USING CARBON AND NITROGEN FOOTPRINTS FOR SUSTAINABILITY INITIATIVES AT COLORADO COLLEGE

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Introduction

Since the industrial revolution, anthropogenic CO_2 and N_r emissions have drastically added to the amount of greenhouse gases (GHG) in the environment (Galloway et al., 2014; Vitousek et al., 1997). The urgency to minimize the effects of anthropogenic-caused climate change is a priority for scientists and countries around the world, as today's GHG emissions will alter the atmospheric concentrations for centuries. This scientific consensus is the basis for initiatives at multiple scales, from international climate commitments (e.g. the Paris Agreement) and regional market-based efforts to reduce GHG emissions (e.g. Regional Greenhouse Initiative) to corporate commitments to reduce emissions as part of larger sustainability efforts (Dyllick & Hockerts, 2002). To this end, 600 American universities have taken the initiative to reduce their GHG emissions by signing the American College and University Presidents' Climate Commitment (ACUPCC), established in 2006 (Second Nature). In 2007, when universities were invited to sign the commitment, Colorado College students urged President Celeste (2002-2011) to sign the ACUPCC, committing to carbon neutrality by of 2020. The Campus Sustainability Council drafted the Colorado College Sustainability Plan (CCSP) to provide President Celeste with more information on the Climate Commitment. The Colorado College Board of Trustees approved signing in 2009, with the goal of "eliminating greenhouse gas emissions by 2020" (Colorado College, 2013).

Colorado College has shaped its sustainability initiatives with the intention of reaching this goal. The College has calculated the GHG emissions and the carbon footprint since 2006; however, nitrogen footprints have yet to reach this kind of popularity. Perhaps it is because carbon emissions are more visible to the public (i.e. burning fossil fuels and transportation) than nitrogen emissions, which are largely in the food production sector (Heller & Keoleian, 2015). Because of nitrogen's ability to move through different parts of the environment, N has lasting effects on various parts of the environment: N_r can be stored or transferred with the terrestrial and aquatic environments, and also converted into NO_x, which contributes to both acid deposition and the formation of tropospheric ozone (Galloway et al., 2003).

In addition, the N footprint has significant benefits to institutions because it is a more holistic view of campus activities. Specifically, the N footprint includes Scope 3 emissions, something that is largely left out of campus C footprints. Scope 1 emissions are direct (on-campus) emissions, Scope 2 emissions are indirect (purchased electricity) emissions, and Scope 3 emissions include indirect emissions associated with campus activities and purchasing (waste, paper, air and car transportation, and food). CC's N footprint uses the beta-test stage of the tool; this research establishes the first N footprint for the College. I calculated the N footprint with the hope that the CC Sustainability Office could utilize both elemental footprints to influence and direct sustainability initiatives, focusing on the most GHG emissions-reducing and cost-effective options possible, including the 2020 C Neutrality goal. For Colorado College, the most effective initiative is to enter in to the wind power purchase agreement (PPA), followed by changes in food purchasing. Using the carbon and nitrogen footprints together is the most effective way for a university to produce and implement strategic sustainability initiatives.

Methods

I calculated Colorado College's Nitrogen Footprint using the Nitrogen Footprint Tool (Leach et al., 2013). To calculate a campus' N Footprint, the Nitrogen Footprint Tool (NFT) examines institutional activities ranging from energy and food consumption to commuting and recycling patterns. The NFT is an Excel Macro document that is in the beta-testing stage (N-Print, 2011), with plans to be a web-based interface hosted by the University of New Hampshire's Sustainability Institute, by the end of 2017 (Jenn Andrews, personal communication).

Production of reactive N (N_r) resulting from institutional activities has previously been overlooked, likely due to the scientific and social focus on C. This is especially true at institutions of higher education, where the C footprint has been the benchmark for sustainability initiatives. The NFT allows institutions to calculate the N footprint associated with their activities, including utilities, transportation, and food. Food production is the largest input to the N footprint. Other inputs to the N footprint include purchased electricity, transportation (commercial and college-owned vehicles), food consumption, and fertilizer. Data regarding all other N footprint inputs besides food production did not have to be calculated as the Sustainability Office and other College departments provided it.

To calculate the N_r associated with food purchasing on CC's campus, I obtained four weeks of itemized receipts from Bon Appetit, CC's food service provider. In order to account for the differences in seasonal purchasing, the four weeks encompassed two weeks from October 2014 and two from February 2015 that did not have large, on-campus events (e.g. Homecoming). I extracted the following information from the receipts: food's name, amount, weight units, and subsequently classified food into categories. Categories include: beverages, cereals, dairy & eggs, fruits, meat, nuts, oil crops, pulses, spices, starchy roots, stimulants, sugar crops, and vegetables. In some instances, weights are given on the receipt, but in many instances there are simply counts or number of cases. In the latter situations, I used Google to find the average weight of one egg to figure out the total weight of 45 dozen eggs. For the 'mixed ingredient' foods, which have a combination of ingredients from different food categories, I divided the total weight of the food evenly between the top two categories (e.g. strawberry yogurt is divided between dairy and fruit categories). To calculate Colorado College's 'foodprint' for the year, I calculated the average weekly purchases for each category and scaled up to a year. Given fluctuations in the population Bon Appetit serves, I estimated the number of calendar days in which 1) school is in session with a full student body and 2) the fraction of that number served during Summer Session. This results in a multiplier of 35.25 weeks of food service (Table 1).

Blocks	Weeks	Student Population	Block-Week-%Pop
8 Blocks	3.5 weeks	100%	8 x 3.5 x 1=28
8 Block Breaks	0.5 weeks	25%	8 x 0.5 x .25=1
1 Half Block	2 weeks	50%	1 x 2 x .50=1
Summer Session*	10.5 weeks	50%	10.5 x 0.5=5.25

TABLE 1: The calculations of a "CC year": multiplying the number of blocks, weeks in a block, and percentage student population on campus to get an estimate of the population served by the dining halls. *The Summer Session calculation accounts for the population on campus from: A&B Blocks, Summer Session Conferences, Bridge Program, International Orientation, NSO, etc.

The food scenarios include Business As Usual (BAU) and changing the percentages of purchased protein (Figure 1). BAU assumes the same food purchasing and no growth in the campus community; however, the emissions from the College's recent purchase of the Colorado Springs Fine Arts Center will be included and will increase CC's future footprints. I modeled the food scenarios by subtracting a percentage of the total kg of a protein to add to another protein/food source, i.e. replacing 10% of bovine with chicken (Figure 1). The scenarios are also assessed based on the feasibility of implementation, based on the stakeholders (defined here as anyone who would support the initiative, regardless if they are ultimately making said decision) in relation to the sustainability initiatives (Table 2).

In addition to the N contained in the food purchased, the NFT incorporates a Virtual Nitrogen Factor (VNF) that examines the entire food production lifecycle: fertilizer use, processing, and transportation (Leach et al., 2013). The VNF is the kg N lost/kg N consumed in a food product. The NFT calculates the total N released by multiplying the weight of food by per mile rate, and a production rate. The VNFs were used with the Real Food Challenge categories for other food scenarios.

'Real' Food is defined as "a common ground where all relevant issues from human rights to environmental sustainability can converge" (Real Food Challenge, 2016). The Real Food Challenge (RFC) describes the four categories in which food is considered real: local and community based, fair, ecologically sound, and humane. In order to be qualified as 'Real Food', the farms had to meet a national standard, such as the USDA Organic Standard, Fair-trade International Certified, and/or the Monterey Bay Aquarium Seafood Watch Guide "Best Choices", as well as a list of certifications regarding ownership, distance, ethical treatment, and organic growing (Real Food Challenge, 2016).

Ecological food is defined as farms and operations that focus on environmental stewardship and minimizing harm in the production of their food. Local food was also assessed in the food production category. Local food is defined as supporting locally owned and operated farms and businesses that are less than 250 miles (food products) or 500 miles (meat) away from the College (Real Food Challenge, 2016). Colorado College's Sustainability Office calculated two months of receipts to find out how much 'real food' was purchased. Colorado College achieved 22% Real Food without becoming a signatory (Ian Johnson, personal communication; Real Food Challenge, 2016).

To calculate virtual N estimates in accordance with the Real Food Challenge standards (Real Food Challenge, 2016) in the NFT, I altered the VNF and food miles associated with food that was ecological, local, and both ecological and local. If the food was classified as ecological, the sustainable VNF was used, and if it was deemed neither ecological nor local food (i.e. conventional food with some organic purchases and standard food miles) the default virtual N values (kg N lost/kg N consumed) were used (Table 3).

In the NFT, two options are given to change the food miles of the product: standard and sustainable ("local") miles. For local food only, the number of food miles was decreased to a maximum of 100 miles, reducing the virtual N associated with transport. In instances where the food purchased was ecologically produced and local, both virtual N factors shifted accordingly (Table 3). These VNF options were used to calculate possible scenarios in accordance with the Real Food Challenge standards, as well as to calculate our current footprint. Using these definitions and the data collected by the Sustainability Office as a guide, I quantified the VNF and food miles of the products. Other RFC standards, such as buying humane and fair-trade foods, are assumed to have no impact on the nitrogen or carbon footprint, so these designations were not included in the elemental footprint calculations.

To calculate the CO_2-e footprint, referred to in this paper as the Carbon (C) footprint, the Sustainability Office interns entered information into the CarbonMAP inventory. CarbonMAP also began as an Excel Macro document, and now it is an online resource that allows graphic and statistical comparison between the years. The calculator has sections for institutional statistics (student population and annual budget) and sections for scopes 1, 2, and 3 emissions. A scope 1 emission encompasses on-campus stationary sources: propane, natural gas, solar, diesel fuel, gasoline, Zamboni propane, and fertilizer. All on-campus fuel usage is accounted for (100% confidence), except for the propane usage and solar generation (~25-30% confidence). Scope 2 emissions are the purchased electricity for Colorado College's campus and the Baca campus (Crestone, CO).[1] Scope 3 emissions include faculty and staff commuting, university sponsored air

[1] As of 2015, the Baca campus has a 35 kW solar array included in their energy profile, eliminating the need to use energy from the grid (Colorado College Baca Campus).
[2] Colorado College spent $1,156,894 on purchased electricity in fiscal year 2016 (Ferguson, 2016).

and car travel, study abroad, solid waste, wastewater, office paper, and any purchased Renewable Energy Credits (RECs). The faculty and staff commuting, car travel, and study abroad all have low confidence factors because the data is based on estimates/averages of miles traveled, destinations, fuel prices, and the fuel efficiency of vehicles.

Food is currently excluded from CC's carbon footprint, as it is a Scope 3 emission and therefore not required in annual reporting. I calculated the carbon footprint of food to have similar categories to the nitrogen footprint for easier comparison for utilization in CC's sustainability initiatives (Figure 2). To calculate the carbon footprint of food, I consulted with Allison Leach and used CO_2-e emissions per kg of food factors from Heller & Keoleian (2015). The ranges of the kg CO_2 eq/kg of certain foods are between 0.06-2.8 kg CO_2 eq/kg (grains, fruits, nuts, some vegetables), 0-9.74 kg CO_2 eq/kg (dairy and eggs), and 1.8-41.8 kg CO_2 eq/kg (meat). I used the average greenhouse gas emissions (kg CO_2 eq/kg) for each food category (Table 4), then multiplied by the kg of food in each category to calculate our food production carbon emissions. Since some categories have wide ranges of emissions factors (e.g. fresh vegetables emit between 0.08 and 13.49 of CO_2 eq/kg, depending on the type of produce), the carbon footprint of food should be seen as an estimate, not an exact calculation. In Heller & Keoleian (2015), beverages, spices, stimulants and sugar crops did not have kg CO_2 eq/kg factors and therefore were excluded from the C to N comparison of the food footprints (Figure 2, Figure 3).

I calculated the N and C savings associated with current and proposed campus sustainability initiatives. The various initiatives were chosen in consultation with Ian Johnson, Director of Sustainability at Colorado College. I chose to examine four scenarios; most of them focused on reducing our dependence on fossil fuels and shifting food purchasing, and estimated the footprint reduction for each element (Figure 1). For the food scenarios, I took a percentage from the total kg in one meat category and added it to the other meat/vegetable category to calculate the shifts in purchasing protein. For the wind PPA scenario, I kept the current kWh for electricity, and changed the category to renewables in the NFT to demonstrate the reduction in emissions. A 25% waste reduction was calculated by subtracting 25% of the current kg in the food consumption.

Results

Colorado College releases 58 MT N/year based on FY 2015 data (Figure 4). Food production (51.6%) and purchased utilities (32.1%) are the two largest contributors, followed by food consumption, fertilizer, and transportation. Meat (47%) and dairy/eggs (32%) purchasing are the two largest contributors to the food production category (Figure 5).

Colorado College's C footprint is 27,549 MT C/year, (25,611.3 MT without food), and uses similar metrics as the N footprint, based on FY 2015 data (Figure 6). The largest contributors to the carbon footprint were utilities usage (70.8%) and transportation (19.9%), with food production and waste making up the remaining 9.3%. Similar to the N footprint, the largest contributors in the food production category are meat (52%) and dairy/eggs (32%) (Figure 7).

Of the scenarios proposed by the Sustainability Office, all in an effort to reach C neutrality by 2020, changing the utilities from coal to a renewable energy source (specifically the wind PPA) will create the largest reduction on both the C and N footprints (Figure 8). Further decreases in C and N associated with energy usage will come from the completion of the C neutral library in Fall 2017 (currently under construction), reducing CC's heating and electricity costs by 6% (Ian Johnson, personal communication).

For food, the most effective means of reducing the N footprint is by replacing 20% of bovine with chicken (1.3% reduction compared to BAU), and/or purchasing all ecological food (22% reduction of footprint, or 7 MT N/yr less than BAU). The comparable N footprint (Figure 3) is 8.9% smaller than the total N food footprint, which includes beverages, spices, stimulants and sugar crops, and is grouped into larger food categories for simplification (Figure 5).

It is important to note that there is uncertainty in the data. The greenhouse gas inventory calculator includes a sliding scale for accuracy of each data input, or confidence factor. Confidence in the data varies from high confidence (utilities, electric bills) to low confidence (commuting miles, based on surveys). There is also variability between the weeks of food data for the C and N footprints, as different seasons of the year have a variety of produce available and the food calculations are based on a few weeks of data.

Discussion

This research demonstrates how the nitrogen and carbon footprint tools can be used together to identify and prioritize sustainability initiatives at the university level. As food and energy demands continue to increase, it is important for the College to establish baseline footprints and begin working towards emissions reductions (Galloway et al., 2014). Footprints are useful in understanding the impact of human activities and operations on the environment, and aid in quantitative data for sustainability initiatives (Čuček et al., 2012). The easiest and most effective way to address CO_2 and NO_x emissions is to utilize alternative fuel and energy sources (Galloway et al., 2003). To reduce the emissions from food production, individuals must take initiative to change their behaviors away from purchasing food with large GHG footprints to those with fewer associated emissions (Heller & Keoleian, 2015).

When assessing the feasibility of campus sustainability initiatives at Colorado College (Table 2), the largest single impact Colorado College could have on its nitrogen and carbon footprints would be to enter into a wind PPA. Colorado College, including the soon-to-be merged Colorado Springs Fine Arts Center, would need approximately 8 MW of generation, or 16,0000 MWh, to operate annually, and Colorado Springs Utilities is currently accepting proposals for a large-scale wind farm near Limon, Colorado (Ian Johnson, personal communication). The wind PPA (final bid pending) is estimated to cost approximately \$20/MWh beyond current electric rates. To provide energy for the current demand of 15,000 MWh annually, with a fixed rate for twenty to twenty five years, the estimated cost for a wind PPA is an additional \$300,000 annually[2] (Mark Ferguson, personal communication).

Further, the cost of electricity per MWh will not increase over time, in contrast the current fossil fuel source of electricity increases +2-10%/MWh/yr (Ian Johnson, personal communication). Entering into the wind PPA demonstrates our commitment to

[2] Colorado College spent \$1,156,894 on purchased electricity in fiscal year 2016 (Ferguson, 2016).

sustainability as a college, and is the path of least resistance to lowering the footprints and completing CC's 2020 Carbon Neutrality goal (and other current sustainability initiatives). Entering into the PPA would reduce the nitrogen footprint by 32.1% (19 MT), and the carbon footprint by 46.6% (13,000 MT).

After energy, addressing food purchasing is the next most effective option for reducing the nitrogen and carbon footprints for the campus. At Colorado College, food production is the largest contributor (51.6%) to the nitrogen footprint and a relatively small (5.7%) part of the carbon footprint. Although food is the largest sector in the N footprint, reducing the food footprint is more difficult considering the stakeholders' preferences, students' high demand for protein on campus, and the cost/difficulty of sourcing 100% ecological food to Colorado College's campus (Figure 8). Changes in diet rely on the willingness of consumers to change their behaviors away from intensive animal protein, towards more sustainable proteins (Heller & Keoleian, 2015).

Once a week, dinner at Rastall (the all-you-can-eat dining hall on campus) does not serve meat for Meatless Monday. However, sales at Benji's and the Preserve (the two dining halls that are pay per item), nearly double in profits on Monday nights and both serve meat (Randy Kruse, personal communication). This suggests that there is little interest in increased vegetarian options and/or some level of resistance to participating in Meatless Monday. Despite the student body's preferences, changing diets and nutritional guidelines to include less meat has a large impact on all greenhouse gas emissions, lowers the demand for energy, and allows possibilities of renewable energy such as biofuels (Fazeni & Steinmüller, 2011). Decreasing the amount of meat purchased could significantly reduce the college's C and N footprints. Bovine alone represents 4% of the retail food sales, 36% of the GHG food emissions nationwide (Heller & Keoleian, 2015), and 17-32% of global GHG emissions for the lifecycle of the food (i.e. farm operations, fertilizer) (Bellarby et al., 2008). Changes in food purchasing at CC, such as replacing 20% bovine with chicken, or replacing 10% of bovine with vegetables, are feasible in implementation, but the student disapproval and/or pushback could be significant.

The ecological VNF and local food miles (Table 3) from the NFT demonstrate the variability that occurs among foods in the amount of virtual N per kg of food, as well as the differences between conventional farming and sustainable/local foods. The N savings in purchasing all ecological on the food footprint (23.3%) and overall (12%), or purchasing all local food on the food footprint and overall (0.1%, 0.1%) (Figure 8) were not significant enough to list changes in food purchasing as the first priority. Red meat is more GHG-intensive than chicken or fish, and if dietary shifts were made towards less intensive meats, the average household's footprint would be reduced more than if the household only bought local food (Weber & Matthews, 2008). Aspects of the RFC criteria, such as buying local, humane, or fair trade foods, have other positive impacts on local economies and communities, but do not alter the N or C footprint enough to justify shifting purchasing patterns based on footprint calculations.

The College's recent purchase of the Colorado Springs Fine Arts Center (CSFAC) will have tremendous educational benefits, for the art department and for the College as a whole. However, the purchase of the Fine Arts Center also adds to our emissions footprints, and will likely counteract the library's carbon savings and other the improvements in sustainability over the last five years. The addition of the Fine Arts Center adds 3 acres to Colorado College's total land footprint (90 acres) (Colorado Springs Fine Arts Center; Colorado College, 2016). To demonstrate our commitments to sustainability as a College, one way to reduce the emissions of the CSFAC would be to serve the most sustainable food possible in their cafeteria, as that will be more feasible given size and age of the center than upgrading the building operations to reduce energy use. This commitment to sustainability would be the most visible at the CSFAC, and would demonstrate the multi-faceted education at CC.

The food consumption and production categories in CC's N footprint include wastewater and human waste (Figure 4). The wastewater footprint for N is larger than for C because it includes both the fluvial wastewater discharges (nitrate and ammonium) and the NO_x (NO, N_2O) emissions, while the C footprint only includes the greenhouse gas (N_2O) produced during treatment. Colorado College's wastewater goes to a secondary treatment system, thus the best way to reduce this piece of N footprint would be for Colorado Springs Utilities to switch to tertiary (biological nutrient reduction) treatment. The C footprint's waste category also includes solid waste (3.9 %, Figure 6).

Further scenarios regarding fertilizer and transportation were discussed but not calculated. The landscape and grounds crew at CC has tested the various fertilizer combinations, and the minimum amount of fertilizer that can be used on campus to maintain a D1 soccer field, recreational quads, as well as to preserve the campus aesthetic is applied (Josh Ortiz, personal communication). The fertilizer usage would only change if there was a strong desire for native landscaping, not recreational quads (which would be unlikely as they are highly used). Transportation could be reduced in a few ways. First, if CC limited the number of field trips each department takes, fleet vehicle emissions could be reduced. However, as an educational institution with the Block Plan[3], field trips are an integral part of all courses. Second, air travel for athletic teams and admissions could be reduced, but most of these trips are necessary because of CC's distance from other DIII colleges, and for recruiting potential students.

Conclusion

In order for Colorado College to reach the 2020 C Neutrality goal, achieve a higher STARS rating as a College, and become a leading liberal arts college in environmental sustainability, steps towards institutional sustainability must be taken as soon as possible to reach or become as close as possible to our climate commitment. Using the footprint tools together ensures Colorado College can measure the amount of resources currently used, establish baseline footprints for released emissions, and utilize these footprints to evaluate the initiatives. There are still improvements to be made on the footprint tools for a comprehensive footprint to include environmental, social, and economic aspects of sustainability (Čuček et al., 2012).

With the data from the C and N footprints, the sustainability solutions can be modeled to address affordability and effectiveness in achieving these goals. Neither footprint encompasses all emissions on campus; however, the N footprint has a more definite picture of the lifecycle of CC's activities because it includes Scope 3 emissions. Additionally, the footprints do not capture the educational, social, and economic benefits that are present with other sustainability initiatives, such as the RFC, Recyclemania, and other campaigns. AASHE STARS criteria captures many of the non-environmental

[3] More information on the benefits of Colorado College's Block Plan: https://www.coloradocollege.edu/basics/blockplan/

benefits to the initiatives from changes in food and utilities, and will also improve our STARS score as an institution (Barnes et al., 2016).

The College has a responsibility to act in ways to mitigate implicit harm on the surrounding Colorado Springs community or the global environment. There are incredible social and environmental benefits for taking action as an institution, and Colorado College must enter into the wind PPA and address food purchasing to ensure the success and longevity of the College and environment.

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Tables

		Initiative			
		20% Beef Replaced with Chicken	10% Beef Replaced with Vegetables	Wind PPA	25% Waste Reduction
COST		$/$+ Ⓟ	$/$+ Ⓟ	$$ ⓅⓅⓅ	$/$+ ⓅⓅⓅ
Stakeholders	Students				
	Board of Trustees	n/a	n/a	*	n/a
	Bon Appetit, Sodexo (Contractors)			n/a	
	Sustainability Office & Facilities	n/a	n/a	*	n/a

Key: Red: high/many institutional barriers
Yellow: medium/some institutional barriers
Green: low/few institutional barriers
Ⓟ: low 'people hours' cost
ⓅⓅ:medium 'people hours' cost, collaboration with multiple groups within CC or companies outside of CC
ⓅⓅⓅ: high 'people hours' cost, requires collaboration with multiple groups or companies, or many individuals

$/$+:low cost, potentially cost saving
$$: mid-range cost
$$$: high cost

*Assuming the cost estimate remains the same when the final cost is released this December, this is initiative is green as the stakeholders: the Sustainability Office and Facilities would not have to seek the Board of Trustee's approval. The stakeholders would only have to build the wind PPA into their budget.

Table 2: Sustainability initiatives, and possible stakeholders in implementation of initiatives, as discussed with Ian Johnson, Director of Sustainability Office. The colors: Red, Yellow, Green, and n/a represent the feasibility of implementation in each sector. The cost of implementation is assessed on monetary cost ($+-$$$) and people-hours cost (Ⓟ- ⓅⓅⓅ), influence the color of the box in the matrix.

Food Category		VNF: (kg N lost/kg N consumed)		Food Miles	
		Conventional & Organic VNF	Sustainable VNF **(RFC Ecological)**	Standard Food Miles	Sustainable Food Miles **(RFC Local)**
Meat	Bovine	6.9	4.8	950	100
	Pigmeat	3.8	2.9	950	100
	Poultry	2.7	2.1	950	100
Dairy & Eggs	Cheese	3.6	2.6	65	65
	Eggs	3.8	2.9	65	65
	Milk	3.6	2.6	65	65
Seafood	Fish	2.4	1.9	950	100
Vegetable Products	Beverages	7.7	5.6	800	100
	Cereals	0.6	0.5	1350	100
	Fruit	7.7	5.6	1500	100
	Nuts	0.4	0.3	1500	100
	Oilcrops	7.7	5.6	800	100
	Pulses	0.4	0.3	1500	100
	Spices	7.7	5.6	800	100
	Starchy Root	0.8	0.7	1500	100
	Stimulants	7.7	5.6	800	100
	Sugar crops	7.7	5.6	800	100
	Vegetables	7.7	5.6	1500	100

Table 3: VNF and Food Miles options to model the standard VNF and food miles, and sustainable VNF and food miles, which were used in conjunction with the Real Food Challenge (RFC) standards for Ecological and Local food in the N footprint calculator.

Food	New CF (kg CO_2 eq/kg product)	Mass kg of food/year	Total kg CO2 eq/year
Chicken	5.05	44838.43	226434.07
Beef	26.45	26146.24	691568.05
Pork	6.87	14661.61	100725.26
Starchy Roots	0.21	30138.11	6329
Soybeans	0.78	36781.43	28689.52
Wheat & Rice	0.58	128861.6	74739.73
Vegetables	0.73	167714.6	122431.66
Fruits	0.364	126481.6	46039.3
Milk	1.34	226811	303926.74
Fish	3.83	3002	11497.66
Nuts	1.17	3550.06	4153.57
Oil	1.63	21055.48	34320.43
Eggs	3.54	23181.76	82063.43
Cheese	9.78	20943.3	204825.47
Total			1937.7 MT

Table 4: The kg CO_2 eq /kg food. The average CO_2 eq per kg of food product data from Heller & Keoleian (2015) was multiplied by the mass per food category per year to calculate the C footprint for food.

Figures

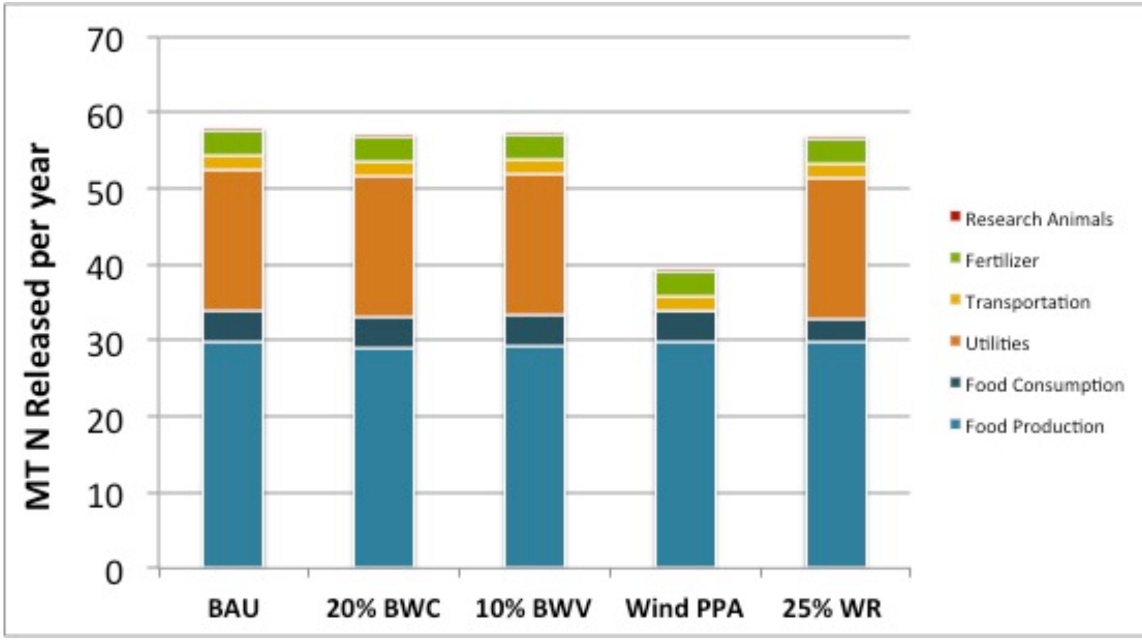

Figure 1: The suggested scenarios to reduce the N footprint. Business as usual (BAU); 20% reduction in bovine purchasing replaced by chicken (20% BWC); 10% reduction of bovine purchasing replaced by vegetables (10% BWV); wind purchase power agreement (PPA); 25% waste reduction (25% WR). The wind PPA has the most impact, with a 32.1% reduction in the N footprint and 53.4% in the C footprint.

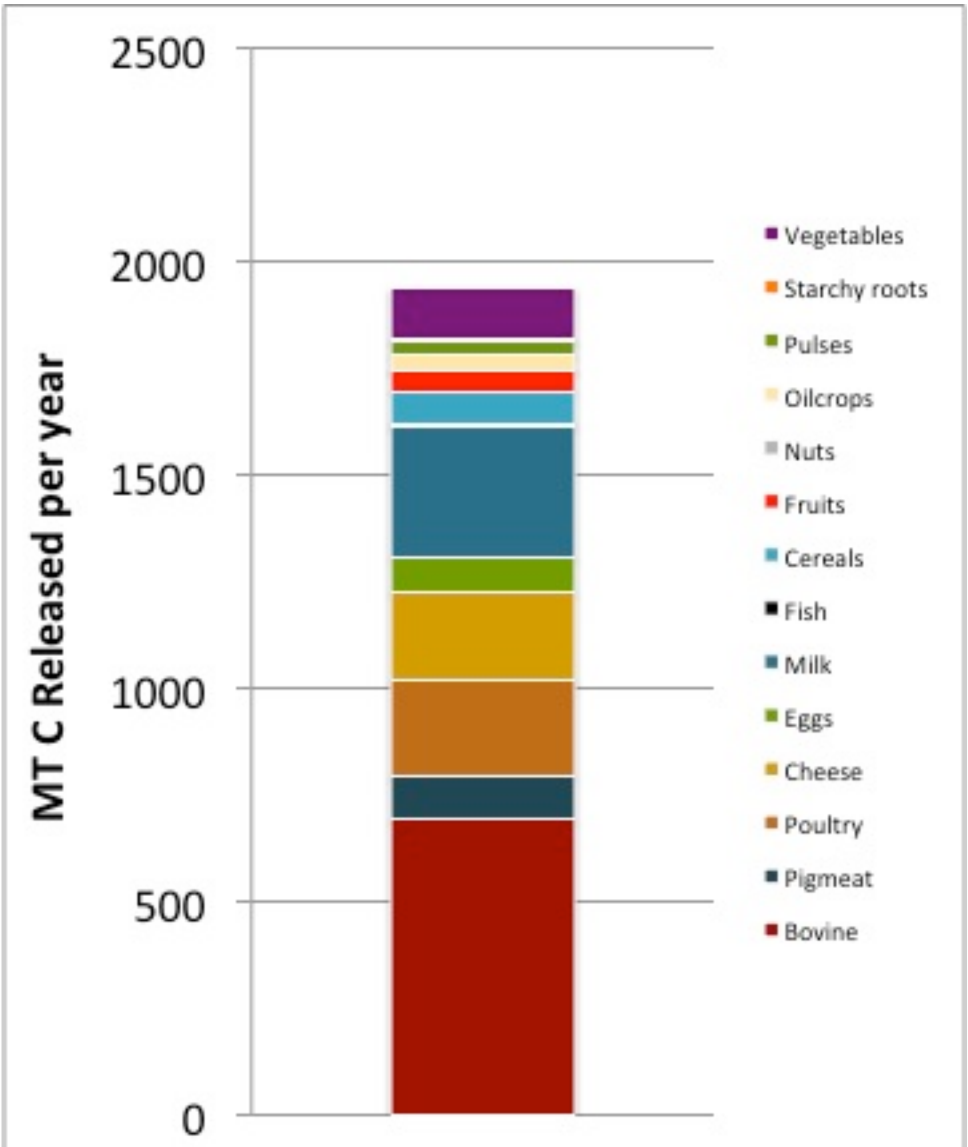

Figure 2: The breakdown of food production for the carbon footprint in kg CO_2 eq/kg food/year. Beverages, spices, stimulants, and sugar crops are not included in the carbon food equivalents. Meat, dairy, and eggs represent 83.6% of the footprint.

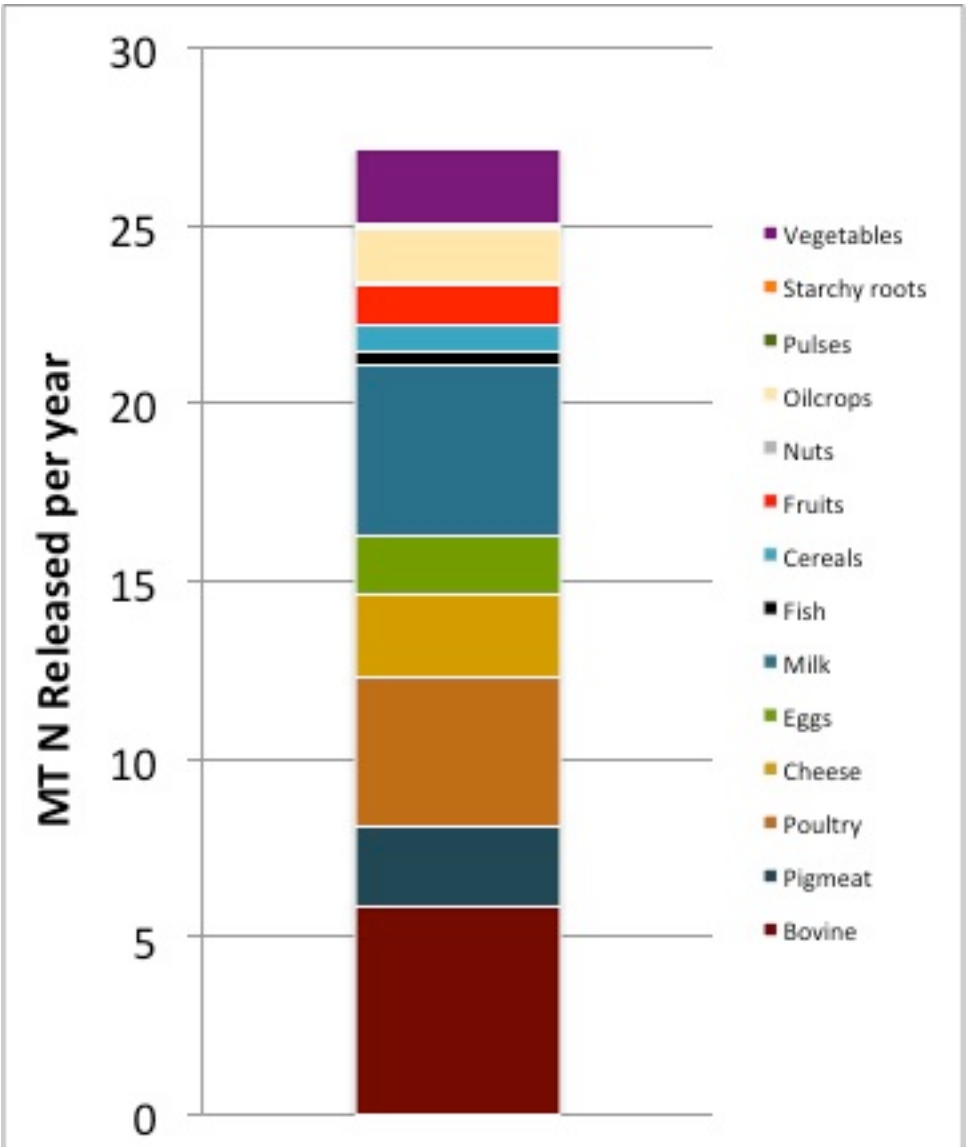

Figure 3: The food production categories for CC in MT N released/year. Meat, dairy & eggs (79%) are the largest contributors in the food production category. The carbon equivalents for food do not include beverages, spices, stimulants, or sugar crops; therefore, these categories were left out in order to have comparable metrics between the N and C footprints.

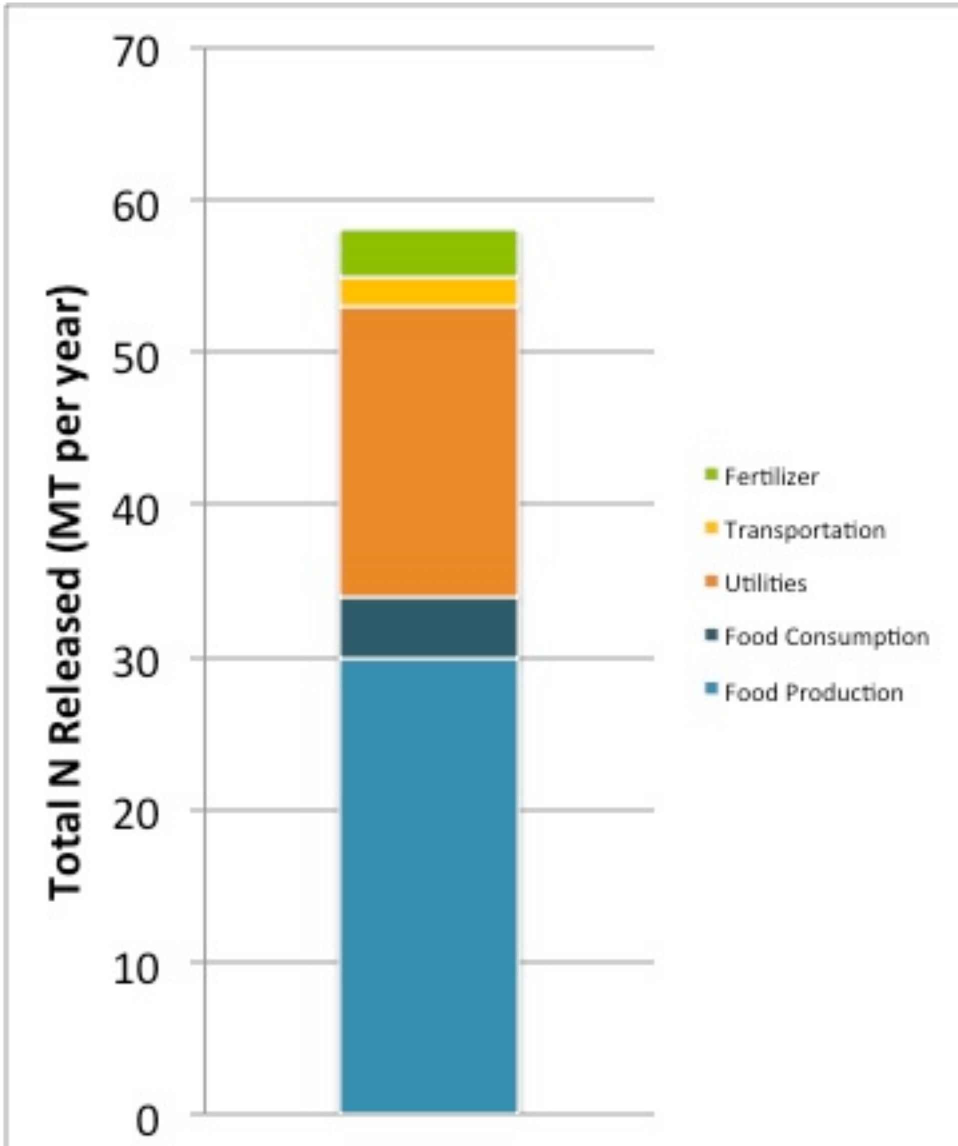

Figure 4: The Nitrogen footprint for Colorado College, as the total MT N per year for the following categories: Food Production (51.6%), Food Consumption, Utilities: heating and electricity, Transportation: fleet vehicles, commercial vehicles, & air travel, and Fertilizer on campus' green space. This does not include research animals or agriculture (less than 0.02% and n/a).

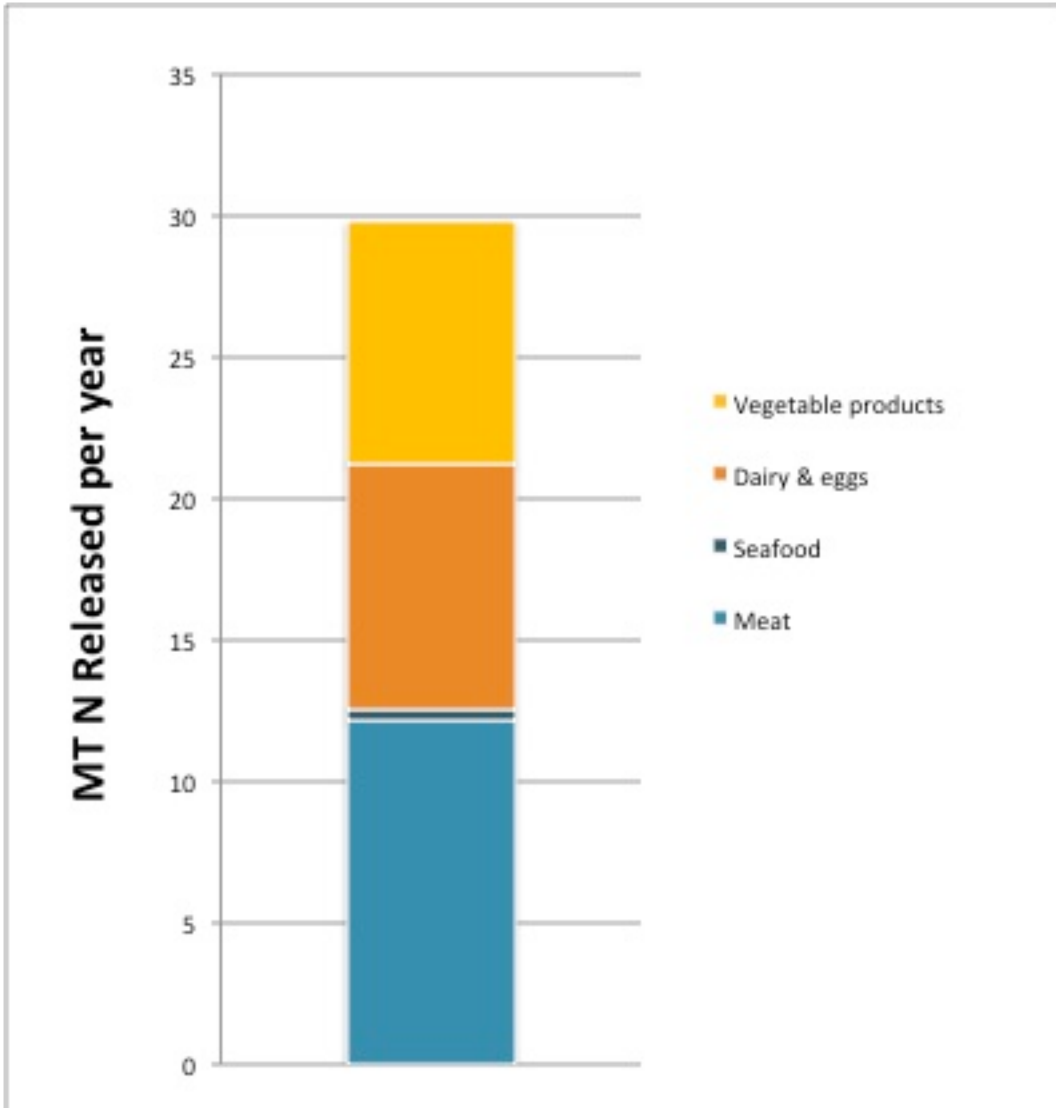

Figure 5: The food production for the N footprint in MT N released per year in four broader categories: meat, dairy &eggs, seafood, and vegetable products. This is food from Figure 3 plus beverages, spices, stimulants, or sugar crops to give the most accurate representation of the N released from food in the N footprint.

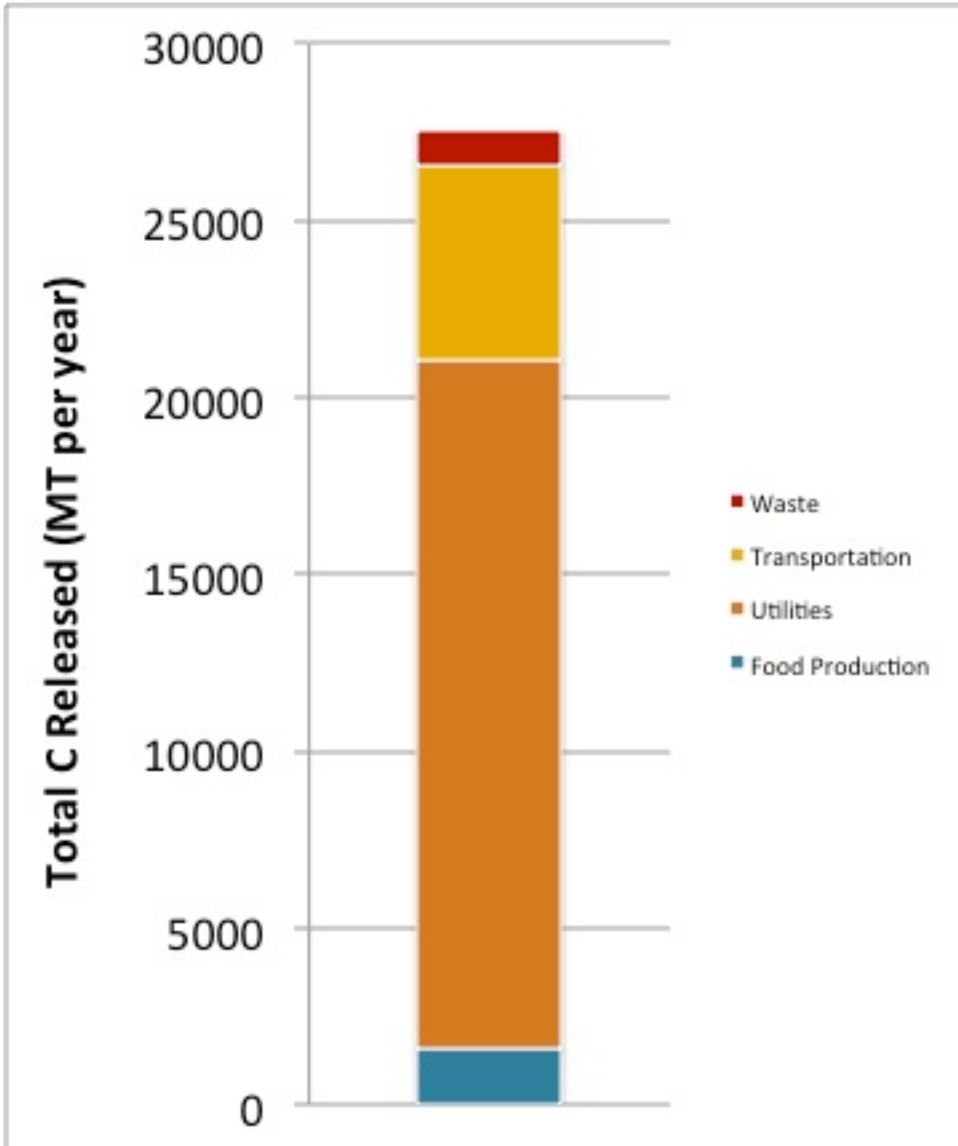

Figure 6: The Carbon footprint for MT C released annually from the following categories: Food Production, Food Consumption/Waste: solid waste & wastewater, Utilities (70.8%): stationary combustion, fugitive emissions, & purchased electricity, transportation: mobile combustion, commuting, other directly financed travel, & air travel. Fertilizer is not included in the Carbon footprint.

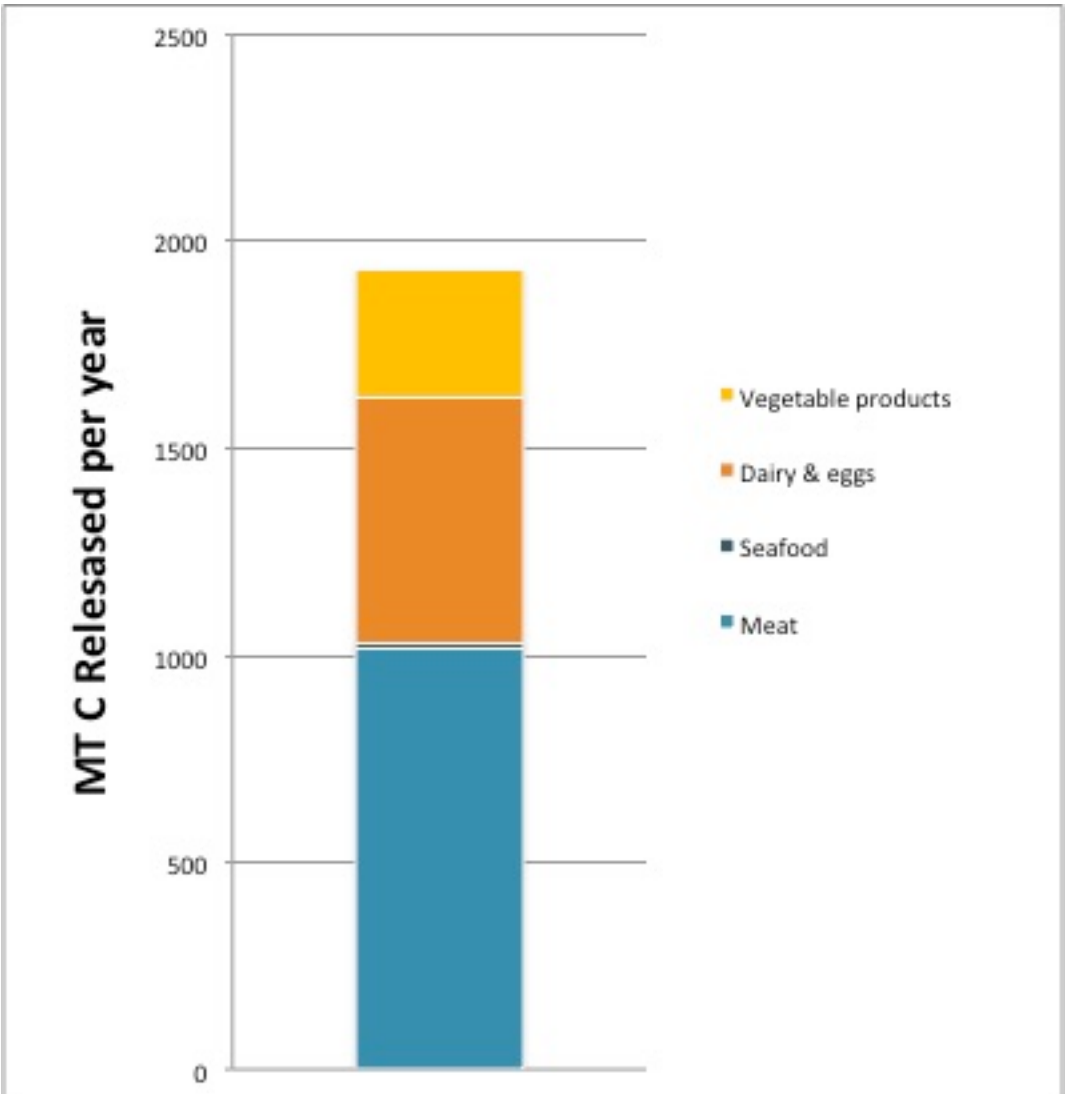

Figure 7: The food production for the C footprint in MT C released per year in four broader categories: meat, dairy &eggs, seafood, and vegetable products, for comparison with Figure 5.

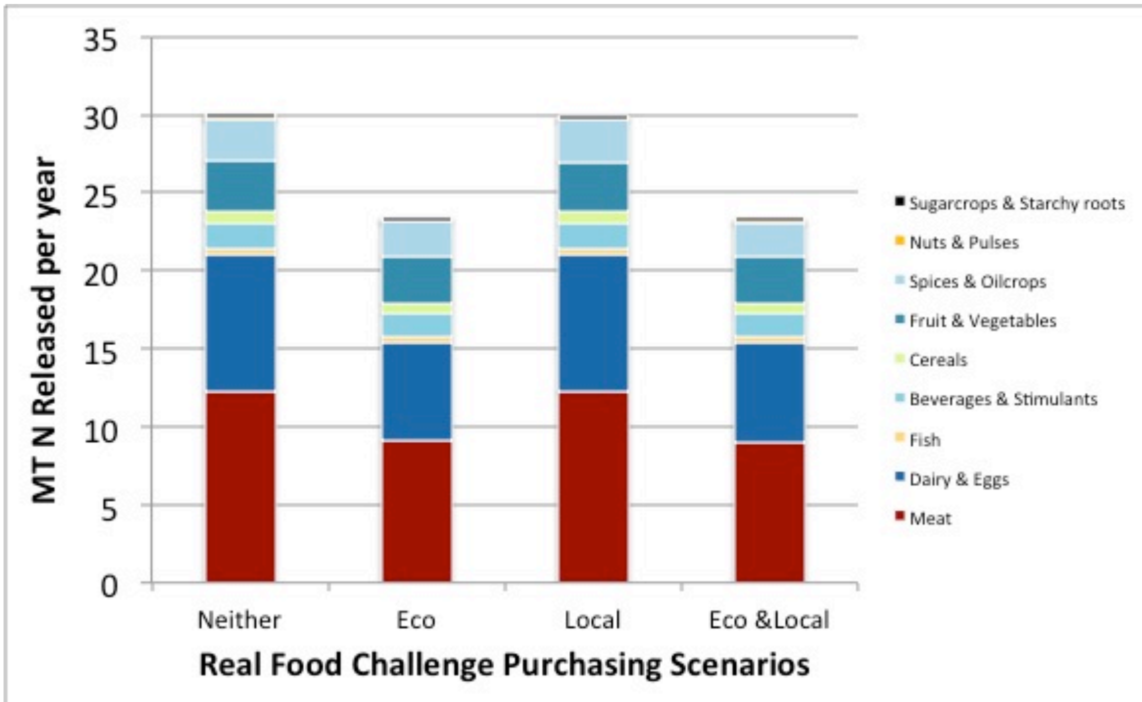

Figure 8: The Real Food purchasing scenarios based on the RFC criteria and food data collected by the Sustainability Office. Purchasing 100% ecological food has the largest impact on the N footprint, reducing it by 12% overall, and 23.3% in the food sector.