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DEPARTMENT OF SUPPLY CHAIN AND INFORMATION SYSTEMS

REVERSE LOGISTICS ANALYSIS OF CARBON EMISSIONS IN THE SUPPLY CHAIN

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ABSTRACT

The purpose of this thesis is to quantify emissions that result from business activities. This is done through the creation of a comprehensive and custom carbon emissions model. Electronic Waste is a large contributor to global warming and greenhouse gas emissions. Companies are becoming more aware of the issue of e-waste, and many have implemented take-back programs and closed – loop supply chains in addition to tracking their carbon emissions. By partnering with a large telecommunications company, this paper works to explore a current closed – loop supply chain and develop a tool to quantify emissions associated with their efforts. It will discuss background information on global warming, electronic waste, and carbon emission tracking. In addition, it will explain the process required to develop an effective model, and discuss the results, limitations, next steps and assumptions utilized. The model is user-friendly, comprehensive and has been given to Company A for implementation and further development.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Chapter 1

Introduction & Methodology

The internet and smart phones have revolutionized our world and the way that we communicate. Major technology companies are constantly launching new products with faster software and increased memory. Consumers now have an average of twenty-eight electronic devices in their household, and while the amount of electronics people have is increasing, the lifespan of electronic devices is growing shorter due to new product creation, technology advancements, and consumer behaviors. ("Basic Information about Electronics Stewardship", 2017) As products release, consumers simply scrap their working cell phones, tablets, and laptops in order to purchase the newest and fastest products on the market. The growth rate of mobile devices alone is five times the growth rate of the global human population. (Boren, 2014)

This leads to the ever-growing problem of waste from electrical and electronic equipment (WEEE), which is referred to as e-waste. Electronics that are improperly disposed of find themselves sitting in landfills around the globe, contributing to harmful effects on the population and the planet. According to the United Nations, twenty to fifty metric tons of e-waste is generated each year. (Bhutta, 2011) The UN does not expect these numbers to slow at any point, and instead anticipates that global e-waste volumes will continue to grow by thirty-three percent in 2017 alone. (Button, 2016)

Currently, the United States produces more e-waste than any other country in the world. Americans throw away 9.4 million tons of electronics annually, and only 12.5 percent of it is recycled correctly. (Button, 2016) The majority of e-waste finds its way to landfills or toxic wastelands where harmful heavy metals release into the atmosphere, ground, and water resources. E-waste that does not go to a landfill is exported overseas into third world countries and impoverished communities. Members of these communities often attempt to extract the precious metals, which can release harmful substances, such as lead, into the environment, increase carbon emissions in the atmosphere, and cause major health issues among members of the community. (Bhutta, 2011)

These staggering facts have led to the creation of several national and worldwide organizations in an effort to combat e-waste. About twenty-five states currently have their own laws regarding proper disposal of electronic waste. The National Strategy for Electronics Stewardship (NSES) and the Environmental Protection Agency (EPA) work to combat e-waste and encourage recycling and "green" purchasing. NSES works to increase the safe handling of used electronics, improve U.S. exports in developing countries, and create incentives for environmentally preferable electronics. The overarching goal is to increase our recycling efforts while minimizing the waste in order to limit the exposure to harmful e-waste. (EPA, 2017)

The Environmental Protection Agency (EPA) and the International E-Waste Management Network work to identify "green" electronic products and build an environmentally safe waste management system for electronic devices.

In addition to national organizations, companies are taking it upon themselves to be socially responsible with e-waste. "Take back programs" and closed loop supply chains are increasing in popularity, as companies attempt to reuse and recycle their materials. Not only does this benefit the environment, but also is often coupled with financial incentives as well. Refer to Figure 1 for an example of a closed loop supply chain. Many companies are beginning to track their carbon emissions to understand how their waste is affecting the environment. The Carbon Disclosure Project (CDP) runs the global disclosure system that allows companies, regions, cities, or states to measure their environmental impact, and houses the largest and most comprehensive collection of self-reported environmental data in the world. In the most recent report, which tracked 1,089 companies, twelve percent of global GHG emissions were represented. The number of companies who have started self-reporting to the CDP has grown steadily, indicating that tracking carbon emissions is extremely important, and provides opportunities to significantly reduce carbon emissions that result from electronic waste. (CDP, 2016)

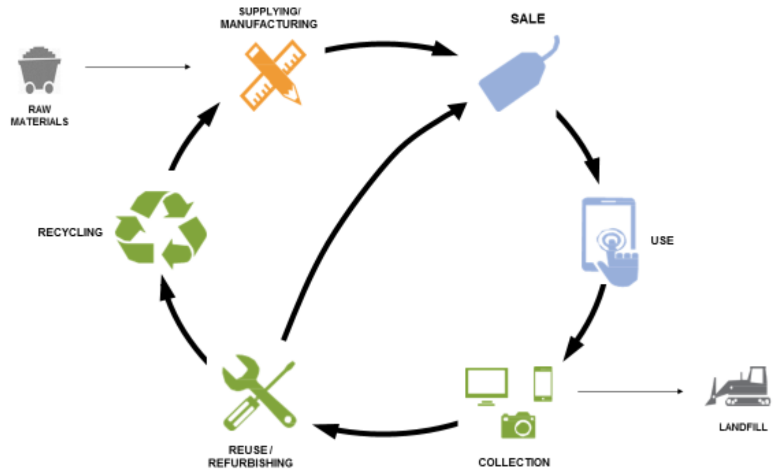

Figure 1: EPA Diagram of an E-waste Closed Loop Supply Chain

Tracking emissions, specifically for electronic waste, is imperative in order for a company to reach their sustainability goals. This thesis will discuss the real-world implications of carbon emissions in reverse logistics systems. In collaboration with a large telecommunications company, this thesis results in a comprehensive carbon emissions model to calculate current emissions expelled annually for the telecommunication company's electronic set top box devices. This will provide a baseline for their current electronic reverse logistics set up and offer recommendations to improve their methods for electronic waste disposal.

The remainder of this thesis will provide background information on global warming to preface the importance of establishing well developed reverse logistics programs to minimize the emissions released into the environment. It will also discuss the process used to develop the carbon emissions model, the results obtained from the completion of the model, and areas that the telecommunications company should focus on improving in the future.

Research in this thesis stems mainly from government sources including databases and online content from the EPA, CDP, and GHG Protocol. The GHG Protocol provides the most commonly used accounting standards for greenhouse gases. 92 percent of Fortune 500 companies use the GHG Protocol when reporting carbon emissions due to the user friendly and comprehensive standardized frameworks, online trainings and tools. (GHG Protocol, 2018) In addition, specific company information was obtained through a corporate contact. The analysis and nature of this thesis results in both quantitative and qualitative insights for electronic waste disposal and greenhouse gas emissions. In an effort to keep proprietary company information private, the company worked with and all individuals associated with this thesis will remain anonymous.

Chapter 2

Company Background

The telecommunications company is a large wireless phone service in the U.S., serving over 146 million customers. In addition, they have more than 18 million customers who utilize their voice connections, providing customers with local telephone service, internet, and digital television. (*Hoovers, 2017*)

A portion of their business is in the television and internet segment. This thesis will refer to this portion of their business as Company A in an effort to protect their privacy. Company A serves mainly the East Coast. Each house served by Company A has an Optical Network Terminal, used to convert a digital fiber optic signal into an analog signal, a router for internet, and two to four set top boxes that receive a signal from the optical network terminal in order to receive television channels. Figures 2 & 3 demonstrate examples of a set top box and optimal network terminal.

Figure 2: Set Top Box

Figure 3: Optimal Network Terminal

Upon the initial meeting, Company A indicated that this project would focus on e-waste relating to their set top boxes. They have a well-established reverse logistics program for their electronic equipment; however, have no quantitative data on the environmental impact of their operation. After much discussion, it was concluded that the most beneficial project scope would be to calculate the current carbon emissions for the set top box reverse logistics program. After identifying the carbon emissions, the analysis would look at the cost of the program, to complete a cost/benefit analysis on the e-waste recycling program in place and their current carbon footprint.

Company A indicated that the key areas for the carbon model would be reverse haul transportation and warehousing, as items returned by the customer are transported back to the distribution center and a clean and screen facility for cleaning, redistribution, and recycling. The model will serve as the base year for carbon emissions and used to set benchmarks and identify areas for improvement moving forward.

Background on Global Warming

Carbon emissions and greenhouse gases have been prominent topics since the early 1950's. Physicist Gilbert N. Plass first theorized that an increase in CO2 consumption would increase radiation, and ultimately raise the average global temperature by 1.1 degrees Celsius every century. While his theories have not been confirmed, they did prove to other scientists that climate change could be a serious problem in the future and identified carbon dioxide as a major contributor to climate change. As more scientists began to reach similar findings on the amount of CO2 in the atmosphere, the public became aware of the impact that greenhouse gases have on the environment. It was announced that the increase in CO2 in the atmosphere by the year 2000 could have measurable changes on climate change. (history.aip.org, 2017).

In 1970, after recognizing that climate change could be a real concern in the future, the U.S. National Oceanic and Atmospheric Administration was founded, which works to predict and understand changes in the climate and weather. ("Our Mission and Vision | National Oceanic and Atmospheric Administration", 2017) A decade later, it came to light that methane and nitrous oxide were also contributing greenhouse gases. The United States Government and the EPA began to encourage establishing an international organization for greenhouse gases. As a result, The World Meteorological Organization and the United Nations Environmental Program created the IPCC (Intergovernmental Panel on Climate Change) in 1988. Its primary purpose is to produce and distribute reports on human induced climate change and to identify ways to slow and ultimately eradicate global warming. (*Oslo, 2017*)

Eventually, this led to the Kyoto Protocol, which became the standard for Carbon Emission Reporting. The Kyoto Protocol is an international agreement, with the goal of setting GHG reduction targets around the world. Originally created from the UN Framework Convention on Climate Change (UNFCCC) at the Earth Summit in 1992, The Kyoto treaty included 191 nations ratifying the agreement when it was finalized in 1997 (Rough Guide to Climate Change, 2011). This treaty required signing nations to cut their annual emissions by an average of 5.2 percent by 2012. In 2001, the United States dropped out of the agreement, and as of 2014, the U.S. was identified as one of the largest contributors to greenhouse gases. In 2015, a new agreement, the Paris Agreement, replaced the Kyoto Protocol in order to limit planet warming to below two degrees.

Green House Gases and the GHG Protocol

Greenhouse gases are the largest contributor to global warming and climate change since the twentieth century. From 1990 to 2010, emissions increased by thirty-five percent, mainly due to human activities such as transportation and electricity. The EPA reports that carbon dioxide is the biggest contributor to global warming, accounting for over seventy-five percent of the greenhouse gases in the atmosphere, and the amount emitted into the atmosphere is steadily increasing. (Climate Change Indicators: Global Greenhouse Gas Emissions", 2016) As the greenhouse gases increase in the environment, a change occurs in the Earth's energy balance, and this causes a warming effect over time.

Each Greenhouse Gas is associated with a global warming potential, which compares the warming effect of different gases on a common scale. The global warming potential (GWP) identifies how much energy one ton of a gas will absorb over one hundred years in relation to carbon dioxide. Having GWPs makes it easy to quantify total emissions released into the atmosphere and identify emission reduction opportunities. Table 1 below provides further detail on the main greenhouse gases and their respective global warming potential. ("Climate Change Indicators: Greenhouse Gases", 2017)

Table 1: EPA Major Long-Lived Greenhouse Gases and Their Characteristics

Greenhouse gas	How it's produced	Average lifetime in the atmosphere	100-year global warming potential
Carbon dioxide	Emitted primarily through the burning of fossil fuels (oil, natural gas, and coal), solid waste, and trees and wood products. Changes in land use also play a role. Deforestation and soil degradation add carbon dioxide to the atmosphere, while forest regrowth takes it out of the atmosphere.	see below*	1
Methane	Emitted during the production and transport of oil and natural gas as well as coal. Methane emissions also result from livestock and agricultural practices and from the anaerobic decay of organic waste in municipal solid waste landfills.	12.4 years**	28–36
Nitrous oxide	Emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.	121 years**	265–298
Fluorinated gases	A group of gases that contain fluorine, including hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride, among other chemicals. These gases are emitted from a variety of industrial processes and commercial and household uses and do not occur naturally. Sometimes used as substitutes for ozone-depleting substances such as chlorofluorocarbons (CFCs).	A few weeks to thousands of years	Varies (the highest is sulfur hexfluoride at 23,500

As GWP's were recognized and the U.S. and nations around the globe began taking strides to reduce greenhouse gases, a protocol was developed to help calculate carbon emissions. The Greenhouse Gas Protocol (GHG Protocol) identifies a standardized framework to both measure and combat greenhouse gases. It provides guidelines for companies on how they can correctly measure emissions from electricity, in their value chains, and in their daily consumption. They have calculation tools directly in line with the Paris Agreement to make sure countries, cities, and businesses alike are all working towards reducing climate change. The corporate standard that they have established covers the seven main greenhouse gases that the Kyoto Protocol uses. These include CO2, methane, nitrous oxide, HFCs, and PCFs. ("About Us: GHG Protocol", 2018) This thesis will use the greenhouse gas protocol to determine emissions specifically for CO2, methane, and nitrous oxide, the three largest contributing GHGs.

There are two different approaches to develop carbon emissions models. The first is an equity share approach, which calculates a company's emissions from operations based on the portion of equity that they have in the production. The second is the control approach, which has companies reporting on one hundred percent of GHG emissions for all operations that it is completely responsible for. If the company does not have control over something, it does not include it in its GHG reporting. The GHG Protocol document provides guidelines to users through all stages of the GHG accounting and reporting. It leads the user through calculating the base year, setting boundaries, and recalculating for subsequent years. (Ranganathan, et al. 2015)

Setting Operational Boundaries

In this thesis, the control approach is utilized, accounting for one hundred percent of emissions that Company A has financial and operational control over. Once the approach has been determined, the next step in creating a carbon emissions model is to identify boundaries for the calculations. GHG emissions are classified as either direct or indirect emissions. They are broken down into various classification levels, known as different scopes. Three scopes exist, each covering different subsets of GHG emissions. The first scope is for direct GHG emissions, resulting from the production process, company vehicles, or any actions that are directly owned or controlled by the company. Scope two is for indirect electricity emissions. This is used to account for energy that is purchased and consumed by the company. Scope two emissions occur directly at the plant where electricity is being generated. The third and final scope is for any other indirect emissions not already reported. The excerpt below discusses the main emissions found from scope three.

“Scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company. Some examples of scope 3 activities are extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services.”

(Ranganathan, et al. 2015)

Scopes one and two are required for reporting purposes, while scope three is optional. All three scopes offer a comprehensive structure for identifying, calculating, and reporting emissions from the main GHGs. Chapter four of the GHG Protocol provides in - depth explanations and examples of each of the three scopes to allow companies to correctly identify and account for the appropriate emissions. In order to avoid double counting, each scope is broken down into extremely specific activities. Figure 4 provides an example of the types of activities found in each scope.

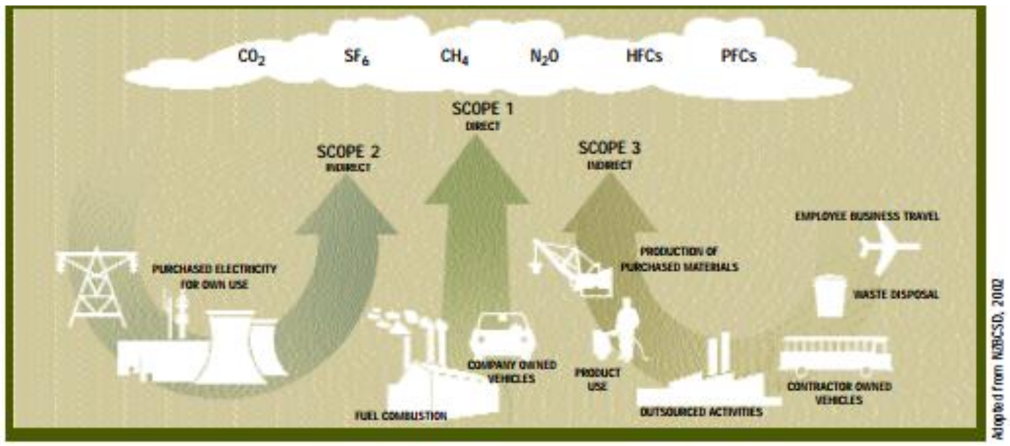

Figure 4: GHG Protocol Scope Emissions

Identifying Emissions Factors

After setting operational boundaries, identifying which scope each portion of the business falls within, and deciding whether to use the equity share or control approach, the correct emission factors need to be assigned. These can be obtained through the EPA, who releases the appropriate emissions factors annually for different fuel, vehicle, and energy types. The emissions factors estimate the amount of emissions released from air pollution and usually consist of long-term averages. Different emission factors exist for each greenhouse gas and are used in calculations.

Once each GHG is identified, an emissions factor has been assigned, and the GHG emissions are identified, each scope must be multiplied by its global warming potential (GWP). The greenhouse gases are added together for the carbon dioxide equivalent (CO2e), which is the standard measurement for carbon footprint.

Chapter 3

Carbon Emissions Model Development

Company A requested a custom carbon emissions model be developed. This allows for customization and usability. The model can be continually referenced, updated, and refined across all product lines. The calculations and methodology included in the GHG Protocol led to the development of this carbon model.

The model focuses solely on the reverse logistics operations in Company A's facility. Specifically, it identifies quantities and accounts for all activities that generate emissions, from the time a set top box leaves a customer's home, until the set top box arrives at the distribution center, is refurbished, and returned back into the product life cycle.

The first step is to create process maps of the current operation. This is completed in order to ensure that every step of the process is accounted for. There are currently three different routes that can be used to have a customer's unit returned. Emissions stem primarily from fuel and transportation (scope 1 emissions) and purchased electricity (scope 2 emissions). Scope 1 emissions occur from owned and operated Company A vehicles, 3PL companies, and customers' personal vehicles.

The model consists of separate tabs with individual calculations; one tab for each set top box return option, one for scope two purchased electricity GHG calculations, and one for the transportation that occurs to move all set top boxes from the distribution center to the clean and screen facility. For all segments, each individual greenhouse gas emission is calculated, then multiplied by their respective GWPs (1, 28, 265) and finally, consolidated into one carbon dioxide equivalent (CO2e).

The EPA offers a document to identify emission factors by vehicle and fuel type, which is seen in Table 2 below. A heavy reliance was placed on this document in order to correctly quantify emissions for the different modes of transportation utilized. Company A uses solely over the road transportation for their reverse logistics program. Medium and heavy – duty trucks are the primary vehicles used, however light – duty trucks and passenger cars are also used. Emission factors differ depending on the vehicle used and whether weight needs to be accounted for. If weight is negligible, vehicle-miles is the correct unit of measurement. However, if full truck loads are used, weight is an important factor for the calculations. In these instances, ton-miles are the correct units, and different emission factors are assigned.

Table 2: EPA Product Transport Emission Factors

Vehicle Type	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Medium- and Heavy-Duty Truck	1.430	0.015	0.013	vehicle-mile
Passenger Car [A]	0.355	0.021	0.015	vehicle-mile
Light-Duty Truck [B]	0.485	0.020	0.022	vehicle-mile
Medium- and Heavy-Duty Truck [C]	0.146	0.0015	0.0014	ton-mile
Rail	0.024	0.0019	0.0006	ton-mile
Waterborne Craft	0.059	0.0005	0.0040	ton-mile
Aircraft	1.307	0.0000	0.0402	ton-mile

Option One: Technician picks up set top boxes

The most expensive and least frequently used option to return a set top box is to have a company technician make house calls to perform a complete disconnect. This process can be seen in Figure 5. The set top boxes are returned to the local garage warehouse center that the technician works out of. From there, boxes are shipped in partial truckloads to transportation hubs. They are then transported to the distribution center located in Pennsylvania. This option is used eleven percent of the time for STB returns, which totals to 265,000 set top boxes annually via technician pickup.

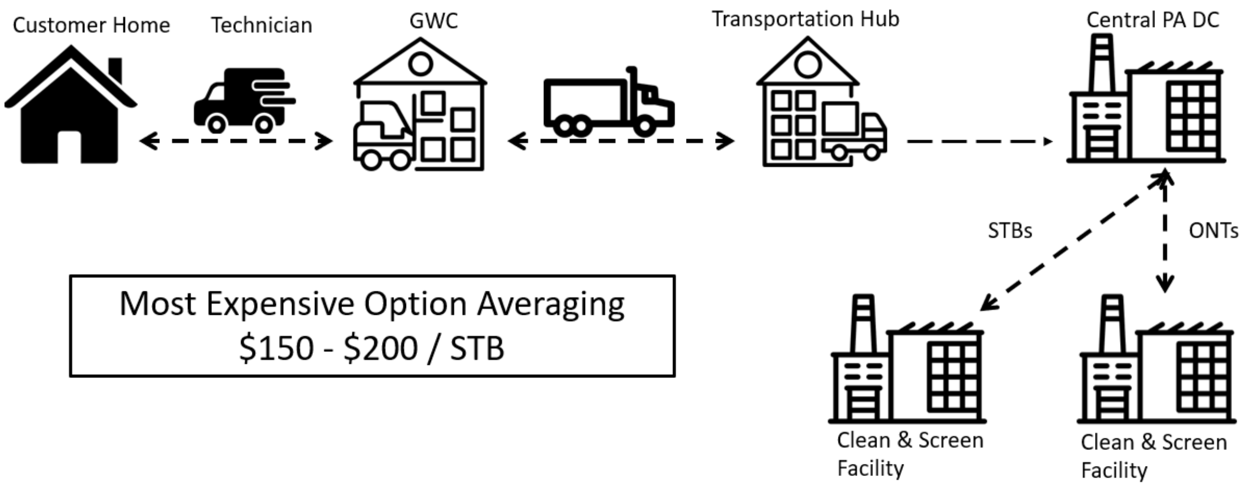

Figure 5: Technician Performs In-Home Disconnect

To calculate GHG emissions for this portion, the model separates each leg of the trip based on the vehicle used and the distance traveled. To estimate the distance technicians must travel to reach customers and return to their garage work centers, a reliance on assumptions and guidance from Company A is required. The vans carry an average of three set top boxes at a time and are not full truck loads. Shipment weight for this portion of the model is negligible. After estimating distances and identifying vehicle emission types, three calculations are run to calculate CO2, CH4, and N2O emissions based on a light-duty truck using motor gasoline. The equation below offers a sample for the methodology used for these calculations.

$$Leg\ 1\ CO2\ Emissions$$
$$= (Shipment\ Distance\ \times\ CO2\ Van\ Emission\ Factor\ )$$
$$\times Number\ of\ Technicians \times days\ worked\ per\ year$$

The set top boxes are sent from a GWC to the closest transportation hub. VBA coding automates calculations for all distances between garage work centers (GWCs) and transportation hubs. Technicians are currently placed at one hundred and seventy different locations across the east coast. The VBA code efficiently identifies the latitude and longitude of all GWCs by connecting to Google API services. Google API is an application-programming interface that allows users to integrate Google Services with other operations. In this model, Google API enables the code in excel to effectively launch Google Maps, run the addresses, and retrieve the latitude and longitude of a specific address. If any additional GWCs are added to their network, Company A can easily inject the new address into the model, and the latitude and longitude field will quickly be populated. The code used is found in Appendix A. Once the latitude and longitudes have been retrieved, the Haversine formula[1] is used to quickly and effectively gauge the distance between a GWC and all of the transportation hubs. The Haversine formula is a navigation equation that calculates the shortest distance over the earth's surface between two different locations. Once distances are calculated, it shows which transportation hub each GWC ships to.

After identifying the closest transportation hub for each GWC, a similar methodology using the vehicle type, distance, and emissions factor is followed to calculate emissions. In instances where weight is not negligible, calculations are refined to account for the weight of the shipment.

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[1] Distance = ACOS(COS(RADIANS(90-LAT1)) *COS(RADIANS(90-LAT2)) +SIN(RADIANS(90-LAT1)) *SIN(RADIANS(90-LAT2)) *COS(RADIANS(Long1-Long2))) *3958.76

A standard tractor trailer holds fifty-two pallets. Each pallet has seventy-two set top boxes, resulting in 3,744 STBs per truck. A reference table included in the carbon emissions model allows one to choose the model of the set top box that is being transported. There are thirteen different models of set top boxes that can be placed in customer homes. The weights range from less than one pound to eight pounds. For mixed shipments, an average weight of 5.86 pounds is used. These models can be seen in Table 3.

$$Emissions = (Distance\ traveled\ \times Emissions\ factor\ \times (Weight\ of\ STB \times Number\ of\ STBs\ per\ truck)$$

Table 3: Set Top Box Weights

STB Weights

Lot	Model	Overall Weight (lbs)	Main	Power Supply
1	CHS335HD	4.77	1.5595	0.42
1	CHS435HD	7.51	2.1095	0.38
2	QIP2500	5.6525	0.9835	0.6915
2	DCT700	0.8985	0.49	0
3	QIP6416-2	8.4365	1.2425	0.8155
3	QIP6200	7.1535	1.2466	0.818
3	QIP2708	8.535	1.1785	0.816
4	QIP7100	3.578	0.9355	0.271
4	QIP7216	8.3345	1.1955	0.8235
5	QIP7232	7.027	1.0135	0.4065
5	QIP7216-2	8.3345	1.1955	0.8235
6	IPC1100	0.877	0.3875	0
6	VMS1100	5.0855	0.867	0
	Average	**5.860961538**		

After STBs arrive at the transportation hubs, they are shipped in full truckloads to the distribution center in Pennsylvania. Three tractor trailers per day travel to/from each transportation hub to the DC. Since the STBs are returned via backhaul, only a portion of the emissions is allocated to reverse logistics.

Once all N2O, CO2, and CH4 is accounted for in Option One, all emissions are multiplied by their respective global warming potentials (GWPs) and converted into metric tons. All emissions are then added together to quantify the CO2e metric tons released into the atmosphere for the Option One.

Option Two: 3PL Service with UPS and Fedex

The second option is to have the customer ship set top boxes back via FedEx or UPS. This process can be seen in Figure 6. Company A ships an empty cardboard disconnect kit out to customers that opt for this option. The customer will pack up their units and ship them back to Company A's distribution center. The emissions that result from utilizing a 3PL fall within scope one emissions. 3PL's are utilized forty-seven percent of the time for Company A's return system. This results in 1.13 million set top boxes being sent back to Company A annually via a 3PL.

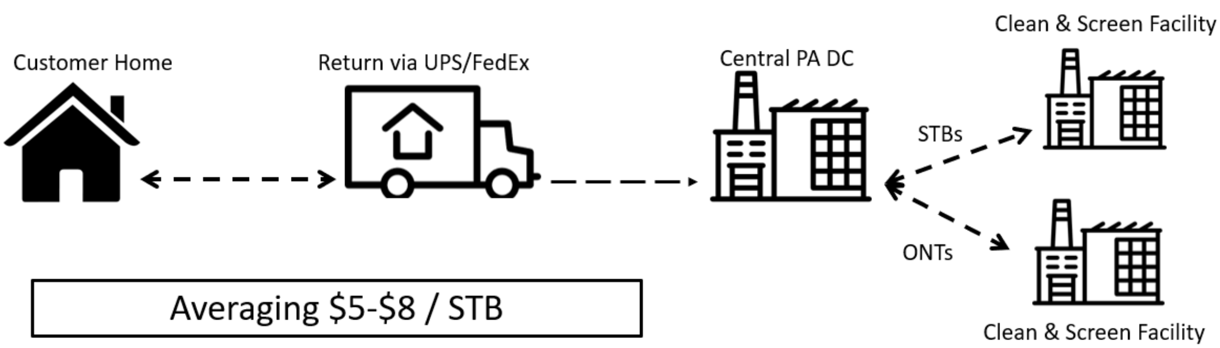

Figure 6: STBs Returned Via 3PL

Calculating emissions for this option relies heavily on stated assumptions. Distances between customers' houses on the East Coast and the final destination in Pennsylvania are systematically estimated and accounted for in the model. The different regions where customers are located, and the miles from these regions back to the PA distribution facility are calculated. On average, the mean distance traveled back to Company A's Distribution center is 199 miles. The average UPS tractor trailer is estimated to have a 65,000-pound weight capacity. Calculations are run for the shipment of empty cardboard disconnect kits to the customer's home as well as the return shipment of both the cardboard kit and set top box. It is estimated that the closest UPS/Fedex terminal network is fifty miles from the shipping origin. In addition, the marginal mileage added for a UPS driver to deliver one package is determined to be one mile.

Once these assumptions are stated, calculations can be completed. Six different calculations are performed; three for the empty disconnect kit, and three for the full disconnect kit and set top box. Emissions are totaled for the distance between the DC to the 3PL terminal network, the terminal network to the customer region, and finally, the last marginal mile that the UPS driver will travel. An example of the calculations completed is shown below.

$$Emissions = Emissions\ Factor\ x\ Avg\ distance\ travelled\ x\ \left(\frac{weight\ of\ package}{weight\ capacity\ of\ 3PL\ truck}\right)$$

The marginal mile was included to determine the environmental effect added by travelling to one additional customer for drop-off / pickup. For this calculation, all emissions from the 3PL are dedicated to the set top box. The calculation for the marginal mile can be seen below.

$$Marginal\ mile\ emissions = Emissions\ Factor\ \times 1\ marginal\ mile$$

After completing the six calculations for each greenhouse gas (CO2, CH4, N2O), each is converted to metric tons and multiplied by their respective GWP (1, 28, 265). They are then summed to provide the total emissions released for this option.

Option Three: Company A Store to DC

The third and final option to return set top boxes is to have the customer drive to one of the ninety-five Company A brick and mortar stores with drop-off capabilities. This process can be seen in Figure 7. Set top boxes are returned daily via backhaul on near empty tractor trailers through Company A's regional distribution network. Forty-seven percent of the time, customers opt to return their set top boxes via this option. One million units are delivered to brick and mortar stores each year.

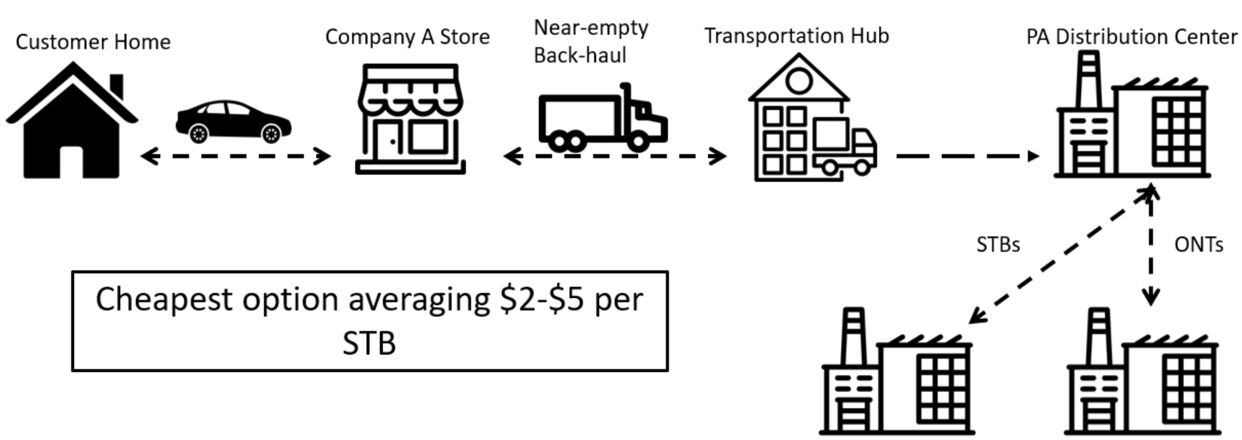

Figure 7: STBs Returned to Store

Each portion of Option Three is calculated separately due to the different vehicles utilized for transportation. A process similar to Option One was used for these calculations. A dropdown menu offers flexibility to choose the correct vehicle for each leg of the journey. Once a vehicle type is chosen, the correct emission factors auto populate. It is estimated that the average customer will make a dedicated trip to deliver the set top box, and that a drop off location will be within fifteen miles of their home. Weight was considered negligible for the customer’s drive and for the daily near-empty backhauls traveling from the brick and mortar facilities to the transportation hubs. Refer to the equation below for a sample of the calculations performed for this route. After each emission has been accounted for, it is converted from pounds to metric tons, multiplied by its GWP and then accumulated into one standard CO2e total.

$$Emissions = (Shipment\ Distance\ \times\ Emission\ Factor\ by\ Vehicle \\ \times Weight\ (unless\ negligible))$$

Distribution Center to Clean & Screen Facility

An average of 2.4 million units are returned across all options each year. They eventually travel from the distribution center to the clean and screen facility. Round trip, the distance between these two locations is 76.55 miles. The clean and screen facility tests each unit to ensure its operability, then cleans, polishes, and buffs them. They are then sent back to the distribution facility for reuse.

A tab in the model was dedicated to this route since every single item returned will travel between the two locations. It was determined that 644 tractor trailers would be used each year for this route ($\frac{2.4\ million\ STBs}{3744\ STBs\ per\ truck}$). Using a mixed shipment weight of 5.86 pounds per STB, the weight of the shipment per tractor trailer is determined to be 10.9717 tons. This calculation can be seen in Table 4.

Table 4: Shipment Weight Calculations

Set top Boxes per truck	3744	Set top Boxes
Set top box model number1	Average	
Box Weight1	5.86	lbs
Shipment Weight (lbs)	21943.44	lbs / truck
Lbs to tons Conversion	0.0005	tons
Shipment Weight (tons)1	10.9717	tons

Once the weight and the distance are identified, it is possible to calculate emissions for CH4, N2O, and CO2. The calculations performed are as followed:

$$Emission = (76.55\ miles\ \times\ emission\ factor\ \times\ 10.97\ tons) \times 644\ trips$$

The calculations are run for each GHG separately before being multiplied by their GWP and summed into one total CO2e emission.

Electricity Calculations

For the warehousing and electricity model, Company A was able to provide square footage, average utility bill costs, and an estimate of the percentage of utilities allocated for set top box activity. From these estimates, the kilowatt hours per year were calculated. The average price per kilowatt hour for a Pennsylvania warehouse is nine cents. This was multiplied by the kilowatt hours per year to have an accurate representation of how much the average utility bill is.

The eGRID summary tables are referenced in order to locate the sub region that Company A falls under and assign the proper energy emission factors. These emission factors are assigned by the Environmental Protection Agency. Pennsylvania, where all of the distribution centers and clean and screen facilities are located was identified on the map shown in Figure 8. It falls within sub region “RFCE”. Table 5 shows the emission factors for each eGRID sub region. As shown, the RFCE region has emissions factors of 858.56 lbs. CO2 / MWH, .02644 lbs. CH4 / MWH, and .01449 lbs. N2O / MWH.

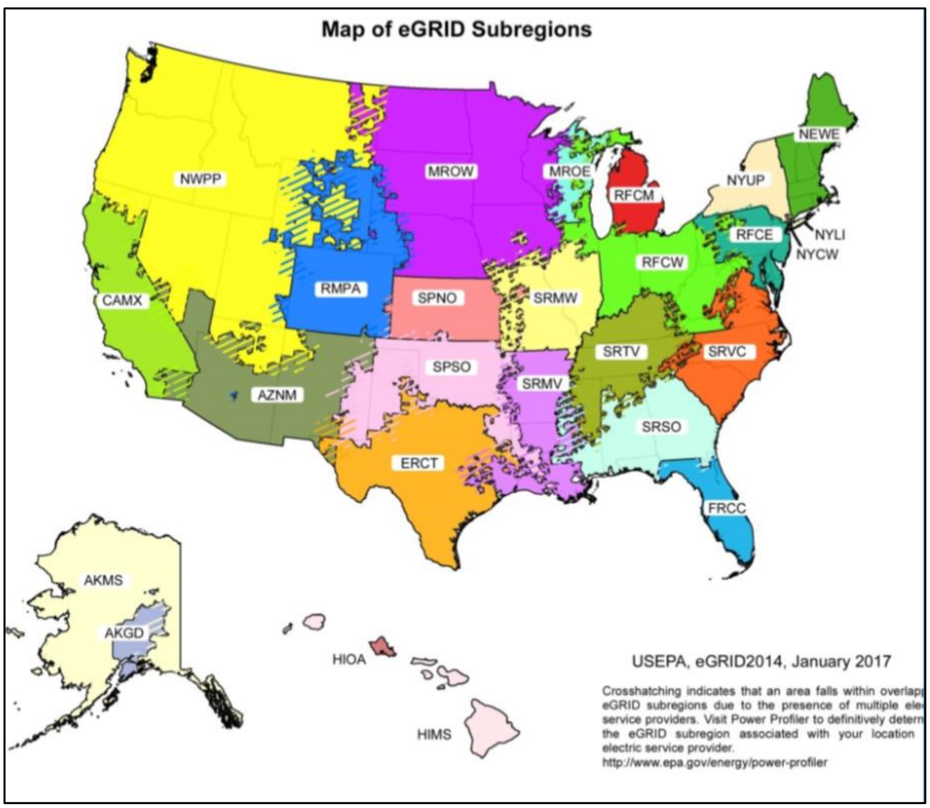

Figure 8: Electricity eGRID Sub Regions

Table 5: Emission Factors by Sub Region

Electricity Emission Factors	Total Output Emission Factors		
eGRID Subregion	CO2 Factor (lb CO2 / MW	CH4 Factor (lb CH4 / MW	N2O Factor (lb N2O / MW
AKGD (ASCC Alaska Grid)	1,268.73	0.02634	0.00759
AKMS (ASCC Miscellaneous)	481.17	0.01865	0.00355
AZNM (WECC Southwest)	1,152.89	0.01865	0.01511
CAMX (WECC California)	650.31	0.03112	0.00567
ERCT (ERCOT All)	1,143.04	0.0167	0.01233
FRCC (FRCC All)	1,125.35	0.04005	0.01185
HIMS (HICC Miscellaneous)	1,200.10	0.06808	0.01268
HIOA (HICC Oahu)	1,576.38	0.09041	0.02155
MORE (MRO East)	1,522.57	0.0243	0.02555
MROW (MRO West)	1,425.15	0.0276	0.02426
NEWE (NPCC New)	637.9	0.07284	0.01071
NWPP (WECC Northwest)	665.75	0.0126	0.01038
NYCW (NPCC NYC/Westchester)	696.7	0.02551	0.00293
NYLI (NPCC Long Island)	1,201.20	0.0782	0.00987
NYUP (NPCC Upstate NY)	408.8	0.01559	0.00383
RFCE (RFC East)	858.56	0.02644	0.01149
RFCM (RFC Michigan)	1,569.23	0.03036	0.02412
RFCW (RFC West)	1,379.48	0.01711	0.02167
RMPA (WECC Rockies)	1,822.65	0.02166	0.02813
SPNO (SPP North)	1,721.65	0.02022	0.02714
SPSO (SPP South)	1,538.63	0.02375	0.01998
SRMV (SERC Mississippi)	1,052.92	0.02095	0.01061
SRMW (SERC Midwest)	1,710.75	0.01958	0.0275
SRSO (SERC South)	1,149.05	0.02266	0.01549
SRTV (SERC Tennessee Valley)	1,337.15	0.01739	0.02078
SRVC (SERC Virginia/Carolina)	932.87	0.02395	0.0146
US Average	1,136.53	0.02378	0.01588

Since the emission factor units are in megawatt hours instead of kilowatt hours, appropriate conversions needed to be completed. One kilowatt hour is equivalent to .001 megawatt hours, resulting in 622 MWH per year allocated to the clean and screen process. With the MWH estimated and the emission factors assigned, emission calculations are performed. Sample calculations are shown below.

$$CO2\ Electricity\ Emissions = 622\ \frac{MWH}{Year} \times 868.56\ \frac{lbs.CO2}{MWH}$$

$$CH4\ Electricity\ Emissions = 622\frac{MWH}{Year} \times\ .02644\ \frac{lbs.CH4}{MWH}$$

$$N20\ Electricity\ Emissions = 622\frac{MWH}{Year} \times .01149\ \frac{lbs.\ N2O}{MWH}$$

This resulted in the number of pounds of CO_2, N_2O, and CH_4 emitted during the year in the distribution and clean and screen facilities. Pounds were then converted to metric tons for consistency. After this conversion, each GHG emission was multiplied by its correct GWP (1, 28, or 265). They were then added together to obtain the total CO_2e emitted annually.

Chapter 4

Results

The creation of this model allows for employees to quickly and easily understand the environmental impact of their current reverse logistics program. Company A requested a comprehensive model that would be flexible enough to accept changes to the inputs. This was completed successfully, and changes to the inputs have been tested with no repercussions. Any additional facilities or locations that they begin to conduct business can quickly be added to the model. The VBA code written will retrieve the coordinates and estimated distance to the distribution facilities.

Upon completion, it was determined that the current reverse logistics program produces 5,968.61 metric tons of carbon dioxide equivalent emissions. This encompasses all CO_2, CH_4, and N_2O emissions. Option One produced 742.72 metric tons of CO_2e for the year. Option Two produced 1,129.7 metric tons of CO_2e. Option Three resulted in 3,773.19 metric tons of annual CO_2e. The route from the distribution center to the clean and screen facility emitted 79.19 metric tons. Finally, the electricity consumed at the distribution center and clean and screen facility resulted in 243.81 metric tons of emissions. The breakdown for all of the routes can be seen in Figure 9.

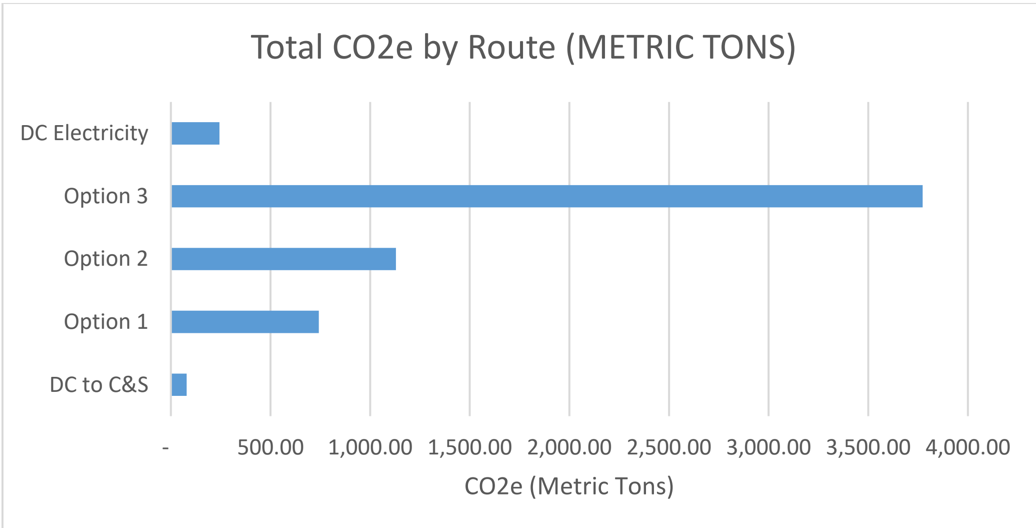

Figure 9: Route Specific Total CO2e

The ultimate goal for Company A is to determine which of the three options is the most environmentally friendly. Some options are more heavily utilized than others, so for consistency, it is important to determine the emissions released per set top box. This allows Company A to correctly and accurately state which route is responsible for the most carbon emissions. Please refer to Table 6 to see emissions per set top box.

Table 6: Emissions produced per STB

Option	Set top boxes	Emissions	Emissions / STB (Metric ton
Option 1	265,032.00	742.72	0.003
Option 2	1,132,404.00	1,129.71	0.001
Option 3	1,011,936.00	3,773.19	0.004

As shown in the table above, Option Three; customers driving to a drop-off location, results in the highest emissions released per set top box returned. .004 metric tons of greenhouse gases are released for every set top box returned. Option One; technicians driving out to customers to perform a full disconnect, produces the second highest volume of emissions per set top box. Each set top box releases .003 metric tons of greenhouse gases during this route.

After identifying Option 3 as the largest contributor to GHGs, each portion of the journey was graphed, to identify the main contributor. This graph can be seen in Figure 10. It is evident that the largest amount of GHGs stems primarily from customers driving an estimated thirty miles round trip to a customer drop-off center. Currently, ninety-five percent of the 3,773.19 metric tons of emissions is expelled through customer travel.

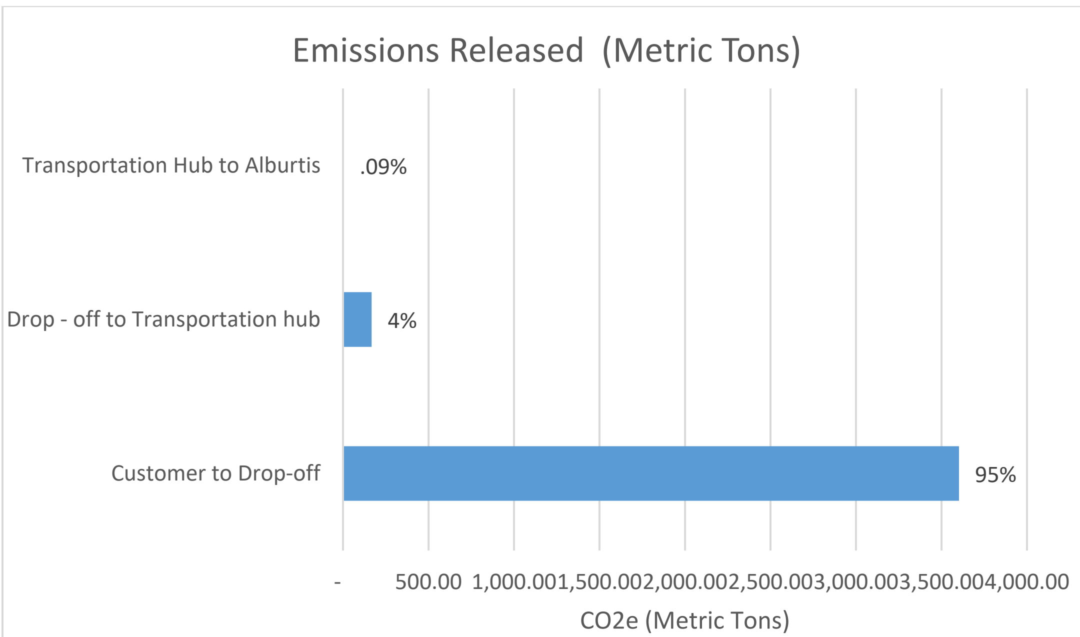

Figure 10: Emissions Released from Option 3

The model includes a summary page to easily access the totals for each route, as well as detailed graphs similar to those referenced above. It has been delivered to Company A in addition to the assumptions, limitations, and next steps that are outlined in this document.

Chapter 5
Discussion

The model created relies heavily on guidance from employee contacts at Company A. In addition, for both the warehousing and transportation models, calculated assumptions are utilized. The transportation models (Option One, Option Two, Option 3, and DC to C&S Transportation) have a higher concentration of assumptions due to the complex nature of the models.

For the transportation models, an average of 200,780 set top boxes returned per month was assumed to be constant for all months. Company A indicated that the average household has two to four set top boxes. For consistency, all calculations in this model assume that a household has three set top boxes. Set top boxes are assumed to be shipped to the nearest transportation hub. It is also expected that ten percent of all round-trip emissions should be allocated to the reverse logistics backhaul portion of the journey.

For the journey between the distribution center and clean and screen facility, it is assumed that 644 tractor trailers are required annually. This is presumed based on the average number of set top boxes returned and the number of pallets that are able to fit in a full truck load.

In the transportation model for Option One, it is assumed that all Company A technicians drive light-duty trucks that run on engine gasoline. Based off guidance provided by Company A, it is expected that a customer will live less than one hour from the closest GWC. Due to these proximities, it is estimated that the technicians will optimize their route to minimize distance, and likely travel forty-five miles round trip to serve an average of three customers per day. Workers are assumed to work 260 days per year; five days a week for fifty-two weeks.

Every other mode of transportation used in Option One is based off of a Class 8 Tractor Trailer (Medium/Heavy duty tractor trailers) running on diesel fuel. For certain portions of the model, tractor trailers are assumed to be less than truckload. In less than truckload shipments, it was determined by Company A that weight is negligible. In the instances where weight is not negligible and set top boxes are shipped full truckload, shipment weight is calculated by assuming an average of 5.86 pounds per STB.

Between the customer's home and the distribution center, a package will stop at a 3PL terminal network. Due to lack of information, it is estimated that the nearest 3PL terminal network is fifty miles away from a customer's home, and that a 3PL medium/heavy– duty vehicle will have a weight capacity of 65,000 pounds. When a package is delivered or picked up from an individuals' home, there is marginal mileage associated with making a dedicated trip. For purposes of this analysis, one mile is assumed to be the additional marginal unit.

For Option Three, passenger cars are presumed to be the vehicles used by customers for dedicated trips to return set top boxes to the nearest drop-off center. The average round trip distance to a drop-off center is assumed to be thirty miles. The number of customers that utilize this option was determined due to the statement that the average household has three STBs. If 1.01 million boxes are returned via Option Three annually, then 337,308 customers drive to Company A drop-off locations each year.

The electricity model also requires some assumptions for completion. Only electricity from the distribution center and clean and screen facility are considered in calculations. It is assumed that seven percent of energy consumption is attributed to set top boxes at the distribution center. Similarly, thirty percent of energy consumption at the clean and screen facility is credited to set top boxes.

Limitations

Due to assumptions and lack of data, this model does have limitations. By focusing specifically on the reverse logistics route, it does not capture any data on emissions from manufacturing, outbound transportation, or distribution processes. In addition, some data for the reverse logistics portion was inaccessible. For the transportation models, many exact locations, including customer addresses, the 3PL terminal networks, and distances between warehouses, could not be provided. Relying solely on assumptions for these distances provide a good estimate for the emissions released, however they are not entirely precise.

Distances between the GWC and the Transportation hub were found via the Haversine Formula. This formula determines the great-circle distance between points on a sphere. It utilizes their longitude and latitude to identify the shortest “as the crow flies” distance. This provides usable distances, however does not account for roadways. As a result, many of the distances used in the model are estimates, and therefore not completely accurate.

For the electricity model, there was not much visibility at the clean and screen facility. As a result, estimates needed to be made for the utility bill. This, too, limited the accuracy of the model.

After the clean and screen process is complete, set top boxes that cannot return back into the distribution cycle are sold to third parties and melted down for parts. Company A did not have any information pertaining to this process or to the number of STBs that are usually sold to third parties. This model does not encompass any of the emissions released due to the breakdown and melting of set top box devices.

Next Steps

After model completion and validation, it was delivered to Company A for implementation. Company A will continue to refine the model for increased accuracy. This model will serve as the base year for their reverse logistics carbon emissions tracking. In the future, they can efficiently and effectively update the model to reflect any changes that occur.

Company A's original goal for this model was to determine how environmentally efficient their current reverse logistics program is. They had implemented this system to minimize e-waste. However, Company A had not taken any steps to determine if the program reduces carbon emissions in addition to limiting the e-waste that makes its way to landfills. The implementation of this model into their everyday practices will allow greater visibility and increase their CSR efforts.

In order to continue updating the model in the future, Company A will need to designate an employee who will be responsible for continuous data collection and updating. Some of the assumptions, such as vehicle types, distances between locations, and utility bills, should be identified for increased accuracy.

The model also shows Company A routes that they can refine. A designated technician driving to customers' homes is not only resulting in over 700 tons of carbon emissions annually, but also costs $150-$200 per set top box for Company A. Focusing on areas that are both environmentally unfriendly and expensive will provide ample opportunities for potential cost savings.

While this current model is a great place to start, it is not fully comprehensive for all of their business needs. It accounts for the main greenhouse gases; methane, nitrous oxide, and carbon dioxide. However, this model does not quantify emissions for the other main GHG. These include chlorofluorocarbon, hydrofluorocarbon, sulfur hexafluoride, and nitrogen trifluoride. A more comprehensive model could be developed to contain these greenhouse gases as well.

In addition, this model focuses only on the reverse logistics components. A potential next step is to continue to develop this model so that it encompasses the manufacturing and distribution process for set top boxes. Eventually, similar processes can be implemented across all lines of business, referencing the GHG Protocol for development.

A final step in this process would be to begin contributing to the CDP. As mentioned earlier, the CDP offers a platform for companies, cities, and regions to report and manage their environmental impacts. Ultimately, this will help Company A manage environmental risk in their business and identify areas for improvement.

Appendix A

VBA Google API Code

```
'Calculate Google Maps distance between two addresses
Public Function GetDistance(start As String, dest As String)
    Dim firstVal As String, secondVal As String, lastVal As String
    firstVal = "http://maps.googleapis.com/maps/api/distancematrix/json?origins="
    secondVal = "&destinations="
    lastVal = "&mode=car&language=pl&sensor=false"
    Set objHTTP = CreateObject("MSXML2.ServerXMLHTTP")
    URL = firstVal & Replace(start, " ", "+") & secondVal & Replace(dest, " ", "+") & lastVal
    objHTTP.Open "GET", URL, False
    objHTTP.setRequestHeader "User-Agent", "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
    objHTTP.send ("")
    If InStr(objHTTP.responseText, """distance"" : {") = 0 Then GoTo ErrorHandl
    Set regex = CreateObject("VBScript.RegExp"): regex.Pattern = """value"".*?([0-9]+)": regex.Global = False
    Set matches = regex.Execute(objHTTP.responseText)
    tmpVal = Replace(matches(0).SubMatches(0), ".", Application.International(xlListSeparator))
    GetDistance = CDbl(tmpVal)
    Exit Function
ErrorHandl:
    GetDistance = -1
End Function
```

Appendix B

Emission Factors

Table 9 Product Transport Emission Factors

Vehicle Type	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Medium- and Heavy-Duty Truck	1.430	0.015	0.013	vehicle-mile
Passenger Car [A]	0.355	0.021	0.015	vehicle-mile
Light-Duty Truck [B]	0.485	0.020	0.022	vehicle-mile
Medium- and Heavy-Duty Truck [C]	0.146	0.0015	0.0014	ton-mile
Rail	0.024	0.0019	0.0006	ton-mile
Waterborne Craft	0.059	0.0005	0.0040	ton-mile
Aircraft	1.307	0.0000	0.0402	ton-mile

Source:
CO_2, CH_4, and N_2O emissions data for on-road vehicles are from Table 2-13 of the U.S. Greenhouse Gas Emissions and Sinks: 1990–2013. Vehicle-miles and passenger-miles data for on-road vehicles are from Table VM-1 of the Federal Highway Administration Highway Statistics 2013.
CO_2e emissions data for non-road vehicles are based on Table A-117 of the U.S. Greenhouse Gas Emissions and Sinks: 1990–2013, which are distributed into CO_2, CH_4, and N_2O emissions based on fuel/vehicle emission factors. Freight ton-mile data for non-road vehicles are from Table 1-50 of the Bureau of Transportation Statistics, National Transportation Statistics for 2014 (Data based on 2011).

Notes:
Vehicle-mile factors are appropriate to use when the entire vehicle is dedicated to transporting the reporting company's product. Ton-mile factors are appropriate when the vehicle is shared with products from other companies.
[A] Passenger car: includes passenger cars, minivans, SUVs, and small pickup trucks (vehicles with wheelbase less than 121 inches).
[B] Light-duty truck: includes full-size pickup trucks, full-size vans, and extended-length SUVs (vehicles with wheelbase greater than 121 inches).
[C] These factors represent a methdology change from previous factors, based on improved data.

Table 6 Electricity Emission Factors

eGRID Subregion	Total Output Emission Factors			Non-Baseload Emission Factors		
	CO_2 Factor (lb CO_2/MWh)	CH_4 Factor (lb CH_4/MWh)	N_2O Factor (lb N_2O/MWh)	CO_2 Factor (lb CO_2/MWh)	CH_4 Factor (lb CH_4/MWh)	N_2O Factor (lb N_2O/MWh)
AKGD (ASCC Alaska Grid)	1,268.73	0.02634	0.00759	1,377.77	0.02866	0.00338
AKMS (ASCC Miscellaneous)	481.17	0.01865	0.00355	1,404.49	0.05564	0.01070
AZNM (WECC Southwest)	1,152.89	0.01865	0.01511	1,236.02	0.02156	0.01052
CAMX (WECC California)	650.31	0.03112	0.00567	1,018.87	0.03761	0.00604
ERCT (ERCOT All)	1,143.04	0.01670	0.01233	1,280.59	0.02153	0.01071
FRCC (FRCC All)	1,125.35	0.04005	0.01185	1,333.93	0.03881	0.01379
HIMS (HICC Miscellaneous)	1,200.10	0.06808	0.01268	1,331.47	0.09682	0.01715
HIOA (HICC Oahu)	1,576.38	0.09041	0.02155	1,402.27	0.11801	0.01943
MROE (MRO East)	1,522.57	0.02430	0.02555	1,739.00	0.03017	0.02626
MROW (MRO West)	1,425.15	0.02760	0.02426	1,965.21	0.05260	0.03272
NEWE (NPCC New England)	637.90	0.07284	0.01071	1,079.73	0.06770	0.01290
NWPP (WECC Northwest)	665.75	0.01260	0.01038	1,579.07	0.03830	0.02284
NYCW (NPCC NYC/Westchester)	696.70	0.02551	0.00293	1,081.11	0.02250	0.00232
NYLI (NPCC Long Island)	1,201.20	0.07820	0.00987	1,303.42	0.03140	0.00356
NYUP (NPCC Upstate NY)	408.80	0.01559	0.00383	1,228.56	0.03900	0.01304
RFCE (RFC East)	858.56	0.02644	0.01149	1,492.01	0.03274	0.01869
RFCM (RFC Michigan)	1,569.23	0.03036	0.02412	1,856.21	0.03391	0.02872
RFCW (RFC West)	1,379.48	0.01711	0.02167	1,791.71	0.02176	0.02785
RMPA (WECC Rockies)	1,822.65	0.02166	0.02813	1,669.58	0.02289	0.02066
SPNO (SPP North)	1,721.65	0.02022	0.02714	2,112.08	0.02611	0.03063
SPSO (SPP South)	1,538.63	0.02375	0.01998	1,590.13	0.02760	0.01619
SRMV (SERC Mississippi Valley)	1,052.92	0.02095	0.01061	1,301.65	0.02743	0.00975
SRMW (SERC Midwest)	1,710.75	0.01958	0.02750	1,917.96	0.02329	0.02884
SRSO (SERC South)	1,149.05	0.02266	0.01549	1,696.79	0.02817	0.02483
SRTV (SERC Tennessee Valley)	1,337.15	0.01739	0.02078	1,743.96	0.02284	0.02611
SRVC (SERC Virginia/Carolina)	932.87	0.02395	0.01460	1,790.57	0.05310	0.02994
US Average	1,136.53	0.02378	0.01588	1,549.36	0.03099	0.01986

Source: EPA eGRID2012, October 2015
Note: Total output emission factors can be used as default factors for estimating GHG emissions from electricity use when developing a carbon footprint or emissions inventory. Annual non-baseload output emission factors should not be used for those purposes, but can be used to estimate GHG emissions reductions from reductions in electricity use.

BIBLIOGRAPHY

"20 Staggering E-Waste Facts." *Earth911.Com*, 8 Feb. 2016, earth911.com/eco-tech/20-e-waste-facts/.

"About Us." *About Us | Greenhouse Gas Protocol*, www.ghgprotocol.org/about-us.

Ahmed, Syed Faraz. "The Global Cost of Electronic Waste." *The Atlantic*, Atlantic Media Company, 29 Sept. 2016, www.theatlantic.com/technology/archive/2016/09/the-global-cost-of-electronic-waste/502019/.

"Basic Information about Electronics Stewardship." *EPA*, Environmental Protection Agency, 27 Sept. 2017, www.epa.gov/smm-electronics/basic-information-about-electronics-stewardship#02.

Bhutta, et al. "Electronic Waste: A Growing Concern in Today's Environment." *Economics Research International*, Hindawi, 15 June 2011, www.hindawi.com/journals/ecri/2011/474230/.

"Big Trucks Emit Huge Amounts Of Carbon Every Year. The EPA Is About To Do Something About It." *ThinkProgress*, thinkprogress.org/big-trucks-emit-huge-amounts-of-carbon-every-year-the-epa-is-about-to-do-something-about-it-5c402732888/.

Boren, Zachary Davies. "There Are Officially More Mobile Devices than People in the World." *The Independent*, Independent Digital News and Media, 7 Oct. 2014, www.independent.co.uk/life-style/gadgets-and-tech/news/there-are-officially-more-mobile-devices-than-people-in-the-world-9780518.html.

"BlueMM." *Excel Formula to Calculate Distance between 2 Latitude, Longitude (Lat/Lon) Points (GPS Positions)*, bluemm.blogspot.com/2007/01/excel-formula-to-calculate-distance.html.

"Business Calculator." *Carbonfund.org*, carbonfund.org/business-calculator/.

The Carbon Dioxide Greenhouse Effect, history.aip.org/climate/co2.htm#L_M021.

"Cleaning Up Electronic Waste (E-Waste)." *EPA*, Environmental Protection Agency, 11 Dec. 2017, www.epa.gov/international-cooperation/cleaning-electronic-waste-e-waste.

"Climate Change Indicators: Global Greenhouse Gas Emissions." *EPA*, Environmental Protection Agency, 17 Dec. 2016, www.epa.gov/climate-indicators/climate-change-indicators-global-greenhouse-gas-emissions.

College, Hack. "The Lesser-Known Facts About E-Waste Recycling." *Business Insider*, Business Insider, 17 Oct. 2012, www.businessinsider.com/the-lesser-known-facts-about-e-waste-recycling-2012-10 https://www.epa.gov/smm-electronics.

Corporate Standard | Greenhouse Gas Protocol, www.ghgprotocol.org/corporate-standard.

"Cost per Mile – The Basic Formula." *Business Economics - A Library of Information*, businessecon.org/2014/03/cost-per-mile-the-basic-formula/.

"EERE: Alternative Fuels Data Center Home Page." *EERE: Alternative Fuels Data Center Home Page*, www.afdc.energy.gov/.

"EPA Center for Corporate Climate Leadership." *EPA*, Environmental Protection Agency, 25 Aug. 2017, www.epa.gov/climateleadership.

EPA, Environmental Protection Agency, nepis.epa.gov/.

Extract from The Rough Guide to Climate Change. "What Is the Kyoto Protocol and Has It Made Any Difference?" *The Guardian*, Guardian News and Media, 11 Mar. 2011, www.theguardian.com/environment/2011/mar/11/kyoto-protocol.

"Global Warming Solutions." *Environment America*, environmentamerica.org/programs/ame/global-warming-solutions.

"Greenhouse Gas Emissions from a Typical Passenger Vehicle." *EPA*, Environmental Protection Agency, 6 Mar. 2018, www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle.

"Greenhouse Gas Equivalencies Calculator." *EPA*, Environmental Protection Agency, 13 Mar. 2018, www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

"Greenhouse Gas Reporting Program (GHGRP)." *EPA*, Environmental Protection Agency, 27 Feb. 2018, www.epa.gov/ghgreporting.

"Greenhouse Gases Equivalencies Calculator - Calculations and References." *EPA*, Environmental Protection Agency, 13 Mar. 2018, www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references.

"The Human and Environmental Effects of E-Waste." *Population Reference Bureau*, www.prb.org/Publications/Articles/2013/e-waste.aspx.

"International E-Waste Management Network (IEMN)." *EPA*, Environmental Protection Agency, 27 Nov. 2017, www.epa.gov/international-cooperation/international-e-waste-management-network-iemn.

International Cooperation, history.aip.org/climate/internat.htm#L_M065.

IPCC - Intergovernmental Panel on Climate Change, www.ipcc.ch/organization/organization_history.shtml.

Lewis, Tanya. "World's E-Waste to Grow 33% by 2017, Says Global Report." *LiveScience*, Purch, 15 Dec. 2013, www.livescience.com/41967-world-e-waste-to-grow-33-percent-2017.html.

MacMillan, Amanda. “Global Warming 101.” *NRDC*, 8 Feb. 2018, www.nrdc.org/stories/global-warming-101.

“Main Greenhouse Gases.” *Center for Climate and Energy Solutions*, 16 Nov. 2017, www.c2es.org/content/main-greenhouse-gases/.

Mathers, Jason. “Green Freight Math: How to Calculate Emissions for a Truck Move.” *EDF Business*, 5 Apr. 2015, business.edf.org/blog/2015/03/24/green-freight-math-how-to-calculate-emissions-for-a-truck-move/.

Ranganathan, Janet, et al. “The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard.” *GHG Protocol*, doi:10.18489/sacj.v52i0.177.s137.

“Recent Publications.” *Recent Publications | CEC Publications*, www3.cec.org/islandora.

Simple Models of Climate, history.aip.org/climate/simple.htm#L_M018.

Our Mission and Vision | National Oceanic and Atmospheric Administration, www.noaa.gov/our-mission-and-vision.

Toro, Ross. “Tracking the World's E-Waste (Infographic).” *LiveScience*, Purch, 15 Dec. 2013, www.livescience.com/41966-tracking-world-e-waste.html.

“Understanding Global Warming Potentials.” *EPA*, Environmental Protection Agency, 14 Feb. 2017, www.epa.gov/ghgemissions/understanding-global-warming-potentials.

United Nations. *Kyoto Protocol*, 30 May 2013, unfccc.int/kyoto_protocol/items/2830.php.

United Parcel Service of America, Inc. “Committed to More: Read the New UPS Corporate Sustainability Report.” *UPS Sustainability*, sustainability.ups.com/.

"United States of America." *STEP E-Waste World Map - Overview USA - STEP*, www.step-initiative.org/Overview_USA.html#Regulatory.

U.S. Ground Maps: UPS, www.ups.com/maps/.

"Verizon Fios Availability." *Verizon Fios Availability & Coverage Map for Internet, TV, Phone Service.*, www.verizon.com/home/fiosavailability/.

"We Set the Standards to Measure and Manage Emissions." *Greenhouse Gas Protocol* |, www.ghgprotocol.org/.

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Thesis Supervisor: Robert Novack

Work Experience

May 2017 – Aug 2017
Commercial Client Planning Intern
Analyzed order entry date behavior in the large order planning process to reduce forecast variation. Resulted in the creation of a predictive risk tool to identify risk associated with each large business deal and the implementation of a historical database.
Dell, Austin, TX
Bryce Stacer

Jun 2016 – Dec 2016
Business Intelligence Co-Op
Executed RFP's for displays, functional ingredients, Dagoba, BarkTHINS, and Brookside with over 30 potential suppliers. By leveraging existing supplier spend to improve flexibility and speed to market, $500,000 of annual cost savings was achieved.
The Hershey Company, Hershey, PA
Robert Hughes

Aug 2017 – Dec 2017
Teaching Assistant
Assisted in introductory supply chain course by grading homework, holding office hours, and answering students' questions.
Penn State University, University Park, Pa
Robert Novack

Jan 2016 – May 2016
Research Assistant
Prepared mass data into usable form for analysis to mitigate counterfeit risk in the supply chain of semiconductors.
Penn State University Center for Supply Chain Research, University Park, PA
Dr. Vidya Mani

Grants Received

Awards: Academic Excellence Scholarship, MIT Excellence Award
Professional Memberships: Sapphire Leadership Program
Dean's list: All Semesters 2014 – 2018