What Are the Greenhouse-Gas-Emission Impacts Associated With Vegan, Vegetarian, and Meat Diets in the United States?

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A Thesis in the Field of Sustainability and Environmental Management
for the Degree of Master of Liberal Arts in Extension Studies

Harvard University

March 2016

Abstract

The United Nations estimates that the growing human population will reach approximately 9.6 billion by 2050. In order to accommodate the subsequently higher demand for food and related strain on resources, careful consideration of diet choice will be essential. This research evaluates the impact on greenhouse gas emissions from three different diets: vegan, vegetarian, and meat-based. This research is important is because greenhouse gas emissions from food are estimated at around 17% of total emissions.

This study measures and evaluates all the steps in the food supply chain related to food production under conditions as they exist in the United States, using the Houston, Texas area as a base for the study. The intent of this research is to increase awareness of the global warming consequences of dietary food choices. My initial expected results—that vegan diets have the least emissions impact and meat-based diets have the highest—were confirmed via life cycle analysis. In this case study, vegan diets had a minimum contribution of 809 kg per person per year, followed closely by the vegetarian diet with 957 kg per person per year. However, a far higher greenhouse gas emission of 2,880 kg per person per year was calculated from the meat-based diet. The data from this study should help guide future food production decisions while also addressing the need for a reduction of greenhouse gas emissions through alternative food choices.

Acknowledgements

I would like to sincerely express my gratitude to everyone who supported me, inspired me, and provided their expertise throughout the whole progression of my thesis.

Daniel Cohan, Associate Professor of Environmental Engineering at Rice University, my Thesis Director whose deep expertise was always available to me in guiding me in the right direction. It has been my honor and pleasure to work with Daniel and learn so much from him.

Mark Leighton, Sustainability Research Advisor, who inspired and encouraged me to explore this area for my thesis. The pre-thesis seminar I took with Mark was incredibly interesting, motivating and useful for conducting this thesis and all the preliminary research and was one of the best classes in my program.

George Clark, PhD, a research librarian who taught me how to use the various Harvard databases including HOLLIS and other numerical/digital databases.

Takuma Ono, LCA Consultant and TA who helped me to learn to navigate the food chain process in Open LCA and analyze these processes for my thesis.

Bob Breslin, my TA and longtime friend who cheered me throughout the whole process of writing this thesis and helped with the editing.

Solomon, my nine-year-old son, who inspired me to start and successfully complete the master program. He was always patient, allowing me to conduct my research and write instead of helping him with his homework.

Table of Contents

List of Tables

List of Figures

Chapter I

Introduction

There are currently an estimated 7.3 billion people living on the Earth (US Census Bureau, 2015), consuming various types of diets based on personal preferences influenced by religion, ethics, health, culture, affordability, and food availability.

The United Nations (UN) forecasts that the ever-growing global population will need to increase food production by 70% by 2050 (United Nations, 2009). This demand will require an increase in the land available for both agriculture and livestock. It is difficult to estimate the exact requirement for innovations in technology that might permit efficiencies in food production processes and utilize less world resources. Moreover, food production required for each type of diet consumes a variety of resources and generates differing amounts of greenhouse gases (GHGs) and other atmospheric pollutants. Therefore, the environmental consequences vary for each of these diets.

However, there are minimal data available to consumers that could inform and explicitly demonstrate the impact of choosing one diet over another in a particular geographic region. Consequently, there is a knowledge and awareness gap that prevents people from making choices of particular diets based not only on health reasons but also on an environmental rationale. According to the Intergovernmental Panel on Climate Change (IPCC), the temperature has risen by approximately 2.8 degrees Celsius over the past 100 years. Simultaneously, these small changes in the world's temperature have tremendous effects on climate, resulting in droughts, heavy rains and/or severe heat waves (IPCC, 2015).

It can be beneficial for a consumer to be aware of the climate effects associated with the choices of their particular diet, considering that agriculture is a major GHG emission contributor. It is therefore valuable to further study, measure, and analyze all the environmental consequences resulting from the production and consumption of different diets, such as vegan, vegetarian, and meat-based.

Taking into consideration the fact that the human population has doubled in the past 50 years and will continue to grow, it is also important to mention the disappearance of natural wild land. Fifty percent of all United States (US) land is currently being used for the production of food in order to sustain the current demand for food (UN, Water and food security, 2014). Food production is also responsible for about 80% of fresh water withdrawals in the US and also accounts for 17% of the fossil fuel energy consumed in the US (Global Emissions, US EPA, 2015).

Several human activities contribute to GHG emissions, but the Environmental Protection Agency (EPA) underestimates the contribution by the agricultural sector (Figure 1). Some of the emissions from transportation, waste, land use change, electricity, industrial processes, and other contributors including fugitive emissions also result from food products and their distribution.

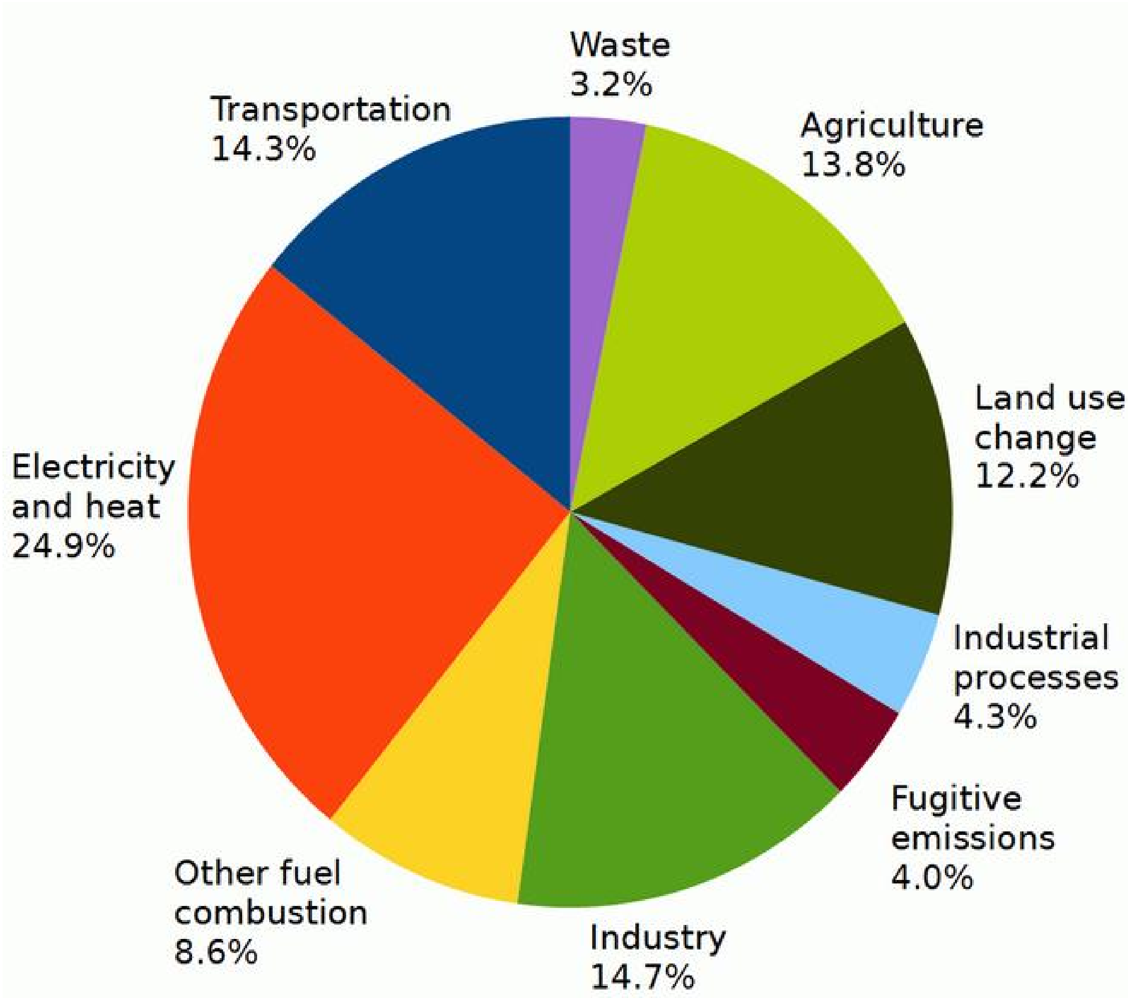

Figure 1. Sources of US carbon dioxide emissions in 2013.
(http://www.epa.gov/climatechange/ghgemissions/gases/co2.html)

Many activities associated with agriculture and livestock production add significantly to global climate change. These contributions can be both direct and indirect. Examples of direct contributors include the emissions attributable to food supply chains, methane emissions from animals, fertilizer, and the fossil fuels used to run farm equipment. Cooking, refrigeration and storage, packaging, marketing, and transportation are all examples of indirect GHG emission contributors that are considered less often, but are of equal importance and deserving of study. Studying and broadcasting the impacts of different dietary choices could contribute to different choices, less GHG emissions, and a more sustainable future.

Research Objectives

My research aims to achieve the following objectives:

- To develop three different diet types representative of vegan, vegetarian, and typical meat-based eating patterns based on conditions in the United States.
- To conduct life cycle analysis (LCA) calculations of the GHG emissions associated with each component of the three diets and to conduct a comparative analysis of these diets in regard to their GHG footprint.

Background

The majority of the scientific community agrees that the Earth's climate is changing, with the preponderance of evidence pointing to anthropocentric actions as the culprit. Climate change is changing our economy, health, and communities in diverse ways. Scientists warn that if we do not aggressively curb climate change now, the results will likely be disastrous (NRDC, 2015).

The overall warming of the planet is due to escalating amounts of GHGs in the atmosphere, whatever their origin. A measure of how much heat a GHG can cause to remain in the Earth's atmosphere is referred to as the global warming potential (GWP). This index is used to compare the relative radiative forcing of different gases without directly calculating the changes in atmospheric concentrations. GWPs are calculated as the ratio of radiative forcing resulting from the emission of 1 kg of a GHG to that from the emission of 1 kg of carbon dioxide over a fixed period of time, such as 100 years (US Energy Information Administration, 2015).

Overview and Breakdown of GHGs

GHG emissions primarily consist of four different gases (Figure 2). The GHGs relevant to food production are carbon dioxide, methane, and nitrous oxide:

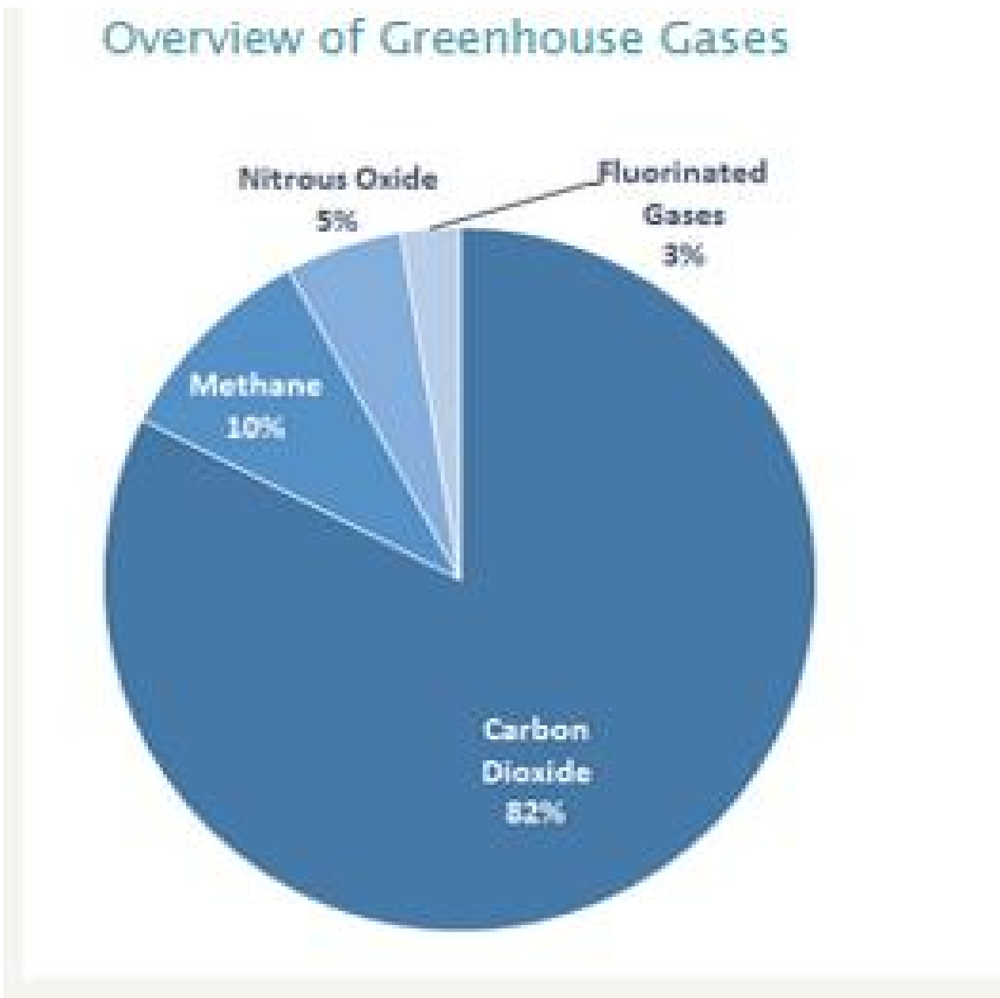

Figure 2. Overview of gases emitted per year in the US, 1990–2013.
(http://www.epa.gov/climatechange/ghgemissions/gases/co2.html)

1. Carbon dioxide (CO_2) — Most anthropogenic carbon dioxide enters the atmosphere via burning waste, trees, coal, oil, and natural gas. Some of the emitted carbon dioxide is removed by plants and by the ocean, but some remains in the atmosphere for centuries.
2. Methane (CH_4) — This important GHG is emitted into the atmosphere by agricultural practices, especially the raising of livestock, which produce methane from their digestive process; the degeneration of organic waste in municipal landfills; and the production and transport of oil, coal, and natural gas. The atmospheric residency of methane is shorter than that of carbon dioxide, but methane is a far more effective radiation blanket during its atmospheric existence. The GWP for methane over 100 years fluctuates between 28 and 36, with an average atmospheric residence time of methane in the atmosphere of 12 years (EPA, 2015).
3. Nitrous oxide (N_2O) — In agriculture, the intensity of this gas depends on a few factors, such as the kind of soil and fertilizers used in the various processes. Nitrous oxide is also discharged into the atmosphere via the combustion of solid waste and fossil fuels. The lifetime of nitrous oxide is substantial, as it remains in the atmosphere for about 114 years. The GWP for 100 years is considered to be 298, which is very high (EPA, 2015).

The impacts that these gases will have on future climate change, people's health, and the overall warming of the Earth will depend on their relative concentrations and the length of time they remain in the atmosphere. All of these gases have an ever-increasing accumulating impact on the Earth's "thickening blanket."

Food Production Wastage

Food production wastage is defined as the gap between what is produced and what is consumed. The wastage gap continues to increase, seeming to indicate that the industry needs to look for production solutions (UNEP, Climate Change, 2014). Occurring simultaneously with the rise of this waste gap are increased losses in water, land, and biodiversity. According to the EPA, the US has the highest consumer food waste footprint per capita in comparison to all other countries (US EPA, 2015). Global food wastage is estimated at 28% of total food produced (Food and Agriculture Organization of the United Nations, 2015). This statistic indicates that waste has become an important environmental and economic issue. Primary causes of this waste are spoilage and losses to pests and weather. Other causes of food loss are from cooking, natural shrinkage (e.g., moisture loss), inadequate climate control, and mold (Loss-Adjusted Food Availability Documentation, USDA, 2015).

According to the UN, the largest contributors to waste are the meat and dairy industries, representing 11% of total food wastage and growing every year (United Nations, 2009). In comparing food wastage by type of food, wastage assigned to animal products (meat, fish, dairy) is about 33% of the total percentage of the carbon print from all food waste (Figure 3). Using data collected over several years by the United States Department of Agriculture (USDA), I calculated the wastage percentages for each food category and applied them to data collected by Haddad (2015) in order to calculate the wastage for each food item in grams (Table 1).

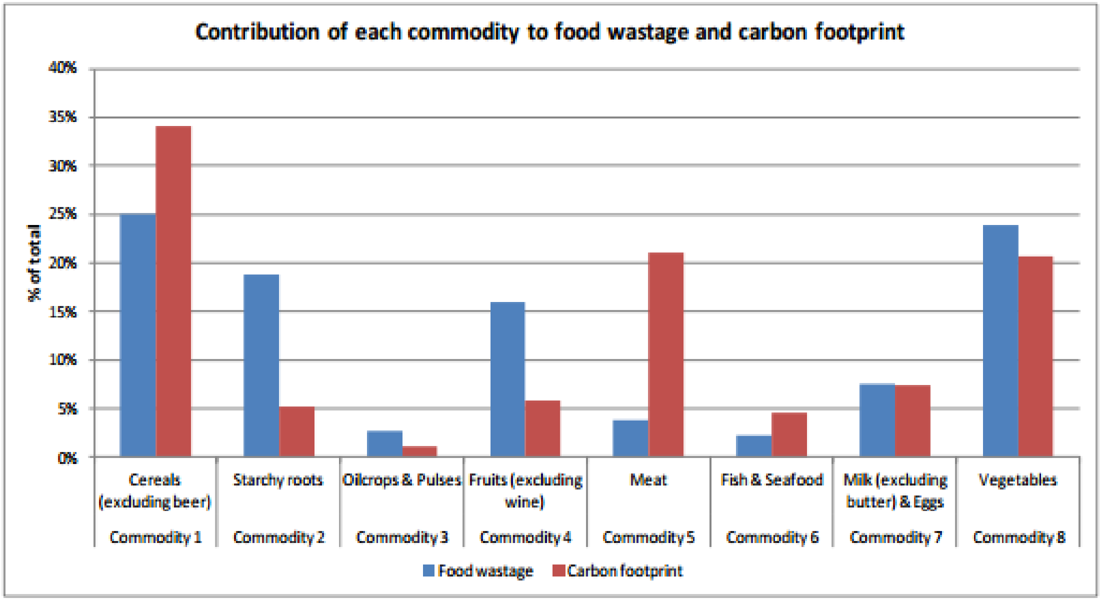

Figure 3. Food wastage footprint technical report, contribution of each commodity to food wastage and carbon footprint. (http://www.fao.org/docrep/018/i3347e/i3347e.pdf)

When all diets are scaled to 2,000 calories/day, the wastage for vegetarian diets revealed the highest content—very close to the meat diet—and the vegan diet had the least wastage (Table 2) (note that waste factors apply to a food category rather than to individual items). Broken down, the percentage of wastage for grains is 44%, vegetables 42%, fruit 40%, dairy 44%, protein foods 35%, fats 61%, and sugars 69% (USDA, 2011).

Table 1. Comparison of wastage of non-scaled diets (bold numbers represent the percentage of food waste for each category taken from the USDA database).

	Meat Based	Wastage (produced/ consumed in gm)	Vegetarian	Wastage (produced / consumed in gm)	Vegan	Wastage (produced / consumed in gm)
Grains		**0.449**		**0.449**		**0.449**
	Yeast Bread and rolls	24	Yeast Bread and rolls	23	Yeast Bread and rolls	23
	Cereals and pasta	32	Cereals and pasta	52	Cereals and pasta	52
	Rice	10	Rice	23	Rice	23
	Other grains	70	Other grains	61	Other grains	61
Vegetables		**0.429**		**0.429**		**0.429**
	Fried potatoes	11	Fried potatoes	3	Fried potatoes	3
	Other white potatos	17	Other white potatos	14	Other white potatos	14
	Dark green vegetables	5	Dark green vegetables	12	Dark green vegetables	12
	Deep yellow vegetables	4	Deep yellow vegetables	8	Deep yellow vegetables	8
	Tomato	13	Tomato	16	Tomato	16
	Lettuce	6	Lettuce	9	Lettuce	9
	Green beans	3	Green beans	2	Green beans	2
	Corn, green peas	6	Corn, green peas	6	Corn, green peas	6
	Other vegetables	20	Other vegetables	37	Other vegetables	37
Fruits		**0.408**		**0.408**		**0.408**
	Citrus fruit and juices	28.18	Citrus fruit and juices	41.66	Citrus fruit and juices	41.66
	Dried fruit	0.41	Dried fruit	2.04	Dried fruit	2.04
	Apples	6.94	Apples	15.11	Apples	15.11
	Bananas	6.13	Bananas	8.99	Bananas	8.99
	Melons and berries	6.54	Melons and berries	6.94	Melons and berries	6.94
	Other fruit	16.34	Other fruit	17.97	Other fruit	17.97
Dairy		**0.449**		**0.449**		**0.449**
	Milk, yogurt	90.8	Milk, yogurt	79.5	Milk, yogurt	0.0
	Cheese	7.2	Cheese	9.4	Cheese	0.0
	Other dairy	20.2	Other dairy	34.1	Other dairy	0.0
Protein		**0.351**		**0.351**		**0.351**
	Red meat	48.1	Red meat	0.0	Red meat	0.0
	Poultry	20.0	Poultry	0.0	Poultry	0.0
	Fish	7.7	Fish	0.0	Fish	0.0
	Other	0.0	Other	0.0	Other	0.0
	Legumes	7.4	Legumes	33.0	Legumes	33.0
	Nuts and seeds	1.2	Nuts and seeds	2.1	Nuts and seeds	2.1
Fats		**0.613**		**0.613**		**0.613**
	Table fats	2.4	Table fats	1.2	Table fats	1.2
	Salad dressing	5.4	Salad dressing	6.1	Salad dressing	6.1
	Other fats	7.8	Other fats	6.7	Other fats	6.7
Sugar		**0.695**		**0.695**		**0.695**
	Sugars	2.4	Sugars	2.1	Sugars	2.1
	Candy	4.7	Candy	3.5	Candy	3.5
	Other sugar	10.1	Other sugar	7.6	Other sugar	7.6
Beverages						
	Fruit drinks and aids		Fruit drinks and aids		Fruit drinks and aids	
	Other beverages		Other beverages		Other beverages	
Alcohol						
	Wine		Wine		Wine	
	Beer and ale		Beer and ale		Beer and ale	
	Other alcohol		Other alcohol		Other alcohol	
Weight in Grams		**521**		**544**		**421**

Table 2. Comparison of wastage from three diets (scaled to 2,000 calories/day)

	Meat Based	Adjusted to 2000 cal Wastage	Vegetarian	Adjusted to 2000 cal Wastage	Vegan	Adjusted to 2000 cal Wastage
Grains						
	Yeast Bread and rolls	18	Yeast Bread and rolls	20	Yeast Bread and rolls	20
	Cereals and pasta	24	Cereals and pasta	45	Cereals and pasta	45
	Rice	8	Rice	20	Rice	20
	Other grains	51	Other grains	52	Other grains	52
Vegetables						
	Fried potatoes	8	Fried potatoes	3	Fried potatoes	3
	Other white potatos	13	Other white potatos	12	Other white potatos	12
	Dark green vegetables	4	Dark green vegetables	10	Dark green vegetables	10
	Deep yellow vegetables	3	Deep yellow vegetables	7	Deep yellow vegetables	7
	Tomato	9	Tomato	14	Tomato	14
	Lettuce	5	Lettuce	8	Lettuce	8
	Green beans	2	Green beans	2	Green beans	2
	Corn, green peas	4	Corn, green peas	5	Corn, green peas	5
	Other vegetables	15	Other vegetables	32	Other vegetables	32
Fruits						
	Citrus fruit and juices	21	Citrus fruit and juices	36	Citrus fruit and juices	36
	Dried fruit	0	Dried fruit	2	Dried fruit	2
	Apples	5	Apples	13	Apples	13
	Bananas	5	Bananas	8	Bananas	8
	Melons and berries	5	Melons and berries	6	Melons and berries	6
	Other fruit	12	Other fruit	16	Other fruit	16
Dairy						
	Milk, yogurt	67	Milk, yogurt	69	Milk, yogurt	0
	Cheese	5	Cheese	8	Cheese	0
	Other dairy	15	Other dairy	30	Other dairy	0
Protein						
	Red meat	36	Red meat	0	Red meat	0
	Poultry	15	Poultry	0	Poultry	0
	Fish	6	Fish	0	Fish	0
	Other	0	Other	0	Other	0
	Legumes	5	Legumes	29	Legumes	29
	Nuts and seeds	1	Nuts and seeds	2	Nuts and seeds	2
Fats						
	Table fats	2	Table fats	1	Table fats	1
	Salad dressing	4	Salad dressing	5	Salad dressing	5
	Other fats	6	Other fats	6	Other fats	6
Sugar						
	Sugars	2	Sugars	2	Sugars	2
	Candy	3	Candy	3	Candy	3
	Other sugar	7	Other sugar	7	Other sugar	7
Beverages						
	Fruit drinks and aids	29	Fruit drinks and aids	37	Fruit drinks and aids	37
	Other beverages	290	Other beverages	228	Other beverages	228
Alcohol						
	Wine	3	Wine	9	Wine	9
	Beer and ale	28	Beer and ale	29	Beer and ale	29
	Other alcohol	2	Other alcohol	13	Other alcohol	13
Weight in Grams		**737**		**787**		**680**

When diets are not scaled to 2,000 calories/day, calculations again show that a vegetarian diet produces the highest amount of waste per person per day (544 g) compared to 521 g for the meat-based diet and 421 g for the vegan diet. Closer inspection of the data reveals a few reasons for these differences: vegan diets consume less mass and avoid all dairy and meat products. Thus, the total weight for a daily vegan diet is 1,784 g versus 2,058 g for vegetarian and 2,277 g for meat-based.

GHG Emissions from Food Production and Consumption

GHG emissions are most often attributed to transportation, but food-chain production (farming, transportation, storage, crop production, processing, livestock-raising, and wastage) is a huge contributor as well. Various GHGs in differing quantities are emitted into the atmosphere and water during each step, and food chain production activities require the use of many natural resources to which deforestation and water and air pollution can be traced. As proof of the seriousness of the food production impact on GHGs, researchers brought evidential data to the Committee on Climate Change in 2010 (CCC, 2015). Their data emphasized that burning fossil fuels emits carbon dioxide in the farming process from machinery, transportation, storage, and cooking, but the most potent GHGs—nitrous oxide and methane—come from enteric fermentation in livestock and from fertilized soil (CCC, 2015).

A study conducted in the UK (UN, 2006) demonstrated that a large reduction in GHG emissions is possible by reducing the waste, packaging, and other indirect activities related to the manufacture of food. Specifically, it showed that the largest reduction in

GHG emissions would come from minimizing meat consumption by the population—a resultant 21% reduction in GHG emissions.

Another large GHG reduction would come from a shift in dietary choices between the various carbon-intensive types of meats. For example, shifting from beef or lamb to poultry would support an 18% GHG reduction in the total meat contribution (UN, 2006). Likewise, studies have found significant potential reductions in GHG emissions by switching from a meat-based diet to a vegetarian or vegan one (Druckman and Jackson, 2012; Wallen, 2004), as well as plant-based intake helping to reduce waste and improve global food availability (Berners-Lee, 2012). The UN (2006) study also offers alternatives beyond dietary changes for reducing GHG emissions, such as packaging, air freight, storage, etc.—the combined effect totaling up to a 53% reduction in emissions (Food and Agriculture Organization of the United Nations, 2006).

The United Nations Environment Program (UNEP) considers meat production and its wastage to contribute significantly to growing GHG emissions, stating that the world's increasing demand for meat significantly contributes to climate change (UNEP, Climate Change, 2014). In addition, the UNEP recommends and encourages more sustainable systems to facilitate efficient meat production and waste reduction. The global meat supply has increased faster than population growth (Figure 4) due to both the industrialization of farming and the ensuing decrease in meat costs.

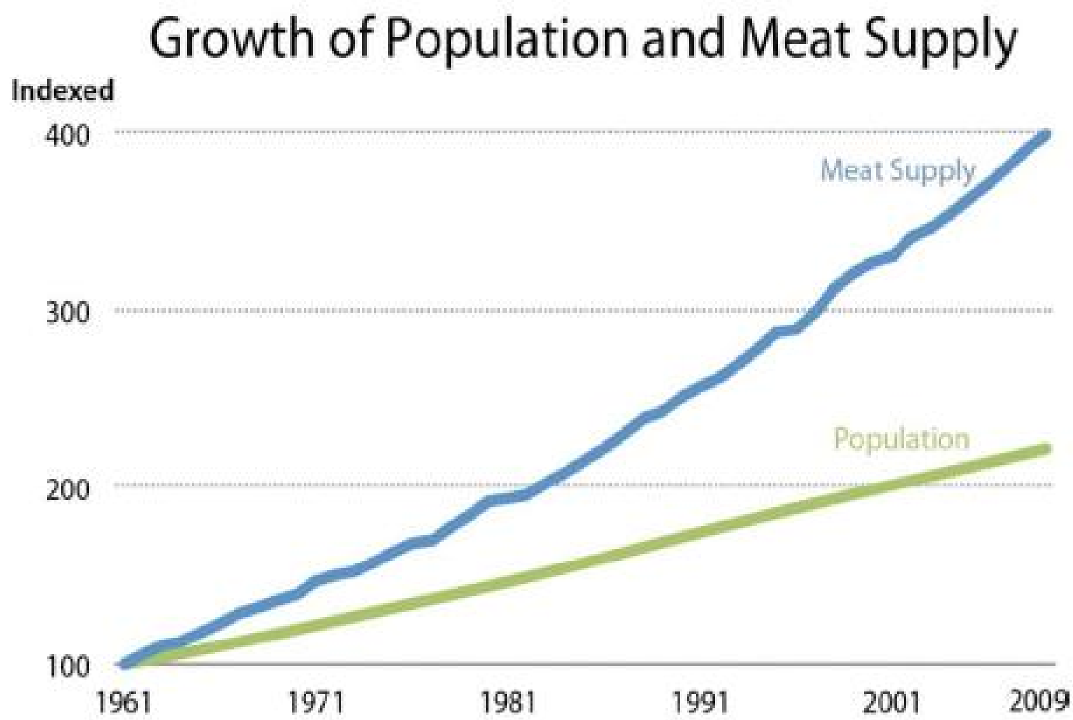

Figure 4. Growth of population and meat supply, indexed 1961=100. (UNEP)

Research conducted in Denmark and Sweden has been focused on individual dietary choices, stressing the consequences of food choices and their connection to climate change (Gonzales, 2007), as well as the opportunity to influence the environment positively or negatively with food choices (Saxe, Larsen, & Mogensen, 2012). The Denmark study further emphasized the need for humanity to develop a sustainable dietary guideline in order to facilitate the efficient use of available resources and the feeding of the population. The developed diet would coordinate all the nutritional and caloric values required for health while decreasing GHGs being emitted by farming (Saxe, Larsen, & Mogensen, 2012). The study in Sweden looked at GHG output by percentage of contribution to emissions using 84 different foods and an LCA analysis. Results indicate that meat and meat products contribute 28% of the total GHG emissions of Sweden, owing to its production, processing, and distribution. They further demonstrate that among all foods examined, meat production per person per year contributes the most to GHG emissions, in the amount of 29 kg of CO_2 per 1 kg of meat, while the smallest contributor to GHG emissions are fruits, with 0.38 CO_2 kg per 1 kg of fruit (Gonzales, 2007).

Further evidence of meat as the primary GHG culprit was confirmed by Scarborough's (2014) analysis. GHG emissions of 61 various foods were analyzed in the UK in each process of the food chain, including processing, packaging, transportation, storage, and refrigeration. Consumption was adjusted to an average 2,000 calories-per-day diet and included 2,041 vegans, 15,751 vegetarians (8,123 of them fish-eaters), and 29,589 meat-eaters. The lowest GHG food emissions were associated with vegan women, while the highest emissions were associated with meat-eating men. Also, meat-based diets produced 2.5 times as many GHG emissions as the vegan diets adjusted to the same 2,000-calorie level (Scarborough, 2014). Bailey et al. (2014) and Espinoza (2012) found more proof of meat and dairy as the largest contributor to GHG emissions and climate change, emphasizing that these foodstuff emissions contribute over 14.5 % of the total global GHG release. These high emissions could be reduced somewhat over time, however, as new technology is allowing for changes in livestock production techniques and related practices, processes, and procedures that are making them more effective and less resource-consumptive (Bailey, Froggatt, & Wellesley, 2014).

Amani and Schiefer (2011) measured the GHG emissions from the food sector in Germany, and similar to most other geographical regions, showed that, among food items, meat production contributes the most to GHG emissions (Amani & Schiefer, 2011). According to this study, 20 factors out of a selected 25 classify red meat specifically as being the most involved in GHG food emissions, causing the authors to promote a change in the current state of food processing to lower its impact on climate change (Amani & Schiefer, 2011).

In the US, Weber and Matthews (2007) studied food-related emissions using the Open LCA tool and encompassing all upstream (supply chain) impacts. Results showed that a vegan diet creates the least GHG emissions (Weber & Matthews, 2007). As an example of their calculations, transportation of food within the US adds 1.2×10^{12} t-kg/year to the GHG output (Weber & Matthews, 2007).

The overall results of all the studies mentioned above agree and confirm that meat products contribute the most of food-related GHG emissions and that there is a correlation between dietary choices and the environmental issues facing our Earth. It is not typical for most people to base their food preferences on environmental sustainability issues, and it is far less common for people to estimate the GHG emissions of the foods they consume, so several countries are working hard to bring this awareness of sustainable food choices to their populations. For example, some countries have implemented taxes on energy and fuels, including energy carbon taxes that target a reduction in emissions coming from food production and distribution. GHG reduction polices in Norway have enabled a documented reduction in GHG emissions due to similar polices (OECD, 2014).

Research Rationale and Hypothesis

The aforementioned peer-reviewed studies demonstrate and emphasize the necessity of further research and a need for a discussion of the correlation between dietary choices and GHG emissions. There are large impacts on human health, resources use, and the environment, but currently, there is little US-based research comparing the GHG footprint of vegan, vegetarian, and meat-based diets. Consequently, there is a knowledge gap in the average person's awareness that is probably affecting our human community's on-going choices toward sustainable diets. Based on the studies to date, it would seem that there would be great value in producing and disseminating the results of food-related environmental footprint studies and publicizing them for the American consumer.

My research begins with the question: What are the GHG emission impacts from vegan, vegetarian, and meat-based diets in the US? I focus on the impact of production-related activities only, even though both the consumption and the production of food emit GHGs. However, - according to most comparable studies, much of the GHG emissions come from the production of food before it leaves the farm. This study looks at the diets producing the highest and the lowest GHG emissions and, by inference, the diet compositions that should be optimal for a climate-stable planet.

Specifically, I hypothesize that a vegan diet has the smallest GHG emission footprint and a meat-based diet the largest, using the US as the baseline case study.

Specific Research Aims

1. The type of foods, quantities, and diet criteria were outlined for each diet prior to beginning the data calculation. Also explained is what is calculated and the quantity, caloric, and nutritional value of each diet's daily recommended standard. I defined the commonly produced and consumed foods and used these for the makeup of the three types of diets. I then quantified the total amounts needed to feed the population of the US for each diet type.

2. For each of these diets I calculated GHG emissions via the Open LCA tool for one person for one day's consumption. The Saxe/Larsen graph represents the comparison data to the previously mentioned Denmark research that utilized a different geographic area (Saxe, -et al. 2013).

3. The final aim is to provide summary recommendations based on the findings and calculations of this research for consumer action and the need for further food processing research.

Chapter II

Methodology

The data needed for this study required respectable published sources. The USDA (USDA, 2010), along with a research study done by Haddad and Tanzman (2015), provided much of the data needed for emissions calculations. Harvard Medical School guidelines and publications were referenced for the composition of the three healthy contrasting diet types.

Data Sources and Criteria

To analyze the three diet types objectively, adjustments to some criteria components of all three were made and included:

- Caloric intake was set at 2,000 calories per person per day, which was taken from both USDA guidelines and caloric intake based on actual consumption data from the surveys of Haddad and Tanzman (Haddad & Tanzman, 2015). Both were considered because the actual caloric consumption data from the surveys were needed to level all to 2,000 calories for compliance with USDA recommendations for healthy living. Having both sets of caloric data also allowed the illustration of differences in footprints under analogous scenarios.
- Food lists and quantities were based on the Haddad and Tanzman surveys of 13,341 people from 1994 to 1996 and 1998.
- Nutritional value sources (protein 25%, grains 25%, fruit 15%, and vegetables 35%) came from the recommendations and the guidelines of the USDA. This nutritional ratio was implemented in conjunction with the data collected from Haddad's surveys.

- Geographic territory was the US.

Open LCA for Calculations

In developing the quantitative diets using sourced data, the Open LCA tool was used to measure the foods' individual GHG footprints. The Open LCA database is a generally accepted analyzer tool for the calculation of environmental effects of various processes and products. The unit used in these measures is kilogram of carbon dioxide per kilogram of food—i.e., how many kg of carbon dioxide are released from 1 kg of a food item (Time for Change, 2015).

The LCA tool was chosen because it enables a diverse variety of factors to be measured and evaluated including food systems, types of diets, nutritional compositions, food quality, midpoint environmental indicators, endpoint indicators of resources, ecosystem quality and services, and human health (Figure 5). Figure 5 illustrates how the processes via LCA are calculated and analyzed and how other processes interact within the entire framework of environmental impacts and nutritional quality.

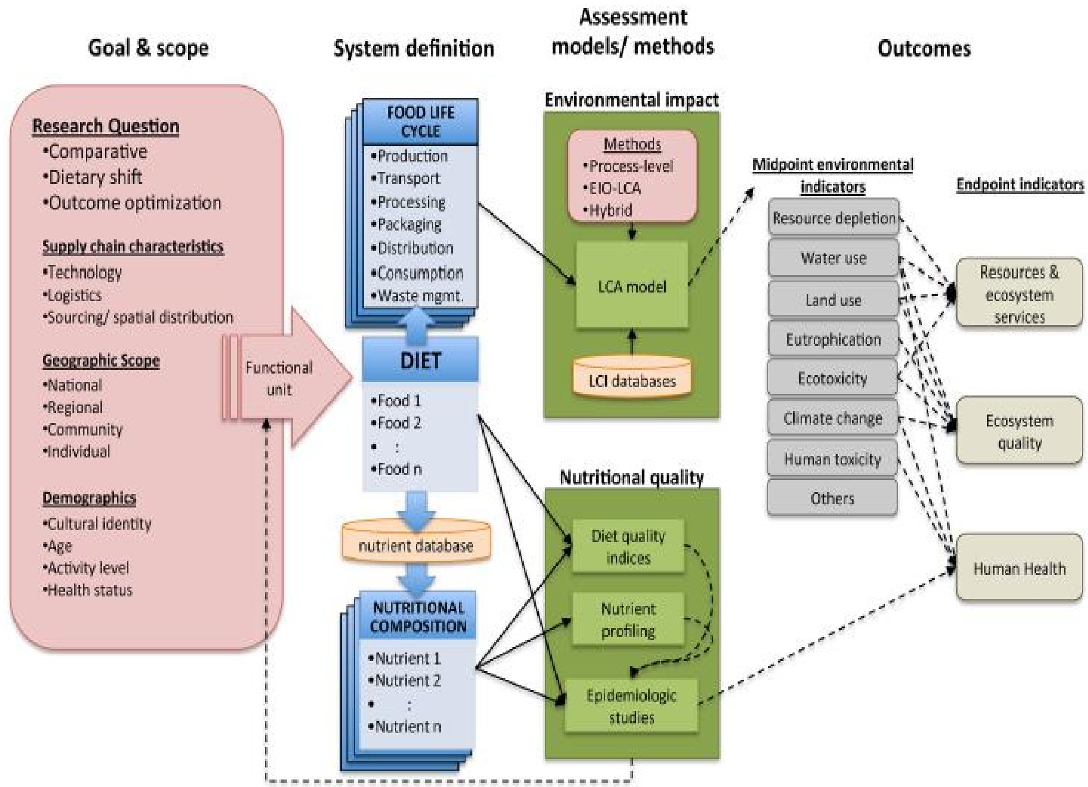

Figure 5. Conceptual framework for diet-level integration of environmental impact and nutritional quality assessment (Heller, 2013).

The life cycle impact assessment of the LCA tool comes with different phases to utilize as applicable. In accordance with ISO 14042 (LCA), there are sub-phases to be followed and addressed: impact category definition, classification, and characterization. Additionally, LCA database calculations encompass all the processes beginning with the materials used in farming and ending at the supermarket—processes such as food production, agriculture, processing, packaging, wholesale, retail, transportation, logistics, and other additional food sector activities. The database also contains calculations of various food categories such as meat, eggs, dairy, fruit, vegetables, beverages, and processed foods.

All of these categories, reviewed and calculated via the Open LCA tool, provided transparency to the process of the GHG emission calculations. In addition to GHG emission analysis, LCA provided data for the analysis of environmental impacts from either the production or the consumption of particular foods. The elements comprising the LCA profile enabled an efficient grouping and measurement of the data.

A comparison analysis of the USDA data against LCA calculations was created to compare a US diet to a Nordic calculation of similar foods based on the Danish LCA Food Database (2004). The New Nordic Diet (NND) was designed in compliance with guidelines from the New Nordic Nutrition Recommendations (Nordic Council 2004) and was structured to provide a healthy, palatable, and environmentally friendly diet of Nordic origin in compliance with the Danish dietary guidelines and recommendations. In addition to statistics, it offers hundreds of various and all-season recipes (Saxe, 2010).

There are areas of the LCA database that still have room for improvement. For example, both the list of food categories and the food processes could be expanded in order to provide more flexibility in the ability to measure additional food items as calculations may become available (Baumann, 2011). And despite the seeming accuracy of the LCA results, there are some researchers who propose that the inventory analysis data might not be totally accurate and that the results could be misleading (Bras-Klapwijk, 1998).

Other Measurement Options

Beyond the methods discussed above, other statistical methods are available to researchers including a “Critical Surface Time” approach that measures environmental and human heath parameters in order to determine such concepts as the area dimensions affected by pollution. One reason that so many methods are available for examining scenarios is because environmental impacts are very complex and necessitate scrutiny from differing perspectives. There are also strategies that combine a few or many methods, reflecting a detailed analysis of food combinations. Considering that GHG emissions have a global impact, it is prudent for researchers to consider all the various methods, make use of all tools, and ascertain any similar studies.

Definition of Diets

The following terminology is used to define what each diet represents and the type of foods included:

- Meat-based diets presume consumption of a combination of plant-based foods in combination with differing kinds of meats and fish and can include milk products, honey, and eggs.
- Vegetarian diets include all vegetables, fruits, milk, dairy products, and eggs and exclude any animal flesh such as fish or meat.
- Vegan diets have the strictest standards because they exclude all types of direct animal meats and fish, as well as any products that are made by or come from animals, such as dairy products, eggs, and honey. Vegan diets are exclusively based on whole plant foods such as vegetables, grains, and fruits.

In order to measure GHG emissions from these three different diets, a spreadsheet was created to display each diet's makeup, including the quantity of foods necessary to comply with a nutritional and caloric daily value recommended by the USDA.

Additionally, a set of data compiled from both the USDA and the Haddad survey was merged, illustrating the actual amounts of foods consumed by the people in the US.

To objectively standardize the metric output, the totals for these diets were made the same in caloric and nutritional value. For compliance, the recommendations and guidelines of the USDA's Healthy Eating Plate were observed. (The old standard food pyramid was replaced in 2005 by this revised Healthy Eating Plate. This newer, healthier version was created by considering research and nutritional values measured over 20 years of monitored eating habits.) Some general recommendations from the USDA are to change to a primarily plant-based diet - choose to eat fish twice a week, and take into consideration that not all proteins are equally healthy (Harvard School of Public School, 2015).

An adjusted Healthy Eating Plate from Harvard Medical School uses the recommendations of the USDA while focusing more on food type (Figure 6). For example, instead of grains it specifically recommends whole grains, and instead of proteins it recommends the consumption of healthy proteins, demonstrating how varying personal choices can make a difference in individual health (Harvard School of Public School, 2015). Overall, the USDA recommendations were used (all four main categories of fruit, protein, grains, and vegetables), along with their associated masses from the Healthy Eating Plate.

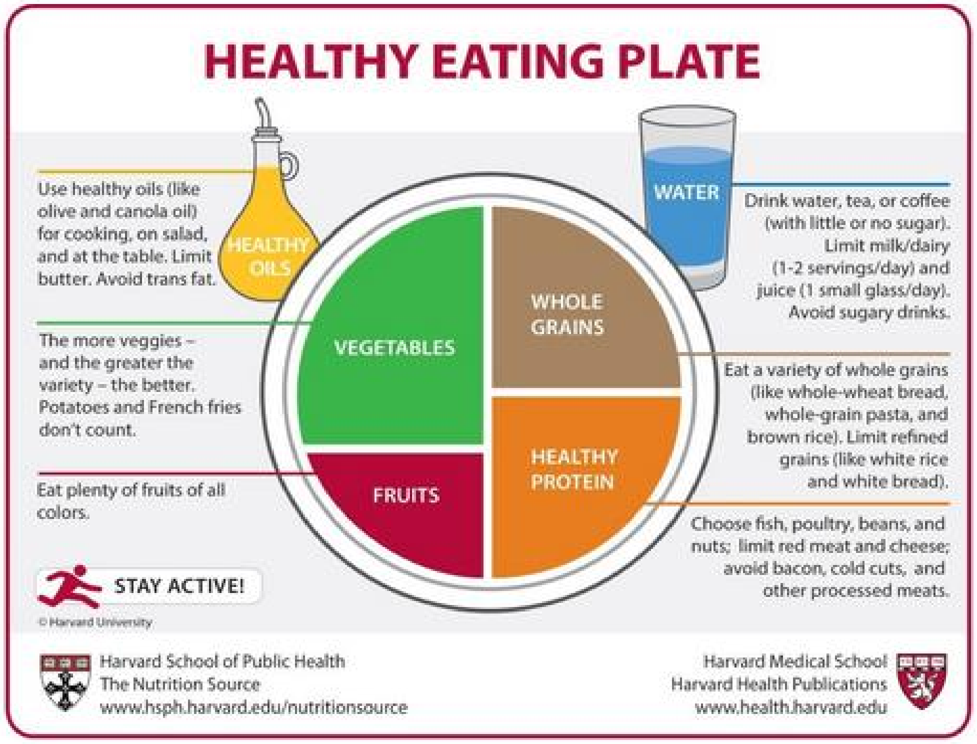

Figure 6. Healthy Eating Plate (Harvard School of Public School, 2015).

The USDA has also developed a food pyramid for a vegetarian diet (Figure 7). The USDA endorses that a vegetarian diet can meet all the nutrients required via a variety of plant-based foods and excluding meats and fish from the overall diet (USDA Choosemyplate.gov, 2015).

The foods in the vegan diet are constructed to meet nutritional bodily needs (Figure 8). Vegans require additional plant-based protein to supplement and provide a complete balanced diet. The USDA recommends for a vegan to consume plant-based protein such as legumes, nuts, and other sources of this type for which a daily portion should consist of five servings. In addition, the USDA has developed food suggestions to help vegans achieve these recommendations and guidelines. Areas of recommendation include the amounts of food, caloric intake, and healthy recipes (USDA Food Patterns, 2010).

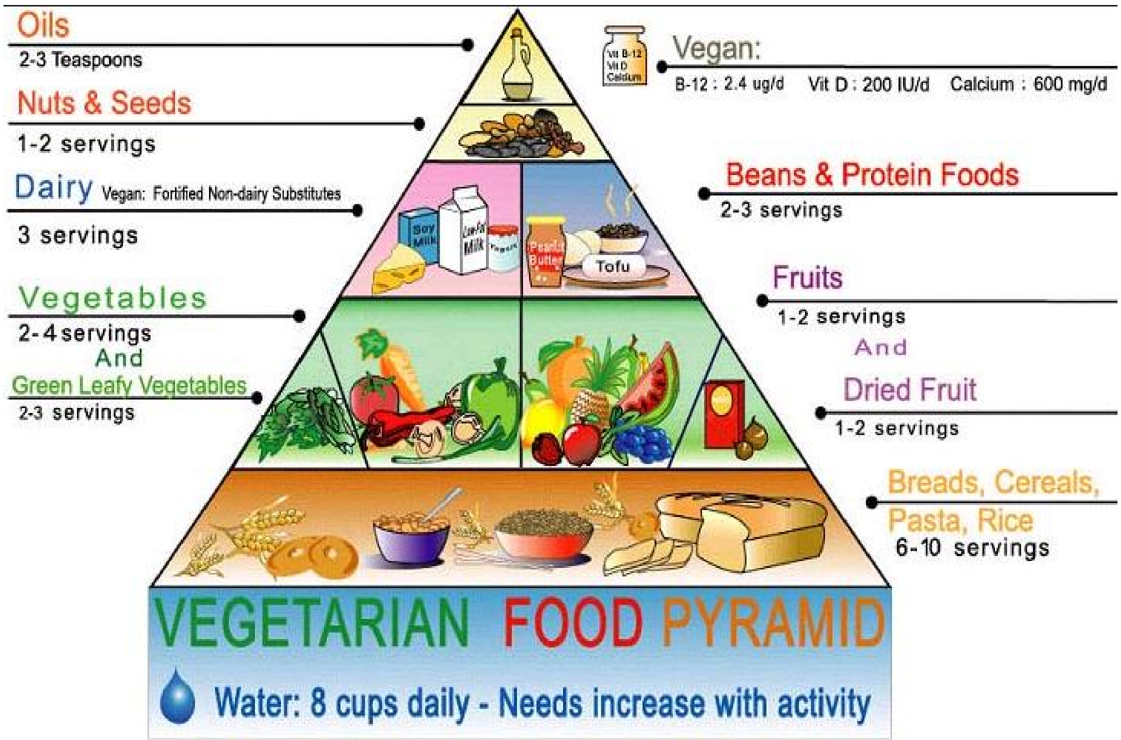

Figure 7. USDA vegetarian food pyramid.

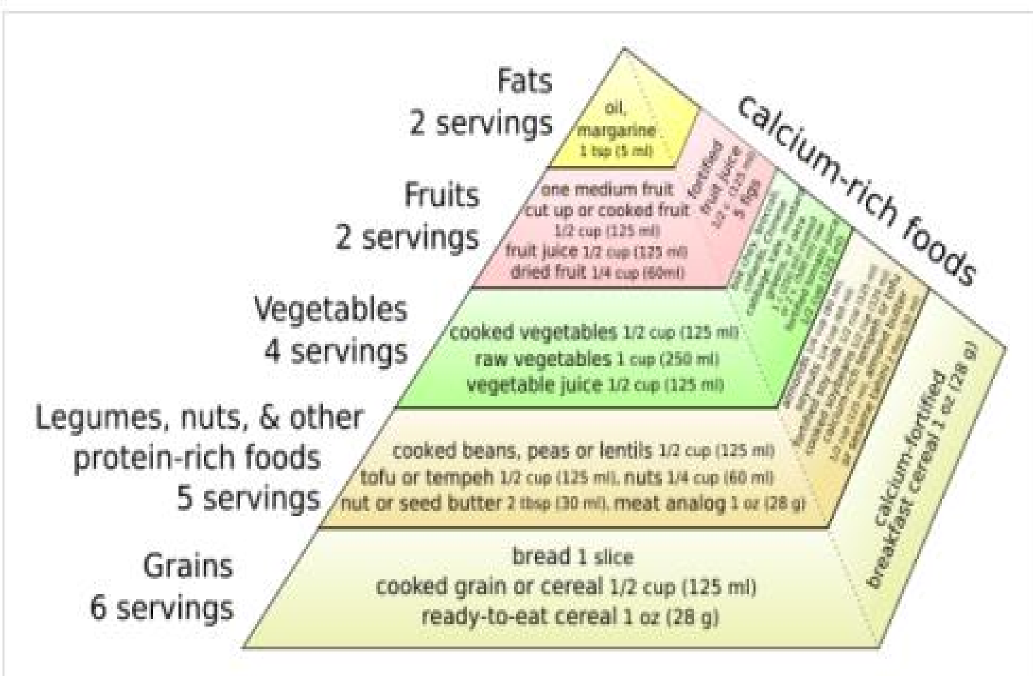

Figure 8. USDA's vegan food pyramid (http://veganfoodpyramid.com/).

GHG Calculations

The results from Haddad's surveys were used to define, measure, and analyze the three diets. The data were collected from surveys of 13,341 participants: 12,543 meat-eaters, 214 vegetarians, and 120 vegans. The participants (6+ years olds) were asked to identify the foods and amounts they consumed in a 24-hour period. This long-running survey was conducted over 3 years in order to measure food intake by individuals, learn their dietary patterns, and document the various nutrients consumed. Within these surveys, some idiosyncrasies were discovered, such as self-described vegetarians eating during the period reported in the surveys and supposedly non-vegetarians not eating meat. Table 3 lists common foods consumed by people in two of the diet categories.

Table 3. Consumption of individual foods for vegetarian and meat-based diets, kg-CO_2-equivalent emitted (Haddad, 2015).

	Self-defined nonvegetarian		Self-defined vegetarian	
	Ate meat (n = 12543)	No meat[2] (n = 436)	Ate meat (n = 214)	No meat[2] (n = 120)
	g/d		g/d	
Total grains	303 ± 2	363 ± 11[3]	294 ± 15	354 ± 18[4]
Yeast breads and rolls	53 ± 0	36 ± 2[3]	52 ± 3	52 ± 4
Cereals and pasta	72 ± 1	74 ± 6	86 ± 8	116 ± 10[3]
Rice	23 ± 1	20 ± 4	23 ± 5	51 ± 6[3]
Total vegetables	197 ± 1	159 ± 8[3]	214 ± 12	250 ± 14[3]
White potatoes	65 ± 1	33 ± 4[3]	52 ± 6	39 ± 7[5]
Fried potatoes	25 ± 0	11 ± 2[3]	16 ± 3[4]	7 ± 4[3]
Dark green vegetables	12 ± 0	8 ± 2	13 ± 3	28 ± 3[3]
Deep yellow vegetables	9 ± 0	7 ± 1	8 ± 2	19 ± 2[3]
Tomato	30 ± 0	33 ± 3	36 ±4	38 ± 5
Lettuce	15 ± 0	16 ± 1	17 ± 2	21 ± 3
Green beans	7 ± 0	4 ± 1[5]	11 ± 2	5 ± 2
Corn, green peas, lima beans	14 ± 0	6 ± 2[3]	13 ± 3	13 ± 3
Other vegetables	46 ± 1	51 ± 4	63 ± 6[4]	87 ± 7[3]
Total fruit	159 ± 2	178 ± 10	200 ± 15[4]	261 ± 18[3]
Citrus fruit and juices	69 ± 1	73 ± 7	95 ± 10[4]	102 ± 12[4]
Dried fruit	0.8 ± 0.1	1.4 ± 0.3	1.9 ± 0.5	4.7 ± 0.6[3]
Other fruit	88 ± 1	102 ± 7	103 ± 10	151 ± 13[3]
Apples	17 ± 0	15 ± 2	20 ± 3	37 ± 4[3]
Bananas	15 ± 0	17 ± 2	22 ± 3[4]	22 ± 4
Melons and berries	16 ± 1	23 ± 4	15 ± 5	17 ± 7
Total milk (calcium equivalents)	297 ± 3	304 ± 15	305 ± 22	274 ± 27
Milk, milk drinks, yogurt	202 ± 2	207 ± 12	213 ± 7	177 ± 21
Cheese	16 ± 0	17 ± 2	18 ± 2	21 ± 3
Total meat	216 ± 1	1 ± 8[3]	160 ± 12[3]	0 ± 14[3]
Red meat	137 ± 1	1 ± 7[3]	80 ± 10[3]	0 ± 12[3]
Poultry	57 ± 1	0 ± 4[3]	42 ± 6[4]	0 ± 8[3]
Fish	22 ± 1	0 ± 3[3]	38 ± 4[3]	0 ± 5[3]
Legumes	21 ± 1	51 ± 4[3]	30 ± 5	94 ± 6[3]
Nuts and seeds	3.5 ± 0.1	6.2 ± 0.7[3]	4.1 ± 1.0	5.5 ± 1.2
Total fats and oils	15 ± 0	12 ± 1	15 ± 1	13 ± 2
Table fats	3.9 ± 0.1	2.7 ± 0.4[5]	3.1 ± 0.5	1.9 ± 0.7[5]
Salad dressings	8.8 ± 0.1	8.7 ± 0.8	10.0 ± 1.1	9.1 ± 1.3
Total sugars and sweets	24.4 ± 0.4	28.5 ± 2.2	20.6 ± 3.2	18.7 ± 3.9
Sugars	3.4 ± 0.1	3.1 ± 0.5	2.7 ± 0.7	2.9 ± 0.9
Candy	6.7 ± 0.2	7.7 ± 1.0	5.5 ± 1.4	4.6 ± 1.7
Total beverages	965 ± 7	806 ± 40[3]	717 ± 58[3]	680 ± 71[3]
Fruit drinks and ades	89 ± 2	119 ± 11[4]	73 ± 15	94 ± 19
Total alcoholic beverages	101 ± 3	75 ± 18	58 ± 26	131 ± 32
Wine	9.8 ± 0.5	7.0 ± 2.5	9.4 ± 3.5	23.0 ± 4.4[5]
Beer and ale	85 ± 3	61 ± 18	47 ± 25	74 ± 31

Table 4. Framework of the three diets, compiled from a three-year survey (Haddad, 2015).

	Meat Based	Mass (g)	Calories	Vegetarian	Mass (g)	Calories	Vegan	Mass (g)	Calories
Grains									
	Yeast Bread and rolls	53	145	Yeast Bread and rolls	52	142	Yeast Bread and rolls	52	142
	Cereals and pasta	72	94	Cereals and pasta	116	151	Cereals and pasta	116	151
	Rice	23	30	Rice	51	67	Rice	51	67
	Other grains	155	575	Other grains	135	501	Other grains	135	501
Vegetables									
	Fried potatoes	25	78	Fried potatoes	7	22	Fried potatoes	7	22
	Other white potatos	40	31	Other white potatos	32	25	Other white potatos	32	25
	Dark green vegetables	12	4	Dark green vegetables	28	9	Dark green vegetables	28	9
	Deep yellow vegetable	9	3	Deep yellow vegetables	19	6	Deep yellow vegetable	19	6
	Tomato	30	5	Tomato	38	6	Tomato	38	6
	Lettuce	15	2	Lettuce	21	3	Lettuce	21	3
	Green beans	7	2	Green beans	5	1	Green beans	5	1
	Corn, green peas	14	11	Corn, green peas	13	10	Corn, green peas	13	10
	Other vegetables	46	30	Other vegetables	87	57	Other vegetables	87	57
Fruits									
	Citrus fruit and juices	69	31	Citrus fruit and juices	102	46	Citrus fruit and juices	102	46
	Dried fruit	1	3	Dried fruit	5	15	Dried fruit	5	15
	Apples	17	9	Apples	37	20	Apples	37	20
	Bananas	15	13	Bananas	22	19	Bananas	22	19
	Melons and berries	16	5	Melons and berries	17	5	Melons and berries	17	5
	Other fruit	40	18	Other fruit	44	20	Other fruit	44	20
Dairy									
	Milk, yogurt	202	85	Milk, yogurt	177	74	Milk, yogurt	0	0
	Cheese	16	60	Cheese	21	79	Cheese	0	0
	Other dairy	45	98	Other dairy	76	166	Other dairy	0	0
Protein									
	Red meat	137	342	Red meat	0	0	Red meat	0	0
	Poultry	57	125	Poultry	0	0	Poultry	0	0
	Fish	22	46	Fish	0	0	Fish	0	0
	Other	0	0	Other	0	0	Other	0	0
	Legumes	21	18	Legumes	94	81	Legumes	94	81
	Nuts and seeds	3.5	19	Nuts and seeds	6	33	Nuts and seeds	6	33
Fats									
	Table fats	4	34	Table fats	2	17	Table fats	2	17
	Salad dressing	9	30	Salad dressing	10	34	Salad dressing	10	34
	Other fats	13	115	Other fats	11	100	Other fats	11	100
Sugar									
	Sugars	3	13	Sugars	3	11	Sugars	3	11
	Candy	7	32	Candy	5	24	Candy	5	24
	Other sugar	15	60	Other sugar	11	46	Other sugar	11	46
Beverages									
	Fruit drinks and aids	89	32	Fruit drinks and aids	94	34	Fruit drinks and aids	94	34
	Other beverages	875	332	Other beverages	586	222	Other beverages	586	222
Alcohol									
	Wine	9.8	8	Wine	23	19	Wine	23	19
	Beer and ale	85	153	Beer and ale	74	133	Beer and ale	74	133
	Other alcohol	6	20	Other alcohol	34	113	Other alcohol	34	113
Weight in Grams		**2277**	**2711**		**2058**	**2311**		**1784**	**1992**

Information and data were extracted from these surveys based on the identified food categorizations and used to create the framework of the three studied diets—meat-based, vegetarian, and vegan (Table 4). Using Table 4, I created individual datasets for each diet and calculated the calories, wastage, and GHG emissions for each food item and the totals per food group.

For the meat-based diet, the column “Self-defined non-vegetarian” with the sub-column “Ate meat” was created from Table 4. Tables 5 and 6 show the meat-based diet numbers for actual consumption and scaled to 2,000 calories, respectively. Table 7 shows the emission amounts (in kilograms and percentages) converted into grams.

Table 5. Meat-based diet (actual consumption) (bold numbers in the wastage column represent the percentage of waste for each category by the USDA).

	Meat Based	Mass (g)	Calories	Wastage (produced / consumed in gm)	CO2 per g of food	Source for (CO2 per g of food)	GHG g/person/day consumed	GHG g/person/day produced
Grains				**0.449**				
	Yeast Bread and rolls	53	145	23.8	0.8	Nordic	44	68
	Cereals and pasta	72	94	32.3	0.9	Nordic	65	97
	Rice	23	30	10.3	3.5	Nordic	81	91
	Other grains	155	575	69.6	0.8	Nordic	119	188
Vegetables				**0.429**			0	
	Fried potatoes	25	78	10.7	0.2	Nordic	5	16
	Other white potatos	40	31	17.1	0.2	Nordic	8	26
	Dark green vegetables	12	4	5.1	3.2	Nordic	38	43
	Deep yellow vegetable	9	3	3.9	3.2	Nordic	28	32
	Tomato	30	5	12.9	5.6	LCA	168	181
	Lettuce	15	2	6.4	1.1	Nordic	17	23
	Green beans	7	2	3.0	0.6	LCA	4	7
	Corn, green peas	14	11	6.0	0.4	LCA	6	12
	Other vegetables	46	30	19.7	3.2	Nordic	146	165
Fruits				**0.408**				
	Citrus fruit and juices	69	31	28.2	1.0	Nordic	69	97
	Dried fruit	1	3	0.4	0.5	Nordic	1	1
	Apples	17	9	6.9	0.5	Nordic	9	16
	Bananas	15	13	6.1	0.5	Nordic	8	14
	Melons and berries	16	5	6.5	0.7	Nordic	11	18
	Other fruit	40	18	16.3	0.5	Nordic	22	38
Dairy				**0.449**				
	Milk, yogurt	202	85	90.8	1.0	Nordic	202	293
	Cheese	16	60	7.2	1.3	LCA	21	28
	Other dairy	45	98	20.2	1.0	Nordic	45	65
Protein				**0.351**				
	Red meat	137	342	48.1	37.3	LCA	5105	5153
	Poultry	57	125	20.0	4.8	LCA	274	294
	Fish	22	46	7.7	16.4	LCA	362	369
	Other	0	0	0.0			0	0
	Legumes	21	18	7.4	0.5	Nordic	10	17
	Nuts and seeds	3.5	19	1.2	0.5	Nordic	2	3
Fats				**0.613**			0	
	Table fats	4	34	2.4	6.7	LCA	26	29
	Salad dressing	9	30	5.4	6.7	LCA	59	65
	Other fats	13	115	7.8	6.7	LCA	85	93
Sugar				**0.695**			0	
	Sugars	3	13	2.4	1.6	LCA	5	8
	Candy	7	32	4.7	6.1	Nordic	41	46
	Other sugar	15	60	10.1	1.0	Nordic	14	24
Beverages								
	Fruit drinks and aids	89	32		0.14	Nordic	12	12
	Other beverages	875	332		0.14	Nordic	122	122
Alcohol								
	Wine	9.8	8		1.4	Nordic	13	13
	Beer and ale	85	153		1.4	Nordic	115	115
	Other alcohol	6	20		1.4	Nordic	8	8
TOTAL		**2277**	**2711**	**521**	**123**		**7370**	**7891**

Table 6. Meat-based diet scaled to 2,000 calories (bold numbers represent the percentage for each food category taken from the USDA).

	Meat Based	Mass (g)	Adjusted Weight to 2000 calories	Calories	Adjusted calories to 2000 calories	Wastage (consumed in gm)	Adjusted to 2000 cal Wastage	CO2 per g of food	Source for column G	GHG g/person/day consumed	Adjusted to 2000 calories GHG consumed	Adjusted to 2000 calories GHG produced
Grains			**0.73774**			**0.449**						
	Yeast Bread and rolls	53	39	145	107	24	18	0.8	Nordic	43.9	32.4	49.9
	Cereals and pasta	72	53	94	69	32	24	0.9	Nordic	64.7	47.7	71.6
	Rice	23	17	30	22	10	8	3.5	Nordic	80.7	59.6	67.2
	Other grains	155	114	575	424	70	51	0.8	Nordic	118.5	87.4	138.8
Vegetables						**0.429**				0.0		
	Fried potatoes	25	18	78	58	11	8	0.2	Nordic	5.2	3.9	11.8
	Other white potatos	40	30	31	23	17	13	0.2	Nordic	8.4	6.2	18.8
	Dark green vegetables	12	9	4	3	5	4	3.2	Nordic	38.0	28.0	31.8
	Deep yellow vegetable	9	7	3	2	4	3	3.2	Nordic	28.5	21.0	23.9
	Tomato	30	22	5	4	13	9	5.6	LCA	168.3	124.2	133.6
	Lettuce	15	11	2	1	6	5	1.1	Nordic	17.0	12.5	17.3
	Green beans	7	5	2	1	3	2	0.6	LCA	4.2	3.1	5.3
	Corn, green peas	14	10	11	8	6	4	0.4	LCA	6.0	4.4	8.9
	Other vegetables	46	34	30	22	20	15	3.2	Nordic	145.6	107.4	121.9
Fruits			0		0	**0.408**						
	Citrus fruit and juices	69	51	31	23	28.18	21	1.00	Nordic	69.0	50.9	71.7
	Dried fruit	1	1	3	2	0.41	0	0.54	Nordic	0.5	0.4	0.7
	Apples	17	13	9	7	6.94	5	0.54	Nordic	9.2	6.8	11.9
	Bananas	15	11	13	10	6.13	5	0.54	Nordic	8.2	6.0	10.5
	Melons and berries	16	12	5	4	6.54	5	0.69	Nordic	11.0	8.1	12.9
	Other fruit	40	30	18	13	16.34	12	0.54	Nordic	21.7	16.0	28.1
Dairy			0		0	**0.449**						
	Milk, yogurt	202	149	85	63	90.8	67	1.0	Nordic	202.0	149.0	216.0
	Cheese	16	12	60	44	7.2	5	1.3	LCA	21.0	15.5	20.8
	Other dairy	45	33	98	72	20.2	15	1.0	Nordic	45.0	33.2	48.1
Protein			0		0	**0.351**						
	Red meat	137	101	342	252	48.1	36	37.3	LCA	5104.6	3765.9	3801.4
	Poultry	57	42	125	92	20.0	15	4.8	LCA	274.2	202.3	217.0
	Fish	22	16	46	34	7.7	6	16.4	LCA	361.7	266.8	272.5
	Other	0	0	0	0	0.0	0			0.0	0.0	0.0
	Legumes	21	15	18	13	7.4	5	0.5	Nordic	9.5	7.0	12.5
	Nuts and seeds	3.5	3	19	14	1.2	1	0.5	Nordic	1.8	1.3	2.2
Fats			0		0	**0.613**				0.0	0.0	
	Table fats	3.9	3	34	25	2.4	2	6.7	LCA	26.2	19.3	21.1
	Salad dressing	8.8	6	30	22	5.4	4	6.7	LCA	59.1	43.6	47.6
	Other fats	12.7	9	115	85	7.8	6	6.7	LCA	85.3	63.0	68.7
Sugar			0		0	**0.695**						
	Sugars	3.4	3	13	10	2.4	2	1.6	LCA	5.3	3.9	5.7
	Candy	6.7	5	32	24	4.7	3	6.1	Nordic	40.9	30.2	33.6
	Other sugar	14.5	11	60	44	10.1	7	1.0	Nordic	14.1	10.4	17.8
Beverages			0		0							
	Fruit drinks and aids	89	66	32	24			0.14	Nordic	12.4	9.1	9.1
	Other beverages	875	646	332	245			0.14	Nordic	121.8	89.8	89.8
Alcohol			0		0							
	Wine	9.8	7	8	6			1.4	Nordic	13.2	9.8	9.8
	Beer and ale	85	63	153	113			1.4	Nordic	114.8	84.7	84.7
	Other alcohol	6	4	20	15			1.4	Nordic	8.1	6.0	6.0
Weight in Grams		**2277**	**1680**	**2711**	**2000**	**521**	**384**	**123**		**7370**	**5437**	**5821**

Table 7. Meat-based diet sample food emissions (Open LCA percents of the GHG emissions of a sampling of meat-based diet items).
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Contribution	Process	Amount	Unit
100.00%	Meat Haddad	0.07527	kg C...
49.49%	beef (farm type 23) - GLO	0.03726	kg C...
21.84%	flatfish fillet, fresh, in supermarket...	0.01644	kg C...
08.93%	rape seed oil, in supermarket - GLO	0.00672	kg C...
07.45%	tomato, standard - GLO	0.00561	kg C...
06.38%	chicken, fresh, in supermarket - GLO	0.00481	kg C...
02.09%	sugar, in supermarket - GLO	0.00157	kg C...
01.74%	cheese, in supermarket - GLO	0.00131	kg C...
00.79%	soy bean, from farm - GLO	0.00060	kg C...
00.58%	corn, at farm - US	0.00043	kg C...
00.56%	potatoes, in supermarket - GLO	0.00042	kg C...
00.15%	boiling of vegetables - GLO	0.00011	kg C...
-00.00%	full milk, in supermarket - GLO	-6.92861E-7	kg C...

For the vegetarian diet, the "Self-defined vegetarian" column with the "No meat" sub-column was produced. The table (Table 8) took into account all the USDA recommendations and guidelines in order to meet the nutritional value standards. The recommended portion amounts were converted into grams and then compared to the daily recommended food intake of the USDA and Haddad's data.

A vegan-based diet was fabricated from the "Self-defined vegetarian" column and used the "No meat" sub-column with one primary difference from the vegetarian diet. All dairy food items and cheeses were excluded from its list to be in compliance with the definition of what a vegan diet is and its acceptable food items. Table 9 lists vegan foods with their caloric intake per person per day.

Table 8. Vegetarian diet— list of vegetarian foods, weights, and calories per day.

	Vegetarian	Weight (g)	Calories
Grains			
	Yeast Bread and rolls	52	142
	Cereals and pasta	116	151
	Rice	51	67
	Other grains	135	501
Vegetables			
	Fried potatoes	7	22
	Other white potatos	32	25
	Dark green vegetables	28	9
	Deep yellow vegetables	19	6
	Tomato	38	6
	Lettuce	21	3
	Green beans	5	1
	Corn, green peas	13	10
	Other vegetables	87	57
Fruits			
	Citrus fruit and juices	102	46
	Dried fruit	5	15
	Apples	37	20
	Bananas	22	19
	Melons and berries	17	5
	Other fruit	44	20
Dairy			
	Milk, yogurt	177	74
	Cheese	21	79
	Other dairy	76	166
Protein			
	Red meat	0	0
	Poultry	0	0
	Fish	0	0
	Other	0	0
	Legumes	94	81
	Nuts and seeds	6	33
Fats			
	Table fats	2	17
	Salad dressing	10	34
	Other fats	11	100
Sugar			
	Sugars	3	11
	Candy	5	24
	Other sugar	11	46
Beverages			
	Fruit drinks and aids	94	34
	Other beverages	586	222
Alcohol			
	Wine	23	19
	Beer and ale	74	133
	Other alcohol	34	113
Weight in Grams		2058	2311

Table 9. Designed daily vegan diet—food items, weight, and calories per day.

	Vegan	Weight (g)	Calories
Grains			
	Yeast Bread and rolls	52	142
	Cereals and pasta	116	151
	Rice	51	67
	Other grains	135	501
Vegetables			
	Fried potatoes	7	22
	Other white potatos	32	25
	Dark green vegetables	28	9
	Deep yellow vegetable	19	6
	Tomato	38	6
	Lettuce	21	3
	Green beans	5	1
	Corn, green peas	13	10
	Other vegetables	87	57
Fruits			
	Citrus fruit and juices	102	46
	Dried fruit	5	15
	Apples	37	20
	Bananas	22	19
	Melons and berries	17	5
	Other fruit	44	20
Dairy			
	Milk, yogurt	0	0
	Cheese	0	0
	Other dairy	0	0
Protein			
	Red meat	0	0
	Poultry	0	0
	Fish	0	0
	Other	0	0
	Legumes	94	81
	Nuts and seeds	6	33
Fats			
	Table fats	2	17
	Salad dressing	10	34
	Other fats	11	100
Sugar			
	Sugars	3	11
	Candy	5	24
	Other sugar	11	46
Beverages			
	Fruit drinks and aids	94	34
	Other beverages	586	222
Alcohol			
	Wine	23	19
	Beer and ale	74	133
	Other alcohol	34	113
Weight in Grams		1784	1992

For measuring GHG emission impacts, the following actions were conducted:

1. Used an existing LCA model to evaluate and measure each food item.

2. Performed an LCA of the whole foods for human consumption using data from the Haddad surveys and the USDA Healthy Plate recommendations.
3. Ranked these diets in accordance with the level of environmental damage.

All the variables associated with each diet, such as production, transportation, refrigeration, and waste disposal, were considered in the construction and structure of the diet tables. The framework of the food product industry is illustrated in Figure 9. The processes include farm supply activities and measures actions necessary to raise livestock and crops with the further additions of processing, sub-processing, distribution, storage, and waste disposal.

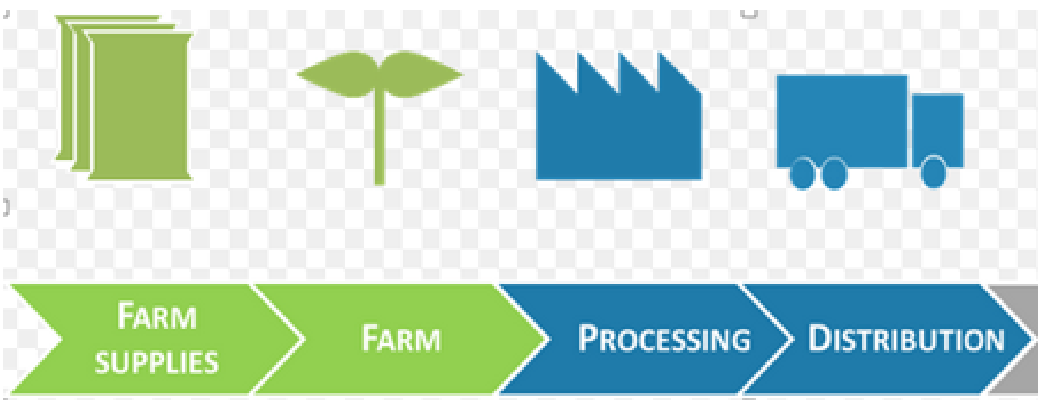

Figure 9. Food life cycle logistic diagram (http://www.lifecyclelogic.com.au/2013/11/lca-perspective-of-food/).

Open LCA GHG calculations draw on both the Open LCA database and a similar study done by Henrik Saxe and Thomas Larsen in Norway (Saxe, Larsen, & Mogensen, 2013). Together, both the calculations from the Open LCA and Saxe's Nordic calculations come from similar sources and databases such as Nexus, which collects global data. The Open LCA data reside at the Ecoinvent Center, Data Management Services, and are maintained by Green Delta (Open LCA, 2013). In Table 6, the "Source for column G” column indicates the data source for the calculation of carbon dioxide per gram of food. The results were calculated manually by inputting the data for each food item. For food items without available data in Open LCA, the data from the Nordic study, which was conducted with similar methods, were used. The percentage of daily GHG emissions was calculated for each diet consisting of the same food items.

The measurements, via a consistent application of the LCA tool, made certain the accuracy and validity of the research. The LCA output allowed me to develop recommendations, not only for the production processes of all the foods associated with these three diets, but also for an associated waste management strategy.

Limitations

Certain steps in the process were not included, such as cooking, packaging, retailing, and distribution. This study examines the GHG impact from the consumption of the three diets using current farm and production practices, but there are currently new farming technologies and techniques available that minimize the environmental impacts of agriculture. The location of the production of these foods is not pertinent in this study; however, it could affect emissions from transport and distribution. Large gaps exist between the amounts of GHG emissions produced by the different food groups. For example, animal-based foods typically produce a much higher level of GHG emissions compared to plant-based foods (Audsley. 2009). The higher emissions result from the larger areas required for growing crops to feed animals, along with non-efficient practices. In addition, through the digestive system of ruminants, a large quantity of methane is released (Scarborough, 2014).

Chapter III

Results

Comparison of three diets (meat-based, vegetarian, and vegan) demonstrates a positive relationship between the amounts of animal-based products consumed with their GHG emissions, using a 2,000-calorie diet as a standard (Table 10). The results exemplify that a diet containing meat consistently leads in carbon dioxide output and that a reduction in meat-based foods could contribute to climate change mitigation.

The impacts from food production for a vegan diet reflect the least GHG emissions when compared with that of a meat-based or vegetarian diet. As per Table 10, vegan diets produce carbon dioxide emissions of 1,798 g/person/day, showing the lowest amount of emissions, versus 7,891 g/person/day from a meat-based diet, demonstrating the highest emissions (Table 10). Vegetarian diets produce slightly higher emissions than a vegan diet, totaling 2,622 g/person/day. The largest individual food group contributor is red meats within the meat-based diet in the amount of 5,153 g/person/day. At the opposite end in a vegan diet, the lowest contributor to GHG emissions is potatoes.

Table 10. Three diets—GHG comparison.

	Meat Based	Mass (g)	GHG g/person/day from consumption	Vegetarian	Mass (g)	GHG g/person/day from consumption	Vegan	Mass (g)	GHG g/person/day from consumption
Grains									
	Yeast Bread and rolls	53	68	Yeast Bread and rolls	52	66.40	Yeast Bread and rolls	52	43.04
	Cereals and pasta	72	97	Cereals and pasta	116	156.32	Cereals and pasta	116	104.20
	Rice	23	91	Rice	51	201.96	Rice	51	179.04
	Other grains	155	188	Other grains	135	163.89	Other grains	135	103.24
Vegetables									
	Fried potatoes	25	16	Fried potatoes	7	4.47	Fried potatoes	7	1.47
	Other white potatos	40	26	Other white potatos	32	20.43	Other white potatos	32	6.72
	Dark green vegetables	12	43	Dark green vegetables	28	100.61	Dark green vegetables	28	88.61
	Deep yellow vegetable	9	32	Deep yellow vegetables	19	68.27	Deep yellow vegetable	19	60.13
	Tomato	30	181	Tomato	38	229.47	Tomato	38	213.18
	Lettuce	15	23	Lettuce	21	32.80	Lettuce	21	23.80
	Green beans	7	7	Green beans	5	5.14	Green beans	5	3.00
	Corn, green peas	14	12	Corn, green peas	13	11.16	Corn, green peas	13	5.59
	Other vegetables	46	165	Other vegetables	87	312.62	Other vegetables	87	275.33
Fruits									
	Citrus fruit and juices	69	97	Citrus fruit and juices	102	143.66	Citrus fruit and juices	102	102.00
	Dried fruit	1	1	Dried fruit	5	4.76	Dried fruit	5	2.72
	Apples	17	16	Apples	37	35.22	Apples	37	20.10
	Bananas	15	14	Bananas	22	20.94	Bananas	22	11.95
	Melons and berries	16	18	Melons and berries	17	18.63	Melons and berries	17	11.69
	Other fruit	40	38	Other fruit	44	41.88	Other fruit	44	23.91
Dairy									
	Milk, yogurt	202	293	Milk, yogurt	177	256.52	Milk, yogurt	0	0.00
	Cheese	16	28	Cheese	21	36.94	Cheese	0	0.00
	Other dairy	45	65	Other dairy	76	110.14	Other dairy	0	0.00
Protein									
	Red meat	137	5153	Red meat	0	0.00	Red meat	0	0.00
	Poultry	57	294	Poultry	0	0.00	Poultry	0	0.00
	Fish	22	369	Fish	0	0.00	Fish	0	0.00
	Other	0	0	Other	0	0.00	Other	0	0.00
	Legumes	21	17	Legumes	94	75.75	Legumes	94	42.73
	Nuts and seeds	3.5	3	Nuts and seeds	6	5.11	Nuts and seeds	6	3.00
Fats									
	Table fats	4	29	Table fats	2	14.67	Table fats	2	13.44
	Salad dressing	9	65	Salad dressing	10	73.33	Salad dressing	10	67.20
	Other fats	13	93	Other fats	11	80.66	Other fats	11	73.92
Sugar									
	Sugars	3	8	Sugars	3	6.79	Sugars	3	4.71
	Candy	7	46	Candy	5	34.02	Candy	5	30.54
	Other sugar	15	24	Other sugar	11	18.32	Other sugar	11	10.68
Beverages									
	Fruit drinks and aids	89	12	Fruit drinks and aids	94	13.08	Fruit drinks and aids	94	13.08
	Other beverages	875	122	Other beverages	586	81.55	Other beverages	586	81.55
Alcohol						0.00			
	Wine	9.8	13	Wine	23	31.07	Wine	23	31.07
	Beer and ale	85	115	Beer and ale	74	99.96	Beer and ale	74	99.96
	Other alcohol	6	8	Other alcohol	34	45.93	Other alcohol	34	45.93
TOTAL		**2277**	**7891**	**TOTAL**	**2058**	**2622**	**TOTAL**	**1784**	**1798**

Table 11 lists the total wastage and GHG food emissions for all three diets per person per year. The total wastage calculations show that the highest GHG food emissions come from a meat-based diet's waste in the amount of 2,880 kg/person/year, followed by the vegetarian diet with 957 kg/person/year and then the vegan diet with smallest contribution of 809 kg/person/year. The difference between the meat-based diet and vegan diet is quite large, indicating that meat-based diets produce 2,000 kg more GHG emissions than a vegan diet per person/year.

Table 11. Yearly totals of wastage and GHG emissions.

Meat Based	Wastage (produced/ consumed in KG/Year	GHG Kg/person/Year from consumption	Vegetarian	Wastage (produced/ consumed in KG/Year	GHG Kg/person/Year from consumption	Vegan	Wastage (produced/ consumed in KG/Year	GHG Kg/person/Year from consumption
	190.11	2,880.07		198.72	957.20		153.79	809.88

Meat-Based Diet Findings

The GHG emissions analysis conducted in LCA produced results for a meat-based diet consumed in the US by one person per day. Of all food emissions, beef production contributes the largest amount of carbon dioxide (49%) to total GHG emissions (Table 12). These metrics indicate a significant influence on the global warming effects of carbon dioxide by meat-based products.

Table 12. Meat-based diet—actual GHG emissions.

Contribution	Process	Amount	Unit
100.00%	Meat Haddad	0.07527	kg C...
49.49%	beef (farm type 23) - GLO	0.03726	kg C...
21.84%	flatfish fillet, fresh, in supermarket...	0.01644	kg C...
08.93%	rape seed oil, in supermarket - GLO	0.00672	kg C...
07.45%	tomato, standard - GLO	0.00561	kg C...
06.38%	chicken, fresh, in supermarket - GLO	0.00481	kg C...
02.09%	sugar, in supermarket - GLO	0.00157	kg C...
01.74%	cheese, in supermarket - GLO	0.00131	kg C...
00.79%	soy bean, from farm - GLO	0.00060	kg C...
00.58%	corn, at farm - US	0.00043	kg C...
00.56%	potatoes, in supermarket - GLO	0.00042	kg C...
00.15%	boiling of vegetables - GLO	0.00011	kg C...
-00.00%	full milk, in supermarket - GLO	-6.92861E-7	kg C...

As part of the analysis, there are input flows and output flows within the process. Various chemicals are consumed and produced throughout food production and are concurrently emitted. As seen in Table 13, the top two chemicals from the consumption of a meat diet are ruthenium-103 in the amount of 4.21 kg and methane at 1 kg. The Open LCA data differentiate two categories of output being emitted into the air and water. This analysis expresses in kilograms the amount of the discharged emissions.

Table 13. Meat-based diet—chemicals released.

Outputs

Flow	Category	Sub-category	Unit	Amount
Ruthenium-103	water	unspecified	kBq	4.21082E...
Methane, chlorodifluoro-, HCFC-22	air	high population density	kg	1.05530E...
COD, Chemical Oxygen Demand	water	unspecified	kg	1.17242E-6
1-Pentene	air	high population density	kg	1.89383E...
Amino compounds	air	unspecified	kg	5.60440E-9
Hydrogen peroxide	air	high population density	kg	1.50127E...
Fluoride	water	unspecified	kg	5.35389E-8
Yttrium-90	water	unspecified	kBq	1.45118E...
Magnesium	water	unspecified	kg	9.86314E-7
soy Meal - GLO	agricultural	Animal production\Anim...	kg	0.00409
Hydrogen	air	high population density	kg	7.67787E...
Methane, trifluoro-, HFC-23	air	high population density	kg	5.61402E...
Butyrolactone	air	high population density	kg	3.34020E...
2-Nitrobenzoic acid	air	high population density	kg	1.51216E...
Methane, tetrachloro-, R-10	water	unspecified	kg	9.50501E...
Cyanide	air	high population density	kg	1.27600E...
Heat, waste	water	unspecified	MJ	0.00296
sugar beet (farm type 20-1) - GLO	agricultural	Operations\Farming on s...	kg	0.00029
Cyanoacetic acid	air	high population density	kg	6.33449E...
Hydrogen-3, Tritium	water	unspecified	kBq	0.01504
Potassium-40	water	unspecified	kBq	3.47586E-8
straw (farm type 20-1) - GLO	agricultural	Operations\Farming on s...	kg	0.00016
Cesium-134	water	unspecified	kBq	5.12958E-7
Benzene, dichloro	air	high population density	kg	7.74745E...
byproduct: Soy oil - GLO	others	Residual data - do not use	kg	0.00089
Nitrite	water	unspecified	kg	4.11370E...
Radon-220	air	high population density	kBq	1.39127E...
Propane	air	high population density	kg	3.16922E-9
pork (farm type 20-1) - GLO	agricultural	Operations\Farming on s...	kg	0.00084
Sodium	air	high population density	kg	2.32410E...
Silicon	air	high population density	kg	2.24741E...
Ammonia	air	high population density	kg	4.93137E-8
bread wheat (farm type 20-1) - GLO	agricultural	Operations\Farming on s...	kg	0.00049
rape seed (farm type 20-1) - GLO	agricultural	Operations\Farming on s...	kg	0.00011

Furthermore, LCA calculations enable the breakdown of the composite gases and clearly demonstrate specific gas emissions from the production of the daily foods consumed. A further breakdown of GHG emissions displays the following percent results, establishing the three main gases produced from meat-based diets: nitrous oxide (42.8%), carbon dioxide (38.9%), and methane (10.9%) (Table 14).

Table 14. Meat-based diet—gases emitted.

Impact category: Global Warming — Cut-off 0.00 %

Contribution	Flow	Amount	Unit
42.83%	Dinitrogen monoxide	0.03224	kg CO2 eq
38.95%	Carbon dioxide	0.02932	kg CO2 eq
10.90%	Methane	0.00821	kg CO2 eq

Another categorical analysis of the meat-based diet reveals that the main contributors towards global warming are in five main groupings—beef production, fertilizer, electricity by natural gas, and other (Figure 10).

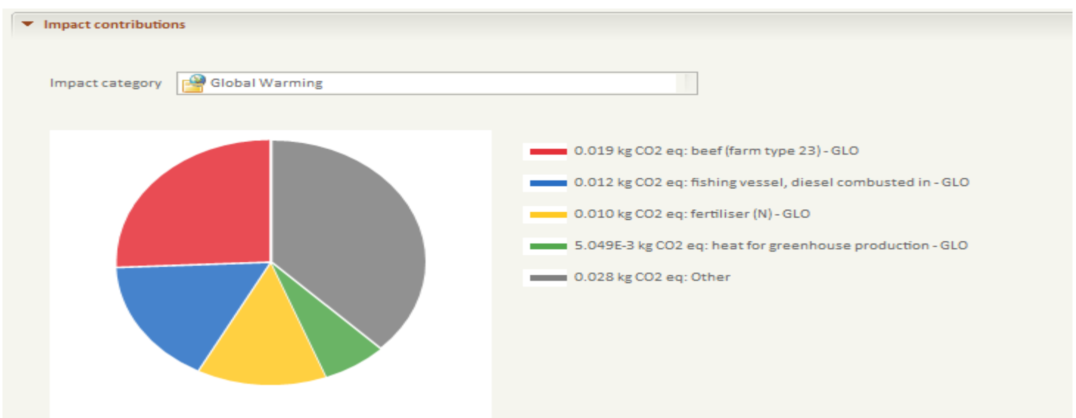

Figure 10. Meat-based diet activity additions to atmospheric carbon dioxide.

Further analysis of the meat-based diet demonstrates which food types contribute the most, percentage-wise, within food-processing activities. As Table 15 shows, beef is the highest contributor with its 25.7% of daily kg/CO_2.

Table 15. Daily GHG emissions—meat-based diet sample.

Impact contributions

Impact category: Global Warming   Cut-off: 0 %

Contribution	Process	Amount	Unit
25.70%	beef (farm type 23) - GLO	0.01934	kg CO2 eq
16.56%	fishing vessel, diesel combusted in - GLO	0.01247	kg CO2 eq
13.57%	fertiliser (N) - GLO	0.01021	kg CO2 eq
06.71%	heat for greenhouse production - GLO	0.00505	kg CO2 eq
04.78%	rape seed, conventional, from farm - GLO	0.00360	kg CO2 eq
04.75%	traction - GLO	0.00358	kg CO2 eq
04.51%	electricity (natural gas) - GLO	0.00340	kg CO2 eq
04.16%	soy bean, from farm - GLO	0.00313	kg CO2 eq
04.13%	diesel (kg) - GLO	0.00311	kg CO2 eq

Vegan Diet Findings

The LCA calculations for a vegan diet reveal that the two food groups producing the most GHG pollutants are tomatoes (213 g/person/day) and other vegetables (275 g/person/day) (Table 16). The explanation for a vegan diet having the greatest mass is that vegetables' bulk is greater than that of a comparable omnivorous intake. Looking at the carbon dioxide emissions per g of food in Table 16, the highest emitters are fats with 6.7 g of carbon dioxide per gram of food per day. The lowest emissions within the vegan diet are green peas, corn, and potatoes. Comparing the actual consumption table and the scaled-to-2,000-calories table, the GHG emission results remain very similar (Table 17).

Table 16. Vegan diet GHG emissions—actual consumption.

Vegan	Mass (g)	CO2 per g of food	GHG g/person/day from consumption
Yeast Bread and rolls	52	1	66.40
Cereals and pasta	116	1	156.32
Rice	51	4	201.96
Other grains	135	1	163.89
Fried potatoes	7	0	4.47
Other white potatos	32	0	20.43
Dark green vegetables	28	3	100.61
Deep yellow vegetable	19	3	68.27
Tomato	38	6	229.47
Lettuce	21	1	32.80
Green beans	5	1	5.14
Corn, green peas	13	0	11.16
Other vegetables	87	3	312.62
Citrus fruit and juices	102	1.00	143.66
Dried fruit	5	0.54	4.76
Apples	37	0.54	35.22
Bananas	22	0.54	20.94
Melons and berries	17	0.69	18.63
Other fruit	44	0.54	41.88
Milk, yogurt	0	1.0	0.00
Cheese	0	1.3	0.00
Other dairy	0	1.0	0.00
Red meat	0	37.3	0.00
Poultry	0	4.8	0.00
Fish	0	16.4	0.00
Other	0		0.00
Legumes	94	0.5	75.75
Nuts and seeds	6	0.5	5.11
Table fats	2	6.7	14.67
Salad dressing	10	6.7	73.33
Other fats	11	6.7	80.66
Sugars	3	1.6	6.79
Candy	5	6.1	34.02
Other sugar	11	1.0	18.32
Fruit drinks and aids	94	0.14	13.08
Other beverages	586	0.14	81.55
Wine	23	1.4	31.07
Beer and ale	74	1.4	99.96
Other alcohol	34	1.4	45.93
TOTAL	**1784**	**123**	**2219**

Table 17. Vegan diet adjusted to 2,000 calories/day.

Vegan	Mass (g)	Adjusted Weight to 2000 calories	CO2 per g of food	GHG g/person/day	Adjusted to 2000 calories GHG produced
		1.00399			
Yeast Bread and rolls	52	45	0.8	43.04	66.57
Cereals and pasta	116	100	0.9	104.20	156.74
Rice	51	44	3.5	179.04	202.67
Other grains	135	117	0.8	103.24	164.30
		0			
Fried potatoes	7	6	0.2	1.47	4.48
Other white potatos	32	28	0.2	6.72	20.46
Dark green vegetables	28	24	3.2	88.61	100.97
Deep yellow vegetables	19	16	3.2	60.13	68.51
Tomato	38	33	5.6	213.18	230.32
Lettuce	21	18	1.1	23.80	32.90
Green beans	5	4	0.6	3.00	5.15
Corn, green peas	13	11	0.4	5.59	11.18
Other vegetables	87	75	3.2	275.33	313.72
		0			
Citrus fruit and juices	102	88	1.00	102.00	144.07
Dried fruit	5	4	0.54	2.72	4.77
Apples	37	32	0.54	20.10	35.30
Bananas	22	19	0.54	11.95	20.99
Melons and berries	17	15	0.69	11.69	18.68
Other fruit	44	38	0.54	23.91	41.97
		0			
Milk, yogurt	0	0	1.0	0.00	0.00
Cheese	0	0	1.3	0.00	0.00
Other dairy	0	0	1.0	0.00	0.00
		0			
Red meat	0	0	37.3	0.00	0.00
Poultry	0	0	4.8	0.00	0.00
Fish	0	0	16.4	0.00	0.00
Other	0	0		0.00	0.00
Legumes	94	81	0.5	42.73	75.92
Nuts and seeds	6	5	0.5	3.00	5.12
		0			
Table fats	2	2	6.7	13.44	14.72
Salad dressing	10	9	6.7	67.20	73.60
Other fats	11	10	6.7	73.92	80.96
		0			
Sugars	3	3	1.6	4.71	6.81
Candy	5	4	6.1	30.54	34.14
Other sugar	11	10	1.0	10.68	18.36
Fruit drinks and aids	94	81	0.14	13.08	13.13
Other beverages	586	507	0.14	81.55	81.87
		0			
Wine	23	20	1.4	31.07	31.19
Beer and ale	74	64	1.4	99.96	100.36
Other alcohol	34	29	1.4	45.93	46.11
TOTAL	**1784**	**1544**	**123**	**1798**	**2226**

Vegetarian Diet Findings

The vegetarian diet was found to produce GHG emissions between meat-based and vegan diets. Within the vegetarian diet, the primary food group contributing to the GHG footprint is “other vegetables” in the amount of 275 grams of g/person/day.

Analysis—Contributions to Global Warming

Comparing the three-diet results from the Open LCA tool analysis confirms the original hypothesis that meat-based diets contribute the most GHG emissions to global warming (Figure 11). The second part of the hypothesis was contradicted in this analysis, though, which stated that a vegan diet would have the least effect on global warming. As Figure 11 shows, the smallest contributor to global warming is the vegetarian diet, producing only 8.2 kg of carbon dioxide.

Even though the vegan diet actually produces less GHG emissions per person per day (Table 10), Open LCA calculated the vegan diet as contributing slightly more to global warming then the vegetarian diet because a higher mass of food is consumed when practicing a vegan diet. However, the largest contributor to global warming of the three is still by far the meat-based diet.

LCIA category	Meat	Vegan	Vegetarian	Unit
Global Warming	4.96140e+3	9.78130e+2	8.25675e+2	kg CO2 eq

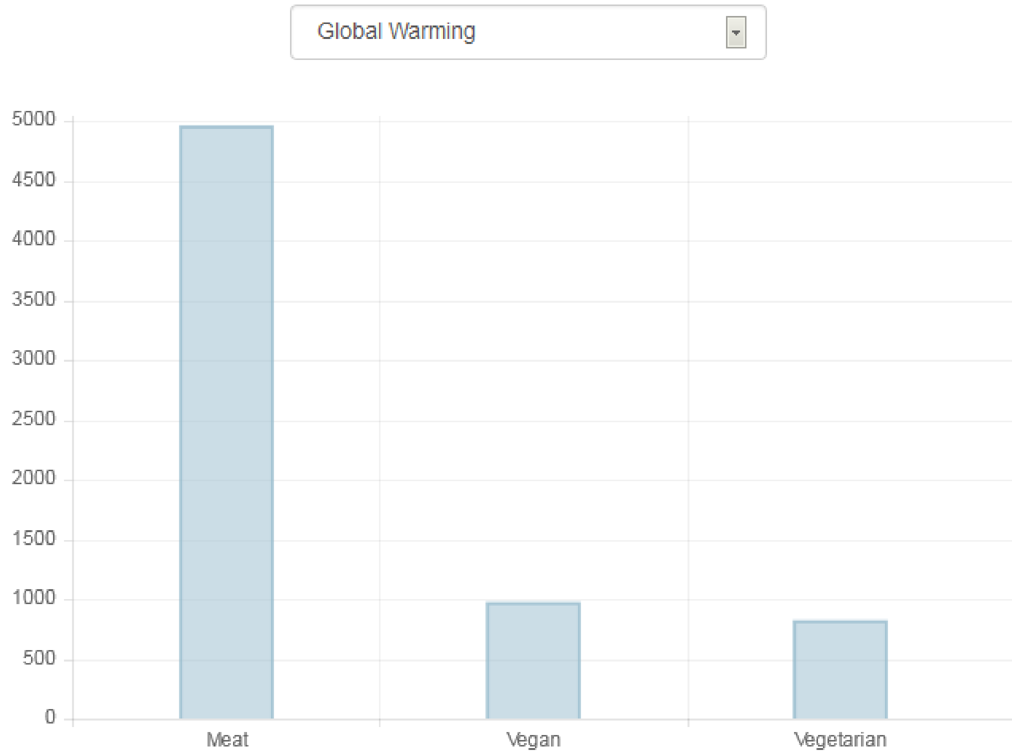

Figure 11. LCA-calculated output for each diet’s impact on global warming.

Chapter IV

Discussion

Based on the analysis of numerous studies and including my own research, the largest contributor to GHG emissions is a meat-based diet, primarily due to the beef production process, consumption, transportation, and waste. I believe that it would be beneficial to conduct further studies regarding a solution to mitigating this meat-related GHG emission issue. This future research could add educational value by bringing awareness to the public about the impacts of an individual's food choice. All of the studies referred to in this paper urge an appeal to the importance of further investigating the GHG emissions that come from particular food types and how GHG emissions from food production and consumption patterns need to be reduced due to their associated impact on climate change and the Earth's environment—and this study adds to the appeal.

Recommendations

The continuously growing demand and concurrent high dependency on natural resources for food production should be a wake-up call for all humankind to review the current food processes and look for alternative food sources, diets, and more efficient and effective methods for food production. Based on the results and findings of this research (and the others with similar focus), I make the following recommendations on how to lower food-caused GHG emissions:

1. Reduce meat consumption. All of the precious studies—and this study—found that red meats produce the highest GHG emissions and therefore contribute the most to food-caused global warming. By lowering the demand for red meats alone, we would support a natural shift toward alternative food groups with less emissions impact.
2. Deliver the awareness gained from these findings to the public concerning the environmental consequences of an individual's food choices. Based on this knowledge, there should be a percentage of people who will shift their food preferences in order to contribute to resource sustainability.
3. Create a "red meat tax" for funding sustainable farming practices and better waste management of livestock ranching. This tax should be at an amount that is comparably significant with the prices of red meat in order to stimulate a shift away from choosing this food type.
4. Encourage plant-based alternatives to red meat products to lower the GHG food footprint. For example, there are many food producers offering items such as soy-based foods as possible substitutes.
5. Encourage personal responsibility for action and behavior changes and attitude and awareness adjustments, related to food choices and their associated global warming impacts.
6. Revise current ranching processes and implement more efficient or alternative cattle raising methods and the procedures for transportation, storage, and wastage (considering that most of the GHG emissions from meat come

entirely from the fermentation process, with methane coming from livestock and from the fertilization of crops needed to feed the livestock).

7. Enforce more stringently the GHG Protocol standards developed by the World Resources Institute and the World Business Council on Sustainable Development for companies and organizations involved in the food chain process in order to encourage more effective processes and procedures that would help reduce GHG emissions (WRI and WBCSD, 2013).

Research Limitations

In the food choice area, there could be some subjectivity and bias. Lifestyle and personal dietary choices can influence food category composition. Other biases might be cultural or nationality based.

Categorization of the foods for each diet

Foods were selected based on the caloric and nutrient consumption guidelines taken from similar research and the USDA recommendations. Presumptively, taking into consideration the fact that some of the food items came from Haddad's study, there is a possibility that certain foods were missed that could have influenced the results of this research.

Examples of foods and diets that were not considered and analyzed are organic foods, locally grown foods, gluten-free foods, mono-food diets, and other existing food types that form additional diets that could potentially have different GHG footprints. Additionally, some consumers have food allergies and are not able to consume certain foods properly—another exception that might potentially have influenced the results/outcome.

Open LCA tool

The Open LCA tool has some limitations in encompassing data. While calculating GHG emissions for each food item, some information is unavailable regarding transportation or transportation distances, as actual foods may differ in required distances traveled. Certain steps in the food chain process are also not considered that might have different outcomes.

Some food items are not available in the LCA database and therefore were substituted with the results from the LCA analysis of the Nordic study. As shown earlier in the paper, a column was created in the tables listing the sources of the calculations: whether from the LCA database or from the Nordic study. The fact that data come from two different sources could have influenced the results.

Alternative tools to Open LCA, such as the Cool Farm Tool and others, exist for this type research. A simultaneous study with an alternative tool could possibly add value by giving comparative additional information about the food-prints of the analyzed foods and diets. Their use could potentially change or corroborate the results and/or conclusions of the research.

Self-populated spreadsheet for food categorization

There are additional variables that could be considered and implemented into the spreadsheet, such as additional diet categories like Mediterranean or Paleo diet, for example. Other dieter criteria that could be considered for the spreadsheet include age, demographics, education, etc. Therefore, the consideration of those additional not-used variables could have potentially affected the results of this research.

Time of year and geographical area

Despite the fact that seasons do not substantially affect food availability in modern USA, during winter there can be lower availability of fruits and vegetables. Depending on the time of the year, people can have different food preferences and nutritional needs. This aspect could potentially affect the choices within the categories and consequently influence the results of the study.

The chosen geographical area, the US, affects the results as people from some states have different food preferences and food habits. Additionally, the US may be too broad of a focus for this type research as opposed to focusing on one state or one city.

Data

Data availability is one of the main limitations for this research as it is the most time-consuming part to gather, and some data are limited or not available. For example, there is no publicly available information on how many people are vegans, vegetarians, and meat-eaters within the US.

Limited food life cycle steps

While analyzing and measuring GHG food emissions from the different diets, I used a limited number of steps for the whole life cycle assessment. For example, in my research, transport to the grocery store and home was left out, as was cooking. Including these steps should add value to this type of research and could possibly change the results.

Social factors

Social factors refer to items such as economic welfare, religious choices, social status, and others that are not taken into consideration while determining the make-up of each diet. Therefore, calculations including these vagaries might reveal a different impact.

Ideas for future research

Based on these results I can foresee opportunities for further research, such as examining different geographical regions and additional diet types including organic, local, imported, gluten- free, etc. In addition there are many data gaps, and thus potential opportunities, to collect more data via surveys of actual vegetarian, vegan, organic, gluten-free and other types of dieters. Simultaneously, there may be challenges in conducting these studies such as deficiencies of past data, or a lack of participation in studies obtaining or discovering people's food habits and every day food routines. In order to stimulate participation in future studies, our government could create grants for universities enabling deeper studies in these areas.

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Appendix A: Meat Based diet -Actual

	Meat Based	Weight (g)	Calories	Wastage (produced/ consumed in gm)	CO2 per g of food	Source for column G	GHG g/person/day consumed	GHG g/person/day produced
Grains				**0.449**				
	Yeast Bread and rolls	53	145	24	1	Nordic	43.9	67.7
	Cereals and pasta	72	94	32	1	Nordic	64.7	97.0
	Rice	23	30	10	4	Nordic	80.7	91.1
	Other grains	155	575	70	1	Nordic	118.5	188.2
Vegetables				**0.429**			0.0	
	Fried potatoes	25	78	11	0	Nordic	5.2	16.0
	Other white potatos	40	31	17	0	Nordic	8.4	25.5
	Dark green vegetables	12	4	5	3	Nordic	38.0	43.1
	Deep yellow vegetables	9	3	4	3	Nordic	28.5	32.3
	Tomato	30	5	13	6	LCA	168.3	181.2
	Lettuce	15	2	6	1	Nordic	17.0	23.4
	Green beans	7	2	3	1	LCA	4.2	7.2
	Corn, green peas	14	11	6	0	LCA	6.0	12.0
	Other vegetables	46	30	20	3	Nordic	145.6	165.3
Fruits				**0.408**				
	Citrus fruit and juices	69	31	28.18	1.00	Nordic	69.0	97.2
	Dried fruit	1	3	0.41	0.54	Nordic	0.5	1.0
	Apples	17	9	6.94	0.54	Nordic	9.2	16.2
	Bananas	15	13	6.13	0.54	Nordic	8.2	14.3
	Melons and berries	16	5	6.54	0.69	Nordic	11.0	17.5
	Other fruit	40	18	16.34	0.54	Nordic	21.7	38.1
Dairy				**0.449**				
	Milk, yogurt	202	85	90.8	1.0	Nordic	202.0	292.8
	Cheese	16	60	7.2	1.3	LCA	21.0	28.1
	Other dairy	45	98	20.2	1.0	Nordic	45.0	65.2
Protein				**0.351**				
	Red meat	137	342	48.1	37.3	LCA	5104.6	5152.8
	Poultry	57	125	20.0	4.8	LCA	274.2	294.2
	Fish	22	46	7.7	16.4	LCA	361.7	369.4
	Other	0	0	0.0			0.0	0.0
	Legumes	21	18	7.4	0.5	Nordic	9.5	16.9
	Nuts and seeds	3.5	19	1.2	0.5	Nordic	1.8	3.0
Fats				**0.613**			0.0	
	Table fats	3.9	34	2.4	6.7	LCA	26.2	28.6
	Salad dressing	8.8	30	5.4	6.7	LCA	59.1	64.5
	Other fats	12.7	115	7.8	6.7	LCA	85.3	93.1
Sugar				**0.695**			0.0	
	Sugars	3.4	13	2.4	1.6	LCA	5.3	7.7
	Candy	6.7	32	4.7	6.1	Nordic	40.9	45.6
	Other sugar	14.5	60	10.1	1.0	Nordic	14.1	24.1
Beverages								
	Fruit drinks and aids	89	32		0.14	Nordic	12.4	12.4
	Other beverages	875	332		0.14	Nordic	121.8	121.8
Alcohol								
	Wine	9.8	8		1.4	Nordic	13.2	13.2
	Beer and ale	85	153		1.4	Nordic	114.8	114.8
	Other alcohol	6	20		1.4	Nordic	8.1	8.1
Weight in Grams		**2277**	**2711**	**521**	**123**		**7370**	**7891**

Appendix B: Vegetarian diet –Actual

Vegetarian	Weight (g)	Calories	Wastage (produced / consumed in gm)	CO2 per g of food	GHG g/person/day consumed	GHG g/person/day produced
			0.449			
Yeast Bread and rolls	52	142	23	1	43.04	66.40
Cereals and pasta	116	151	52	1	104.20	156.32
Rice	51	67	23	4	179.04	201.96
Other grains	135	501	61	1	103.24	163.89
			0.429			
Fried potatoes	7	22	3	0	1.47	4.47
Other white potatos	32	25	14	0	6.72	20.43
Dark green vegetables	28	9	12	3	88.61	100.61
Deep yellow vegetables	19	6	8	3	60.13	68.27
Tomato	38	6	16	6	213.18	229.47
Lettuce	21	3	9	1	23.80	32.80
Green beans	5	1	2	1	3.00	5.14
Corn, green peas	13	10	6	0	5.59	11.16
Other vegetables	87	57	37	3	275.33	312.62
			0.408			
Citrus fruit and juices	102	46	41.66	1.00	102.00	143.66
Dried fruit	5	15	2.04	0.54	2.72	4.76
Apples	37	20	15.11	0.54	20.10	35.22
Bananas	22	19	8.99	0.54	11.95	20.94
Melons and berries	17	5	6.94	0.69	11.69	18.63
Other fruit	44	20	17.97	0.54	23.91	41.88
			0.449			
Milk, yogurt	177	74	79.5	1.0	177.00	256.52
Cheese	21	79	9.4	1.3	27.51	36.94
Other dairy	76	166	34.1	1.0	76.00	110.14
			0.351			
Red meat	0	0	0.0	37.3	0.00	0.00
Poultry	0	0	0.0	4.8	0.00	0.00
Fish	0	0	0.0	16.4	0.00	0.00
Other	0	0	0.0		0.00	0.00
Legumes	94	81	33.0	0.5	42.73	75.75
Nuts and seeds	6	33	2.1	0.5	3.00	5.11
			0.613			
Table fats	2	17	1.2	6.7	13.44	14.67
Salad dressing	10	34	6.1	6.7	67.20	73.33
Other fats	11	100	6.7	6.7	73.92	80.66
			0.695			
Sugars	3	11	2.1	1.6	4.71	6.79
Candy	5	24	3.5	6.1	30.54	34.02
Other sugar	11	46	7.6	1.0	10.68	18.32
Fruit drinks and aids	94	34		0.14	13.08	13.08
Other beverages	586	222		0.14	81.55	81.55
					0.00	0.00
Wine	23	19		1.4	31.07	31.07
Beer and ale	74	133		1.4	99.96	99.96
Other alcohol	34	113		1.4	45.93	45.93
	2058	**2311**	**544**	**123**	**2078**	

Appendix C: Vegan Diet-Actual

Vegan	Weight (g)	Calories	Wastage (produced / consumed in gm)	CO2 per g of food	GHG g/person/day consumed	GHG g/person/day produced
			0.449			
Yeast Bread and rolls	52	142	23	1	43.04	66.40
Cereals and pasta	116	151	52	1	104.20	156.32
Rice	51	67	23	4	179.04	201.96
Other grains	135	501	61	1	103.24	163.89
			0.429			
Fried potatoes	7	22	3	0	1.47	4.47
Other white potatos	32	25	14	0	6.72	20.43
Dark green vegetables	28	9	12	3	88.61	100.61
Deep yellow vegetables	19	6	8	3	60.13	68.27
Tomato	38	6	16	6	213.18	229.47
Lettuce	21	3	9	1	23.80	32.80
Green beans	5	1	2	1	3.00	5.14
Corn, green peas	13	10	6	0	5.59	11.16
Other vegetables	87	57	37	3	275.33	312.62
			0.408			
Citrus fruit and juices	102	46	41.66	1.00	102.00	143.66
Dried fruit	5	15	2.04	0.54	2.72	4.76
Apples	37	20	15.11	0.54	20.10	35.22
Bananas	22	19	8.99	0.54	11.95	20.94
Melons and berries	17	5	6.94	0.69	11.69	18.63
Other fruit	44	20	17.97	0.54	23.91	41.88
			0.449			
Milk, yogurt	0	0	0.0	1.0	0.00	0.00
Cheese	0	0	0.0	1.3	0.00	0.00
Other dairy	0	0	0.0	1.0	0.00	0.00
			0.351			
Red meat	0	0	0.0	37.3	0.00	0.00
Poultry	0	0	0.0	4.8	0.00	0.00
Fish	0	0	0.0	16.4	0.00	0.00
Other	0	0	0.0		0.00	0.00
Legumes	94	81	33.0	0.5	42.73	75.75
Nuts and seeds	6	33	2.1	0.5	3.00	5.11
			0.613			
Table fats	2	17	1.2	6.7	13.44	14.67
Salad dressing	10	34	6.1	6.7	67.20	73.33
Other fats	11	100	6.7	6.7	73.92	80.66
			0.695			
Sugars	3	11	2.1	1.6	4.71	6.79
Candy	5	24	3.5	6.1	30.54	34.02
Other sugar	11	46	7.6	1.0	10.68	18.32
Fruit drinks and aids	94	34		0.14	13.08	13.08
Other beverages	586	222		0.14	81.55	81.55
Wine	23	19		1.4	31.07	31.07
Beer and ale	74	133		1.4	99.96	99.96
Other alcohol	34	113		1.4	45.93	45.93
	1784	1992	421	123	1798	

Appendix D: Meat based diet-Scaled to 2000 calories

	Meat Based	Weight (g)	Adjusted Weight to 2000	Calories	Adjusted calories to 2000	Wastage (produced/ consumed in gm)	Adjusted to 2000 cal Wastage	CO2 per g of food	Source for column G	GHG g/person/day consumed	Adjusted to 2000 calories GHG consumed	Adjusted to 2000 calories GHG produced
Grains			**0.737735**			**0.449**						
	Yeast Bread and rolls	53	39	145	107	24	18	1	Nordic	43.9	32.4	49.9
	Cereals and pasta	72	53	94	69	32	24	1	Nordic	64.7	47.7	71.6
	Rice	23	17	30	22	10	8	4	Nordic	80.7	59.6	67.2
	Other grains	155	114	575	424	70	51	1	Nordic	118.5	87.4	138.8
Vegetables						**0.429**				0.0		
	Fried potatoes	25	18	78	58	11	8	0	Nordic	5.2	3.9	11.8
	Other white potatos	40	30	31	23	17	13	0	Nordic	8.4	6.2	18.8
	Dark green vegetables	12	9	4	3	5	4	3	Nordic	38.0	28.0	31.8
	Deep yellow vegetables	9	7	3	2	4	3	3	Nordic	28.5	21.0	23.9
	Tomato	30	22	5	4	13	9	6	LCA	168.3	124.2	133.6
	Lettuce	15	11	2	1	6	5	1	Nordic	17.0	12.5	17.3
	Green beans	7	5	2	1	3	2	1	LCA	4.2	3.1	5.3
	Corn, green peas	14	10	11	8	6	4	0	LCA	6.0	4.4	8.9
	Other vegetables	46	34	30	22	20	15	3	Nordic	145.6	107.4	121.9
Fruits			0		0	**0.408**						
	Citrus fruit and juices	69	51	31	23	28.18	21	1.00	Nordic	69.0	50.9	71.7
	Dried fruit	1	1	3	2	0.41	0	0.54	Nordic	0.5	0.4	0.7
	Apples	17	13	9	7	6.94	5	0.54	Nordic	9.2	6.8	11.9
	Bananas	15	11	13	10	6.13	5	0.54	Nordic	8.2	6.0	10.5
	Melons and berries	16	12	5	4	6.54	5	0.69	Nordic	11.0	8.1	12.9
	Other fruit	40	30	18	13	16.34	12	0.54	Nordic	21.7	16.0	28.1
Dairy			0		0	**0.449**						
	Milk, yogurt	202	149	85	63	90.8	67	1.0	Nordic	202.0	149.0	216.0
	Cheese	16	12	60	44	7.2	5	1.3	LCA	21.0	15.5	20.8
	Other dairy	45	33	98	72	20.2	15	1.0	Nordic	45.0	33.2	48.1
Protein			0		0	**0.351**						
	Red meat	137	101	342	252	48.1	36	37.3	LCA	5104.6	3765.9	3801.4
	Poultry	57	42	125	92	20.0	15	4.8	LCA	274.2	202.3	217.0
	Fish	22	16	46	34	7.7	6	16.4	LCA	361.7	266.8	272.5
	Other	0	0	0	0	0.0	0			0.0	0.0	0.0
	Legumes	21	15	18	13	7.4	5	0.5	Nordic	9.5	7.0	12.5
	Nuts and seeds	3.5	3	19	14	1.2	1	0.5	Nordic	1.8	1.3	2.2
Fats			0		0	**0.613**				0.0	0.0	
	Table fats	3.9	3	34	25	2.4	2	6.7	LCA	26.2	19.3	21.1
	Salad dressing	8.8	6	30	22	5.4	4	6.7	LCA	59.1	43.6	47.6
	Other fats	12.7	9	115	85	7.8	6	6.7	LCA	85.3	63.0	68.7
Sugar			0		0	**0.695**						
	Sugars	3.4	3	13	10	2.4	2	1.6	LCA	5.3	3.9	5.7
	Candy	6.7	5	32	24	4.7	3	6.1	Nordic	40.9	30.2	33.6
	Other sugar	14.5	11	60	44	10.1	7	1.0	Nordic	14.1	10.4	17.8
Beverages			0		0							
	Fruit drinks and aids	89	66	32	24		29	0.14	Nordic	12.4	9.1	38.6
	Other beverages	875	646	332	245		290	0.14	Nordic	121.8	89.8	379.8
Alcohol			0		0							
	Wine	9.8	7	8	6		3	1.4	Nordic	13.2	9.8	13.0
	Beer and ale	85	63	153	113		28	1.4	Nordic	114.8	84.7	112.9
	Other alcohol	6	4	20	15		2	1.4	Nordic	8.1	6.0	8.0
Weight in Grams		**2277**	**1680**	**2711**	**2000**	**521**	**737**	**123**		**7370**	**5437**	**6174**

Appendix E: Vegetarian diet-Scaled to 2000 calories

Vegetarian	Weight (g)	Adjusted Weight to 2000	Calories	Adjusted calories to 2000	Wastage (produced / consumed in gm)	Adjusted to 2000 cal Wastage	CO2 per g of food	GHG g/person/day consumed	Adjusted to 2000 calories GHG consumed	Adjusted to 2000 calories GHG produced
		0.865505			**0.449**					
Yeast Bread and rolls	52	45	142	123	23	20	1	43.04	37.25	57.47
Cereals and pasta	116	100	151	131	52	45	1	104.20	90.19	135.30
Rice	51	44	67	58	23	20	4	179.04	154.96	174.79
Other grains	135	117	501	433	61	52	1	103.24	89.35	141.85
		0		0	**0.429**					
Fried potatoes	7	6	22	19	3	3	0	1.47	1.27	3.87
Other white potatos	32	28	25	21	14	12	0	6.72	5.82	17.69
Dark green vegetables	28	24	9	8	12	10	3	88.61	76.70	87.08
Deep yellow vegetables	19	16	6	5	8	7	3	60.13	52.04	59.09
Tomato	38	33	6	5	16	14	6	213.18	184.51	198.60
Lettuce	21	18	3	2	9	8	1	23.80	20.60	28.39
Green beans	5	4	1	1	2	2	1	3.00	2.60	4.45
Corn, green peas	13	11	10	9	6	5	0	5.59	4.84	9.66
Other vegetables	87	75	57	49	37	32	3	275.33	238.30	270.57
		0		0	**0.408**					
Citrus fruit and juices	102	88	46	40	41.66	36	1.00	102.00	88.28	124.34
Dried fruit	5	4	15	13	2.04	2	0.54	2.72	2.35	4.12
Apples	37	32	20	17	15.11	13	0.54	20.10	17.40	30.48
Bananas	22	19	19	17	8.99	8	0.54	11.95	10.35	18.12
Melons and berries	17	15	5	5	6.94	6	0.69	11.69	10.12	16.13
Other fruit	44	38	20	17	17.97	16	0.54	23.91	20.69	36.25
		0		0	**0.449**					
Milk, yogurt	177	153	74	64	79.5	69	1.0	177.00	153.19	222.02
Cheese	21	18	79	68	9.4	8	1.3	27.51	23.81	31.98
Other dairy	76	66	166	143	34.1	30	1.0	76.00	65.78	95.33
		0		0	**0.351**					
Red meat	0	0	0	0	0.0	0	37.3	0.00	0.00	0.00
Poultry	0	0	0	0	0.0	0	4.8	0.00	0.00	0.00
Fish	0	0	0	0	0.0	0	16.4	0.00	0.00	0.00
Other	0	0	0	0	0.0	0		0.00	0.00	0.00
Legumes	94	81	81	70	33.0	29	0.5	42.73	36.98	65.57
Nuts and seeds	6	5	33	28	2.1	2	0.5	3.00	2.60	4.42
		0		0	**0.613**					
Table fats	2	2	17	15	1.2	1	6.7	13.44	11.63	12.69
Salad dressing	10	9	34	30	6.1	5	6.7	67.20	58.16	63.47
Other fats	11	10	100	86	6.7	6	6.7	73.92	63.98	69.81
		0		0	**0.695**					
Sugars	3	3	11	10	2.1	2	1.6	4.71	4.08	5.88
Candy	5	4	24	21	3.5	3	6.1	30.54	26.43	29.44
Other sugar	11	10	46	39	7.6	7	1.0	10.68	9.24	15.86
		0		0						
Fruit drinks and aids	94	81	34	29		37	0.14	13.08	11.32	47.87
Other beverages	586	507	222	192		228	0.14	81.55	70.58	298.45
		0		0						
Wine	23	20	19	16		9	1.4	31.07	26.89	35.83
Beer and ale	74	64	133	115		29	1.4	99.96	86.51	115.29
Other alcohol	34	29	113	98		13	1.4	45.93	39.75	52.97
	2058	**1782**	**2311**	**2000**	**544**	**787**	**123**	**2078**	**1799**	**2585**

Appendix F: Vegan diet-Scaled to 2000 calories

Vegan	Weight (g)	Adjusted Weight to 2000	Calories	Adjusted calories to 2000	Wastage (produced / consumed in gm)	Adjusted to 2000 cal Wastage	CO2 per g of food	GHG g/person/day	Adjusted to 2000 calories GHG consumed	Adjusted to 2000 calories GHG produced
		1.00399			0.449					
Yeast Bread and rolls	52	45	142	143	23	20	1	43.04	43.21	66.57
Cereals and pasta	116	100	151	152	52	45	1	104.20	104.62	156.74
Rice	51	44	67	67	23	20	4	179.04	179.76	202.67
Other grains	135	117	501	503	61	52	1	103.24	103.65	164.30
		0		0	0.429					
Fried potatoes	7	6	22	22	3	3	0	1.47	1.48	4.48
Other white potatos	32	28	25	25	14	12	0	6.72	6.75	20.46
Dark green vegetables	28	24	9	9	12	10	3	88.61	88.97	100.97
Deep yellow vegetables	19	16	6	6	8	7	3	60.13	60.37	68.51
Tomato	38	33	6	6	16	14	6	213.18	214.03	230.32
Lettuce	21	18	3	3	9	8	1	23.80	23.90	32.90
Green beans	5	4	1	1	2	2	1	3.00	3.01	5.15
Corn, green peas	13	11	10	10	6	5	0	5.59	5.61	11.18
Other vegetables	87	75	57	57	37	32	3	275.33	276.43	313.72
		0		0	0.408					
Citrus fruit and juices	102	88	46	46	41.66	36	1.00	102.00	102.41	144.07
Dried fruit	5	4	15	15	2.04	2	0.54	2.72	2.73	4.77
Apples	37	32	20	20	15.11	13	0.54	20.10	20.18	35.30
Bananas	22	19	19	19	8.99	8	0.54	11.95	12.00	20.99
Melons and berries	17	15	5	5	6.94	6	0.69	11.69	11.73	18.68
Other fruit	44	38	20	20	17.97	16	0.54	23.91	24.00	41.97
		0		0	0.449					
Milk, yogurt	0	0	0	0	0.0	0	1.0	0.00	0.00	0.00
Cheese	0	0	0	0	0.0	0	1.3	0.00	0.00	0.00
Other dairy	0	0	0	0	0.0	0	1.0	0.00	0.00	0.00
		0		0	0.351					
Red meat	0	0	0	0	0.0	0	37.3	0.00	0.00	0.00
Poultry	0	0	0	0	0.0	0	4.8	0.00	0.00	0.00
Fish	0	0	0	0	0.0	0	16.4	0.00	0.00	0.00
Other	0	0	0	0	0.0	0		0.00	0.00	0.00
Legumes	94	81	81	81	33.0	29	0.5	42.73	42.90	75.92
Nuts and seeds	6	5	33	33	2.1	2	0.5	3.00	3.01	5.12
		0		0	0.613					
Table fats	2	2	17	18	1.2	1	6.7	13.44	13.49	14.72
Salad dressing	10	9	34	34	6.1	5	6.7	67.20	67.47	73.60
Other fats	11	10	100	100	6.7	6	6.7	73.92	74.22	80.96
		0		0	0.695					
Sugars	3	3	11	12	2.1	2	1.6	4.71	4.73	6.81
Candy	5	4	24	24	3.5	3	6.1	30.54	30.66	34.14
Other sugar	11	10	46	46	7.6	7	1.0	10.68	10.72	18.36
		0		0						
Fruit drinks and aids	94	81	34	34		37	0.14	13.08	13.13	13.13
Other beverages	586	507	222	223		228	0.14	81.55	81.87	81.87
		0		0						
Wine	23	20	19	19		9	1.4	31.07	31.19	31.19
Beer and ale	74	64	133	134		29	1.4	99.96	100.36	100.36
Other alcohol	34	29	113	114		13	1.4	45.93	46.11	46.11
	1784	1544	1992	2000	421	680	123	1798	1805	2226