Menus of Change Impact on the Carbon Footprints of Top Dining Meals at Boston College

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Abstract

Global food production currently accounts for over a third of the globes occupied land, and has contributed 30% of total anthropogenic greenhouse (GHG) emissions (Hallström et al., 2015). An extensive literature review demonstrates that the foods in our diets have an impact on the world around us, and we have set out to find what impact the top meals at Boston College's dining halls are having on the environment. The goals of our study are to first identify the top meals at both main dining facilities on campus, and quantify the individual meal's environmental impacts, then work within the partnership Boston College has with Menus of Change initiative to identify the areas within the top grossing meals to potentially reduce the impact that Boston College is having through dining services. We find that in line with previous LCA literature, the highest emitting meals are those that contain ruminant meat, and the lowest environmental footprint associated with foods on campus, are high in plant rich foods. We have demonstrated that there are clear tangible switches that could be implemented in our dining services that have large potential for reducing the associated footprints with students preferred meals on campus. Our research intends to add to the evidence that an understanding of our individual diets and choices on the environment is on of the most direct ways to reduce your carbon footprint, and we hope that our findings can be used to enact change on campus.

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Introduction

Global food production currently accounts for over a third of the globes occupied land, and has contributed 30% of total anthropogenic greenhouse (GHG) emissions (Hallström et al., 2015).

Understanding that our every day meals are having an impact on the environment is becoming increasingly important as a way to combat climate change. An extensive literature review demonstrates that the foods in our diets have an impact on the world around us, and we have set out to find what impact the top meals at Boston College's dining halls are having on the environment. The goals of our study are to first identify the top meals at both main dining facilities on campus, and quantify the individual meal's environmental impacts, then work within the partnership Boston College has with Menus of Change initiative to identify the areas within the top grossing meals to potentially reduce the impact that Boston College is having through dining services.

In order to begin our research we set up several meetings with Julianne Stelmaszyk, the Sustainability Director for BC Dining, to find out what meals students prefer at Lower Dining Hall and McElroy Commons (Mac). From there, we conducted an extensive literature review covering information in the United States and around the globe regarding the Life Cycle Assessments (LCA) of the food production systems impacts on the environment, mostly from a farm production phase to ready for sale. Understanding the life cycles of the ingredients that go into each of our meals illustrates the impact that different elements of our diets have, as well as gives a unique opportunity to explore what ingredient swaps can be made in order to reduce this impact. Working within the structure of Menu's of Change, which is a sustainability and health initiative that advances an agenda across the food service industry to demonstrate that there are many ways to improve our food choices for both our own health and the health of the environment (www.menusofchange.org). Boston College is one of the universities that works within the menus of change framework to improve the health of students and sustainability of the school and we hope that our research can allow Boston College to work within this already established partnership and framework coupled with our findings, in order to effectively reduce the dining halls' impact on the environment without compromising the tastes and preferences of students and emphasizing the principles of Menus of Change.

Top Dining Meals at Boston College

We chose to analyze the top meals at Boston College in order to really understand what students prefer to buy on campus so that we could work within the preferred tastes and recommend strategies to specifically reduce the impact of the meals that are eaten the most often. The Screaming Eagle sandwich is the most popular meal at lower, followed by the Grateful Burger and

the Salad bar (Personal Comm, Stelmaszyk 2019). The Screaming Eagle is the popular steak and cheese sub or chicken and cheese sub and is by far the most popular meal in Lower, both for dinner and lunch time meals. In conversation with one of the Assistant Managers at Lower, Steve Poletynski, we found out that the screaming eagle is served 9 meal periods per week, 5 times for dinner and 4 times for lunch. Steve also informed us that as far as the options between steak or chicken, students prefer steak 70% of the time, and chicken is only 30% of the total meals. The Grateful Burger, which is a sustainable split protein patty made of 60% grass-fed beef and 40% mushroom/vegetable base, is served every day for lunch and dinner, for a total of 14 meal periods (Personal Comm, Poletynski 2019).

At Mac, the top dining meals come from the wrap station, with the most popular options chosen being the Honey-Q Chicken Wrap and the Buffalo Chicken wrap. Additionally, the Chicken Parm Griller and the Grilling Grains station are also popular across both lunch and dinner periods (Personal Comm, Stelmaszyk 2019). We were not able to obtain data as far as how often each of these meals are featured at Mac, so we can only assess the individual impact of each meal, whereas for lower we will be able to calculate the total impact of a semester based on the current serving quota. In order to calculate these impacts we read through many papers to discover the environmental impact of the different ingredients in each of the meals at Lower and Mac. The recipes for each of the top meals at Lower and Mac are shown below in Table 1 (Personal Comm, Stelmaszyk 2019).

Steak and Cheese	*Chicken and Cheese*	*Grateful Burger*	*Salad Bar (top items)*

• .25 lb shaved steak • .0625 lb American cheese	• .25 lb shaved chicken • .0625 lb American cheese	• 1 Grateful burger patty, 3.2 oz grateful beef • 1 slice brioche roll	• Lettuce • Kale • Arugula • Spinach • Broccoli • Carrots • Cucumbers Note: Unable to accurately get exact recipe data, so we use the top ingredients in addition to sales reports provided by Juli, to asses a 4 month impact of Sale
Honey Q Chicken Wrap	*Buffalo Chicken Caesar*	*Chicken Parmesan*	*Grilling Grains Bowl*
• .25 LB chicken fritter chunks • .0313 QU BBQ sauce • .0039 lb clover honey • 1 8’’ flour tortilla • .063 lb romaine lettuce • .0313 Qt creamy caesar dressing • .0313 LB parmesan cheese	• .25 LB chicken fritter chunks • 0313 QU buffalo sauce • 1 8’’ flour tortilla • .063 LB romaine lettuce • .0313 QT Creamy Caesar dressing • .0313 LB parmesan cheese	• 1 ultra thin pizza shell • .25 lb chicken • .1248 qt spaghetti sauce • .0625 lb potato chips • 1 pickle	• 6 oz jasmine rice • 2 oz quinoa red • .0313 quart Mayo • .0002 quart sriracha chili sauce • .0312 quart kimchi • .0625 LB cabbage • .0625 LB brussel sprouts • .0625 LB carrot, • .05 quart egg • .015 LB Scallions Choice of one protein: • .08 LB pork belly • .125 LB salmon Atlantic, farmed

Life Cycle Assessment Review

Over the past couple decades, research regarding the environmental impacts associated with different food items is growing. This impact is most often quantified based on Life Cycle Analyses (LCA), which are standardized methods that calculate the impact of a product throughout its life cycle (Hallström et al., 2015). For our research we identified several LCA studies of importance with regard to individual foods as well as different diets in order to understand how to make insightful recommendations to reduce the dining footprints based on our review of the literature. Each ingredient has a unique lifecycle and specific production practices that lead to the differing foodprints, and demonstrate that what we eat matters. Production is directly influenced by consumer demand, and as such the UN FAO reveled that the greenhouse emissions (GHGE) associated with meat and dairy production is accounts for 14.5% of global GHGE, and it is estimates that changing our current diets has the potential to reduce GHGE by up to 50% (Rose et al., 2019). The food LCA studies that we implement in our project, closely examine each relevant step in the supply chain of specific ingredients, recording the GHGE values in kg CO2-equivalents (CO2-eq) per kg of ingredient (Rose et al., 2019). These emission values were mostly representative of the impacts of farm-to-gate production (up until the point of sale) and illustrate the global warming potential, demonstrating that human activities, including our diets, are amplifying the greenhouse effect by emitting additional carbon dioxide, methane and nitrous oxide (Heller et al, 2015). A few of our studies also discussed further environmental impacts such as the energy demand; all products require some input of energy in their life cycles, directly and/or indirectly, and with the data provided through a study at University of Michigan, the cumulative energy demand (CED) of the meals at Boston College was able to be extrapolated (Heller et al, 2016).

It is important to note that the majority of LCA literature is predominantly concentrated in Europe, and while we were able to find a few studies in the United States that were useful, 68% of the global warming potential (GWP) data is concentrated in Europe. North America only accounts for 10% of the compiled GWP data (Clune et al, 2017). From a broader perspective, the global GWP values are consistently lowest for field grown vegetables, cereals and pulses (excluding rice), and the highest GWP values are attributed to beef and lamb; chicken, fish, and dairy account for the intermediate values of GWP (Clune et al, 2017). Across a review of 369 LCA's there emerges a clear hierarchy within ingredients and demonstrate that our choices not only matter, but some options are significantly more impactful than others (Clune et al, 2017). Interestingly, the global

average for the impact of beef is less than the newly researched value specifically found in the United States, which could indicate that the production practices across the US are not as sustainable as other practices across the globe (Clune et al, 2017; Asem-Hiablie et al, 2018). One study echoes this hierarchy among different food impacts, reporting that the impacts of ruminant meat (i.e. beef) were 20-100 times higher than plants, moreover other products such as eggs, poultry and seafood were consistently 2-25 times greater than the low impacts of plant production (Clark & Tilman, 2017).

Dairy is an animal product that falls well below beef in terms of impact, however because it is a direct product of ruminant livestock, it still has one of the largest GWP values (Clune et al. 2017). Furthermore, it is an ingredient that was worth looking into, as it is present in 75% of the top meals at Boston College. The Innovation Center for US dairy has voluntarily set the goal to reduce the GHGE impact of the dairy supply chain by 25% by 2020 through a number of ways (Thoma et al., 2012). In reviewing the LCAs that are specifically focused on the US dairy supply, research has found that the carbon footprint of the industry, which is equivalent to 2% of GHG emissions (over half of which is just cheese), could be reduced by up to 90% in a number of ways; some of which refer to feed, energy and herd management practice, and one of which that requires a reduction of annual milk production overall (Thoma et al., 2012). 190 billion pounds of milk are produced each year, 1/3 of which is used for cheese alone (Thoma et al. 2013). The average carbon footprint of cheddar cheese is 8.7 kg CO_2 per kg of cheese, meaning 1 kg of cheese is equivalent to driving 24 miles in your car (Thoma et al., 2012). While cheese may be 3-4 times less in GWP than beef itself, it is almost triple the GWP values of chicken and fish, and significantly more harmful in terms of GHGE of all field grown vegetables multiplying the impact of the constantly lowest emitting food by up to 23 (Clune et al., 2017; Thoma et al., 2013).

A study in the UK demonstrated a quantifiable difference between meat eaters, fish eaters, vegetarians and vegans in order to assess how different each diet could be (Scarborough et al., 2013). It is presumable that all meat-eaters do not consume the same amounts of meat, meaning that their impacts could vary based on the amount of meat that takes up the majority portion of ones diet. In fact, reductions from a diet that consists of more than 100 g of meat per day to a diet which consumes less than 50 g, could effectively reduce a consumers carbon footprint by up to 920 kg CO_2 per year; reduction to a vegetarian diet or a vegan diet from high meat would result in 1,230 kg CO_2 per year and 1,560 kg CO_2 per year (Scarborough et al., 2013). Clearly, transitioning

animal based diets to more or complete plant based diets as a way to combat emissions could be very effective.

Due to this clear hierarchy among the food choices within our every day diets it is imperative to understand the ways in which we can reduce this impact both in production phases and our everyday choices. While there are improved agricultural practices that could be implemented to reduce both the GHGE and CED of different ingredients, past literature demonstrates that dietary shifts toward low impact food and an increase in the amount of food produced per input of feed and/or fertilizer, would have the largest potential to reduce the impact in place of commonly suggested swaps of grass fed beef or organic agriculture to mitigate conventional method impacts (Clark & Tilman, 2017). Due to dietary changes having the greatest reduction potential, we decided that we would leverage the Menus of Change initiatives in order to work within the sustainability model that Boston College already uses as a framework.

Menus of Change

Menus of Change (MOC) is an initiative which works to inform different partners within the food industry about healthy, sustainable and delicious choices and encourages chefs and food service operators, such as Boston College to engage in these practices (Menus of Change Annual Report (MOCAR), 2018). Notably, MOC advance the notion of plant-forward based menus, emphasizing the importance of a style of cooking that is not exclusively plant-based, however still centers fruits, vegetables, whole grains, beans, nuts, plant oils, and soy foods, all of which support the goals of being both healthy and sustainable (MOCAR, 2018). Climate Change is one of the drivers behind the MOC initiative and they recognize the importance of swapping proteins, such as poultry and beef, with plant based alternatives to fall in line with the research that shows a plant rich diet is one of the top ways to combat climate change (MOCAR, 2018; Rose et al, 2019; Scarborough et al., 2013). According to the 2018 MOC Annual Report, plant forward food choices features a variety of things, but most importantly recognizes the environmental importance of putting animal based food in a reduced and/or optional role in order to decreased purchasing of red meat and prioritize lower emitting animal based proteins such as fish, but also highlights vegan and vegetarian options which contribute and even smaller impact than fish and poultry. Menus of Change takes a firm stance that the food service industry has a critical role in addressing climate and water issues globally, which is important to highlight because research shows that the projected GHG emissions from the food industry alone could nearly surpass the threshold that

keeps the world below a temperature rise of 2 degrees, and thus lead to the catastrophic results scientific literature is alluding to if the climate warms to this extent (MOCAR, 2018).

The Grateful Burger is a great example of the MOC principles in action, as it is a blended burger that incorporates mushrooms and other vegetables, in addition to beef, in order to provide a beef burger that has a much lesser impact on the environment. The restaurant industry is currently driving this trend of reducing red meat consumption as a viable way to reduce GHG, however there is considerable efforts that still need to be made in order to promote the increase of sustainable animal proteins in recipes, as well as protein which are sourced from producers that are implementing growing and production practices that are more in tune with environmental needs (MOCAR, 2018).

Menus of Change has compiled *The Principles of Healthy, Sustainable Menus,* as a strategic guide that supports innovation within the food service industry with a diverse set of strategies and incorporates findings from both environmental and nutritional literature to guide optimal menus. This allows the foodservice industry to be creative, but also advocates for sustainability and transparency (MOCAR, 2018). For our research, we wanted to understand a few of these principles, namely those which have the largest potential to reduce Boston College food footprint, in effort to show the school that dedication to the Menus of Change initiatives is a viable way to add variety into the Dining Halls on campus as well as promote more sustainable diets that students can enjoy, whether or not they are aware they are making less of an impact.

In the General Operation strategy section, Principle 4: "Leverage globally inspired, plant-forward culinary changes", details the effectiveness of switching diets to mostly plant-based foods (MOCAR, 2018). Growing plants for food has less of an impact on the environment than raising livestock as illustrated in extensive LCA research, and MOC is choosing to leverage this in their plant forward strategy, emphasizing that no other single decision can have as great of a benefit in the advancement of global environmental sustainability (MOCAR, 2018). In a similar vein, the Foods and Ingredients section of the MOC principles, has several worthy strategies that can be leveraged by the dining halls to reduce the environmental footprint. Of the principles worth highlighting, the first principle "Think produce first", is echoing the operational strategy of more plant forward menus, but specifically supports the research that shows field grown vegetables and field grown fruit consistently have the lowest GHG impact (MOCAR 2018; Clune et al. 2017). Produce should fill half the plate, and it is widely known that many consumers are not consuming

enough produce, thus this principle is important not only from an environmental perspective, but a nutritional one as well.

Principle 4 within the food and ingredients section, “Move nuts and legumes to the center of the plate” is a principle that advocates for protein switches. Moving away from animal protein toward plant protein and recognizes the added bonus of legumes, as they are known for replacing nitrogen in the soil and are extremely efficient as far as protein production per acre, which falls in line with improving input efficiency to produce more food per inputs (MOCAR, 2018; Clark & Tilman, 2017). Legumes include soy foods, such as tofu, which is an excellent replacement for animal proteins, and we aim to quantify the potential of plant based proteins to reduce the impacts of Boston College’s most popular recipes.

While each of the Menus of Change 12 operational principles and 14 foods and ingredients principles are important in their own way in advancing the MOC initiative as a whole, the final principle that we noted as crucial in reducing the footprint of BC’s dining halls is Principle 10, “Eat less red meat, less often” (MOCAR, 2018). It is notable that MOC is not outright requesting the removal of red meat entirely, as that would be unrealistic based on consumer demand. Instead, this principle aims to compromise; suggesting that a maximum of two 3 oz savings is nutritionally recommended and achievable through a variety of strategies (MOCAR, 2018). There is a very unique and direct opportunity here for BC to reduce the food footprint, as one of the top meals in the dining hall is the Steak and Cheese. The current recipe, as shown previously, utilizes a 4 oz portion of steak, which is often doubled by students who choose the large sub, meaning that the serving size potentially could be 8-oz per sub. While it is not realistic to think that the dining hall, which responds to consumer demand, would make a protein swap in this popular sub, however limiting the times served per week could be a viable option. The current serving quota of 9 times per week 4 lunches and 5 dinners far surpasses the the MOC principle recommendation to limit red meat to 2- 3 oz servings. We chose to highlight the principle, as there is likely a substantial reduction possible to achieve with the same recipe and a simple reduction in the serving amounts each week.

It is without question that the Menus of Change initiative, which has already been adopted by Boston College dining, has many viable strategies and creative ideas that don't necessarily compromise the taste and excitement of food but do indeed promote the necessary change in our food system to combat climate change.

Data

For our specific research goals, we compiled the LCA data that was available in the US and the GWP emission equivalents and CED. Majority of the GWP and CED impacts pulled for our ingredients, comes mostly from the literature review of LCA in food systems done by Heller et al., in 2016. Additionally, beef and dairy were pulled from the USDA and the U.S. Dairy reports, as that appeared the best way to be as accurate in calculation as possible. There are some ingredients that we could not include in the recipe due to a lack of data, but many researchers have noted that the ingredients that lack data are often not significant contributors to the total sum of both CED and GWP values of a meal. Additionally we have sales reports from Juli, in which we used primarily for information regarding the salad bar, pulling the ingredients based on buying weight over a four month period.

Methods

In order to calculate the energy and carbon footprints of top dining meals, each ingredient in the top 8 recipes were converted into kilograms, ensuring common unit values so we can leverage the LCA data found for cumulative farm to gate impacts. Meat and seafood ingredients were converted to "kg of edible boneless weight", non-meat and other miscellaneous ingredients were converted to "kg of food" for each ingredient included in the top meals at Lower and Mac. As mentioned prior, due to availability of LCA data, some ingredients were omitted in the calculations, notably the dressings and sauces (e.g., BBQ Cannonball Sauce in the Buffalo Caesar Wrap). Additionally some impacts of a few of our ingredients were calculated by using the most comparable ingredient (e.g., cucumber LCA was used to calculate pickle impact). The Grateful burger emissions and energy estimates were calculated by attributing 60% of the 3.2 ounce paddy to beef, in accordance with the companies recipe, and equal distribution was given to each of the vegetables reported on their website.

To calculate the total GWP (kg CO_2 eq) and CED (MJ / Kg) of each meal, the usable ingredient of each recipe underwent a simple calculation, in which we multiplied the weight of an ingredient (in Kg or converted Kg) by the respective GWP or CED value and then summed the resulting values to obtain a kg CO_2 eq and MJ impact associated with each individual meal. In order to assess the total impact at Boston College, we reached out to gather information on weekly menu scheduling at both Lower and Mac. We were unable to get data on sales for Mac Dining Hall, as we never were able to get in touch with any of the managers. However, we were able to

inquire about Lower information for the Screaming Eagle and Grateful Burger. Salad sales were calculated on an sales-order basis over four months of available data due to variability in sizes offered at the dining hall and variable record keeping from cashiers. Steve Poletynski's estimates for the number meals served during lunch and dinner periods (i.e., 1,000 Screaming eagles are sold each lunch) were then used to estimate the meal count per week. This was then multiplied by 16, to simulate the 16-week or semester impact of these meals. From here we calculated the GHGE associated with one semester's worth of each of the top meals at Lower to understand how serving quotas may be amplifying some of the environmental consequences.

To accomplish quantifying potential changes and to determine sustainable swaps from animal focused to plant focused, we leveraged a few of the MOC principles. For example, we calculated the potential impact of "serving less red meat less often" by decreasing menu scheduling for the Screaming Eagle to two times per week for both lunch and dinner, at Lower Dining Hall. Additionally calculations were made to simulate different student choices to diversify the protein choices and relieve the current impact for the Screaming Eagle. For all menu items where a protein choice was applicable, we added tofu as a plant-based alternative, which we know has a lower impact than chicken, steak, and salmon. This was done in order to reflect multiple recommended MOC principles such as "Move nuts and legumes to the center of the plate" and "Serve less red-

meat less often" to quantify what a reduction of animal protein sources could potentially look like for Boston College's food footprint.

Results

Our results across both dining halls echo the LCA literature, with beef consistently having emissions significantly higher than any other food group, and vegetables consistently at the bottom of the food impact hierarchy. At lower dining hall the measured impact of a single serving of steak and cheese is 8.13 kg CO_2 which is two times greater than the chicken and cheese at 3.6 kg CO_2; and about 4 times greater than the grateful burger and the salad bar at 2.4 kg CO_2 and 2.17 kg CO_2 respectively (Figure 1). Figure 2 illustrates a semesters worth of Lower's top dining meals at Boston College and the disparity amongst of a semesters worth of each of the top dining meals is quite pronounced. With Boston College's current menu schedule and student demand, the impact of steak and cheese sums to 1,223,641.53 kg CO_2 per semester, twice the cumulative impact of the chicken & cheese at 613,049.73 kg CO_2, 6 times higher than the impact of the Grateful burger (123,031 kg CO_2), and 72 times the impact of the salad bar which aggregated sales data estimates a 4 month period impact at 16,911 kg CO_2 (Figure 2).

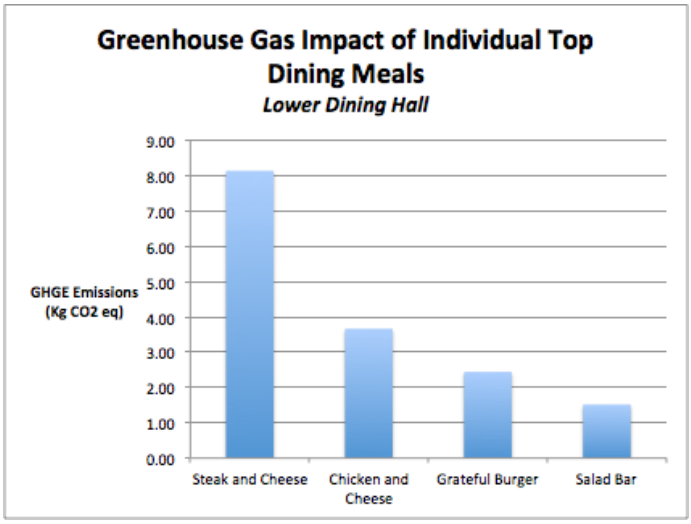

Figure 1. Greenhouse Gas Impact, (kg CO_2-eq) of Individual Top Dining Meals: The Screaming Eagle Sub (steak and cheese & chicken and cheese) the Grateful Burger and the Salad bar.

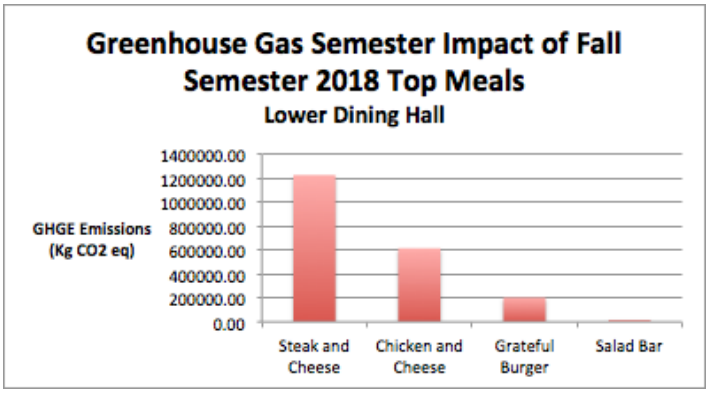

Figure 2. Greenhouse gas impact, kg CO_2-eq, of one semester's worth of each of the top dining meals.Calculated based on serving quota from the steak and cheese, chicken and cheese, and the grateful burger, per individual serving.

Our results also illustrate the cumulative energy demands (CED) of each of the top meals at the dining halls and there is clear differences between each meal. Figure 3 shows the individual CED of each recipe, the steak and cheese sub requires the most energy, totaling 23.25 MJ, which is slightly higher than the requirement for the poultry alternative at 18.65 MJ. Interestingly, while the salad bar only require half the energy input of the steak and cheese, the CED of 12.74 MJ is 3 times that of the Grateful burger which only requires 4.03 MJ (Figure 3).

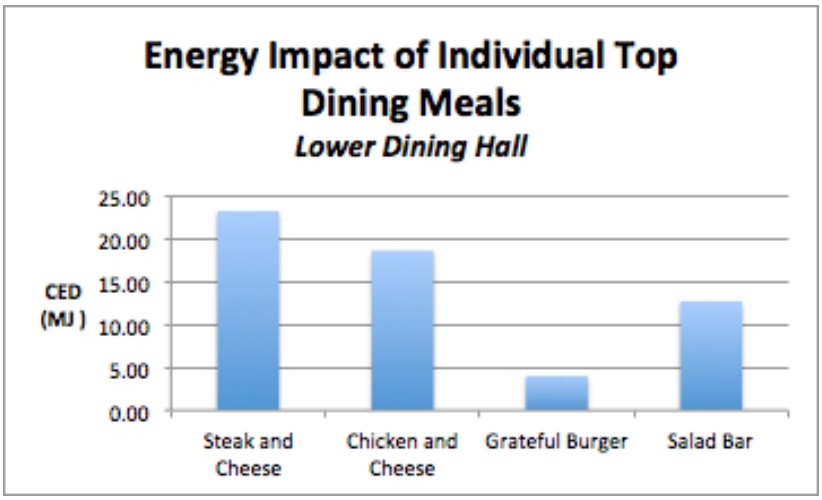

Figure 3. Cumulative Energy Demand (CED),in *MJ*, of top dining hall meals at lower: Screaming Eagle Options: Steak and Cheese & Chicken and Cheese, Grateful Burger and Salad Bar, per individual meal.

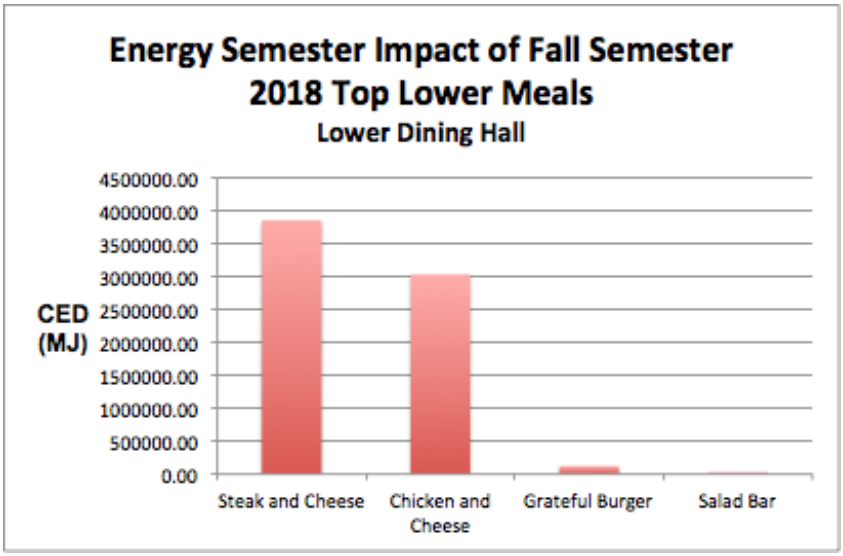

Figure 4. Cumulative Energy Demand (CED),in MJ, of top dining hall meals at lower: Screaming Eagle Options: Steak and Cheese & Chicken and Cheese, Grateful Burger and Salad Bar, based off of sales report during the fall 2018 semester.

Over the course of the semester the CED required for the Screaming Eagle subs, total over 3 million MJ, with the steak and cheese reaching up to 3,850,000 MJ (Figure 4). The Grateful burger is over 30 times less energy intensive than the steak and cheese based on current serving quotas, and although the Salad Bar contributes a higher individual energy demand, as shown in Figure 3, it has less of an overall impact throughout the

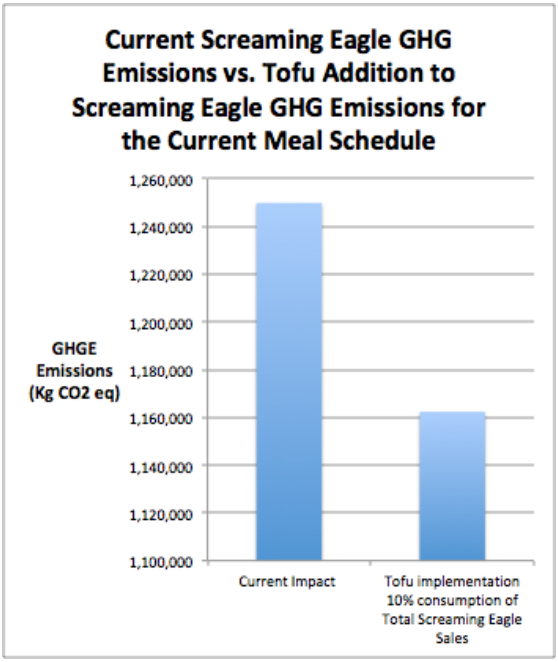

Figure 5. Measuring the potential reduction in GHGE, kg CO_2-eq impact by implementing a protein switch in the Screaming Eagle Sub. Comparison of current impact of just steak and chicken options vs if 10% of the orders were a plant based protein tofu. Based on the current 9 times per week serving quota.

semester than any of the other meals totaling the CED at 1,378 MJ (Figure 4, see discussion regarding salad bar).

Importantly, our research aimed to quantify ways in which Boston College Dining can reduce their impact by leveraging Menus of Change Principles. While this can be done in a number of ways Figure 5 and 6 demonstrate comparisons of our current impacts with potential impacts of hypothetical scenarios that BC could viably implement. In Figure 5, we tested what the potential impact of a semesters worth of Screaming Eagle subs could be reduce to if tofu was substituted for 10% of the options chosen by students. Currently steak accounts for 70% of sales, and chicken 30%, and we found that reduction of steak percentage to 60% of total sales with the addition of 10% tofu, would save just under 100,000 kg CO_2 per semester that plant based proteins were substituted in place of steak in the recipe. Our results in

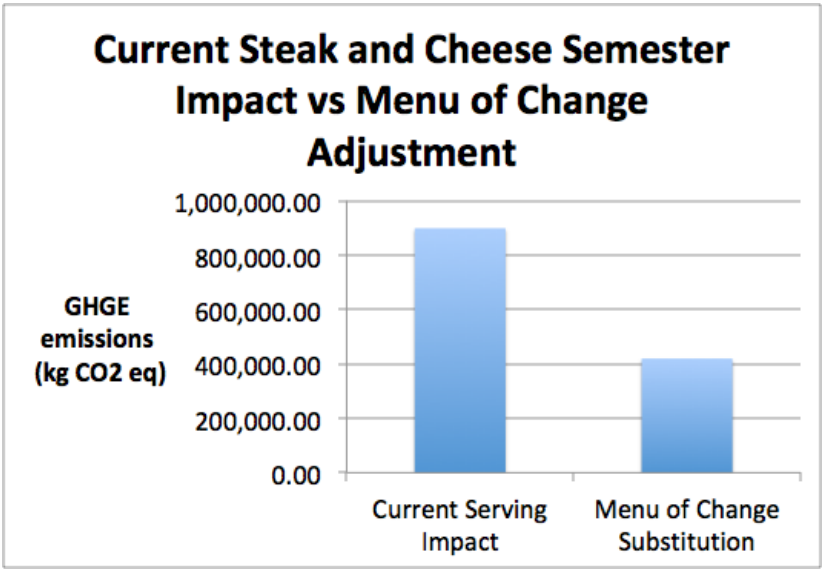

Figure 6. GHG emission equivalent comparison, kg CO2 eq, of impact based on serving the steak and cheese 4 times a week per lunch and 4-5 times a week for dinner vs. 2 times per lunch, 2 times per dinner.

Figure 6 illustrate the effectiveness of Menus of Change principle, "eating less red meat less often", as we tested what the potential semester impact could be if Lower were to only serve the Steak and Cheese, specifically, 4 times a week vs the current 9. This implementation has the potential to quadruple the reduction success of the 10% protein swap demonstrated in Fig. 5, as Boston College would cut GHGE by over 400,000 kg CO_2 (Figure 6).

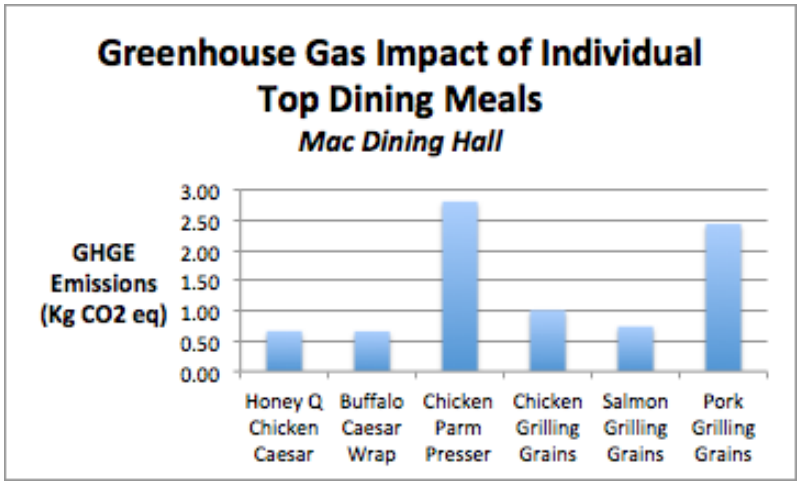

Figure 7. Greenhouse gas impact, kg CO_2-eq, of Individual Top Dining Meals at Mac: The Honey Q Chicken Caesar Wrap, Buffalo Caesar Wrap, Chicken Parm Presser, and The Grilling Grains (Chicken, Salmon, and Pork)

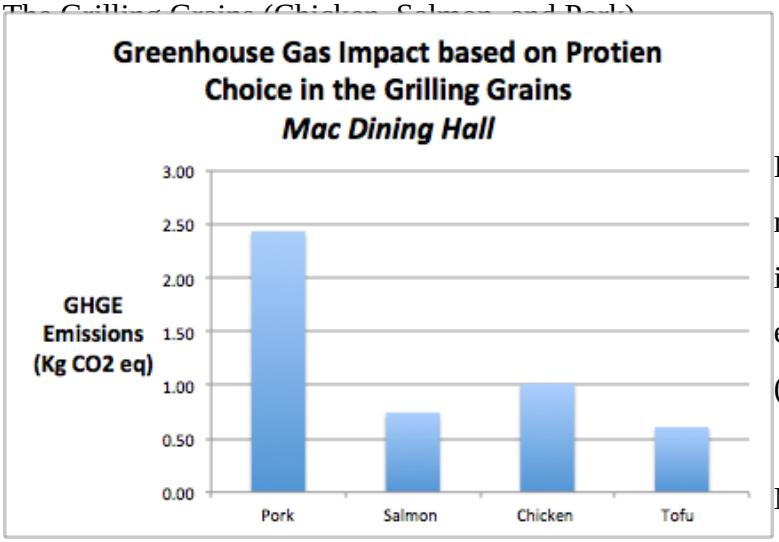

Figure 8. Grilling Grains Greenhouse gas impact, kg CO2-eq, based on protein choice. Tofu was added as an additional protein option for comparison.

Across campus at McElroy (Mac) there is not a beef recipe that tops the most eaten meal, however there is still evidence of disparity between the top meals in the dining hall. Figure 7 highlights the individual impacts of each meal, with the Chicken Parm Presser topping the list at over 2.81 kg CO_2 followed by the Pork Grilling Grains (2.44 kg CO_2), the Chicken grilling grains (1.01 kg CO_2), the Salmon grilling grain (0.74 kg CO_2). The Honey q and Buffalo Caesar wraps round out the choices, with the least impact both with greenhouse gas emissions calculated at 0.66 kg CO_2 (Figure 7).

The Grilling Grains station at Mac allows students to chose from different protein options to select from. Figure 8 quantifies the different impacts of each choice currently offered, Pork, Chicken and Salmon, as well as an additional tofu option to test how a plant based protein could change the emissions

per serving. Pork is the highest greenhouse gas contributor, and is equivalent to over twice the emissions that come from the chicken option, and triple that of the salmon option. If tofu was offered as a protein choice, it would equate to approximately .61 kg CO_2 per serving, 4 times less than the pork option of the same dish (Figure 8).

The CED results from Mac the individual meals at Mac shows that Pork, a ruminant meat, requires 12.47 MJ of energy input, followed closely by the farmed salmon option (11.01 MJ), both of which more than double the Chicken Grilling Grains, Buffalo Caesar and Honey Q Wrap which require 5.96 MJ, 4.54 MJ, 4.00 MJ, and 3.99 MJ respectively (Figure 9).

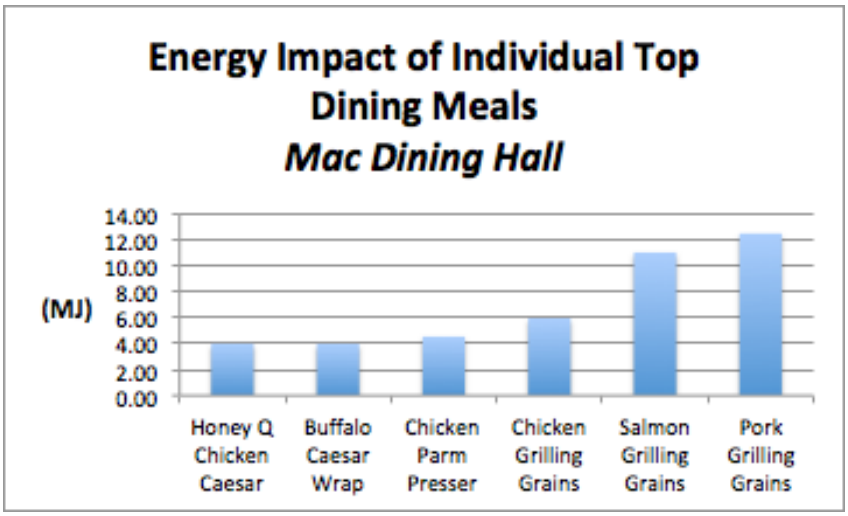

Figure 9. Cumulative Energy Demand (CED), *MJ*, of Individual Top Dining Meals at Mac Dining Hall: The Honey Q Chicken Caesar Wrap, Buffalo Caesar Wrap, Chicken Parm Presser, and The Grilling Grains (Chicken, Salmon, and Pork).

Similar to our proposal testing the potential for impact reduction in Fig. 5, 6, & 8, we explored the potential GHGE reduction of a plant based protein in substitute for the chicken in the recipe, and we again calculated through the compiled LCA data, that the footprint of an individual meal can be reduced by up to half if there is a swap for chicken, an animal protein, to tofu, a plant based protein (Figure 10). Interestingly, a "Tofu Parm Presser" would have over 3 times the emissions as the Honey Q and Buffalo original chicken wraps, and 7 times the emissions value of the Honey Q and Buffalo tofu alternatives. However, in all three recipes there was a .30 kg CO_2 reduction in each of the recipes with the proposed protein swap (Figure 10).

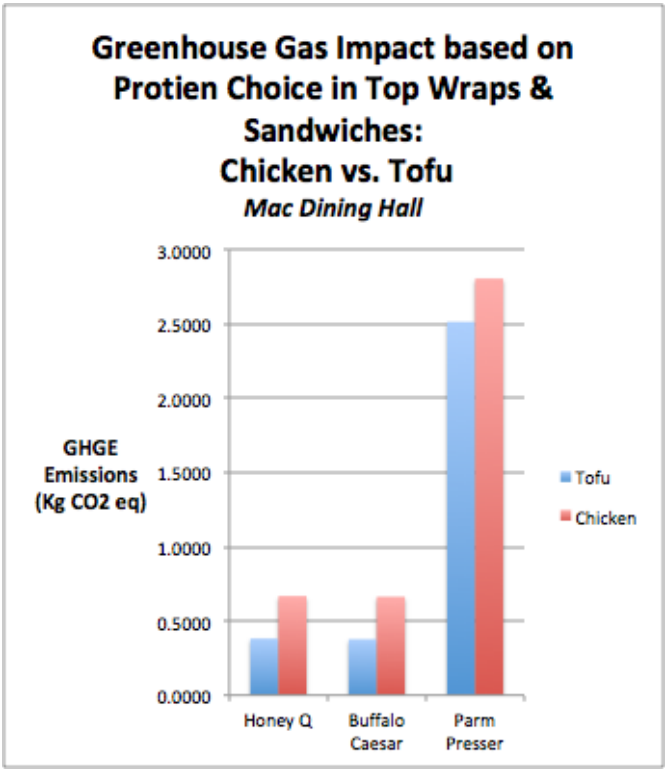

Figure 10. Greenhouse gas impact, kg CO_2-eq, based on the current recipe of menu items: The Honey Q Chicken Caesar Wrap, Buffalo Caesar Wrap, Chicken Parm Presser compared to potential GHGE if tofu were to be implemented as a protein flip in the recipe.

Overall our results demonstrate that ruminant meat, beef and pork, are consistently the highest emitting individual meals across both dining halls on campus, and there is also clear evidence that shows that adjustments to the serving frequency of red meat and plant based protein substitutions has a substantial reduction impact to greenhouse gas emissions.

Discussion

While our results do mimic the trends of previous LCA studies and meal impact assessment research, it is important to note that each of our calculated impact estimates are likely skewed. There is currently not a large body of research regarding the United States food system in terms of life cycle assessments, however it is something that is currently developing and will continue to develop. With that being said, some of our values may be off due to differing emission rates in different regions and or different practices in which are carried out to produce each ingredient. Furthermore, we know for sure that these estimates are not the entire emissions or energy demand, as they do not account for anything past retail, meaning we were not able to factor in any of the relevant emissions or energy demand related to any point in the supply chain after Boston College purchases. This would indicate that our estimates are actually less than what the actual footprint is and therefore that should be kept in mind when making any steps to reduce impact.

In the case of the Screaming Eagle sub, it is very likely that the impact is up to twice as much because many students choose the large sub with a double meat portion, however we were unable to get information on how often students are choosing regular over a large sub sandwich. With this in mind, the MOC principles of eating less red meat less often, leveraging plant forward menus, and centering legumes and nuts on the plate are that much more important; if the actual food footprint is higher than we have calculated based on the available data to us, then the reduction scenarios would need to be taken very seriously in order to enable tangible reductions in the overall impact.

For salad, on the other hand, it is likely that our calculation is an underestimate just based off of the fact that we had no way to accurately no portion size or ingredients that students are choosing each meal, and therefore our estimates are very rough based on the buying data which could also have ingredients that are popularly used within in the salad bar used elsewhere further leading to miscalculation. However it is important to remember that there is not many ingredients within the salad bar options that could increase the impact by a significant amount, and so the LCA established hierarchy of Low to High GHGE values remains present in our findings. It is without a doubt that beef is consistently contributing the highest emission value, followed by pork, salmon, chicken and tofu regarding protein source. Tofu is not the only plant forward option that could be tested as an alternative to ruminant and non ruminant meats, and there are many options that could be leveraged for both taste and sustainability with further research into what students might prefer.

Although we have calculated a semesters impact for Lower dining hall attributable to each meal, it is important to note that this sales data is not exact, as the Dining Halls do not have a reliable way of tracking actual meal sales, however due to the popularity of the meals, Steve was confident his estimates were in a ballpark range, and so we thought it could be impactful to see what a semester of screaming eagle subs means for the environment. It should be noticed that the steak and cheese is the highest emitting meal across campus, yet it is also the 2nd most popular by volume estimate, and so our research has demonstrated a very identifiable meal that changes could be made to. While we were unable to obtain sales quota for Mac, that is something that could very easily be done going forward and would be very useful in understanding how the individual impacts add up based on consumer demand. Estimates such as those Steve provided us with would

be helpful as preliminary exploration, however it would be ideal to have a better monitoring system in place that could electronically provide more accurate data.

While we did not directly measure what taking cheese out of a recipe might do, it is interesting to notice the disparity between our hypothetical tofu parm presser and the honey q and buffalo wraps, this is likely an indication that cheese is having a high impact that is pronounced in the absence of beef. Dairy is worth noting because although our results did not directly quantify values of dairy free meals, the literature suggest that moving away from dairy is also a viable way to reduce impact, and in a sandwich like the presser a swap from chicken to poultry does not actually make a large difference relative to the already higher emission total.

Continued research into the dining halls impact on the environment could be really impactful in creating small scale changes that have large scale ripple effects on the planet as we have demonstrated in the different reduction potentials of only a few of the many many possible solutions to creating a more sustainable diet. Further exploration into student preferences for sustainable choices, as well as more concrete data from dining hall transactions could be really beneficial in enhancing the initial goals of our project.

Recommendations

Based on this project we have compiled a list of recommendations that have potential to reduce Boston College dining impact, while this is not an exhaustive list, we hope that it may be helpful in creating a more sustainable diet in the interest of the planet.

1. Students at Boston should consider decreasing the total consumption of high GHGE meals such as the Steak and Cheese, and suggest that occasionally purchasing a Grateful Burger or Salad bar.
2. Boston College Dining should leverage Menus of Change Principles through:
    A. Reducing the serving quota of Screaming Eagle subs, specifically the Steak and Cheese option, from 9 meal periods a week to 4 meal period a week.
    B. Implementing a plant based protein alternative in all of the top recipes as an option for students, this does not have to be a tofu for meat swap, as there are many plant proteins that could be highlighted in the dining halls
3. Further research into additional meals at Boston College and their impacts, as perhaps there could be low emitting meals that students do like and the Dining services could amplify the low GHGE options in a presentable and enticing way.

4. The dining halls could additionally implement a label system, which would need further research, but could effectively communicate to students which meals are having the highest impacts so there is a greater awareness on campus.

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