Retail Carbon Footprints: Measuring Impacts from Real Estate and Technology

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CARBON FOOTPRINTS AND RETAIL BEHAVIORS OF CONSUMERS

21st century consumers face unprecedented choice when purchasing goods and services. A growing body of research has been investigating what impact consumer choices have on carbon use, GhG emissions, and climate change. The research has a shared concensus, consumer decisions are carbon emitting. However, some consumer decisions, choices by logistics and supply chain providers, transportation and even technological solutions contribute to more GhG emissions than less.

As a real estate group, our goal was to focus on how real estate, urban planning and technology impacts the total GhG emissions that a retail consumer initiates when they make a purchase. We present in our research where all decision makers can make a contribution to minimize the carbon footprint from their business and retail behaviors.

"Our goal is to understand the carbon footprints of consumer retail behavior. As the purchase and delivery of goods has expanded to include numerous channels, we want to measure the role of real estate, transportation, and technology. The objective is to help those involved in the supply, delivery, and reception of goods to minimize carbon footprints."

DR. ANDREA CHEGUT
MIT REAL ESTATE INNOVATION LAB

WHICH RETAIL STRATEGY PROVIDES THE LOWEST GHG EMISSIONS OUTPUT?

Over the last quarter of a century, no asset class in real estate has seen more transformation than the retail sector, due to advances in technology, innovations in the supply chain and ever-advancing changes in consumer behavior. Where once consumers flocked to suburban shopping malls and the brick-and-mortar stores of city streets, ecommerce - combined with next-day delivery capability - has completely altered how we purchase all forms of goods. Coinciding with this transformation, climate change across the globe has now reached a point where it is unquestionably impacting our environment, economy and resiliency as a society. The question we must now ask is which of these forms of consumer behavior leads to lower carbon emissions, and is better for the world in which we live. This analytical study aims to investigate and measure consumers' Greenhouse Gas (GhG) emissions while engaging in either ecommerce purchasing or the more traditional purchasing from brick-and-mortar stores.

Identification Strategy

Our study began by reviewing previous research conducted in this area and focused on the major factors that have had the most impact on carbon emissions, such as transportation. However, as the retail ecosystem has expanded, it has become clear that there are numerous other factors that are having a major impact on GhG emission levels. These include the real estate footprint of buildings, logistical systems, the production of packaging and boxes, and new technologies.

PRECEDENT STUDIES

The question of which system has a greater impact on GhG emissions has led to research on how these different types of retail behaviors are impacting GhG emissions, and numerous articles and publications have been generated in recent years. Previous research takes into account various assumptions about consumer behavior, the logistics ecosystem and consumer transport. Notably, these studies suggest that carbon emissions are generally lower for consumer retail strategies that engage in ecommerce. Our goal within this study is to dig further into these findings, expand on previous assumptions and introduce a number of increasingly significant factors.

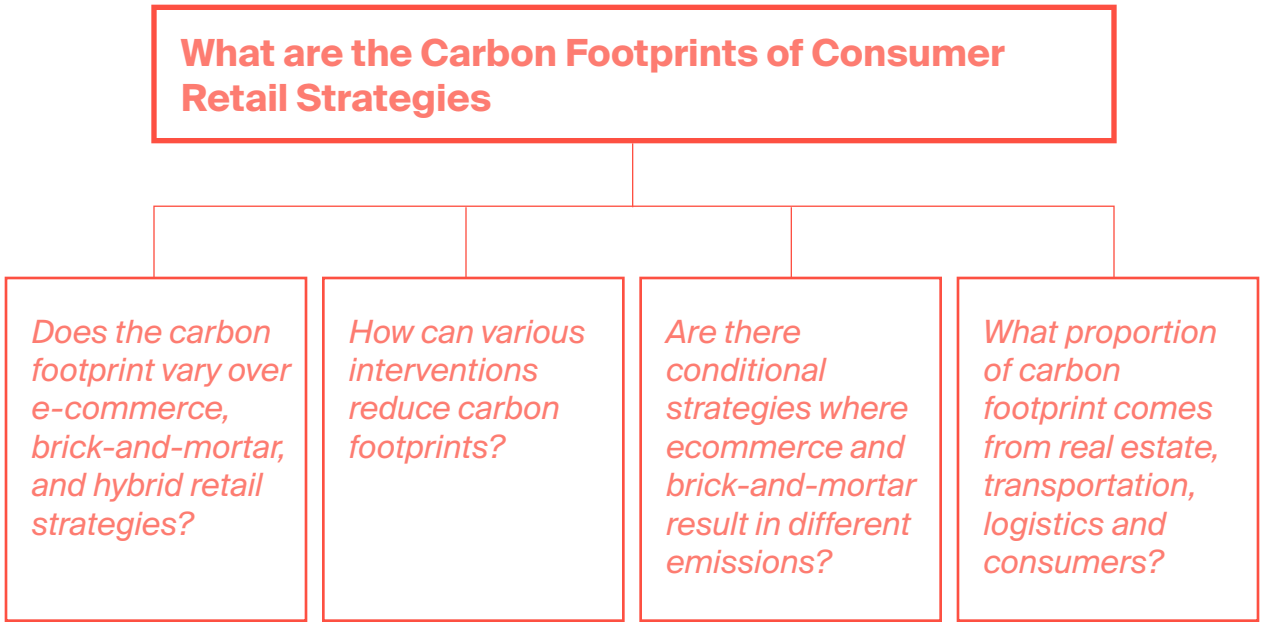
Author	Country and Institution	Year Published	Title	Findings
Weideli	United states, France MIT, EPFL	2012	Environmental analysis of us online shopping	'pure players' of ecommerce have fewer emissions on average that hybrid models with in-person shopping trips by car
Blanco, Sheffi	United States, MIT	2017	Green Logistics	Presents a systematic methodology for measuring carbon footprint impact.
Blanco	United States, MIT	2017	Estimating the CO2 intensity of intermodal freight transportation	Suggests employing public transport infrastructure for logistics parcel delivery.
Pineda Blanco	United States, UC Davis	2018	Changes in Online Shopping Behavior During the Last Decade	Determines that a specific sector of the population is more drawn towards online shopping. Presents relationships between shopper characteristics.
Prologis	United States, Prologis Research	2018	The Modern Supply Chain: A New Model for Defining Logistics Real Estate	Framework for determining the development criteria of new last-mile properties.
He et. al.	PR China, Shanghai University	2019	Product carbon footprint across sustainable supply chain	Presents a comprehensive study of the constituent parts of the supply chain and how to make a full assessment.
Shahmohammadi, Van Loon, et. al.	United States, ES&T Magazine	2020	Comparative Greenhouse Gas Footprinting of Online versus Traditional Shopping for Fast-Moving Consumer Goods: A Stochastic Approach	Analyzes data from multiple countries to determine that e-commerce is not always the least carbon-intensive form of retail.

Table 1. Precedent Studies.

“The question is not whether ecommerce or brick-and-mortar retail is better or worse for GHG emissions. It is more about what decisions consumers, retailers, ecommerce and logistics stakeholders can make to minimize GHG emissions. There is something that everyone in the supply chain can do to help mitigate climate change.”

JAMES SCOTT
MIT REAL ESTATE INNOVATION LAB

RESEARCH APPROACH



As outlined, this study aims to measure the carbon footprint of consumer behaviors in ecommerce by assembling the relevant variables and then simulating scenarios where a range of parameters can be modified. To aid in this research, a Monte Carlo simulation was executed using 10,000 trials to produce measurable results which were then plotted for analysis to illustrate which strategy produced the lowest GHG emissions. In total, we did close to 48 different simulations for a total of 480,000 trials. Furthermore, it gave us the opportunity to construct opinions on which solutions have the greatest chance to succeed in this context.

In order to help focus our research we also constructed four essential questions which we aimed to answer in the course of our analysis:

- Does the carbon footprint vary over ecommerce, brick-and-mortar and hybrid retail strategies?
- How can various interventions reduce carbon footprints?
- Are there conditional strategies where ecommerce and brick-and-mortar result in different emissions?
- What proportion of our carbon footprint comes from real estate, transportation, logistics and consumers?

For the purpose of establishing a measurable framework, and to help look at the big picture of the supply chain while getting a better understanding of the carbon footprint of each fulfilled order, we also developed a system map taking into account the logistics, consumer, real estate, packaging and transportation elements of the process. Finally, it should also be noted that we focused primarily on the aspects of the final part of the supply chain, or the last-mile portion of the overall process, as this is the most distinct and where the true differences between traditional purchasing and ecommerce purchasing happen.

BREAKING DOWN FURTHER RETAIL CARBON FOOTPRINT

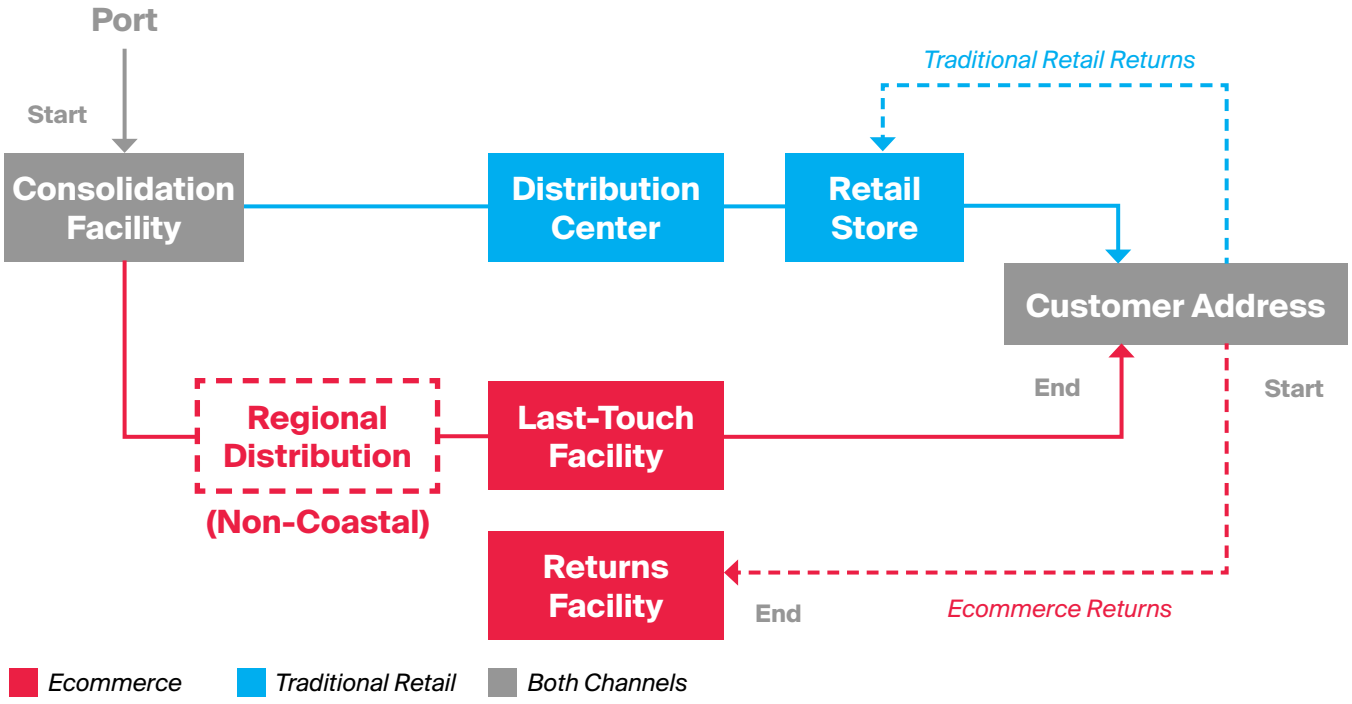


Fig 1. Retail Supply Chain Model: Brick-and-Mortar and Ecommerce.

Retail Supply Chain Model: Sources of Emissions

The port facility serves as a placeholder title for the origin of the product. The product then begins its trip through the supply chain by traveling to the Consolidation Center, which is the first layer of property, common to all channels.

The path then forks for both channels. In the ecommerce channel, the next step for the parcel becomes the Last-Mile facility, where the product is handled for the final time before getting shipped to the end customer address. In the non-coastal state markets (these are, as the name implies, states without direct access to either the Pacific or Atlantic oceans), the product passes through one additional preceding property called a Regional Distribution Center.

In the traditional retail channel, once items have left the Consolidation Facility, they arrive at a Distribution Center and are then shipped to the Retail Store, where individual shoppers head to in order to pick up the product and bring home, traveling in a vehicle of their own choosing.

Beginning at the customer address in all retail channels, the returns are sent back to an alternate distribution center or retail store, depending on the channel. Reverse logistics GhG emissions are conceptualized.

ASSESSING CARBON FOOTPRINTS

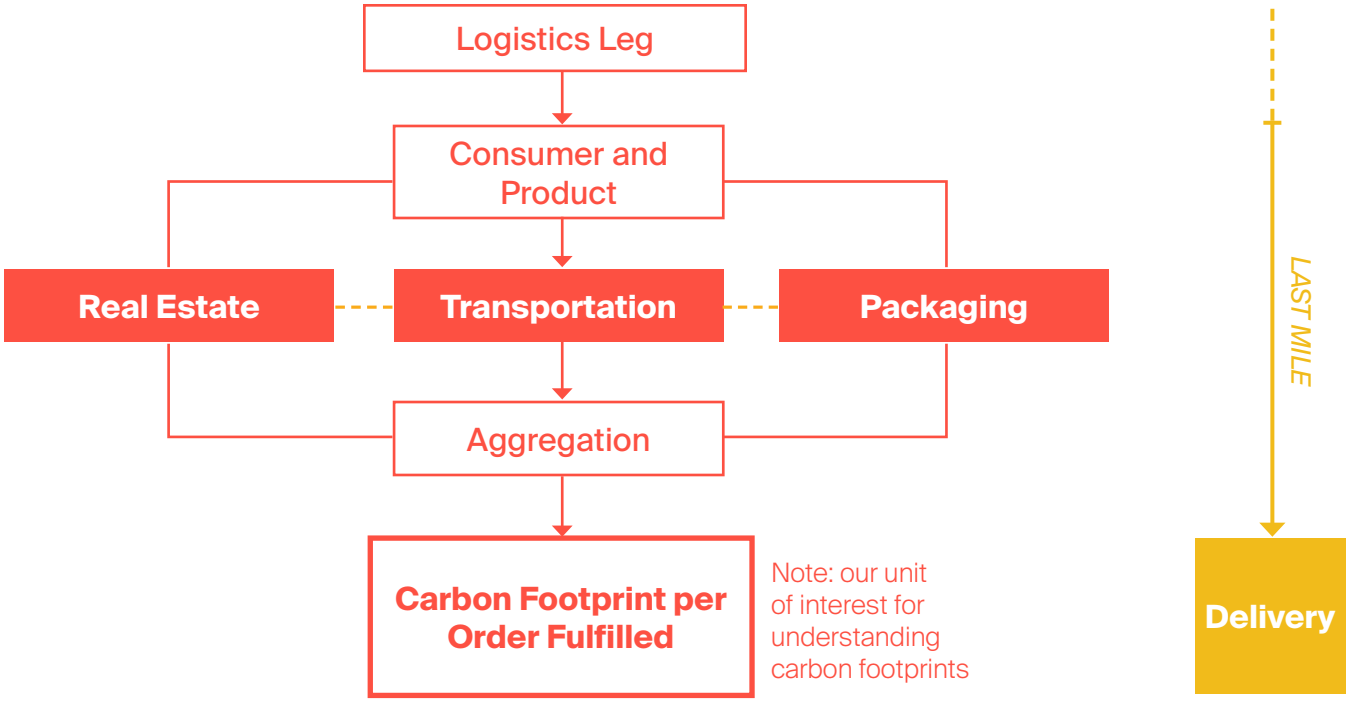


Fig 2. Model of Carbon Footprints per order.

While this analysis found similar conclusions to previous studies, the research showcases how important the role of real estate and, more importantly, its location is in helping mitigate consumers' GhG emissions. We illustrate that when consumers increase the number of their purchases - whether by isolating household shopping trips into one large trip to gather as many goods as possible in one pickup, or by consolidating many purchases into the e-commerce logistics ecosystem - there is a principal of scale that consumers are tapping into. However, consumer behavior does not generally work this way. The average U.S. consumer makes at least 300 shopping trips per annum[1], and these individual trips are unable to consolidate enough to compete with the reduction of carbon emissions that the e-commerce system brings. It is also important to remember there is another layer of complexity when factoring in that consumers can make specific choices that impact their own GhG emission footprint.

1. Statista. (n.d.). Consumers' weekly grocery shopping trips in the United States from 2006 to 2019. Retrieved January 2021, from https://www.statista.com/statistics/251728/weekly-number-of-us-grocery-shopping-trips-per-household/

“In traditional brick-and-mortar, ecommerce, and combined retail strategies, boxes account for some of the largest carbon pollutants in the ecosystem.”

DIEGO FERNÁNDEZ BRISEÑO
MIT REAL ESTATE INNOVATION LAB

SIMPLE MODEL

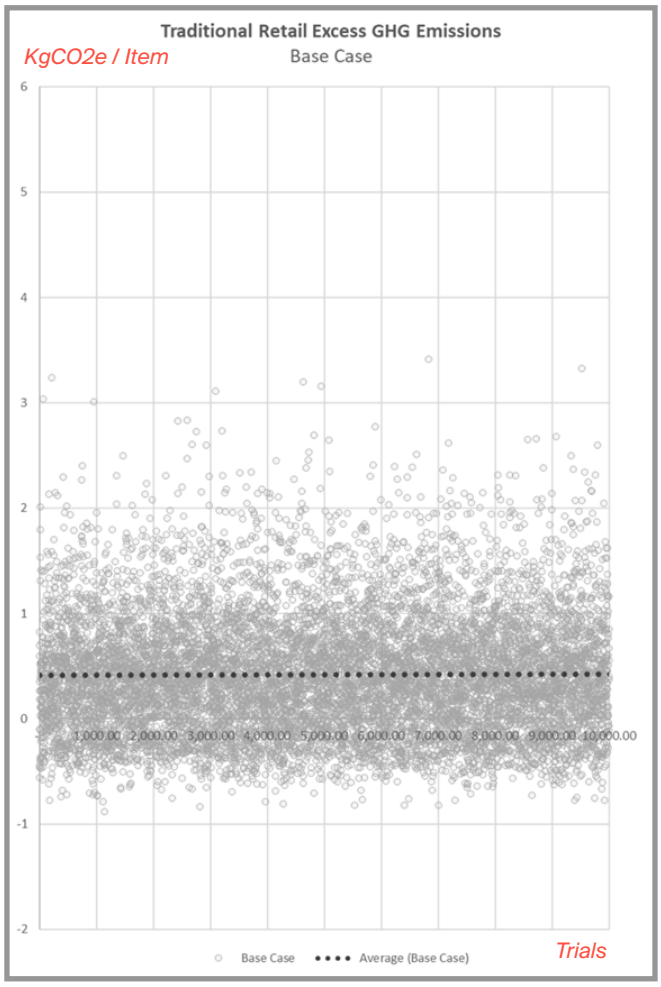


Fig 3. GHG Emissions by Brick-and-Mortar vs. Ecommerce.

Base Case Scenario

The primary findings are shown on the base case simulation results, which will be used as a benchmark to compare the different interventions' impact. By using our standard method of subtracting ecommerce values from traditional retail ones, the marginal results range from a maximum of 3.400 kgCO2e/product to a minimum of 0.880 kgCO2e/product. These are the extremes. However, the mean sits closer to 0.440, which is where a large concentration of the trials are.

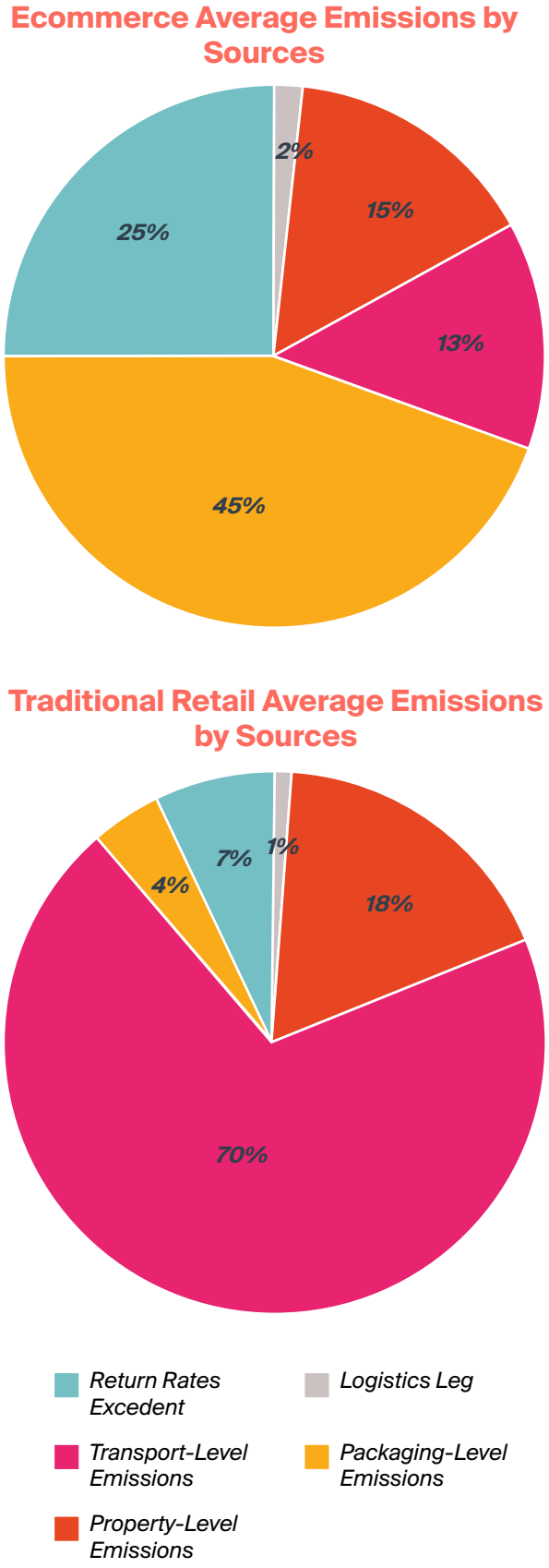
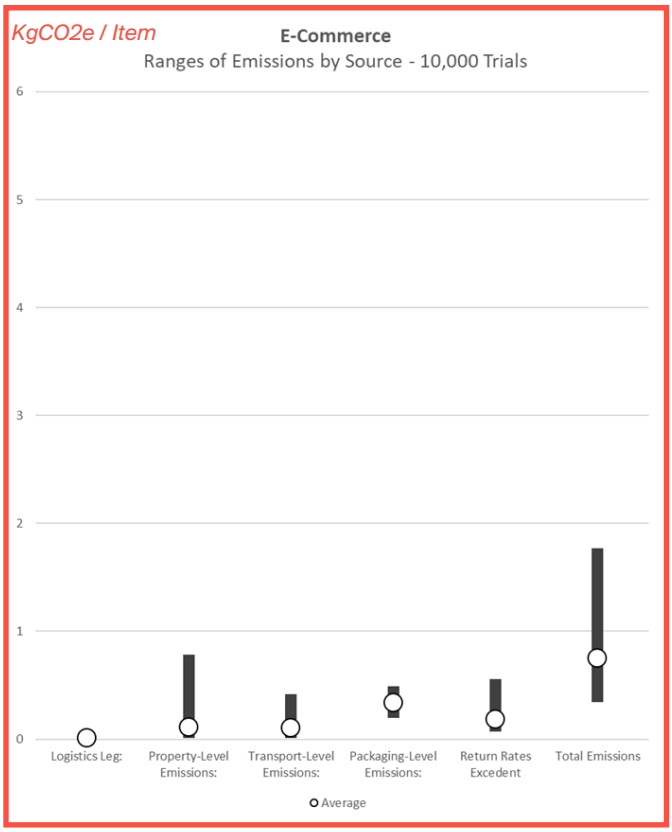


Fig 4. GHG emissions Breakdown by Sources.



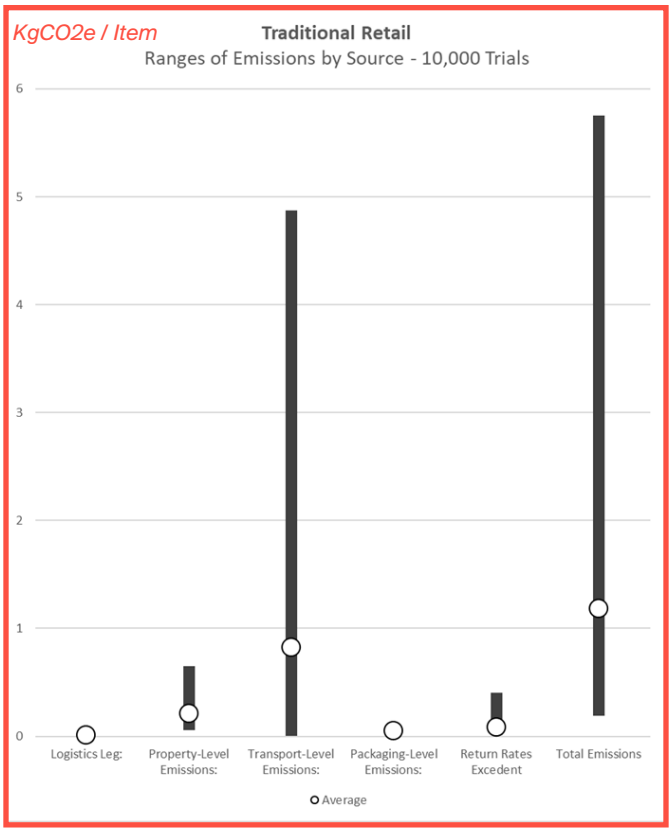
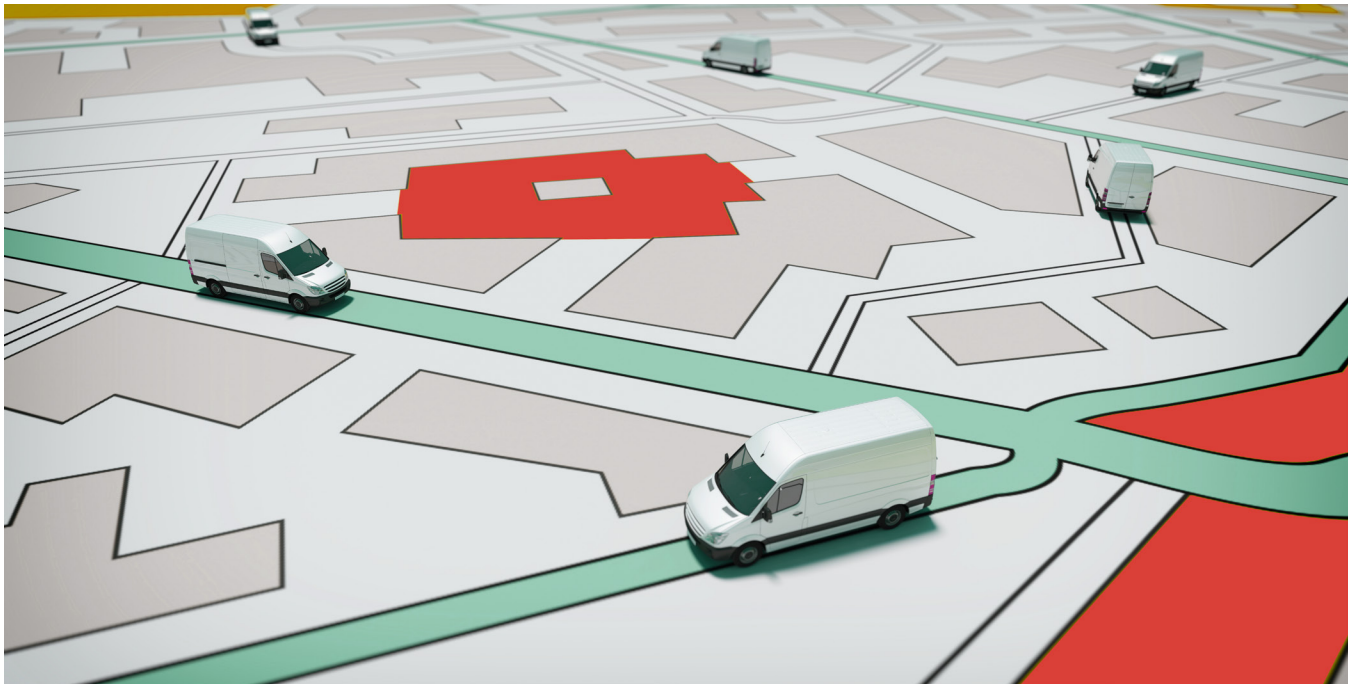


Fig 5. Breakdown of Carbon Footprints by Ecommerce and Brick-and-Mortar Retail.

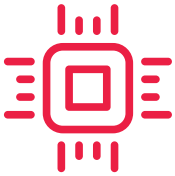
The figures above illustrate the leading factors of GhG emissions for both ecommerce and brick-and-mortar retail. For ecommerce, property-level emissions are the greatest contributor to overall emissions, while transport-level emissions contribute the most significantly in traditional retail.



INTERVENTIONS IN THE SIMULATION: WAYS TO DECREASE THE CARBON FOOTPRINT

"Location, Location, Location"

Optimize real estate location selection and urban planning permitting to limit GHG emissions for supply chain operations.



"Change the Tech"

Technological change will have an impact for both consumers and firms as they switch out their technology.

"Shift the Scale"

What becomes the largest efficiency is changing the scale of goods that can be delivered or brought at one time.

"Nudge the Behavior"

Investing in technology that disrupts the existing modes off delivery will help the system remove carbon emissions substantially.

Technology can help reduce the carbon footprint

In the coming years, we will see a number of new technologies being developed and deployed to help lower GhG emissions. Among these are electric fleets, drones and autonomous vehicles. However, these technological advances will not be a solution until frictions in the ecosystem are fundamentally addressed. For example, drones may help with rural delivery carbon emissions, but in the meantime existing carrier services such as the U.S. Post Office already provide an invaluable service of delivery packages every day. In contrast, clean energy solutions, job growth, decreased GhG emissions and cost-efficient electricity sources for electric and autonomous vehicles are a far more important investment.

Packages and Returns contribute to GhG emissions

Furthermore, we've established that some of the greatest investments we can make in limiting our GhG emissions are in respect to how packages are boxed or returned to stores. In both traditional e-commerce and combined retail strategies, boxes account for some of the largest carbon pollutants in the ecosystem. Removing layers of packaging, changing boxing dimensions to be more efficient, or even removing boxes altogether can reduce carbon emissions by up to 36% percent. Moreover, free returns have led consumers to feel more comfortable adopting ecommerce as a viable retail option, which then leads to an increase in GhG emissions. Further investment in alternative materials, as well as advanced technologies like Reality Capture and Image Recognition – possibly leading to a reduction in returns - can lead to decreased trips and more intelligent packaging.

INTERVENTIONS IN THE SIMULATION: DETAILS

Intervention: "Delivery fleet electrification."
Description: All supply trucks are electrified. Passenger cars are the only vehicles left without electrifying.

Intervention: "Everybody electrifies."
Description: All vehicles are electric, passenger and supply.

Intervention: "I own a Prius."
Description: All passenger vehicles are hybrid (tailpipe GHG is less than 256).

Intervention: "I own a Tesla."
Description: All passenger vehicles are electric (GHG is equal to mileage * jurisdiction electricity GHG intensity).

Intervention: "Bundle Packages."
Description: Average product per shipped box is 2.0.

Intervention: "Let's go shopping."
Description: Average basket size for the traditional retail consumer is 10.0 products on average per shopping trip (base case uses 2.60 on average).

Intervention: "Locker use."
Description: Last-delivery vehicle does not deliver to individual addresses, but rather to a centralized location (reduces the distance of the last portion of the drop trip for ecommerce).

Intervention: "Region 1 Hyperurban."
Description: Uses only urban metro jurisdictions such as NYC Metro, LA Metro, Chicago Metro, South Florida Metro, etc.

Intervention: "Region 2 Coastal."
Description: Uses only state-level jurisdictions which have a direct access to an ocean. Examples include Florida, Texas, Oregon and Maine.

Intervention: "Region 3 Noncoastal."
Description: Uses only state-level jurisdictions which do not have direct access to an ocean. Such as Ohio, Wyoming, Michigan, Nevada, etc.

Intervention: "LastTouchTM Facility."
Description: Utilizes Q-zero (minimum distance) for the second distance quartile of the properties trip to an address. In other words, last-mile facilities are shifted to have the same average distance as traditional retail stores.

Intervention: "No boxes."
Description: Reduces 80% of cardboard boxes for ecommerce and replaces them with the GHG emissions of paper bags.

Intervention: "Out for a hyperurban walk."
Description: Uses only urban metro jurisdictions and reduces all emissions for the passenger vehicle, as this element is replaced by a zero-emissions transport mode. Such as walking or biking.

Intervention: "Restrict Returns."
Description: Reduces 50% of ecommerce excess-GHG attributed to returns. This intervention reduces ecommerce returns to approximately 15% overall. Traditional retail has an average of 7.5%.

AVERAGE AND OUTLIER TRIAL OUTCOMES FROM SIMULATIONS

In the "Urban Last-Mile Facility" scenario, the location improvement accounts for a 50% decrease in all emissions coming from the transportation source. This strategy, combined with making vehicles more efficient, can bring the urban shopper further from the point of indifference between choosing ecommerce or driving to the nearest store, helping cement the advantages of the former.

In an extreme case, the savings from "Urban Last-Mile Facility" could be so important as to even render shopping trips using public transport equivalent to ecommerce.

In the "I Own An Electric" scenario, on average, increasing the efficiency of the personal shopper vehicle effectively enables the brick and mortar shopper to engage in personal trips over ordering online because the emissions lower by such a substantial amount that it makes the shopper indifferent to both strategies, from a carbon emission point of view.

Moreover, in an extreme case where the shopper belongs to a jurisdiction with a low fossil fuel component in electricity, it could even result in surplus emissions for ecommerce, when comparing. This effectively unburdens the shopper from any inefficiencies in the system.

In an "Everybody Electrifies" average scenario, ecommerce will not be able to compete with brick and mortar if the shopper electrifies, unless a more efficient alternative delivery vehicle contender appears. Or, unless the composition of electricity country-wide is cleaner.

In the case that the carbon-conscious shopper does not wish to purchase an EV, they should know that they can always increase the amount of products purchased in a single click. In the "Bundles Packages" scenario, on average, a shopper can make significant reductions that can result in 30% less total emissions when ordering two or more products that fit inside the same box.

However, it also turns out that bundling items in brick-and-mortar shopping has a much more impactful effect than bundling in ecommerce. As emissions get reduced by 50% in total when purchasing 10 or more products in a single car trip.

According to the "No Boxes" scenario, a retailer who is willing to eliminate a significant portion of the boxes will see 36% of the total ecommerce emissions reduced. This is an easy target to achieve by ecommerce retailers that can substantially tilt the balance in their favor.

In the "Restrict Returns" scenario, a shopper can become more informed about the sizing and qualities of the product they are ordering and restrain from returning items. By doing so, they improve the overall efficiency of the system and the carbon footprint. In an extreme scenario, where an online retailer uses augmented reality capture to reduce almost all returns while maintaining the same volume of orders, the shopper will achieve similar revenue margins to those of brick and mortar with a much more carbon-clean operation.

Lastly, the "Out For A Walk" scenario has the lowest footprint for traditional retail, less than ecommerce in 100% of the cases. As transportation carries such a consequential weight for the brick and mortar channel, this means that any effort to aminorate this part will yield great results.

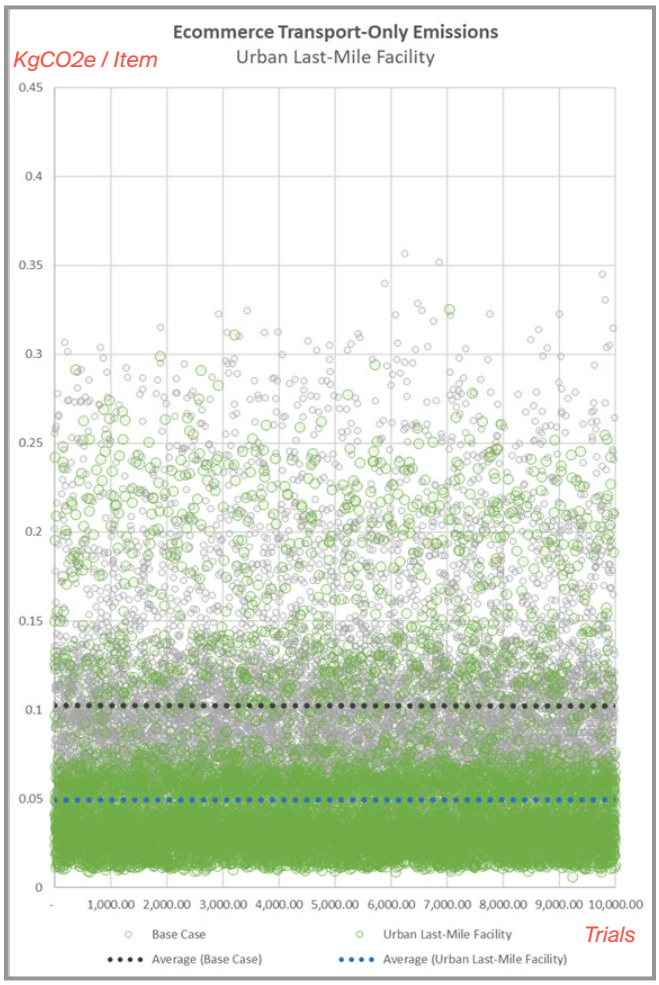
Only in the extreme event that fulfilment can also be done from within the same urban area, and using efficient EVs for delivery, will ecommerce pose competition for brick and mortar, in carbon terms.

As a comparison between strategies;

- Reducing 80% of the packaging in ecommerce will save only half of emissions than a brick and mortar shopper who elects to buy 10 products or more.
- Reducing 80% of the boxes also carries similar savings in percentage than electrifying the personal car, however in absolute terms the electric personal car saves almost twice the emissions than the reduced boxing.
- Consolidating orders in ecommerce helps reduce half of the emissions that would otherwise be reduced by using a personal electric vehicle.
- Similarly, a trip done by foot saves twice the amount of emissions than an EV car trip.

INTERVENTIONS IN THE SIMULATION: SHIFTING THE CARBON FOOTPRINT

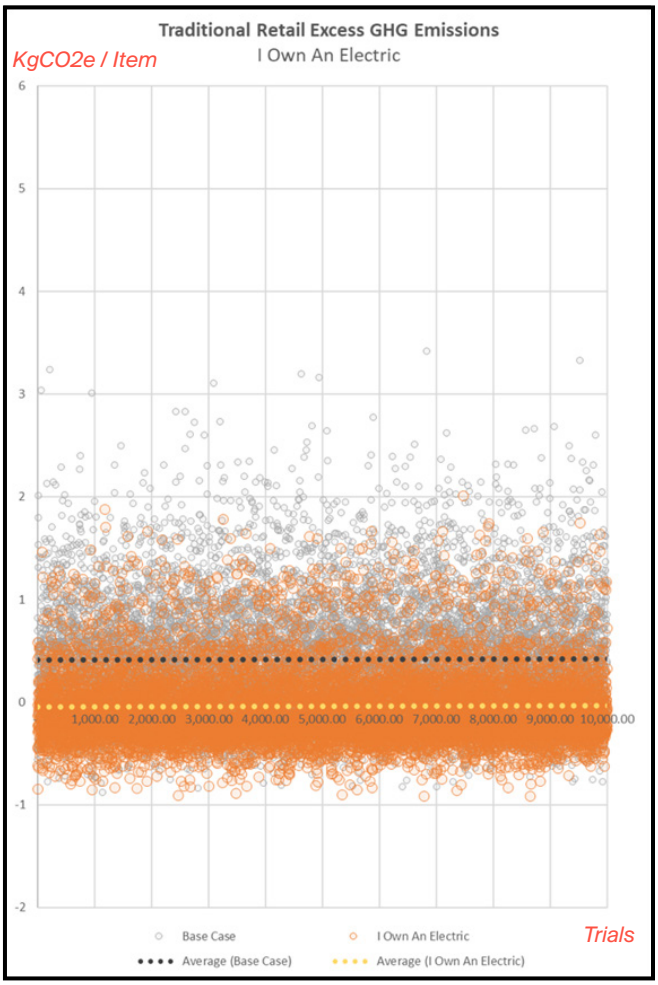
"Location, Location, Location"



This graph indicates that the average emissions from the ecommerce activity see littler change when incorporating this scheme. This is due to added inefficiencies in the process and to inconveniences, which could translate to consumers being required to use a passenger vehicle to gather their items. It also represents greater use of square footage and installing facilities capable of handling packages.

Key Recommendation:
Logistics and supply chains can choose better locations to distribute packages from.

"Change the Tech"

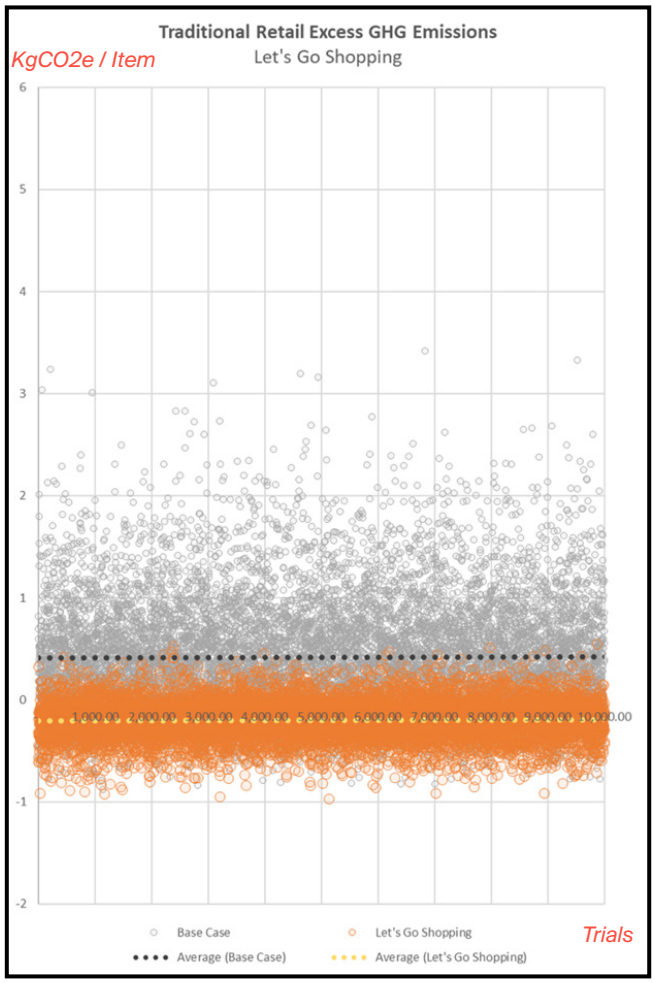


The graph above shows a scenario where the passenger vehicle, used by the traditional consumer, is electric. In this market, manufacturers – such as Tesla – demonstrate efficient passenger EVs that pose a substantial reduction of GhG emissions in the most intensive leg of the traditional shopper channel: transportation.

Key Recommendation:
Switching to EVs will make a tremendous impact on lowering GHGs, but this does not suggest consumers should increase their trips to stores.

INTERVENTIONS IN THE SIMULATION: SHIFTING THE CARBON FOOTPRINT

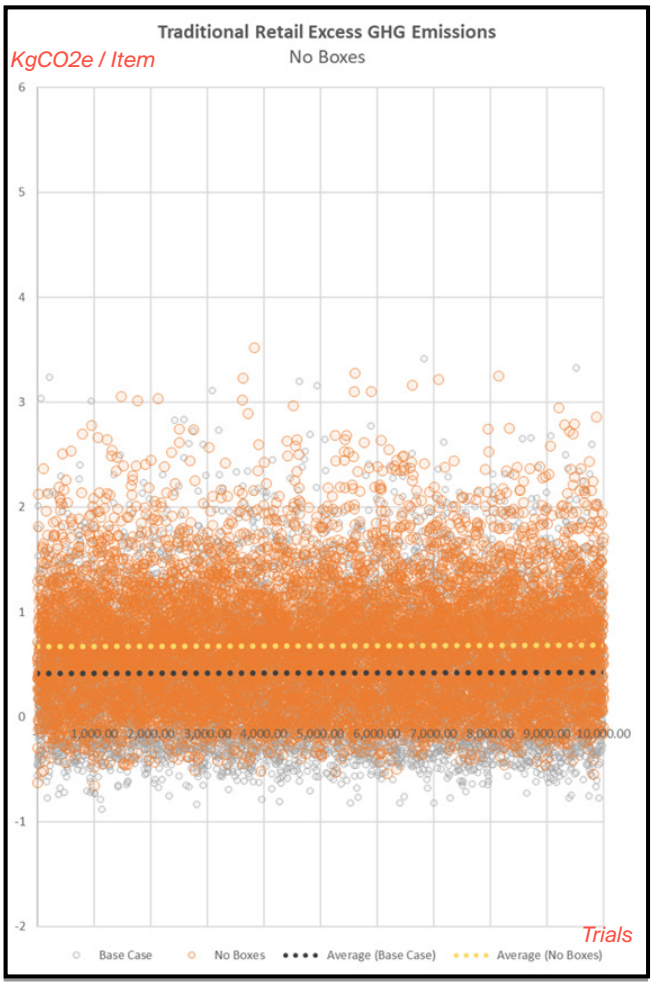
"Shift the Scale"



An innovation that greatly reduces the emissions in traditional shopping is ordering in larger quantities. In the base case, the average basket size is 2.60 product per purchase in a traditional retail store. If this number is increased to 10 products per purchase, the negative impact of traditional shopping is minimized by almost four-fold. This results in the average traditional retail case in our simulation to become more environmentally-friendly than ecommerce.

Key Recommendation:
Consolidate shopping trips by buying items in bulk when doing brick-and-mortar shopping.

"Nudge the Behavior"



Perhaps the clearest case of emissions reduction in our study is that of the traditional retail hopper in large urban centers who elects not to use a car and instead walks or bikes to the nearest store. This is the case for most Americans living in large cities. This scenario reflects savings of up to 69% over ecommerce.

Key Recommendation:
Walk to the store, if you can. Urban or enhanced mixed use development that centralizes consumption is best for health and the environment.

INTERVENTION SAVINGS SUMMARY

in Table 2, we summarize the outcomes of 12 interventions, across four different geography types to result in just under half a million trials. This big data helps us to glean where there is sensitivity within consumer behavior outright, and where changes by stakeholders can be made to help minimize carbon foot prints. Our results point to important changes that real estate can make to improve site selection to minimize transportation distances. Consumers can conciously bundle their goods, walk to pick them up or increasingly switch to EVs. Urban planners can actively choose to consider carbon footprints in their zoning decisions. Finally, everyone can work to minimize returns and card board box consumption. These two factors create a significant rebound in the amount of carbon emissions that each package contributes.

A	B	C	D	E	F	G
Name	Ecommerce has more emissions in (Trials):	Trad. Retail has more emissions in (Trials):	Avg. Emissions for Ecommerce (kgCO2e / Item):	Change in Emissions over Base Case (Ecommerce):	Avg. Emissions for Traditional Retail (kgCO2e / Item):	Change in Emissions over Base Case (Brick-and-Mortar):
Base Case	25%	75%	0.749	-	1.181	-
Urban Last-Mile Facility	21%	79%	0.676	-10%	1.165	0%
Locker Use	23%	77%	0.725	-3%	1.182	0%
I Own An Electric	63%	37%	0.747	0%	0.726	-38%
Delivery Fleet Electrification	22%	78%	0.714	-5%	1.175	0%
Everybody Electrifies	60%	40%	0.713	-5%	0.721	-39%
I own a Hybrid	54%	46%	0.747	0%	0.730	-38%
Bundle Packages	13%	87%	0.528	-30%	1.160	-2%
Let's go Shopping	88%	12%	0.748	0%	0.565	-52%
No Boxes	10%	90%	0.479	-36%	1.177	0%
Restrict Returns	20%	80%	0.653	-13%	1.177	0%
Out For A Walk	100%	0%	0.747	0%	0.366	-69%

Table 2. Intervention Savings Summary.

OVERALL FINDINGS

In the past three decades, one of the asset classes that has seen the most transformation is undoubtedly the retail sector. Advances in technology, innovations in the supply chain, and consumer behavior changes have led property owners and operators to remain in constant evolution to cater to the new needs and trends of their patrons.

The latest and most prominent of these changes over the last few years is the consolidation of ecommerce as a solid contender for the preferred choice of the American consumer. Wooing customers away from the brick and mortar stores and delighting them with new options, such as same-day-delivery, has greatly contributed to this. Impulsed by worldwide events such as the Covid-19 pandemic, ecommerce will continue to evolve and become more ubiquitous in the American shopper's life.

The environmental impact of ecommerce has just started to be explored and quantified by researchers. A necessary question is whether these changes can signify a reduction in the greenhouse gas emissions that threaten to alter the climate and life of our planet. Our research shows that sometimes the behavioral changes that consumers elect to adopt, even if these are simple, can translate into significant savings.

Our research also illustrated how necessary it is to reconsider the basic components of the supply chain and how to solve the issues within. The inefficiencies outlined in our study point towards specific elements and clues to which changes within the real estate sector can be adopted to minimize this impact, such as better locations, more efficient facilities, or being closer to the end customer.

Future Research

Further research will also provide a valuation framework for logistics real estate developers and operators who wish to develop and redevelop properties in areas that will bring increased value to their tenants. The findings of the Monte Carlo simulation can be used to assess the value of particular locations as key drivers to reducing carbon emissions. This environmental impact, when paired together with savings in costs and better customer service, will represent a rent premium that developers can capitalize on.

It will also be pertinent to analyze the relevancy of ESG investment funds and the role companies will have to face as governments worldwide introduce new policies and legislation. We hope our study is also of use for teams seeking to explore net-zero solutions.

“In the end, real estate and urban planning can work together to make a principal contribution to carbon emissions- site selection. Unlike any other form of real estate, retail and ecommerce can make the greatest impact on climate as the location and transportation interaction can fundamentally alter the total emissions for consumers. It should be included in every debate, for every site going forward. ”

DR. ANDREA CHEGUT
MIT REAL ESTATE INNOVATION LAB

APPENDIX I: ASSUMPTIONS

Below is an explanation of each of the assumptions incorporated into the carbon footprint simulation model used.

General Assumptions

GHG of electricity

KgCO2e / kWh

The carbon footprint of electricity is calculated per the basis of kWh used. Every jurisdiction has a different mix percentage of generation sources (gas, coal, nuclear, wind, etc.), and this mix determines the overall environmental impact of the jurisdiction. For this study, data for each individual U.S. state was used. This GHG figure impacts all activities related to electricity for the selected jurisdiction.

Source: U.S. Energy Information Administration (EIA)

Jurisdiction chosen

Population percentage

Our simulation selects a different U.S. state based on the population percentage from the whole. This way, in every trial, larger populations have a higher chance of being selected. For some jurisdictions with large metro areas, such as California and Florida, the population figure for these is separated from the statewide occurrence percentage.

Source: U.S. Census Bureau

Basket Size

Items purchased

For traditional retail, an average basket size was estimated from U.S. consumer data. The basket size varies by product type, so an average was estimated using the ecommerce product types in a particular year.

Return rates

Percentage of total orders

A McKinsey report indicates that ecommerce during the COVID-19 pandemic grew by 100% when compared to the same period in the previous year. This new inflow of ecommerce consumers means that return rates should see an increase in 2020 when we assume a correlation with inexperience. In the future, as these new consumers become more acquainted with this activity, we predict return rates will fall thereafter.

Source: McKinsey & Company

Transportation Assumptions

Vehicle Mileage - Internal Combustion

KgCO2e / mile

The EPA determines the environmental impact per mile of each vehicle in the U.S. market through a standardized testing program. For our study, a threshold was used to select only internal combustion cars (not hybrid) that range from 0.256 to .900 KgCO2e per mile for the base case simulation. Later in the study, an intervention that consists of replacing the passenger vehicle with a hybrid one is introduced.

Source: Environmental Protection Agency (EPA), fueleconomy.gov

Vehicle Mileage - Electric

kWh/ mile

Research was done on the currently available and future electric vehicles (EVs) in the U.S. car market to determine an average mileage. EVs' mileage is calculated as the range in miles of a full battery charge, under regular driving conditions, multiplied by the electricity intensity of the selected jurisdiction.

Source: EV manufacturers, consumer magazines

Vehicle parcel capacity

Packages fulfilled

An estimate was calculated using the cubic space inside each vehicle type divided by the typical package volume. In our study, there are three different delivery vehicle types: a large trailer truck, a smaller semi-truck, and a delivery van used for the last-mile portion of the trip.

Trip Distances

Miles

Locational data from industrial distribution buildings were combined with data from the geographical, population-weighted center for U.S. counties where

these properties are located. Each of the linear distances to the center of the population was then interpolated and adjusted for the traffic grid shape and congestion. The data was distributed and assigned to each jurisdiction based on a selected quartile. In our study, the distance quartiles are fundamental to understanding the variation in miles in every trial, and how the outcome changes depending on which combination of quartiles is used.
Source: Prologis, Inc.

Real Estate Assumptions

Order throughput per property

Orders fulfilled

Fulfillment figures were used to determine the number of orders that pass through a fulfillment property daily under normal operating circumstances. This figure was then weighted using the population percentage in every jurisdiction to estimate the number of properties necessary to serve the entire population. Based on this, we arrived at an average number of orders per property and per jurisdiction.

Energy consumption per building type

kWh / year / SF

A benchmark was used to estimate an average yearly energy consumption per square foot (SF) of gross building area (GBA). This figure is then divided into the order throughout the property in question, and the result is the corresponding emissions attributable to every single package.
Source: GRESB

Packaging Assumptions

GHGs of packaging

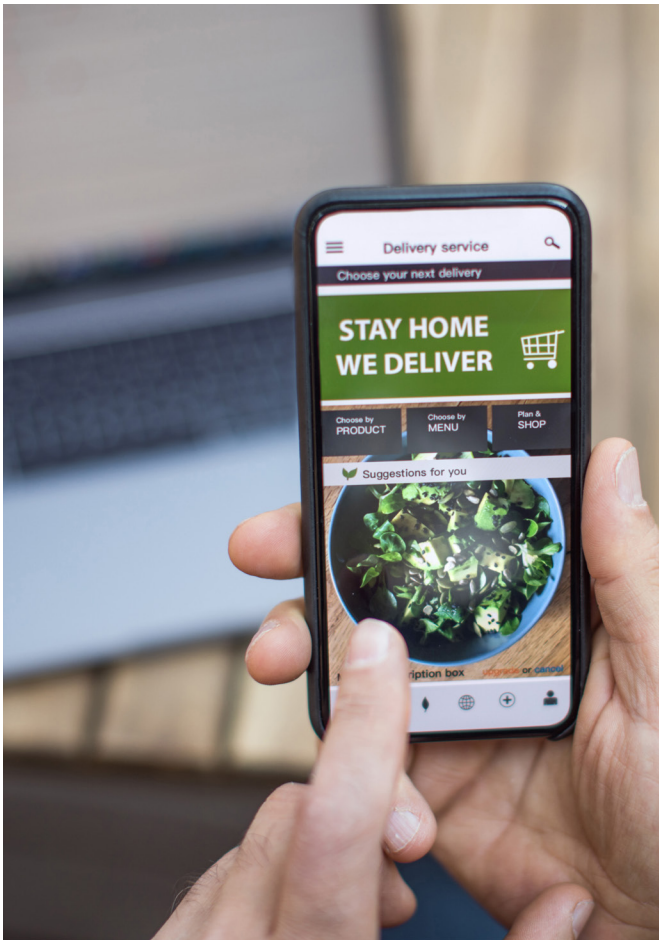
KgCO2e / Kg

We aggregated greenhouse emissions of the cardboard, paper, and plastic components of typical packaging material, and then multiplied by the average packaging weight per order. In the case of traditional retail, only the paper and plastic components were used, as a cardboard box is not typically required. Our source of choice for this information was the most stringent we found. This source considers a total embodied carbon figure for cardboard, inclusive of the manufacturing process.
Source: United States Environmental Protection Agency, Stockholm Environment Institute

Ecommerce sales by type of product

Percentage of orders

Different studies and publications indicate the percentage of each product category that is purchased through commerce. These percentage figures vary by year. Our study encompasses the product mix since 2016 and then predicts what the mix will look like up to 2025.
Source: ProLogis, Inc.



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