Comparing Carbon Footprints of Two Retail Business Models: Traditional Retail vs. Subscription Ecommerce

Client: [Redacted]

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Abstract

Growth in online purchases for apparel is changing the way that customers engage with retail companies, reducing the number of trips they take to the physical store, and increasing the number of packages delivered through curriers. Among the many implications of these changes, these new business models dramatically impact that carbon footprint of the retail industry, including the carbon footprint of transportation, utility use, and the integration of technology into a shopping experience. We examine the carbon footprint of our client, a subscription retailer that ships curated boxes of apparel to customers across the United States and outlying territories. This analysis incorporates methodology from the Carbon Disclosure Project (CDP), which focuses on carbon emissions in three scopes of a business or organization. We also look at the implications of apparel retail as it moves online over the coming years and explores answers to questions like "how will the carbon footprint of the retail industry shift in the future?" and, "what are the best ways for us to measure carbon footprints of ecommerce retailers?" We present recommendations for how the client can reduce its carbon footprint, starting with the changes that will make the greatest contribution to this reduction. Finally, we suggest ways that carbon footprinting models may be best adapted given rapid and increasing changes to modern retail business models so that footprinting across brick-and-mortar and ecommerce businesses becomes more consistent and comparable in the future.

Introduction

Few industries have been as drastically impacted by the internet as the retail industry. The last two decades have popularized digital commerce and changed how retailers sell products and consumers purchase goods. Seventy-nine percent of Americans now shop online, up from twenty-two percent in 2000.[1] While major retailers serve their customers through both brick-and-mortar and digital channels, observable growth in the retail industry is almost entirely attributable to ecommerce. Ecommerce sales made up 8% of all retail sales in the United States in 2017, and that number is expected to grow 15% every year until 2021.[2] Indeed, the proliferation of online shopping has enabled new ecommerce retailers to serve millions of customers every year without owning and operating a single physical store.

The steady decline of brick-and-mortar retail and fast-paced growth of ecommerce has changed the way that retailers do business with their customers, suppliers, third party logistics providers. For example, as online purchases increase, retailers will need to ship direct-to-consumer more often, increasing the use and reliance of third-party logistics companies like UPS, FedEx, and USPS. Shifts in the way products move through the supply chain and to end-consumer also impact the overall environmental footprint of a retail business. While the environmental impacts of brick-and-mortar retail have been well-documented and understood, the environmental impact of pure ecommerce businesses is both less researched and reported on across retail segments.

For decades, leading retailers that are invested in environmental sustainability have disclosed their carbon footprint through standardized reporting mechanisms or agencies. Their reported carbon footprint is typically comprised of the carbon emissions associated with their brick-and-mortar operations, though some retailers also selectively report the carbon emissions from upstream actors and actions including distribution centers, transportation, and product manufacturing. Most retailers working to reduce their carbon footprint have focused on improving efficiencies at their brick-and-mortar retail locations and distribution centers. There is limited literature that examines how ecommerce businesses can reduce their impact, and virtually no research published about the environmental impact of specific retail business models within ecommerce.

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[1] Smith, Aaron and Monica Anderson. "Online Shopping and E-commerce." Pew Research Center Internet and Technology. 19 Dec 2016. http://www.pewinternet.org/2016/12/19/online-shopping-and-e-commerce/
[2] "10 ECommerce Trends for 2018." Absolunet. Jan 2018. http://10ecommercetrends.com/

One newer type of ecommerce business is the subscription model. Subscription services provide, "retail as a service," to customers who receive conventional products by delivery for a monthly or quarterly fee.[3] There are two primary subscription models. The first is a curated subscription service which introduces shoppers to new products by sending new-to-market products on a monthly or quarterly cadence. Either customers or the company choose the products delivered to the customer. According to a McKinsey study[4], curated subscription retail makes up 55% of all subscription retail in the United States. Replenishment is a second type of subscription ecommerce model. A replenishment subscription allows customers to sign up for regular delivery of routinely-used products. Amazon's "Subscribe and Save" is one example. Replenishment subscriptions make up 32% of all subscription retail in the United States.

Our analysis focuses on curation subscription services for two primary reasons. First, curation subscription represents the largest type of subscription services in the US and as such, the findings and recommendations from this study can be applied to a larger subset of retailers in the current market. Secondly, curation subscription services have nuanced elements in the business model that distinguish it from both traditional retail and replenishment subscription services. Most curated subscription services in the market do not give consumers control or insight over what products they will receive. This is especially true for food, beauty, and apparel categories. We hypothesize that this business model with a customer "surprise element" typically has higher return rates compared to conventional ecommerce or other curated subscription models where customers pick out the items in their delivery.

The Weber et al and Weise et al studies both concluded that ecommerce retail produces fewer CO_2 emissions than traditional brick-and-mortar retailing in several conditions.[5,6] Neither

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[3] Weinswig, Deborah. "Disruptors Face Disruption in Subscription Retail." Forbes. 30 June, 2018. https://www.forbes.com/sites/deborahweinswig/2018/06/30/disruptors-face-disruption-in-subscription-retail/#588999911ee4

[4] Chen, Tony. Fenyo, Ken, Yang, Silvia, Zhang, Jessica. *Thinking inside the subscription box: New research on e-commerce consumers.* February 2018. https://www.mckinsey.com/industries/high-tech/our-insights/thinking-inside-the-subscription-box-new-research-on-ecommerce-consumers

[5] Weber, Christopher, Chris Hendrickson, Paulina Jaramillo, Scott Matthews, Amy Nagengast, and Rachael Nealer. "Life cycle comparison of traditional retail and e-commerce logistics for electronic products: A case study of buy.com." Carnegie Mellon Green Design Institute. 8 Dec 2008. https://www.researchgate.net/publication/224559288_Life_cycle_comparison_of_traditional_retail_and_e-commerce_logistics_for_electronic_products_A_case_study_of_buycom

study specified the type of ecommerce model. We believe that a study into specific ecommerce models, such as curation subscription services, will further underline the smaller carbon footprint of ecommerce compared to traditional retail. Our analysis examines the carbon footprint of traditional brick-and-mortar retailers compared to a curation subscription ecommerce company.

Using data provided from an undisclosed subscription-based ecommerce business (hereafter, "client") and data from published studies, we aim to identify the nodes in each business model that contribute most significantly to carbon emissions. To do this, we analyzed two systems. The first is the brick-and-mortar system which includes headquarter, retail store, and warehouse operations. The second system, ecommerce, includes all business actions from inbound transportation to customer delivery and headquarter operations.

We do not analyze the full lifecycle of these two systems in this study. Figure 1 on the next page outlines the full lifecycle of a garment, from fiber cultivation to disposal. We assume, that for both systems, fiber cultivation, spinning and weaving, dyeing, cut and sew, importing, the customer use phase, and garment disposal are very similar in the brick and mortar and ecommerce business models. The main differences lie in the nuances of each systems, outlined in red in Figure 1. This study focuses these subsections of each system and analyzes the carbon footprint associated with these two parts of each system.

It's important to note that while this study focuses on quantifying the differences between these two business models and systems, the scope of our project does not focus on the most carbon-intensive parts of the garment lifecycle. Decades of studies and research have shown that the most carbon-intensive and resource-depleting factors in garment production are at the very beginning and end of the lifecycle. Fiber cultivation, spinning and weaving, and dyeing typically make up between 15-30% of a garment's total lifetime CO_2e. The customer use phase can make up between 60-80% of the garment's total lifetime CO_2e.[7]. However, little research has been made to compare the carbon footprint of subscription ecommerce business models to traditional brick and mortar business models, so it is necessary to focus exclusively on these differences.

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[6] Wiesea, Anne, Waldemar Toporowskia, and Stephan Zielkeb. "Transport-related CO_2 effects of online and brick-and-mortar shopping: A comparison and sensitivity analysis of clothing retailing." Transportation Research. Aug 2012. https://www.sciencedirect.com/science/article/pii/S1361920912000521

[7] "A Product Lifecycle Approach to Sustainability." Levi Strauss & Co. March 2009. http://www.levistrauss.com/wp-content/uploads/2014/01/A-Product-Lifecyle-Approach-to-Sustainability.pdf

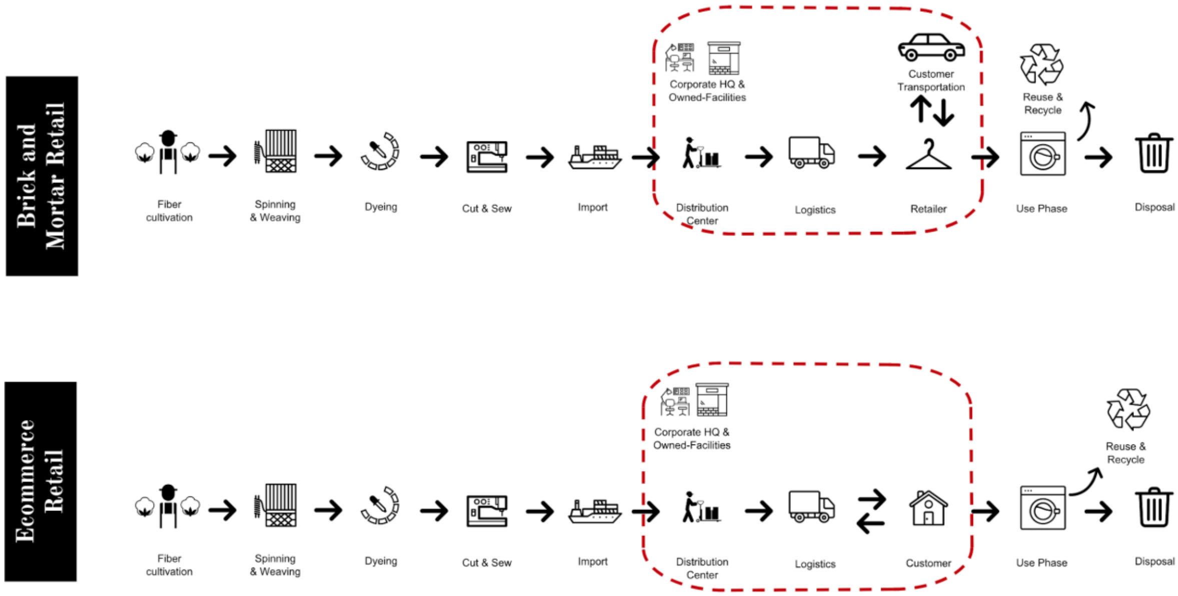

Figure 1. Full Lifecycle of Garment with Call-Out on Scope of Study's Analysis.
Note: The scope of this analysis focuses on the parts of each system outlined inside each red box.

Types of Retail Business Models: Brick-and-Mortar and Ecommerce

Traditionally, brick-and-mortar retailers have served their customers from a constructed, physical location. Customers go to the location to make their purchases and return home with goods in hand. These businesses offer consumers both a way to purchase goods, but also a means of entertainment. While many once brick-and-mortar businesses have added ecommerce options in the modern era, brick-and-mortar retailers still dominate downtown and central business districts of major cities.

Ecommerce businesses operate on the internet. They do not have physical locations at which customers can speak to service representatives or handle and test out products. They do usually have physical office space where employees keep the website up and running, however most of the customer interaction takes place through the internet. These businesses benefit from well-designed websites, easy and secure payment-taking mechanisms, and inexpensive, fast delivery to the customer. Barriers to entry are comparatively low, especially with strong word-of-mouth marketing and promotion.

Most retailers in 2018 operate in a hybrid model between brick-and-mortar and ecommerce, in which the company will have some physical locations for customers to interact with employees and test out products, as well as an online shopping platform for customers to order products 24/7. Traditional retailers like Nordstrom falls into this category as they have moved nearly 20% of their sales online.[8] Nontraditional retailers like Casper or Everlane are also following this model, opening stores for customers to test out products in dense cities, but still delivering products to customer homes, shipped from a centralized warehouse.

The primary elements that differentiate the carbon footprint impacts of brick-and-mortar and ecommerce businesses in this paper focus on the ways that the two types of businesses differ in delivering goods to customers. For the most part, the supply chains that lead into the businesses are the same-- procurement of raw materials, weaving, dying, sewing and manufacture of goods often takes place at a supplier, often overseas. The supplier then ships the goods to a warehouse, where the retailer sorts and categorizes the goods.

At this point, the supply chains begin to differ. In a brick-and-mortar model, the warehouse distributes products to each of the retail locations, where employees then display the products for customers to test and purchase. Customers bring the products from the retail location to their homes for "use." In contrast, an online retailer will distribute from the warehouse directly to the consumer, often through a third-party logistics provider like FedEx or UPS. This "last mile" of distribution either from retail store to consumer or from warehouse to consumer, is a topic of great conversation and debate in carbon footprint accounting literature. Should the carbon associated with last mile transportation be part of each retailers' carbon footprint? If carbon should only be included in the footprint if the element is core to the business model, is last mile transportation core to either business model? We highlight some of these debates and lend our own methodology to the conversation below.

Background of Organizational Carbon Footprinting

Though the term "carbon footprint" is commonly referenced in public domain areas like the media, politics, and industry, academic literature provides several conflicting definitions of

[8] "Internet Retailer: Nordstrom's Online Sales Grow." Digital Commerce 360. https://www.digitalcommerce360.com/2018/05/18/nordstroms-online-sales-grow-18-in-q1/

the term, many of which are industry-specific.[9,10] Carbon footprinting is a relatively new field, first described in an academic paper in 2008. The most recognized concept of carbon footprinting was proposed by Wiedmann et al. and defines it as a, “measure of the total amount of greenhouse gasses that are directly or indirectly caused by an activity, usually expressed in equivalent tons of carbon dioxide (CO_2).” [11]

Organizations perform carbon footprinting many ways, but most commonly they calculate the greenhouse gas (GHG) emissions associated with an enterprise, product, or project. The *GHG Protocol Corporate Standard* breaks down an enterprise’s GHG emissions into three scopes. Scope one emissions are those that come from on-site fuel combustion and company-owned vehicle emissions. Scope two emissions are those associated with all purchased utilities for all company-owned sites (warehouses, factories, retail locations, and offices). Scope three emissions are those that do not fit into scopes one and two and can include everything from inbound and outbound transportation, to waste disposal, to business travel, to outsourced manufacturing processes and much more (see figure 2). A carbon footprint is typically calculated by multiplying activity data by a standard emissions factor, like a grid emissions factor which refers to CO_2 emissions (tCO_2/MWh) associated with each unit of electricity provided by an electricity system.

[9] Sundha, Parul and Uma Melkania. “Carbon footprinting: a tool for environmental management.” International Journal of Agriculture, Environment and Biotechnology. Apr 2016. http://ndpublisher.in/admin/issues/ijaebv9n2n.pdf

[10] A. Barnett, R. W. Barraclough, V. Becerra, and S. Nasuto. “A history of product carbon footprinting.” Technologies for Sustainable Built Environments. 2013. https://www.reading.ac.uk/web/files/tsbe/Barnett_TSBE_Conference_Paper_2013.pdf

[11] Tao Gao, Qing Liu, and Jianping Wang. “A comparative study of carbon footprint and assessment standards.” International Journal of Low-Carbon Technologies. 25 June 2013. https://academic.oup.com/ijlct/article/9/3/237/812115

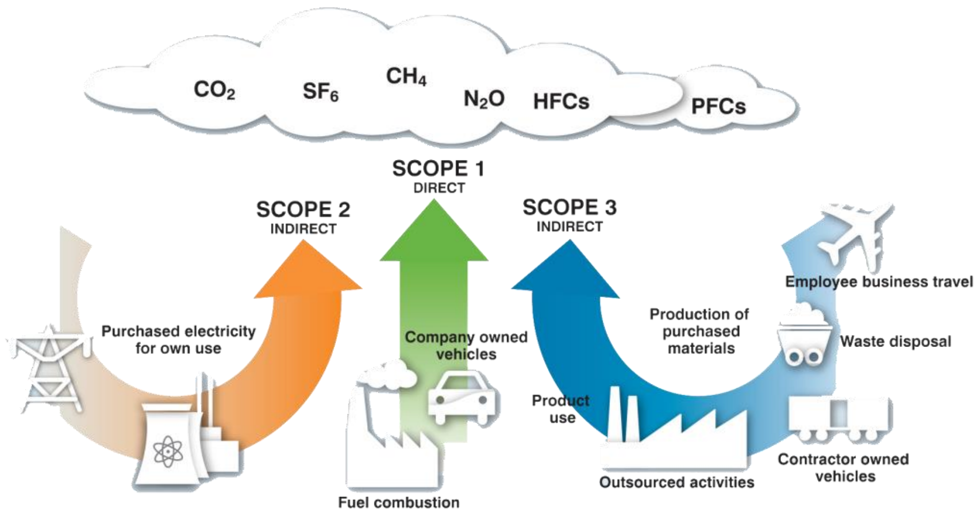

Figure 2. Greenhouse gas emissions organized by scope. These distinctions are important in distinguishing the various steps of CDP methodology. https://www.epa.gov/greeningepa/greenhouse-gases-epa

When a company calculates its carbon footprint, they should take the following considerations into account:

1. *Define the organizational boundaries*: identify which parts of the business the company will evaluate
2. *Establish operational boundaries*: these boundaries dictate which sources of carbon the company will quantify. The most prominent carbon reporting mechanisms in the industry -- The GHG Protocol and the CDP -- agree that at a minimum scope 1 and 2 should be included in organizational carbon footprinting efforts. Scope 3 is optional for many reporting schemes.
3. *Communicate gaps and assumptions in data* that have been made in calculating the footprint.

Methodology

To analyze compare the carbon footprint between traditional brick and mortar retail and subscription retail, we compare the client's carbon footprint to six brick and mortar retailers. The client's carbon footprint included the company's utilities, waste, inbound transportation, outbound transportation, customer returns, and off-site computer use. We used information disclosed in CDP reports to calculate the brick and mortar footprint on a comparable basis (e.g., CO2e per square-foot, CO2e per $10,000). Figure 3 below highlights the category or research question analyzed for each carbon footprint, as well as the data source or model used to compute the carbon footprint.

	Category or research question	Data Source or model
Client Carbon Footprint	Utilities	eGRID (EPA)
	Waste	Waste Reduction Model (WARM, EPA)
	Inbound Transportation	FedEx Customer Emissions and GREET
	Outbound Transportation	GREET
	Returns Transportation	GREET
	Off-site Computer Usage	client
Brick & Mortar-Ecommerce Comparison	How do brick-and-mortar retailers compare to one another in their carbon footprints?	CDP
	How do we compare brick-and-mortar retailers of different sizes?	
	How do carbon footprints of brick-and-mortar and ecommerce retailers compare?	

Figure 3. Carbon Footprint Input Categories with associated data sources and models used for calculation

Ecommerce Company Methods

To analyze an ecommerce retail company, we collected primary data from our client and used annual and monthly figures to approximate an annual carbon footprint. The annual footprint associated with energy and gas consumption we calculated from energy bills (June 1, 2017 through May 31, 2018) from all company-owned locations including headquarter offices and distribution centers[12]. We used state-specific grid emissions factors found in the EPA's egrid tool to calculate region specific emissions.

We received data on all inbound transactions, allowing us to calculate inbound transportation from June 1, 2017 through May 30, 2018. All inbound and outbound transportation emissions we calculated using GREET. We assumed that inbound deliveries to the distribution centers were made on HD truck combination long haul, low sulfur diesel, and we used the well-to-tank low sulfur diesel emissions model available on GREET. We received June

[12] We did not receive data about the Indiana warehouse as it is owned and operated by a third-party logistics provider. We used the Pennsylvania warehouse quantity, scaled by the size of the Indiana warehouse and applied the relevant grid emissions factor to estimate Indiana warehouse utility footprint.

1, 2017 to May 30, 2018 data from our client on outbound transportation used the same well-to-tank model as for inbound transportation, but we assumed that that packages were delivered to customers via short haul low sulfur diesel trucks. Because customers return 80% of packages to our client, we also include the carbon emissions associated with the packages' return travel in the analysis. We assume that the footprint associate with returns is identical to outbound transportation, but one-pound lighter per box and scaled to 80%.

We accounted for the carbon emissions of the energy associated with the client's offsite stylists and engineers by assuming that they work from an average laptop, which uses 12 watts of energy per hour[13]. There are 4,500 stylists across the US and they work, on average, 20 hours per week. The 115 engineers work 40-hour work weeks. We used Dell's estimates for carbon emissions associated with laptop usage and scale by part time or full-time employment and associated computer use[14].

Lastly, we used the EPA's Waste Reduction Model (WARM) model to approximate the carbon use and savings associated with waste. The EPA created WARM to help companies track and voluntarily report greenhouse gas (GHG) emissions reductions from several different waste management practices. The model attributes the carbon emissions associated with non-recyclable waste to the company's overall footprint. Recycled and reused materials, however, have a net neutral impact on a company's carbon footprint. Thus, in this case, carbon emissions associated with waste come from the client's use of polymailer bags for clothing returns. Because the client recycles corrugated cardboard and resells hangers, these waste streams do not contribute to their overall footprint. However, our model does consider national recycling rates for cardboard, which were 35% recover in 2017 according to the US EPA.[15] Thus, we assume that 65% of all shipped cardboard is not recycled. We categorized cardboard in WARM as cardboard containers, and hangers as PET material. We assumed that waste was over 95% flexible plastic -- mostly comprised of plastic packaging from vendor deliveries and polymailers from customer returns. We classified polymailers as low-density polyethylene in WARM.

[13] O'Connell, Scott and Markus Stutz. "Product carbon footprint (PCF) assessment of Dell laptop - Results and recommendations." Sustainable Systems and Technology. June 2010.
[14] "Dell Latitude 3380." Dell Computer. Aug 2018. https://i.dell.com/sites/csdocuments/CorpComm_Docs/en/carbon-footprint-latitude-3380.pdf?newtab=true
[15] "National Overview: Facts and Figures on Materials, Wastes and Recycling." United States Environmental Protection Agency. Oct 2018. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials

Ultimately, we compared the results of the brick-and-mortar retail analysis to the results of the ecommerce business analysis by looking at absolute emissions as well as emissions scaled to different metrics. We compared all the retailers-- physical and ecommerce-- by their total square footage, annual revenues, and annual costs of goods sold, to draw inferences about their emissions efficiencies. For this analysis, we focused on only scope two emissions, for the reasons described previously.

Brick & Mortar to Ecommerce Comparison

We sought to answer three main questions about brick-and-mortar with ecommerce retail:

1) How do brick-and-mortar retailers' carbon footprints compare? Why do they vary?
2) How might we compare brick-and-mortar retailers of different sizes?
3) How do carbon footprints of brick-and-mortar retailers compare to ecommerce subscription retail?

There are two methods that we considered for this analysis as both are widely used in the carbon footprinting field. The first, life cycle assessment, looks at a process from one point in the supply chain through to a final point and assesses all the inputs and outputs of environmental impacts (carbon emissions, water, waste, land use and more) throughout that process. The analysis usually starts at the "cradle" accounting for raw material extraction, the manufacturing process, and works through the whole supply chain to the "gate," the point when the customer takes ownership of the product, or to the "grave," when the consumer disposes of what remains of the product. The life cycle assessment technique requires that we follow a specific product through the process (a t-shirt or a pair of shoes, perhaps), however determining what exactly that product would be became difficult across many different companies-- the logical unit of comparison for Nike would be a sneaker, while for Nordstrom it might be a sweater. Likewise, such data about the transportation of a specific good through a retail supply chain is exceptionally difficult to find without a direct line into each of these companies. For these two glaring reasons, we needed to consider an alternative methodology.

Instead, we used a carbon accounting method that relies on company self-disclosures of their scope one, two, and three emissions facilitated by the Carbon Disclosure Project (CDP)[16]. First, we looked at the carbon footprint of six brick-and-mortar retailers by looking at their self-reported scope one and scope two emissions as reported through CDP. Scope one and two emission data for this type of analysis across many different retailers is readily accessible and standardized through CDP. Thus, we used this data to compare scope one and two carbon emissions across six US-based apparel retailers including: Nike, Gap, Abercrombie & Fitch, Macy's, Nordstrom, and Levi Strauss.

In order to compare brick-and-mortar and ecommerce business models, we made a few adjustments to the CDP methodology. First, we removed scope 1 emissions from the analysis because our client has limited associated scope 1 emissions (they do not generate any of their own energy on site). We also eliminated scope 3 from this portion of the analysis because CDP does not consistently report scope 3 emissions, resulting in few options for brick-and-mortar retailers available for comparison to the client in this analysis. Limited scope 3 data reported by brick-and-mortar companies makes comparison of business models particularly difficult, but this led us to focus exclusively on scope 2 emissions, the purchased sources of energy.

We plotted the scope 2 emissions for all the companies, including our client, and we scaled by revenue. The normalizing process is particularly important in this context because our client is significantly smaller than the rest of the comparable companies. We also added a second ecommerce company called Net-a-Porter to this portion of the analysis as a benchmark.

We make a few assumptions about the data in this analysis. Firstly, we assume that the self-reported data provided by each of these companies to CDP is accurate. While this is not entirely a fair assumption as companies have an incentive to under report their emissions, it is the only publicly available data that we have from all these companies. We assume that all of the companies under-report in similar manners and given the uniqueness of the data, and the identical reporting mechanisms across companies, we assume these numbers are a logical starting point for our analysis. Secondly, we use averages to look at the ways customers engage with brick-and-mortar retail (average distance to the store, average number of items purchased, average miles per gallon for a car that takes customers to the store). We use these averages to

[16] The Carbon Disclosure Project is a nonprofit organization that runs a carbon footprint disclosure system that allows companies, municipalities, and investors around the world to measure and compare their impacts. Research organizational footprints on their website: www.cdp.net.

begin to uncover patterns in the data but understand that some of the most interesting results take place at the margins and outliers. Lastly, we generalize about department stores versus specialty stores versus ecommerce companies. We acknowledge that companies within a single category are not identical, however noting these patterns across categories help us to identify patterns for further study moving forward.

Results

Part I: Brick-and-Mortar Retail

First, we looked at each company's absolute emissions (see Figure 4). From smallest to largest absolute emissions, the companies are Levi Strauss, Abercrombie & Fitch, Nike, GAP, Nordstrom, and Macy's. The order is the same for both scope one and scope two emissions, however, note that the scale of scope two emissions are much greater than scope one

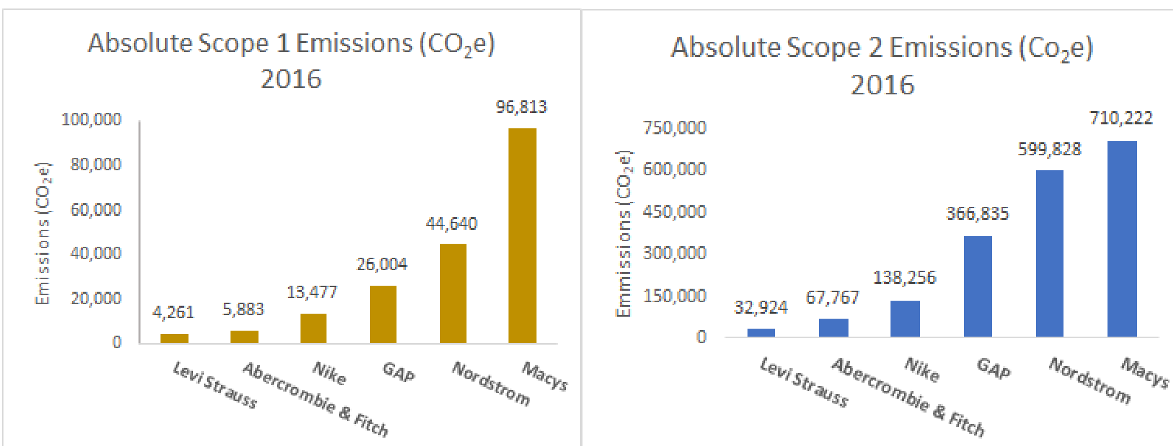

Figure 4. Scope 1 and scope 2 absolute emissions of brick-and-mortar retailers.

emissions. From an absolute emissions perspective, it is logical that the largest companies with the largest retail stores also have the largest scope one and two carbon emissions. It is important to note that Nike is one of the largest companies by revenue of the six chosen retailers, and yet has a carbon footprint much lower than Nordstrom and Macy's, which underlines the company's relative carbon efficiency.

Because these companies vary significantly in size along many different metrics, absolute CO_2e emissions may not be the best way to compare across all of them. Macy's, for instance, has the largest retail footprint, which may be one of the reasons why it has the largest carbon footprint. Likewise, Nike is the largest company of the retailers by annual revenue, so that may influence its carbon footprint in relation to the other retailers. As such, we needed to consider some ways to normalize the companies by size to compare across brick-and-mortar retailers, and eventually, to compare with an ecommerce apparel retailer.

We normalized the carbon footprints of brick-and-mortar retailers using three different metrics: revenue, cost of goods sold, and retail square footage. Revenue is a common way to normalize across many companies of different sizes as it measures the scale and reach of a

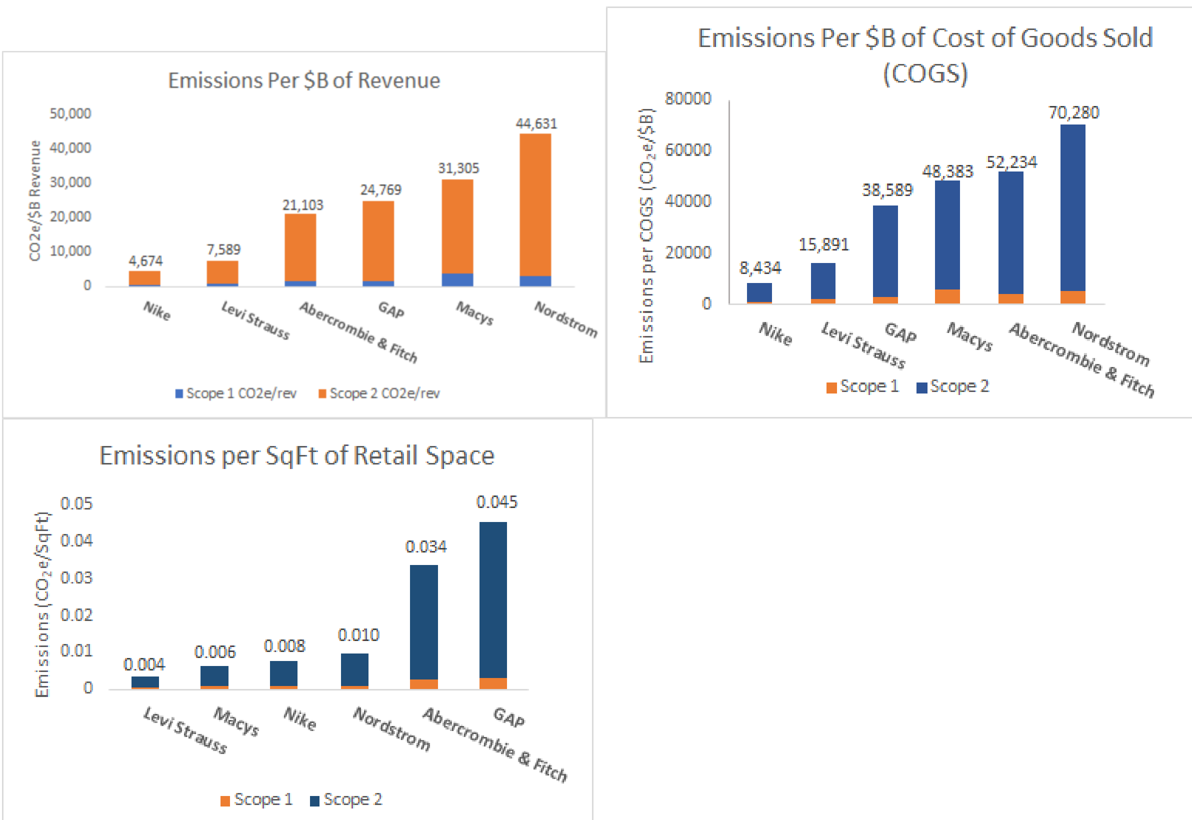

Figure 5. Scope 1 and 2 emissions normalized by revenue, cost of goods sold, and square footage of retail space.

company financially. We normalized by cost of goods sold (COGS) as it is a measure of the value of a company's inventory which is integral to retail and apparel companies. We also normalized by retail square footage to give us a sense of what the carbon footprint of each company is per square foot of retail space.

From smallest to largest carbon footprint by revenue, the companies ordered Nike, Levi Strauss, Abercrombie & Fitch, Gap, Macy's and Nordstrom, with Nordstrom almost five times larger carbon footprint than Nike per billion dollars of revenue. When we normalized by COGS, Nike had the smallest footprint, followed by Levi Strauss, Gap, Macy's, Abercrombie & Fitch, and then Nordstrom. When we normalized by retail square footage, Levi Strauss had the smallest footprint followed by Macy's, Nike, Nordstrom, Abercrombie & Fitch, and Gap (see Figure 5).

From a carbon footprint perspective, standardizing by retail square footage makes the most sense as there is an obvious connection between the amount of square footage a retailer operates and the amount of utilities and resulting carbon impact associated with those utilities. However, given that we will ultimately compare brick-and-mortar retail to an ecommerce company, normalizing by square footage of retail space gives the ecommerce company an unrealistic advantage as they operate no retail space. As such, at the comparison stage, we suggest revenue as a normalizing factor among the brick-and-mortar retail companies showcased above and the ecommerce company comparable.

Part 2: Ecommerce Retail

In this next section, we summarize the client's carbon footprint results. Figure 6 below outlines the emissions categories analyzed to compute the carbon footprint and shows the associated CO_2e with each emissions category. An explanation of each category is offered below.

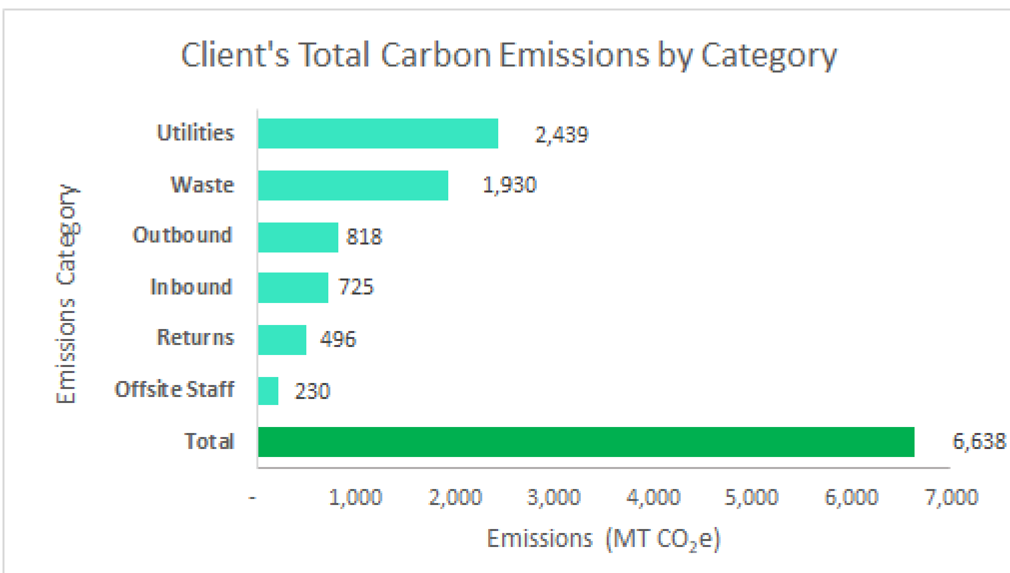

Figure 6. Total Carbon Emissions for Client broken down by the category of emissions source totals 6,636 MT CO_2e for one year. The largest emissions source is utilities followed by waste, including both onsite warehouse waste and waste associated with the corrugated boxes that customers send to landfill at an estimated rate of 65%.

Utilities: We calculated the carbon footprint from utilities using data from our Master Project client. All measurements are in metric tonnes CO_2e. Gas and electricity totaled 2,439 metric tonnes of CO_2e (see Appendix A for numerical results). On a per unit basis, natural gas emits more CO_2e, however overall the client's use of electricity contributes a greater amount to the carbon footprint as the company uses significantly more electricity year-round than it does natural gas. Moreover, the client does not use any natural gas in the California facilities, which are powered entirely by electricity from the grid. Results of the sensitivity analysis comparing grid emissions factors (GEF) and quantity of energy used overall highlight that GEF has a greater impact on carbon footprint associated with utilities than the quantity of energy used from the electric grid (see Appendix B for sensitivity analysis results).

Inbound Transportation: Inbound transportation accounted for 697 tons of CO_2e, which was calculated by FedEx who manages all inbound shipments for the client. FedEx Customer Emissions Calculations (CEC) is designed to calculate FedEx emissions associated with the movement of customers' shipments with FedEx Express, FedEx Ground and FedEx Freight. The methodology used is consistent with the World Resources Institutes (WRI) GHG Protocol. Emissions associated with shipments are calculated based on the weight, distance, service type, and the routing associated with a shipment. In addition to transport-related emissions, including third-party transport emissions, the methodology includes facility-based emissions associated with electricity and natural gas use. Using raw inbound data from our client, we used information from the FedEx CEC to test the reliability of the FedEx data -- namely the breakdown of transportation type. All inbound shipments to the client's distribution centers come via rail (30.8%), truck (53.4%), and "other" (15.7%) which does not include ship or air. We used the Argonne GREET models, to approximate the emissions associated with each ton mile traveled by transportation mode. GREET is an analytical tool that simulates the emissions output of various vehicle and fuel combinations. Our calculations approximate 430 metric tons of CO_2e associated with inbound shipments. We ran a Monte Carlo analysis on the data to see how our results compared to the possible outcomes. Appendix C shows the results, which indicate that our results are within two standard deviations of the FedEx results. The current CO_2e impact of our client's inbound transportation are 1.5 standard deviations above the mean. The difference between the Monte Carlo results and the FedEx Customer Emissions Report could be due to random variation in the data. This study analyzed inbound data from March 2017 to March 2018 while the FedEx data analyzed inbound shipments that fell between June 2017 and June 2018.

Outbound Transportation: Outbound transportation totaled 818 metric tonnes of CO_2e (see Appendix D for summary of emissions breakdown). Data used represents shipments to customers between March 2017 and March 2018, which totals to 851,383 packages to customers. It was not possible to get complete outbound data, so our model includes some assumptions which we discuss in this section. While we did not have the exact distance traveled from distribution center to customer, we were able to approximate these distances using GIS modeling. We had data on the origin of each shipment and the end 3-digit zip codes associated with each customer. We also had the number of packages traveled to each 3-digit zip code from each distribution center. Using this data, we created a GIS map of all 929 3-digit zips in the United States and created 929 central points within each zip area to calculate the distance between each central point and each of the client's distribution centers. Figure 7 is a heat map of the number of packages delivered to each 3-digit zip code from each distribution center. Figure 8 is a heat map of the average CO2e per package for each 3-digit zip. The full-size maps for each of the maps below are available in Appendix E.

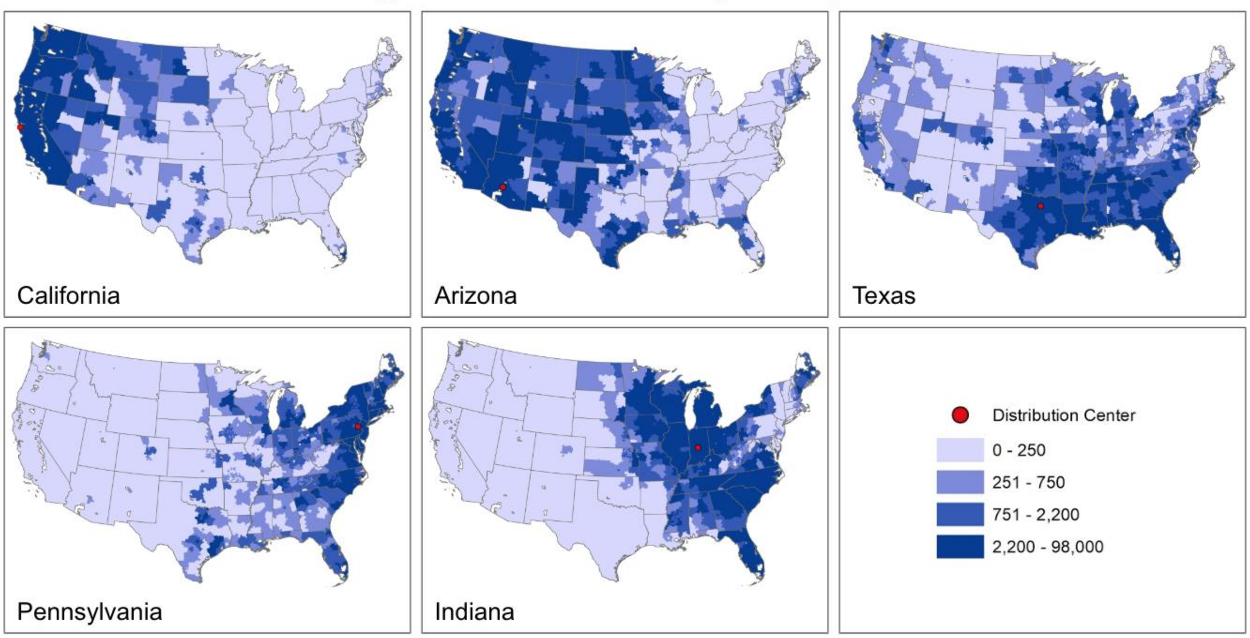

Figure 7. Number of Packages Delivered to Each Zip Code by Distribution Center

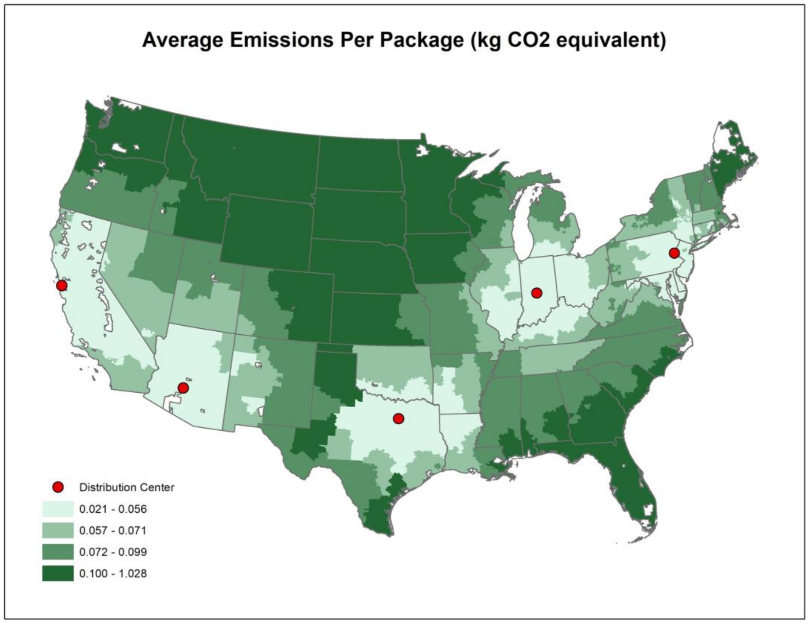

Figure 8. Average Emissions per Package CO_2e

Returns: Eighty percent of shipments to customers result in returns which is typically one pound lighter, according to our client. We calculated that returns are responsible for 515 metric tonnes of CO_2e. Appendix F includes a summary of these emissions. Together, outbound and reverse logistics accounts for 1,333 metric tonnes of CO_2e, the second most carbon-intensive part of the business. Figure 8 shows the CO_2e per package. Lighter colors indicate fewer emissions, which increase as the color darkens. Emissions per package are lowest closest to distribution centers. Some cities with the largest number of customers (ex. Seattle, Minneapolis) have some of the highest emissions per package.

Off-Site Computer Use: We calculated the carbon emissions associated with employee and laptop use at the company-- relatively small by person, but large in aggregate. The average Dell laptop produces approximately 0.05 kg per hour of use. With 4,500 stylists and 115 full time engineers at headquarters, the resulting carbon footprint of the client's laptop use is 255 MT CO_2 per year[17]. This footprint is projected to grow as the number of stylists and engineers increase with overall company growth.

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[17] Gellert, Andrew. "How do laptops affect the environment?" Sciencing. 25 April 2017. https://sciencing.com/laptops-affect-environment-23252.html

Waste: We use the EPA's WARM model to calculate how much carbon emissions were generated or avoided with the client's waste stream. The WARM tool calculated that our client diverts 750 metric tonnes of CO_2e away from landfill (see Appendix G) due to their ability to reuse and resell PET plastic hangers and to recycle corrugated cardboard. This result estimates waste values for Pennsylvania and California distribution centers based on data for the other three distribution centers and does not include waste from the client's headquarters. The model also does not account for the energy required to transport the hangers or recycling cardboard to the secondary markets. We take the average of the recycling and landfill rates from the three distribution centers for which we do have data and use the numbers as proxies for Pennsylvania and California warehouses. As such, we estimate that the client has an LDPE-related carbon impact of 1.24 MT CO_2e, a diverted impact of 297 MT CO_2e from hanger recycling, and a diverted impact of 453 MT CO_2e from recycling all cardboard.

We also account for the carbon footprint impact of the client shipping cardboard boxes to all its customers. Given an average US recycling rate of 35%, we assume that 65% of delivered corrugated boxes are thrown into landfill and associate 2,680 MT CO_2e with this waste stream (this value accounts for the 35% of boxes that consumers recycle).

Discussion

Comparing brick-and-mortar with ecommerce

After completing the analyses of brick-and-mortar companies and the ecommerce client separately, we combined scope 2 data from all categories to look at the similarities and differences in emissions categories among all apparel companies in our analysis. We normalized all companies by their revenues and then compared across the six brick-and-mortar companies, Net-A-Porter, and the client.

As is highlighted in Figure 10, the two ecommerce companies have the lowest scope 2 emissions across all of the clothing retail companies, which is to be expected given how much less physical space they own and operate. We recall that across all companies, utilities contribute most to scope 2 emissions, which increase with the amount of space a given company must heat, light and power. It is also not surprising that our ecommerce client has greater scope 2 emissions than Net-A-Porter (per $ billion revenue), as Net-A-Porter is a European ecommerce company with a more favorable associated grid emissions factor[18].

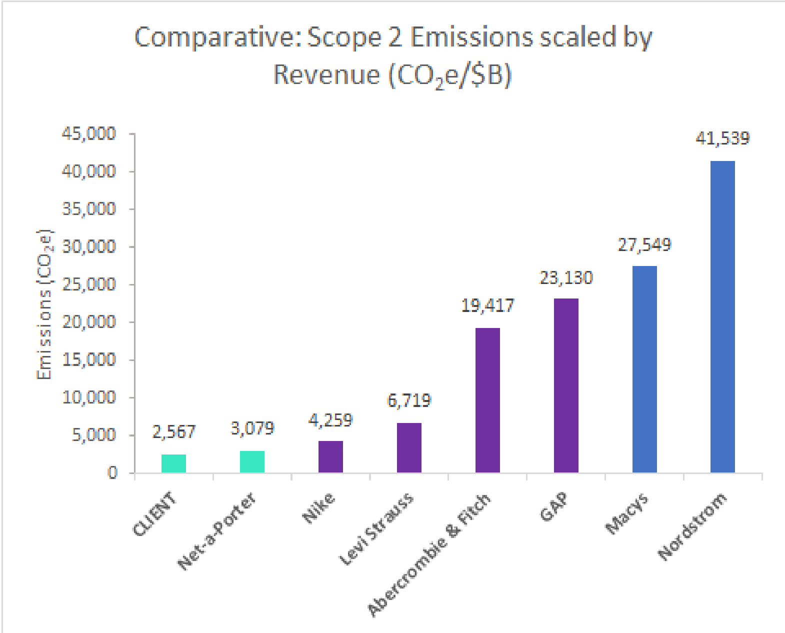

Figure 10. Comparison of scope 2 carbon footprints among: client, ecommerce retailer (teal), brand retailers (purple), and department stores (blue). Carbon footprints are smallest for ecommerce companies, then for brand retailers, and footprints for department stores are largest.

Implications of Client Results

The ecommerce company's carbon footprint is most significant in the utilities category, followed closely by the carbon footprint associated with its outbound and return delivery transportation. The largest contributor to the utilities footprint by unit is the natural gas, which the client only uses in its Pennsylvania, Texas and Arizona facilities (for the purpose of this analysis, we also assume it is used in the Indiana facility, though we do not have specific data to confirm this assumption; see figure 11). As the data indicates, these facilities rely on natural gas for heating during winter months but use it only sparingly in the summer months. In contrast, we see a greater amount of emissions associated with electricity use year-round, with a slight dip in October through December. The greater quantity of emissions associated with electricity use is likely because all the San Francisco facilities only use electricity. This reality, combined with the

[18] London, where Net-A-Porter is headquartered, is powered by 27% renewable and biomass-based energy. As of 2015, only 5% of Pennsylvania's grid was powered by renewable energy.
"Pennsylvania State Profile and Energy Estimates." US Energy Information Administration. Nov 2018. https://www.eia.gov/state/?sid=PA

myriad more uses for electricity than natural gas, keep the quantity the client uses higher than natural gas year-round. Lastly, we see variation throughout the year in utility use with no clear seasonality pattern, as we might expect with use of electricity for heating in certain regions. However, we hypothesize that the greatest electricity use variation throughout the year may be due to fluctuations in subscription box demand, with peaks in electricity use associated with the busiest seasons of the year, especially January when customers restart their boxes after the holiday season.

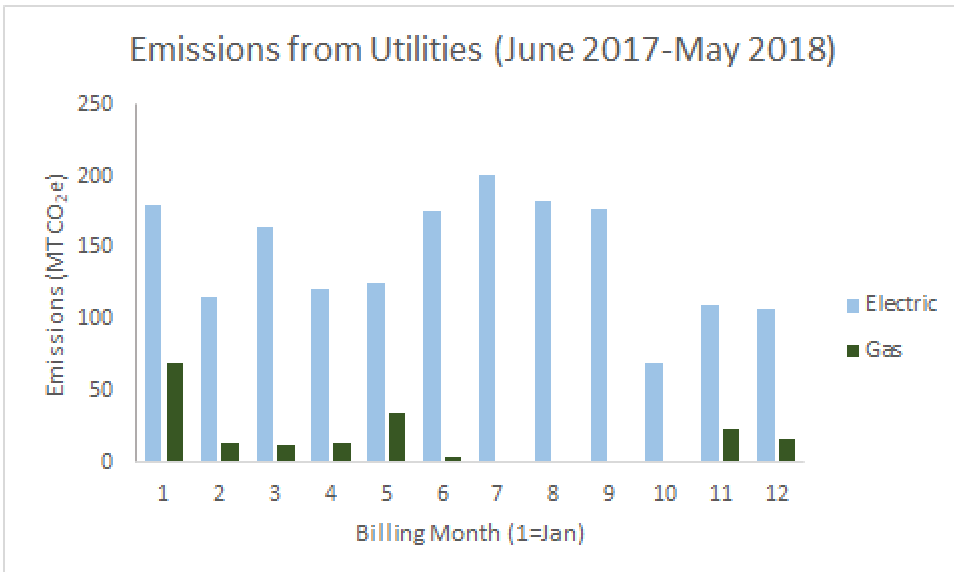

Figure 11. Emissions from Utilities (June 2017-May 2018). Graph highlights the carbon emissions associated with electric and gas utility usage through the five warehouses and headquarters. Billing month 1 is January so that the chart shows fluctuations in energy usage seasonally.

Outbound deliveries and returns are the second highest category of contribution to the overall client carbon footprint. In this instance, the company ships unique boxes to each individual client via FedEx or USPS and then the client returns whatever clothing he or she does not want to keep-- a return rate around 80%. This contribution is significant because the packages each follow a slightly different path to reach the customer rather than the coordinated deliveries that take place with inbound deliveries.

In contrast, the amount of carbon that waste contributes to the overall carbon footprint is relatively small as the primary contributor to that waste footprint comes from polymailers that are returned to the company full of unwanted clothes. Polymailers are light and small, which keeps their relative contribution significantly smaller than other waste products. Our analysis does not yet account for the waste at the customer's home associated with ecommerce delivery, including cardboard boxes, tissue paper, stickers, receipts, and the like. Including this in our analysis could significantly increase the carbon footprint associated with waste, as the average recycling rate in the US is about 35%, though this varies by municipality[19].

Last Mile Delivery

One of the most significant contributing factors to all retail model carbon footprints is the "last mile" delivery. Last mile delivery is the "critical, final phase of supply chain management where goods move from a supplier to a customer,"[20] often within a range of 50 miles or less.[21] Business decisions about last mile delivery services are, and should be treated as triple-bottom-line decisions for the business, with financial (profitability, efficiency), social (traffic congestion, community interactions), and environmental (emissions, vehicle miles) implications.[22]

In the traditional model, when customers need goods immediately, often the best way to acquire them is by going to the store and retrieving the goods. Driving a car to the store to acquire only one or a couple of goods, makes this trip significantly less CO_2e efficient compared to ordering the few goods via an ecommerce website. However, if a customer transports via bike or public transportation or if he/she purchases at least 24 goods during that trip, then the CO_2e emissions become more comparable between the ecommerce and traditional models.[23]

In ecommerce delivery, most goods in the United States are delivered by small truck, often through third party distribution companies like UPS, FedEx and USPS. In these cases, trucks operate using diesel fuel and are often filled for delivery to space, rather than weight,

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[19] "Municipal Solid Waste." United States Environmental Protection Agency. https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/

[20] Scott, Marcia et al. "Improving Freight Movement in Delaware Central Business Districts." Institute for Public Administration, College of Education and Public Policy, University of Delaware. November 2009. http://www.ipa.udel.edu/publications/FreightMovementCDBs.pdf

[21] Goodman, Russell W. "Whatever You Call It, Just Don't Think of Last-Mile Logistics, Last." Global Logistics and Supply Chain Strategies. December 2005. https://www.kn-portal.com/fileadmin/_public/documents/material/KNUCLRP_LastMile_Logistics.pdf

[22] Agatz, N., Kroon, L., Spliet, R., and A. Wagelmans. "Designing Sustainable Last-Mile Delivery Services in Online Retailing." European Research Consortium for Informatics and Mathematics (ERCIM) News. Issue 105, April 2016. https://ercim-news.ercim.eu/en105/special/designing-sustainable-last-mile-delivery-services-in-online-retailing

[23] Edwards, J.B., McKinnon, A.C., and S.L. Cullinane. "Comparative analysis of the carbon footprints of conventional and online retailing: A "last mile" perspective." International Journal of Physical Distribution and Logistics Management. October 2009.

capacity. Such deliveries are relatively efficient on a per-customer basis because companies combine dozens of deliveries together in a single trip. Alternative delivery methods, like bike messenger or electric vehicle delivery, even further reduce the carbon footprint of these delivery trips to the point where such a leg of the trip can contribute next to zero CO_2e emissions to the total delivery process. Regardless of the mode of delivery transportation, ecommerce delivery, because of increased route and transportation efficiencies per customer, will almost always result in fewer emissions than having a customer retrieve goods from the store independently.

In traditional retail models, customers are responsible for the last mile transportation of goods between the store and the home. Details, and therefore the carbon footprint impact, of this retail trip vary depending on the urban or rural location, the mode of transportation the customer uses, the number of goods the customer purchases during the trip, and the number of stops the customer makes during the outing. One study by Weber et. al. uses averages to estimate the CO_2e impact of this customer trip (2009). [24] They find that the average customer travels 14 miles round trip to the store and has car fuel efficiency of 22 miles/gallon. In this study, they find that the customer's car trip to the store constitutes approximately 65% of the total carbon footprint of last mile delivery of the product, which, in turn, makes this method of last mile delivery relatively inefficient compared to ecommerce door-to-door delivery. The carbon footprint impact of this method decreases when customers combine multiple shopping destinations into one trip.

The Weber study also find that CO_2e emission impacts associated with traditional retail are significantly lower when customers commute by bike or public transportation during their trip or if they purchase many items during one trip (24 items retrieved at the store by car is roughly equivalent to the CO_2e emissions of one item online and delivered). Access to bike transportation or public transportation for running errands correlates closely with proximity to urban centers, which also have greater densities of retailers. As such, purchasing goods from brick-and-mortar locations in urban areas, allowing for bike or public transportation over shorter distances, on average have lower carbon footprints than such trips in suburban and rural areas.

[24] Weber, C.L., Hendrickson, C.T., Matthews, H.S., Nagengast, A., Nealer, R., and P. Jaramillo. "Life Cycle Comparison of Traditional Retail and E-commerce Logistics for Electronic Products: A Case Study of buy.com." Sustainable Systems and Technology, May 2009. http://ieeexplore.ieee.org/abstract/document/5156681/

Recommendations and Conclusions

Utilities: There are several options the client can consider reducing their overall footprint associated with utilities. The three main levers that influence emissions from utilities include the grid emissions factor of the building locations, energy sources of buildings, and building utilization. While the client does not have decision-making power over whether they use natural gas once they have leased a warehouse, the client can opt to rent facilities in locations that do not use natural gas or have lower grid emissions. For example, grid emissions factors are significantly more favorable in upstate New York because a greater proportion of the energy in that location comes from renewable sources (hydroelectricity). We suggest that such favorable GEF contribute to a decision about where to locate the next distribution warehouse. Also of note, GEF in Europe tend to be even more favorable than those in the US, indicating that expansion into Europe will likely mean that the client's additional carbon footprint emissions are proportionately lower than continued expansion in the US (assuming that a European expansion caters to European customers).

The maps in Figure 7 indicate that the further away a customer is from a distribution center, the higher the CO2e associated with a package. Areas such as Miami, Dallas, Seattle, and Minneapolis represent cities with a high number of deliveries and carbon footprint. Should the client open a new distribution center, they should consider setting up a distribution center in the Pacific Northwest or Southeast region to reduce their overall carbon emissions associated outbound delivery.

Relatedly, the client can take steps to reduce its dependence on fossil-fuel derived electricity and heat sources, installing solar or wind power generators or purchasing alternative energy through their utility providers. Power Purchase Agreements (PPAs) are a contract between a project developer and a retailer (backed by a financial counterparty). The project developer owns, operates, and maintains the renewable system for a term of typically 15-25 years. The retailer agrees to pay for all the system production at a fixed price for the life of the agreement. While PPAs are only available in some municipalities, onsite PPAs provide retailers the ability to offset on-site electricity consumption, potentially reduce scope 2 carbon emissions, and provide a long-term hedge and/or savings opportunity against future electricity prices. PPAs offer a unique method for retailers to install onsite solar or other alternative distributed generation technologies as compared to capital purchases because there are no up-front cash outlay and capital expenditures considerations. A case study on a power purchasing agreement is available in appendix H.

The client could consider entering a PPA in areas that contain the following components: areas where the cost per MWh costs are highest and areas where the cost per MWh through PPA pricing models are lowest. Figure 12 shows the cost per MWh for each location where the client has distribution centers. San Francisco, South San Francisco, and Mohnton have the highest cost per megawatt hour, but the distribution centers in Dallas, Bethlehem, and South San Francisco represent the highest savings potential. The cost of solar per MWh came from two primary sources. LevelTen Energy publishes a PPA Price Index every quarter which highlights the changes in solar and wind energy across the country based on analysis they do on hundreds of PPA contracts they analyze. Most of the solar PPA pricing was pulled from the Q3 report[25]. Arizona was not included in the latest LevelTen Energy report, so we took the price listed on the Levelized Cost of Electricity Calculator[26] which was developed by the University of Texas - Austin Energy Institute. It's important to note that the solar costs per MWh noted below reflects the sole cost of electricity and does not encompass access fees and taxes which could significantly alter total electricity prices. Since the University of Austin's Energy Calculator includes the levelized cost of electricity, we assume that the cost for Phoenix does include the total cost. As such, the saving potential in our model perhaps overestimates the total electricity savings PPAs offer. It also assumes that electricity usage will remain constant year over year.

City	Annual Electricity Cost	Current $/MWh	Cheapest Technology (County Data)	Cheapest Energy Price ($/MWh)	Cost of Solar Power (Utility, MWh)	Cost of Solar Power (Utility, kWh)	Savings Switching to Solar
Bethlehem	$115,827	$ 97.77	Natural Gas Combined Cycle	$69.30	$34.89	$0.03	$74,493.08
Dallas	$153,532	$ 91.74	Natural Gas Combined Cycle	$57.96	$23.50	$0.02	$114,202.32
Mohnton	$9,182	$ 268.86	Natural Gas Combined Cycle	$69.11	$34.89	$0.03	$7,990.85
Phoenix	$120,994	$ 124.49	Solar (Utility)	$66.00	$66.00	$0.07	$56,849.97
Pittsburgh	$2,971	$ 126.88	Natural Gas Combined Cycle	$79.21	$33.83	$0.03	$2,178.89
San Francisco	$29,621	$ 244.04	Natural Gas Combined Cycle	$59.82	$26.85	$0.03	$26,361.75
South San Francisco	$69,830	$ 247.38	Natural Gas Combined Cycle	$59.90	$26.85	$0.03	$62,251.32
Grand Total	**4,291,389**						$344,328.18

Figure 12. Potential Electricity Cost Savings for Each Distribution Center (annual)

[25] Lukin, Ryan. Q3 PPA Index. Report by LevelTen Energy. https://leveltenenergy.com/blog/ppa-price-index/q3-ppa-price-index/

[26] The University of Texas - Austin created a Levelized Cost of Electricity Calculator which is free to access at http://calculators.energy.utexas.edu/lcoe_map/#/county/tech

Considering the cost savings potential at each site, we recommend that the client work with a developer to scope out PPA solar projects for the distribution centers located in Dallas, Phoenix, and Bethlehem. Solar is the cheapest energy source in the Phoenix area, and the other two locations offer the highest savings potential of all distribution centers. Solar projects in three regions can save the client approximately $240,000 annually or 5.7% of their electricity costs.

Outbound and returns transportation: The two biggest opportunities here revolve around the wheel-to-wheel emissions in transportation and reducing the returns from customers. The client can reduce CO_2e emissions associated with wheel-to-well by improving the fuel efficiency of the delivery fleet to which it contracts for outbound deliveries and returns. Several third-party logistics companies use hybrid electric fleets and new truck technology on the horizon indicates that low-emitting or zero-emitting hydrogen fuel cell technology may be available through companies like FedEx and UPS in the coming years[27,28]. During the subsequent RFPs for logistics providers, the client should include a clause to 1) give preference to providers that offer low-emitting or zero-emitting fleets, specifying a minimum number of miles that the provider travels using these vehicles and 2) carbon footprint tracking of all deliveries. Contracting with logistics providers dedicated to reducing their emissions for themselves and their customers through efficient travel and technological innovation will significantly reduce outbound emissions.

Another way to reduce emissions is to reduce return rates and/or the weight of returns. This would positively impact the carbon footprint by decreasing the amount of weight that is shipped back to the warehouses or eliminate the return entirely (when customer keep all five items in their box). To do this, the client can focus on improving the algorithm that selects clothing to customers. Improving the algorithm could reduce return rates, and thus, reduce carbon emissions.

Figure 14 shows the reduction of CO_2e when only rate of return is reduced. Figure 13 demonstrates the savings in CO_2e that the client can gain with a dual approach -- reductions in

[27]Cooper, Daniel. "FedEx adds a hydrogen fuel cell van to its fleet." Engadget. May 2018. https://www.engadget.com/2018/05/01/fedex-hydrogen-fuel-cell-van/

[28] "UPS Unveils First Extended Range Fuel Cell Electric Delivery Vehicle." UPS Press Room. 2 May 2017. https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1493730807330-217

weight and reduced return rates. All things equal, a reduction in return rate has a stronger net effect that reducing weight alone.

Figure 13. Total CO_2e savings from Reductions in Return Rate Alone

CO2e Savings (kg)

Return Rate								
80%	77.5%	75.0%	72.5%	70.0%	67.5%	65.0%	62.5%	60.0%
-	15,488	30,976	46,463	61,951	77,439	92,927	108,414	123,902

Figure 14. Total CO_2e savings from Reductions in Return Rate and Package Weight

CO2e Savings (kg)

Avg Package Weight (lbs)	Return Rate 80%	77.5%	75.0%	72.5%	70.0%	67.5%	65.0%	62.5%	60.0%
3.47	(50,348)	(33,286)	(16,225)	836	17,897	34,958	52,019	69,080	86,141
3.39	(37,761)	(21,093)	(4,425)	12,243	28,910	45,578	62,246	78,914	95,582
3.31	(25,174)	(8,899)	7,375	23,650	39,924	56,198	72,473	88,747	105,022
3.23	(12,587)	3,294	19,175	35,056	50,938	66,819	82,700	98,581	114,462
3.15	-	15,488	30,976	46,463	61,951	77,439	92,927	108,414	123,902
3.07	12,587	27,681	42,776	57,870	72,965	88,059	103,153	118,248	133,342
2.99	25,174	39,875	54,576	69,277	83,978	98,679	113,380	128,081	142,782
2.91	37,761	52,068	66,376	80,684	94,992	109,299	123,607	137,915	152,223
2.83	50,348	64,262	78,176	92,091	106,005	119,919	133,834	147,748	161,663

Inbound transportation: Since the client's inbound shipments come predominantly through rail and truck, which are less carbon intensive than air freight, the biggest opportunity to reduce inbound shipments is to address the mix of transportation modes used in shipping. Apart from ships, rail is the least intensive transportation vehicle. If more deliveries to distribution centers can be moved to rail, the client can reduce its inbound-associated emissions. A larger opportunity would be to contract with 3PLs who use hybrid fleets. By moving to a truck fleet with lower wheel-to-wheel emissions, the client could significantly reduce its inbound emissions.

Lastly, though this analysis does not incorporate such deliveries into the analysis, best carbon accounting practices indicate that transportation by air is up to 10 times more carbon intensive than the next highest emitting mode, truck (and 16 times more emitting than train, 50 times more emitting than boat)[29]. Reducing air freight for both inbound and outbound (especially international) deliveries will significantly reduce transportation-related emissions.

[29] Berg, Nate. "The future of freight: More shipping, less emissions?" GreenBiz. 5 Jan 2016. https://www.greenbiz.com/article/future-freight-more-shipping-less-emissions

Waste: Because of the significant contribution of corrugated waste to the client's carbon footprint, we suggest that the client take actions to minimize the associated carbon footprint. One way to address this would be to change the returns packaging to allow for clients to return unwanted clothing in the original box. It's possible this would increase the weight of returns slightly, so we would need to do a carbon cost-benefit analysis to determine if this would be a carbon-helpful solution. The client could also use reusable packaging like the way that Rent the Runway operates. Alternatively, the client could use polymailer bags when they ship to the client, instead of using corrugated boxes at all.

Polybags constitute a large use of plastic in the supply chain. Other retailers who have investigated more sustainable substitutes have concluded that polybags are imperative to ensure that garments stay clean as they are transported from the factory or consolidator to the distribution center.[30] A Patagonia study and found that 30% of garments that were shipped without polybags were damaged through transportation or at the distribution center. Furthermore, alternatives methods including paper mailers or removing the polybag for reuse at the shipping station did not work as effectively or added considerable labor costs.[31] The study concluded that the most sustainable measure the retailer could take was to have vendors fold the clothing small enough to reduce the required size of each polybag. Doing so allowed Patagonia to halve the amount of plastic they used on polybags and ensured that their products stayed clean and undamaged through distribution. Our recommendation is that the client explore ways to reduce the amount of plastic in polybags by maximizing the number of garments wrapped in a single polybag or exploring how they can reduce the size of each polybag by requiring vendors to fold the clothing in half before putting them into a polybag.

There are also alternative materials available to avoid the use of plastics altogether including four options currently on the market. Figure 15 shows polybag options by category, the differences in sustainability, and example materials for each category. The most sustainable options are both biodegradable, bio-based, and are made up of starch blends, which leave behind no plastic residuals. Cassava root bags are one example of this. A simple search on Alibaba

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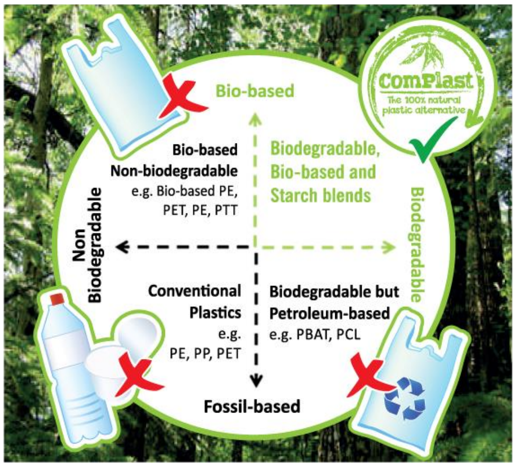
[30] Cohen, Nelli. "Patagonia's Plastic Packaging – A study on the challenges of garment delivery." Patagonia.com. 11 July, 2014. Accessed 14 October 2018. https://www.patagonia.com/blog/2014/07/patagonias-plastic-packaging-a-study-on-the-challenges-of-garment-delivery/
[31] Ibid.

yielded dozens of vendors who produce and sell starch-based bags which range in cost between $0.01-$0.02 per bag. We recommend that the client ask their vendors to use such starch-based bags in inbound shipping to reduce the amount of plastic in the supply chain. To better understand the carbon impact of this change, the client would need to better understand the amount of inbound plastic waste they create and dispose of.

Figure 15. Polybag Options by Material and Sustainability Category. Source: Complast, https://complast.co.nz/



Employee Travel: Globally, travel contributes nearly 10% to total global emissions and air travel accounts for about half of that[32]. Several companies track employee travel to understand associated financial and carbon footprint costs. With global supplier and customer networks, employees of many companies need to travel to create and maintain these important business relationships. In the case of clothing retailers, travel becomes especially important in the process of verifying labor and environmental conditions at the manufacturing sites. While some alternatives to travel may be possible, such as phone and video conferencing for meetings, some travel for most retail companies is inevitable and these companies are implementing creative solutions to minimize the carbon impact associated with this travel.

Microsoft, for instance, has implemented a cost for carbon. Individual businesses within Microsoft are responsible for the amount of carbon their teams use and for offsetting the carbon impacts of employee travel when necessary[33]. Universities like the University of Cambridge

[32] Borgar, A, J Borken-Kleefeldb, GP Petersa. "The climate impact of travel behavior: A German case study with illustrative mitigation options." Environmental Science & Policy. Vol 33, Nov 2013, 273-282 https://www.sciencedirect.com/science/article/pii/S1462901113001366
[33] "The Microsoft Carbon Fee: Theory & Practice." Microsoft. Dec 2013. file:///C:/Users/amelihar/Downloads/microsoft_carbon_fee_guide.pdf

have required that all staff reduce annual air travel by 25% and the schools will purchase carbon offsets for the rest of the air travel. At Yale, the University is adding a $50 fee for domestic flights and $100 for international flights to put toward carbon offsets.[34] Other companies have given their employees incentives to travel via car or train instead of air (when possible).

Carbon offsets: one ubiquitous approach that companies take to reduce their carbon footprints is through carbon offsets. Carbon offsets are credits that companies or individuals can purchase to support a project that sequesters carbon as an attempt to mitigate the impacts of a project that emits carbon. Status quo company operations like product delivery, employee travel, or heating buildings do emit carbon, so companies can invest in projects like replanting forests or building solar arrays to offset the impacts of such activities.

Nonprofit organizations and academia have been critical of carbon offset programs in recent years for a couple of reasons. Firstly, carbon offsets tend to sequester carbon in rural areas while carbon emissions take place in urban areas and along highway corridors. Location of such emissions versus location of sequestration can have disproportionately negative consequences for people, organisms, and environments in those regions. Secondly, carbon offsets are not universally regulated. While there are some companies that certify carbon offsets, no federal laws regulate how long carbon must be sequestered, if certain types of sequestration are more effective than others, and how payment from offsets is used. Lastly, experts worry that by giving companies and individuals the option to offset their carbon, such companies lose the incentive to reduce their overall carbon usage. It is environmentally favorable for a person to not travel by airplane at all, but could offsetting the travel through carbon credits encourage individuals to travel more than they need to?

Despite these issues, companies and individuals do use carbon offsets often with the argument that some investment into carbon emissions reductions are better than none, especially if the company cannot avoid such emissions in the short term. Microsoft, for instance, encourages its employees to travel sparingly, but if employees do travel, the company has put a price on carbon and requires businesses to offset employee travel commensurate with that cost[35].

[34] "Yale Divinity School aims to offset environmental impact of travelling." Yale Sustainability. 5 Nov 2018. https://sustainability.yale.edu/news/yale-divinity-school-aims-offset-environmental-impact-travelling
[35] "Microsoft Global Carbon Fee: Global." United Nations Framework Convention on Climate Change. Nov 2018. https://unfccc.int/climate-action/momentum-for-change/financing-for-climate-friendly/microsoft-global-carbon-fee

Similarly, airlines like Delta and British Airways give customers the option to carbon offset their travel when they purchase travel. And conferences like Greenbuild offer their attendees the option to offset their carbon emissions associated with travel and attendance to the conference through third party verified organizations.

Ultimately, the largest category contributing to the client's carbon emissions is utility usage, so focusing on reduction in this category will have the greatest overall impact on reducing the company's carbon footprint. To reduce emissions in this category, the client should focus on two areas for continued research. Firstly, the client should incorporate grid emissions factors into its warehouse expansion strategy, favoring regions of the United States and Europe with favorable GEFs including upstate New York and Scandinavia. Secondly, the client should examine opportunities to incorporate renewable energy sources at their current warehouses. Power purchasing agreements with utility companies or subsidized solar panels will inevitably be financially feasible depending on the number of sunny days in each region and the state-level renewable energy incentives available to property owners. States like California, Pennsylvania, and Arizona offer solar rebates and the US government offers a 30% solar investment tax credit for all commercial and residential solar development.

Limitations and Opportunities for Future Research

This analysis was a first attempt at quantifying brick-and-mortar and ecommerce subscription retail carbon footprints and comparing the two business models. This process highlighted limitations in our approach and the approach to carbon footprinting broadly, as well as areas for future research.

1. Analyzing theses business models using a carbon footprint scope 1, 2, and 3 framework does not give an apples-to-apples comparison between traditional retail and ecommerce subscription models because ecommerce has very limited scope 2 emissions compared to brick-and-mortar retailers, which operate several hundred or thousand retail stores. The frameworks and reporting mechanisms that have been used in the retail industry thus far should be adapted to accommodate and account for core business actions. Scope 3 emissions are central to ecommerce business models, so research into how reporting

mechanisms and carbon accounting should be reanalyzed by the lifecycle assessment industry.

2. While this study aims to compare the carbon footprints associated with the business models of traditional retail and ecommerce subscription, this study does not analyze the most carbon intensive part of retail -- material production (nor the second most carbon-intensive part of retail, the use phase). Indeed, emissions associated with transportation and warehouse operations make up a small fraction of the total carbon emissions of products and businesses. As such, we recommend our client also analyze the impacts associated with the product of clothing for their private label brands. Tools to help in that assessment include the Sustainable Apparel Coalition's Materials Sustainability Index and their other facility, product, and brand tools.
3. Lastly, we want to highlight the inherent inconsistencies in comparing carbon footprints across different companies. While organizations like the Carbon Disclosure Project aim to streamline these approaches, the organization focuses on streamlining scope one and scope 2 carbon footprint reporting. In the case of an ecommerce company, where most of the carbon footprint is considered part of scope 3 emissions, this reporting mechanism does not allow direct comparisons across businesses. This process further highlights the problems with self-reporting, asking companies to calculate their own footprints and incorporating the data they have on hand. While such processes are the best we currently have, we do not believe it unreasonable to suspect that most self-reported carbon footprints are under-reported (and inconsistently under-reported across companies) and thus also flawed as comparisons to other organizations.

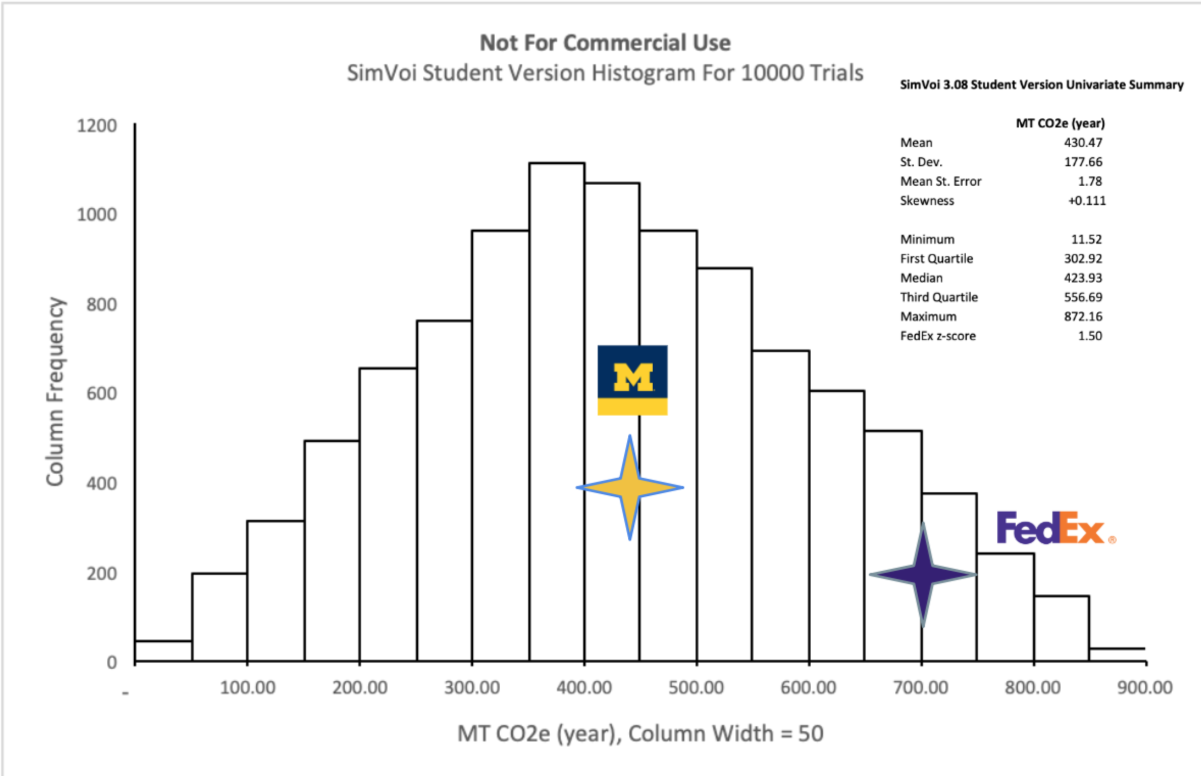
Appendix A: Gas and Electric Calculations for CO_2 equivalents

Sum of MT CO2e Emitted	*Utility Category*		
Billing Month	Electric	Gas	Grand Total
1	180.30	70.17	250.47
2	115.04	13.89	128.93
3	165.03	12.59	177.63
4	120.81	13.93	134.74
5	124.78	34.47	159.24
6	176.28	4.65	180.94
7	200.14	-	200.14
8	183.05	0.17	183.22
9	177.09	0.28	177.37
10	69.57	0.32	69.89
11	110.66	23.44	134.10
12	106.99	16.09	123.08
Grand Total	**1,729.76**	**190.00**	**1,919.76**

Appendix B: Sensitivity Analysis of Grid Emissions Factor and Energy Use

320.23	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500	0.550	0.600	0.650	0.700	0.750	0.800	0.850
40,000.00	313.35	315.35	317.35	319.35	321.35	323.35	325.35	327.35	329.35	331.35	333.35	335.35	337.35	339.35	341.35
50,000.00	314.85	317.35	319.85	322.35	324.85	327.35	329.85	332.35	334.85	337.35	339.85	342.35	344.85	347.35	349.85
60,000.00	316.35	319.35	322.35	325.35	328.35	331.35	334.35	337.35	340.35	343.35	346.35	349.35	352.35	355.35	358.35
70,000.00	317.85	321.35	324.85	328.35	331.85	335.35	338.85	342.35	345.85	349.35	352.85	356.35	359.85	363.35	366.85
80,000.00	319.35	323.35	327.35	331.35	335.35	339.35	343.35	347.35	351.35	355.35	359.35	363.35	367.35	371.35	375.35
90,000.00	320.85	325.35	329.85	334.35	338.85	343.35	347.85	352.35	356.85	361.35	365.85	370.35	374.85	379.35	383.85
100,000.00	322.35	327.35	332.35	337.35	342.35	347.35	352.35	357.35	362.35	367.35	372.35	377.35	382.35	387.35	392.35
110,000.00	323.85	329.35	334.85	340.35	345.85	351.35	356.85	362.35	367.85	373.35	378.85	384.35	389.85	395.35	400.85
120,000.00	325.35	331.35	337.35	343.35	349.35	355.35	361.35	367.35	373.35	379.35	385.35	391.35	397.35	403.35	409.35
130,000.00	326.85	333.35	339.85	346.35	352.85	359.35	365.85	372.35	378.85	385.35	391.85	398.35	404.85	411.35	417.85
140,000.00	328.35	335.35	342.35	349.35	356.35	363.35	370.35	377.35	384.35	391.35	398.35	405.35	412.35	419.35	426.35
150,000.00	329.85	337.35	344.85	352.35	359.85	367.35	374.85	382.35	389.85	397.35	404.85	412.35	419.85	427.35	434.85
160,000.00	331.35	339.35	347.35	355.35	363.35	371.35	379.35	387.35	395.35	403.35	411.35	419.35	427.35	435.35	443.35
170,000.00	332.85	341.35	349.85	358.35	366.85	375.35	383.85	392.35	400.85	409.35	417.85	426.35	434.85	443.35	451.85
180,000.00	334.35	343.35	352.35	361.35	370.35	379.35	388.35	397.35	406.35	415.35	424.35	433.35	442.35	451.35	460.35
190,000.00	335.85	345.35	354.85	364.35	373.85	383.35	392.85	402.35	411.85	421.35	430.85	440.35	449.85	459.35	468.85
200,000.00	337.35	347.35	357.35	367.35	377.35	387.35	397.35	407.35	417.35	427.35	437.35	447.35	457.35	467.35	477.35
210,000.00	338.85	349.35	359.85	370.35	380.85	391.35	401.85	412.35	422.85	433.35	443.85	454.35	464.85	475.35	485.85
220,000.00	340.35	351.35	362.35	373.35	384.35	395.35	406.35	417.35	428.35	439.35	450.35	461.35	472.35	483.35	494.35
230,000.00	341.85	353.35	364.85	376.35	387.85	399.35	410.85	422.35	433.85	445.35	456.85	468.35	479.85	491.35	502.85
240,000.00	343.35	355.35	367.35	379.35	391.35	403.35	415.35	427.35	439.35	451.35	463.35	475.35	487.35	499.35	511.35
250,000.00	344.85	357.35	369.85	382.35	394.85	407.35	419.85	432.35	444.85	457.35	469.85	482.35	494.85	507.35	519.85
260,000.00	346.35	359.35	372.35	385.35	398.35	411.35	424.35	437.35	450.35	463.35	476.35	489.35	502.35	515.35	528.35
270,000.00	347.85	361.35	374.85	388.35	401.85	415.35	428.85	442.35	455.85	469.35	482.85	496.35	509.85	523.35	536.85
280,000.00	349.35	363.35	377.35	391.35	405.35	419.35	433.35	447.35	461.35	475.35	489.35	503.35	517.35	531.35	545.35
290,000.00	350.85	365.35	379.85	394.35	408.85	423.35	437.85	452.35	466.85	481.35	495.85	510.35	524.85	539.35	553.85
300,000.00	352.35	367.35	382.35	397.35	412.35	427.35	442.35	457.35	472.35	487.35	502.35	517.35	532.35	547.35	562.35

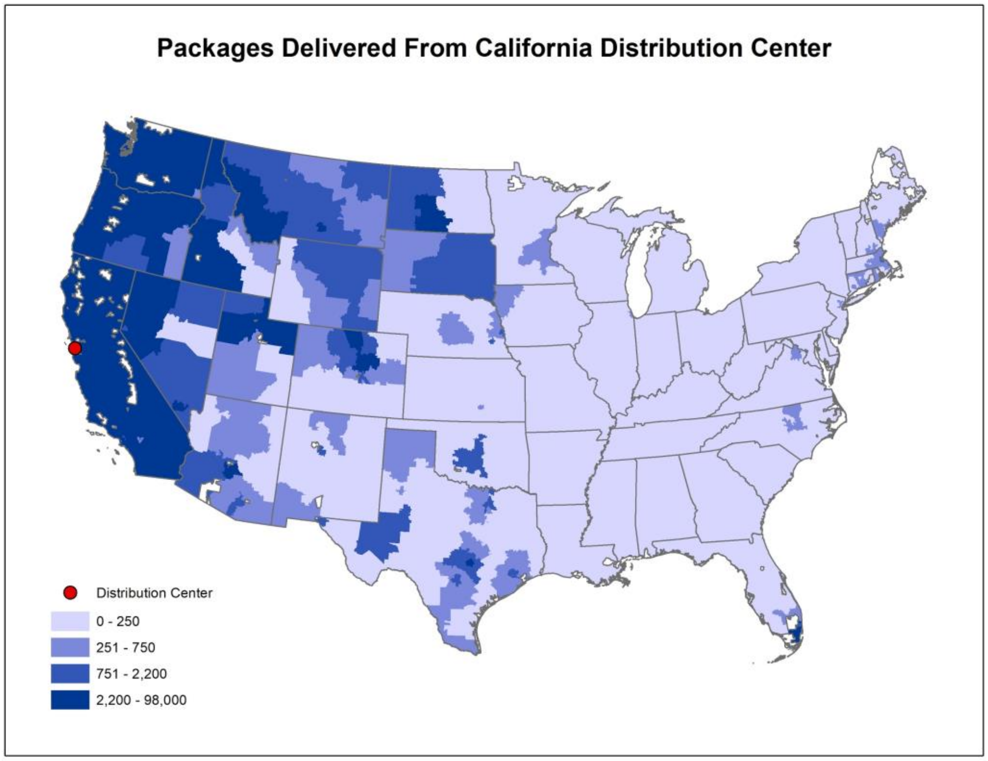
Appendix C: Sensitivity Analysis of Inbound Data

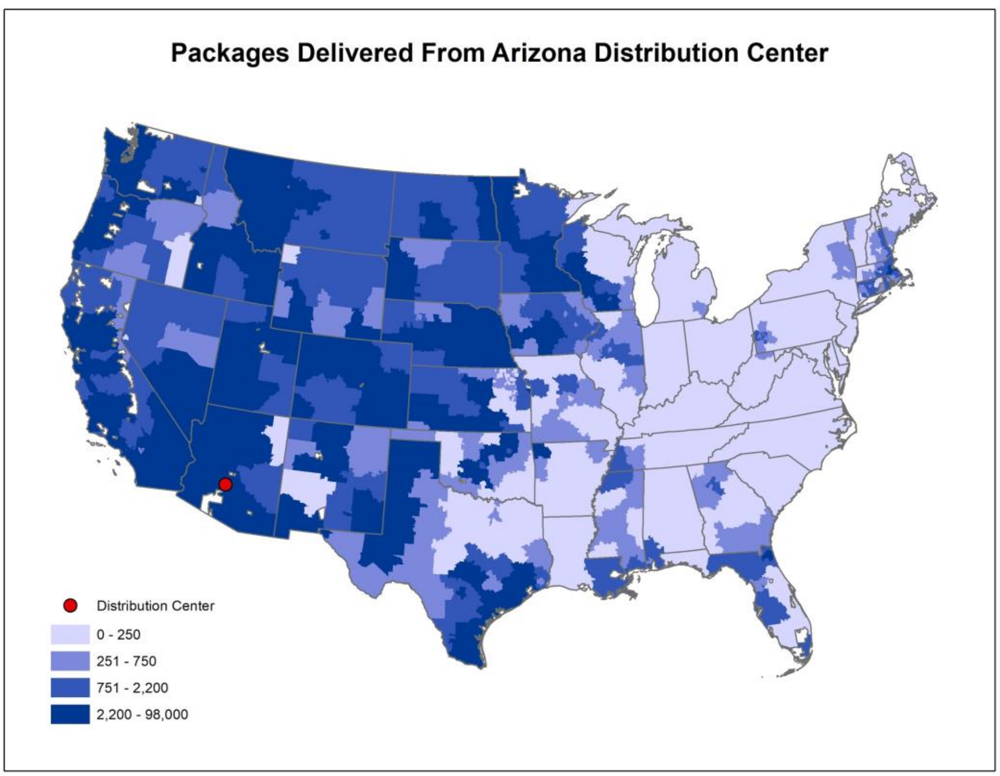


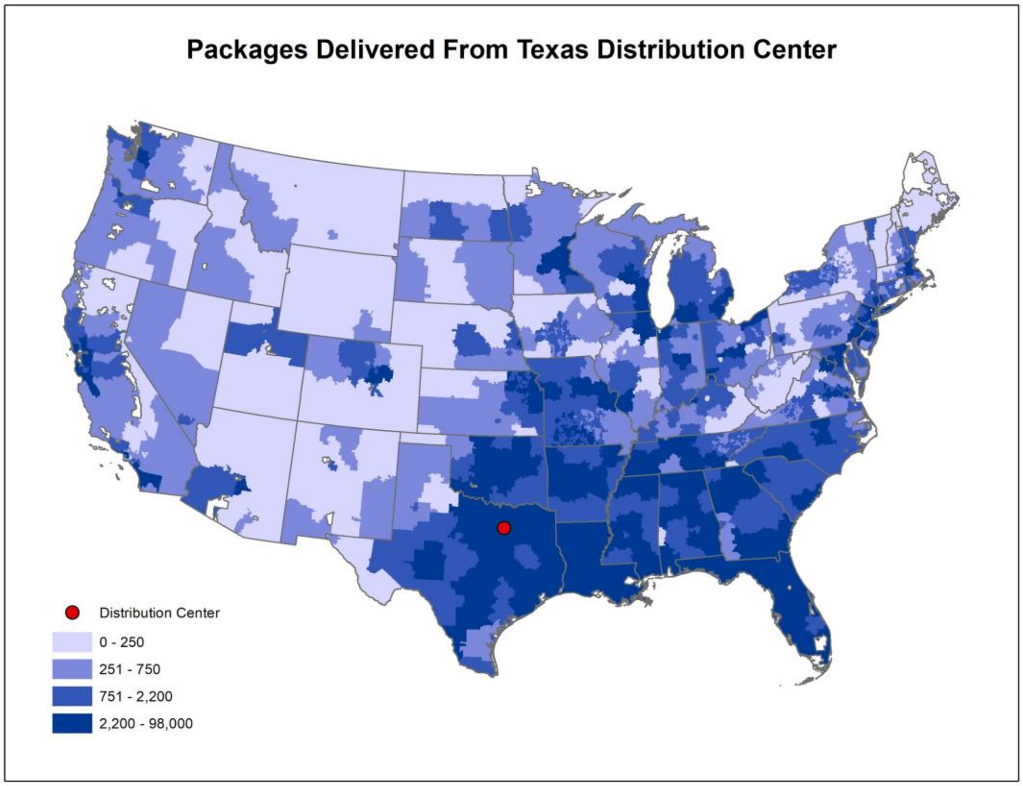
Appendix D: Outbound CO_2e by Month (March 2017 - March 2018)

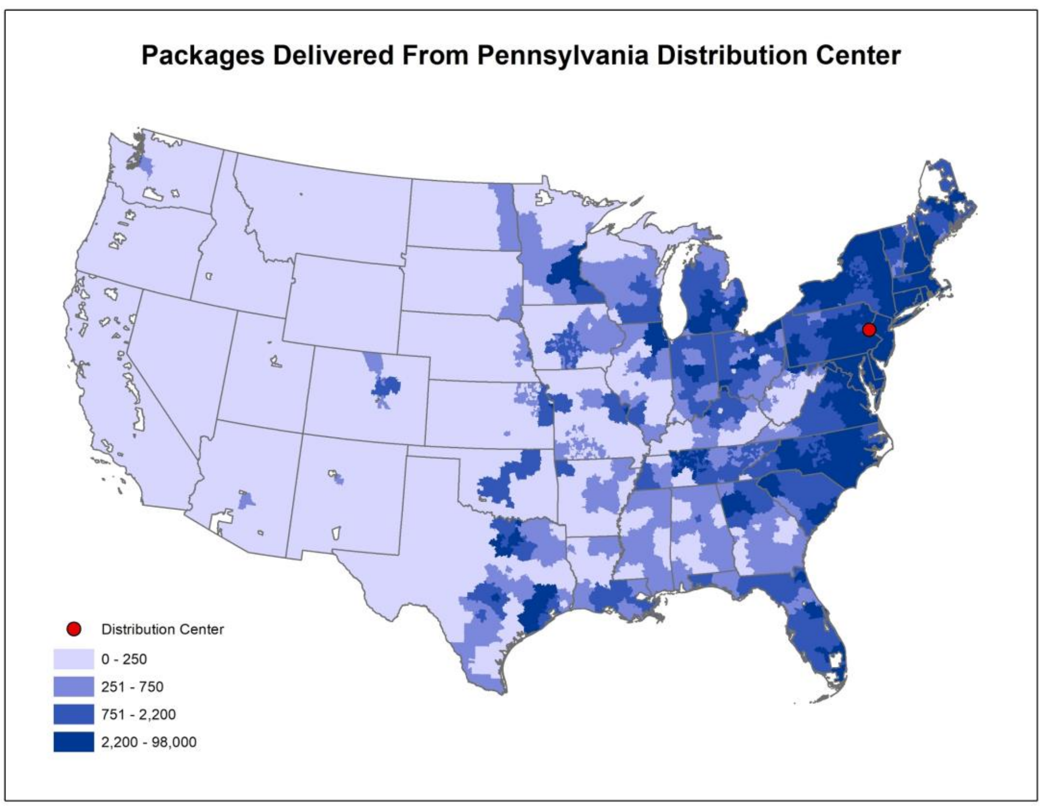
Row Labels	Sum of Miles traveled_substituted	Sum of pkg_ct	Sum of Package Weight (Tons)	Sum of kg CO2e per zip
2017				
Mar	5,244,838.59	727,812.00	1,408.25	56,451.34
Apr	5,100,493.44	685,871.00	1,279.96	51,274.05
May	5,063,560.70	763,021.00	1,384.40	55,410.01
Jun	5,105,783.89	822,694.00	1,474.84	58,565.61
Jul	4,934,127.99	749,850.00	1,377.32	54,355.40
Aug	5,295,156.13	841,404.00	1,682.73	64,383.54
Sep	5,122,163.48	811,117.00	1,784.18	67,815.98
Oct	5,121,189.19	876,858.00	2,025.78	78,261.36
Nov	5,040,554.61	829,560.00	1,961.62	74,976.98
Dec	4,734,148.94	774,578.00	1,824.97	68,527.94
2018				
Jan	4,712,186.55	851,383.00	1,949.17	73,538.39
Feb	4,818,499.45	826,286.00	1,786.48	68,682.25
Mar	4,115,703.73	585,068.00	1,222.71	46,621.44
Grand Total	**64,408,406.69**	**10,145,502.00**	**21,162.42**	**818,864.29**

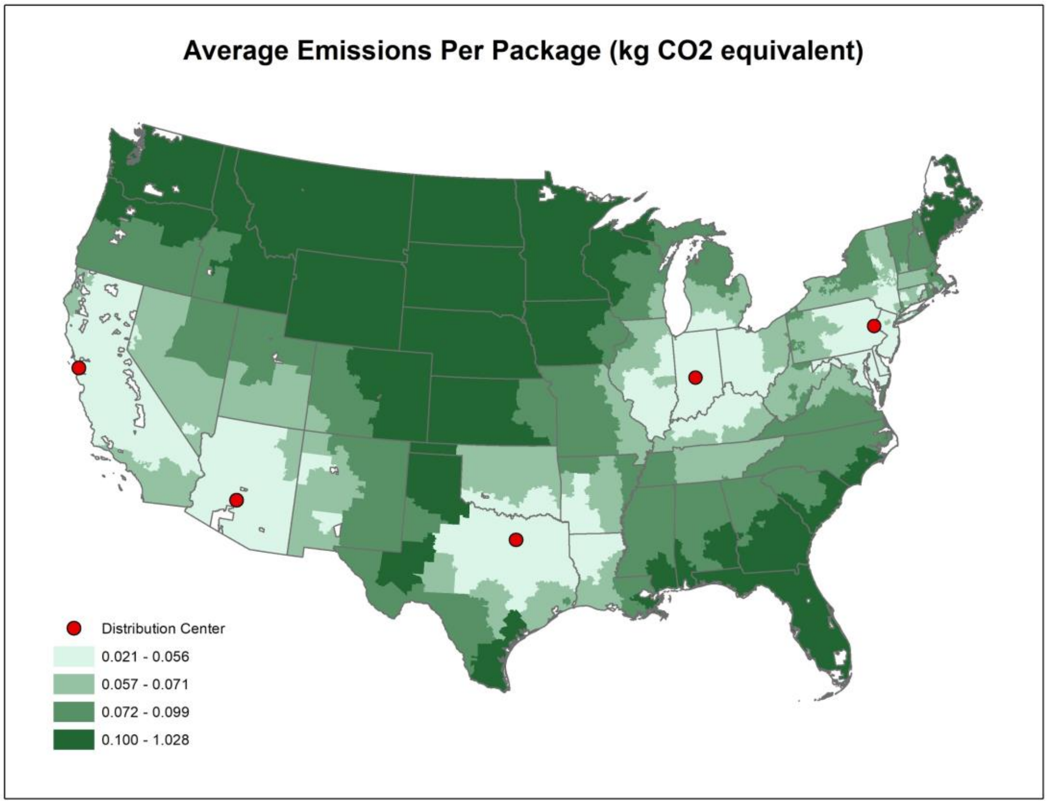
Appendix E. Full Size Maps from Outbound Analysis






Packages Delivered From Texas Distribution Center
Distribution Center
0 - 250
251 - 750
751 - 2,200
2,200 - 98,000


Packages Delivered From Pennsylvania Distribution Center
Distribution Center
0 - 250
251 - 750
751 - 2,200
2,200 - 98,000



Appendix F: Returns CO_2e by Month (March 2017 - March 2018)

Row Labels	Sum of Miles traveled_substituted	Sum of pkg_ct	Sum of Package Weight (Tons)	Sum of kg CO2e per zip
2017				
Mar	4,179,599.76	587,690.00	843.28	33,811.23
Apr	4,092,514.80	551,437.00	753.36	30,063.99
May	4,071,540.54	614,383.00	807.53	32,510.29
Jun	4,070,242.06	643,572.00	831.94	33,807.99
Jul	4,036,424.52	625,691.00	836.42	32,919.12
Aug	4,219,075.29	676,201.00	1,014.24	38,650.81
Sep	4,094,083.27	655,422.00	1,114.00	41,983.96
Oct	4,124,298.04	706,339.00	1,278.67	48,915.89
Nov	3,965,898.40	690,994.00	1,288.46	47,434.70
Dec	3,793,671.74	625,082.00	1,160.20	42,877.36
2018				
Jan	3,743,136.08	676,920.00	1,211.30	45,473.44
Feb	3,895,509.84	651,375.00	1,082.63	42,364.37
Mar	3,270,051.70	481,003.00	764.73	29,323.07
Grand Total	**51,556,046.03**	**8,186,109.00**	**12,986.75**	**500,136.21**

Appendix G: Waste Calculations for CO_2 equivalents

Arizona (annual)

Material	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
LDPE	-	NA	10.25	-	NA	NA	0.21	0.00
PET	59.06	-	-	-	NA	NA	(129.99)	(131.19)
Corrugated Containers	-	19.40	-	-	NA	NA	(60.54)	(65.10)

Indiana (annual)

Material	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
LDPE	-	NA	20.00	-	NA	NA	0.41	0.00
PET	-	74.93	-	-	NA	NA	(83.72)	(85.24)
Corrugated Containers	-	28.40	-	-	NA	NA	(88.63)	(95.30)

Texas (annual)

Material	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Total $MTCO_2E$	Change (Alt - Base) $MTCO_2E$
LDPE	-	NA	14.60	-	NA	NA	0.30	0.00
Corrugated Containers	-	39.50	-	-	NA	NA	(123.27)	(132.55)

Appendix H: Case Study on Power Purchasing Agreement

In a renewable power purchasing agreement (for solar, wind or other types of renewable energy sources), a developer, host and utility make a financial agreement to support and create this new energy source. The developer builds the asset (design, permitting, financing and installation). The host owns the property where the array will be built and often pays a lower than market price for use of the power generated from the asset. A utility company purchases all the excess power generated by the asset and left over after the host's use. These agreements typically last for between 10 and 25 years, depending on the projected payback period for the project.

Given the client's significant rooftop space at its assets, they have the potential to become a host in a power purchase agreement between a developer and a utility. This solution is beneficial for several reasons. Firstly, the host has no or low upfront capital costs for use of this renewable energy asset and the developer remains responsible for maintenance of the asset for the duration of the agreement. Secondly, the host receives discounted electricity from renewable sources often at lower cost than electricity from the grid. Third, solar assets increase the resale value of the asset as they can be sold with the asset before the end of the PPA contract[36]. PPAs for renewable energy assets are especially valuable in states with commitments to grow renewable energy generation in the coming decade. Of the locations where the client has warehouse locations, Pennsylvania and California have the most aggressive renewable targets[37].

[36] "Solar Power Purchase Agreements." Solar Energy Industry Association. Nov 2018. https://www.seia.org/research-resources/solar-power-purchase-agreements
[37] "State Renewable Portfolio Standards and Goals." National Conference of State Legislatures. 20 July 2018. http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx