

*Evaluating an Environmental Sustainability Program and Related Metrics at a
Continuing Care Retirement Community*

by

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April 22, 2022

EXECUTIVE SUMMARY

More than 2,000 Continuing Care Retirement Communities, or CCRCs, exist across the United States. CCRCs provide a variety of amenities for their residents, including multiple types of residences, dining services, medical facilities, gyms, and more. CCRCs have the potential to implement numerous sustainability initiatives on their campuses and to influence local efforts to mitigate climate change. This Master's Project sought to help Carol Woods, a non-profit CCRC located in Chapel Hill, NC, understand its current environmental footprint focusing on Dining Services and Buildings & Facilities, develop possible sustainability metrics, and explore potential interventions to improve its environmental sustainability.

The methods we used in this project can be summarized as comparative benchmarking and current state analysis. For comparative benchmarking, this project examines both other CCRCs' sustainability efforts and small-to-medium colleges and universities with outstanding sustainability practices. Our current state analysis focuses on Dining Services and Buildings & Facilities. We adopt a mass-balance framework to identify the amount of input and the corresponding output. Specifically, we looked into Carol Woods' food purchasing records to identify the food products with significant environmental impacts. For the output measurements, we conducted a food waste audit and calculated its environmental footprint. In the sector of Buildings & Facilities, we conducted an energy audit focusing on annual electricity consumption and natural gas consumption from 2016 to 2020 as well as evaluated Carol Woods' institutional vehicle fleet. The outputs of the analysis are greenhouse emissions in terms of electricity and natural gas consumption as well as the environmental performance of Carol Woods' vehicles.

In the Dining sector, results have shown that GHGs led by Carol Woods' animal protein ordering total around 135,730 kgCO₂e in one month. Results of the waste audit show that Carol Woods composts between 400 and 500 pounds of food waste per day. Additionally, Carol Woods has a significant amount of animal protein in their food waste and beef is a key contributor to greenhouse gas emissions. In the Buildings & Facilities sector, Carol Woods' GHG emissions from electricity consumption over six years stabilize at around 3,100 metric tons annually. The dining building and Building 4 (medical center) account for major parts of the emissions. Natural gas consumption has witnessed a decline from 2017 to 2019, a drop of over 40%. Fifteen vehicles owned by Carol Woods were included in our analysis with the cleanest vehicle being the 2018 Chrysler Pacifica van and the dirtiest being the 1999 Chevrolet C2500.

To improve sustainability in its Dining Services, we recommend Carol Woods reduce the amount of animal protein ordered, switch to buying a number of its ingredients locally instead of

from large food vendors, increase its internal tracking of recipes and resident complaints, switch to reusable to-go containers, and reconsider its approach to food disbursement and handling of leftover foods. As for improving sustainability in Buildings & Facilities, we recommend that Carol Woods perform ongoing maintenance of building equipment, install LED lights in places where they are not currently, expand solar arrays, and establish an energy dashboard for tracking. To make its transportation operations more sustainable, we recommend Carol Woods conduct an annual transportation survey for institutional fleets, residents, and employees, and purchase a hybrid van and electric truck to replace the most polluting vehicles they currently have.

To continue gaining a deeper understanding of Carol Woods' environmental impact, we suggest multiple avenues for further research. For Dining Services, we recommend that an updated purchase audit be conducted to align with their most recent menu. We also recommend continuing the waste audit, which we believe is an ideal opportunity for residents to get involved. Lastly, further research should be conducted to better understand the sustainability certifications held by food suppliers and which foods are most beneficial to buy locally. For Buildings & Facilities, we recommend that Carol Woods implement the use of the Energy Use Index (EUI) and conduct a more in-depth study of the Siemens electricity data to better interpret the variations in energy usage across the campus.

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I. CLIENT OVERVIEW AND PROJECT IMPORTANCE

Client Overview

Carol Woods is an approximately 500-resident, non-profit continuing care retirement community (CCRC) located in Chapel Hill, North Carolina. The 120-acre Carol Woods campus is home to three kinds of accommodations to meet the changing needs of its residents: independent living, assisted living, and nursing care. Living arrangements include apartments, single and duplex cottages, and townhomes, as well as nursing facilities. Carol Woods is very much a campus, incorporating a dining hall, fitness areas, clinics, a library, gardens, and more. Carol Woods emphasizes an independent lifestyle and empowers its residents to stay engaged intellectually, physically, and socially (Carol Woods, 2021). As of February 2022, Carol Woods had 408 residents in independent living and 90 residents in assisting living or nursing care (Healy, 2022).

Carol Woods residents are active members in nearly every aspect of the community, and can choose to serve on one or more of over 80 resident-run committees, ranging from the Dining Services Committee to Safety & Security. Many Carol Woods residents have a keen interest in sustainability, both at the global, climate-change scale and also at the local action level. Residents are very interested in making Carol Woods as sustainable as possible to aid in reducing the campus's environmental footprint, and many serve on the Energy Conservation and Sustainability Committee to help reach this goal. Carol Woods has already made great strides in sustainability, such as becoming a Certified Wildlife Habitat, installing electric car charging stations, composting dining waste, and utilizing green products throughout much of its operations. The role of this Master's Project, through a partnership with the Energy Conservation and Sustainability Committee, is to help Carol Woods understand its current environmental footprint, identify current and possible metrics to be measured on the campus, and suggest interventions to improve its environmental sustainability.

Project Value: Sustainability and CCRCs

Over 28,900 residential care communities exist in the United States (American Health Care Association, 2020), around 2,000 of which are CCRCs (Breeding, 2018). CCRCs offer a full continuum of living situations for the elderly to assist them as they age and their needs change (AARP, 2022). Many CCRCs across the US operate similarly to Carol Woods, offering housing, dining services, recreation,

healthcare, and more. With these services comes a large environmental footprint caused by the inputs (food, electricity, natural gas, landscaping materials and chemicals, etc.) and outputs (solid waste, Greenhouse Gas (GHG) emissions, pollution) of the campuses. While individual CCRC's promote a number of sustainability programs and initiatives, such as energy efficiency (Shoemake, 2018) and community gardens (Baker, 2018), our initial literature review suggests that most, if not all, CCRCs lack a comprehensive sustainability plan. The most recent update from the International Panel on Climate Change (IPCC) emphasizes the urgency of the climate crisis, which has largely been caused by human activity (IPCC, 2021), and the need for action by all organizations. Because of their size and complexity, CCRCs have the capability to make a notable impact on their local efforts to mitigate climate change. Just as many colleges and universities are designing and implementing sustainability plans to mitigate their impact from operations, CCRCs can adopt sustainability strategies to use their campus-like facilities as positive actors in fighting climate change. Implementing sustainability practices not only contributes to local climate change efforts and appease residents, but also has a strong business case for reducing costs, improving operations, boosting image, and retaining employees (Cote, 2021). Similarly, sustainability initiatives adopted by CCRCs could prove to be a positive marketing tool to attract new residents interested in lowering their environmental impact and contributing to their communities (Shoemake, 2018).

II. OBJECTIVES

This Master's Project seeks to aid Carol Woods in its pursuit of campus-wide sustainability by gaining an understanding of its current environmental footprint focusing on Dining Services and Buildings & Facilities - and to explore potential future interventions to lessen their impact on natural resources while working within the financial and operational limitations that exist on the campus. Dining and Buildings & Facilities were chosen because Carol Woods expressed clear interest in these areas, and our team felt that actionable steps could be taken for environmental improvement in these areas. We seek to answer three primary questions:

- In what ways does Carol Woods most impact the environment through its Dining Services and Building & Facilities operations and how does this compare to similar facilities, such as other CCRCs or similarly sized college campuses?
- In the areas of Dining Services and Buildings & Facilities, what facets of environmental sustainability are currently being measured and which metrics are not? Of those metrics not being measured, which should begin to be measured to produce beneficial data?
- What interventions will have the greatest impact on Carol Woods' triple bottom line (environment, social, economic) that are achievable given financial and operations constraints? What is the anticipated cost and/or cost savings of these interventions? Are these capital (cost), administrative (no cost), or resident behavior changes?

To achieve these objectives, our team utilized comparative benchmarking and a current state analysis. Our current state analysis included an order invoice audit and a waste audit for Dining Services, and electricity, natural gas, and vehicle fleet audits for Buildings and Facilities. Each of these methods are described in detail in their respective sections below.

III. COMPARATIVE BENCHMARKING

As outlined above, Carol Woods is one of about 2,000 CCRCs in the United States. Understanding what similarly-designed campuses are doing for environmental sustainability can help Carol Woods to understand how they measure up to their peers and what their desired sustainability state might be. Carol Woods' design and operations reflect the components of many other CCRCs, but also resembles small college campuses in that included components are residential areas, dining facilities, medical facilities, gyms, gardens, walking trails, and more. For this reason, our comparative benchmarking explores both CCRC sustainability efforts and those of small-to-medium colleges and universities.

Continuing Care Retirement Communities

This team completed the comparative benchmarking using two methods: 1) attempting to contact other CCRCs who are in similar associations as Carol Woods and 2) doing internet research. To complete the first method, we asked the Carol Woods administration to send an inquiry out to the listservs they are on as part of associations, certifications, and communities of practice. The administration did not generally share with us the names of these listservs, or which CCRCs specifically participate in them, though from a forwarded email we did learn of one listserv, the LeadingAge Life Plan Community. From this listserv, Carol Woods received one response from another CCRC provider, Landis Communities, which oversees numerous properties, including Landis Homes. Landis Homes forwarded a number of popular press articles about their sustainability efforts, which can be summarized as:

- **Landis Homes** (Lititz, PA): The Landis Homes community has a LEED Gold Certified building on its campus expansion (Good, 2008) and has participated in stream and wetland restoration projects across its campus (MOST, n.d.). Residents participate in bee and plant conservation initiatives in partnership with the administration (Gates, 2017).

The administration only received a response from one other CCRC in Virginia, Goodwin House, from the other listserv requests. Our team had a meeting with Goodwin House to discuss sustainability at CCRCs. During this meeting, Goodwin House was most interested in the sustainability measures that Carol Woods was taking. Goodwin House only had two sustainability actions: a "Green Team" (similar to Carol Wood's "Climate Crowd") and utilizing composting. The Goodwin House representatives were unable to give us any specific steps to take to become more sustainable but were interested in the future steps Carol Woods might take for sustainability. For this reason, the first method of using listservs for comparative benchmarking with other CCRCs resulted in the identification of only one other CCRC that is

similar to Carol Woods in its sustainability practices, and no other CCRCs that are notably further along than Carol Woods in their sustainability practices.

This team also utilized internet searches for popular press articles to find the sustainability measures that other CCRCs were taking. After significant searching, we were only able to find popular press information about three additional CCRCs that are taking steps for sustainability:

- **Pennswood Village** (Newtown, PA): Pennswood Village has a personal care building with LEED Gold Certification, and has also installed a geothermal heating and cooling system for some of the buildings. The campus has a recycling program and community garden, and, through a partnership with a nearby town, has installed a stormwater management system under its meadow (Baker, 2018).
- **Williamette View** (Milwaukee, OR): This CCRC recently built a new, eco-friendly building on its campus. The building features solar panels on the roof and living roofs to cover the carports. All of the residential units feature Energy Star appliances, and any trees that were removed on the property during construction were repurposed inside the building (Breeding, 2018).
- **Kendal Properties** (various locations): This CCRC parent company embraces numerous sustainability practices across its thirteen properties across the US, including composting, electric vehicle charging stations, rainwater capture, tree planting programs, and more. Residents take a very strong role in implementing these strategies, similar to Carol Woods. Kendal's newest campus, Enso Village (Healdsburg, CA), is set to be the most comprehensively sustainable of all. This campus is being designed with environmental sustainability at the forefront. The community will utilize solar power for a significant amount of its energy, is focusing on using its land effectively, and will follow all standards put forth by LEED Gold, CalGreen, and Title 24 (Kendal, 2022).

In our research, we were unable to find any CCRC that has a holistic and comprehensive sustainability plan for its campus. The Enso Village property, which is under construction, seems to have the most complete sustainability objectives. Our team had particular interest in Enso Village for this reason and attempted to make contact with its representatives; however, we were unable to reach anyone from Kendal Senior Living Communities for an interview.

The fact that we identified no other CCRCs taking a comprehensive sustainability approach means that Carol Woods has the potential to be a leader in this space. Carol Woods is already thinking

holistically about its environmental impact and could prove to be a key player in encouraging sustainability at CCRCs across the country.

Colleges and Universities

CCRCs and Institutions of Higher Education (IHE) both have similar amenities and IHE is increasingly focusing on-campus sustainability efforts. In our benchmarking approach, we reviewed the approaches of other colleges and universities in sustainability strategies and actions, informing Carol Woods' own plan. Our scope of this benchmarking includes colleges with similar acreages or amenities to Carol Woods, or those with top sustainability performance based on 2020 Sustainable Campus Index released by the Association for the Advancement of Sustainability in Higher Education including IHEs such as Bowdoin College, University of Washington, College of Charleston, and Smith College etc. Figure 1 illustrates four pillars to sustainable solutions where we distilled them from our IHE benchmarking research and summarized into four areas relevant to CCRC's. Below we will describe each area, and provide one example from an IHE similar to CCRC in acreage or amenity.

First, sustainability-minded colleges and universities typically set carbon neutrality goals through specific actions including GHG management, energy efficiency improvement, travel-related emissions reduction, and minimizing impact of operations on annual emissions. For example, Smith College has implemented a series of buildings and energy upgrades such as LED lighting installation, double glazing, building sealing, insulation as well as equipment replacement etc (Smith College, n.d.).

The second area is waste management including materials flow analysis, procurement, food waste management, and system regeneration. Institutions set goals to track and manage its waste streams, prioritize its purchasing of products that can be reused or recycled, improve the sustainability of food procurement, and promote composting on campus. For instance, Bowdoin College use food management software to accurately predict menus to match food production and consumption. If overproduction occurs, the dining department works with students to distribute surplus food to local nonprofits (Bowdoin, n.d.).

Integrated learning is summarized as another important area of universities' sustainable solutions. It aims to create opportunities for students, faculty, and staff to deepen their understanding of environmental sustainability through awareness building, increased staff involvement, and public access to online resources. A good example is that Antioch University Los Angeles launched Sustainability Vision web pages including images and description of its sustainability vision, Sustainability Committee, sustainability projects, and a list of resources and partners. Antioch University Los Angeles also aims to

educate the faculty on the concept of sustainability and offer definitions and examples of sustainability (Antioch University, 2015).

The fourth area is cultivation of a sustainability culture by creating a sustainability vision with objectives, fostering justice, equity and diversity initiatives across campus, engaging community partnerships to meet their goals, and integrating the core values of sustainability into the institution’s daily operation and living environment. For example, Colorado College offers sustainability-focused activities that involve students through community engagement and maintains partnership with large food services supplier Sodexo to educate on proper waste treatment (Colorado College, 2021).



Figure 1. Summary of sustainable solutions at colleges and universities

The benchmarking of IHE provide four areas and at least 16 sub areas that could inform efforts by Carol Woods and other CCRCs to achieve sustainability goals. Carol Woods has already been sustainability minded and examples of IHEs’ actions in four areas can help Carol Woods form a more comprehensive sustainability thinking.

IV. CURRENT STATE ANALYSIS

Carol Woods is focused on becoming a more comprehensively responsible campus across environmental and social measures. The organization has categorized its current work and goals into four main areas in its “Sustainability Definitions and Pillars” (Carol Woods, 2021):

1. Environmental Stewardship,
2. Inclusive Growth,
3. Engaged Social Community,
4. Responsible Economic impact.

For the purposes of this current state analysis, and because of our focus on Dining and Buildings & Facilities, we will focus on the Environmental Stewardship pillar. A detailed schematic of this scope is provided in Figure 2.

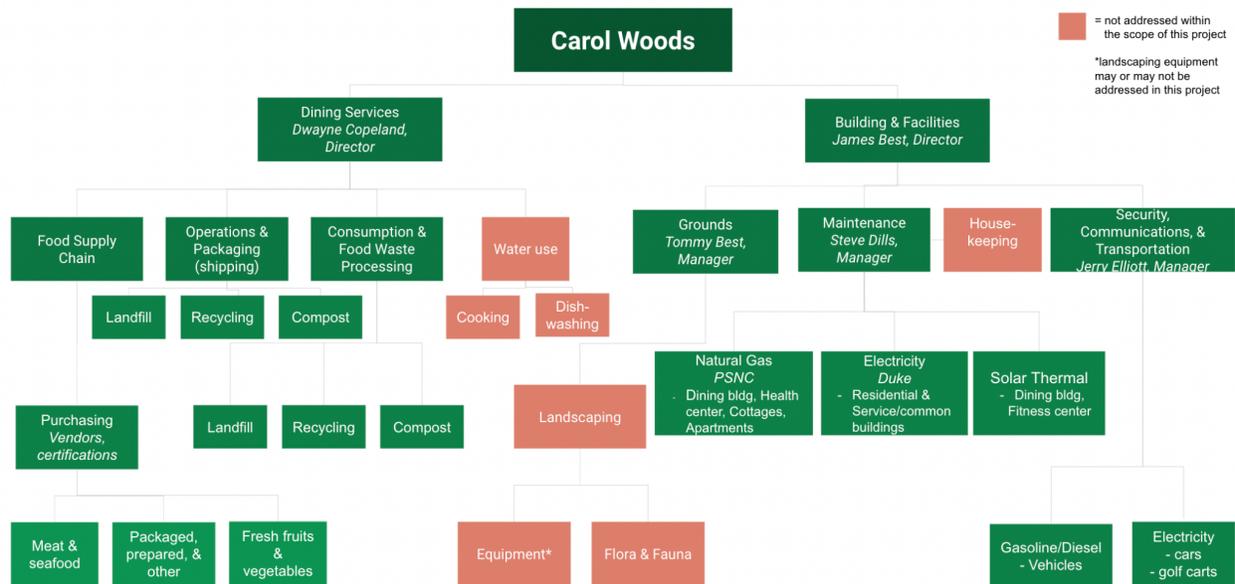


Figure 2. Scope of project focus on Dining Service and Buildings & Facilities

Dining Services Overview

Dining Services at Carol Woods serve the entire campus of residents and employees (should employees choose to purchase their meals on campus) from its one, main kitchen. The main kitchen services the main dining hall, as well as Buildings 4, 5, 6, and 7, which provide assisted living and nursing care (a map of the campus can be seen in Appendix A, Figure 1). Residents visit the dining hall, and can either dine-in or take-out, while food for residents in Buildings 4, 5, 6, and 7 are taken to those buildings

by heated meal delivery carts. The main kitchen offers breakfast, lunch, and dinner every day of the week. Meals are included as part of residents' monthly fees. Each resident is given 30 meal credits per month to use as they wish, though most residents use this for one meal per day. The remainder of meals are either purchased for additional fees or made at home by residents.

Currently, Dining Services utilize CompostNow to dispose of their preparation scraps, unprepared but expired foods, and leftover prepared foods. CompostNow is a localized composting service that provides empty compost bins for a wide variety of compostable materials and picks them up when full for a monthly charge (CompostNow, 2022). All unprepared foods and leftover prepared foods are put into the CompostNow bins, including vegetables, fruits, dairy, meat, and seafood. The exception to this is the pre-made to-go lunches, which are for sale in the fridge case in the dining hall throughout the day; these meals are put out to be free for the taking at the end of the day. Typically, all of these free meals are taken by residents, but any leftovers are still composted. Dining Services also purchase compostable to-go meal supplies, such as paper clamshells containers, so these materials may be composted as well. Additionally, employees are allowed to eat leftover foods after each meal service on-site, but are not allowed to take leftover foods off of the premises. Staff believe that employee meals account for only a small amount of food waste reduction.

Dining services use a rotating menu system that changes through the seasons. To offer this rotating menu, dining services purchase ingredients and supplies from four main vendors: US Foods, Fresh Point, Inland Seafood, and Sysco. Fresh, shelf-stable prepared, and frozen foods, as well as kitchen and serving supplies, are ordered from these vendors. What is ordered from each vendor varies with availability. At the time of this study, Carol Woods administration and Dining Services were exploring the possibility of purchasing a software that would help them limit food waste from over-ordering.

Buildings and Facilities Overview

Buildings & Facilities encompasses all built structures managed and maintained by Carol Woods, the Carol Woods-owned transportation fleet, and the landscaping equipment owned by Carol Woods.

A large contributor to Carol Woods' energy consumption is electricity usage. Carol Woods purchases all of their electricity from Duke Energy for the use of heating, lighting, hot water, and recharging the vehicle fleet. Electricity use in buildings covers residential buildings, cottages, townhomes, and common/service buildings. The electrical energy used in the cottages is not measured by any meter except that it is included in the grand total reported on the monthly Duke energy bill. Carol Woods has ten major buildings, consisting of the main building with social/assembly hall, a dining

building, three assisted living buildings, health center, three apartment buildings, and a fitness center. Each of the buildings has a Siemens smart meter, which records electricity use hourly.

Natural gas is a secondary form of energy distribution. A natural gas meter is installed at each building providing monthly usage. Water-sourced heat pump is powered by natural gas to deliver heat. Overall, six major and 40 minor gas meters exist in residences where each unit on the map (refer to Appendix A) has a measuring meter.

Carol Woods transportation is also included in our scope of analysis. Currently, Carol Woods owns 18 vehicles including buses, vans, sedans, SUVs, and box trucks. Vehicles are assigned different functions, such as housekeeping, marketing, staff use, security, and medical response.

Dining Services: Order Invoice Audit

Literature Review

Consensus from the academic and global development communities is increasing that humans' means of food production for our growing population (and growing desire for on-demand variety in what we eat) is impacting our land, water, climate, and people (Borunda, 2021). A feedback loop is emerging between climate and our food systems, as the climate is projected to increasingly impact what and when we eat in the coming decades. Rising temperatures, water scarcity, and shrinking available land is making our food and agriculture choices more crucial than ever (Nelson et. al., 2009). The impacts of our relationship with food and its production will only become more dramatic within our lifetime (van Dijk et. al., 2021).

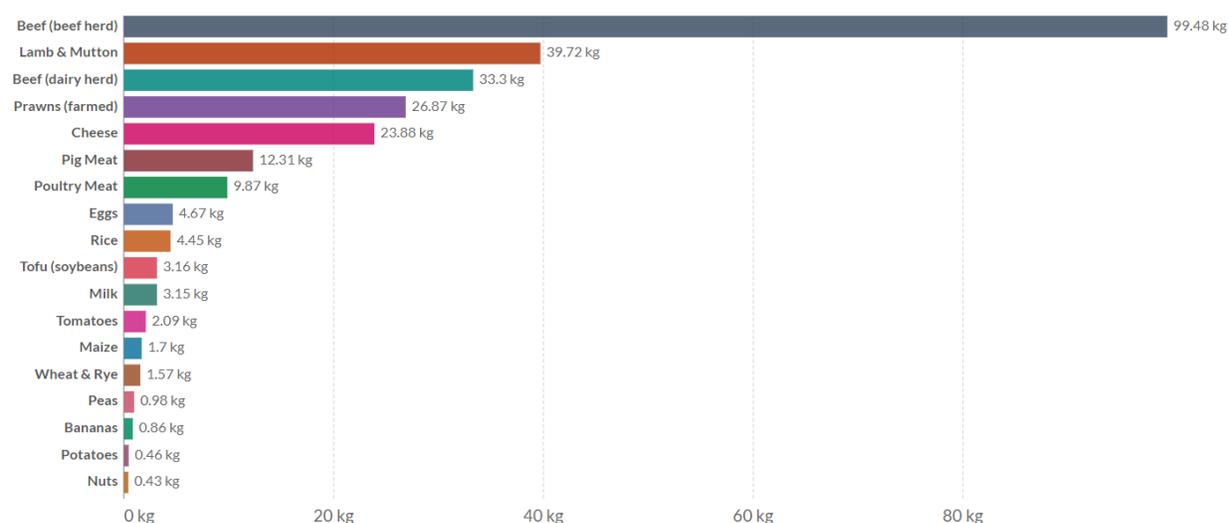
Many factors go into calculating the overall environmental impact of a particular food, and often calculations are designed to focus on the impacted resource of interest. Factors or natural resources included in calculating a food's environmental impact might include, but are certainly not limited to: combined GHG emissions over the life cycle of the product (from harvest, processing, distribution/transport, etc.), specific GHG emissions (such as carbon dioxide or methane), amount of land cleared, soil erosion, water use/demand, nutrient and chemical runoff, or social impact (Cucurachi et.al., 2021).

What foods individuals, businesses, restaurants, and dining facilities choose to purchase, and at what quantities, impact the earth and its climate. Certain foods are worse for the environment, climate, and people than others. In terms of greatest environmental impact, animal protein (or "meat," which

includes livestock, poultry, and seafood, as well dairy and eggs), is at the top of most lists. Poore and Nemecek (2018) showed, however, that even within the same food group, environmental impacts varied greatly among producers. On average, beef (for both meat and dairy), lamb, prawns, cheese, pork, and eggs had the greatest greenhouse gas emissions per kilogram of food product, as shown in Figure 3. Other, non-animal-protein foods known to have large environmental impacts include bananas, almonds, sugar, coffee, palm oil, avocados, and soybeans. Farmed salmon is also of particular note (Clift, 2015).

Greenhouse gas emissions per kilogram of food product

Greenhouse gas emissions are measured in kilograms of carbon dioxide equivalents (kgCO₂e) per kilogram of food product. This means non-CO₂ greenhouse gases are included and weighted by their relative warming impact.



Source: Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers.

OurWorldInData.org/environmental-impacts-of-food • CC BY

Figure 3. Greenhouse gas emissions per kilogram of food product

Certain agricultural practices, as well as small changes in consumer behavior, can help to mitigate these impacts of these foods with high environmental footprints. Practices such as rotational farming, organic farming, agroforestry, integrated pest management, and modern irrigation can help to reduce overall environmental impacts (UCSUSA, 2021). Consumer purchasing behaviors can also make a difference, such as buying local and limiting red meat intake. Research has shown that small changes in an individual's diet can have major positive impacts for the environment - substituting just 10% of animal protein consumption with plant proteins (and in some cases, seafood) can reduce dietary carbon footprint by up to 33% (Stylianou et. al. 2021). As seen in Figure 4, plant-based foods tend to be less resource-intensive than animal-based foods (WRI, 2016). As a bonus, these more environmentally friendly food choices have also been shown to be beneficial for human health (Tufts, 2019), which is an important consideration for nutritionists at CCRCs.

Animal-Based Foods Are More Resource-Intensive than Plant-Based Foods

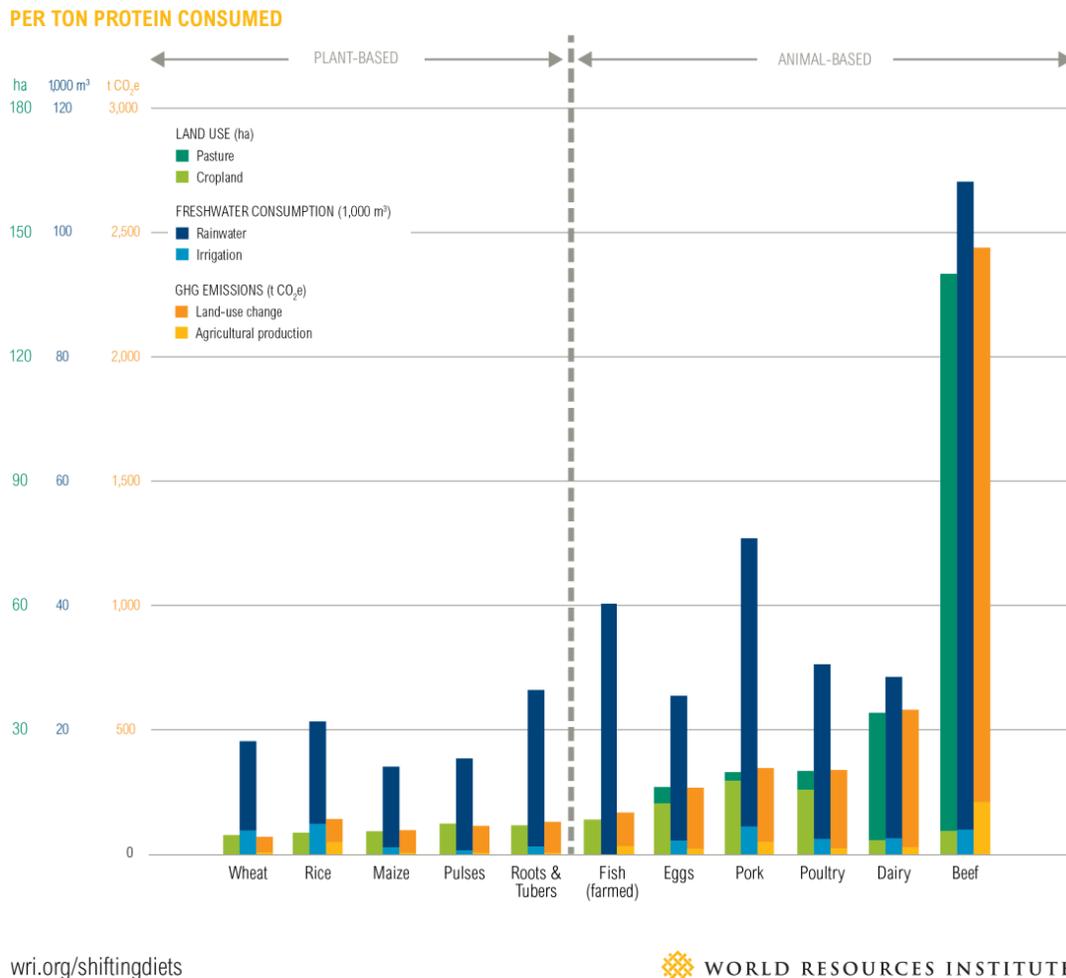


Figure 4. Environmental Impact of Animal-Based vs. Plant-Based foods

Carol Woods utilizes three main vendors for their Dining Services supplies: US Foods, Inland Seafood, and Sysco (and their subsidiary FreshPoint). All of these vendors have sustainability goals listed on their websites. US Foods and Sysco have the most robust Corporate Social Responsibility (CSR) reports. US Foods has goals and metrics around “People, Planet, and Product” and its highlights in the area of “Product” include certified sustainable palm oil and an in-house sustainable fisheries certification (US Foods, 2021). Sysco’s 2025 Sustainability Goals center on “People, Product, Planet” and highlights from their “Product” area include a focus on sustainable beef, sustainable sourcing of fish, and humane practices (Sysco, 2022). Inland Seafood does not have a full sustainability report, but outlines such practices as local sourcing, third-party certifications, and pre-competitive agreements, among others, on its website (Inland Seafood, 2015).

Methods

The order invoice audit was completed to better understand how much of each type of food product Carol Woods is ordering in one month and the environmental impact (specifically GHG emissions) of those ordering habits. Carol Woods provided us with Dining Services order invoices for three months in 2021: August, September, and October. Some invoices for the end of July and beginning of November were also received, though these were considered incomplete data sets for these months. These invoices included orders from all four main vendors: US Foods, Fresh Point, Inland Seafood, and Sysco. The most complete and robust data set came from the month of September, so this was the month that was used in our data analysis. All order invoices were in PDF format, so first all PDFs were converted into Excel Spreadsheets. This was either done via the PDF-to-Excel spreadsheet converter tool in Adobe Acrobat Pro (US Foods), use of optical character recognition (OCR) software Abbyy Finereader (FreshPoint), or manual transcription (Inland Seafood and Sysco). The tool used to convert the PDFs depended on the quality and content of the PDF scan.

Because some of the data sets were so large (notably US Foods), our team reached out to the Center for Data and Visualization Science at Duke University Libraries. We were paired with a data analyst, Eric Monson, who helped us sort the data sets from the invoices. Eric wrote a Python code that categorized the US Foods and Fresh Point order invoices into categories such as “chicken,” “broccoli,” or “ice cream.” The code also used quantities and weights on the order invoice to calculate the total amount of each category ordered.

Once these weights were totaled, we calculated the environmental impact of each food group of interest by multiplying the total weight ordered by that food’s carbon dioxide equivalent (CO₂e), which is a combination of the product’s GHG emissions over its lifecycle. We used the values provided by Poore and Nemecek in their highly-cited 2019 study on the environmental impacts of different food groups (see Figure 3). We selected lamb/mutton, beef (herd), pork (and pork products), cheese, farmed fish, and poultry (chicken and turkey) as food items of interest, based on Poore and Nemecek’s research and portrayed in Figure 5 below by Our World in Data (2021). To get to final values, we converted the pounds of food weighed to kilograms, then multiplied that by the given CO₂e factor. Totals of each food item of interest from different vendors (i.e., salmon is ordered from both US Food and inland seafood) were combined to get category totals.

Not all quantities of the items of interest were captured in our measurements, because they may be ingredients in other prepared foods that are ordered, such as beef or cheese as ingredients in prepared lasagna. Further, we specifically omitted beef (dairy herd) measurements, which included milk,

ice cream, creamer, and yogurt. These items were omitted because we did not feel that we could actually capture the true amount included in a month’s order since many of these items appear as ingredients in other prepared foods. We also omitted eggs and wild-caught fish. Eggs were omitted because of their relatively lower GHG emissions and wild-caught fish was emitted because a CO2e factor could not be located for use. However, based on order invoices, we felt that these amounts were negligible enough to omit without major impacts on the results.

Additionally, because each company works with different suppliers and utilizes different sustainability metrics, the environmental impact of an item (salmon, for example) may be different at US Foods and Inland Seafood. However, we combined the totals ordered from these vendors and used the Poore and Nemecek values for consistency. There were also fish ordered that we were unable to identify as farmed or wild caught, and these were not included in calculations because the certification of the supplier was unknown.

Food	Greenhouse gas emissions per kilogram kgCO ₂ e per kilogram
Beef (beef herd)	99.48 kg
Dark Chocolate	46.65 kg
Lamb & Mutton	39.72 kg
Beef (dairy herd)	33.30 kg
Coffee	28.53 kg
Prawns (farmed)	26.87 kg
Cheese	23.88 kg
Fish (farmed)	13.63 kg
Pig Meat	12.31 kg
Poultry Meat	9.87 kg
Eggs	4.67 kg
Rice	4.45 kg

Figure 5. Greenhouse gas emissions per kilogram of food product

Results

As shown in Figures 6, 7, and 8, Carol Wood’s largest greenhouse gas emissions in Dining Services’ ordering comes from beef. Beef, which was ordered from all three animal protein vendors, accounted for ~22% of the total high-environmental-impact animal protein ordered and 67% of the total GHG emissions. The next highest animal protein impact is poultry meat, which included chicken and turkey meat products, purchased from US Foods and Inland Seafood. Poultry meat accounted for 43% of the total considered animal protein ordered and 13% of the total GHG emissions. Cheese products were the next most impactful, making up 11% of total weight and ~7% of total GHG emissions. The next most environmentally impactful was the pork meat, comprising 12% of order weight and ~5% of total GHG

emissions. Farmed fish, lamb/mutton, and farmed prawns (shrimp) made up the remaining order weight and all accounted for roughly 2% of the GHG emissions.

Total pounds of considered animal protein ordered during the month of September is 9,074.23 pounds. When converted to kilograms and multiplied by the kgCO₂e factor, this comes out to 132,729.9 kgCO₂e. This is equivalent to 132.7 metric tons of CO₂e.

Item	US Foods		Sysco		Inland Seafood		Combined			
	Pounds	kgCO ₂ e	Pounds	kgCO ₂ e	Pounds	kgCO ₂ e	TOTAL POUNDS	% of total lbs	TOTAL kgCO ₂ e	% total kgCO ₂ e
Beef	1741	78557	107	4833	133	6014	1981	22	89403	67
Cheese	704	7624	259	1860	37	396	999	11	9881	7
Fish (farmed)	173	1071			453	2803	627	7	3874	3
Lamb/Mutton	158	2851					158	2	2851	2
Pork Meat	1076	6009	60	335			1136	13	6344	5
Poultry Meat	3913	17516			40	179	3953	44	17695	13
Prawns (farmed)	220	2681					220	2	2681	2
TOTAL							9074	100	132730	100

Figure 6. Total pounds of animal protein ordered in categories of interest

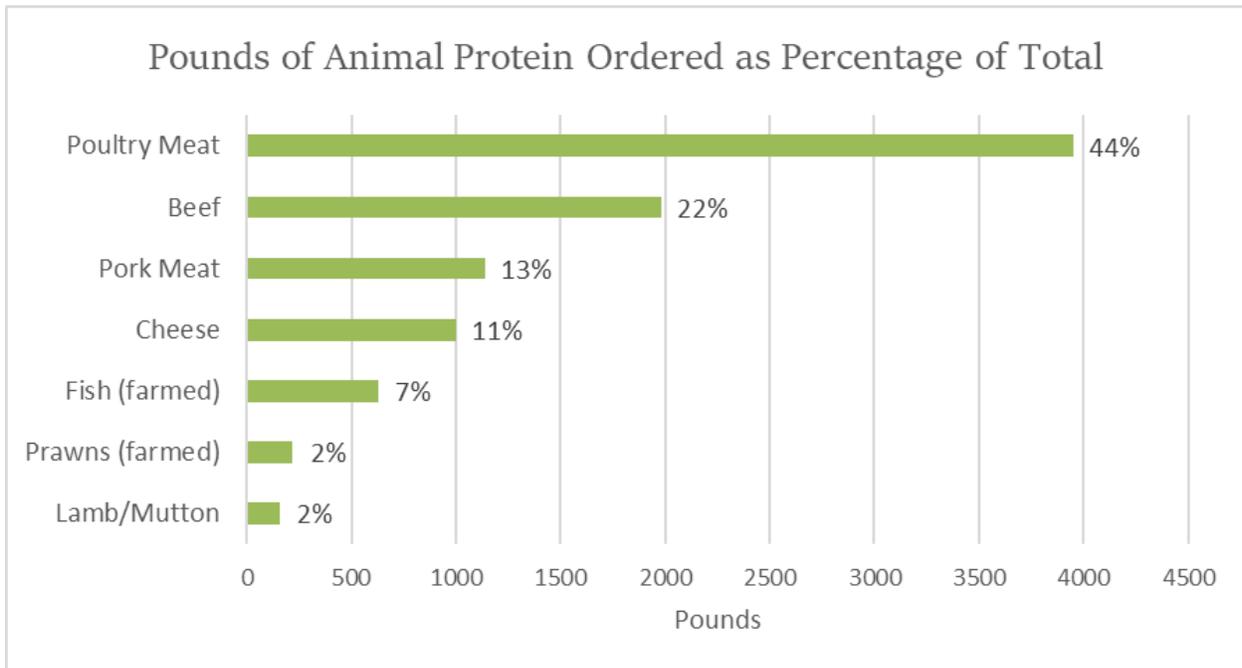


Figure 7. Summary of animal protein ordered by pounds and percentage

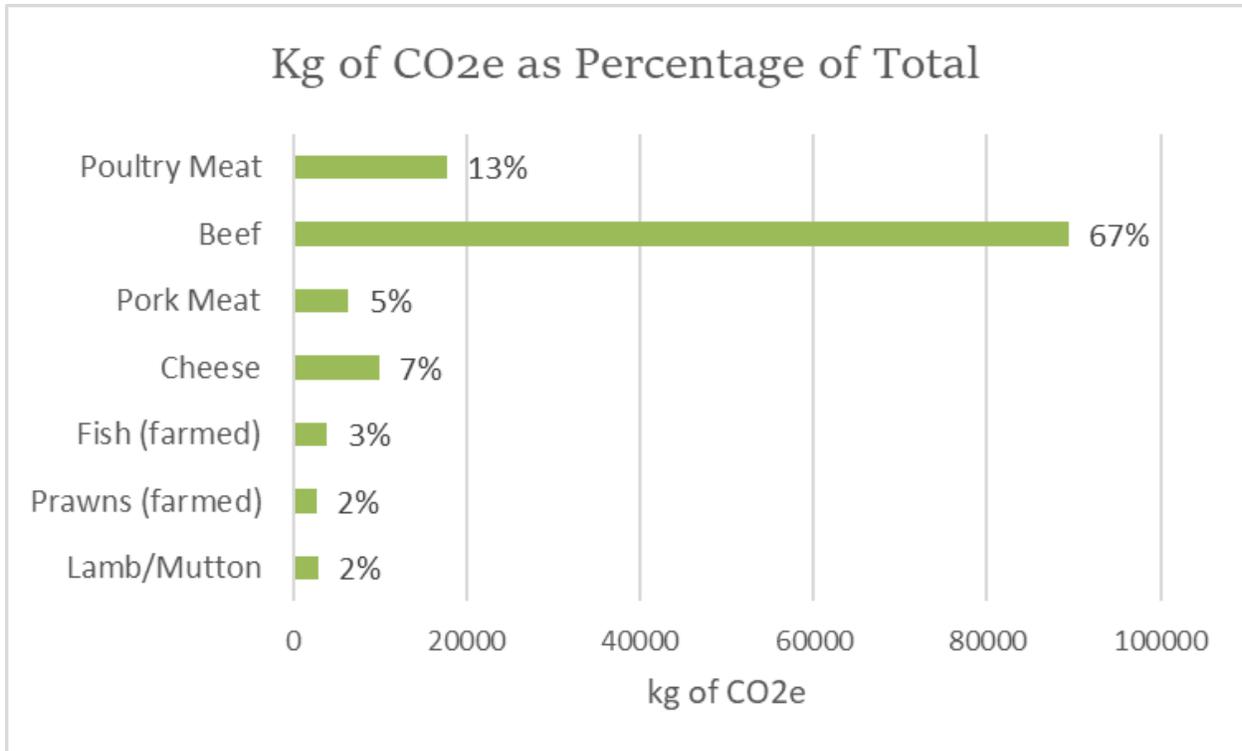


Figure 8. Total GHG emissions by type of animal protein ordered as percentage of total

Discussion

Currently, the CO₂e or GHGs caused by Carol Woods’ animal protein ordering (of those proteins considered) total 135, 729.8 kgCO₂e, or 132.7 metric tons in one month. If we assume this as a monthly average and multiply it by 12 months, the total is 1,592.76 metric tons for the year. This is the equivalent of 318 cars driving the average distance each year, or filling the gas tanks of 34 SUVs 46 times each (Laird, 2020). Notably, this does not even include all animals proteins ordered for the campus, just those considered “high environmental impact” through the literature review and by this research team.

If Carol Woods seeks to reduce their environmental impact, a 10% reduction in animal protein order, based on Stylianou et. al. (2021), would be a reasonable starting point. As shown in Figure 9 below, a 10% reduction per month would help Carol Woods to reduce their GHG emission contribution by 13,273 kgCO₂e or 13.273 metric tons. This equates to taking 2.6 cars off of the road full time for one year, or removing the same GHGs produced by 530.9 propane tanks (Laird, 2020). Because beef is a significant contributor to CO₂e emissions, this suggests that Carol Woods can still make notable impact without going completely vegetarian, but by simply reducing the amount of red meat ordered.

Item	10% Reduction			
	90% of total lbs	90% of total kgCO ₂ e	Change in Pounds	Change in kgCO ₂ e
Beef	1783	80463	198	8940
Cheese	899	8893	100	988
Fish (farmed)	564	3487	63	387
Lamb/Mutton	142	2566	16	285
Pork Meat	1023	5710	114	634
Poultry Meat	3557	15926	395	1770
Prawns (farmed)	198	2413	22	268
TOTAL	8167	119457	907	13273

Figure 9. Potential positive CO₂e impact from ordering 10% less animal protein

Reducing the amount of food ordered will not only help Carol Woods to reduce its environmental impact but will also help cut costs in the kitchen and save money for the organization at large. By cutting costs previously allocated to animal-based proteins, Carol Woods can divert these funds to the purchase of plant-based proteins, more quality/local goods, and/or other health or nutrition initiatives across the campus.

Carol Wood's greatest environmental impact from ordering animal proteins comes from ordering beef (meat herd). This is due to beef's significant CO₂e factor. We did not specifically calculate or account for beef (dairy herd) products, which included milk, creamer, ice cream, and yogurt because these items may also be present in many pre-prepared foods. We also did not include eggs in the animal protein calculations because they also are included in many pre-prepared foods and are often ordered powdered/dry, which is not representative of the actual weight of eggs produced. We did not calculate wild-caught fish because Poore and Nemecek's article did not include a CO₂e factor for these, and we did not want to introduce another inconsistent factor into the calculations. This means that the total pounds of animal protein ordered does not include these items, and therefore is not captured in Carol Wood's total GHG contributions in its purchase of animal proteins.

While we did not do specific calculations for beef (dairy herd), eggs, and wild caught fish, these products can be very high environmental-impact foods. Carol Woods orders very large quantities of these in the way of milk, cream, ice cream, yogurt, shelled and powdered eggs, and fresh and frozen fish [primarily from] from US Foods, which may not utilize local or sustainably-certified vendors in all cases. We also did not calculate the CO₂e for coffee, as we were focused on animal proteins. However, coffee has a notable CO₂e contribution factor.

Also of mention is that Carol Woods changed its menu rotation and ordering style between the time that the order invoice audit and waste audit were completed. When talking with the chefs, they

expressed that they do not think that the amount of items ordered has changed that much, but rather the combination and order that things are cooked. However, when talking with kitchen staff, they expressed that they believe that food waste from the new menu is half of what it used to be with the old menu. This means that the data collected for our invoice audit and the data collected from the waste audit are from two separate ordering schemes. This warrants further exploration.

To better understand the “mass balance” of Carol Woods’ Dining Services, we also at the “output” of food waste in addition to the “input” of food ordered. We did this through a waste audit, which is described in detail next.

Dining Services: Food Waste Audit

Literature Review

The term “food waste” captures the fit-for-human-consumption, but unconsumed, food that is delivered to, prepped, prepared, served, and/or leftover at a dining facility. This includes foods that expire or rot while in storage at the facility, scraps from the preparation of the food, leftover prepared foods, and “plate waste,” which is served but not eaten (EPA, 2021). Food waste is different than food loss in that it has made it through the supply chain to its final product stage; food loss occurs when food expires, rots, or is deemed unfit for human consumption during production, processing, or transport (UNEP, n.d.).

More food is wasted in the United States than in any other country, totaling over 80 billion pounds per year (US EPA, 2021). This comes out to about 219 pounds of food per person per year, or approximately one pound of food per person per day (RTS, 2021). Food takes up more space in landfills than any other item, and this has notable implications for climate change. This is because in an anaerobic environment such as landfills, food decomposition produces the GHG methane, which is 26 times more potent than carbon dioxide (Broosbank, 2021). Globally, food waste contributes between 10% and 11% of total greenhouse gas emissions (WWF, 2021).

Limiting food waste has a number of positive implications for both businesses and the environment. A goal to limit food waste can save an organization money in the ordering, storage, and disposal of foods (Hanson and Mitchell, 2017). Ordering a lower volume and quantity of foods saves organizations money upfront, while preparing less foods saves money in garbage and composting costs. Next, reducing food could positively impact our environment through reducing the use of water, energy,

chemicals, human capital, and more that is required for its production. It also limits the greenhouse gasses produced by wasted food in landfills, which would help to mitigate climate change (USDA, 2021).

Methods

To estimate the amount of food waste produced by Carol Woods’ main kitchen, a food waste audit was conducted. The audit was conducted for two full days: Friday, February 11th and Sunday, February 13th. Both a weekday and weekend day were chosen to capture a better sample of the variability that might occur between weekdays and weekend days. The menu served on these days can be found in Appendix A, Figure 2. The Dining Services staff were instructed to not throw any food away at all, but rather set it aside to be weighed. The two MEM students on this team, Chelsea and Xinyi, arrived on-site at Carol Woods at 8:30am both days and measured both food preparation scraps and all leftover foods. The schedule for both days was approximately as follows:

9:00am	Weigh early morning preparation scraps
9:30am	Begin weighing breakfast leftovers as they arrive; typically takes 45 minutes to complete
10:30am	Digitally transcribe written records from the morning measurements
1:00pm	Weigh late morning preparation scraps
1:30pm	Begin weighing lunch service leftovers as they arrive; typically takes one- to one-and-a-half hours
2:30pm	Digitally transcribe written records from the afternoon measurements
5:00pm	Weigh afternoon preparation scraps
5:30pm	Begin weighing dinner service leftovers as they arrive; typically takes one- to one-and-a-half hours
6:30pm	Begin weighing any rotational (thrown away every two days) leftover foods, typically from the salad and dessert bars; typically takes thirty minutes
7:00pm	Digitally transcribe written records from the evening measurements

Table 1. Schedule of Food Waste Auditing

All food preparation scraps – such as eggshells, vegetable stems, or animal bones, for example – were measured as the kitchen disposed of them and were tracked separately in our spreadsheets. Specifically attributing certain sets of scraps to a particular meal was difficult and not tracked in this

manner because of the cadence of preparation (i.e., preparation scraps measured mid-morning could be from lunch or dinner preparation). These scraps were then thrown into the CompostNow Bins.

Each set of meal service measurements for leftover prepared foods was separated by their service area: Main Building/Dining Hall, Building 4, Building 5, and Buildings 6 & 7 (one service cart is used for both buildings). Leftover food would begin to arrive in the kitchen by building after each meal service. Our team began to empty all leftover prepared foods from their serving containers into a large plastic bin provided by the kitchen. This tub weighed nine pounds and this weight was subtracted from the final total with the food in it. Leftover foods would be commingled in the bin and at approximately every 40 pounds, the tub would be weighed and the total weight recorded. Once this weight was recorded, the food would be moved to the compost bins.

On the first day of the waste audit, foods were almost entirely commingled (meats, cooked vegetables, raw vegetables, etc.) and only specific, “stand-out” items were separately measured. For example, completely untouched quiches were counted separately on the first day. However, at the end of the first day, the team decided that we would like to more specifically categorize, separate, and weigh things to understand what types of foods might be having the greatest impact. Therefore, on the second day, all animal proteins began to be weighed separately in addition to stand-out items. (Not enough time existed for every type of food to be separated and weighed individually, and some foods with many combined ingredients such as soup would make such measurements difficult.) All weights were combined and totaled for each building at each mealtime.

To calculate the environmental footprint of the wasted food, this team utilized the Carbon Dioxide equivalent (CO₂e) GHG emissions, which combines the individual GHGs that a food’s production, transport, and disposal contribute. These GHG’s include carbon dioxide, methane, nitrous oxide, and others. Specifically, we used the CO₂ equivalent measurements as put forth by Poore and Nemecek, as was used in the Order Invoice Audit. The total weights (in pounds) of specified food categories were multiplied by that food’s CO₂e emissions to obtain the environmental impact of that food.

Results

Figure 10 below shows the weight (in pounds) of the food wasted on Friday and Sunday. Overall, there were 459.4 and 519.4 pounds of leftover waste on Friday and Sunday, respectively. In addition, there were 174.4 and 89.4 pounds of preparation waste on Friday and Sunday, respectively. Each building’s leftover waste is also calculated, and of all the buildings, the main building contributed the

largest amount of leftover waste on both days, 261 pounds on Friday and 293.6 pounds on Sunday.



Figure 10. Food Waste Summary on Friday and Sunday

Figure 11 and 12 present the food waste, broken down by specific food product and weight on each of the two days. On Friday, the food waste included 40 pounds of beef, 3 pounds of ham, 24.76 pounds of salmon, 29.63 of quiches, 75.2 pounds of soup, and other commingled waste such as 25.2 pounds of sausage, eggs, biscuits, grits, hash, and bacon, etc. In order to better understand the key environmental impact of food waste, we have formulated a more detailed breakdown of food waste on Sunday, as shown in Figure 12. Notably, a total of 49 pounds of the raw chicken went bad and was thrown away and considered as preparation waste. Although this seems an anomaly, these larger bulk waste occasions do happen at times, and this was a good example of that. All animal proteins were individually weighted for leftover waste, including eggs (14.2 lbs), pork (3.2 lbs), beef (6.6 lbs), trout (11.6), catfish (13.4 lbs), and meatloaf (5.2 lbs). Other leftovers that contributed a significant portion of the total were also measured including potatoes (26.2 lbs), quiches (29.8 lbs), corn (22.9 lbs), pizza (10.2

lbs), and soup (52 lbs).

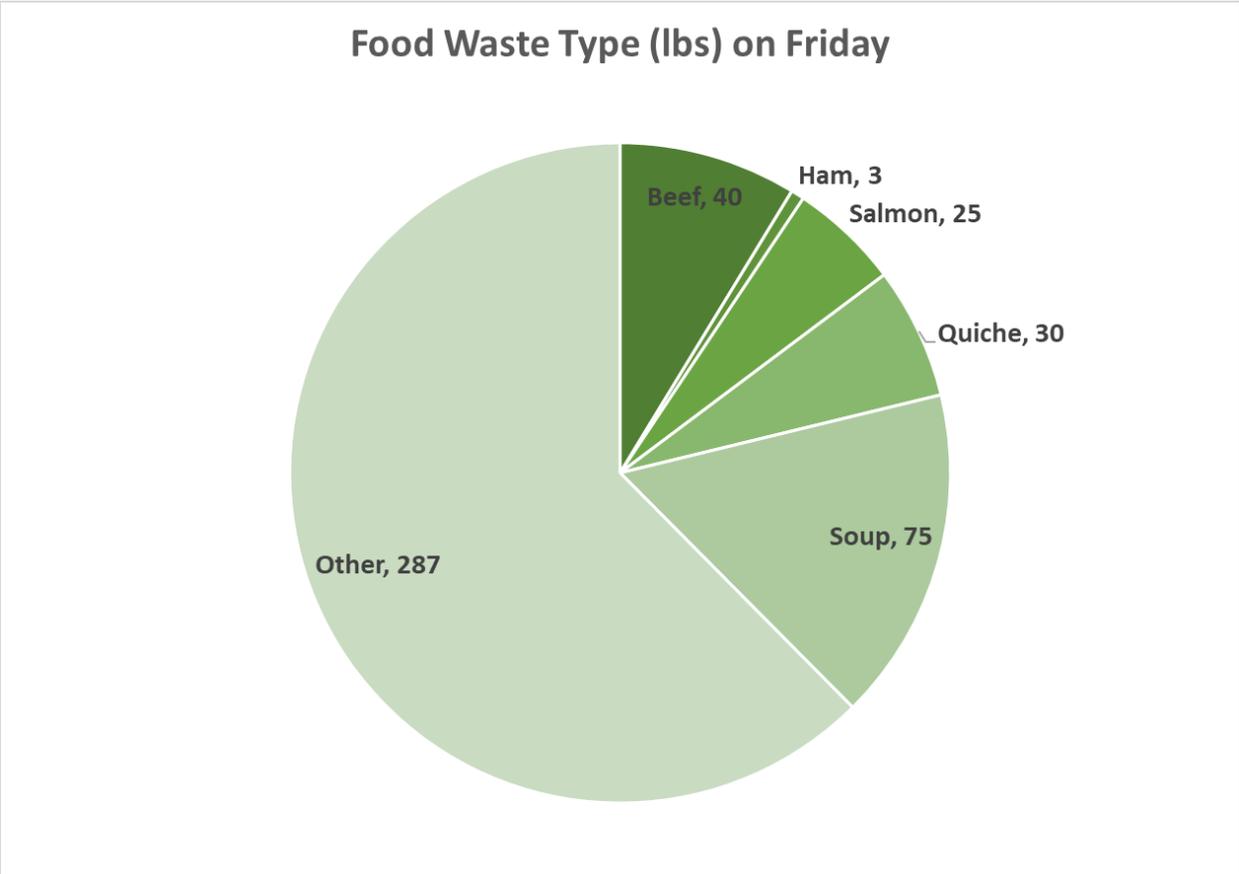


Figure 11. Food Waste Summary by Type on Friday

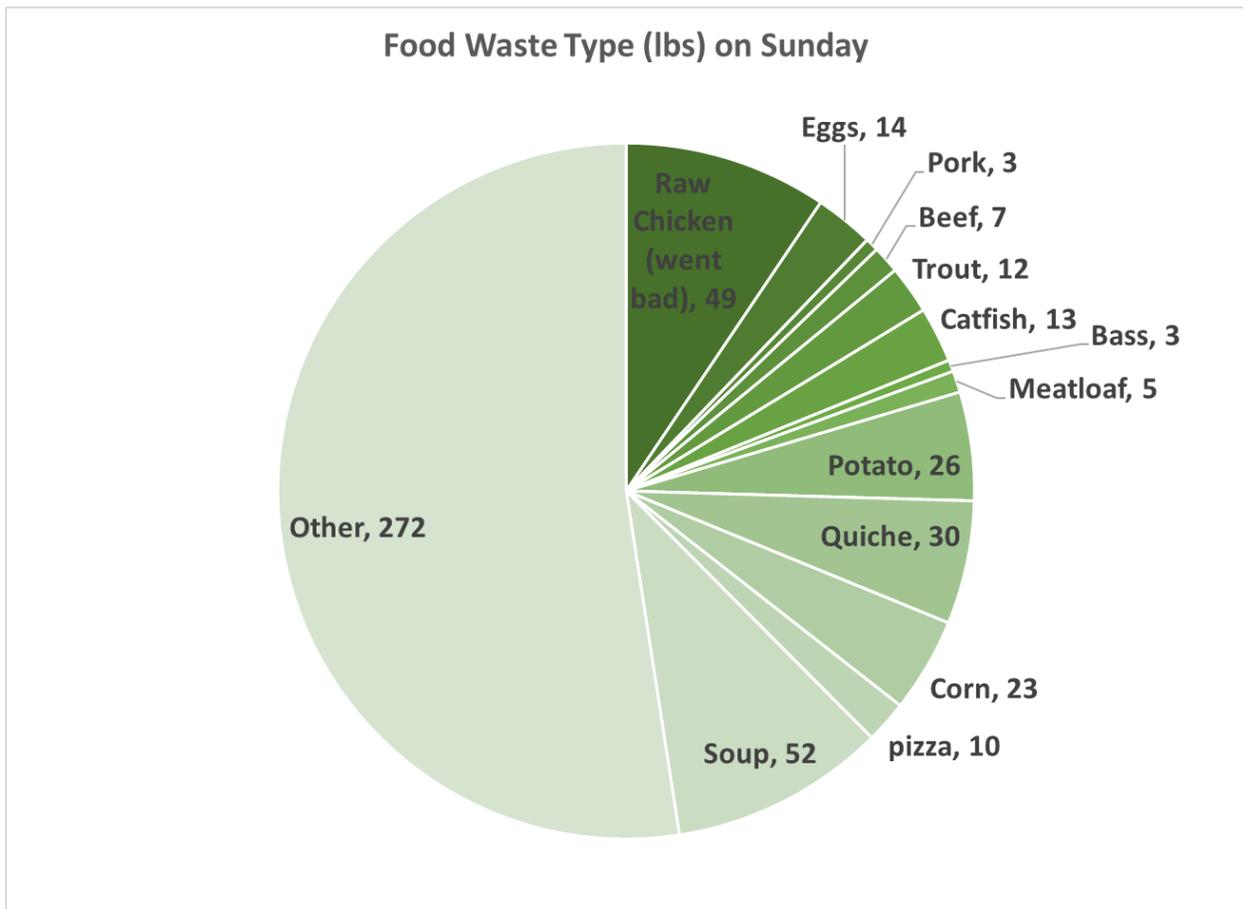


Figure 12. Food Waste Summary by Type on Sunday

Figure 13 and 14 below identify the carbon footprint of the major food items wasted in Carol Woods on Friday and Sunday. GHG emissions are calculated in kilograms of carbon dioxide equivalents (kgCO₂e) per kilogram of food type. It is worth noting that beef had the largest carbon impact among all food products on both days, with 1804.93 kgCO₂e on Friday and 485.53 kgCO₂e on Sunday. Besides, according to Figure 14, other major contributors to GHG emissions from Carol Woods food waste were chicken (219.37 kgCO₂e) and fish (171.87 kgCO₂e). Food products including beef, chicken, and fish combined accounted for more than 94% of the GHG emissions listed in our chart for Sunday's summary.

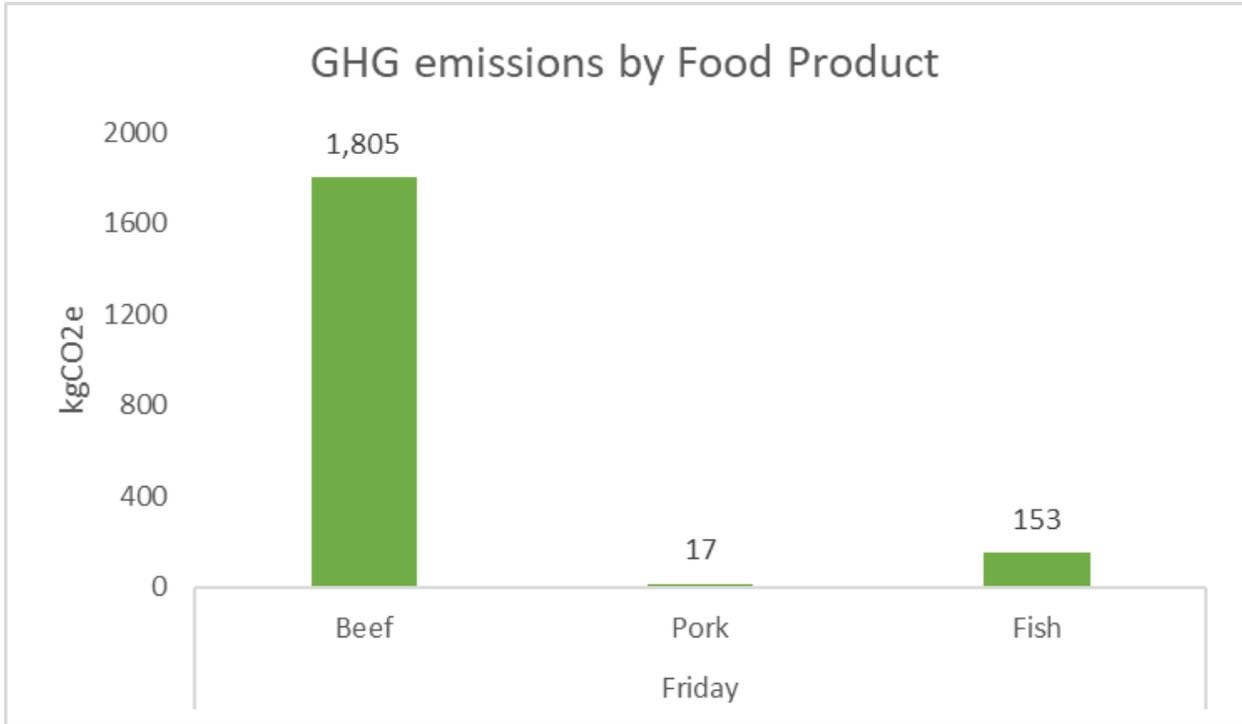


Figure 13. Summary of greenhouse gas emissions on Friday

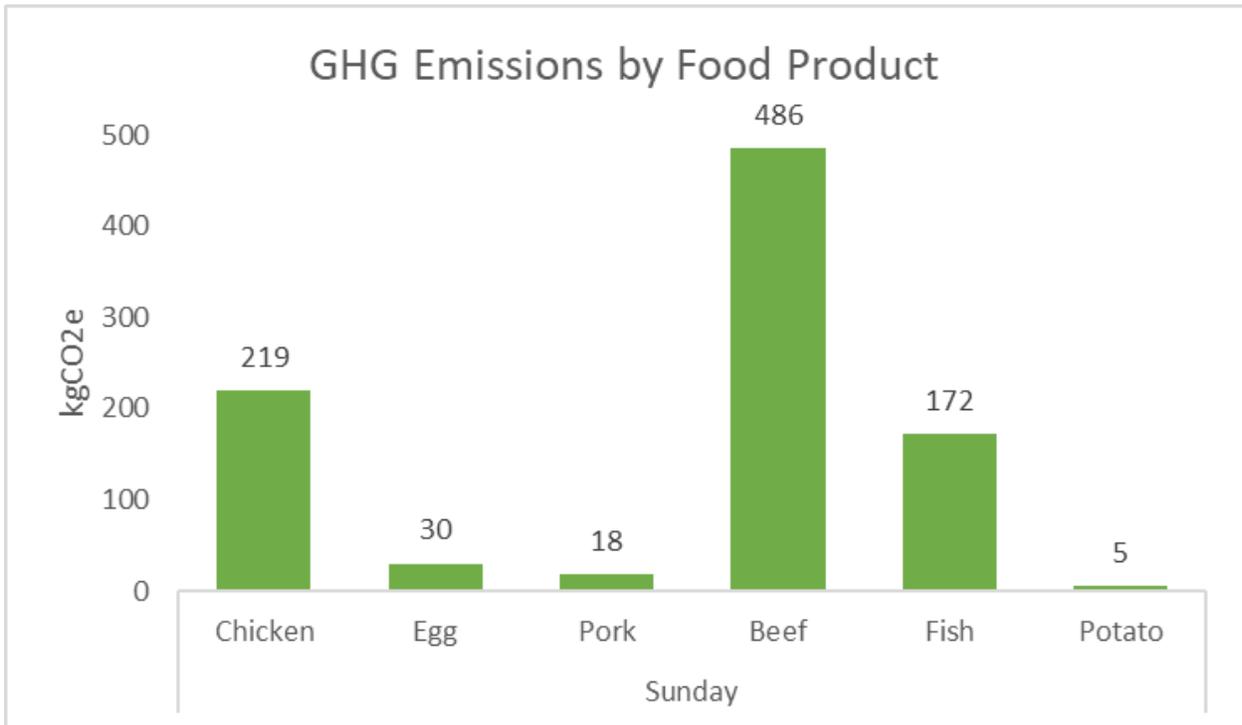


Figure 14. Summary of greenhouse gas emissions on Sunday

Discussion

Carol Woods has a significant amount of animal protein in their food waste, though other food groups also take up more than half of the total weight. The total food waste did not differ drastically from a weekday to a weekend day (12% less the weekday), which leads us to believe that some average of these numbers is the amount of food that is thrown away each day (489.4 lbs). One thing mentioned by chefs and other kitchen staff is they feel a need to over-prepare food so that nothing runs out and no residents become upset for this reason. However, no official way of tracking the occurrence of such events over time seems to exist.

Our waste audit included three main limitations. First, our study did not capture plate waste. This is because some food served from the main dining hall is eaten at the dining hall, while other is taken to-go by residents to be consumed at home or otherwise not in the dining hall. The exact split of eat-in and to-go foods is unknown. Additionally, given the daily average of 489.4lbs wasted, Carol Woods is approaching exceeding the US daily average of one pound of food waste per person. Had we captured plate waste, Carol Woods may have exceeded this number. This is especially possible because residents typically only eat one meal per day at Carol Woods, and our study also did not capture any waste from individual grocery purchasing or take-out from non-Carol Woods restaurants. These numbers also may be skewed by the fact that compostable serving materials, such as to-go containers, may or may not have been included in our measurements.

Second, While talking with kitchen staff, two staff members mentioned that more food was cooked than normal on Friday the 11th, which may have made our measurements less representative of an average weekday service. One employee pointed out that some chefs simply cook more than others (“over cook”). Another employee pointed out that on Friday, one ingredient needed to be used, so the kitchen made more of the dishes that included that particular ingredient. Also of note is that Sunday, February 13th was Superbowl Sunday. While kickoff was not until 6:30pm EST, friends and families may begin celebrating early in the day. This may have impacted the number of Carol Woods residents who opted in for lunch and/or dinner from the dining hall that day.

Third, handling leftovers within the Dining Services has changed notably because of COVID-19. In the past, meal leftovers that were easily reheatable, such as soups or casseroles, were sent to the “Employee Cafe.” Here, employees could purchase food at a highly discounted rate and this system would help to lessen the volume of wasted food. However, this has not taken place since COVID began. Additionally, sometime before the COVID-19 pandemic, Carol Woods would donate leftover foods to a local shelter in Chapel Hill. This would typically take place on a Friday evening, and the leftovers from

Friday and sometimes that Thursday would be saved and donated to the shelter. This also lessened the amount of food that went into the compost bins, which ultimately would lessen the amount that Carol Woods would pay for CompostNow services.

Buildings & Facilities

The second part of the current state analysis focused on metrics of energy flows under the Buildings & Facilities scope in Carol Woods. Specifically, we conducted an analysis on consumption of both electricity and natural gas, which we considered to be the two major contributors to energy consumption in Carol Woods, and which both are included in our scope of GHG inventory analysis. We also completed an audit of the institutional transportation vehicle fleet at Carol Woods, which typically consume fossil fuels and contribute to GHG emissions.

A mass-balance framework is used to assess the amount of input and the corresponding output. By counting what enters and leaves the system, potentially unknown mass flows can be identified using a mass-balance framework (Modell et al., 2021). In this case, we adopted the mass-balance framework for energy consumption calculation to identify Carol Woods' energy consumption flows, where the energy usage can be considered as the input and the corresponding emissions can be an output factor.

A GHG inventory estimates the quantity of GHG associated with community sources and activities taking place during a chosen analysis year. In this study, we calculate GHG emissions based on the U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (US Community Protocol). Through years of analysis, Carol Woods is able to:

- Track GHG emission performance over time
- Establish GHG emission benchmarks with similar communities
- Facilitate climate action planning
- Advance community action
- Demonstrate responsibility and leadership



Figure 15. Mass-balance Framework

Buildings & Facilities: Electricity Consumption

Literature Review

The Intergovernmental Panel on Climate Change's (IPCC) Special Report on Global Warming of 1.5°C sets out a clear obligation: we must pursue “rapid, far-reaching, and unprecedented changes in all aspects of society” to limit temperature rise to 1.5°C above pre-industrial levels otherwise we will suffer irreversible damage to our society, economy, and the environment (IPCC, 2018).

In all climate scenarios that hold global temperature rises to 1.5°C, electricity's share of final energy consumption increases steadily between 2020 and 2050 (Rogelj, et al., 2018). Reasons for this trend are multifaceted but demonstrate the trend of electrifying will facilitate decarbonization in a faster rate than alternative energy options (CDP, 2020).

Greenhouse gases come from a number of sources across the United States: vehicles, industrial plants, homes, buildings and agricultural activities, etc (CRS, 2019). Historically, the power sector has been the largest source of greenhouse gas emissions in the United States (EPA, 2020). Over the past decade, however, emissions from the power sector have been greatly reduced. If this trend continues, it will greatly help the U.S. meet its 2050 emissions targets.

The U.S. Environmental Protection Agency's (EPA) ENERGY STAR Portfolio Manager has been tracking energy use in CCRCs. Specifically, energy use intensity (EUI) ranges from less than 100 kBtu/ft² to more than 1000 kBtu/ft² across all senior care communities (EnergyStar, n.d.). Variations in energy consumption depend on equipment efficiency and energy management practices, as well as changes in climate and business activities. As energy costs continue to rise, energy use accounts for an increasing proportion of overhead costs. Energy efficiency is key to reversing this trend and can help CRC reduce energy bills so they can invest more in residential care and reduce their greenhouse gas footprint.

Method

To conduct the energy current state analysis under the mass-balance framework, electricity consumption (input) and GHG emissions (output) are calculated in this section.

Carol Woods purchases its electricity from Duke Energy for heating, cooling, lighting, hot water, and recharging vehicles, etc. Additionally, ten Siemens meters are installed in ten major buildings of Carol Woods.

Based on information collected from interviews with Director of Buildings & Facilities and Manger of Maintenance Department, we received data on the electricity consumption of Carol Woods from 2016 to 2021. We analyzed annual monthly electricity usage data and produced bar charts to visualize Carol Woods' electricity usage for six consecutive years. Using monthly electricity data from the ten major buildings from August 2020 to August 2021, we identified the key contributors of electricity consumption among different buildings.

For the output side of the mass-balance framework, GHG emission metrics were developed in terms of the electricity consumption. The steps of GHG emission calculation are described below:

- **Step 1:** Obtain Carol Woods electricity consumption data. As aforementioned, the annual electricity consumption data from 2016 to 2021 were summarized in KWH.
- **Step 2:** Choose the emission factor for the electric utility serving Carol Woods. Local emission factors should be adopted because the power mix and utility emission factors may vary widely. For Duke Energy specifically, 42% of electricity is generated by natural gas or fuel oil and 33% is by coal. The specific emission factor is obtained from the EPA's Carbon Footprint Calculator guide by using VLOOKUP in the Excel to match the local zip code with the corresponding emission factor (1.0795718 lb/KWH).
- **Step 3:** Calculate the Carol Woods' annual CO₂e emissions associated with electricity usage. Carol Woods purchase all of their electricity from Duke Energy that generates electricity in power plants located outside the community boundary. According to the the US Community Protocol, GHG emissions of this type are calculated by multiplying the community's annual electricity use in kWh or MWh (i.e., the "activity factor") by the appropriate average annual electricity GHG emission factor. The following calculations should be performed for Carol Woods' annual electricity consumption:

$$\text{Annual CO}_2\text{e emissions (metric tons/year)} = \text{electricity} \times \text{CO}_2\text{e emission factor} \times 0.000489694$$

Where:

- *Electricity is Carol Woods' annual electricity use in KWH from Step 1,*
- *The CO₂e emission factor is calculated from Step 2, and*
- *The number 0.000489694 is the conversion factor to convert from pounds to metric tons (1 pound=0.000489694 metric tons).*

For Example, CO₂e emissions in 2016 related to electricity use = 6,337,427 KWH*1.0796 lb/KWH*0.000489694= 3103 tons

Results

Overall, Carol Woods' annual electricity use was relatively stable between 2016 and 2021, with an annual percentage change of less than 5% (Figure 16). Consequently, Carol Woods witnessed a consistent trend in CO2-equivalent emissions from purchasing power (Figure 17). Specifically, the largest change occurs in 2019 where Carol Woods saw a 4.45% decrease from the previous year.

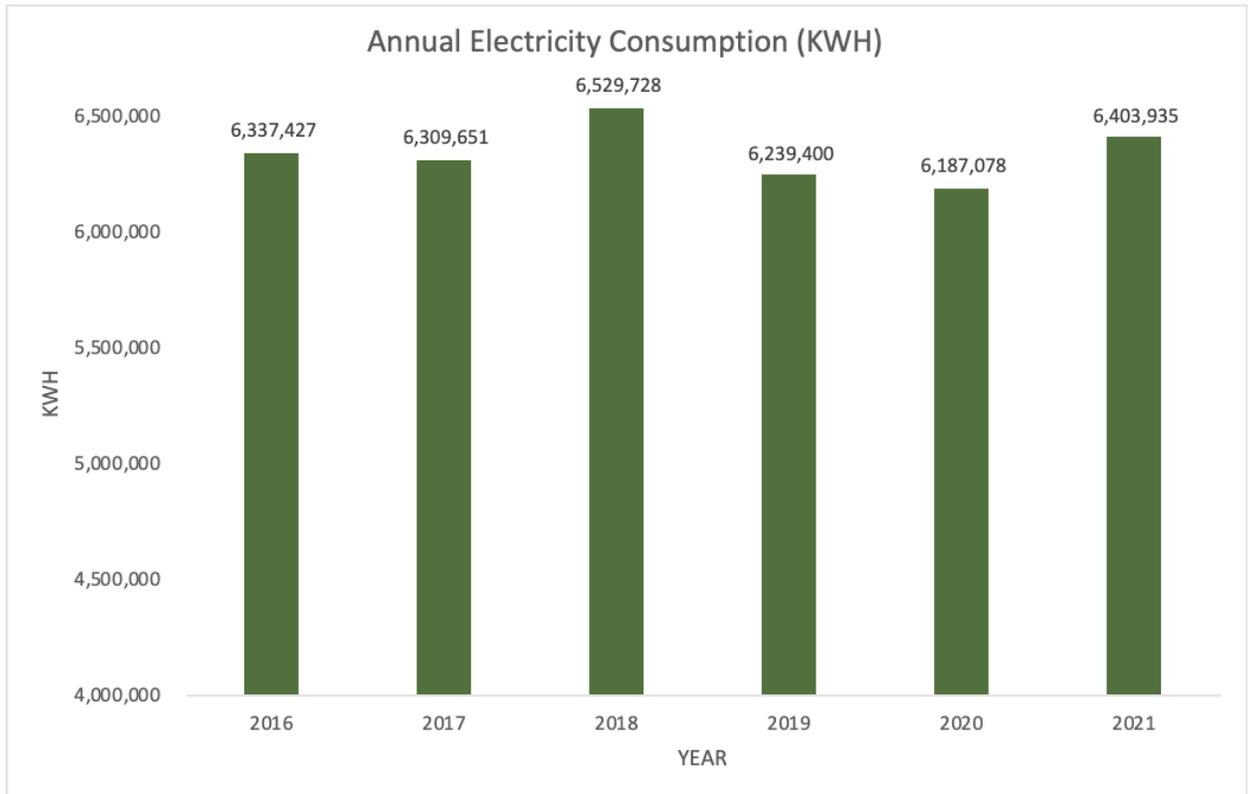


Figure 16. Annual Electricity Consumption from 2016 to 2021

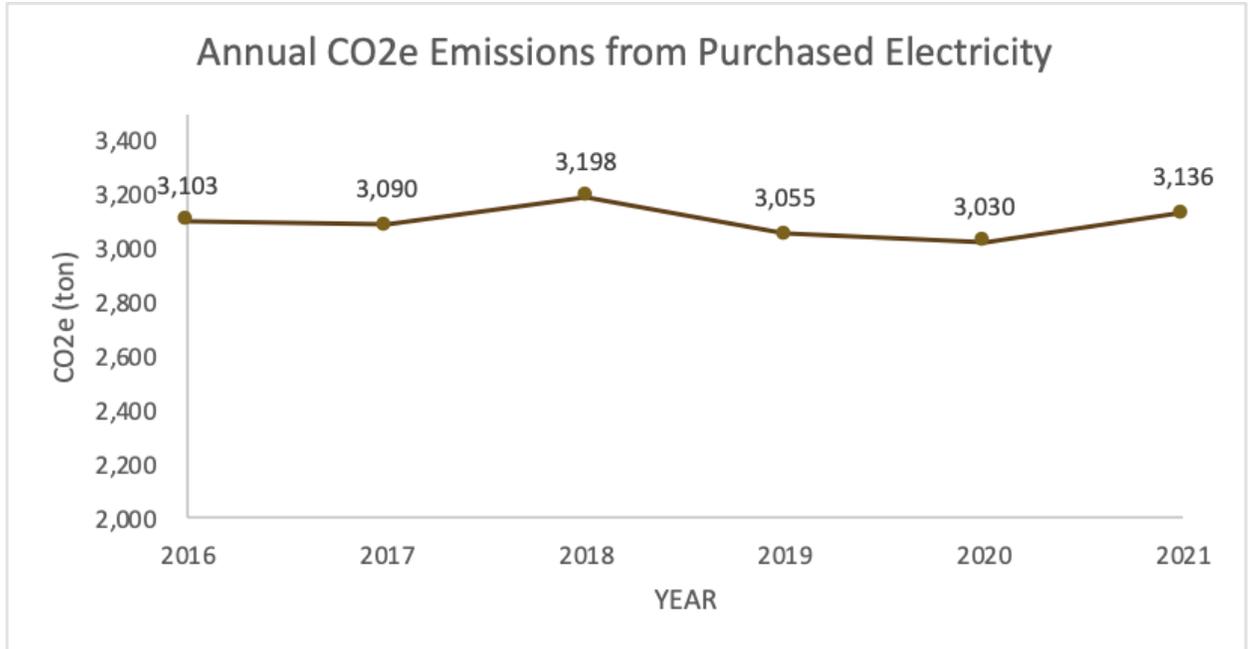


Figure 17. Annual CO2 emissions from 2016 to 2021

Between August 2020 and August 2021, Carol Woods' ten major buildings contributed an average of 65% of the total electricity consumption on campus. Among them, Building 4 is the main component of electricity consumption, accounting for more than 30% of ten buildings on average (Figure 18). Electricity consumption is high in June, July and August, and low in months from September to May.

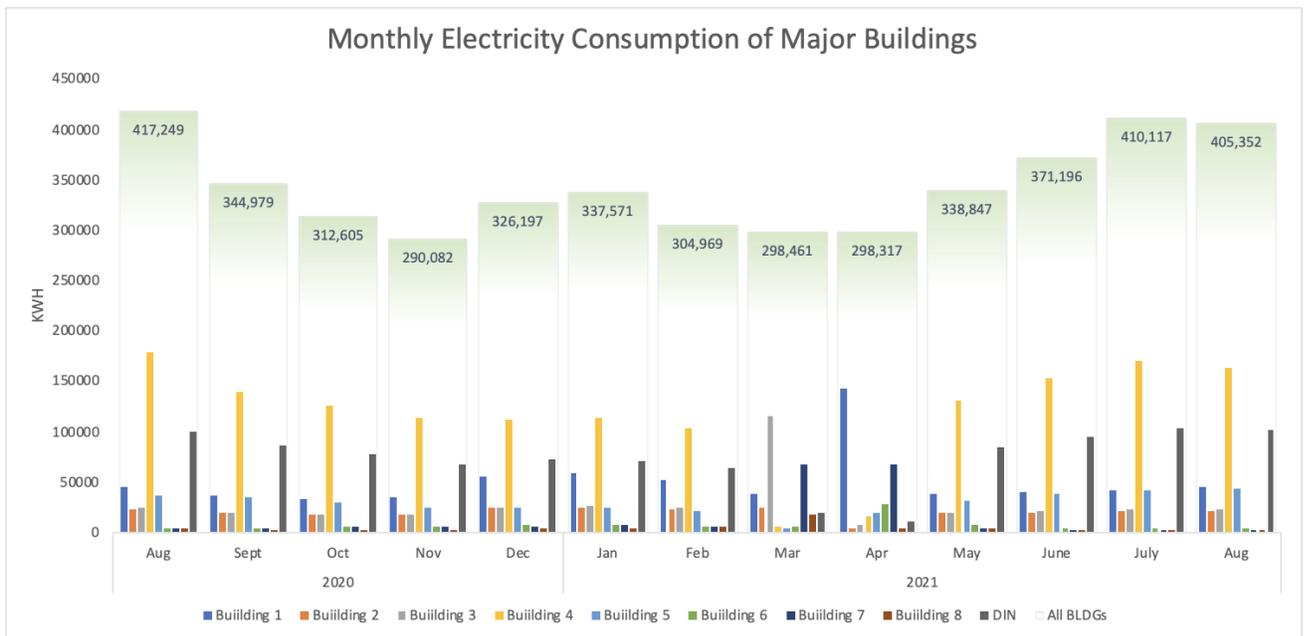


Figure 18. Major building's monthly electricity consumption

Discussion

Overall, Carol Woods's electricity consumption was steady from 2016 to 2021. The peak is in the summer due to air conditioning, and winter use is relatively low.

This study aims to lay a solid foundation of current state analysis in electricity consumption and GHG emissions. However, other important metrics such as the energy efficiency calculation is not taken into account in our study. Measuring energy efficiency of buildings could be beneficial to compare and evaluate different building's energy consumption performance. Data such as Carol Woods' population from 2016 to 2021, occupancy rate, and floor plan could also be included to conduct the analysis of electricity consumption efficiency in each building.

Buildings & Facilities: Natural Gas Consumption

Literature Review

In this section, we did not find related literature review in CCRC context. Therefore, we start the literature review in a national level and apply that to Carol Woods.

In the United States, the main uses of natural gas are to heat buildings, cook food, and dry clothes (Aras, 2008). Around 50% of homes in the United States consume natural gas for heating and water. In 2020, the United States consumed approximately 30.5 trillion cubic feet (Tcf) of natural gas, accounting for around 34% of total U.S. energy consumption (EIA, 2021). In 2020, the housing sector accounts for about 15% of the total natural gas usage, and the natural gas is the source of approximately 23% of the total U.S. residential energy consumption (EIA 2022).

Identifying the natural gas consumption is critical for Carol Woods and other CCRCs to understand its energy usage pattern, upgrade the community's infrastructure, and move forward with more proactive climate targets.

Methods

This section introduces our method of calculating natural gas consumption and its corresponding GHG emissions by adopting the mass-balance framework.

Natural gas is one of the most widely used stationary fuels in US community. Monthly gas consumption data from 2016 to 2021 were obtained from Carol Woods and tracked by PSNC Energy. The natural gas usage is reported in therms (equivalent to 100,000 Btu) for each month from 2016 to 2021. We imported the data into Excel and aggregated the monthly gas usage into annual consumption data. We also averaged the year-on-year monthly consumption from 2016 to 2021.

Greenhouse gas emissions are calculated at the output end of our mass-balance framework. After determining the annual consumption of Carol Woods natural gas using methods described above, we selected the emission factor (5.388678 kgCO₂e per therm) of natural gas according to the Conversion Factor Introduction Guide released by Carbon Trust. Carbon dioxide equivalent emissions are calculated

in metric tons and converted into graphs. The formula of emission calculation for natural gas consumption is presented below:

$$\text{Annual CO}_2\text{e emissions (metric tons/year)} = \text{natural gas} \times \text{CO}_2\text{e emission factor} \times 0.001$$

Where:

- *Natural gas is Carol Woods' annual natural gas use in therms,*
- *The CO₂e emission factor is 5.388678 kgCO₂e per therm*
- *The number 0.001 is the conversion factor to convert from kilograms to metric tons*

Results

Figure 19 shows the natural gas consumption pattern in Carol Woods from 2016 to 2021. Notably, Carol Woods saw a major decline in natural gas consumption between 2017 and 2019, a drop of over 42%. Then, from 2019 to 2021, it stabilizes at 100,000 thermal gas. Looking at high peak month of natural gas usage, we found that the average consumption is the highest in January and stays relatively high in November, December, February, and March. The monthly consumption decreases over 76% between January and July.

Greenhouse gas emissions from natural gas fuels are consistent with their consumption patterns. Figure 21 shows monthly greenhouse gas emissions from 2016 to 2021. While emissions have dropped significantly since 2017, the peak months all follow the similar pattern, with higher emissions in winter than in summer.

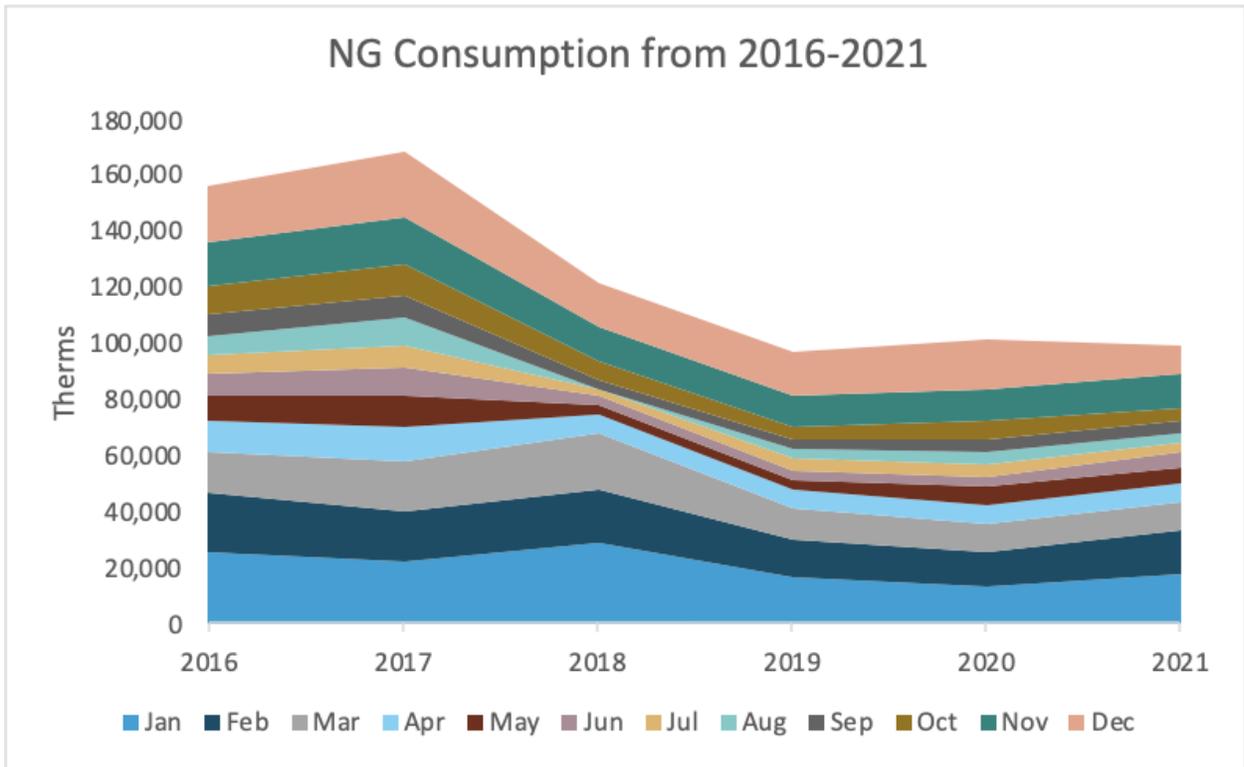


Figure 19. Natural Gas Consumption from 2016 to 2021

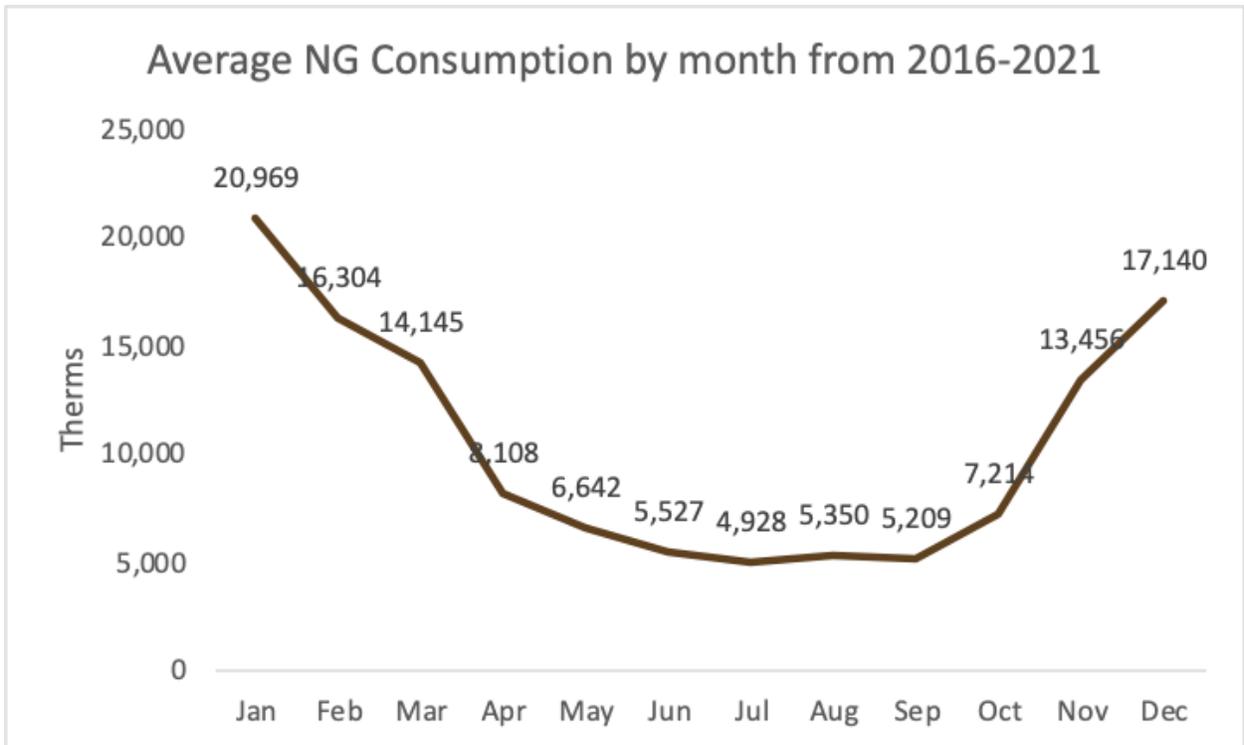


Figure 20. Monthly natural gas consumption from 2016 to 2021

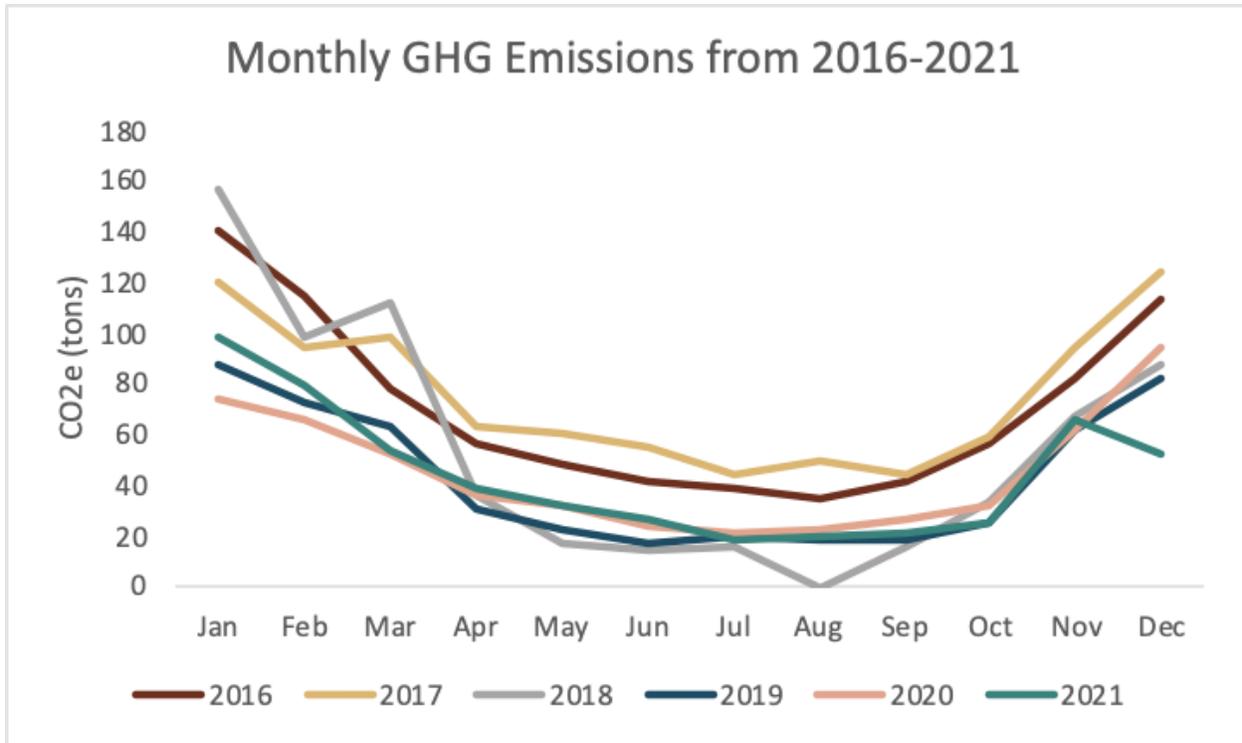


Figure 21. Monthly greenhouse gas emissions from 2016 to 2021

Discussion

Overall, Carol Woods saw a drop of natural gas usage between 2017 and 2019, and remained flat in the subsequent years. As we looked at the Cooling Degree Days (CDD), a measure of how much cooling is necessary given the recorded temperatures for a particular weather station for a given time period relative to a base of 65°F by using Energy Star, we did not observe a similar pattern as shown in Figure 19. Therefore, the drop in natural gas usage is likely not weather-related.

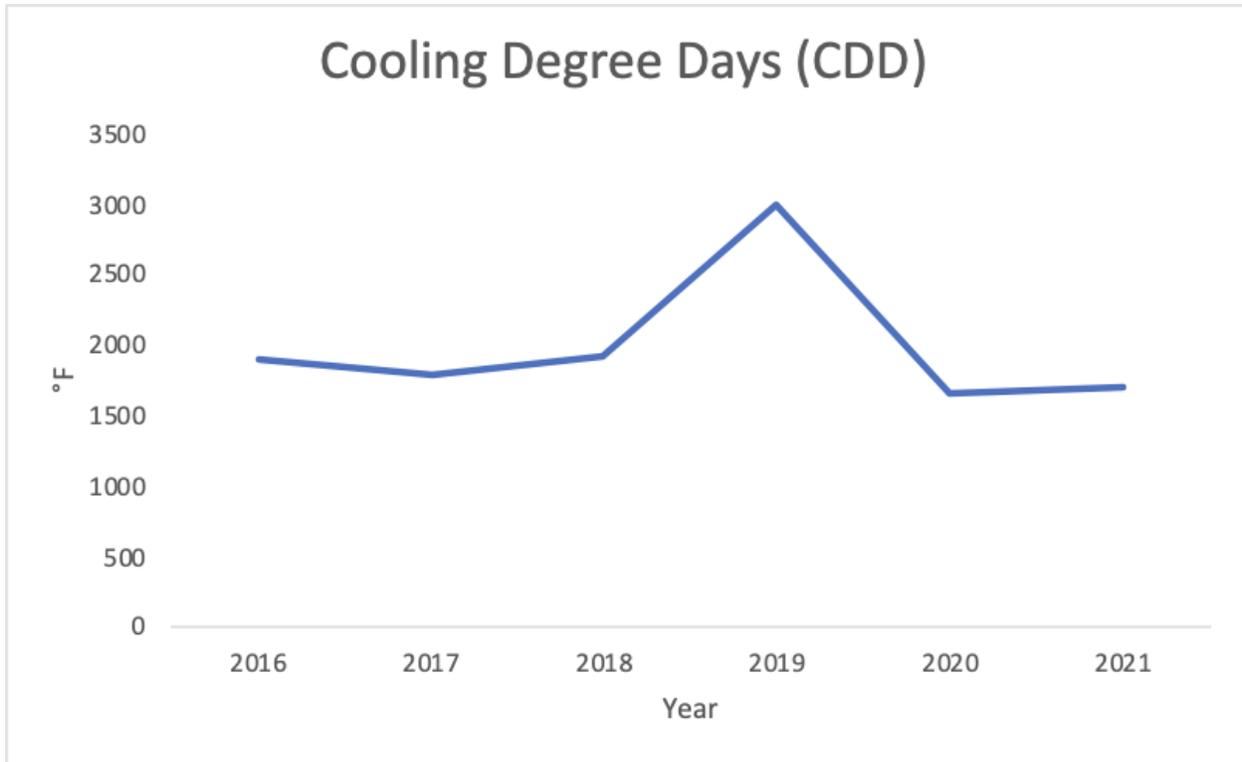


Figure 22. Cooling Degree Days (CDD)

Looking closely at monthly natural gas consumption, we found that the consumption was the highest during the winter and remained low in the summer. This is partly because there is a higher demand for heating in service buildings and residential areas, whereas in the summer electricity consumption reaches the peak due to cooling needs. Further research can be conducted on the analysis of natural gas consumption on each building and identifying the daily peaking hours/locations. Other metrics such as per capita natural gas use or per household natural gas use can also be developed in the future studies.

Transportation and Vehicle Fleet

Literature Review

Like nearly all CCRCs and college campuses, Carol Woods' institutional fleet serves its residents regularly and is critical for its employees to complete daily tasks to keep the facilities and grounds operating smoothly. As of 2019, the transportation sector is the largest contributor of GHG emissions in the United States at 29%, and emissions in this sector have increased more than any other in the last 30 years (EPA, 2021). These emissions come primarily from the use of fossil fuels to power cars, trucks,

trains, planes, and ships. Gasoline and diesel, which are petroleum-based, comprise over 90% of the fuel needed for the transportation sector (EPA, 2021). Light-duty vehicles such as cars and pick-up trucks make up the largest portion of GHG emissions within the transportation sector (Lieberman, 2019). These vehicles emit primary GHGs carbon dioxide (CO₂), nitrous oxide (N₂O), and methane (CH₄), among others, though in reports these are often combined into carbon dioxide equivalents (CO₂e).

Vehicles that use fossil fuel for power not only harm the environment by contributing to the greenhouse effect with increased GHG emissions, but also contribute to poor air quality by emitting particulates. These particulates are directly linked to poor health outcomes such as cardiovascular and respiratory problems. These particulates can also congregate in the atmosphere, leading to acid rain and smog. Additionally, the chemicals, fuels, and oils needed in the transportation sector can often contaminate surface waters through runoff and accumulation, directly impacting human and environmental health. Lastly, fossil-fuel-powered vehicles often contribute to noise pollution, and the development of passenger-vehicle infrastructure impacts land conservation efforts (Rodrigue, 2022).

“Decarbonization” and alternatives to vehicles that rely on fossil fuels are growing, as is interest and demand for public transportation options, which has the potential to reduce the number of passenger vehicles on the road. Hybrid and electric vehicles, as well as solar charging options, improved/increasing infrastructure, and other advanced technologies, could help to reduce the environmental and social impact of greenhouse gas emissions and their cumulative impact on climate change (EPA, 2021).

Methods

A institutional vehicle fleet audit was completed to evaluate Carol Woods’ transportation sector from the perspective of vehicles’ fuel economy and emission performance. A fleet list of Carol Woods’ vehicles was obtained from the Buildings & Facilities Division. The spreadsheet keeps records of each vehicle’s year, make, model type, status, and retirement year, etc. We identified each vehicle’s environmental impact, and quantified its emission performance that can be taken into consideration for future vehicle purchases in Carol Woods. First, we listed each vehicle’s basic performance such as MPG, fuel range, and gallons/100 miles from the EPA Fuel Economy, the official government source for fuel economy information. Second, we input the vehicle's energy impact performance, indicating the quantity of barrels of petroleum the vehicle will likely consume annually.

Two kinds of GHG emissions are listed for each vehicle:

- Tailpipe CO2 emissions; This type of emission includes carbon emissions from vehicle exhaust, which typically accounts for 99% of greenhouse gas emissions. The emission is shown in grams per mile.
- Upstream GHG emissions; This type of emission includes CO2, methane, and nitrous oxide emitted from all fuel use steps using GREET 1_2020 Model (U.S. Department of Energy, Argonne National Laboratory). Methane and nitrous oxide emissions are converted into a CO2 equivalent. Because the 2018 Chrysler Pacifica (H) is a hybrid van, GHG emissions depend on how electricity is generated in its particular area. In this study, we used Carol Woods' zip code to find the emissions including both tailpipe and upstream emissions.

GHG emission score and smog rating are then obtained for each vehicle. GHG emission score is directed by US Environmental Protection Agency (EPA), indicating a rating scale used to show all vehicle exhaust emissions of carbon dioxide since 1984 compared with other models. The rating ranges from 1 to 10 where vehicles with a score of 10 being the cleanest. The EPA smog rating refers to the total amount of air pollutants emitted by vehicles that are harmful to health and form smog. Ratings range from 1 to 10 where vehicles with a score of 10 being the best. This rating does not include greenhouse gas emissions. We assigned values for both ratings based on each vehicle's location (North Carolina), MPG, and Tailpipe emissions. We assigned equal weight to both parameters and arrived at a final score of the same range from 1(worst) to 10 (best).

Results

Overall, we analyzed 15 vehicles of Carol Woods in fuel economy, energy impact performance, GHG emissions (upstream & tailpipe), GHG rating, EPA smog rating, and average score. As shown in Figure 23, vehicles' fuel economy has been displayed in combined MPG and gallons/ 100 miles. Specifically, Carol Woods has an average MPG of about 20.68 miles/gallon, ranging from 8.39 MPG on the 2016 Freightliner M2 to 32 MPG on the 2018 Chrysler Pacifica (H). The indicator of gallons/100 miles ranges from 3.1 on the 2018 Chrysler Pacifica (H) to 19 on the 1999 Chevrolet C2500 with an average of 5 gallons/100 miles. The next parameter is the vehicle's energy impact performance, which averages 14.55 barrels/year, with the highest being a 1999 Chevrolet C2500 and the lowest being a 2018 Chrysler Pacifica (H).

According to Figure 24, emissions from tailpipe account for more than 80% of the combined emissions of both upstream and tailpipe. The vehicle with the highest emission is the 1999 Chevrolet C2500 and the lowest is the hybrid van. In terms of GHG rating, the 2018 Chrysler Pacifica van is the cleanest, whereas the Freightliner and Ford Series are the worst. The final average score ranges from 5 to 8.5. However, it is noteworthy that though Chevrolet, Ford E Series, and Freightliner M2 don't have smog ratings and thus final average score, their GHG ratings are the three lowest.

Year	Make	Model	Type	Assignment	EPA Fuel Economy		Energy Impact Performance (barrels/yr)
					City MPG	Gallons/100mile	
2011	TOYOTA	SIENNA	VAN	MARKETING	18	5	14.9
2006	TOYOTA	AVALON	SEDAN	STAFF USE	20	4.3	12.9
2013	TOYOTA	SIENNA	VAN	TRANSPORTATION	19	4.8	14.2
2015	DODGE	CARAVAN	VAN	TRANSPORTATION	17	5	14.9
2017	DODGE	CARAVAN	VAN	TRANSPORTATION	17	5	14.9
2018	TOYOTA	SIENNA XLE	VAN	TRANSPORTATION	19		
2019	TOYOTA	SIENNA XLE	VAN	TRANSPORTATION	19		
2020	TOYOTA	SIENNA XLE	VAN	TRANSPORTATION	19		
2000	TOYOTA	AVALON	SEDAN	STAFF USE	19	4.5	13.5
1999	CHEVROLET	C2500	C2500	SECURITY	11	8.3	24.8
2018	CHRYSLER	PACIFICA (H)	VAN	MEDICAL RESPONSE	84 MPGe (Elec+Gas); 32 MPG (Gas)	40kWh for first 33mi; 3.1	3.6
2019	FORD	E SERIES	BUS	TRANSPORTATION	13		
2020	TOYOTA	RAV4	SUV	SECURITY	27	3.3	9.9
2008	SUBARU	FORRESTER	SUV	SECURITY	20	4.5	13.5
2016	FREIGHTLINER	M2	BOXTRUCK	HOUSEKEEPING			

Figure 23. Summary of vehicle's fuel economy and energy performance

Year	Make	Model	Type	Assignment	GHG Emissions (grams/mi)		GHG Rating (Tailpipe)	EPA Smog Rating	Average Score
					upstream	Tailpipe			
2011	TOYOTA	SIENNA	VAN	MARKETING	89	444	5	5	5
2006	TOYOTA	AVALON	SEDAN	STAFF USE	78	386	7	5	6
2013	TOYOTA	SIENNA	VAN	TRANSPORTATION	91	417	5	5	5
2015	DODGE	CARAVAN	VAN	TRANSPORTATION	89	445	4	6	5
2017	DODGE	CARAVAN	VAN	TRANSPORTATION	89	445	4	6	5
2018	TOYOTA	SIENNA XLE	VAN	TRANSPORTATION				4	
2019	TOYOTA	SIENNA XLE	VAN	TRANSPORTATION				4	
2020	TOYOTA	SIENNA XLE	VAN	TRANSPORTATION				4	
2000	TOYOTA	AVALON	SEDAN	STAFF USE	81	404	6		
1999	CHEVROLET	C2500	C2500	SECURITY	149	741	3		
2018	CHRYSLER	PACIFICA (H)	VAN	MEDICAL RESPONSE	114		10	7	8.5
2019	FORD	E SERIES	BUS	TRANSPORTATION			1		
2020	TOYOTA	RAV4	SUV	SECURITY	69	296	7	6	6.5
2008	SUBARU	FORRESTER	SUV	SECURITY	81	404	6	5	5.5
2016	FREIGHTLINER	M2	BOXTRUCK	HOUSEKEEPING			1		

Figure 24. Summary of vehicle's emission performance

Discussion

Fifteen vehicles are included in our analysis and presented in terms of their basic performance and environmental impact performance. It should be noted that Carol Woods own 18 vehicles in total, three of which are not included in our study due to the lack of data. They can be updated and included in our analysis once their performance information are obtained.

The figures in the table above are estimated based on the EPA assumption of 45% of highway driving and 55% of city driving. These numbers may vary because carol Woods vehicles are mostly used on campus. In addition, our study assigns equal weights to GHG emission rating and smog rating for calculating the final score. In the future study of Carol Woods' transportation and vehicles, parameters can be personalized and weighted differently to meet the specific needs of Carol Woods. The above tables are standardized on the basis of assumptions for comparative analysis.

The Smartway certificate is another way of identifying greener performance for Carol Woods' future vehicles. Compared with other vehicles, vehicles with Smartway certification perform very well in terms of environmental protection in terms of both smog levels and GHG emissions.

V. RECOMMENDATIONS

Dining Services

Dining Services recommendations are based on our findings from secondary research, quantitative analysis, and discussion with staff. For reducing greenhouse gas emissions through adjusting its ordering strategy, we recommend the following for Carol Woods:

1. Reduce the amount of beef ordered by at least by 10%. Other animal proteins should at least stay at current ordering levels or also reduced by 10% or more based on the research of Stylianou et. al. (2021) to reach potential GHG emissions reductions of up to 33%
2. Begin replacing a larger portion of currently-ordered animal proteins with more plant-based proteins or meat substitutes, such as legumes, fungi, tofu, seitan, Impossible Meats, Beyond Meats, or a local vendor such as Delight Soy Foods.
3. Reduce the amount of farmed fish that is being ordered and/or switch to a more local, seasonal vendor, such as North Carolina-based Locals Seafood or another vendor verified from the “Got to be NC” (2021) local foods initiative.
4. Support the local economy and local foods vendors wherever possible. One good opportunities is to order coffee from a local roaster that prioritizes sustainable practices (as opposed to US Foods) to support the local economy and reduce the environmental impact of this food category. Little Waves Coffee Roasters, Caballo Rojo Coffee, Joe Van Gogh, and Derby Coffee Roasters are just a few examples of local vendors.

To help Carol Woods reduce the amount of food waste it produces, we have the following recommendations:

1. Track residents' complaints of food running out in an official way to better understand how often this occurs and what measures should be put in place to prevent it.
2. Create a cooking playbook for every staple menu recipe to help make ordering and prepping more uniform across cooks.
3. Continue the internal audit of food waste by utilizing residents as volunteers and track the amount of specific items being thrown out to recognize what is regularly not being finished. UNEP offers a guide to do this (UNEP, 2014).
4. Begin donating leftovers foods that are eligible to a local shelter. The Good Samaritan Act protects organizations against liability for donations (USDA, 2021).

Buildings & Facilities

Recommendations are based on a gap analysis between benchmarking of desired performance and Carol Woods' current state analysis. For Carol Woods' energy solutions, we recommend the following metrics and actions to be taken in the future:

1. Perform ongoing preventative maintenance of building equipment and systems and organize regular visual inspection for energy use and wasters; This will ensure efficiency and extend equipment life.
2. Expand solar array and implement other renewable or energy-efficient solutions; Solar activities can include solar electricity and solar hot water, etc. Increased efficiency and transition to renewable energy can lower GHG emissions and other pollutants and reduce energy bills.
3. Establish energy dashboard and energy metering system for tracking Carol Woods' buildings and facilities; The availability of data is important for Carol Woods' to measure the whole campus' progress on energy usage, understand baselines, and set carbon reduction target in the future.

For Carol Woods' transportation strategies, we recommend the following metrics and actions:

1. Conduct an annual transportation survey of Carol Woods' employees and residents, understanding their commuting behaviors; This can help Carol Woods adjust their plan on service commuting schedules and new vehicles purchasing options.
2. For future vehicle purchasing, it is recommended to purchase a hybrid van and an electric truck such as Chrysler Pacifica hybrid van and Lightning Electric E-450 Box Truck that have better environmental performance.

VI. FUTURE RESEARCH

Dining Services

To better understand how Carol Wood's new menu aligns purchasing with food waste, an updated invoice audit should be performed with the new menu orders. This will help Carol Woods to better understand how to order the correct amount of food based on waste. This new invoice audit should also look into which items are sourced with sustainability certifications, grown humanely, or sourced locally. Further, the waste audit should be continued on a regular and specific basis to understand what types of foods are repeatedly thrown away, or which ones are thrown away in large amounts.

Buildings & Facilities

Further research can be more specific on the studies such as the relationship of electricity usage against degree-days. Other metrics can also be adopted in the future study of Carol Woods' Buildings & Facilities sector such as the energy use index (EUI), which is defined as the energy consumption per unit conditioned floor area and is expressed Btu per square foot (Fairey & Goldstein, 2016). Moreover, Siemens data can be a potential area for future research in order to acquire a deeper interpretations of Carol Woods' electricity consumption. Computer procedures will be needed for studying Siemens data such as Python.

LITERARY CITATIONS

AARP. (2022 January 27). *How Continuing Care Retirement Communities Work*. American Association of Retired Persons. Retrieved April 14, 2022 from <https://www.aarp.org/caregiving/basics/info-2017/continuing-care-retirement-communities.html>

American Health Care Association. (2020). *Facts and Figures*. American Health Care Association. Retrieved September 27, 2021 from <https://www.ahcancal.org/Assisted-Living/Facts-and-Figures/Pages/default.aspx>

Antioch University. (2015). *Climate action plan - antioch.edu*. Retrieved March 26, 2022, from <https://www.antioch.edu/wp-content/uploads/2017/01/AULA-ClimateActionPlan2015.pdf>

Aras, N. (2008). *Forecasting Residential Consumption of Natural Gas Using Genetic Algorithms*. *Energy Exploration & Exploitation*, 26(4), 241-266. Retrieved February 28, 2022, from <https://journals.sagepub.com/doi/abs/10.1260/014459808787548705>

Baker, Beth. (September 7, 2018). *Green Retirement Communities are Sprouting*. Next Avenue. Retrieved September 27, 2021 from <https://www.nextavenue.org/green-retirement-communities-are-sprouting/>

Borunda, Alejandra. (December 27, 2021). *How small changes to our diet can benefit the planet*. National Geographic. Retrieved February 10, 2022 from <https://www.nationalgeographic.com/environment/article/how-small-changes-to-our-diet-can-benefit-the-planet?loggedin=true>

Bowdoin. (n.d.). *Composting and food waste*. Bowdoin Sustainability. Retrieved March 1, 2022, from <https://www.bowdoin.edu/sustainability/sustainability-initiatives/composting-and-food-waste.html>

Bowdoin. (n.d.). *Energy solutions*. Bowdoin Sustainability. Retrieved March 1, 2022, from <https://www.bowdoin.edu/sustainability/energy-solutions/index.html>

Breeding, Brad. (September 24, 2018). *A Closer Look: Examining the CRCC Market in the US*. My Life Site. Retrieved September 27, 2021 from <https://mylifesite.net/blog/post/examining-crcr-market-in-u-s/>

Broosbank, K. (2021). *Composting to avoid methane production*. Government of Western Australia Department of Primary Industries and Regional Development. Retrieved March 23, 2022 from <https://www.agric.wa.gov.au/climate-change/composting-avoid-methane-production>

Carol Woods. (2021). *Well Being*. Carol Woods. Retrieved September 27, 2021 from <https://www.carolwoods.org/well-being-dimensions-of-wellness>

- CDP. (2020, June). *Setting 1.5°C-aligned science-based targets*. CDP Disclosure Insight Action. Retrieved February 28, 2022, from <https://sciencebasedtargets.org/resources/files/SBTi-Power-Sector-15C-guide-FINAL.pdf>
- Clift, Cortney. (2015, April 23). *11 Foods You Didn't Know Were Hurting the Planet*. Brit + Co. Retrieved February 11, 2022 from <https://www.brit.co/food-thats-bad-for-the-environment/>
- Colorado College. (2021). *Www.coloradocollege.edu*. Retrieved March 26, 2022, from https://www.coloradocollege.edu/offices/sustainability/state-of-sustainability-/SUS_SOS21.pdf
- CompostNow. (2022). *About Us*. CompostNow. Retrieved March 21, 2022 from <https://compostnow.org/about/>
- Congressional Research Service. (2019, January 7). *U.S. Carbon Dioxide Emissions in the Electricity Sector: Factors, Trends, and Projections*. Congressional Research Service. Retrieved February 28, 2022, from <https://crsreports.congress.gov/product/pdf/R/R45453>
- Cote, Catherine. (April 13, 2021). *Making the Business Case for Sustainability*. Harvard Business Review. Retrieved September 27, 2021 from <https://online.hbs.edu/blog/post/business-case-for-sustainability>
- Cucurachi, S., Scherer, L., Guinee, J., Tukker, A. (2019, November 19). *Life Cycle Assessment of Food Systems*. One Earth, 1(3), 292-297. Retrieved February 11, 2022 from <https://www.sciencedirect.com/science/article/pii/S2590332219301289>
- Demirbas, A. (2006). *The importance of natural gas as a world fuel*. Energy Sources, Part B: Economics, Planning, and Policy, 1(4), 413–420. Retrieved February 28, 2022 from <https://doi.org/10.1080/15567240500402586>
- Edwards, J., Othman, M., Crossin, E., & Burn, S. (2017, August 14). *Life cycle inventory and mass-balance of municipal food waste management systems: Decision Support Methods Beyond the waste hierarchy*. Waste Management, 69, 577-591.. Retrieved September 28, 2021, from <https://www.sciencedirect.com/science/article/pii/S0956053X17305810?via%3Dihub>
- EIA. (2021, December 7). *Natural gas explained - Use of natural gas*. United States Energy Information Administration (EIA). Retrieved February 28, 2022, from <https://www.eia.gov/energyexplained/natural-gas/use-of-natural-gas.php#:~:text=The%20United%20States%20used%20about,of%20U.S.%20total%20energy%20consumption.>
- EnergyStar Portfolio Manager. (n.d.). *Energy use in senior care communities*. United States Environmental Protection Agency. Retrieved March 21, 2022, from https://www.energystar.gov/sites/default/files/tools/DataTrends_SeniorCare_20150129.pdf?b0c9-dad4

EPA. (2020, September). *1.4 Natural Gas Combustion*. Retrieved February 28, 2022, from https://www.epa.gov/sites/default/files/2020-09/documents/1.4_natural_gas_combustion.pdf

EPA (2021). *Carbon Pollution from Transportation*. US Environmental Protection Agency. Retrieved February 10, 2022 from [https://www.epa.gov/transportation-air-pollution-and-climate-change/carbon-pollution-transportation#:~:text=%E2%80%8BGreenhouse%20gas%20\(GHG\)%20emissions,terms%20than%20any%20other%20sector.](https://www.epa.gov/transportation-air-pollution-and-climate-change/carbon-pollution-transportation#:~:text=%E2%80%8BGreenhouse%20gas%20(GHG)%20emissions,terms%20than%20any%20other%20sector.)

EPA. (2021). *Greenhouse Gas Emissions from a Typical Passenger Vehicle*. United States Environmental Protection Agency. Retrieved February 20, 2022 from [https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle#:~:text=of%20CO2.-,Are%20there%20other%20sources%20of%20greenhouse%20gas%20\(GHG\)%20emissions%20from,emissions%20from%20leaking%20air%20conditioners.](https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle#:~:text=of%20CO2.-,Are%20there%20other%20sources%20of%20greenhouse%20gas%20(GHG)%20emissions%20from,emissions%20from%20leaking%20air%20conditioners.)

EPA. (2020). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018*. EPA. Retrieved February 28, 2022, from <https://www.epa.gov/guidance>

EPA (2021). *Sources of Greenhouse Gas Emissions*. United States Environmental Protection Agency. Retrieved February 20, 2022 from [https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#:~:text=Transportation%20\(29%20percent%20of%202019,ships%2C%20trains%2C%20and%20planes.](https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#:~:text=Transportation%20(29%20percent%20of%202019,ships%2C%20trains%2C%20and%20planes.)

Fairey, P., & Goldstein, D. B. (2016). *Metrics for Energy Efficient Buildings: How Do We Measure Efficiency?* ACEEE. Retrieved February 27, 2022, from https://www.aceee.org/files/proceedings/2016/data/papers/9_421.pdf

Gates, M. (2017). *Landis Homes Residents Cherish Community's Resources*. Landis Homes. Retrieved March 23, 2022 from <https://www.landishomes.org/2017/05/17/back-to-nature/>

Good, L. (2008). *Building Green Benefits Landis Homes*. Mennonite Creation Care Network. Retrieved March 23, 2022 from <https://mennocreationcare.org/building-green-benefits-landis-homes/>

Got to be NC Agriculture. (2022). *Find Local*. NC Department of Agriculture & Consumer Services. Retrieved March 25, 2022 from <https://gottobenc.com/find-local/>

Hanson, C. and Mitchell, P. (March 2017). *The Business Case for Reducing Food Loss and Waste*. Champions 12.3. Retrieved February 10, 2022 from <https://champions123.org/publication/business-case-reducing-food-loss-and-waste>

Healy, Robert. (March 2022). Retrieved March 28, 2022.

- Inland Seafood. (2015). *Sustainability*. Inland Seafood. Retrieved February 10, 2022 from <https://www.inlandseafood.com/pages/sustainability>
- IPCC. (2021). *AR6 Climate Change 2021: The Physical Science Basis*. International Panel on Climate Change. Retrieved September 27, 2021 from <https://www.ipcc.ch/report/ar6/wg1/>
- IPCC. (2018). *Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development*. International Panel on Climate Change. Retrieved February 20, 2022 from https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter2_Low_Res.pdf
- IPCC. (2018). *Summary for Policymakers*. International Panel on Climate Change. Retrieved February 20, 2022 from https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf
- Kendal. (2022). *Sustainability*. Kendal Senior Living Communities. Retrieved February 20, 2022 from <https://www.kendal.org/2021/01/14/sustainability-2/>
- Laird, S. (2020, November 9). *A Guide to CO2 Told by Cats, Cars & Kegs*. Means and Matters by Bank of the West. Retrieved February 20, 2022 from <https://meansandmatters.bankofthewest.com/article/sustainable-living/taking-action/a-guide-to-co2-told-by-cats-cars-and-kegs/>
- Lieberman, Bruce. (2019, September 22). *A brief introduction to climate change and transportation*. *Yale Climate Connections*. Retrieved February 20, 2022 from <https://yaleclimateconnections.org/2019/09/a-brief-introduction-to-climate-change-and-transportation/>
- Michael, J. and Modell, H. (2021, April 7). *Validating the core concept of "mass balance"*. *Advances in Physiology Education*, 45, 276-280. Retrieved March 20, 2022, from <https://journals.physiology.org/doi/full/10.1152/advan.00235.2020#:~:text=%E2%80%9CDEFINITI%ON%20of%20Core%20Concept%20of,applies%20to%20all%20physical%20systems.>
- MOST. (n.d.). *Landis Homes Stream and Floodplain Restoration*. Municipal Online Stormwater Training Program. Retrieved March 23, 2022 from <https://mostcenter.umd.edu/case-story-content/landis-homes-stream-and-floodplain-restoration>
- Nelson, G., Rosegrant, M., Koo, J., Robertson, R., Sulser T., Zhu T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing M., and Le, D. (2009). *Climate change: Impact on agriculture and costs of adaptation*. International Food Policy Research Institute. Retrieved February 10, 2022 from <https://www.ifpri.org/publication/climate-change-impact-agriculture-and-costs-adaptation>
- Our World in Data. (2021, June). *Environmental Impacts of Food Production*. Retrieved February 10, 2022 from <https://ourworldindata.org/environmental-impacts-of-food>

- Poore, J. and Nemecek, T. (2018, June 1). *Reducing food's environmental impacts through producers and consumers*. *Science*, 360(6392), 987-992. Retrieved February 11, 2022 from <https://www.science.org/doi/10.1126/science.aag0216>
- Rodrigue, Jean-Paul. (2022). *Transportation and the Environment*. The Geography of Transport Systems. Retrieved February 20, 2022 from <https://transportgeography.org/contents/chapter4/transportation-and-environment/>
- RTS. (2021). *RTS Food Waste Guide 2021*. Recycle Track Systems. Retrieved February 10, 2022 from https://www.rts.com/wp-content/uploads/2021/04/RTS_Food_Waste_Guide_2021.pdf
- Shoemake, Emily. (March 29, 2018). *Communities Moving Towards Environmental Sustainability*. Presbyterian Senior Living. Retrieved September 27, 2021 from <https://www.presbyterianseniorliving.org/blog/communities-moving-towards-environmental-sustainability>
- Smith College. (n.d.). *Climate action*. Smith College. Retrieved March 26, 2022, from <https://www.smith.edu/about-smith/sustainable-smith/action-and-impact/climate-action>
- Stylianou, K. S., Fulgoni, V. L., & Jolliet, O. (2021). *Small targeted dietary changes can yield substantial gains for human health and the environment*. *Nature Food*, 2(8), 616–627. Retrieved February 11, 2022 from <https://doi.org/10.1038/s43016-021-00343-4>
- Sysco. (2022). *Sysco 2021 Corporate Social Responsibility Report*. Sysco Foods. Retrieved February 10, 2022 from <https://www.sysco.com/About/Company-Profile/Corporate-Social-Responsibility>
<https://www.sysco.com/dam/jcr:fd7c07d9-d612-4918-a3d4-1549fcee8708/Sysco%202021%20Corporate%20Social%20Responsibility%20Report.pdf>
- Tufts. (2019, August). *Sustainable Eating: The Key to a Healthy Future*. Tufts University Health and Nutrition Newsletter, 37(6), 4-5. Retrieved February 11, 2022 from <https://www.proquest.com/docview/2277920781/fulltextPDF/18447A595C094F30PQ/1?accountid=10598>
- UCSUSA. (2021, June 1). *What is Sustainable Agriculture?* Union of Concerned Scientists. Retrieved February 11, 2022 from <https://www.ucsusa.org/resources/what-sustainable-agriculture>
- UNEP. (n.d.) *Definition of Food Loss and Waste*. United Nations Environment Program. Retrieved February 10, 2022 from <https://www.unep.org/thinkeatsave/about/definition-food-loss-and-waste>
- UNEP. (2014). *Prevention and reduction of food and drink waste in businesses and households*. United Nations Environment Program. Retrieved February 25, 2022 from https://wedocs.unep.org/bitstream/handle/20.500.11822/25194/food_waste_prevention_guidance.pdf?sequence=1&isAllowed=y

USDA. (2021). *Why Should We Care About Food Waste?* United States Department of Agriculture. Retrieved February 10, 2022 from <https://www.usda.gov/foodlossandwaste/why>

USDA. (2021, July 29). *Good Samaritan Act Provides Liability Protection For Food Donations*. United States Department of Agriculture. Retrieved February 20, 2022 from <https://www.usda.gov/media/blog/2020/08/13/good-samaritan-act-provides-liability-protection-food-donations>

US EPA. (2021). *Sustainable Management of Food Basics*. US Environmental Protection Agency. Retrieved February 10, 2022 from <https://www.epa.gov/sustainable-management-food/sustainable-management-food-basics#:~:text=Food%20waste%20refers%20to%20food,or%20combusted%20with%20energy%20recovery.>

US Foods. (2021). *2020 Corporate Social Responsibility Report*. US Foods, Incorporated. Retrieved February 10, 2022 from <https://www.usfoods.com/about-us-foods/corporate-social-responsibility.html>
https://www.usfoods.com/content/dam/usf/pdf/dce/supporting_materials/CSR-2020-Report.pdf

Van Dijk, M., Morley, T., Rau, M., & Saghai, Y. (2021, July 21). *A meta-analysis of projected global good demand and population at risk of hunger for the period 2010-2050*. *Nature Food*, 2(7), 494-501. Retrieved February 11, 2022 from <https://www.nature.com/articles/s43016-021-00322-9>

Vergara, S. E., & Tchobanoglous, G. (June 28, 2012). *Municipal solid waste and the environment: A global perspective*. *Annual Reviews*. Retrieved September 30, 2021, from <https://www.annualreviews.org/doi/10.1146/annurev-environ-050511-122532>.

WRI. (2016, April 20). *Animal-based Foods are More Resource-Intensive than Plant-Based Foods*. World Resources Institute. Retrieved February 11, 2022 from <https://www.wri.org/data/animal-based-foods-are-more-resource-intensive-plant-based-foods>

WRI. (n.d.). *The Greenhouse Gas Protocol*. World Resources Institute. Retrieved September 30, 2021, from <https://ghgprotocol.org/sites/default/files/ghgp/standards/ghg-protocol-revised.pdf>.

WWF. (July 21, 2021). *Over 1 Billion Tonnes More Food Being Wasted Than Previously Estimated, Contributing 10% of All Greenhouse Gas Emissions*. World Wildlife Fund. Retrieved February 10, 2022 from <https://www.worldwildlife.org/press-releases/over-1-billion-tonnes-more-food-being-wasted-than-previously-estimated-contributing-10-of-all-greenhouse-gas-emissions>

Appendix A

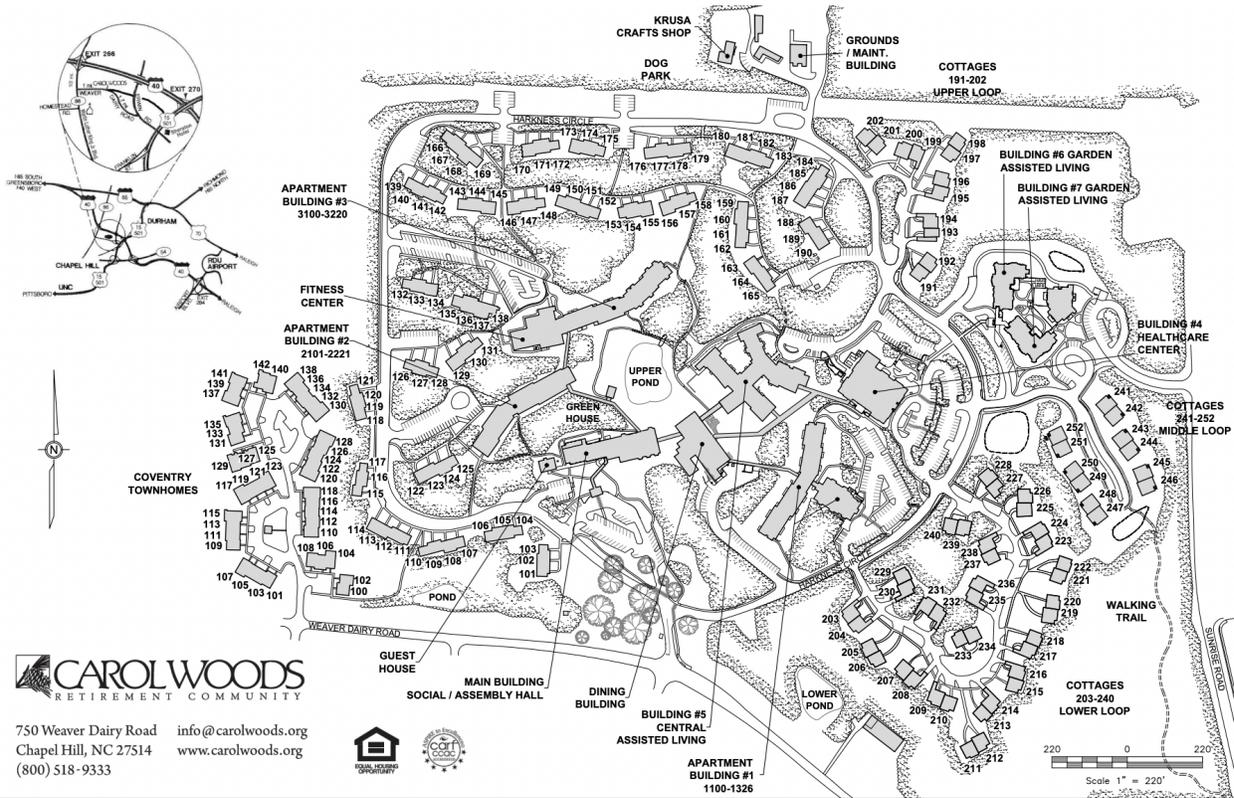


Figure 25. Map of the Carol Woods campus

MONDAY 2/7	TUESDAY 2/8	WEDNESDAY 2/9	THURSDAY 2/10	FRIDAY 2/11	SATURDAY 2/12	SUNDAY 2/13
BREAKFAST – Take Out 8:00 – 9:00 am						
LUNCH – Take Out 11:30 – 1:30 pm			Carvery Service 12:00 – 1:30 pm			
Daily Soup ♥F Minestrone Daily Salad GF♥ Chicken Salad	Daily Soup GF♥ Cream of Asparagus Daily Salad GF♥ Tuna Salad	Daily Soup GF♥ Split Pea Daily Salad GF Seafood	Daily Soup VF Tomato Gouda Daily Salad GF♥ Chicken Salad	Daily Soup GF Chicken and Duck Gumbo Daily Salad GF♥ Pimento Cheese	Daily Soup GF Manhattan Clam Chowder Daily Salad GF Shrimp Salad	Daily Soup GF♥ Broccoli and Cheese Daily Salad GF♥ Turkey Salad
GF♥F 3 Bean Chili F Grilled Reuben Sandwich Fish Sticks V Tomato and Onion Quiche GF♥F Steamed Spinach GF♥F Roasted Carrots GF♥F Grilled Zucchini GF♥F Baked Tater Tots GF V Mashed Potatoes / Gravy	V♥F Vegetarian Slider / Fixings GF Slider (Mini Burger) / Fixings Chicken Chasseur V Broccoli and Cheddar Quiche GF♥F Sautéed Cherry Tomatoes GF VF Baked Beans GF♥F Jasmine Rice GF V French Fries GF V Mashed Potatoes / Gravy	V Eggplant Parmesan GF♥ Turkey Breast / GF V Cranberry Orange Glaze F Spaghetti and Meat Sauce V Vegetable Quiche GF♥F Honey Ginger Carrots GF♥F Sautéed Spinach with Garlic GF♥F Lima Beans GF V Mashed Potatoes / Gravy	VF Grilled Sharp Cheddar on Whole Wheat Bread GF♥ Grilled Chicken Breast GF V Greek Salad V Mushroom and Swiss Quiche GF♥F Grilled Artichokes GF♥F Broccoli GF♥F Potatoes O'Brien GF V Mashed Potatoes / Gravy	V♥F Vegetarian Spaghetti Bake Chicken Pot Pie GF♥ Baked Salmon V Sundried Tomato and Artichoke Quiche GF♥F Baked Acorn Squash GF VF Braised Endive with Blue Cheese GF♥F Green Beans V Onion Rings GF V Mashed Potatoes / Gravy	V Goat Cheese Macaroni GF Cuban Pork Carnitas ♥ Chicken Marsala V Asparagus and Swiss Quiche GF♥F Asparagus GF♥F Saffron Rice GF♥F Broccoli Rabe GF V Mashed Potatoes / Gravy	GF♥F Chana Masala GF Roasted Strip Loin GF♥ Baked Trout / V♥ Hollandaise Sauce F Turkey Divan V Gouda Cheese and Vegetable Quiche GF♥F Julienne Carrots GF♥F Fresh Steamed Spinach GF♥F Corn on the Cob GF V Basmati Rice GF♥F Baked Potato GF V Mashed Potatoes / Gravy
EVENING MEAL – Take Out 4:30 – 6:30 pm			Carvery Service 5:00 – 6:30 pm			
VF Vegetarian Fajitas ♥ Swiss Steak / Onions and Mushrooms in Brown Gravy GF♥ Baked Cod / ♥ Tarragon Sauce V Tomato and Onion Quiche GF♥F Broccoli GF♥F Assorted Grilled Peppers GF♥F Corn on the Cob GF♥F Black Beans GF V Rice GF V Mashed Potatoes / Gravy	V♥F Wild Mushroom Parmesan Orzo GF♥ Fresh Catch of the Day / V♥ White Wine Sauce GF♥ Baked Chicken Tenders / V Smoky Honey Mustard Sauce V Broccoli & Cheddar Quiche GF♥F Grilled Kale GF♥F Baked Acorn Squash GF♥F Green Beans w/ Almonds GF♥F Fingerling Potatoes GF V Mashed Potatoes / Gravy	GF♥F Vegetarian Shepherd's Pie GF♥ Grilled Pork Tenderloin with Rosemary GF♥ Shrimp Scampi with Crème Sauce V Vegetable Quiche GF♥F Roasted Beets GF♥F Steamed Asparagus GF♥F Brown Rice GF VF Sweet Potato Fries GF V Mashed Potatoes / Gravy	GF VF Tofu Cabbage Stir Fry GF♥ Seared Scallops Braised Beef Short Ribs V Mushroom and Swiss Quiche GF♥F Roasted Root Vegetables GF♥F Braised Kale GF♥F Roasted Cauliflower / GF V Cheese Sauce GF♥ White Rice GF V Mashed Potatoes / Gravy	GF♥F Wild Mushroom Nut Pie ♥ Beef Goulash / V♥ Egg Noodles GF Baked Ham / GF V Raisin Sauce V Sundried Tomato and Artichoke Quiche GF♥F Grilled Zucchini GF♥F Braised Mustard Greens GF V Sweet Potato Soufflé GF V Mashed Potatoes / Gravy	GF♥F Vegetable Rice Stuffed Peppers GF♥F Filet Mignon GF Shrimp Syracuse V Asparagus and Swiss Quiche GF♥F Sautéed Collard Greens GF♥F Sautéed Cherry Tomatoes with Pesto GF♥F Fire Roasted Apples GF♥F Brown Rice GF♥F Oven Roasted Potatoes GF V Mashed Potatoes / Gravy	V♥ Fettucine / V♥ Bruschetta Home Style Meatloaf Fried Catfish V Gouda Cheese and Vegetable Quiche GF♥F Steamed Yellow Squash and Onions GF♥F Swiss Chard GF♥F Coleslaw V Hush Puppies GF V Mashed Potatoes / Gravy

Figure 26. Menu for the week of February 7, 2022 through February 13, 2022

Appendix B

This appendix provides the worksheet for completing a waste audit in the same manner that was completed for this project.

Carol Woods Dining Services Waste Audit Worksheet

Supplies needed: gloves and hairnets (available in kitchen); clipboard; pens; digital bathroom scale; large, durable container (such as a Rubbermaid; the kitchen should have large plastic containers available)

Directions: To complete an accurate food waste audit over the course of one calendar day, all food preparation scraps, leftover foods, and rotten or expired foods that would normally be thrown into the CompostNow collection bins in the main dining facility should be held before being weighed. *No food should be thrown away as compost on those days until after it is weighed.* Preparation scraps and expired/rotten food can be weighed throughout the day and meal leftovers should be weighed after each meal and after employees have taken any food they want. Do not forget about pre-packaged meals (typically in the cold display case), cold/salad bar foods, and desserts that are rotated throughout the week and thrown out at the end of the night. This food waste audit can be as specific or general as the auditors like, though if foods are separated out by specific type (potatoes, chicken, cheese, etc.), a more accurate environmental impact can be calculated. The food waste audit is most easily completed with more than one person.

As preparation scraps and/or rotten/expired food is collected in the large bins throughout the day, the auditors should either separate the food into items of interest to be weighed separately, or leave them all mixed as “comingled.” Similarly, after each meal is over, all leftover foods will be brought by into the kitchen in serving trays and in the hot carts taken to Buildings 4, 5, 6, & 7. Begin to fill the large tub with either separated or comingled foods (be sure to measure preparation scraps, rotten/expired foods, and leftovers separately). Once a bin begins to get too heavy to pick up, it should be placed on the digital scale and weighed. Record the item description and weight on the other side of this sheet. Once you have recorded the weight, the foods can be thrown into the CompostNow bins. Repeat this process as many times as necessary to weigh all of the food. Follow the instructions on the back of this sheet to calculate each food’s environmental impact. You can also use Excel if it is easier.

Table of CO2e factors

Food	Greenhouse gas emissions per kilogram kgCO ₂ eq per kilogram
Apples	0.43 kg
Bananas	0.86 kg
Barley	1.18 kg
Beef (beef herd)	99.48 kg
Beef (dairy herd)	33.30 kg
Beet Sugar	1.81 kg
Berries & Grapes	1.53 kg
Brassicas	0.51 kg
Cane Sugar	3.20 kg
Cassava	1.32 kg
Cheese	23.88 kg
Citrus Fruit	0.39 kg
Coffee	28.53 kg
Dark Chocolate	46.65 kg
Eggs	4.67 kg
Fish (farmed)	13.63 kg
Groundnuts	3.23 kg
Lamb & Mutton	39.72 kg
Maize	1.70 kg
Milk	3.15 kg
Nuts	0.43 kg
Oatmeal	2.48 kg
Onions & Leeks	0.50 kg
Other Fruit	1.05 kg
Other Pulses	1.79 kg
Other Vegetables	0.53 kg
Peas	0.98 kg
Pig Meat	12.31 kg
Potatoes	0.46 kg
Poultry Meat	9.87 kg

Prawns (farmed)	26.87 kg
Rice	4.45 kg
Root Vegetables	0.43 kg
Soymilk	0.98 kg
Tofu (soybeans)	3.16 kg
Tomatoes	2.09 kg
Wheat & Rye	1.57 kg
Wine	1.79 kg

Source: <https://ourworldindata.org/environmental-impacts-of-food>