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Estimating Environmental Emissions from Produce Waste Redistribution in the Capital Region

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Abstract

Every year in New York's Capital Region a large amount of food goes to waste, and about one-half of produce (fruits and vegetable) that is produced is wasted. However, many organizations in the Capital Region have put in efforts to redistribute this surplus produce to the food insecure to help improve their diets. This project looked at how that surplus produce is redistributed to the food insecure in the Capital Region, the life cycle energy consumption and associated greenhouse gas emissions of that redistribution, and how that redistribution could be improved. Working with local partners through survey data collection, interviews, and energy and emission modeling, we quantified the amount of surplus produce being redirected from the waste stream to consumers and determined the energy consumption and greenhouse gas (GHG) emissions of transporting the surplus produce in the Capital Region. We used Argonne National Laboratory's The Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) Model to calculate greenhouse gas emissions from the transportation of the surplus produce from food banks and grocery stores to food pantries and soup kitchens, and we used the Environmental Protection Agency's (EPA) Waste Reduction Model (WARM) to calculate the environmental impact of alternatives of redistributing the surplus produce, such as landfilling or composting the excess produce.

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Introduction & Background:

Feeding America estimates that about 70 billion pounds of food are wasted every year in the United States (Hadley, 2016). Additionally, about half of produce (fruits and vegetables) grown in the US is wasted (Goldenberg, 2016). However, many people in the United States suffer from food insecurity, meaning they do not have access to a reliable amount of nutritious food. According to a survey by Feeding America in 2015, 13% of households in the US were food insecure and 5% of households were very food insecure. This survey also recognized some patterns of who food insecurity was most likely to affect. Of food insecure households 30% were headed by a single woman, while 22% were headed by a single man, 17% of the households included children, and 41% were Hispanic or black households (Feeding America, 2015).

In the New York Capital Region, which is comprised of Albany, Columbia, Greene, Fulton, Montgomery, Rensselaer, Saratoga, Schenectady, Schoharie, Warren, and Washington Counties, 11.98% of households were food insecure in 2016. While this is slightly lower than the New York State average of 13.9% and below the national average (13%), food insecurity is still a large problem in the Capital Region (Rissew, 2016). Food insecurity levels for racial/ethnic minorities in the Capital Region are much higher than the average. African Americans face food insecurity at a rate of 16.1% and Hispanics face food insecurity at a rate of 22.4%. Compared with the New York State rate of food insecurity, African Americans and Hispanics are at a large disadvantage. In the Capital Region, Albany and Schenectady have the highest food insecurity rates, 13.3% and 12.5% respectively, these two counties also hold the Capital Region’s two largest cities (Rissew, 2016). Many people who are food insecure rely on food pantries to help provide themselves and their families with food (Saint Louis, 2016). Approximately 80,000 people in the Capital Region are food insecure but only about 43,500 people regularly visit food pantries in the Capital Region. That means almost half of food insecure people in the Capital Region are not utilizing food pantries to get access to healthy foods. The reasons for this may have to do with stigma, lack of transportation, or the hours of operation for many food pantries may not be optimal for people to visit them (Buteux Reade, 2016).

Food insecurity is a public health issue because it can cause malnutrition as well as other chronic health issues, such as diabetes, heart disease, high blood pressure, hyperlipidemia, obesity, and mental health issues such as depression. Inadequate access to healthy foods often leads to obesity (Rissew, 2016). In fact, in 2014 it was found that one third of the 15.5 million people served by Feeding America, the US’s second largest organization that helps feed the food insecure, had type 2 diabetes. Diabetes can cause many comorbidities such as blindness and/or amputations. Inconsistent access to food worsens the effects of the diabetes causing a serious problem for the food insecure who are both unable to consistently get food and when they do get food it is often unhealthy (Saint Louis, 2016). Food insecurity is also more likely to have negative effects on children, because of their developing bodies and minds, and the elderly, because of their weaker immune systems and need for better nutrition to keep their bodies healthy (Kickstarter, 2015).

In order to combat the issue of food insecurity in the Capital Region many organizations have put in efforts to provide more nutritious food to those who don't have access. Many of these organizations redirect food surplus, meaning excess food that would otherwise be thrown away to food pantries to be given to those who are food insecure. There are several reasons for food waste in the US. One reason is because farmer's may not be able to afford to harvest an entire field. Another reason is a grocery store may order too much food and not be able to sell it all before it goes bad. Food is often still useable after its expiration date but stores cannot sell it anymore (Lipinski, 2013). Restaurants often throw out unused or uneaten food. Also, "ugly" fruits and vegetables, meaning fruits and vegetables that are malformed but still fine to eat, are often thrown out because grocery stores believe they won't be able to sell them (Hansman, 2015).

The food distribution chain typically works as follows, farms sell food to restaurants, food retail places like grocery stores, food pantries, food banks, and farmer's markets. Food goes directly from restaurants, retail stores, and farmer's markets to the consumer. Food banks donate food to food panties which donate to soup kitchens. Food banks and food pantries also give directly to consumers and some consumers donate back to food banks and pantries. Food panties and banks also accept donations from restaurants and retail places. Restaurants, retail stores, and farmer markets also donate to food pantries and soup kitchens. Also, restaurants, retail stores, farmer markets, food pantries, and soup kitchens donate to food banks. Excess food that is not used in this chain is usually thrown away as waste and landfilled or sometimes composted (Food Waste Reduction Alliance, 2014). A diagram of the food distribution chain can be seen in Figure 1.

Food Distribution Chain

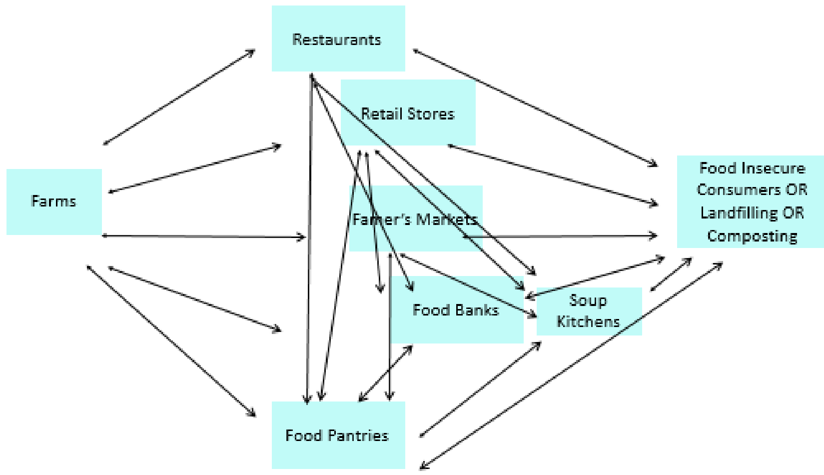


Figure 1:

In this project, we looked specifically at directing produce away from the waste stream, so taking produce away from being disposed of, and instead redistributing it to the food insecure. We also evaluated landfilling and composting as alternative waste management methods to compare GHG emissions from redistribution, landfilling, and composting. Figure 2 shows the specific part of the food redistribution process we evaluated in this project. Black arrows show the current redistribution system and red arrows show the alternatives to redistribution we evaluated.

Food Redistribution System Evaluated in this Project

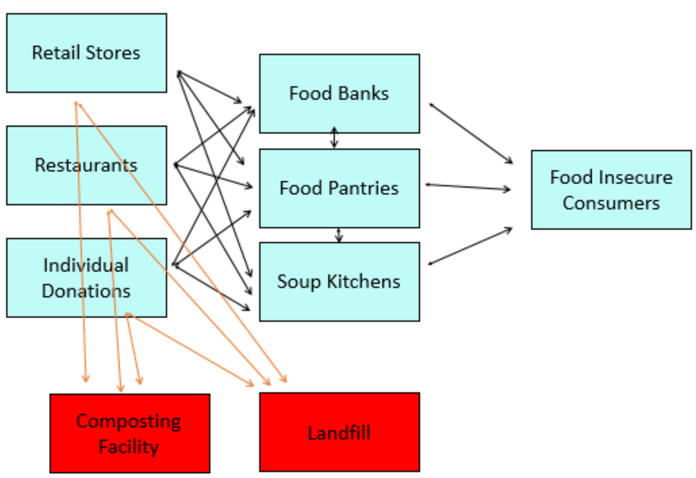


Figure 2:

Many organizations that work to combat food insecurity exist nationally and locally. The Houston Food Pantry in Texas is working to improve food access for its patrons. This food pantry is also working to improve its patrons' health by taking their blood sugar when they come into get food. For those with high blood sugar the pantry offers to hand pick healthy groceries from the pantry for them (Saint Louis, 2016). Starbucks, the popular coffee chain, made a pledge to donate 100% of its unsold food, that's safe to eat, to food banks. Through this program, the company hopes to provide 50 million meals to the food insecure by the year 2021 (Hadley, 2016). In 2016, the Environmental Protection Agency (EPA) started an initiative meaning to encourage religious groups in the US to donate excess foods, including produce that many religious organizations grow themselves, to the food insecure. This was part of the EPA's initiative to reduce food waste by 50% by the year 2030 (Godoy, 2016). In Baltimore, Gather Baltimore is an organization working to take food waste and redistribute it to the food insecure. The program has had great success in improving people's access to healthy foods by creating good relationships with local farms and businesses (Kickstarter, 2015). A startup company in San Francisco is selling "ugly" fruits and vegetables at a reduced price. This project is greatly reducing waste by saving a portion of the 6 billion pounds of "ugly" fruits and vegetables that are thrown out each year (Hansman, 2015). In 2011, students at the University of Maryland started collecting food that was going to be thrown out from dining halls and sports events and redistributed it to the food needy. By 2014 the students had collected and saved more than 400,000 pounds of food that would have otherwise been wasted (Benz et al, 2014). Daily Table, a new grocery store - the first store opened in Boston in 2015, buys food that might be thrown out by other vendors for various reasons and sells the food at reduced prices. This business strategy allows people with limited income to afford healthy foods (Hoffman, 2015).

In New York's Capital Region, Capital Root's Squash Hunger Program takes food donations from food gardeners, farmers, and grocery stores and redistributes these donations to food pantries and shelters. The program distributes about 40 tons of fresh produce to food pantries and shelters each year (Capital Roots, 2016). Another organization working to improve access to food for the food insecure in the Capital Region is Honest Weight Food Co-op. This organization takes food donations from various sources; grocery stores, restaurants, individuals, etc., and delivers the foods to food pantries and shelters throughout the Capital Region (Honest Weight Food Co-op, 2017). The Food Pantries for the Capital District is a partnership between 56 different food pantries in the Capital Region. Food Pantries for the Capital District coordinates the delivery of surplus food between food banks, food pantries, and soup kitchens, as well as providing funding, education, and training to all of its member food pantries (The Food Pantries for the Capital District, 2017). The St. James food pantry in Albany allows patrons to pick up food once a month but patrons can also get fresh bread and produce from the pantry anytime it is open. CoNSERNS-U in Rensselaer serves 340 food insecure households regularly each month and around the holidays serves more than 600 households. CoNSERNS-U focuses a lot on helping food insecure kids get proper nutrition. Hope 7 in Troy and Wynantskill serves families both in rural and urban settings. Patrons of the Hope 7 food pantries have full access to the pantries once a month and can get foods like milk, eggs, produce, and bread. Also in the Capital Region, University at Albany and Siena College have been working with the Food Pantries coalition to develop a study that assess the barriers many food insecure people face in utilizing food pantries. This project could help many food insecure people get better access to nutritious foods on a reliable basis (Buteux Reade, 2016).

Redistributing this food surplus not only helps those who are food insecure but cuts down on waste which causes a large problem for the environment. When food is thrown out it is often brought to landfills where the food decomposes and releases a dangerous greenhouse gas (GHG), methane, which contributes to climate change (Godoy, 2016). There is also evidence that large amounts of food waste are negatively impacting animals. Discarded food is often eaten by animals and the massive amount of food waste in the US has caused the overpopulation of some species which has negatively impacted the ecosystem (Conniff, 2016). A lot of previous research has been done evaluating the environmental impact of food waste, looking at the impact of landfilling and alternatives like composting and anaerobic digestion, a process during which organic materials, often food waste, are converted into biogas (US Environmental Protection Agency, 2016). However, we found little research on the environmental impact of the food redistribution process by itself. Redistributing large amounts of food surplus with vehicles also causes environmental problems by contributing to the release of large amounts of GHGs.

The food production process, including the growing, rearing, farming, processing, transporting, storing, cooking, and disposal of food, is one of the largest contributors to GHG emissions in the US at 17% of all emissions. (Green Eatz, 2016). There are many different ways to reduce emissions from this process, this project specifically looked at ways to make the redistribution and disposal of food more environmentally effective. Transportation is estimated to contribute to 26% of total GHG emission in the US yearly, this includes cars, trucks, commercial aircraft, railroads, and other sources. And medium and heavy duty trucks, which are the vehicles typically used in distribution and redistribution of food contribute to 23% of total emissions from transportation. GHGs emitted from the combustion of fuels include carbon dioxide, methane, nitrous oxide, and various hydrofluorocarbons, while HFCs are emitted from leaks and end-of-life disposal from air conditioners and coolers used to cool people and food stored on freights. These GHG emissions contribute to global warming by trapping heat in the atmosphere (US Environmental Protection Agency, 2016). Due to the large amount of GHG emissions released from transportation, which food redistribution is a part of, it is important to look at ways to decrease GHG emissions from food redistribution in order to decrease it’s negative effect on the environment.

As part of a larger project looking at how food redistribution (focused on produce) in the Capital Region works and the nutritional value provided from redistributed produce, we looked at how redistribution impacts the environment, in terms of GHG emissions released from produce redistribution, and other strategies to manage produce waste in order to decrease GHG emissions from the process. This study was a proof of concept, in the future we want to look at all realms of food redistribution (including breads, meats, and other foods), but first we wanted to see if we could operationalize the idea with produce.

Our research questions that we hoped to answer through this study were: What are the current GHG emissions from produce redistribution in the Capital Region? How does this compare to other surplus produce management methods? What is the best strategy to manage surplus produce from a perspective of minimizing GHG emissions?

Energy Models:

In order to calculate GHG emissions from the redistribution of surplus produce in the Capital Region and emissions from alternate waste management methods we determined that two different energy models would have to be used; a transportation model to calculate GHG's from the current redistribution system and one that calculates GHG emissions from various alternative waste management methods. In order to determine the best models to use for this project various energy models were researched. In evaluating these energy models, their uses, their strengths and limitations, and the inputs that would be needed were considered. The transportation models considered were The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model (GREET), Waste Reduction Model (WARM), Co-Digestion Economic Analysis Tool (CoEAT), the Computer Program to Calculate Emissions from Road Transport (COPERT), Motor Vehicle Emissions Simulator (MOVES), Transport Emission Model for Line Sources (TREM), the Transport Emissions Evaluation Models for Projects (TEEMP), and Study on Transport Emissions of All Modes (STREAM).

CoEAT was developed by the EPA – Southwest and uses information about food waste being used in a co-digestion system and the co-digestion system itself to calculate the economic, environmental, and operational costs of waste co-digestion systems. Co-digestion is a process where facilities convert various wastes (in this case produce waste) into renewable energy sources to avoid sending waste to landfills. This model was not used because it only includes one alternate waste management method (co-digestion) and we wanted to evaluate various waste management methods (US Environmental Protection Agency, 2016).

COPERT was created by the European Environment Agency. The model takes information about vehicles (mileage, model, fuel, etc.) and uses this information to calculate air pollution and GHG emissions from the vehicle's road transport (EMISIA, 2014). COPERT has been used in a previous study to calculate methane and nitrous oxide emission factors (Bourka, 2015). This model was not used because it would require inputs not available to us as researchers (percentage of kilometers on urban and rural roads, and highways) (EMISIA, 2014).

The next model considered was the EPA's MOVES. This model also uses information about vehicles to estimate emissions from cars, trucks, and non-highway mobile sources (US Environmental Protection Agency, 2017). MOVES was used in a study looking at air pollution and its health effects to calculate emission factors of GHGs in grams per vehicle kilometer (Shekarrizfard, 2015). In another study that compared emissions from alternative fuels, transit buses, and rail technologies, MOVES was used to calculate emissions factors again (Xu, 2015). This model was decided against because, similarly to COPERT, it would require inputs that we did not have access to (fraction of travel happening on ramps, hours spent by drivers on mandatory rest) (US Environmental Protection Agency, 2017).

TREM was developed by the Department of Environment and Planning at the University of Aveiro to calculate the emissions of different types of air pollutants based on vehicle information and transport activity (Aveiro, n.d.). TREM was used to calculate road traffic air pollution emissions in a study looking at urban development trends' effects on air quality (Bandeira, 2011). The reason why this model was not used was because it was designed mainly for urban areas and there are many areas in New York's Capital Region that are rural, so this model would not be the best fit for the target area of this project (Department of Environment and Planning, University of Aveiro, n.d.).

TEEMP was developed by Clear Air Asia with the Institute for Transportation and Development Policy (ITDP), the Asian Development Bank (ADB), Cambridge Systematics, and the United Nations Environment Program – Global Environment Facility (UNEP-GEF). The model aims to calculate total emissions from transport projects using information about the type of project such as; the type of road, starting year, traffic volume, etc. This model was not a good match for this project because in order to properly use the model we would have to know information about redistribution routes that we would not be able to get access to, such as the lane width and length (Clean Air Asia, n.d.).

STREAM was created by CE Delft to compare emissions from various transportation methods. For example, the model could compare the emissions from a freight train to trucks (CE Delft, n.d.). Although being able to compare different types of transport could be useful, for the scope of this project, food surplus will likely only be transported by truck and no other methods (trains, ship, etc.). Also, this model would not help with calculating emissions from produce surplus management alternatives other than different methods of transportation, and in this project we wanted to look at waste management alternatives like composting and landfilling.

GREET was developed by the Department of Energy and Argonne National Laboratory. The model uses information about vehicle type (mileage, model, equipment usage), fleet information (number of vehicles being used) and transportation route (miles traveled) to calculate the GHG emissions from a fleet of vehicles from well to wheel, meaning over the entire life course of the fuel (US Department of Energy, 2012). Well to wheel combines GHG emissions from fuel production (well to pump) and emissions from a vehicle’s operational activities (pump to wheels) in order to calculate the total environmental impact of a vehicle’s transportation activities (Burnham, 2010). Both the inputs and outputs for this model are ideal for the scope of this project. In addition, GREET calculates emissions from transportation processes and their supply chain processes such as fuel production, vehicle usage and maintenance. The comprehensive scope of GREET is another comparative advantage. For these reasons, this model was used to calculate GHG emissions from the current system of redistributing surplus produce in the Capital Region.

GREET has previously been used in several studies. It was used in one study to calculate GHG emissions from combustion of diesel and to calculate emissions associated with the provision, transport, and distribution of fuel (Ebner, 2014). GREET has also been used to calculate total the environmental impact of a vehicle's transportation activities from hauling feedstock (Rankin, 2014).

WARM was developed by the Environmental Protection Agency (EPA) to evaluate the difference in GHG emissions from current practices and potential alternative methods. Alternatives that are able to be evaluated using WARM are source reduction, recycling, combustion, composting, anaerobic digestion, and landfilling (US Environmental Protection Agency, 2017). Because of the various waste management methods included in this model WARM was used to evaluate GHG emissions from alternative methods of dealing with the Capital Region’s surplus produce to see if another waste management method would emit less GHGs than redistribution.

WARM has previously been used to calculate avoided landfill and transport emissions in a study looking at the environmental impacts of converting food waste to ethanol. (Ebner, 2014). In another study looking at the environmental impact of an anaerobic codigestion system, WARM was used to calculate avoided landfill emissions (Rankin, 2014). Another study used WARM to compare emissions from composting food scraps to landfilling food scraps (Brown, 2016).

Methods:

The dataset for the preliminary results in this study came from The Food Pantries for the Capital District. This dataset included monthly data from 2016 on produce donation sources, recipient pantries, and weights of produce surplus per donation. Geocoding and network analysis, using the addresses of produce donation sources and recipients, were used to calculate the road travel distance between produce donation sources and recipients. Network analysis was completed by Dr. Beth Feingold using the Network Analyst extension and Geocoding Tools of ArcGIS (version 10.2, ESRI Corporation, Redlands, CA). It was assumed that trucks redistributing produce would make each trip between each source and destination individually. It was also assumed that each truck would make a round trip. For this reason, each distance from source to donation was doubled to get round trip distance. The round trip distance for every donation trip in a month was summed to get the total monthly distance traveled during produce redistribution by trucks for The Food Pantries for the Capital District.

The Food Pantries for the Capital District uses four different vehicles to redistribute surplus produce; two diesel box trucks, one with a fuel economy of 10 mpg and the other with a fuel economy of 15 mpg, one of these box trucks also has a cooler, a 1999 passenger bus that uses leaded gasoline, and a 1994 Chevrolet passenger van that also uses unleaded gasoline. According to Angie Pender-Fox the Program Director for The Food Pantries for The Capital District, only the two box trucks are used daily for food redistribution. So, for the purposes of this study, it was assumed that only the two box trucks were used for surplus produce redistribution. It was assumed that the trucks would split up redistribution equally and each truck would do half of the overall travel. To account for this assumption, the total monthly distance traveled was divided by two to give the distance each truck would travel for monthly redistribution individually. The monthly distances traveled per truck can be seen in Table 1.

Table 1: Monthly Distances Traveled Per Truck in 2016

Month	Distance Per Truck (Miles)
Jan	0.4525
Feb	114.2700
March	95.0784
April	9.7301
May	722.3889
June	131.0790
July	347.9260
Aug	381.2876
Sept	251.3550
Oct	201.1025
Nov	73.2741
Dec	79.8917
Annually	2407.8360
Monthly	200.6530

These monthly distances were put into GREET to get the monthly GHG emissions from surplus produce redistribution, results were given in short tons of GHG which were then converted to metric tons of GHG by multiplying by a factor of 0.907185. Although GREET gives results in both short tons of GHG and barrels of oil, we used short tons of GHG converted to metric tons to evaluate results in this study. This is because WARM gives its results in metric tons of carbon dioxide equivalent and comparing metric tons of GHG and metric tons of carbon dioxide equivalent is a more equitable comparison than barrels of oil to metric tons of carbon dioxide equivalent. Other assumptions put into GREET were the use of two diesel freight trucks with a fuel economy of 12.5 mpg. 12.5 mpg was used because GREET only allows one fuel economy to be used per vehicle type, so the average of 10 mpg and 15 mpg (the actually fuel economies of the two box trucks used by The Food Pantries for the Capital District) was used in GREET. Also, the area for Source of Electricity was changed from the US average to area 6, the area including New York.

One of the diesel box trucks used for produce redistribution by The Food Pantries for the Capital District has a cooler held at constant temperature. Energy emissions from refrigeration are important to calculate for an accurate estimation of GHG emissions from redistribution. Since GREET doesn't give the option to account for the emissions from refrigeration for on-road fleets, we had to figure out another way to estimate those emissions. The average annual energy use of a walk-in cooler is 42,182 kWh/year (Navigant Counseling, Inc, 2009). According to the EPA 7.03 x 10^{-4} metric tons of carbon dioxide are released for every kWh. This calculation only included carbon dioxide and no other greenhouse gases. Also, it was unclear what the assumption for electricity mix was for this calculation (US Environmental Protection Agency, 2017). So using this conversion, an average walk in coolers release 29.6539 metric tons of carbon dioxide yearly and 2.4712 metric tons of carbon dioxide monthly. These calculations were added to monthly and annual results from GREET to get a better calculation of total GHG emissions from the two box trucks used during redistribution

The data from The Food Pantries for the Capital District also included the weight of produce donated per donation. The weight of produce donated per donation was summed for each month to give the monthly weight of produce being redistributed. The monthly weight of produce donations can be seen in Table 2. These monthly weights were entered into WARM to evaluate GHG emissions from the alternative surplus produce management strategies of composting and landfilling.

Table 2: Monthly Produce Donation Weights in 2016

Month	Food Weight (Tons)
Jan	0.065
Feb	1.160
March	0.139
April	0.140
May	5.914
June	1.895
July	2.247
Aug	1.655
Sept	1.369
Oct	0.641
Nov	0.977
Dec	0.402
Annually	16.602
Monthly	1.384

Although WARM does have an option to account for the GHG emissions from the transport of waste (in this case produce waste) to landfilling or composting facilities, unlike GREET, WARM does not include a life cycle analysis of fuel and so does not the give complete GHG emissions from transport. For this reason, GHG emissions from transporting surplus produce to landfilling and composting facilities were calculated in GREET. It was assumed The Food Pantries for the Capital District would transport produce waste from the donation source to the Albany Landfill for landfilling and Empire Zero, which brings its compost to Schenectady County Composting and Recycling Facility, for composting. Again, geocoding and network analysis, using the addresses of produce donation sources and the Albany Landfill and Schenectady County Composting and Recycling Facility, were used to calculate the road travel distance between produce donation sources and the landfilling and composting destinations. The distance from each donation source to the Albany Landfill and Schenectady County Composting and Recycling Facility were doubled, to give round trip distance, and then added up for each month to give the total monthly distance that would be traveled by trucks to transport produce surplus to landfilling and composting facilities. The assumption that both of The Food Pantries for the Capital District's box trucks would be used for transport was kept and so each monthly transport distance was divided by two to give the distance each truck would be traveling monthly. Monthly distances traveled to the Albany Landfill and Schenectady County Composting and Recycling are given in Table 3. These distances were entered in GREET with all other assumptions remaining the same as before when calculating GHG emissions from redistribution. We did not add in GHG emissions released from the cooler in one of the trucks because it was assumed if the produce was being transported to a landfill or composting facility the food would not need to be refrigerated.

Table 3: Monthly Travel to Albany Landfill and Schenectady County Compost & Recycling Facility

Month	Miles to Albany Landfill Per Truck	Miles to Schenectady County Compost Facility Per Truck
Jan	10.7817	17.8072
Feb	61.8516	114.4900
March	63.3443	118.8134
April	32.3451	53.4216
May	657.8675	1555.5860
June	238.7168	531.4987
July	319.6788	888.5114
Aug	337.6335	616.7889
Sept	278.6911	506.1126
Oct	159.6267	333.2715
Nov	129.1792	221.5996

Dec	146.2845	251.8313
Annually	2436.0010	5209.7330
Monthly Average	203.0001	434.1444

We also evaluated several alternative waste management strategies that combined composting and redistribution. Table 4 shows the alternative waste management scenarios considered.

Table 4: Alternative Management Scenarios Evaluated

Reference	Current system (no composting)
Scenario 1	Reduce travel by 25% + Compost 25% of produce (Annually)
Scenario 2	Reduce travel by 50% + Compost 50% of produce (Annually)
Scenario 3	Reduce travel by 25% + Compost 25% of produce (Monthly)
Scenario 4	Reduce travel by 50% + Compost 50% of produce (Monthly)

GHG emissions from these alternative scenarios were calculated by first calculating what monthly and annual travel for redistribution would be if reduced by 25% and 50%. Then these reduced monthly and annual travel distances were entered in GREET with all other assumptions remaining the same to get GHG emissions in short tons which were then converted to metric tons. We assumed the GHG emissions from refrigeration would also be decreased by the amount that redistribution was decreased. The assumption was made that if monthly and annual travel was decreased by X% then X% more of produce would have to be composted monthly and annually. To account for this, we calculated 25% and 50% of annual and monthly food donation weights and then entered these amounts in WARM to get GHG emissions from landfilling and composting. Emissions from the travel to Albany Landfill and Schenectady County Composting and Recycling Facility were calculated by assuming that in this new scenario the monthly distances traveled to Albany Landfill and Schenectady County Composting and Recycling Facility would decrease to 25% and 50% of original travel distances. These distances were entered in GREET with all other assumptions remaining the same. GHG emissions from reduced travel and increased composting were added together to give the total GHG emissions from alternate surplus produce management methods.

Alternative fuels were also evaluated to see if using a more different fuel type would decrease GHG emissions from redistribution. Alternative fuel types of diesel HEV, biodiesel (B100), and electricity were evaluated in GREET using the same assumptions made previously to evaluate surplus produce redistribution, except GREET fuel economy assumptions were used instead of 12.5 mpg. We assumed that GREET's fuel economy assumptions for each fuel type would be more accurate for each alternative fuel type rather than the previously assumed fuel economy of 12.5 mpg which was given to us by The Food Pantries for the Capital District regarding their two diesel box trucks.

Preliminary Results:

The preliminary results that tell monthly and annual GHG emissions from the current redistribution process can be seen in Table 5. Currently, approximately 34.0991 metric tons of GHG are released from the produce redistribution process in the Capital Region annually. This is a large amount of GHG emissions. Comparatively, this amount of GHG emissions is equal to GHG emissions of 81,486 miles traveled by an average passenger car, carbon dioxide released from 3.6 homes' energy use for a year, or carbon sequestered by 32.2 acres of forest (US Environmental Protection Agency, 2017).

Table 5: GHG Emissions from Current Redistribution Process

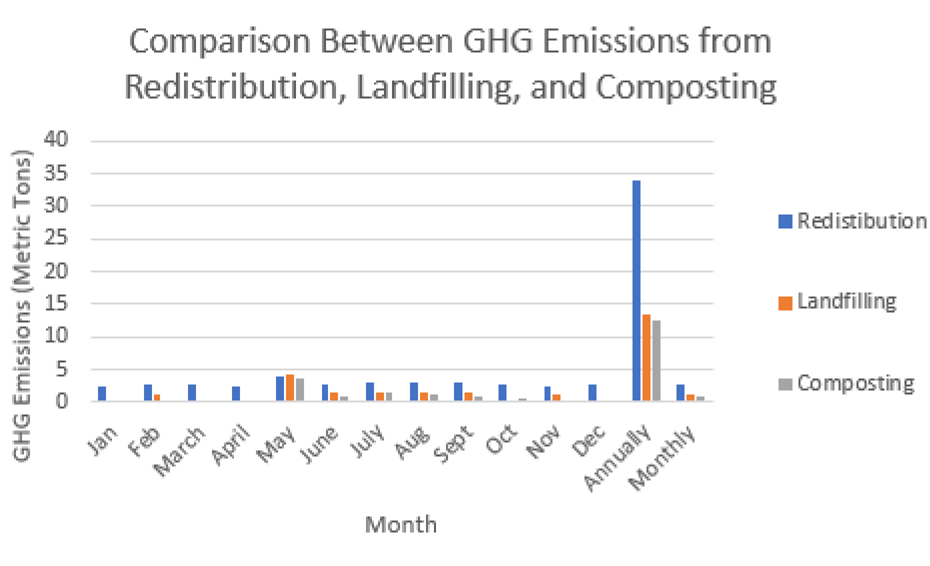
Month	GHG Emissions (Metric Tons)
Jan	2.4712
Feb	2.6526
March	2.6526
April	2.4712
May	3.8319
June	2.743
July	3.1062
Aug	3.1969
Sept	2.9248
Oct	2.8341
Nov	2.5619
Dec	2.6526
Annually	34.0991
Monthly Average	2.8341

There are many ways to reduce these emissions. One option is to use alternate waste management strategies such as landfilling or composting rather than redistribution. GHG emissions from landfilling and composting can be seen in Table 6. GHG emissions from the landfilling and composting of produce waste, calculated in WARM, were added to the GHG emissions from the transport of produce waste to the Albany Landfill and Schenectady County Compost and Recycling Facility, calculated in GREET. These results gave us total emissions from choosing to landfill or compost rather than redistribute surplus produce.

Table 6: Total GHG Emissions from Landfilling and Composting Surplus Produce

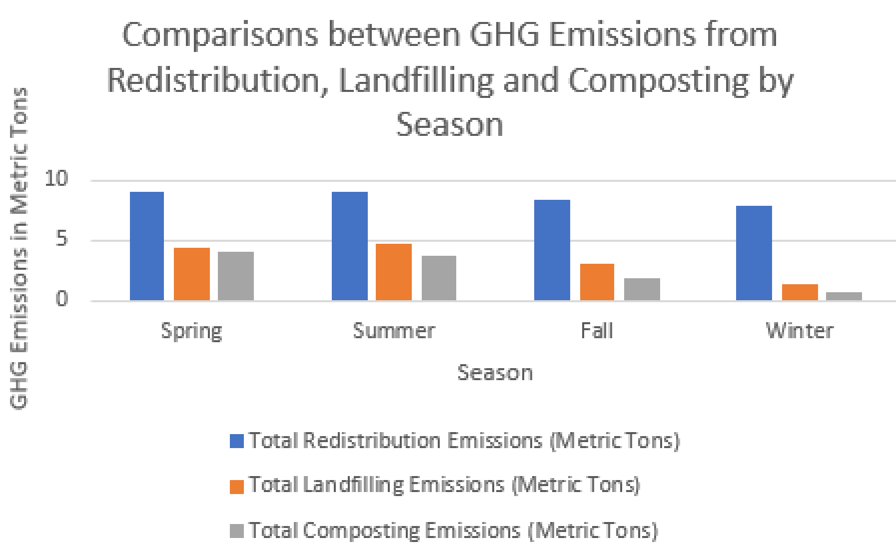
Month	Total Landfilling Emissions (Metric tons)	Total Composting Emissions (Metric tons)
Jan	0	0
Feb	1.0907	0.1814
March	0.0907	0.1814
April	0.0907	0.0907
May	4.1793	3.8123
June	1.4536	0.9979
July	1.5443	1.6329
Aug	1.6350	1.0886
Sept	1.5443	0.9072
Oct	0.2722	0.6350
Nov	1.2722	0.3629
Dec	0.2722	0.4536
Annually	13.4452	12.5254
Monthly	1.3629	0.8165

According to these preliminary results, compared to redistribution, composting and landfilling are more environmentally effective. Composting released the least GHG emissions at 12.5254 metric tons of GHG yearly. The full comparison between redistribution, landfilling, and composting can be seen in Graph 1.



Graph 1:

Graph 2 shows comparisons between redistribution, landfilling, and composting by season. Across seasons, emissions from redistribution, landfilling, and composting were fairly even with emissions from redistribution, composting, and landfilling being the lowest in winter. Emissions from redistribution and landfilling were highest in the summer while emissions from composting were highest in the spring.



Graph 2:

Since, composting released the least GHG emissions annually when compared to redistribution and landfilling we looked at composting as the main alternative waste management strategy to explore. However, since human need is also a strong factor in considering how to reduce GHG emissions from redistribution, it is not ethical to compost all surplus produce because access to fresh fruits and vegetables would be taken away from many food insecure people in the Capital Region if this were to happen. Instead, we looked at strategies to combine composting and redistribution. Through this method, we hoped that GHG emissions would be reduced while still keeping access to fresh produce for the food insecure. The GHG emissions (in metric tons) from these alternative management strategies can be seen in Table 7. These results show that reducing redistribution by 50% and instead composting 50% of produce surplus on a monthly basis reduced GHG emissions by the greatest percentage. However, reducing redistribution this much is likely not realistic and would probably impact food insecure people's access to fresh produce. Composting still should be considered when looking at ways to make the current redistribution system more environmentally effective. There are still many other alternative strategies to reduce GHG emissions from the produce redistribution process that should be explored.

Table 7: GHG Emissions from Alternative Management Strategies

Management Method	Emissions from Redistribution (Metric Tons)	Emissions from Composting (Metric Tons)	Emissions from transport to composting facility (Metric Tons)	Total Emissions (Metric Tons)	Decrease in Emissions
Current Annual	34.0991	0.0	0.0	34.0991	N/A
Decrease Redistribution 25% and Increase Composting 25% (Annually)	25.5960	4.3566	2.3587	32.3113	5.24%
Decrease Redistribution 50% and Increase Composting 50% (Annually)	17.0042	3.1770	4.8081	24.9893	26.70%
Current Monthly	2.8341	0.0	0.0	2.8341	N/A
Decrease Redistribution 25% and Increase	2.1256	0	.1814	2.3070	18.60%

Composting 25% (Monthly)					
Decrease Redistribution 50% and Increase Composting 50% (Monthly)	1.4170	0	.3629	1.7799	37.20%

Another alternative strategy to reduce GHG emissions from the redistribution process is to use vehicles that run on alternative fuels to redistribute the surplus produce. Biodiesel (B100), diesel HEV, and electricity were the alternative fuels compared to diesel. We used GREET to calculate GHG emissions from vehicles using alternative fuels using both the monthly average of miles traveled per vehicle for redistribution and the annual vehicle miles traveled per vehicle for redistribution. These results are only GHG emissions from vehicles during redistribution and do not include GHG emissions from cooler use during redistribution. Results from evaluating alternative fuels can be seen in Table 8. Biodiesel and electricity both released less GHG emissions than diesel, with biodiesel releasing the least GHGs. Diesel HEV released more GHG emissions than diesel.

Table 8: GHG Emissions from Alternate Fuels

	Emissions from Diesel (Metric Tons)	Emissions from Diesel HEV (Metric Tons)	Emissions from Biodiesel (B100) (Metric Tons)	Emissions from Electricity (Metric Tons)
Monthly Average	0.3628	0.6350	0.1814	.2721
Annually	4.4452	7.3482	2.2680	3.5380

Discussion:

Preliminary results of this study found that between the current produce redistribution system, landfilling produce surplus, and composting produce surplus, composting released the least GHGs. Through decreasing vehicle travel for redistribution by optimizing redistribution routes, and increasing the amount of surplus produce composted these primary results show that GHG emissions from the redistribution process could be decreased. These results will be important as we develop a model that optimizes the surplus produce redistribution process so that food insecure people have maximum access to fresh produce while keeping GHG emissions at a minimum.

This project is important for public and environmental health because redistributing surplus produce with vehicles releases large amounts of GHGs and consequently has a negative environmental impact. By determining the optimal way to decrease these emissions while also keeping access to fresh produce for the food insecure we could significantly lessen the environmental impact of the produce redistribution process in the Capital Region while still maintaining an important human need. While many organizations are working to improve food insecure people's access to produce, which is a very important goal, few projects have looked at the environmental effects of redistribution. This project tried to fill that gap by calculating the amount of GHGs being released by the current produce redistribution process in the Capital Region and comparing this to alternative surplus produce management strategies.

In absence of more comprehensive results, we can give several recommendations. Composting releases less GHG emissions than landfilling so we can recommend that food panties compost any leftover produce, how little it may be, rather than send it to a landfill. Composting is better for the environment than landfilling because landfilling releases methane while composted materials release carbon dioxide. Methane is worse for the environment than carbon dioxide because methane can hold almost 25 times more heat in it than carbon dioxide. Even though many landfills have gas collection systems that collect gas released from landfills and burn it or convert it into energy, most of these gas collection systems are not entirely effective. In fact, the EPA estimates that most landfill gas collection systems only recover 60% to 90% of methane, this leaves a large amount of methane still being released into the environment (Lindeberg et al, 2017). Composting at food pantries' locations would also reduce emissions from transporting surplus produce to composting facilities. Also, emissions from cooler use were one of the largest contributors to GHG emissions from redistribution. If food redistributors could somehow reduce emissions from cooler use this would greatly reduce GHG emissions. Finally, using different vehicles that use more environmentally effective fuel could also help decrease GHG emissions from redistribution. Our preliminary results showed that biodiesel and electricity both released significantly less GHGs than diesel, with biodiesel releasing the least. However, because many of the food pantries in the Capital Region have limited budgets, this recommendation is likely not realistic. Also, emissions from the manufacturing of the new cars would have to be accounted for.

Limitations:

There are several limitations in this study which prevented a complete calculation of GHG emissions from food redistribution in the Capital Region. Firstly, we only used data from the 56 member pantries of The Food Pantries for the Capital District to calculate GHG emissions, and there are many other food pantries that are not included here. Since, we did not have data about routes and produce donation weights and frequencies from every food pantry in the Capital Region our GHG calculations are incomplete and do not calculate GHG emissions from the entire produce redistribution process in the Capital Region. Instead, our preliminary results are a starting point to show a rough estimation of the environmental impact of the redistribution process in the Capital Region.

Another limitation of this study is that we made several assumptions about the redistribution routes for network analysis that may not hold in reality. We assumed that during redistribution each truck went from the source individually to each pantry. Most likely, this assumption is not true and each truck picks up produce donations from multiple sources on a single trip before dropping off the donations at their destinations. Due to this our calculations are likely an overestimation of true GHG emissions from the redistribution process. We also calculated round trip mileage by multiplying the distance from source to destination by two. This implies that the trucks return to the source after delivering the food, which they don't. Instead, they return to The Food Pantries for the Capital District's location. We made the same assumption about round trips for the waste management alternatives when calculating mileage traveled from sources to the Albany Landfill and Schenectady County Composting and Recycling Facility. We also assumed that for landfilling and composting that The Food Pantries for The Capital District's vehicles would be bringing produce waste to Albany Landfill and Schenectady County Composting and Recycling Facility. In reality, the donation sources would likely transport the produce waste themselves or the waste would be picked up by the facility. However, we did not have information about vehicles used by these organizations so we could not calculate GHG emissions based on their vehicles. These assumptions, if false, would affect the mileage traveled by each truck and therefore, the calculations of GHG emission from the redistribution process.

Also, network analysis done to calculate route mileage was not done using the true streetway dataset for New York State. In other words, it doesn't account for, for instance, if there is a no right turn onto a certain street or other driving restrictions. Since, we did not have this information the mileage traveled by each truck was not completely accurate. These inaccuracies could have affected the accuracy of GHG emission calculations.

Our estimations of GHG emissions from refrigeration of surplus produce were not calculated based on The Food Pantries for the Capital District's cooler use but instead were estimated based on yearly averages of cooler use in the United States. Not using a more accurate method of calculating these emissions could have negatively affected the accuracy of our calculations of GHG emissions from vehicle redistribution of produce. In order to properly calculate the GHG emissions from cooler use a more exact method of calculation should be used in the future.

Another limitation is that we did not assess technologies which convert produce waste into electricity or fertilizers, which are other important waste management alternatives. Also, in our evaluation of the environmental impact of the redistribution system we only assessed energy and GHG emissions. Other important measures of environmental impact we did not evaluate in this study are water quality, water quantity, and biodiversity. Finally, our life cycle assessment approach was simplified and did not account for the environmental benefits of avoiding agricultural production due to reusing food surplus.

Future Research:

In the future, we intend to do more research about the produce redistribution process in the Capital Region to get a more accurate calculation of GHG emissions from this process and to better be able to determine ways to decrease GHG emissions from the produce redistribution process. Firstly, we intend to collect data from more food pantries in the Capital Region. Some of the other non-profits that donate and serve food we hope to get data from are Honest Weight Food Co-op, Capital Roots, and Food not Bombs, all of which are major figures in the surplus produce redistribution process in the Capital Region. Also, we want to do more research with The Food Pantries for the Capital District to find out more about their redistribution routes. This includes finding out if the assumptions we made for network analysis hold in reality. We also intend to use a more advanced network analysis for more accurate vehicle mileage calculations. This will help us more accurately calculate vehicle mileage during produce redistribution. By doing these things we will be able to more accurately calculate current GHG emissions from the produce redistribution process in the Capital Region. Additionally, this further research will help us in determining an optimal route for the redistribution process that will give food insecure people improved access to fresh produce while decreasing GHG emissions from the process.

Finally, we intend to look at the influence of other factors towards GHG emissions from the produce production process, such as farming choices, to get a more complete estimation of GHG emissions from the entire produce production process and supply chain and ways to reduce GHG emissions from this process. As already mentioned, the entire food production process accounts for approximately 17% of GHG emission in the United States (Green Eatz, 2016). There are many ways to reduce GHG emissions in the produce production process other than reducing emissions from produce redistribution. It is important to look at the entire produce production process to determine what actions, besides optimizing redistribution routes and increasing composting, can be done to reduce GHG emission from this process.

Conclusion:

Our preliminary results show that the current produce redistribution process in New York's Capital Region emits 34.0991 metric tons of GHG annually. Optimizing redistribution routes, increasing composting of surplus produce, and using biodiesel run vehicles for redistribution all seem like promising options for ways to reduce GHG emissions from the redistribution process. However, a lot of future research remains to be done to get a more accurate calculation of GHG emissions from surplus produce redistribution in the Capital Region and to further analyze the benefits of and issues with alternative waste management strategies.

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