000 g malt	532.2119625	g CO2e/kWH (Ontario grid)	240,033,761.80	240.03	5.63%
Lager yeast production	3	Raw material processing	80.00	kg/year	?	kg CO2e/kg yeast produced	0.00	0.00	0.00%
Spring Water	3	Raw material processing	134,170.00	hL/year	?	kg CO2e/hL spring water extracted	0.00	0.00	0.00%
Bottle production	3	Raw material processing	802,908.29	kg/year	0.395	kg CO2e/kg green glass	317,148,773.76	317.15	7.44%
Bottle crowns	3	Raw material processing	2,640,000.00	g in crowns/year	0.07	g CO2/g steel	184,800.00	0.18	0.00%
Aluminum cans (473mL)	3	Raw material processing	68.00	tonnes/year in cans	1.75	tonnes CO2/tonne aluminum	119,000,000.00	119.00	2.79%
Aluminum cans (355mL)	3	Raw material processing	36,673,866.67	grams/year in cans	1.75	grams CO2/gram aluminum	64,179,266.67	64.18	1.51%
Can lids	3	Raw material processing	12,400,000.00	g aluminum/year	1.75	g CO2/g aluminum	21,700,000.00	21.70	0.51%
20L kegs	3	Raw material processing	3,238,646.88	grams steel/year in new 20L kegs	0.07	g CO2/g steel	226,705.28	0.23	0.01%
30L kegs	3	Raw material processing	8,482,170.40	grams steel/year in new 30L kegs	0.07	g CO2/g steel	593,751.93	0.59	0.01%
50L kegs	3	Raw material processing	23,133,192.00	grams steel/year in new 50L kegs	0.07	g CO2/g steel	1,619,323.44	1.62	0.04%
Barley transportation	3	Transportation and distribution	84,783.39	L diesel/year	2.676327051	kg CO2/L diesel	226,908,082.73	226.91	5.32%
Malted barley transportation	3	Transportation and distribution	124,214.93	km/year	2.676327051	kg CO2/L diesel	332,439,773.59	332.44	7.80%
Lager yeast transportation	3	Transportation and distribution	0.08	tonnes/year	0.61324	kg CO2/tonne km	49.06	0.00	0.00%
Hops transportation (air)	3	Transportation and distribution	13,735.00	kg/year hops	0.000603555	kg CO2/kg km	8,289.83	0.01	0.00%
Hops transportation (truck)	3	Transportation and distribution	21.35	L diesel/year	2.676327051	kg CO2/L diesel	57,138.18	0.06	0.00%
Hops transportation (air + truck)	3	Transportation and distribution	N/A	N/A	N/A	N/A	65,428.00	0.07	0.00%
Spring water transportation	3	Transportation and distribution	177.87	L diesel/year	2.676327051	kg CO2/L diesel	476,041.20	0.48	0.01%
Bottle transportation	3	Transportation and distribution	48.05	km with full cargo ship load	3.28639E-05	kg CO2/kg km	1.58	0.00	0.00%
Bottle crown transportation	3	Transportation and distribution	312.65	L diesel/year (one way)	2.676327051	kg CO2/L diesel	836,740.62	0.84	0.02%
Aluminum cans (473mL) transportation	3	Transportation and distribution	5,038.41	L diesel/year (one way)	2.676326532	kg CO2/L diesel	13,484,438.32	13.48	0.32%
Aluminum cans (355mL) transportation	3	Transportation and distribution	294.02	L diesel/year (one-way)	2.676326532	kg CO2/L diesel	786,882.28	0.79	0.02%
Can lids transportation	3	Transportation and distribution	12.49	L diesel/year (one way)	2.676326532	kg CO2/L diesel	33,430.73	0.03	0.00%
20L kegs transportation	3	Transportation and distribution	0.27	km/year by ocean freighter	3.28639E-05	kg CO2/kg km	0.00	0.00	0.00%
30L kegs transportation	3	Transportation and distribution	0.71	km/year by ocean freighter	3.28639E-05	kg CO2/kg km	0.00	0.00	0.00%
50L kegs transportation	3	Transportation and distribution	1.95	km/year by ocean freighter	3.28639E-05	kg CO2/kg km	0.06	0.00	0.00%
Waste and recycling transportation	3	Transportation and distribution	353.80	tonnes/year	2.676326532	kg CO2/L diesel	0.00	0.00	0.00%
TOTAL 2016 GHGs							**4,263,634,721.07**	**4,263.35**	**100.00%**
2016 GHGs per hL beer produced							**45,915.71**	**0.04591571**	

Appendix G: Website content analysis environmental keyword frequencies

Table 1 Environmental keyword frequency from website content analysis of 85 Ontario Craft Breweries. Environmental keywords were found from 15 of 85 breweries. The "Keyword" column shows the keywords found from the website content analysis, while the "Count of keywords" column shows the frequency of the keywords appearing in the 15 brewery websites..

Keyword	Count of Keywords
accountability	1
B-Corps	1
biodiesel	1
carbon neutral	1
clean commute	1
closed loop	1
compost	1
eco-friendly	1
employee education	1
environmental impact	2
environmental performance	1
environmental sustainability	1
environmentally conscious	1
environmentally responsible	1
green	1
green electricity	1
grown on site	1
ink reduction	1
local	2
locally sourced	1
low-emission heating and cooling	1
nothing goes to waste	1
organic waste	1
paper reduction	1
re-use	1
recyclable	2
recycle	1
reduce energy usage	1
remove chemical usage	1
renewable energy	1
renewable power	1
responsibly sourced	1
reusable bottles	1
sustainable	4
sustainable environmental best practices	1
sustainable packaging	1
sustainably sourced energy	1
transparency	1
waste diversion	1
water conservation	1
Grand Total	**46**

Appendix H: Comparison of website content analysis test and re-test

Table 1 lists the keywords identified from test 1, the frequency of these keywords in test 1, and the frequency of these keywords in test 2. All keywords found in test 1 were also found (and with the same frequency) as in test 2.

Table 1 Environmental keywords and their frequencies identified from a review of Ontario Craft Brewery websites. "Keywords" includes keywords found from test 1. "Keyword count from test 2" represents the frequency of keywords found from test 2 (i.e. the re-test), and "Keyword count from test 1" represents the frequency of keywords found from test 1.

Keywords	Keyword count from test 2	Keyword count from test 1
"nothing goes to waste"	1	1
accountability	1	1
Benefit Corporation certified	1	1
best practices	1	1
biodegradable	1	1
biodiesel	1	1
Carbon neutral	1	1
clean commute	1	1
closed loop	1	1
compost	1	1
eco-friendly	1	1
employee education	1	1
Environmental impact	2	2
environmental performance	1	1
environmental sustainability	1	1
Environmentally conscious	1	1
environmentally responsible	1	1
fuel savings	1	1
green	1	1
green electricity	1	1
grown on site	1	1
ink reduction	1	1
local	3	3
low-emission heating and cooling	1	1
organic waste	1	1
paper reduction	1	1
re-use	1	1
recyclable	1	1
Recycle	2	2
reduce energy usage	1	1
remove chemical usage	1	1
renewable energy	1	1
renewable power	1	1
responsibly sourced	1	1
Reusable bottles	1	1
Sustainable	4	4
sustainable environmental	1	1
sustainable packaging	1	1
sustainably sourced energy	1	1
transparency	1	1
waste diversion	1	1
water conservation	1	1
(blank)	22	
Grand Total	**71**	**49**

Table 2 lists the keywords identified from test 2, along with the frequency of these keywords from test 1 and test 2. Note that the scope of the second test was slighlty larger, thereby capturing more keywords than in test 1. Furthermore, the test and re-test were conducted in February, 2017 and April, 2018 (respectively) which may have impacted the keywords and their frequencies.

Table 2 Environmental keywords and their frequencies identified from a review of Ontario Craft Brewery websites. "Keywords" includes keywords found from test 2. "Keyword count from test 2" represents the frequency of keywords found from test 2 (i.e. the re-test), and "Keyword count from test 1" represents the frequency of keywords found from test 1.

Keywords	Keyword count from test 2	Keyword count from test 1
all-natural beer	1	1
all-natural ingredients	7	5
aquifer water	1	1
Benefit Corporation certification	2	2
biodegradable dishware	1	
biodiesel	1	
bottle re-use	1	1
Bullfrog Power	1	
carbon neutral	1	1
central cooling	1	
clean commute	1	
closed-loop	1	1
eco-friendly	1	
efficient lighting	1	
environmental impact	2	1
environmental performance	1	1
environmental stewards	1	1
environmental sustainability	1	1
environmentally conscious	1	1
environmentally responsible	1	1
fuel-efficiency	1	
green electricity	1	1
green natural gas	1	1
green office	1	
hops grown on-site	1	1
local	3	3
local beer	1	1
local farmers	1	1
local ingradients	1	1
local ingredients	2	2
locally crafted	1	1
locally sourced water and malt	1	1
locally-produced	1	1
lowering water usage	1	1
monitor water usage	1	1
natural ingredients	1	1
on-site carbon sequestration	1	1
organic	1	1
own wastewater plant	1	1
re-usable bottles	1	
recycled grain	1	1
recycled material paper bags	1	
recycling	1	1
reduced energy consumption	1	1
reducing emissions	1	
renewable electricity	1	
renewable energy	1	1
responsibly sourced	1	1
reusable bottles	1	
steam	1	
sustainability	1	1
sustainable	2	2
sustainable craft brewing	1	1
sustainable environmental best practices	1	1
sustainable packaging	1	1
sustainably sourced energy	1	
use of spent grains	1	
waste diversion	1	
water conservation	1	
Grand Total	**71**	**49**

Appendix I: Interview sub questions for coding purposes

1) A. Does your company measure its electricity usage? B. If so, does your company have plans in place to minimize electricity use? C. Are you aware of your company's electricity composition (i.e. percentage sourced from renewable vs. non-renewable energy)?

2) A. Does your company measure its greenhouse gas (GHG) emissions? B. If so, does your company have any GHG reduction programs in place? C. What is your company's process and considerations for developing GHG reduction targets? D. Do you measure direct and indirect GHG emissions?

3) Do you see managing electricity use and reducing GHG emissions as priorities in your business model? Why or why not?

4) Regardless of whether you collect baseline GHG emissions data, what do you see as the main challenges and benefits of collecting baseline GHG emissions data? Prompt: for example, do you see a marketing opportunity for promoting your beer as environmentally sustainable for reducing its carbon footprint? Is cost a consideration?

5) A. Does your company have any sustainability initiatives? B. What are the main challenges in implementing/maintaining these programs? C. If you do not have a program in place, what are your reasons for opting not to? D. Do you foresee development of a program(s) in the future?

6) A. Have you heard of Ontario's cap and trade program? B. If so, what do you know of it? C. How do you think this carbon pricing scheme will impact your company?

7) Do you have any ideas on an effective carbon pricing mechanism that should be applied in Ontario aside from cap and trade?

8) A. Do you think the beer industry is doing enough to reduce its GHG emissions? B. How do you think your company compares to others in this industry?

Appendix J: Tables of interview data

Table 1 is a summary table of all the codes, and their frequencies, following coding of transcriptions. The "count of codes" represents the number of times the "code name" was applied to the interview transcripts.

Table 1 Codes and their frequencies applied to the 13 interview transcripts. "Codes" is the title of the code applied to the transcript, and "Count of codes" shows the number of times the code was applied during coding across the 13 interview transcripts.

Codes	Count of codes
Cost savings of electricity	5
Cost savings of environmental initiatives	2
Customer engagement	1
Environmental benefits of carbon action	1
Financial benefits carbon action	1
Financial benefits of carbon action	1
Financial capital barrier	20
Human capital barrier	7
Information benefits of carbon action	1
Measuring direct greenhouse gas emissions	3
Other environmental brewery priorities	6
Physical capital barrier	3
Reducing direct greenhouse gas emissions	4
Sustainability certification	2
Sustainability marketing	8
Technical capital barrier	8
Time barrier	3
Unknown benefits of carbon action	2
Unknown challenges of carbon action	1
Does not measure electricity	7
Does not know electricity composition	10
Electricity reduction is a business priority	7
Greenhouse gas reduction is a business priority	9
Have heard of Cap and Trade	5
Cap and Trade will not have direct brewery impacts	1
Aware of Cap and Trade alternatives	2
Industry is acting effectively on greenhouse gas emission improvements	2
Industry is conscious of greenhouse gas emissions	2
Average greenhouse gas brewery performance	5
Greenhouse gas reduction is not a business priority	7
Measures electricity	4
Plans to reduce electricity in future	2
Not measuring indirect greenhouse gas emissions	1

Do not know alternatives to Cap and Trade	8
Not sure of industry action on greenhouse gas reductions	2
Above average greenhouse gas brewery performance	5
Peer knowledge sharing of environmental performance improvements	2
Plans to measure electricity	3
Knows electricity composition	4
Not measuring direct greenhouse gas emissions	6
May measure direct greenhouse gas emissions	5
Not sure if Cap and Trade industry impacts	1
Industry is not acting affectively on greenhouse gas emission improvements	8
Uses 100% renewable energy	1
May measure indirect greenhouse gas emissions	1
Know what Cap and Trade is	4
Cap and Trade will not impact brewery	2
Not planning to measure direct greenhouse gas emissions	3
Do not support Cap and Trade	1
Cap and Trade will have negative brewery impacts	3
Cap and Trade will have negative industry impacts	2
Above average environmental actions brewery performance	2
Support Cap and Trade	1
Reducing electricity	4
Do not know of Cap and Trade	4
Does not plan to reduce electricity	3
Not sure of greenhouse gas brewery performance	1
Does not have plans to measure electricity	2
Other policy suggestions	1
Brewery access to government/third party programs	2
Environmental health is a motivator for brewery action	10
Electricity reduction is not a business priority	7
Not sure how Cap and Trade works operationally	1
Need more government/third party programs	2
Need more efficient government/third party programs	2
Greenhouse gas reduction will be a business priority	3
Planning to reduce greenhouse gas emissions	1
Alternative business priority	5
Sustainability is part of our business model	1
Cost savings is a priority in our business model	1
Cost of electricity is high	1
Environmental planning is a benefit of measuring greenhouse gas emissions	1
Cost saving of measuring greenhouse gas emissions	1
Grand Total	**260**

Table 2 Codes assigned for test and re-test of interview coding for P2 and P3 (participants two and three).

Codes	Test 1 codes	Test 2 codes
Above average environmental actions brewery performance	1	1
Above average greenhouse gas brewery performance	1	1
Alternative business priority	1	1
Brewery access to government/third party programs	1	1
Brewery has sustainability initiatives	1	1
Cost savings of electricity	2	1
Do not know alternatives to Cap and Trade	2	2
Do not know of Cap and Trade	1	1
Does not know electricity composition	2	2
Electricity measurement and reduction is a business priority	1	1
Financial benefits of carbon action	1	1
Financial capital barrier to measuring and reducing GHGs	1	1
Financial capital barriers to measuring and reducing electricity	1	1
Financial capital barriers to measuring and reducing GHGs	1	1
Greenhouse gas measurement and reduction is a business priority	2	2
Have heard of Cap and Trade	1	1
Industry is not acting affectively on greenhouse gas emission improvements	1	1
Measures electricity	2	2
Measuring direct greenhouse gas emissions	1	1
Not measuring direct greenhouse gas emissions	1	1
Not measuring indirect greenhouse gas emissions	1	1
Not planning to measure or reduce indirect greenhouse gas emissions	1	1
Not sure of industry action on greenhouse gas reductions	1	
Plans to reduce electricity in future	1	1
Reducing direct greenhouse gas emissions	1	1
Reducing electricity	1	1
Technical expertise barrier to measuring and reducing GHGs	1	1
Grand Total	**32**	**30**

Table 3 Numeric code test 1 and numeric code test 2 columns were used as data input to a Krippendorff's Alpha statistic calculator (source: dFreelon.org). Numbers 1 through 27 represent codes applied from tests 1 and 2, and "0" indicates disagreeing codes between tests 1 and 2. The agreeance column lists whether there was an agreement in the numeric code assigned for each evalauted line of transcript from test 1 and test 2.

Numeric code input for KALPHA calculation: test 1	Numeric code input for KALPHA calculation: test 1	Agreeance?
1	1	Y
2	2	Y
3	3	Y
4	4	Y
5	5	Y
6	0	N
7	7	Y
8	8	Y
9	9	Y
10	10	Y
11	11	Y
12	12	Y
13	13	Y
14	14	Y
15	15	Y
16	16	Y
17	17	Y
18	18	Y
19	19	Y
20	20	Y
21	21	Y
22	22	Y
23	0	N
24	24	Y
25	25	Y
26	26	Y
27	27	Y

Appendix K: Emission factors for greenhouse gas calculations

Product/process	Emission factor	Emission factor unit	Source/Standard	Table/Figure/Page
Steel production	0.07	tonnes CO2/tonne steel	2017 Canadian National Inventory Submission to the United Nations Framework Convention on Climate Change (using 2015 inventory)	Table 2(I).A-Hs2
Steam production	67.800	kgCO2e/1000lbs steam	Rolff, D. (2011). LCA of deep lake water cooling in Toronto. (Unpublished master's paper). University of Toronto, Toronto, Canada.	Page 18
Refrigeration and cooling	0.040	kgCO2e/tonne hour	Rolff, D. (2011). LCA of deep lake water cooling in Toronto. (Unpublished master's paper). University of Toronto, Toronto, Canada.	Page 22
Fuel consumption for Class 7 and 8 vehicles	0.39	L/km	2017 Canadian National Inventory Submission to the United Nations Framework Convention on Climate Change (using 2015 inventory)	Table 1.A(a)s3
Road diesel	10.131	kg CO2/US gallon	WRI Emission Factors from Cross Sector Tools, 2017	CO2 for road diesel fuel: Table 12
Road diesel	2.676327051	kg CO2/L diesel	(conversion) WRI Emission Factors from Cross Sector Tools, 2017	CO2 for road diesel fuel: Table 12
Gasoline/petrol	8.59873	kg CO2/US gallon	WRI Emission Factors from Cross Sector Tools 2017	CO2 for gasoline/petrol: Table 12
Gasoline/petrol	2.271544142	kg CO2/L gasoline	(conversion) WRI Emission Factors from Cross Sector Tools, 2017	CO2 for gasoline/petrol: Table 12
Jet fuel	9.428	kg CO2/US gallon	WRI Emission Factors from Cross Sector Tools 2017	CO2 for jetfuel: Table 12
Jet fuel emissions	0.61324	kg CO2/tonne km	WRI Emission Factors from Cross Sector Tools 2017	Table 16
Rail transportation	0.0252	kg CO2/short tonne mile	WRI Emission Factors from Cross Sector Tools 2017	CO2 for rail transportation: Table 16
Rail transportation	2.77782E-05	kg CO2/kg mile	WRI Emission Factors from Cross Sector Tools 2017	CO2 for rail transportation: Table 16
Ocean container transportation	0.048	kg CO2/short tonne mile	WRI Emission Factors from Cross Sector Tools 2017	Table 16
Ocean container transportation	3.286E-05	kg CO2/kg km	(converted) WRI Emission Factors from Cross Sector Tools 2017	Table 16
Biofuel	8.10442	kg/US gallon biodiesel	WRI Emission Factors from Cross Sector Tools 2017	CO2 for biofuel: Table 12
Biofuel	2.140961256	kg/L biodiesel	(Converted) WRI Emission Factors from Cross Sector Tools 2017	CO2 for biofuel: Table 12
Waste to landfill	0.05	tonnes CH4/tonne waste	2017 Canadian National Inventory Submission to the United Nations Framework Convention on Climate Change (using 2015 inventory)	Table 5.a
Waste to landfill	1.40	tonnes CO2e/tonne waste	(conversion) 2017 Canadian National Inventory Submission to the United Nations Framework Convention on Climate Change (using 2015 inventory)	
Waste incinerated	413.57	kt CO2/kt waste	2017 Canadian National Inventory Submission to the United Nations Framework Convention on Climate Change (using 2015 inventory)	Table 5.a
Waste incinerated	0.26	kt CH4/kt waste	2017 Canadian National Inventory Submission to the United Nations Framework Convention on Climate Change (using 2015 inventory)	Table 5
Waste incinerated	0.44	kt N2O/kt waste	2017 Canadian National Inventory Submission to the United Nations Framework Convention on Climate Change (using 2015 inventory)	Table 5
Organic compost	21.89	kt CH4/kt waste	2017 Canadian National Inventory Submission to the United Nations Framework Convention on Climate Change (using 2015 inventory)	Table 5
Organic compost	1.31	kt N2O/kt waste	2017 Canadian National Inventory Submission to the United Nations Framework Convention on Climate Change (using 2015 inventory)	Table 5
Freight truck fuel efficiency	2.676326532	kg CO2/L diesel	WRI Emission Factors from Cross Sector Tools 2017	GHG Protocol emission factors from cross sectortools March 2017
Max load Class 7/8 vehicle	13,381.50	kg/truck load	https://en.wikipedia.org/wiki/Truck_classification	US GVWR truck classifications
CH4 (GWP)	28	g CO2e/g CH4	2014 IPCC GWP (AR5) found in IPCC 2014 Climate Change report and GHG Protocol "Global Warming Potential Values"	Box 3.2, Page 87
CO2 (GWP)	1	g CO2e/g CO2	2014 IPCC GWP (AR5) found in IPCC 2014 Climate Change report and GHG Protocol "Global Warming Potential Values"	Box 3.2, Page 88
N2O (GWP)	265	g CO2e/g N2O	2014 IPCC GWP (AR5) found in IPCC 2014 Climate Change report and GHG Protocol "Global Warming Potential Values"	Box 3.2, Page 89
paper packaging waste	1.34	kg CO2e/kg waste	BUWAL 250; Ecoinvent	Table 1, Cimini & Moresi, 2016
cardboard packaging waste	1.73	kg CO2e/kg waste	BUWAL 250; Ecoinvent	Table 1, Cimini & Moresi, 2016
paper recycling	-0.0635	kg CO2e/kg recycled	BUWAL 250; Ecoinvent	Table 1, Cimini & Moresi, 2016
plastic recycling (includes PE, not PVC)	-0.332	kg CO2e/kg recycled	BUWAL 250; Ecoinvent	Table 1, Cimini & Moresi, 2016
glass recycling	-0.376	kg CO2e/kg recycled	BUWAL 250	Table 1, Cimini & Moresi, 2016
aluminum recycling	-10.6	kg CO2e/kg recycled	BUWAL 250	Table 1, Cimini & Moresi, 2016
Steel recycling	-1.69	kg CO2e/kg recycled	BUWAL 250	Table 1, Cimini & Moresi, 2016
Aluminum can production	1.75	tonnes CO2/tonne aluminum	2017 Canadian National Inventory Submission to the United Nations Framework Convention on Climate Change (using 2015 inventory)	Table 2(I).A
Aluminum can (50% recycled) production	8.96	kg CO2e/kg can produced	International Aluminum Institute, 2013	Table 1, Cimini & Moresi, 2016
Aluminum can (99% purity) production	11.5	kg CO2e/kg can produced	Idemat 2001	Table 1, Cimini & Moresi, 2016
Green glass (net)	0.314	kg CO2e/kg glass	Turner, Williams & Kemp, 2015	Table 6, calculated from study LCA (and in same Table, literature values listed)
Green glass (gross)	0.395	kg CO2e/kg green glass	Turner, Williams & Kemp, 2015	Table 6, calculated from study LCA (and in same Table, literature values listed)
Brown glass (net)	0.314	kg CO2e/kg glass	Turner, Williams & Kemp, 2015	Table 6, calculated from study LCA (and in same Table, literature values listed)
Brown glass (gross)	0.395	kg CO2e/kg glass	Turner, Williams & Kemp, 2015	Table 6, calculated from study LCA (and in same Table, literature values listed)
Aluminum cans (net)	8.143	kg CO2e/kg	Turner, Williams & Kemp, 2015	Table 6, calculated from study LCA (and in same Table, literature values listed)
Aluminum cans (gross)	1.113	kg CO2e/kg	Turner, Williams & Kemp, 2015	Table 6, calculated from study LCA (and in same Table, literature values listed)
Mixed plastics (net)	1.024	kg CO2e/kg	Turner, Williams & Kemp, 2015	Table 6, calculated from study LCA (and in same Table, literature values listed)
Mixed plastics (gross)	0.339	kg CO2e/kg	Turner, Williams & Kemp, 2015	Table 6, calculated from study LCA (and in same Table, literature values listed)
Barley (produced Europe or USA)	0.26	kg CO2e/kg	BIER (2012)	Table 1, Cimini & Moresi, 2016
Barley Malting	0.292 (+-) .084	kg CO2e/kg	Chicago Manufacturing Centre (2009)	Table 1, Cimini & Moresi, 2016
Barley malting	0.000256277	kWh/g malt	The Climate Conservancy (2008)	The Carbon Footprint of Fat Tire Amber Ale (report)
Fermentation	15	g CO2/473.176 mL	https://www.theguardian.com/environment/green-living-blog/2010/jun/04/carbon-footprint-beer	Value taken from book "How Bad are Bananas?: The Carbon Footprint of Everything" by Mark berners Lee (2010)
Hops emissions	11.492766	g CO2e/L beer	The Climate Conservancy (2008)	The Carbon Footprint of Fat Tire Amber Ale (report)
Max number of containers on ocean freighter	10,000	TEU/freighter ship	https://en.wikipedia.org/wiki/Container_ship	(TEU=Twenty-foot equivalent continer units)
Max weight of one container on ocean freighter	16727256	g/container	https://en.wikipedia.org/wiki/Container_ship	(TEU=Twenty-foot equivalent continer units)
bottle cap weights	2.2	g steel/bottle cap		
355mL can weight	14.9	g aluminum/aluminum can		
473mL can weight	18.79	g aluminum/aluminum can		
Nuclear power generation	0.15	g CO2e/kWh	Intrinsik Corporation (2016)	Table E-1, page ii
Natural gas power generation	525.00	g CO2e/kWh	Intrinsik Corporation (2016)	Table E-1, page ii
Hydro power generation	0.00	g CO2e/kWh	Intrinsik Corporation (2016)	Table E-1, page ii
Wind power generation	0.74	g CO2e/kWh	Intrinsik Corporation (2016)	Table E-1, page ii
Biofuel power generation	0.17	kg CO2e/kWh	Intrinsik Corporation (2016)	Table E-1, page ii
Solar power generation	6.15	g CO2e/kWh	Intrinsik Corporation (2016)	Table E-1, page ii

Appendix L: Brewery operational process map

Figure 1 shows a stream flow diagram for the case company's operations. The diagram is divided into brewery, product distribution, and other travel activities.

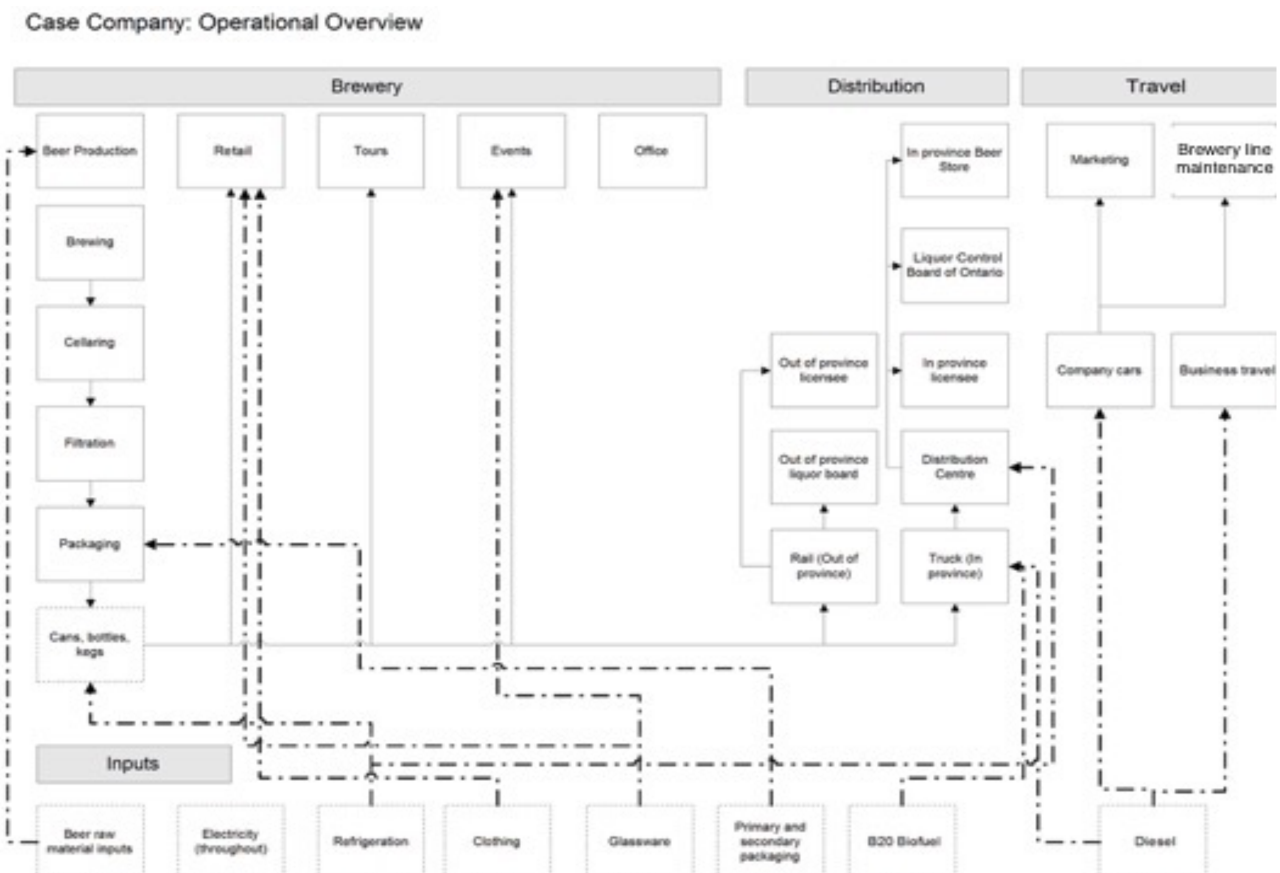

Figure 1 Case company operations within the brewery, and travel encompassed outside the brewery. The dashed lines connect product inputs to their product use, and solid lines connect movement of the final brewery product or employees through the operations.

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