Roasting Sustainability:
Sustainability Assessment for Coffee Lab International
And Vermont Artisan Coffee & Tea Co

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Preface

As a student doubling majoring in Environmental Studies and Economics at the University of Colorado at Boulder, I am particularly interested in the link between sustainability and successful business practices. In our society, the economy and the environment are perceived as adversaries all too frequently. However, my academic background provides me with a unique perspective to appreciate both the economic and environmental tradeoffs in daily business operations. Sustainability is an important aspect for the longevity of any business. This thesis examines the sustainability of two small businesses, Vermont Artisan Coffee and Tea Co. and Coffee Lab International.

Acknowledgements

This project would not have been possible without the help of several individuals. I would like to acknowledge of few of these important figures and their contributions. Firstly, I would like to thank Mané Alves who made this entire project possible. After learning about my interests and areas of study, Mr. Alves described some of the sustainability goals he has tried to incorporate in his businesses and explained that he was in the beginning stages of relocating his businesses. He intended to design a new building, which he would use to continue to incorporate sustainable business practices. Mr. Alves invited me to help him in this process and gave me access to all available financial records and energy bills, which I used to create this sustainability assessment. He also provided me with full access to his building for two days during my business visit in January. I met with several of his employees during my business visit, all of which were more than happy to explain their involvement with the businesses and provide very useful insight regarding daily business practices. I would like to give a special thanks to Renée Adams for providing me with all of the necessary financial records, energy bills, and business information. Ms. Adams was my primary contact at Vermont Artisan Coffee and Tea Co. and Coffee Lab International. She made the assessment much more comprehensive and my life a whole lot easier. Finally, I would like to thank Holly Alves for all pictures used in this paper and housing me during my business visit.

Secondly, I would like to thank my three advisors: Dale Miller, Dave Newport, and Keith Stockton. This committee was very helpful over the eight-month thesis process. All of the comments made on the drafts were very much appreciated and strengthened the content of my thesis. Each advisor made special arrangements to meet me in person several times to discuss the content of my project. I am very pleased with my committee selection and am very happy that you three decided to be apart of my project.

Lastly, I would like to acknowledge my younger cousin Zoe who was diagnosed with lymphoma in February. Even though she was forced to leave her new beginning at college to receive treatment, she never complained and always kept her optimistic personality. There were several times throughout this process that I was exhausted and frustrated with this project, but she inspired me to stop complaining and simply work harder to complete it. Thank you Zoe and get better soon.

Abstract

This thesis is a sustainability assessment in which energy and resource consumption are analyzed for two sister businesses, Coffee Lab International and Vermont Artisan Coffee and Tea Co., located in Waterbury, Vermont owned by Mané Alves. The paper begins by providing background information of the coffee industry and investigating a newly emerging market, sustainable coffee. Categories analyzed at the businesses include electricity consumption, propane consumption, water consumption, transportation, waste, and their associated carbon dioxide emissions. A combination of energy bills, business records, and personal observations were used to examine the previously mentioned categories. The purpose of this thesis is to serve as a baseline reference for Mr. Alves to compare the effectiveness of future sustainable initiatives. Mr. Alves is proposing to construct a new building to house his coffee businesses. At the end of the paper, several recommendations are provided for areas in which the sustainability of both businesses can be improved.

Introduction

This honors thesis examines in the Environmental Studies department at the University of Colorado – Boulder how Coffee Lab International and Vermont Artisan Coffee and Tea Co. can reduce their carbon dioxide emissions without compromising their financial successes. This paper analyzes and evaluates the sustainability of two sister coffee businesses, Coffee Lab International (CLI) and Vermont Artisan Coffee and Tea Co (VAC) located in Waterbury, Vermont. Both businesses are owned by Mané Alves and reside in the same, rented office space. In September 2014, Mr. Alves bought two acres of land in Waterbury Center with the intention to design a new building to house his businesses. Construction for the new building is expected to commence in June. This construction provides Mr. Alves a unique opportunity to make significant changes in order to improve the sustainability of his businesses.

This thesis is both intended as an academic paper for my peers in the Environmental Studies department as well as a report to supplement Mr. Alves in his process of designing the new building for CLI & VAC. I will start by providing background information related to the coffee industry and lifecycle process. I address several aspects that outside of the scope of this thesis in the background introduction; however, it is important to consider the full lifecycle of coffee before addressing one particular process. The analysis of this thesis is two-part. First, I will create a baseline for the two businesses using a variety of information in order to evaluate the current level of sustainability. This baseline is intended to serve as a record for CLI & VAC in which they can evaluate their progress by comparing to future levels. The baseline consists of a variety of different categories including energy consumption, carbon dioxide emissions, water usage, packaging, waste, and transportation. Second, I will make specific recommendations at the end of this paper for the new building to improve from what they are currently doing, the baseline. I will not only show the environmental benefit associated with each recommendation, but I will also consider the financial costs associated with each initiative.

Background

In this section, I have included information necessary to the foundation of this paper. First, I outline business characteristics of Coffee Lab International and Vermont Artisan Coffee and Tea Co to give a better understanding the scope of this project. Then, I describe features of the coffee industry including the process, the economics, and the industry's carbon footprint. After that, I provide a definition of a newly, emerging niche market in the coffee industry: sustainable coffee. This section's purpose is to provide general information necessary to move forward in the paper. No analysis occurs in this section.

Business Information

In 1995, Mané Alves founded Coffee Lab International (CLI), a specialty coffee laboratory. This independent laboratory specializes in the physical and sensorial evaluation of coffee. Services that CLI offer are green and roasted coffee analyses, green coffee sourcing, proprietary blend development, shelf life studies, and coffee equipment evaluation. Dunkin Donuts, CLI's biggest client, contract CLI to produce daily, analytical reports regarding the quality of their coffee beans and k-cups. Additionally, CLI periodically offers a multitude of different certification classes for the sensorial and physical aspects of coffee roasting and cupping through the CLI School of Coffee. The CLI School of Coffee is certified by the Specialty Coffee Association of America (SCAA) and Coffee Quality Institute (CQI). SCAA, founded in 1982, is the most prominent specialty coffee organization, which is in charge of setting growing, roasting, and brewing standards for premium coffees. The School of Coffee offers a variety of world-class courses ranging from 1-day calibration (renewal) courses to 2-day barista courses to 6-day certification courses. The prices for these classes range from $300-$1500 per person.

Vermont Artisan Coffee and Tea Co (VAC) is the second sister business founded by Mr. Alves. VAC uses the green coffee beans and teas sourced from around the world by CLI to create premium coffee and tea products. VAC only uses the finest arabica beans and sells their roasted coffee and tea directly to individual consumers, local cafés, restaurants, and specialty food stores. At VAC, higher prices reflect higher quality. A 12-oz bag of coffee costs $10-15, while a 12-oz Dunkin Donuts or Starbucks bag costs $6-9; however, VAC is price competitive with competitors in the organic, specialty coffee market.

While VAC and CLI are two independent businesses, they share the same owner and 5000 square foot office space. To avoid confusion, I may refer to them as a single entity (CLI & VAC) at times later in the paper such as quantifying carbon emissions related to energy consumption. However, it is important to recognize that both companies not only provide vastly different services, but also are structured differently. VAC sells consumable beverage products both retail and wholesale throughout the New England region. In contrast, CLI generates the majority of its revenue from multi-period contracts with large coffee, roasting companies. In 2014, VAC generated $874,450 in revenue, of which 88% is attributed to coffee and 12% tea. Similarly, CLI generated approximately $780,000 in revenue in 2014. Mr. Alves employs 12 full-time staff members between the two businesses.

Coffee (General Information)

There are two types of coffee: arabica, grown at high altitudes in Latin America and Northeast Africa, and Robusta, grown at low altitudes in Asia and Sub-Saharan Africa. Arabica coffee accounts for 2/3 of global output and is distinguished by having more aromas and less caffeine than Robusta coffee. The arabica bean is considered superior in taste and quality compared to the Robusta bean (SCAA 2012). Coffea is a flowering plant native to Africa and Asia, which produces a fruit known as a cherry. Each cherry holds two seeds known as coffee beans. It takes three to four years for coffea to mature and produce coffee cherries; however, once the plant is mature, it can produce cherries for 20 to 30 years. Approximately 2000 cherries are required to produce one pound of roasted coffee.

Coffee is grown in sub-tropical, humid climates no further than 1000 miles away from the equator. Brazil and Vietnam are the two largest coffee producing nations exporting 1.8 and 1.3 million metric tons in 2011, respectively (FAOSTAT 2012). "The United States imported more than 21.5 million bags during the 2008/09 coffee year, accounting for more than one quarter of global coffee (un-roasted) imports, making it the world's largest single buyer" (SCAA 2012). A "bag" is most commonly defined in the coffee industry as a 60-kilogram jute bag of green coffee beans. The largest coffee consuming nations do not have the capability of growing coffee; therefore, equatorial countries export a large percentage of green coffee beans. This geographical imbalance of coffee production and consumption leads to coffee being the second most valued global trade commodity (behind petroleum), which significantly stimulates global and local economies but also contributes to global environmental degradation, more specifically global carbon dioxide emissions (Loureiro and Lotade 2005).

Coffee (Pre-roasting Processes)

The following section outlines the life cycle process of a coffee bean. A coffee bean is the seed of coffea. Traditionally, coffee beans are planted in the wet season so the roots can be firmly established. After three to four years

Harvested coffee cherries from El Salvador of maturation, the tree will begin to bear fruit. Coffea's fruit is known as a cherry, which contains two coffee beans. The cherries are harvested either by hand or machine. A machine will generally practice a method known as 'strip picking', which means the entire plant is harvested at one time. Farms that practice hand harvesting will use a process known as selectively picked, where only the ripe cherries are harvested. Since this process is labor intensive, it generally produces coffee beans at a higher cost. However, this process is commonly used when producing high-grade arabica beans. Generally, there is only one harvest per year in coffee producing countries.

The cherries should be processed quickly after they have been harvested in order to prevent spoilage. There are two different methods of processing: a dry method and a wet method. Traditionally, the dry method is practiced in countries with limited water resources. The cherries are spread out on a large, sun-lit surface and continuously raked and turned throughout the day. Once the moisture content of the cherries drops to 11 percent, the dried husk is removed in a process known as hulling. The first step of the wet method uses a pulping machine to remove the skin and pulp from the coffee bean. These processed beans are then put into a water-filled fermentation tank, where the beans will be stored for 12 to 48 hours. Naturally occurring enzymes break down a slick layer of mucilage (called the parenchyma) attached to the bean. After the fermentation process, the beans are ready for dried to the 11 percent moisture content necessary for storing. Beans are either sun dried or machine dried depending on the farms resources.


Mr. Alves examining the dry method process of green coffee beans at a Guatemalan farm

After the beans have been processed, the green coffee beans are ready for export. Green coffee is usually packaged in jute bags, loaded into shipping containers, and transported by ship to importing nations. “Approximately seven million tons of green coffee is produced worldwide each year” (NCA 1). The green coffee is shipped to coffee roasters that use large roasting machines to transform green coffee into brown beans. Typically, roasting machines average a constant temperature of 550 degrees Fahrenheit. The beans are continuously rotated in these large machines until their internal temperature reaches 400 degrees Fahrenheit. At this temperature, the beans begin to turn brown because the oil, known as caffeol, locked inside the bean begins to materialize. This heating process, pyrolysis, gives roasted coffee its signature appearance and aroma. Following the roasting process, the coffee beans are ground, which allows for the full extraction of flavor and aroma to be captured. Finally, the ground coffee beans are brewed with boiling water to produce a cup of coffee.

While the above information described a unified roasting process, there are many subtleties, which define the type of coffee that is produced. “Roasting is a technical skill which approaches an art form” (NCA 2). A matter of seconds can alter the composition of an entire batch of roasted coffee beans. Chemical reactions during pyrolysis cause the properties of roasted coffee beans to be drastically different than green coffee beans. Physically, roasted coffee beans are darker, smoother, firmer, and lighter in weight than green coffee beans. Roasted coffee beans are categorized by color: light, medium, medium-dark, or dark. Light roasts are light brown in color and produce a mild flavored coffee. Medium roasts, often referred to as American roast, are medium brown in color and have a stronger flavor than light roasts. Medium-dark roasts are dark brown in color and produce a rich flavored coffee with a slight bitterness aftertaste. Coffee beans used for dark roasts are shiny with an oily surface. The flavor is full and bitter; however, dark roasts produce the least acidic coffee. (NCA 2).

Note the difference in color between green coffee beans (left) and roasted coffee beans (right). Roasted coffee also has the signature ‘coffee’ aroma and is lighter in weight.

Coffee (Economics)

As mentioned earlier, coffee is the second most valuable world commodity after petroleum. Coffee is a valuable commodity because of its high, global demand. It is estimated that 54% of Americans over the age of 18 drink coffee daily. “In 2010, world consumption of coffee was 132 million bags” (International Trade Centre 2011). This high, global demand has made coffee a very important aspect to the global economy in both developing and developed nations. “World coffee trade accounted for approximately $16.5 billion in 2010” (International Trade Centre 2011). Additionally, “the International Coffee Organization (ICO) estimated total coffee sector employment at 26 million persons in 52 exporting countries” (ICC 105-5 2010).

Coffee is not grown in the United States; however, the retail market for coffee is significant. The United States imports more than 20 million bags of green coffee beans annually. In 2012, the retail value of the US coffee market was estimated at $30 billion. Of this $30 billion, specialty coffee, such as the coffee beans roasted by VAC, represents a 37% volume share and nearly 50% value share (SCAA 2012). Specialty coffee is newly emerging niche market that is growing at a rapid rate. Consumers prefer specialty coffee for its taste and perception. Specialty coffee is usually more environmentally conscious and often certified by an independent third part organization.

Coffee (Climate Change)

Coffee is a sensitive crop that requires a specific set of climatic characteristics (e.g. temperature, humidity, season length, and precipitation) in order to yield the ideal bean. According to the International Panel on Climate Change, the global temperature has increased by 0.85 degrees Celsius over the period 1880-2010. Additionally, “each of the last three decades has been successively warmer than any preceding decade since 1850” (IPCC 2013). “It is clear that coffee regions will be increasingly affected, all becoming warmer, many also becoming either wetter or drier” (Baker and Hagger 2007; Gay *et al*. 2006; International Trade Centre 2011; Laderach *et al.* 2011). Therefore, the coffee industry has an incentive to strive towards a reduction in global carbon emissions to minimize the effects from a changing climate.

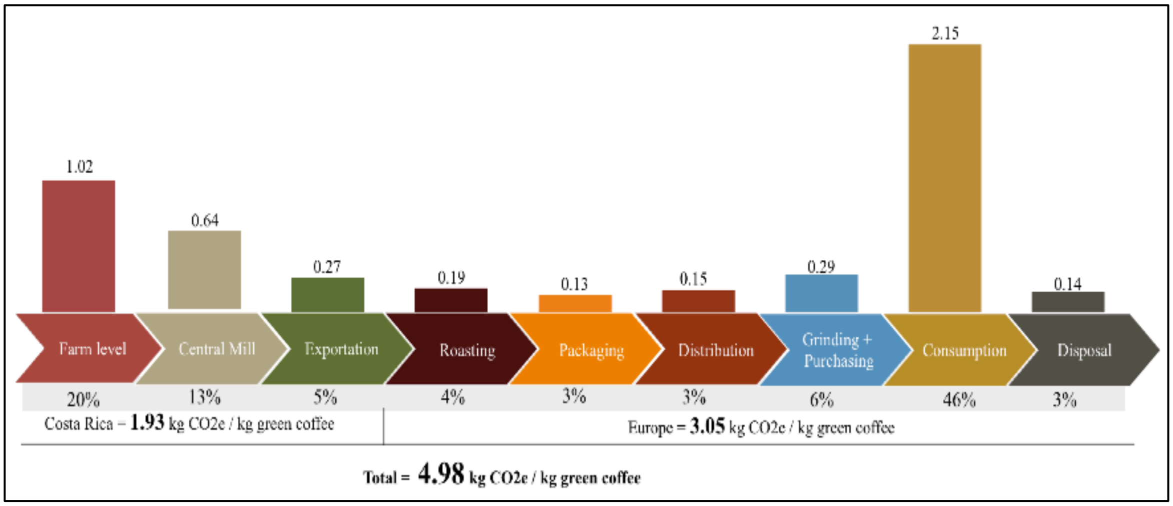
While the idea of reducing global carbon emissions is daunting for any industry, the coffee industry understands the looming effects that a changing climate presents for their valued product. Therefore, many industry leaders are taking charge and devising climate change strategies. For example, the five largest coffee producing companies (Kuerig Green Mountain, JM Smucker, Nestle, Starbucks, and Kraft) all have readily available climate change policies available on their websites. The integrity and effectiveness of such plans is still undetermined; however, it shows that the coffee industry has taken a “do-it-yourself” strategy with significant agents supposedly buying into the process.

Coffee (Carbon Footprint)

"The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product" (Wiedmann and Minx 2008). A carbon footprint is an important analysis tool for quantifying an activity’s contribution to climate change; however, little scientific literature has been published regarding carbon emissions from the coffee sector. Agriculture, as a whole, accounts for approximately 10-12% of total anthropogenic emissions of greenhouse gases (Smith *et al.* 2007).

The combination of two reports (Killian *et al.* 2013; and Tchibo GmbH 2008) calculated the carbon footprint for a pound a green coffee grown on a Costa Rican farm and exported for consumption in Germany. Their findings concluded that 4.98 pounds of CO_{2e} are emitted into the atmosphere for every pound of green coffee across the entire supply chain. Approximately, 40% of the greenhouse gas emissions were generated before the green coffee reached Europe, while the latter 60% of the greenhouse gas emissions were generated after exportation. The three largest sources of greenhouse gas generation were *farm level* (20%), *central mill* (13%), and the *consumer* (46%). At *farm level*, 95% of the greenhouse gas emissions were attributed to the use of chemical fertilizers. Most of the emissions generated by the *consumer* are driven by the high demand of energy required for the preparation of coffee with an automatic coffee machine. In their study, the roasting phase contributed 0.19 pounds of CO_{2e} for a pound of green coffee. "According to Publicly Available Specification (PAS) 2050, clause 5.4.2.3, the direct CO_{2e} emissions of the roaster gas are excluded from the assessment since they are arising from the coffee bean, a biogenic carbon source" (Tchibo GmbH 2008). I do not focus on carbon dioxide emitted from the coffee beans in the assessment for this reason.

Below is a graphical representation taken from the Killian *et al*. 2013 paper:



Life Cycle Carbon Emissions for 1 kg of Green Coffee – Ownership of this graphic belongs to Killian *et al.* 2013.

Sustainable Coffee

Some critics consider the term ‘sustainable coffee’ an oxymoron due to its geographical disparity between production and consumption and its energy intensive process; however, beans certified ‘organic,’ ‘Fair Trade,’ ‘shade-grown,’ and/or ‘Bird Friendly’ (terms that are usually synonymous with sustainable) are readily available at most stores for socially conscious coffee consumers. The term ‘sustainable coffee’ was first mentioned in scientific literature in the 1986 (Gutman and Davidson 1986) and gained significant prominence in the late 1990s (Chacón *et* al. 1999; McLean and Rice 1999; Njoroge 1997; Rosenow 1998). Sustainable coffee requires meeting certain third party standards such as organic and fair-trade certification; however, “a lack of a generally accepted definition of sustainable coffee results in confusion for producers and consumers on terms of the standards’ meaning, stringency, and legitimacy” (Bitzer, Francken, and Glasbergen 2008).

Sustainable coffee is only achievable through a joint effort from growers, roasters, and consumers. Growers must commit to using sustainable growing practices such as shade grown coffee and organic fertilizer. Additionally, they must produce an exceptional product using these sustainable growing practices since roasters compete on taste rather than price. Roasters sourcing these coffee beans must fairly compensate growers. The most common organization ensuring the proper payment of growers and their workers is Fair Trade. Furthermore, consumers must be willing to pay a premium for the better tasting, sustainable-certified coffee.

Sustainable coffee relates to environmentally and socially friendly practices that consider total energy, land, and resource usage required to produce the final coffee product. Specialty coffee identifies with proper physical and sensorial properties of the coffee product. While sustainable coffee and specialty coffee are not necessarily the same, many specialty coffee products are a result of sustainable practices. This is due to the fact that both specialty and sustainable coffee appeal to a similar consumer, who is willing to pay a premium for the better product. For this reason, specialty and sustainable coffee are used synonymously in this paper. "The market for sustainable coffees has grown dramatically from a small niche industry to become a significant part of the mainstream market. Though specialty coffee comprises less than 20% of the total coffee market, it accounts for more than 40% of coffee profits" (Linton 2008).

Fair Trade Coffee

Fair trade is a social movement dedicated to helping producers in developing countries by improving trade conditions and promoting sustainability. Fair trade is a market-based approach to empowering third world farmers. The premise for fair trade is that consumers care about the livelihood of the commodity farmers. Fair trade certifying organizations such as Fairtrade International, Fair Trade USA, and World Fair Trade Organization certify a product by ensuring the farmer a minimum price and linking farmers directly with importers. Organizations like this function because consumers are willing to pay a premium for a higher quality, socially responsible product (Loureiro and McCluskey 2000; Loureiro and Lotade 2005; De Pelsmacker, Driesen, and Rayp 2005). Fair trade labeling began with coffee but spread to a variety of commodity goods that are produced at small-scale levels including cocoa, tea, bananas, clothes, gold, etc. However, coffee remains the most well-established fair trade commodity in today's markets.

"Certification and labeling of fair trade products, which allowed them to be sold by mainstream retailers, began in 1988 in the Netherlands with the Max Havelaar Foundation label for coffee" (Elliot 2012). This idea has evolved and now several, major certifying organizations exist. Although there are several different certifying organizations, they maintain the same mission of empowering farmers, reducing the exploitation of said farmers, and promoting sustainability. Fair trade organizations provide farmers with the means to conduct trade without exploitation. Farmers are vulnerable to middlemen who pay cash for their commodities because credit is unavailable to many farmers in third world countries. These middlemen offer the farmers a fraction of their harvest's worth because there options are usually limited. Not only do fair trade organizations promote economic sustainability for farmers, but they also promote environmental sustainability. "Protecting the environment goes hand-in-hand with protecting the future livelihoods of local communities" (Fair Trade USA). Fair trade certifying organizations require strict protection of local ecosystems as well as endorse the use of sustainable agriculture methods.

International Coffee Agreement

The International Coffee Agreement (ICA) plays an integral role in the sustainability of coffee from an economics perspective. The ICA was established in 1962 as an economic guideline for coffee producing and coffee importing nations. Since its commencement in 1962, there have been a total of 6 subsequent ICAs in 1968, 1976, 1983, 1994, 2001, and 2007. The International Coffee Organization (ICO) was created in 1963 as a result of the 1962 ICA. Countries governed by the ICO represent 94% of coffee production and 75% of coffee consumption (ICO 1). Its mission is "to strengthen the global coffee sector and promote sustainable expansion in a market-based environment for the betterment of all participants in the coffee sector" (ICO 1). Early ICAs contained quota systems to control the global commodity price; however, this economic tool was abandoned to allow for the establishment of a global market equilibrium (ICO 2). Recently, quota systems have only been implemented to combat high price volatility in the times of economic distress. "The 2007 ICA's multiple references to 'sustainability' and 'sustainable development' illustrate the role of sustainability as one of the defining elements of the entire Agreement" (Potts 2008). The current agreement has a total of 45 members: 39 exporting members and six importing members, of which the European Union represents 27 nations as a single member (ICO 3).

Literature Review

This is a literature review focusing on the evolution of sustainability within our society and several tools that have been used to evaluate sustainability historically.

Sustainability

In 1972, *Blueprint for Survival* was published in a British Periodical, *The Ecologist*. It was the first time 'sustainability' appeared as a major theme: "Indefinite growth of whatever type cannot be sustained by finite resources. The principal defect of the industrial way of life with its ethos of expansion is that it is not sustainable" (Goldsmith and Allen 1972). Sustainability has evolved over the last four decades, but the core fundamentals outlined in *Blueprint for Survival* still exist.

"In the 1980s the term 'sustainability' moved out of the confines of books with limited circulation, technical articles, and reports into one wider popular sphere and into the operational planning of important agencies" (Kidd 1992). The popularization of sustainability led to many books, institutes, and legislations. In 1987, the United Nations Word Commission on Environment and Development published a report called *Our Common Future*, also known as the Bruntland Report. This report provided the standard definition for sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (*WCED* 1987). Most scholars refer to this definition as the starting point for the concept of sustainability.

Sustainability Assessment Tools

Just as there are many definitions of sustainability, there are many different sustainability assessment tools. While these tools are defined and organized in different manners, they all produce reports attempting to quantify sustainability. There are three categories, which define a sustainability assessment: “1) indicators and indices, 2) product-related assessment tools with the focus on the material and/or energy flows of a product or service from a life cycle perspective, and 3) integrated assessments, which are a collection of tools usually focused on policy change or project implementation” (Ness *et al*. 2007).

Indicators are specifically defined to measure quantifiable states of economic, social, and/or environmental development. “Indices are very useful in focusing attention and, often simplify the problem” (Atkinson *et al*. 1997). Sustainability indices are individually constructed to offer explicit insight on a particular aspect of sustainability. One paper (Singh *et al*. 2012) identifies and describes more fifty different sustainability indices that focus on categories such as development, innovation, economy, industry, eco-system, products, cities, etc. Common sustainability indices include: Genuine Progress Indicator (GPI), Human Development Index (HDI), Ecological Footprint (EF), and Environmental Performance Index (EPI).

Product related assessments “evaluate resource use and environmental impacts along the production chain or through the life cycle of a product” (Ness *et al*. 2007). These sustainability assessment tools provide quantifiable environmental externalities for a particular stage of a given product. Companies use this information to better understand the distribution of environmental harm regarding a particular product and make business operation decisions accordingly. The most common product related assessment is the Life Cycle Assessment (LCA), which is described later in this literature review.

Integrated assessments, the third category of sustainability analysis tools, are usually used to support policy or project decisions. “In the context of sustainability assessment, integrated assessment tools have an ex-ante focus and often are carried out in the form of scenarios (Ness *et al*. 2007).” Risk Analysis and Cost Benefit Analysis are two integrated assessment tools that do not explicitly pertain to sustainability issues but can be applied with proper technique. The Environmental Impact Assessment (EIA) is one of the most common integrated assessments solely focusing on aspects related to sustainability and is described in depth later in this literature review.

Life Cycle Assessment (LCA)

A Life Cycle Assessment (LCA) is a common scientific tool used to access the environmental impact of a product, which considers the entire life of the product. It provides a comprehensive analysis of the entire product system life cycle including production, manufacturing, packaging, consumption, and disposal. “In 1990, the Society of Environmental Toxicology and Chemistry (SETAC) sponsored an international workshop (in Smugglers Notch, Vermont) where the term ‘life cycle assessment’ was coined” (Klopffer and Grahl 2014). In 1997, seven years after its inception by SETAC, International Organization for Standardization (ISO) standardized the LCA. ISO recognizes LCA as a tool to “evaluate the environmental burdens associated with a product, process, or activity by identifying, quantifying, and assessing: energy and materials used, waste created, and opportunities to effect environmental improvements" (ISO 2012).

"LCA is distinguished from other environmental assessment methods by two constitutive and unique features: the analysis from 'cradle-to-grave' and the 'functional unit'" (Klopffer and Grahl 2014). 'Cradle-to-grave' embodies the idea that every step of the product's life cycle is included in the analysis. 'The functional unit' provides the LCA with ground for comparison and evaluation, which is important when assessing the product's overall environmental impact. The LCA has been a successful environmental assessment tool because it is can be applied to any product given sufficient life cycle data. LCA provides an in-depth analysis of the product in every stage of its life, which is can highlight certain stages as more harmful than others.

Many private interest groups have completed LCAs regarding the coffee industry (Salomone 2003). The coffee industry has a large environmental impact due to cultivation, transportation, production, packaging, and consumption of coffee productions. Major coffee companies such as Kuerig Green Mountain Roasters and Starbucks provide LCAs for certain products.

Environmental Impact Assessment

Historically, the Environmental Impact Assessment (EIA) pioneered a path for sustainability assessments. EIA was established in the 1960s as a result of the increasing awareness for environmental pollution. "EIA can be defined as the systematic identification and evaluations of the potential impacts of a proposed projects, plans, programs, or legislative actions relative to the physical-chemical, biological, cultural, and socioeconomic components of the environment" (Canter 1977). The Environmental Protection Agency (EPA) has used EIAs as a mechanism to evaluate proposed plans since its creation in 1970.

EIA is typically conducted before a project has been implemented in order to ensure the developers have considered the environmental externalities associated with a particular project. EIA takes into account numerous different environmental aspects such as water quality, air pollution, habitat destruction, waste, noise, etc.

Global Reporting Initiative

Global Reporting Initiative (GRI) is prominent non-profit organization that promotes economic sustainability by providing comprehensive sustainability reporting guidelines for businesses in order to contribute towards global sustainable development. "GRI's mission is to make sustainability reporting standard practice for all companies and organization and envision a sustainable global economy where organizations manage their economic, environmental, social, and governance performance and impacts responsibly, and report transparently" (GRI 1).

"Since its conception in 1999, the GRI has rapidly become the leader among voluntary worldwide sustainability reporting systems" (Brown *et al*. 2007). "In the 10-year period from 2000 to 2009, the GRI guidelines have been used as the basis for more than 4,700 sustainability reports by organizations in more than 70 countries. More than half of these reports were produced in 2008 and 2009 alone" (Gehman 2011).

Methods

In order to collect data for this sustainability analysis, I used a combination of business records, energy bills, and personal observations. This section describes what information was important for my calculations and how I accumulated this information. I focused primarily on the energy usage, business operations, and physical building characteristics in which CLI & VAC are currently located (80 Commercial Drive Waterbury, Vermont).

Business Visit

I visited CLI & VAC for two days in the beginning of January to better understand their business operations, make observations regarding resource and energy usage, and discuss ideas regarding the design of their new building. The next few paragraphs describe my visit.

I spent two full days at CLI & VAC learning about their business operations and making personal observations. I spent the majority of the first day meeting with employees to better comprehend the business operations. First, Holly Alves, President of VAC, gave me a tour of the layout of the building and a brief description of the business functions. As I toured the building, I noted room characteristics such as light fixtures, electronics, and machinery, which I used later to in my analysis.

Next I met with Eric Svensson, CLI's Lab Operations Manager, who explained the daily functions at CLI. He explained each individual machine in their lab and its coffee-testing purpose, which includes a variety of physical components such as moisture content, carbon dioxide level, and color. In addition to testing the physical components of coffee, CLI also tests sensorial components of coffee. I was fortunate enough to observe this technique, known as cupping. Precise amounts of roasted coffee beans were placed into ceramic mugs in groups of six. Different tables signified different coffee beans from different farms and/or country. These precise amounts of roasted coffee were then ground and returned to the mug. Once each individual mug contained ground coffee beans, the mugs were filled with boiling water and left to sit for three to five minutes. Cupping uses a combination of smell and taste in order to provide a full, sensorial evaluation. After the coffee sits for several minutes, a coffee bean crust forms at the top of the mug. Mr. Svensson and his team used their spoons to break the crust and stir the coffee, which is where their first evaluation of smell was recorded. Next they collected a spoonful of the brewed coffee and made a slurping action, which accentuates the full flavor. This was their second and final evaluation.

Mr. Alves tasting several different coffees in the cupping process

After meeting with Mr. Svensson and his team at CLI, I met with Angela Heath, roastery manager at VAC. Ms. Heath explained that VAC roasts on demand and in small batches every weekday because freshness is key to producing great tasting coffee. Next, she explained the science behind roasting coffee and the separate parts and their purposes of the physical roasting machine including the drum, the hopper, and the cooling tray. The majority of her work uses VAC's uniquely designed and largest coffee roaster. This machine has a load capacity of 60 kilograms and runs on propane. Ms. Heath concluded the interview by showing me the packaging process. They have two primary types of bags depending whether the coffee is being sold retail (12 oz. plastic bag with a one-way release valve) or wholesale (5 lb. brown paper bag lined with cellophane). The bags are then sorted by client and shipping method (usually UPS ground).

VAC's largest and most used roaster

Finally, I met with Renée Adams, General Manager of both CLI & VAC, to learn about the businesses' financial operations. Ms. Adams has been with CLI & VAC for 13 years and was extremely helpful with gathering information useful for this thesis. She provided me with energy bills, financial records, and shipping records at my request. We spent the rest of the first day talking about the specific type of information I would need to conduct the analysis of this thesis, which she provided the next day.

I spent the majority of the second day sifting through records and information that Ms. Adams gathered for me – most of which are used formally later in my results section. In addition to reviewing records, I also met with Tony Millus, tea operations manager, who explained VAC's processes related to tea. He explained that the tea comes from many countries around the world similar to coffee; however, it is already dried and ready for packaging. VAC uses an impressive piece of Japanese machinery to package the tea. Mr. Millus showed me how the automated machine works. The machine requires near constant attention; however, most of the actions are subtle manipulations to increase performance and productivity. The machine requires a supplementary air compressor to power the machine in order to ensure electrical reliability for the rest of the business.

At the end of the second day, Mr. Alves invited me to sit in on a floor plan design meeting for the new building with Joseph Architects LLC, a local architecture firm specializing in sustainable design. We met with Joe Greene, principal, and Brian Riopelle, designer, to discuss logistics of the floor plan. For the most part, I did not speak at the meeting unless spoken too; however, it was a fascinating experience, and I learned about several important features that plan to be implemented in the new building. At the end of the meeting, I did inquire about pursuing LEED certification and its implied additional cost, which I examine in the discussion section.

Energy Consumption

The two major forms of energy used directly by CLI & VAC are electricity and propane. This information was made available through the businesses' monthly energy bills; however due to logistics related to renting the building and switching natural gas suppliers, the data only represents a small portion of the businesses' history. Furthermore to complicate the situation, CLI & VAC are billed as one entity so it was not possible to create energy audits for each business; therefore for the most part, I decided to consider the two businesses as one entity in regards to energy consumption. Once I gathered overall electricity and propane usage data for the businesses, I identified the major areas of consumption and calculated the allocation of energy in these areas.

Electricity is primarily used to aluminate the building, package tea, and power electronics, while propane is used to heat the building in the winter and to roast coffee. In addition to total energy consumption, I also calculated the carbon emissions associated with the use of each fuel source. This is a simple calculation for propane because there is a known amount of carbon dioxide produced for a given unit of energy (i.e. 139 pounds of CO_2 emitted per million Btu of energy) as well as a known amount of energy density for propane (91,000 Btu per gallon of propane). Therefore, 12.6 pounds of CO2 is produced for every gallon of propane consumed. However, electricity is more complicated because it comes from a variety of sources – all of which have different carbon dioxide and energy densities. Therefore, I spoke with Dorothy Schnure, Corporate Spokesperson at Green Mountain Power, who informed me that Green Mountain Power's carbon intensity of electricity is 360 lbs. per MWh.

Transportation

Using a combination of distance calculating websites and information provided by Ms. Adams regarding the quantity of green coffee and its country of origin purchased by VAC, I computed carbon dioxide emissions directly related to the upstream transportation of green coffee for VAC in 2014. Ms. Adams specifically provided the number of bags, the weight of a bag in kilograms, and the country of origin. Using simple Google searches, I identified one particular, arbitrary coffee-growing region from each country. Similarly, I identified the closest seaport to each coffee-growing region using Searates.com. In order to calculate mileage for truck and sea freight transportation, I used Google Maps and Searates.com, respectively. See appendix A for specific coffee-growing regions, their respective seaport, and the corresponding mileage. Finally, I calculated carbon emissions associated with both truck and sea freight transportation using conversions provided by the United States Environmental Protection Agency. The carbon intensity of sea freight is 0.048 kg CO_2 per ton-mile, while the carbon intensity of truck transportation is 0.297 kg CO_2 per ton-mile (EPA 1).

Originally, I wanted to calculate similar carbon dioxide emissions associated with downstream transportation; however, sufficient data was not available. Therefore, I decided to calculate the carbon emissions associated with a 5 lb. package of roasted coffee and tea products shipped to Boulder, Colorado. I then compared this information to carbon emissions associated with the roasting process as a frame of reference. While a majority of VAC's products are shipped within the Northeastern United States, I calculated the carbon emissions for a shipment to Boulder, Colorado because I received a similarly weighted package from VAC on March 7th.

One of the defining characteristics of CLI & VAC is the close relationship with many small coffee growers around the world; however, these relationships require Mr. Alves to travel to coffee-growing regions almost half of the year. Ideally, I would have calculated Mr. Alves' total carbon dioxide emissions associated with personal air travel, but I was unable to obtain such records. I decided to calculate the carbon dioxide emissions associated to one round-trip flight to Bogotá, Columbia and compare it to the carbon dioxide emission equivalent in terms of coffee roasting production. I chose to focus on Columbia for a couple of reasons: 1) Mr. Alves has business down there so it is a country in which he visits annually, and 2) when considering all possible coffee growing regions, the distance to Colombia was approximately the mean. Colombia was chosen to be representative of an average business trip for Mr. Alves.

Finally, I estimated the amount of carbon dioxide associated with all employees commuting to and from work in a year. In this calculation I made several reasonable assumptions, and all assumptions are noted in this paragraph. I first assumed that the average round-trip commute for all 13 employees of CLI & VAC is 15 miles. The second assumption in this calculation is that the employees' vehicle fleet averages 20 miles per gallon. Thirdly, I assume that all 13 employees travel to and from work every working day of the year (i.e. 251 working days). Lastly, I use the following carbon intensity of gasoline to compute the total amount of carbon dioxide emitted in a year for all employees: 19.64 pounds of carbon dioxide per gallon of gasoline (EIA 2014).

Waste

Total waste production was difficult to quantify because Casella Waste Management, waste disposal and recycling company, charges a contractual, flat rate for the services provided to CLI & VAC, which is independent of weight. However, I did observe areas in which waste is generated and diverted in daily business operations, which I describe later in the results section.

Results

In this section, I have provided my findings gathered from financial records, energy bills, and personal observations for the existing building that houses CLI & VAC. Categories include energy and water consumption, packaging, waste, and transportation. Since data regarding energy consumption was most accessible, accurate, and detailed, I focus disproportionately (from a sustainability standpoint) more about energy consumption, than the other categories. Additionally, I calculate the associated carbon dioxide emissions for categories where applicable.

Electricity (Costs)

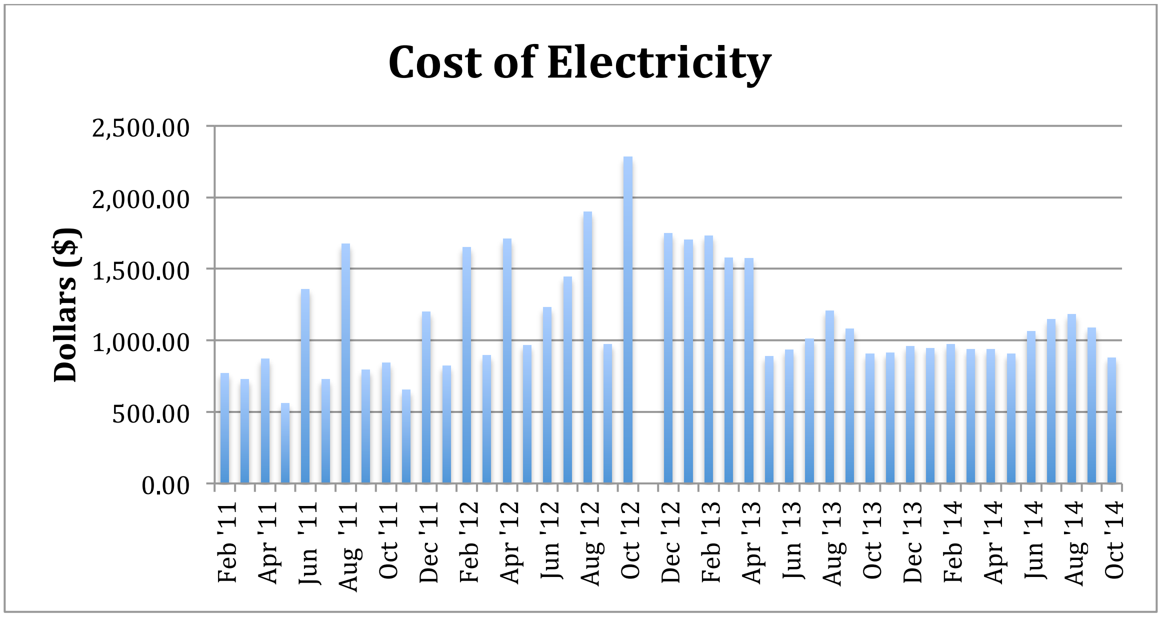


Figure 1 – Cost of Electricity

Using a combination of financial records and energy bills, I constructed a graph representing the monthly cost of electricity for CLI & VAC from January 2011 to September 2014. It does not appear that time of year has an affect on the cost of electricity for CLI & VAC. While electricity costs have fluctuated for CLI & VAC over the past three years, the cost from October 2013 to October 2014 was fairly constant. Additionally, the price of a kWh of electricity appears to have remained fairly constant during this timespan because, as shown in Figure 2, electricity consumption for CLI & VAC has remained relatively constant.

Electricity (Consumption)

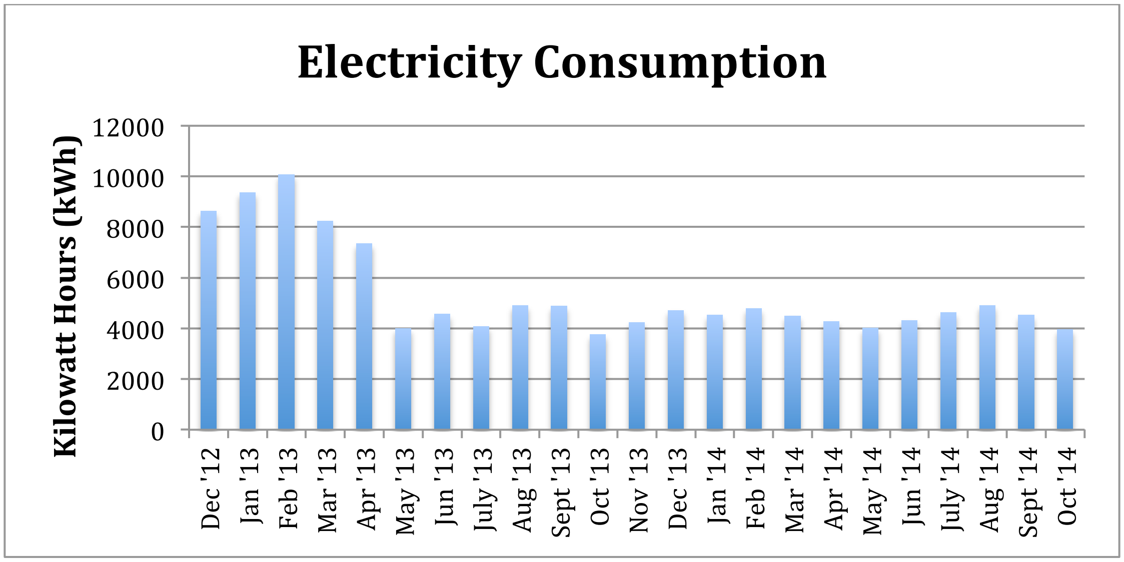


Figure 2 - Electricity Consumption

Using energy bills, I constructed a graph of the business' electrical usage. This data was provided by Ms. Adams and only dated back to Dec'12 due to a change in electricity supplier. Over a year span (October '13 – October '14), CLI & VAC consumed a total of 53,369 kWh of electrical energy with an average monthly consumption rate of 4,447.42 kWh.

At CLI & VAC's current location, there are 65 two-tube florescent light fixtures (130 40-watt tubes) and 35 four-tube fluorescent light fixtures (140 40-watt tubes). Therefore, the combined wattage for two-tube and four-tube florescent light fixtures is 5,200 and 5,600 watts, respectively. Since it is very difficult and inaccurate to estimate the average daily use of each light fixture, I calculated the energy required to turn on every light for an hour, which resulted in 10.8 kWh in electricity consumption. If every light was powered for the entirety of the workweek (40 hours), it would result in 432 kWh of electricity consumption.

Electricity required to power electronic machines comprises the remaining portion of electricity consumption. Large electronics such as the tea-packaging machine and coffee testing machines consume a majority of the electricity at CLI & VAC. While I was visiting the businesses, I collected information regarding their electronics. Data (e.g. power consumption and daily usage) necessary to make useful analyses were not readily available; therefore, I decided provide a record of current electronics, which can be found in Appendix A. The record is intended to serve as a future reference to see how electronics how changed in quantity and type.

Electricity (Carbon Emissions)

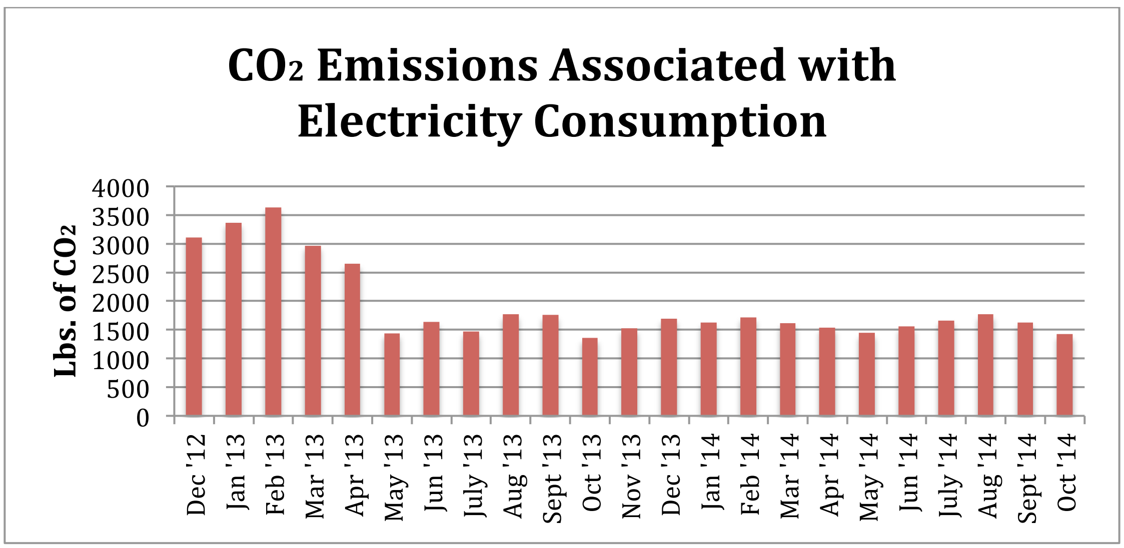


Figure 3.1 - CO_2 Emissions Associated with Electricity Consumption

Green Mountain Power (GMP), a local electricity utility in the state of Vermont, supplies CLI & VAC. GMP is a small, progressive utility "focused on providing its customers with a balance of the most reliable, affordable, smart, and clean energy" (GMP – Mission 2015). GMP is a unique electricity supplier because they produce the majority of their electricity from non-fossil sources. Utilities generate electricity from a multitude of sources and purchase surplus electricity from other utilities to meet their client's energy demand. Below, Figure 3.2 illustrates GMP's expected fuel mix for 2015. Due to the complex nature of the United States' electrical grid, it is nearly impossible to identify where certain electricity was generated. Therefore, I contacted Dorothy Schnure, a corporate spokesman at GMP, to obtain the carbon intensity of GMP's electricity. Ms. Schnure explained that GMP estimates 360 pounds of carbon dioxide emissions are produced for every MWh of electricity, which was used to construct Figure 3.1. Due to GMP's progressive business model, 360 pounds of carbon dioxide per MWh of electricity is significantly lower than the national, non-baseload average of 1,520 pounds of carbon dioxide per MWh of electricity (EPA 2). Over the same year span (October '13 – October '14), CLI & VAC produced 19,213 pounds of carbon dioxide attributed to its electricity consumption.

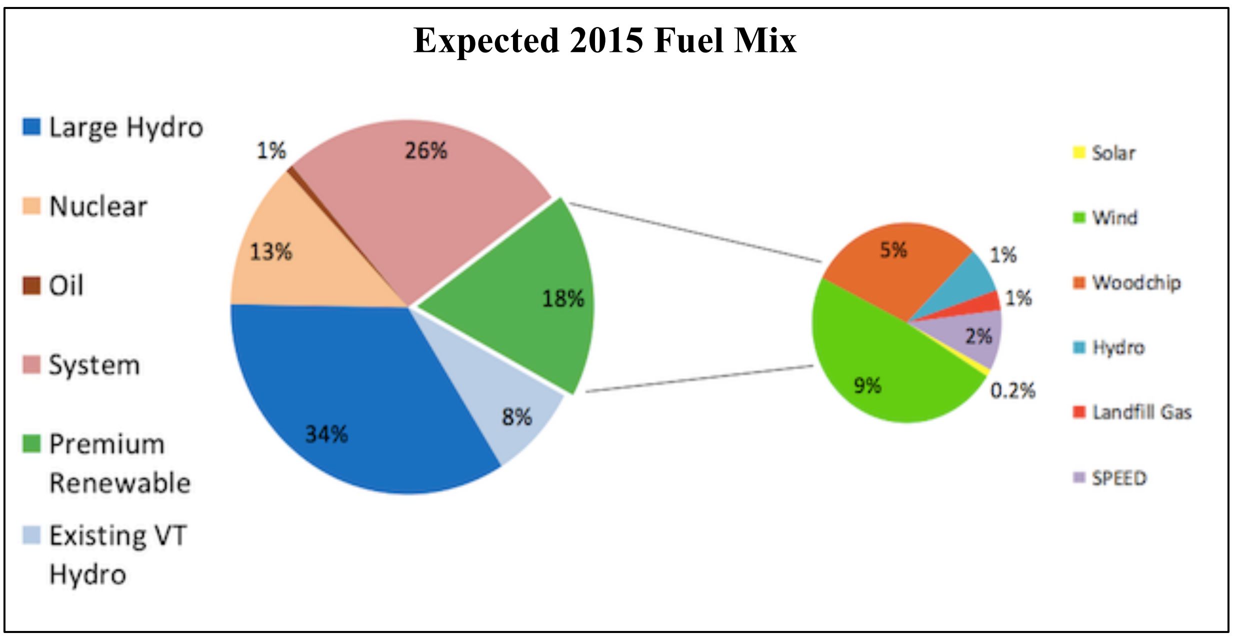


Figure 3.2 - Expected 2015 Fuel Mix. This graphic was adapted from two graphics found on GMP's website (Fuel Mix 2015). It is important to note that "System" is synonymous with "Market Purchases". It is also important to note that fossil fuels comprise an

abnormally small amount of the fuel mix, hence the low carbon intensity (1 MWh = 360 lbs. of CO_2 emissions). The national average carbon intensity for one MWh is approximately 1500 pounds or four times dirtier in terms of global air pollution.

Propane (Costs)

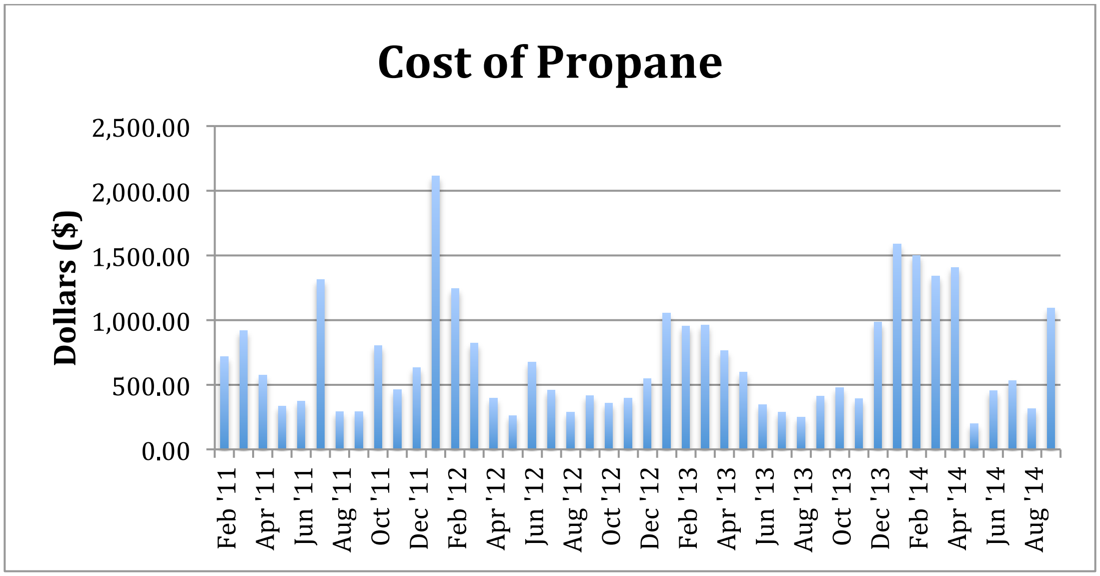


Figure 5.1 – Cost of Propane

Using financial records, I constructed a graph representing the monthly cost of propane for CLI & VAC from February 2011 to August 2014. It is apparent that CLI & VAC spend more money on propane during the winter months. As seen in Figures 6.1 and 6.2, CLI & VAC consume larger quantities of propane during the winters, which is reflected in Figure 5.1 with higher costs. Fluctuations in the total cost of propane over the past three years for CLI & VAC are due to a combination of propane consumption and the cost of a gallon of propane.

Propane (Consumption)

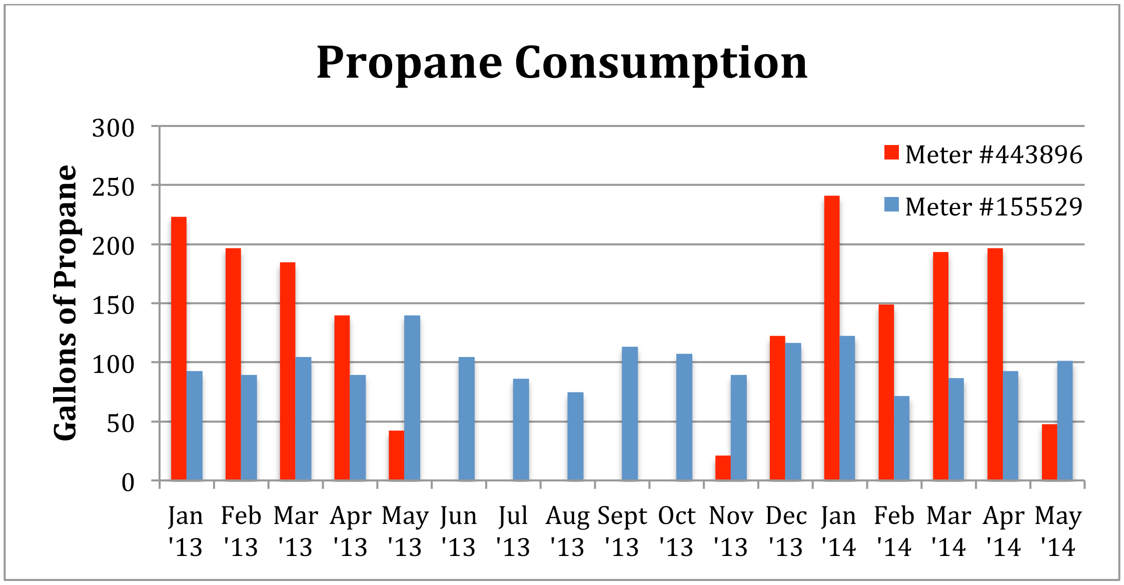


Figure 6.1 – Propane Consumption. This graph captures the propane usage for the business since January 2013. There are two propane meters for the business. Meter #155529 measures the amount of propane consumed for coffee roasting processes. Meter #443896 is used to heat the building (i.e. propane consumption is zero during summer months). Propane consumption data is limited to Jan '13 to May '14 due to a switch in propane suppliers, of which the latter supplier provided inadequate information.

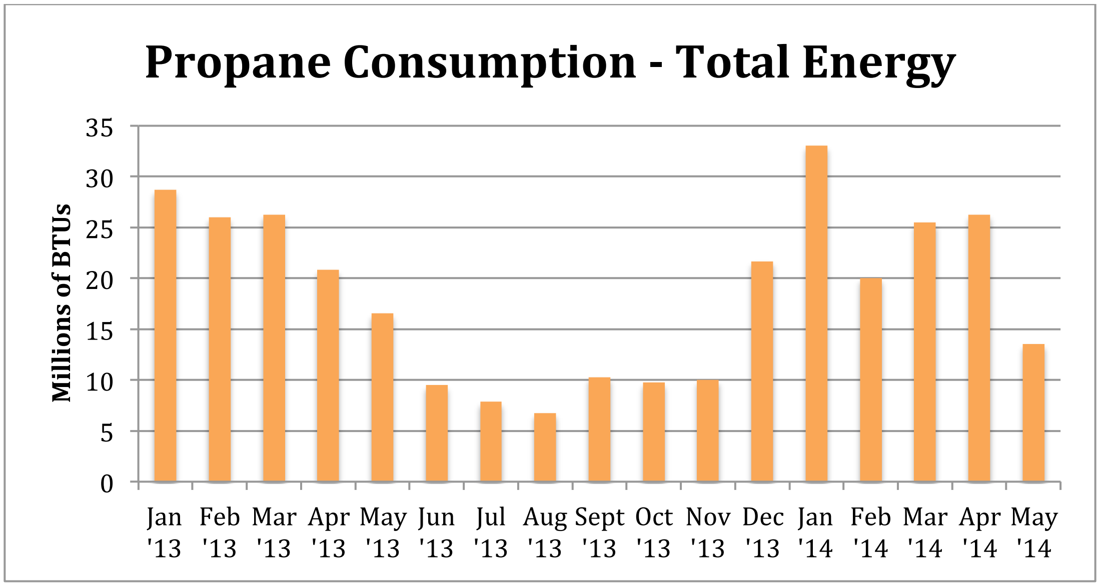


Figure 6.2 – Propane Consumption – Total Energy

In 2013, CLI & VAC consumed a total of 2134.7 gallons of propane for both heating and roasting processes. Assuming the energy density of propane is approximately 91,000 British Thermal Units (BTUs) for every gallon, CLI & VAC consumed 194,257,700 BTUs of energy from propane for both heating and roasting processes. While it is important to understand overall energy consumption, it is also important to understand the amount of energy required to produce 1 pound of coffee. Since coffee production data was not readily available by month, I was unable to construct a graphical representation. However, I used the information accessible to me to calculate the estimated energy required to produce 1 pound of roasted coffee. Using the 2013 propane energy consumption (194,257,700 BTU) and the 2014 coffee production (92864 lbs.), I found that it requires approximately 1181.4 BTU from propane to produce a pound of roasted coffee.

Propane (Carbon Dioxide Emissions)

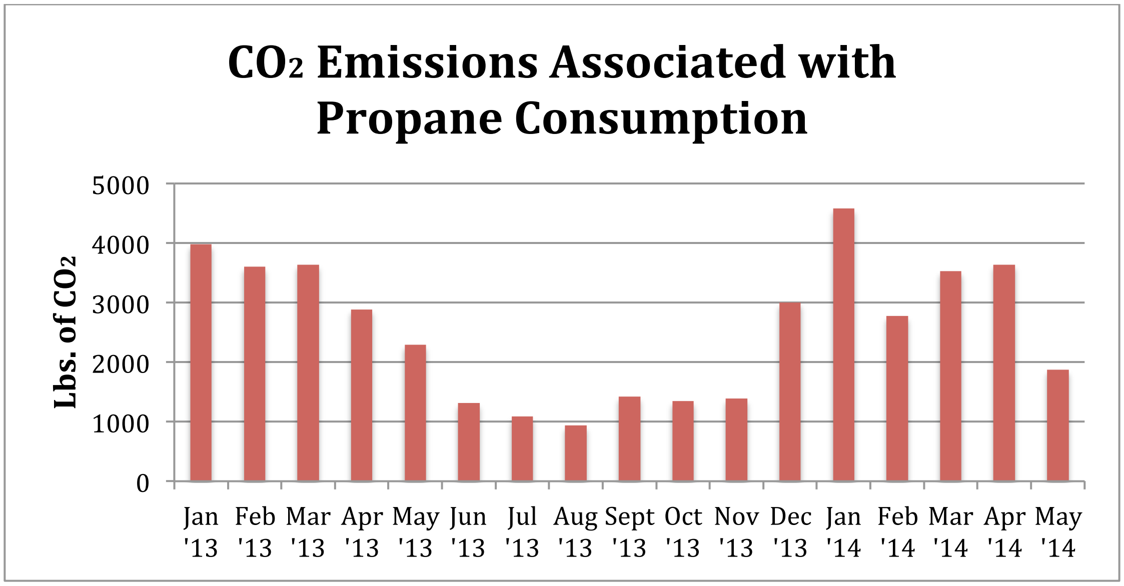


Figure 7.1 – CO_2 Emissions Associated with Propane Consumption.

CLI & VAC have switched propane suppliers several times in the past decade, which is the reason for the limited time frame. However, unlike electricity, carbon dioxide emissions associated with propane is much easier to calculate. There are 91,000 BTU for every gallon of propane, and 139 pounds of CO_2 emitted for every 1,000,000 BTU. Essentially, 12.6 pounds of carbon dioxide are emitted for every gallon of propane consumed. In 2013, CLI & VAC produced 26,897.22 pounds of carbon dioxide due to the consumption of propane.

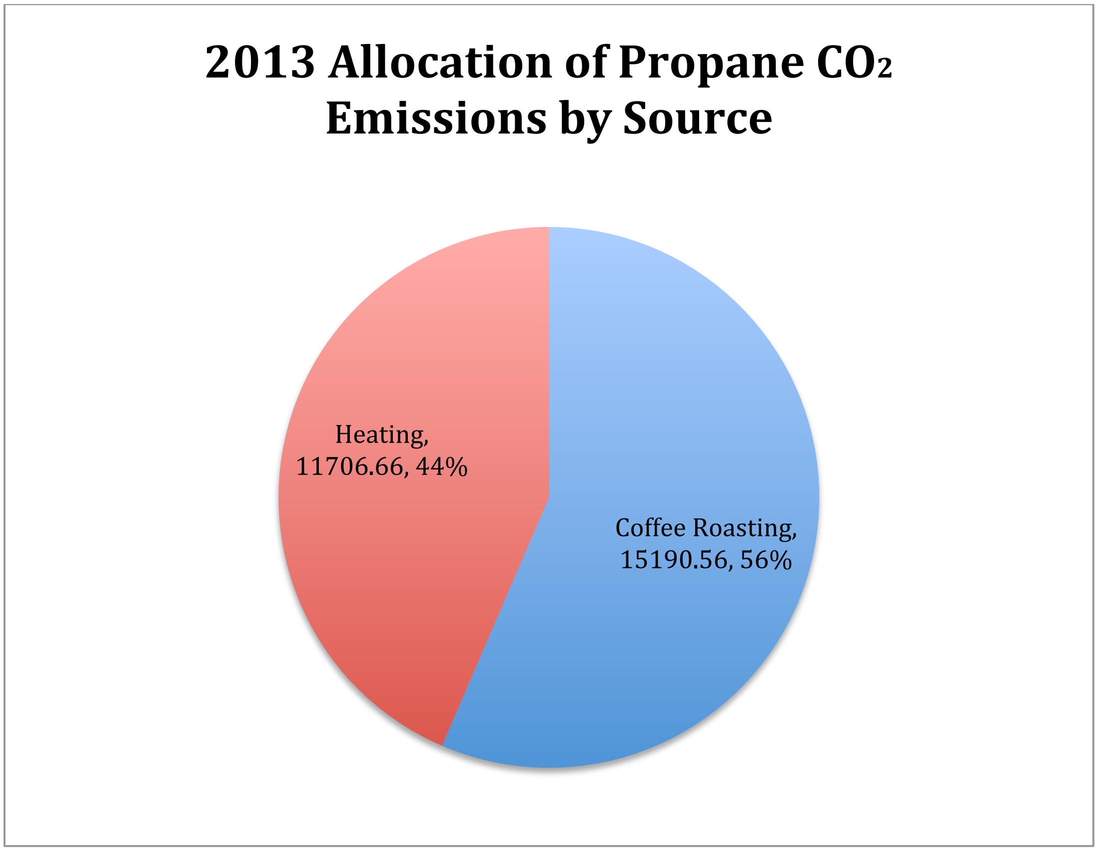


Figure 7.2 – 2013 Allocation of Propane CO_2 Emissions by Source. In 2013, CLI & VAC produced 11,706.66 lbs. of CO_2 as a result of heating their building space. In 2013, CLI & VAC produced 15,190.56 lbs. of CO_2 directly associated with burning propane for coffee roasting processes. While is coffee roasting processes account for more of the total CO_2 emissions, heating the building was only required for 7 months in 2013.

Figure 7.2 explains how carbon dioxide emissions from propane usage relate between the two major sources: heating and coffee roasting processes. It is important to note that carbon dioxide is directly emitted from the coffee bean during the roasting process. I have decided to disregard this carbon dioxide emission because it comes from a biogenic source. The carbon dioxide released from the coffee bean in the roasting process would be ultimately emitted into the atmosphere in its natural decomposition process.

While I have discussed total propane consumption associated with the roasting processes, it is also important to understand the amount of carbon dioxide emitted for every pound of roasted coffee produced. Since coffee production data was not readily available by month, I was unable to construct a graphical representation. However, I used the information accessible to me to calculate an estimated carbon dioxide emissions for a pound of roasted coffee. Using 2013 carbon dioxide emissions from the coffee roasting process (15190.56 lbs.) and 2014 coffee production (92864 lbs.), I found that approximately 0.16 pounds of carbon dioxide from propane is directly emitted into the atmosphere for every pound of roasted coffee produced.

Similarly, it is also important to note the amount of carbon dioxide emissions required to heat the building from propane consumption for every square foot of office space. Using 2013 carbon dioxide emissions from heating (11706.66 lbs.) and the square footage of the current building (5000 sq. ft.), I calculated that approximately 2.3 pounds of carbon dioxide are emitted for every square foot of building space in 2013 in order to sufficiently heat the building.

Total CO_2 Emissions Associated With Energy Consumption

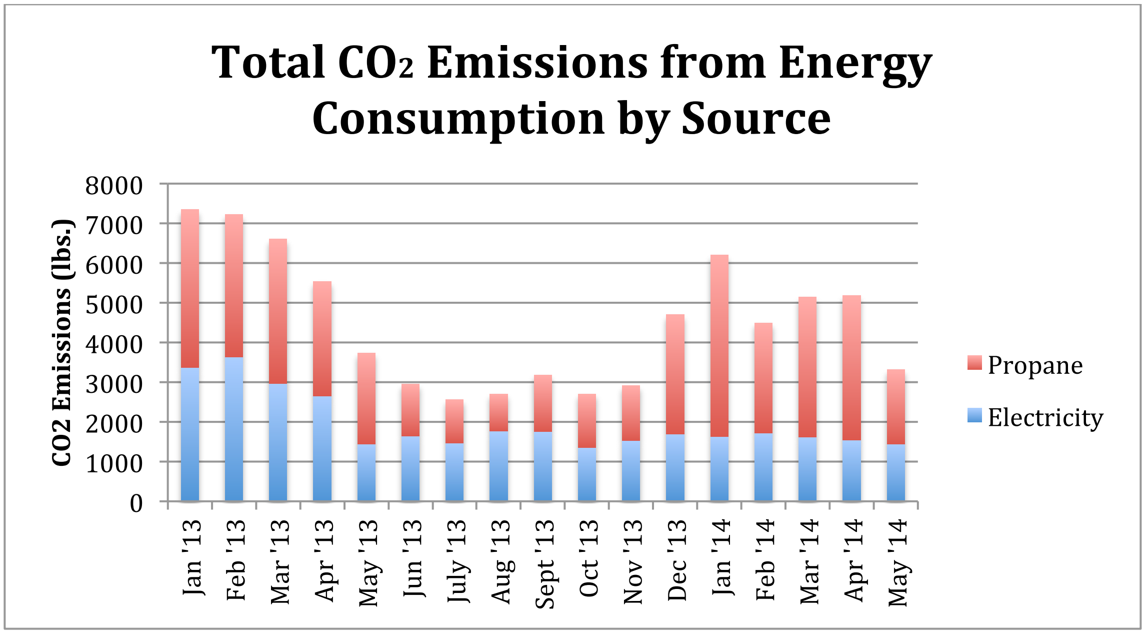


Figure 8 – Total CO_2 Emissions from Energy Consumption by Source. This graphic illustrates two important concepts. First, it provides total carbon dioxide emissions for CLI & VAC by month from January 2013 to May 2014. Second, it provides a graphical comparison for the amount of carbon dioxide emissions by month for the two major energy sources: propane and electricity. Total carbon dioxide emissions associated with energy consumption at CLI & VAC in 2013 was 52,162.38 pounds.

Packaging

At VAC, roasted coffee is packaged in three different bags depending on its purpose. Coffee intended for wholesale is packaged in 5-lb. brown paper bags lined with cellophane. These bags are 100% compostable if the metal sealing wire is removed and have a shelf life capacity of approximately 2-4 weeks. Coffee intended for retail is packaged in 12 oz. plastic bags with a one-way valve. These bags are non-recyclable and non-compostable. VAC uses these bags because of the one-way valve feature. When whole-bean, roasted coffee is packaged fresh, carbon dioxide is released and builds up inside the bag. This excess of carbon dioxide creates two problems: 1) excess carbon dioxide in the bags will cause the coffee beans to spoil and 2) the bags will fill with carbon dioxide until a seam of the bag breaks. The one-way valve is designed to release this excess carbon dioxide mitigating these two problems and allowing for a significantly longer shelf life. The third type of packaging is intended for Stowe Mountain Lodge. Single serving ground coffee is packaged in small, personalized plastic bags intended for the hotel's guests. Stowe Mountain Lodge provides these bags individually in their guest's hotel rooms as a courtesy. It is important to note that in the current building, most of the coffee packaging process is done manually.

Tea packaging is quite different than the coffee process. Most of the tea process is automated using high-tech, Japanese machinery. VAC tea packaging machine has a 2 KW power consumption and is supplemented by a commercial air compressor to increase reliability. Tea enters the input location and ends up individually packaged in 2-3 oz. tea sachets. Sixteen individual sachets are packaged together in a recyclable, aluminum container. VAC will occasionally package larger quantities for certain wholesale accounts, but the standard method of packaging is the aluminum container described previously. Besides placing the tea in the input area of the machine and sorting 16 sachets in each aluminum container, the tea packaging process is entirely automated.

Waste

Waste produced by CLI & VAC was very difficult to quantify because Casella Waste Management charges a flat, contractual rate for their waste disposal services independent of weight. Physical waste is generated by CLI & VAC from a variety of sources. CLI & VAC both recycle when applicable. In this section I will highlight several contributors to waste along with disposal practices currently implemented in CLI & VAC's daily functions.

The majority of physical waste generated by CLI arises from an excess of supplied product. Since CLI is a testing facility, companies contract CLI to evaluate their coffee products; however, their clients usually supply excess product to ensure accurate screenings and better results. One of CLI's more apparent waste generation sources is Dunkin Donuts, their largest client. CLI conducts daily evaluations of their roasted coffee and K-cups. CLI receives three boxes of K-cups (12 K-cups per box) for everyday the Dunkin Donuts facility is manufacturing. CLI analyzes six K-cups from one of the boxes and disposes of the other six K-cups. A second box is stored in an offsite facility for a year and then CLI analyzes six K-cups to evaluate shelf life quality. The other six K-cups are disposed of. The third box is extra in case there is a flaw with one of the other two boxes. In summary, CLI analyzes a total of 12 K-cups out of the 36 that were sent to them. In due time, all 36 K-cups are thrown away without producing any consumable coffee product. Assuming CLI received a shipment of K-cups from Dunkin Donuts every working day (251 days) in 2014, CLI threw away a total of 9,036 K-cups and 753 boxes. K-cups are have gained significant prominence in the coffee sector because of their convenience; however, a recyclable K-cup product does not exist in the market. Companies such as Kuerig Green Mountain are in the process of designing recyclable K-cups and have committed to manufacturing 100% recyclable K-cups by 2020. VAC has no intention to ever produce any K-cup products.

Another noted source of waste generation from CLI is spent coffee grounds. As discussed earlier, cupping is an important process for the sensorial evaluation of coffee; however, the process leads to a significant amount of unconsumed coffee and coffee grounds. CLI & VAC does not currently compost spent coffee grounds, food products, or unusable coffee beans.

From personal observations, it appeared that VAC generates a greater quantity of waste from a greater variety of sources; however, they also currently implement more waste diversion techniques compared to CLI. Waste is generated during the tea and coffee packaging processes described previously. Most of the waste from the packaging processes is unusable, non-recyclable paper products and recyclable cardboard. Furthermore, the packaging itself presents waste problems for the end consumer. Green coffee is transported to VAC using 60 kg jute bags and wood pallets; however, both are stored and donated to interested parties. Jute bags are an environmentally friendly product utilized by local farmers in their gardens. The wood pallets are collected by a handful of locals throughout the year. The coffee roasting process generates physical waste in the form of chaff, air pollution, and excess roasted coffee. Chaff, the husk of the coffee, is released during the roasting process and has a similar consistency to sawdust. A normal week of roasting will generate approximately a full trashcan of chaff. The chaff is removed from the roaster daily and stored in trashcans. The chaff is donated to local farmers, who utilize it as an acidic nutrient in their gardens. Air pollution is another byproduct of the coffee roasting process. As mentioned before, carbon dioxide is emitted as a result of burning propane; however, other air pollutants are also produced in the process. Roasting coffee generates air pollutants such as particulate matter (PM), smoke, odor, nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOCs), and organic acids. VAC does not currently utilize any techniques to reduce the amount of air pollutants emitted from the business.

Finally, CLI & VAC generate a significant amount of unsellable roasted coffee for a variety of reasons. Unsellable roasted coffee is defined as excess roasted coffee or roasted coffee that was not intended for sale. Roasted coffee not intended for sale is generated mostly by CLI in the cupping process and roasting classes. All excess roasted coffee is donated to Vermont Foodbank, a local food shelf. In 2014, CLI & VAC donated a combined 10,684 pounds of roasted coffee. This is 10,684 pounds of waste that was diverted from the landfill and utilized by disenfranchised, local community members.

Water Consumption

Data regarding water consumption was not readily available because CLI & VAC do not pay a water bill. Instead, the cost of water consumption is internalized by the landlord and reflected in their monthly rent. However, I did observe sources of water consumption during my visit, and overall the water consumption seemed relatively insignificant. Water is consumed by three different sources: restrooms, dishwashers, and the cupping process. There are two commercial dishwashers that are used approximately once a day to clean the ceramic mugs and spoons used in the cupping process. Water is used directly in cupping process to brew coffee. In total, I estimate that CLI & VAC uses 50-100 gallons of water daily.

Transportation

In this section I separated transportation into four categories: upstream shipping, downstream shipping, personal air travel, and employee commute. I intended to provide total carbon dioxide emissions for all four categories in 2014; however, I only obtained sufficient data for upstream shipping and employee commute. For downstream shipping and personal air travel, I calculated the carbon emissions for one single activity and related it back to carbon dioxide emissions from coffee production.

Transportation (Upstream Shipping)

Country	# of Bags	Weight of Bag (kg)	Total Weight (tons)	Truck Ton-miles	Truck CO2 Emissions (lbs)	Sea Freight Ton-miles	Sea Freight CO2 Emissions (lbs)
Brazil	60	60	3.97	2004	1309.41	20545	2169.56
Columbia	90	70	6.94	3750	2450.29	16229	1713.81
Costa Rica	2	70	0.15	67	43.86	373	39.38
El Salvador	30	70	2.31	856	559.63	7707	813.84
Ethiopia	151	60	9.99	5942	3882.65	75683	7992.17
Guatemala	8	60	0.53	272	178.05	1070	112.97
Honduras	55	60	3.64	2321	1516.41	7366	777.89
Kenya	15	60	0.99	814	532.19	9271	979.06
Nicaragua	90	70	6.94	3181	2078.21	21787	2300.73
Peru	38	60	2.51	1689	1103.54	10176	1074.57
Sumatra	142	60	9.39	5757	3761.69	105994	11192.99
Total	**681**		**47.38**	**26654.34**	**17,415.95**	**276202.39**	**29,166.97**

Figure 9 - 2014 CO_2 Emissions (Upstream Transportation).

Figure 9 is representative of carbon dioxide emissions associated with upstream transportation for VAC in 2014. As stated in the methods section, Ms. Adams provided necessary information (i.e. number of bags, weight of bags, and country of origin); coffee growing regions and seaports were chosen (while minimizing travel distance) arbitrarily.

The carbon intensity of truck transportation is 0.297 kg CO_2 per ton-mile, while the carbon intensity of sea freight is 0.048 kg CO_2 per ton-mile (EPA 1). In 2014, carbon dioxide emissions associated with the transportation of green coffee to VAC totaled 46,582.92 pounds. In comparison, recall that CLI & VAC produced 52,162.38 pounds of carbon dioxide from total energy consumption in 2013.

Transportation (Downstream Shipping)

Example	One-way Trip	Weight of Shipment		Carbon Intensity	CO2 Emissions	
CO2 Emissions from Shipping Package to Boulder, Colorado	Waterbury to Boulder (miles)	(lbs)	(tons)	(kg of CO2 per ton-mile)	(kg)	(lbs)
	1932	5	0.0025	0.297	1.43	3.16

Figure 10 - Downstream Shipping CO_2 Emissions Example

In this example I calculated the carbon dioxide emissions associated with shipping one package from Waterbury to Boulder, Colorado. I modeled this example off an order I purchased on March 4th, 2015. The contents of the cardboard package were three aluminum tins of tea, a 12 oz. bag of roasted coffee, and several empty packages for research purposes. The packaged weighed approximately 5 pounds and the estimated mileage of the package was 1932 miles. The carbon dioxide emissions associated with this shipment was 3.16 pounds. Recall from a previous section that approximately 0.16 pounds of carbon dioxide emissions are produced for every pound of roasting coffee; therefore, carbon dioxide emissions associated with this shipment to Boulder, Colorado is equivalent to producing 19.75 pounds of roasted coffee

Transportation (Personal Air Travel)

Example:	Round Trip Flight	Round Trip Flight	Carbon Intensity of Personal Air Travel	C02 Emissions	CO2 Emissions
CO2 Emission Calculation for one round-trip flight to Columbia for Mr. Alves	Burlington to Boston (miles)	Boston to Bogotá, Columbia (miles)	Round Trip Flight Distance >300 miles (kg CO2 per passenger mile)	(kg)	(lbs)
	351.74	5264.3	0.185	1038.97	2,285.73

Figure 11 - Personal Air Travel CO_2 Emissions Example

In this example I calculated the total carbon dioxide emissions associated with one passenger (Mr. Alves) for a single round-trip flight from Burlington International Airport to Dorado International Airport in Bogotá, Columbia. The carbon intensity for personal air travel for air travel is 0.185 kg CO_2 per passenger mile (EPA 1). One round-trip flight from Vermont to Colombia produces approximately 2,285.73 lbs. of carbon dioxide for a single passenger (assuming layover in Boston and all flights are at full capacity). For comparison reasons, the carbon dioxide emissions associated with this round-trip flight from Vermont to Columbia are equivalent to producing 14,285.81 pounds of roasted coffee or approximately 1/6 of VAC's total coffee production in 2014.

Transportation (Employee Commute)

15 miles	13 employees	1 gallon of gas	251 working days	19.64 lbs. of CO2	=	**48,063.99**	Lbs. of CO2 associated with all employees in commuting to/from work in 2014
1 day per employee		20 miles	1 year	1 gallon of gas			

Figure 12 - Annual CO_2 Emissions Associated with Commuting

Figure 12 is representative of the annual total carbon dioxide emissions associated with the commute of all CLI & VAC's employees. It is important to note that the average distance traveled by employee and average fuel economy are both assumptions made in order to calculate this estimate. According to this estimate, annual carbon dioxide emissions associated with employees commuting to and from work is 48,063 pounds. For comparison reasons, recall that carbon dioxide emissions associated with 2013 total energy consumption was 52,162.38 pounds. In other words, annual carbon dioxide emissions associated with commuting to and from work is equivalent to approximately 92% of carbon dioxide emissions associated with total energy consumption in 2013.

Summary (Carbon Dioxide Emissions by Scope)

CLI & VAC CO2 Emissions 2014								
SCOPES 1 & 2								
ENERGY USE IN BUILDINGS	Collected units	Quantity	CO2 factor (lbs/unit)	Total CO2 (lbs)	Total CO2 (tons)	Total CO2 (Metric tons)	Percent	
Propane	(gallons)	2,135	12.60	26,897	13	12	58.3	
Electricity	(kWh)	53,369	0.36	19,213	10	9	41.7	
Total CO2				**46,110**	**23**	**21**		*Reported*
Building sf				5,000	5,000	5,000		
Total CO2/sf				9.2220	0.0046	0.0042		
SCOPE 3								
UPSTREAM SHIPPING	Units	Quantity	CO2e factor (lbs/unit)	Total CO2e (lbs)	Total CO2e (tons)	Total CO2 (Metric tons)	Percent	
Trucking	(ton-miles)	26,654	0.6534	17,416	9	8	37.4	
Sea Freight	(ton-miles)	276,202	0.1056	29,167	15	13	62.6	
Total CO2				**46,583**	**23**	**21**		*Reported*
COMMUTING	Units	Quantity	CO2e factor (lbs/unit)	Total CO2e (lbs)	Total CO2e (tons)	Total CO2 (Metric tons)		
Car	miles	48,945	0.982	48,064	24	22		
Total CO2				**48,064**	**24**	**22**		*Reported*
Total Scope 3 CO2				**94,647**				

Figure 13 – CLI & VAC CO2 Emissions 2014

Figure 13 is a table representative of the four major annual carbon dioxide emission sources that I examined at CLI & VAC. The table is broken down by scope, a common reference in the carbon dioxide recording industry. Scope 1 emissions are defined as all direct carbon dioxide emissions associated with CLI & VAC. Scope 2 emissions are defined as indirect carbon dioxide emissions associated with CLI & VAC. The inherent difference between Scope 1 and Scope 2 emissions is the ownership of the entity in which the carbon dioxide is being emitted into the atmosphere. For example, the carbon dioxide emissions associated with the burning of propane in roasters is considered Scope 1, while the carbon dioxide emissions associated with the electricity generation station is considered Scope 2. Scope 3 emissions are other indirect carbon emissions not covered in Scope 2. Scope 3 emissions are generated independently from and not owned by CLI & VAC.

Discussion

Even though Mr. Alves has incorporated sustainable practices throughout his businesses for several years, I did my best to keep an analytical, unbiased mindset throughout the duration of this project. It was my intention to provide CLI & VAC with a quantifiable assessment of their energy and resource usage in order to improve their sustainability. Additionally, this assessment serves as a baseline for the businesses to compare business practices over time. A baseline regarding energy and resource usage has never been provided to Mr. Alves; therefore, it has been difficult to quantify the effectiveness of any initiative intended to reduce carbon emissions. It is my hope that this document will serve as a baseline to compare the effectiveness of future initiatives.

Limitations

One of the major limitations I faced while gathering information for this thesis was a lack of accessible information. I could not gather sufficient information for many categories that I wished to thoroughly examine. For example, I could not collect information regarding the quantity of annual waste generation or water consumption at CLI & VAC. As mentioned earlier, Casella Waste Management charges a contractual flat rate independent of weight for their services. Water bills are sent to the CLI & VAC's landlord and are representative of all businesses sharing the building. Even though I could not gather annual information for these categories, I felt it was still important to include what I could estimate related to these categories because they are necessary for a complete sustainability assessment. Future sustainability assessments for CLI & VAC will have a better chance to quantify this information because these businesses will reside in a new building owned and operated by Mr. Alves.

Furthermore, I had difficulties gathering information dating back more than five years. Several factors contributed to this lack of information. Electricity and propane suppliers have changed multiple times over the course of CLI & VAC's existence. The information provided by each energy supplier changed in their billing statements so there was an informational disconnect in years prior to the data provided in this thesis. Data related to shipping and transportation was another limitation to this thesis. While total carbon dioxide associated with upstream shipping and employee were estimated, I could not gather sufficient data for either downstream shipping or personal air travel. However, I calculated the carbon dioxide emissions of a single shipment/flight, which provides some insight on the environmental impact of the activity.

Lifecycle of Coffee

Roasting and testing coffee, the two primary services CLI & VAC provide, are small aspects of a coffee bean's total lifecycle. As mentioned earlier, carbon dioxide emissions directly associated with the roasting process equate to approximately 0.42 pounds for every pound of green coffee or 3.8% of the total carbon dioxide emissions associated with the coffee lifecycle process (Killian *et al*. 2013). Other levels such as farm processes, exportation, and final consumption have a much higher contribution to the carbon dioxide emissions associated with the coffee process. Since these levels have much higher carbon dioxide emission rates, it may be easier to provide solutions, which will have a greater reduction in the lifecycle carbon dioxide output associated with coffee. For example, the use of chemical fertilizers at coffee farms results in 2.1 pounds of carbon dioxide – approximately five times the amount produced during the entire roasting process. While CLI & VAC does not have direct control upon factors such as fertilizer application, CLI & VAC can make suggestions to their coffee producers as well as chose to not buy from farmers who do not integrate sustainable practices into their business models. Furthermore, it is important for CLI & VAC to continue to 'do their part'. The coffee industry has decided to take a 'do it yourself' standpoint regarding the reduction of greenhouse gasses, which compromises the long-term wellbeing of the industry. Sustainable initiatives practiced by CLI & VAC will have little to no impact on global greenhouse gas concentrations; however, in order to create substantial, systematic change, all businesses associated with the coffee industry must comply with this process.

LEED Certified Building

After sitting in on a meeting with Mr. Alves, Joe Greene (Architect), and Brian Riopelle (Designer), I inquired whether they were planning to pursue LEED certification for the new building. Mr. Greene and Mr. Riopelle explained that it had not yet been considered for this building; however, they had previous experience with LEED certification. They explained they were successful in all six of their previous buildings in which they sought LEED certification. Mr. Alves was interested in learning more about the certification process and how achievable it would be.

Mr. Greene and Mr. Riopelle concluded that the current design of the building would yield a minimum of 31 credits, and base level LEED certification requires 40 credits. According to Mr. Riopelle, these additional 9 credits (minimum) would require a significant investment to cover the upgrades to the mechanical systems, application fee, and consultant fees. Mr. Riopelle provided an estimate of the premium to achieve base level certification at $20,000-$30,000. Consequently, Mr. Alves has since decided to forgo pursuing LEED certification. Instead of seeking LEED certification, he expressed interest in using this money for sustainable capital investments (e.g. geothermal to supplement the building heating).

Mr. Alves has tried to incorporate sustainable, environmentally friendly practices throughout his businesses since its creation in 1995. While I believe LEED certification would have provided a certain level of sustainable credibility for Mr. Alves and his new building, I understand his reluctance to pursue the certification for the premium estimated by Mr. Riopelle.

Recommendations

In this section, I describe several recommendations to reduce carbon dioxide emissions associated with CLI & VAC's business practices. The construction of the new building allows for Mr. Alves to consider significant changes to the business practices and physical building characteristics of CLI & VAC, which could increase the sustainability of Mr. Alves' businesses. Since Mr. Alves has decided to not pursue LEED certification for his new building, I recommend explicitly using the $20,000-$30,000 estimated premium to investment in initiatives to directly increase the sustainability of CLI & VAC.

Usine

Mr. Alves plans to create a third business to compliment CLI & VAC, which will reside in the new building. The implementation Usine, a coffee shop selling VAC's roasted coffee, is sure to have several effects such as increasing energy and water consumption. I will use the 2013 Starbucks Responsibility Report to estimate the increase for both water and energy consumption. I expect the estimates provided to be biased upward because the average Starbucks store attracts more consumer attention than Usine will. Therefore, Usine will most likely consume less water and electricity per square foot per month compared to the Starbucks estimates.

In an earlier section, it was estimated that CLI & VAC currently consume 50-100 gallons of water daily. In the 2013 Starbucks Responsibility Report, it was estimated that Starbuck stores consume approximately 20 gallons of water per square foot per month (Starbucks 1). Using this statistic and information from the preliminary design plans (i.e. Usine Café will be 800 square feet), Usine will consume 192,000 gallons of water annually or 526 gallons of water daily. In 2014, CLI & VAC consumed 53,369 kWh of electricity, but the establishment of Usine will lead to an increase in electricity consumption. The average Starbucks store used 6.32 kWh of electricity per square foot per month. Assuming this benchmark and the 800 square footage of space, Usine will consume 5,056 kWh of electricity per month or 60,672 kWh annually. Finally, the establishment of Usine will generate a greater quantity of waste (e.g. coffee cups, spent coffee grounds, assorted complimentary coffee products, etc.). I do not have an estimate for the amount of waste that will be generated; however, I will provide best practices to reduce this waste and/or divert it from the landfill in the following section.

Even with the likely upward bias from the estimates in the previous paragraph, the establishment of Usine will indisputably increase both the water and electricity consumption along with waste generation. I will briefly describe several sustainable initiatives to reduce the impact of the establishment of Usine below:

1. Electricity Consumption
    a. Energy Efficient Appliances
        i. Assuming many appliances for Usine have not been purchased, I recommend only purchasing appliances that meet Energy Star qualifications. This will not only minimize Usine's electricity consumption, but also potentially save the business money in the long run. A net present value calculation can determine the payback period for an Energy Star appliance.
    b. I recommend Usine uses Starbucks' energy intensity (6.32 kWh per square foot per month) as a target for electricity consumption. Starbucks is a leader in the retail coffee market and publicly boasts their energy efficiency, so I believe this is a good initial target for Usine.
2. Water Consumption
    a. Water Saving Appliances/Methods
        i. Water saving appliances should be purchased for Usine in order to decrease the amount of water wasted during daily processes.

    ii. Cleaning methods provide a significant potential for water consumption savings. Certain features Starbucks have implemented to reduce water consumption are low-use water faucets and 'hand-metered water systems' to replace dipper wells.

  b. I recommend Usine uses Starbuck' water consumption intensity (20 gallons of water per square foot per month) as an initial target for water consumption.

3. Waste
   a. Compostable/Reusable Products (e.g. hot and cold beverage cups)
      i. Compostable is the better option; however, I have received inconsistent information regarding the existence of a composting facility capable of managing eco-based plastic waste
      ii. Usine should strive to be zero-waste
   b. Incentivize the use of reusable mugs
      i. Costumers who use reusable mugs should receive a small discount. A program to incentive the use of reusable mugs does several things:
         1. Decreases overall waste
         2. Increases customer loyalty
         3. Increases marketability
            a. Research (Nielsen 2014) indicates consumers are willing to pay a premium for products from a

businesses with a reputation of incorporating sustainable practices

ii. Provide all employees with VAC/CLI reusable mugs

Composting

I recommend the establishment of composting at the new building. With the addition of a coffee house, Mr. Alves' businesses will generate a substantial amount of compostable material, which can be turned into high-grade compost. Source of compostable material are chaff (by product of roasting process), spent coffee grounds (by product of cupping process, Usine, and personal coffee consumption), food scraps (by product of Usine and personal consumption) and unusable green coffee beans (by product of VAC). These four identified sources are not the only sources of compostable material; however, there are four sources, which will not only lead to high-grade compost but also a significant amount of diverted landfill waste. Composting is an inexpensive initiative, which can improve the sustainability of Mr. Alves' businesses. If Mr. Alves is not interested in composting at his facility, I recommend contracting a composting service such as Grow Compost, a local composting facility, to collect the businesses' compostable material.

Solar Power Installations

Mr. Alves discussed solar installations to the building at the beginning of this project. I have not discussed this idea with him since my business visit in January; however, it is my recommendation to not pursue a solar energy installation for several reasons. Firstly, the proposed building site is not located in a necessarily solar friendly location. Waterbury, Vermont only receives 159 days of sunshine annually is ranked in the lowest 10% for solar potential in the United States (Lopez *et al.* 2012). Additionally, the proposed building will not have a south facing rooftop; therefore, the solar installation would most likely be installed on the ground to maximize electrical generation. Secondly, CLI & VAC receive electricity from Green Mountain Power, a progressive utility focused upon providing renewable energy. Green Mountain Power estimates one MWh of electrical energy produces only 360 pounds of carbon dioxide, much lower than the national average. Therefore, the carbon dioxide emissions associated with electricity consumption is relatively low for CLI & VAC. I believe the large initial cost required to purchase a solar power system could be used more effectively.

Geothermal Heat Pump

It was my initial intention to calculate a net present value for a geothermal heat pump installation at the new building; however, I was unable make this calculation due to a lack of information from time constraints. Mr. Alves ordered two geothermal energy potential surveys for the building's location, but the results were not been provided before my defense draft was required, April 6th, 2015. Additionally, I did not receive cost estimates for the system. I cannot provide a recommendation without this information, but I will discuss the potential cost and carbon dioxide savings from a heat pump installation. Ideally, a geothermal heat pump could supply enough energy to the building to offset all propane used for heating purposes. If successful, Mr. Alves could offset approximately 1,000 gallons of propane or 11,000 pounds of carbon dioxide annually. Assuming a $2.50 price for a gallon of propane, Mr. will save approximately $2,500 annually in fuel costs.

Biomass Coffee Roaster

Mr. Alves purchased a biomass powered coffee roaster in 2014. This machine provides an opportunity to reduce the propane consumption directly related to the coffee roasting process. Recall that for every pound of roasted coffee, 0.16 pounds of carbon dioxide from propane consumption is produced. Assuming that quality of the final product is not compromised using this machine, I recommend using it when possible since biomass pellets are not only renewable but also cost competitive with propane. For every six pounds of roasted coffee produced on this machine, one pound of carbon dioxide will be offset. While this may not have a very large impact on total carbon dioxide emissions, I believe this machine offers several other purposes, which make it worthwhile. First of all, roasting coffee in a renewable fashion is innovative and will increase the marketability of VAC's final products. As mentioned earlier, consumers are willing to pay a higher premium for products from businesses that incorporate sustainability into their daily business practices. Roasting coffee on renewable resources is uncommon and provides a uniqueness to VAC's final product, which can differentiate their product from the competition.

Transportation

I focused on four different categories related to transportation associated with CLI & VAC's business practices: upstream shipping, downstream shipping, personal air travel, and commuting. I provided annual carbon dioxide emission information for two of these four categories (i.e. upstream shipping and commuting). For the other two categories (downstream shipping and personal air travel), I did not collect sufficient information to make such calculations. Consequently, I provided carbon dioxide emission information for one particular activity for each transportation category. Sufficient information to estimate annual carbon dioxide emissions for each category exists; however, I was unable to obtain this information for this project. I recommend CLI & VAC collect this information for future research to calculate an annual estimate regarding total carbon dioxide emissions for personal air travel and downstream shipping. Furthermore, I believe there is room for improvement in regards to reducing the carbon dioxide emission associated with CLI & VAC. In the following paragraphs I will provide solutions to reduce carbon dioxide emissions for personal air travel and commuting.

Assuming personal air travel is essential for the success of CLI & VAC, the next best option to reduce carbon dioxide emissions is to condense the trips (i.e. visit several countries and farms to reduce the amount of trips from coffee growing regions to Vermont). While it is my understanding that Mr. Alves appreciates both the financial and environmental benefits from condensing multiple trips into one, I would like to provide an estimated savings in terms of carbon dioxide emissions for this practice. In the results section, I calculated the carbon dioxide emissions associated with one round-trip flight from Vermont to Columbia for a single passenger (2,285.73 lbs. of carbon dioxide). Using the same methodology, three different round-trip flights from Vermont to Bogotá, Columbia, Guatemala City, Guatemala, and Tegucigalpa, Honduras (with layovers in Boston) results in 6,157.3 pounds of carbon dioxide for a single passenger. Instead if a single passenger traveled from Vermont, to Guatemala, to Honduras, to Columbia, and then back to Vermont, it would result in a total of 2,669.1 pounds of carbon dioxide – a savings in terms of carbon dioxide emissions of 3,488.2 pounds or a reduction of 56.7%.

This example illustrates that there is a significant potential to reduce carbon dioxide emissions by condensing multiple trips to coffee growing regions into one trip with multiple stops. Therefore, I recommended minimizing the total number of flights from Vermont to coffee growing regions by maximizing the number of coffee growing regions visited on a single trip.

The best way to reduce carbon dioxide emissions for commuting is by minimizing the number of cars driving to the businesses; however, since the new building that will house CLI & VAC is located in rural Vermont, there are not many carpooling nor public transportation options. The proposed building site resides in a slightly more bike-friendly area. Therefore, I recommend any employee who lives close enough to ride a bike to work. If one less vehicle drives to CLI & VAC on a daily basis (with the same assumptions holding true as in the results section) a total of 3,697 pounds of carbon dioxide will be offset annually.

New Building Construction

Even though I did not conduct an analysis regarding the embedded carbon dioxide emissions associated the construction of the new building, I believe it is important to discuss. The construction process and the products used during this process have a high carbon intensity so it is important for Mr. Alves to consider both the process and the products. The embedded cost of carbon dioxide in new construction is highly variable and not very well researched. However, Charles Kibert, Ph.D, Director of Powell Center for Construction & Environment at the Rinker School of Building Construction at University of Florida, indicated that estimated embedded carbon dioxide emissions for new constructions is between 200 to 700 kg CO_2e per square meter or 40.89 to 143.12 lbs. CO_2e per square foot (Keppie 2013). Assuming the 15,000 square foot projection for the new building, the embedded carbon dioxide emissions associated with the new construction will be between 613,350 to 2,146,800 lbs. of CO_2e. Recall that 2013 total carbon dioxide emissions from energy consumption was 52,162.38. Assuming this figure is representative for annual energy consumption, CLI & VAC could operate for 11.76 to 41.16 years before carbon dioxide emissions from energy consumption equates the carbon dioxide emissions associated with the construction of the new building.

Therefore, it is important to seriously consider the construction practices, which will be used for the new building. I do not have specific recommendations regarding the actual construction process; however, I do have recommendations for the preparations stages leading up to the construction. First, I recommend hiring a contractor with a substantial history of sustainable development. This contractor should be familiar with the most cost-effective, environmentally friendly processes for construction. It is important to consider the materials used for the new building, as certain materials have a much higher embedded carbon content than others. Additionally, it is important to consider the waste generated throughout the construction process. By minimizing waste, one is not only minimizing financial costs but also minimizing the embedded carbon dioxide associated with each material. Finally, I recommend the use of a commissioning authority to ensure the final product (new building) is as intended. I believe this should be financed either by the architect company or contracting company to guarantee the product provided functions as it was proposed.

Final Remarks

This thesis quantified (where data was sufficient) the current level of annual energy and resource usage and associated carbon dioxide emissions for CLI & VAC . The information in this thesis is intended to serve as a reference baseline for Mr. Alves to quantify improvements in sustainability for his businesses. I have hypothesized changes in energy and/or resource consumption assuming the adoption of certain proposed plans; however, it will be important to reevaluate the businesses' energy and resource consumption once the building has been fully functional for 12 to 18 months. This can be done in-house following the outline illustrated in the methods section of this paper. To make this process easier and more efficient, I recommend recording monthly energy and resource usages. A wealth of literature (Heller and Wizander 2011; Kolstad 2014; Nielsen 2014) indicates there is a link between sustainability and successful business practices. Energy and resource consumption information can be documented just like any financial information in organizational software such as Excel or QuickBooks.

Furthermore, I recommend performing this reevaluation bi-annually to continue to strive towards improving the sustainability of the businesses. Self-imposed reduction goals or a sustainability plan should be set following the biannual reevaluation in order to incentivize more sustainable business practices. Additionally, owning (in contrast to renting) building space will allow for better data, which should be added to the biannual sustainability report (e.g. monthly water consumption data).

Ultimately, a goal of sustainability is to reduce total carbon dioxide emissions and resource consumption; however, occasionally 'sustainable' business decisions result in increased energy and resource consumption. When discussing sustainability topics such as reducing carbon dioxide emissions, the most important characteristic is the total amount (weight) of carbon dioxide emitted into the atmosphere. That being said, a useful tool to compare productivity related to carbon dioxide emissions is the business' carbon intensity. This idea originates from a global level, where a country's carbon dioxide emissions (metric tons) are divided by a country's GDP (thousands of dollars). This illustrates how monetarily productive the country is in relation to their carbon dioxide emissions. As long as it is understood that total carbon dioxide emissions are the primary concern regarding sustainability, this tactic can be utilized to compare the businesses' productivity over time related to their carbon output.

Appendix A

Type of Electronic	Business	Quantity	Power Consumption (W)
Forklift	VAC	2	
Tea Machine	VAC	1	2000
Commercial Dishwasher	CLI & VAC	2	
Water Filtration System	CLI	2	
Full Size Freezer	CLI & VAC	1	600
Electric Water Heater	CLI	7	1500
Coffee Grinder	CLI	2	
Vacuum Oven (testing machine)	CLI	2	
Convection Oven (testing machine)	CLI	1	
Espresso Machine			
Hand Dryer	CLI & VAC	2	1500
Kuerig Machines	CLI	2	1500 (max); 200-400 (continuous)
Rapid Moisture Test	CLI	1	
Head Space Analyzer	CLI	1	
Fish Tank Tester	CLI	1	
Color Reader (testing machine)	CLI	2	
Refrigerator	CLI & VAC	1	600
Computers	CLI & VAC	10	300
Landline Phone	CLI & VAC	8	
Printers	CLI & VAC	5	
Paper Shredder	CLI & VAC	1	360
Coffee Maker	CLI & VAC	5	~600-1200
Coffee Mill (Bunn)	CLI & VAC	1	
Roasters	VAC	9	All roasters are drastically different, but all use a little electricity for automated functions

Appendix B

Country	Coffee Growing Region	Seaport of Origin	Growing Region to Seaport (miles)	Seaport to Seaport (miles)
Brazil	São João do Manhuaçu	Vitoria	170	5177
Columbia	Medellin	Turbo	205	2337
Costa Rica	San Jose	Puerto Limon	100	2417
El Salvador	Ahuachapan	Acajutla	35	3329
Ethiopia	Harar	Berbera, Somalia	260	7578
Guatemala	Coban	Puerto Barrios	180	2022
Honduras	Olancho	Puerto Cortes	303	2025
Kenya	Mt. Kenya	Malindi	486	9345
Nicaragua	Matagalpa	Puerto Sandino	123	3137
Peru	Chanchamayo Province	General San Martin	337	4049
Sumatra	Aceh	Medan	278	11286

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