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Original Research

Culinary FEVER (Food Emissions Visualization Education Resource): A Unique Educational Tool to Empower the Public to Reimagine Food Choices for Environmental Sustainability

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Abstract: This paper provides an educational tool to help the public better understand the greenhouse gas (GHG) emissions from the food they choose to eat on a daily basis. Using balloons filled with the representative volume of GHGs emitted through the growth, harvest, production, and transportation of various food choices, participants are able to visualize the impact of their food choices without the burden of analyzing a graph or table. Additionally, displaying the typical GHG metric of equivalent kilograms of carbon dioxide (kg CO_2e) in the volume this gas would occupy at standard pressure and temperature allows for greater clarity in these results. Distribution methods for this visualization tool described herein range from science classrooms to Science, Technology, Engineering, and Mathematics (STEM) outreach events and to restaurants and grocery stores. Several tools are provided as part of this research, including a spreadsheet that incorporates these calculations, presentation slides, a worksheet for the in-class method, and poster images for eateries. For each method, participants are asked to select a protein, vegetable, and starch option to fill their plate and the resulting GHG volume is then calculated based on their selections. This provides context and allows for discussion and reshaping of our contributions to climate change.

Keywords: *Sustainable Food, Greenhouse Gas Emissions, STEM Education, STEM Outreach, Climate Change, Restaurants, Visualization Tool*

Introduction

Climate Change Science

The average US household produces approximately 1.3 tons (1179 kg) of CO_2e emissions per household per year. Just how much gas is this? To visualize that volume of gas, 1.3 tons of CO_2e would fill a single balloon 10.3 meters in diameter.

Climate change and its impact on humanity is one of the greatest obstacles we face as a society (IPCC 2018; Hawken 2017). Adapting quickly to the consequences of climate change is critical for ensuring the availability of ample food and fresh water for future generations. Greenhouse gases (GHGs), including carbon dioxide (CO_2) and methane (CH_4), impact the Earth's energy balance by absorbing outgoing radiation and re-releasing it, sometimes back

COMMON GROUND

to the Earth's surface. This recirculation of thermal energy back to the Earth's surface causes the Earth's average temperature to increase, resulting in global warming.

Today's atmospheric CO_2 levels are over 400 parts per million (ppm) (IPCC 2018). Figure 1 shows atmospheric CO_2 concentrations and natural variations over the past 800,000 years. When Homo sapiens first arrived 300,000 years ago, the Earth's CO_2 atmospheric concentration was approximately 250 ppm. Today's levels are clearly not within the range of natural variation. Current humans are inhabiting an Earth far different from anything our ancestors experienced in the past.

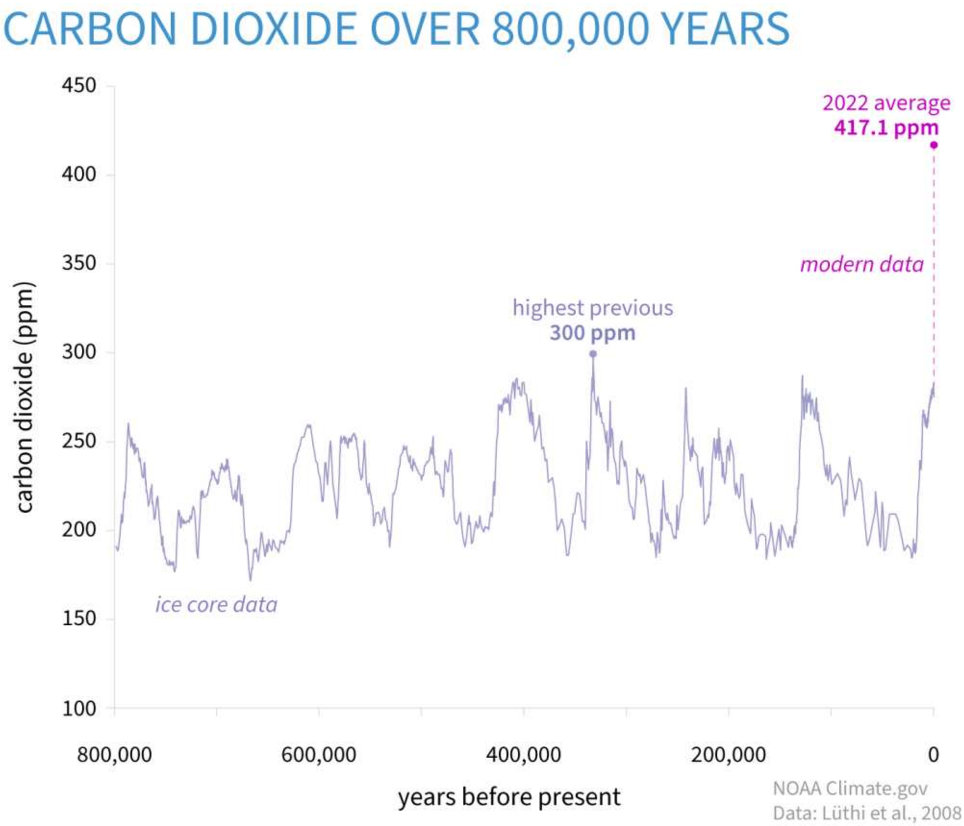

Figure 1: Carbon Dioxide over 800,000 Years
Source: Modified from Lindsey 2023

Until recently, much of the concern about CO_2 emissions at the general public level and recommendations for improvement revolved around renewable energy (Kaplan 1999; Gardner and Lehr 2013), house lighting (Liu, Keoleian, and Saitou 2017), vehicles (US Department of Transportation, n.d.), and single-use items (Spokas 2008; Anderson 2008). While these are important, food is also a critical component contributing to our GHG emissions.

Food and Climate Change Connection

Our society makes important food choices multiple times a day in deciding what to consume. Collectively, these choices can have an enormous impact on our global emissions (Garnett 2011; Tubiello et al. 2021; Halpern et al. 2022). If this significance is properly and widely communicated, it can help mitigate future runaway emissions (NCAR & UCAR Science Education 2015).

Food and climate change are linked in a critical bilateral relationship. First, our food system contributes 10–30 percent of global GHG emissions (Clark and Tilman 2017), making it one of the most prominent sectors contributing to global warming. Second, the effects of climate change, such as global warming and altered plant hardiness zones, will negatively impact the ability to grow sufficient food for our growing population (Binns et al. 2021).

This paper seeks to provide a tool to increase public literacy about how food connects to our climate system, empowering the public to make food choices that can reduce this negative impact. This paper describes a visualization tool based on sound scientific concepts that can be used in classrooms, public events, restaurants, and any other venue to allow people to quickly see the difference in emissions ranging from a beef hamburger to a bowl of black beans without having to decipher a chart or graph. This simple communication tool can help the general public better understand the wide-ranging impact of their food choices on climate change. By decoding this information and providing this computational tool, creative humans can develop their own applications of this knowledge in unlimited ways.

A Visual Learning Tool to Improve Understanding of Food Emissions

The Power of a Visual Tool

Mirroring the habits of scientific literature, many resources that try to convey the impact of our food choices to the public do so with a plethora of numbers and figures using the metric of "a kilogram of CO_2 equivalent (kg CO_2e)." While necessary for a clear standard across scientific disciplines, the usage highlights a few issues in distribution among the general population. The first being "what the heck does a kilogram of equivalent CO_2 look like?" As it turns out, many of us share in this confusion.

First, the kilogram (kg) is an internationally recognized unit of mass that is largely unfamiliar to the United States—a nation that contributes heavily to climate change (Boden, Marland, and Andres 1999; Union of Concerned Scientists 2023). Even countries that utilize the kilogram may not necessarily know what a kilogram of gas looks like. In order to demystify this concept, balloons will provide the public with a familiar visual resource that reshapes an ambiguous unit of mass to an easily visualized volumetric representation. This resource can then be applied time and time again to help discern new emissions data and to make appropriate choices thereafter.

Additionally, the *equivalent* (e) part of the equivalent kilogram of CO_2 is a standardized unit used to consolidate all GHG emissions into one metric and place them on an equal playing field when considering their impact on the Earth's temperature. For example, methane (CH_4), which is more than twenty-five times more effective than CO_2 at trapping heat and releasing it back to the Earth over a one-hundred-year period (IPCC 2013). Translated to the comparable amount of CO_2 (*equivalent* CO_2), this would provide the same Earth-warming over the same time period. Consolidating this metric allows researchers to easily compare and track emissions from various GHG molecules and is included in the final balloon size calculation of this tool. However, the simplicity of this visualization tool makes it easier to provide users with a visual cue of the impact of their food choices without the burden of this complicated explanation of conversions.

Current Visualization Resources

The concept of utilizing visual aids to understand complex concepts is not a new one. School-aged children are taught their fractions with various kinds of toys: base ten blocks, counting chips, fraction wheels, etc. This use of visual aids can also be seen in higher education with diagrams, infographics, and class demonstrations. Experienced presenters avidly utilize pictures and props to engage effectively with their audiences. These methods develop a point of reference for the target audience, helping them to grasp concepts and deepen their understanding (Guo et al. 2020; Saleh 2011). The following examples are mainstream methods of distribution that would benefit in using an appropriate visualization tool.

"3.52 [kg] of carbon sounds minimal. How much damage could it do?" says Sara Pascoe, an English-born comedian, in a 2021 documentary released by BBC Horizon entitled *Feast to Save the Planet* (Overton 2021). Although the UK adopted the metric system in 1965, Pascoe and fellow participants still exhibit obvious confusion when faced with this data (USMA 2020). Even after seeing both a bar chart and a number representing her meal's kilogram of CO_2e emissions, it still was not clear to her just how much gas the numbers were representing. Seeing this confusion within a country that commonly uses the metric system highlights just how important visualization tools are in an effort to increase climate change literacy and action.

In addition to documentaries, there have been steps to increase widespread knowledge of the impact of our food choices via food calculators. There are many strewn throughout the internet, but a popular example is the release of Chipotle's "Real Footprint" calculator in the fall of 2020. While this launch has increased discourse around the topic, the calculator itself leaves something to be desired. Instead of comparing the various food options available at the restaurant, it compares foods from other fast-food restaurants. The goal for Chipotle's calculator is less to educate consumers on GHG emissions and more to encourage choosing Chipotle over competitors. A more comprehensible and impartial example of these calculators is a diet carbon footprint calculator from the BBC News that aims to inform consumers without the underlying business strategy (Stylianou, Guibourg, and Briggs 2023). This calculator does try to relate the emissions to everyday things that the general population understands, such as water usage or your car's gas consumption. Features of particular interest include allowing the user to choose one food item at a time, calculating the kilogram of emissions for a whole year, and comparing that food item with other foods in the same group. Our proposed tools calculate the emissions for one meal as opposed to emissions for eating one avocado per week for a whole year. The motivation for our work is to fill a need in distributing this information in a digestible way to the general public, and we believe that being able to see your daily impact provides a simpler concept to understand.

The tools currently available fail to link GHG emissions to effective visualization imagery, but rather than rendering these tools obsolete, the provided spreadsheet augments these tools by allowing the user to input the CO2e from any application and receive the associated balloon diameter or number of balloons. This can be used for applications beyond the food system (i.e., transportation and lighting). Please see the third tab in the calculation spreadsheet provided in the Google Drive link in the Appendix of this paper.

Culinary FEVER: Food Emissions Visualization Education Resource

This summary is provided for the reader to better understand the background. If you want to geek out with the details, here it is. Do not be intimidated by this; the spreadsheet provided per this research calculates the results for the user who would prefer to avoid calculational complications.

CleanMetrics Website

The basis of our calculations was taken from an emissions calculator by CleanMetrics (see Figure 2), a free online interactive website based on Carbon Scope Data (CleanMetrics, n.d.).This database is a comprehensive life-cycle inventory (LCI) that provides carbon, energy, and water data for numerous materials, including many North American-based foods. Output from the CleanMetrics calculation was used to build the spreadsheet for this visualization tool. For portion sizes, ¼ lb each of protein, vegetable, and starch were considered to be one serving size. Based on CleanMetric default, 1,400 miles was used as the average transportation distance and 30.4 percent was used for the amount of food waste at the consumer level (USDA, n.d.).

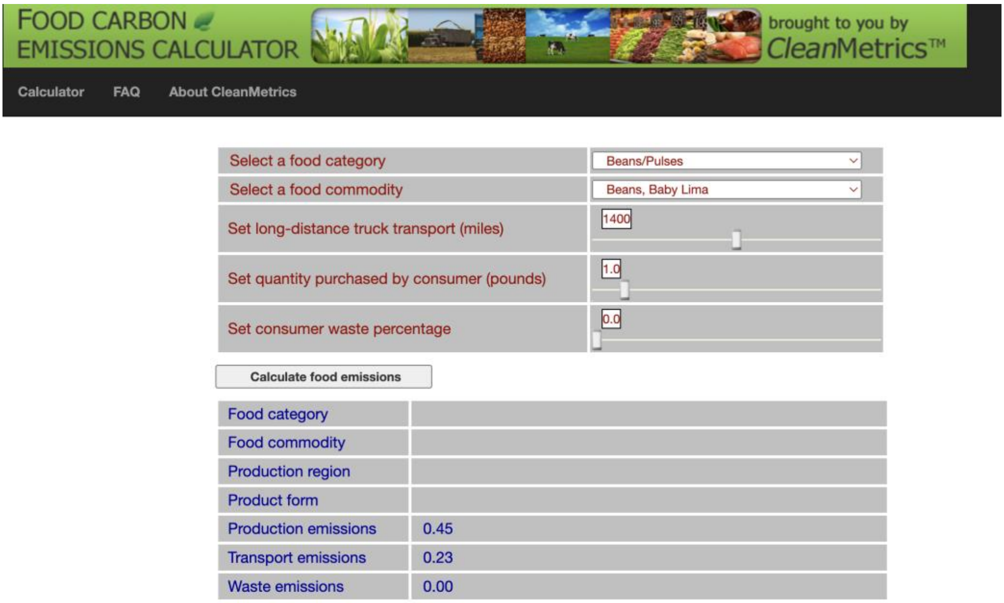

Figure 2: Screenshot from CleanMetrics Online Food Calculation Tool
Source: CleanMetrics, n.d.

It is important to note that this tool uses the CleanMetrics data without modification. In particular, this is complicated for the proteins presented herein. The emission data for beans is based on beans in their dry form. The emission data for beef and poultry is based on raw, frozen meat. These food states incorporate some inaccuracies within CleanMetrics data, which results in all of these protein sources having higher emissions than they would if we had modified these values. For the beans, presenting data as re-hydrated beans would increase their weight and therefore drop their emissions per ¼ lb serving. For the beef and poultry, editing the meat to an unfrozen state would also drop their emissions per ¼ lb serving. Relying on the CleanMetrics vetting process for their data was more reliable than trying to make these modifications, and the magnitude of the differences between these food choices would not change appreciably.

Step through the Calculations

The spreadsheet containing the calculations for the foods we chose to include in our tool can be found in the provided spreadsheet and printed table of results in the Google Drive folder referenced in the Appendix of this paper. A screenshot of this tool is found in Figure 3. If this spreadsheet is not available, Figures 9 through 12 show the results for every possible food combination in this resource.

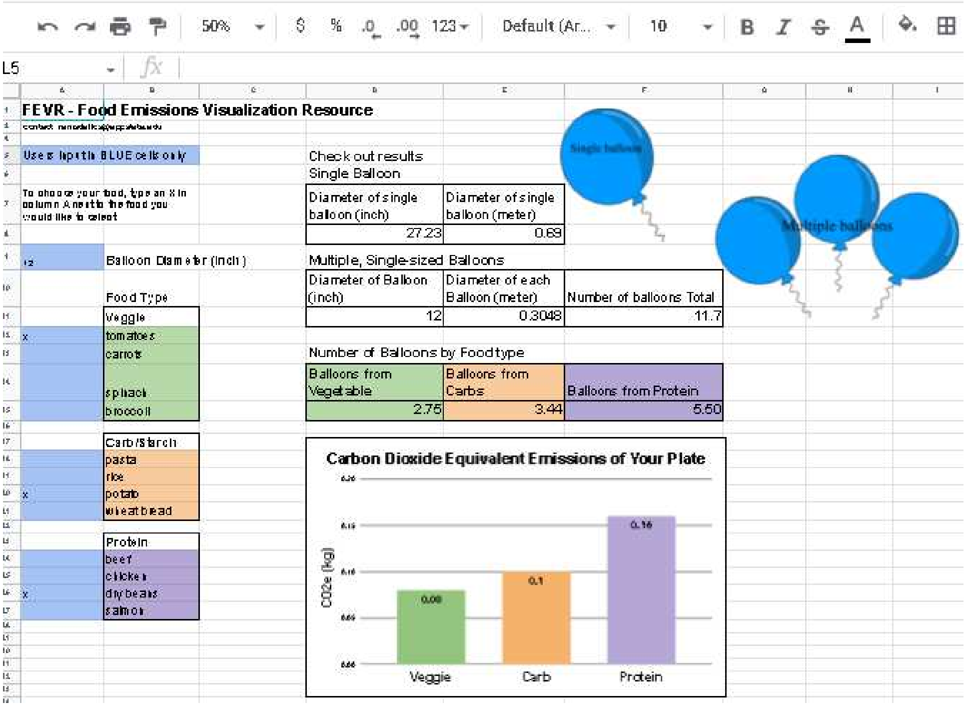

Figure 3: Screenshot of FEVER Spreadsheet Provided as Open-Source Content for Anyone Wishing to Utilize This Tool
Note: In this image, tomatoes, potatoes, and lentils are chosen.

(1) Ideal gas equation:

$$PV = nRT \Rightarrow V = \frac{nRT}{P}$$

(2) Convert from grams to moles:

$$1\ kg\ CO_2 = 1000\ g\ CO_2$$

$$1000\ g\ CO_2\left(\frac{1\ mol}{44g}\right) = 22.7\ mol\ CO_2$$

(3) Calculate V at standard conditions (STP) from the Ideal gas equation in step 1

$$V = \frac{(22.7\ mol)(0.0821\ \frac{L^*atm}{mol^*K})(273K)}{1\ atm} = 509\ L\ at\ 273K,\ 1\ atm$$

(4) Volume of a sphere

$$V = (\tfrac{4}{3})\pi r^3$$

$$509\ L = (\tfrac{4}{3})(\pi)(r^3)$$

$$4.95\ m = r$$

$$Diameter = (r)(2) = (4.95\ m)(2)$$

$$(4.95\ m)(2) = 9.90\ m\ in\ diameter$$

(5) Multiple Balloons

$$Number\ of\ balloons\ (d\ diameter,\ in\ meters) = \frac{Total\ Emissions\ Volume\ (m^3)}{(\frac{1}{6}\pi d^3)}$$

Figure 4: Overview of Calculations Contained in the FEVER Spreadsheet

Methods of Distribution

All proposed activities associated with this educational tool aim to provide the participant with a greater understanding of the individual impact of our food choices on the environment. The in-class activity involves the participants in the scientific calculation, allowing for a more technical understanding. Meanwhile, the outreach and foodservice variations use balloons as a visual tool, removing the mathematical calculations and making it more digestible for a wider audience. Please refer to the material provided in the Appendix for links to a prepared presentation, worksheet, and table posters which can be used to augment these distribution activities.

In-classroom Distribution

This in-class activity is intended for upper-level high school or introductory college-level physics or chemistry classrooms. This concept can be used in younger classrooms, but it would have to be adapted based on their ability to perform the necessary chemistry-based calculations. A modified Science, Technology, Engineering, and Mathematics (STEM) outreach distribution approach (see section "STEM Outreach or Museum Distribution") may be a better method for the K-8 audience.

In preparation for this session, the facilitator is encouraged to personalize this presentation material included with this resource by adding additional slides appropriate for the course in which they are using this resource. Additionally, the facilitator should download and print an appropriate number of copies of the paper worksheets. Keeping with the theme of sustainability, these are intended to be printed two-sided, cut in half, and used for multiple events, reducing the amount of paper used for this activity.

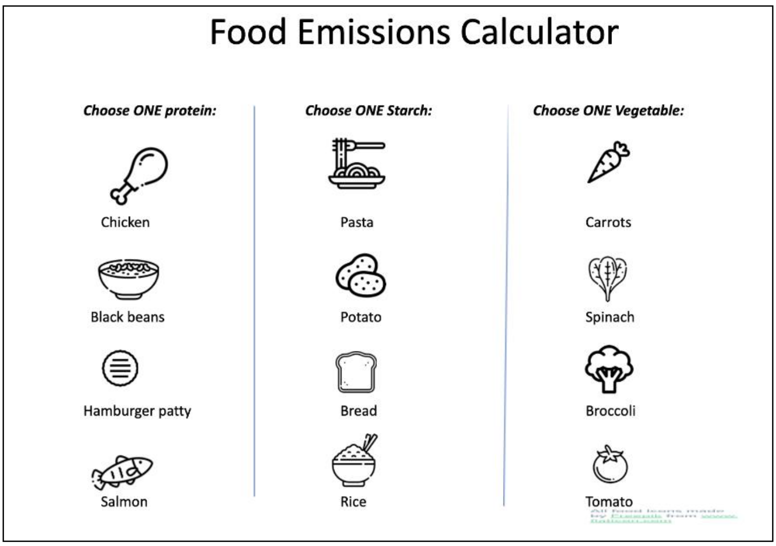

Figure 5: Classroom Worksheet (Front Side) and Presentation Slide—Food Options

TOTAL emissions for your selection (protein + starch + vegetable) = ____________ kg CO_2
(instructor to provide this information)

Grams of CO_2 (1000 g = 1 kg) = ____________ g CO_2

Moles of CO_2 (44 g / mole CO_2) = __________ moles CO_2

Volume CO_2 at T = 75° F(300K), P = 1 atm (PV = nRT & R=0.08206 L atm $mol^{-1}K^{-1}$) = _______ Liter CO_2

Volume CO_2 in m^3 (1000 L = 1 m^3) = ______ m^3 CO_2

Radius of balloon filled with this amount of CO_2 at atmospheric conditions ($V = \frac{4}{3} \pi r^3$) = ______ m radius

Diameter of balloon filled with this amount of CO_2 at atmospheric conditions = ______ m diameter
Number of 12-inch (0.3 m) balloons filled with this amount of CO_2 at atmospheric conditions = ______

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Figure 6: Classroom Worksheet (Back Side—Chemistry Calculations

This lesson would begin by asking the students if they know the amount of CO_2e that is emitted for them to eat an average meal. Students can then be encouraged to make approximations of the size of the balloon that would hold this quantity of CO_2 at atmospheric pressure and temperature. Time should be provided to discuss their initial thoughts in small groups.

Next, the instructor can distribute the worksheet (Figures 5 and 6) and project the image of food options from the provided presentation. There are three columns: proteins, starches, and vegetables. Within each column, there are four choices:

- Protein: beef, chicken, salmon, black beans
- Starch: pasta, potato, bread, rice
- Vegetables: carrot, spinach, broccoli, tomato

Students then choose their imaginary meal—one item from each column—by circling their choices on their worksheet. An additional benefit of this exercise is the recognition of which food items are a protein, starch, or a vegetable and how to build a balanced plate. Once this is done, the instructor can go to the next slide in the presentation (Figure 7), which gives the kilogram of CO_2e for each food choice.

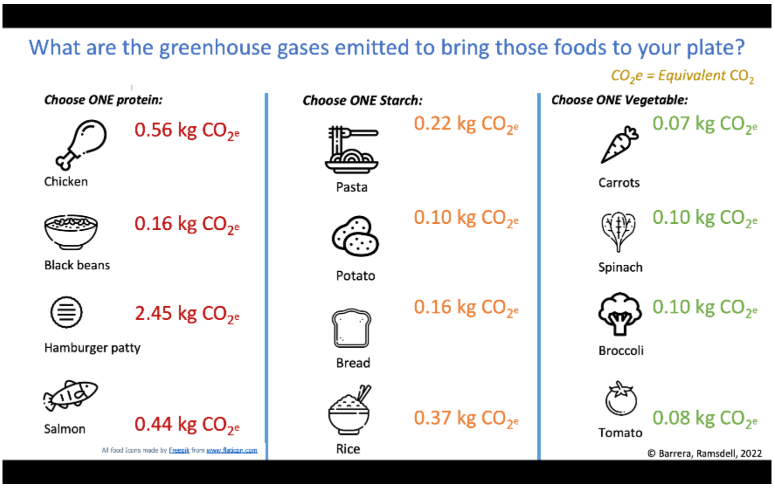

Figure 7: Presentation Slides—Food Options with Emissions

The students are then asked to add the kilogram CO_2e for their three items and use this data on the back of the worksheet (Figure 6) to calculate the final volume. From the final volume, they can now calculate the number of balloons it would take to hold that volume. This worksheet is intended to be in a format that is step-by-step so students can work either independently or in small groups to calculate their final balloon diameter.

Next, the instructor can make the calculation spreadsheet available to the students so that they can verify the accuracy of their calculations. This can then lead to a vibrant classroom discussion where students can compare their results, discuss the GHG emissions of their food choices, and compare these results to their initial estimates. Again, this paper is not intended to describe these differences but rather to highlight the magnitude of the variation between food choices.

STEM Outreach or Museum Distribution

This distribution method is intended for a community-type outreach venue involving several booths for participants (K-12 and beyond) to visit and learn more about STEM topics. Science museums are also an appropriate venue for this distribution method. These venues encourage hands-on participation, but it can be difficult to develop a safe, hands-on activity for content related to food. This activity is an answer to a lack of food-related climate change outreach booths and will allow participants to have an enjoyable interactive experience while learning a critical lesson about their food choices. It will also have a peer-educational component as participants compare their emission results with other participants once they leave the booth.

The set-up of this booth involves a table stationed with one or two hosts. The table should have a tablecloth, signage, plates, and fake food. The setup of this demo is simple. As the participant approaches the table, they will take a plate. They will then choose from an array of fake (plastic or paper cutout) foods which are divided into vegetables, proteins, and starches. From each category, they will choose one item to build a plate of food, which they will present to the booth host. The host will then refer to a pre-programmed spreadsheet (see Appendix) in which they will select each item of food by typing an 'x' next to the corresponding item. Additionally, the results can be found in the tables in Figures 8 through 11.

Protein		Starch		Vegetable		Total kg CO2e	Diameter of single balloon, m	Volume, m^3	Number of 12-inch balloons
Chicken	0.56	Pasta	0.22	Carrot	0.07	0.85	0.94	0.43	29.2
Chicken	0.56	Pasta	0.22	Spinach	0.1	0.88	0.95	0.45	30.2
Chicken	0.56	Pasta	0.22	Broccoli	0.1	0.88	0.95	0.45	30.2
Chicken	0.56	Pasta	0.22	Tomato	0.08	0.86	0.94	0.44	29.5
Chicken	0.56	Potato	0.1	Carrot	0.07	0.73	0.89	0.37	25.1
Chicken	0.56	Potato	0.1	Spinach	0.1	0.76	0.90	0.39	26.1
Chicken	0.56	Potato	0.1	Broccoli	0.1	0.76	0.90	0.39	26.1
Chicken	0.56	Potato	0.1	Tomato	0.08	0.74	0.90	0.38	25.4
Chicken	0.56	Bread	0.16	Carrot	0.07	0.79	0.92	0.40	27.1
Chicken	0.56	Bread	0.16	Spinach	0.1	0.82	0.93	0.42	28.2
Chicken	0.56	Bread	0.16	Broccoli	0.1	0.82	0.93	0.42	28.2
Chicken	0.56	Bread	0.16	Tomato	0.08	0.8	0.92	0.41	27.5
Chicken	0.56	Rice	0.37	Carrot	0.07	1	0.99	0.51	34.3
Chicken	0.56	Rice	0.37	Spinach	0.1	1.03	1.00	0.52	35.4
Chicken	0.56	Rice	0.37	Broccoli	0.1	1.03	1.00	0.52	35.4
Chicken	0.56	Rice	0.37	Tomato	0.08	1.01	0.99	0.51	34.7

Figure 8: Summary of All Results for Chicken

Protein		Starch		Vegetable		Total kg CO2e	Diameter of single balloon, m	Volume, m^3	Number of 12-inch balloons
Black Beans	0.16	Pasta	0.22	Carrot	0.07	0.45	0.76	0.23	15.5
Black Beans	0.16	Pasta	0.22	Spinach	0.1	0.48	0.78	0.24	16.5
Black Beans	0.16	Pasta	0.22	Broccoli	0.1	0.48	0.78	0.24	16.5
Black Beans	0.16	Pasta	0.22	Tomato	0.08	0.46	0.76	0.23	15.8
Black Beans	0.16	Potato	0.1	Carrot	0.07	0.33	0.68	0.17	11.3
Black Beans	0.16	Potato	0.1	Spinach	0.1	0.36	0.70	0.18	12.4
Black Beans	0.16	Potato	0.1	Broccoli	0.1	0.36	0.70	0.18	12.4
Black Beans	0.16	Potato	0.1	Tomato	0.08	0.34	0.69	0.17	11.7
Black Beans	0.16	Bread	0.16	Carrot	0.07	0.39	0.72	0.20	13.4
Black Beans	0.16	Bread	0.16	Spinach	0.1	0.42	0.74	0.21	14.4
Black Beans	0.16	Bread	0.16	Broccoli	0.1	0.42	0.74	0.21	14.4
Black Beans	0.16	Bread	0.16	Tomato	0.08	0.4	0.73	0.20	13.7
Black Beans	0.16	Rice	0.37	Carrot	0.07	0.6	0.84	0.31	20.6
Black Beans	0.16	Rice	0.37	Spinach	0.1	0.63	0.85	0.32	21.6
Black Beans	0.16	Rice	0.37	Broccoli	0.1	0.63	0.85	0.32	21.6
Black Beans	0.16	Rice	0.37	Tomato	0.08	0.61	0.84	0.31	20.9

Figure 9: Summary of All Results for Black Beans

Protein		Starch		Vegetable		Total kg CO2e	Diameter of single balloon, m	Volume, m^3	Number of 12-inch balloons
Beef Patty	2.45	Pasta	0.22	Carrot	0.07	2.74	1.39	1.40	94.1
Beef Patty	2.45	Pasta	0.22	Spinach	0.1	2.77	1.39	1.41	95.1
Beef Patty	2.45	Pasta	0.22	Broccoli	0.1	2.77	1.39	1.41	95.1
Beef Patty	2.45	Pasta	0.22	Tomato	0.08	2.75	1.39	1.40	94.4
Beef Patty	2.45	Potato	0.1	Carrot	0.07	2.62	1.37	1.33	90.0
Beef Patty	2.45	Potato	0.1	Spinach	0.1	2.65	1.37	1.35	91.0
Beef Patty	2.45	Potato	0.1	Broccoli	0.1	2.65	1.37	1.35	91.0
Beef Patty	2.45	Potato	0.1	Tomato	0.08	2.63	1.37	1.34	90.3
Beef Patty	2.45	Bread	0.16	Carrot	0.07	2.68	1.38	1.36	92.0
Beef Patty	2.45	Bread	0.16	Spinach	0.1	2.71	1.38	1.38	93.1
Beef Patty	2.45	Bread	0.16	Broccoli	0.1	2.71	1.38	1.38	93.1
Beef Patty	2.45	Bread	0.16	Tomato	0.08	2.69	1.38	1.37	92.4
Beef Patty	2.45	Rice	0.37	Carrot	0.07	2.89	1.41	1.47	99.2
Beef Patty	2.45	Rice	0.37	Spinach	0.1	2.92	1.42	1.49	100.3
Beef Patty	2.45	Rice	0.37	Broccoli	0.1	2.92	1.42	1.49	100.3
Beef Patty	2.45	Rice	0.37	Tomato	0.08	2.9	1.41	1.48	99.6

Figure 10: Summary of All Results for Beef Patty

Protein		Starch		Vegetable		Total kg CO2e	Diameter of single balloon, m	Volume, m^3	Number of 12-inch balloons
Salmon	0.44	Pasta	0.22	Carrot	0.07	0.73	0.89	0.37	25.1
Salmon	0.44	Pasta	0.22	Spinach	0.1	0.76	0.90	0.39	26.1
Salmon	0.44	Pasta	0.22	Broccoli	0.1	0.76	0.90	0.39	26.1
Salmon	0.44	Pasta	0.22	Tomato	0.08	0.74	0.90	0.38	25.4
Salmon	0.44	Potato	0.1	Carrot	0.07	0.61	0.84	0.31	20.9
Salmon	0.44	Potato	0.1	Spinach	0.1	0.64	0.85	0.33	22.0
Salmon	0.44	Potato	0.1	Broccoli	0.1	0.64	0.85	0.33	22.0
Salmon	0.44	Potato	0.1	Tomato	0.08	0.62	0.84	0.32	21.3
Salmon	0.44	Bread	0.16	Carrot	0.07	0.67	0.87	0.34	23.0
Salmon	0.44	Bread	0.16	Spinach	0.1	0.7	0.88	0.36	24.0
Salmon	0.44	Bread	0.16	Broccoli	0.1	0.7	0.88	0.36	24.0
Salmon	0.44	Bread	0.16	Tomato	0.08	0.68	0.87	0.35	23.4
Salmon	0.44	Rice	0.37	Carrot	0.07	0.88	0.95	0.45	30.2
Salmon	0.44	Rice	0.37	Spinach	0.1	0.91	0.96	0.46	31.2
Salmon	0.44	Rice	0.37	Broccoli	0.1	0.91	0.96	0.46	31.2
Salmon	0.44	Rice	0.37	Tomato	0.08	0.89	0.95	0.45	30.6

Figure 11: Summary of all results for Salmon

The spreadsheet will generate a few numbers:

- The kilogram CO_2e of these food choices;
- The diameter of a single balloon (assumingly spherically-shaped), which would contain the GHGs that would be emitted from the growth and production of these foods; and,
- The number of smaller, standard-sized balloons (i.e., 12-in diameter) that would contain the GHGs that would be emitted from the growth and production of these foods.

Creativity is encouraged regarding "take-aways" to give participants. Unfortunately, the single balloon size and bundle(s) of smaller balloons are prohibitively large to distribute to each participant. However, distributing a visible item is an important educational opportunity of this booth as participants can then compare their results with other participants at the event and note the foods that resulted in the varying emissions.

A low-budget "take-away" idea is to provide a blank name tag and markers. Once the results are calculated, the participant can write the total number of balloons from their selection and use the markers to draw their food choices on this name tag. If an additional budget is available, stickers of each food item can be pre-printed and adhered to the name tag. Alternatively, a single balloon can be distributed to each participant with paper hangtags that can be added to each participant's balloon, describing how many of these balloons would be filled to contain the GHGs to produce their meal selection. The possibilities are endless!

If sufficient funds are available, small and very large balloons can be purchased as a booth-display to allow the hosts to point to the variety of possible balloon sizes. For the range of foods described in this activity, the minimum single balloon size (beans, potato, carrot) is 0.68 meter and the maximum single balloon size (beef burger, rice, spinach or broccoli) is 1.42 meter. Alternatively, bundles of balloons can be displayed for reference. For the range of foods described in this activity, the minimum number of 12-inch (0.3 m) balloons (beans, potato, carrot) is 11.3 and the maximum number of 12-inch (0.3 m) balloons (beef burger, rice, spinach or broccoli) is 100.3 balloons.

It is important to be mindful of the purchase of single-use items such as plates since this booth is focused on environmental sustainability. A small stack of sturdy, reusable plastic or bamboo plates, 100 percent latex balloons, and cotton string in place of plastic gift-wrap ribbon are all good options. In regards to distributing balloons, while 100 percent latex balloons are a more biodegradable option, one must also consider latex allergies. Additionally, while some latex balloons are sold as biodegradable, the research indicates that the breakdown of latex is varied and balloons pose a threat to wildlife (Gilmour and Lavers 2021). With that note, you are encouraged to use your best judgment when distributing materials.

Foodservice Distribution

Lastly, this visualization method can be implemented in restaurants, cafeteria settings, and grocery stores to help customers better understand the environmental impact of their food choices in a commercial food setting. For the sake of brevity, this paper will highlight implementing this as an educational tool in a university cafeteria; however, this tool can be modified for other foodservice settings, such as restaurants, grocery stores, food trucks, fast food establishments, and anywhere else food is sold. These displays help involve retailers in the education of a sustainable food system.

In a study published in the journal *Food Policy*, University of Copenhagen researchers gave insight into how carbon emission labels on food products influenced consumer behavior regardless of the participants' perceptions about climate change (Edenbrandt, Lagerkvist, and Nordström 2021). The researchers found that even among participants who avoid food-related climate change information, if shown the climate labels, the occurrence of purchasing lower carbon-emitting food options increased. Additionally, another recent study showed that diners are swayed to choose more eco-friendly food options when the menu identifies these differences (De-loyde et al. 2022). These are promising findings for climate change education and a reason to implement the visualization tool in various commercial food settings.

This method would involve a static display of balloons to represent the GHG emissions of two or more combinations of food choices. In contrast to the STEM outreach distribution method described above, this does not require giving balloons to participants, so the bundle of balloons could be displayed for the full visualization impact.

For example, let us consider the grill area of a cafeteria where the menu includes beef, turkey, and vegetarian burger options. A display containing a beef burger with eighty-four balloons, a chicken sandwich with nineteen balloons, and a vegetable burger with nine balloons could be located close to the grill. Perhaps, for added clarity, balloon bundles could be different colors; brown for beef, tan for turkey, and green for vegetable. It would be important for the display to clearly state that this volume represents the equivalent CO_2 GHG emissions. The flyer in Figure 12 is an example of one that can be used on this display table to help with this description.

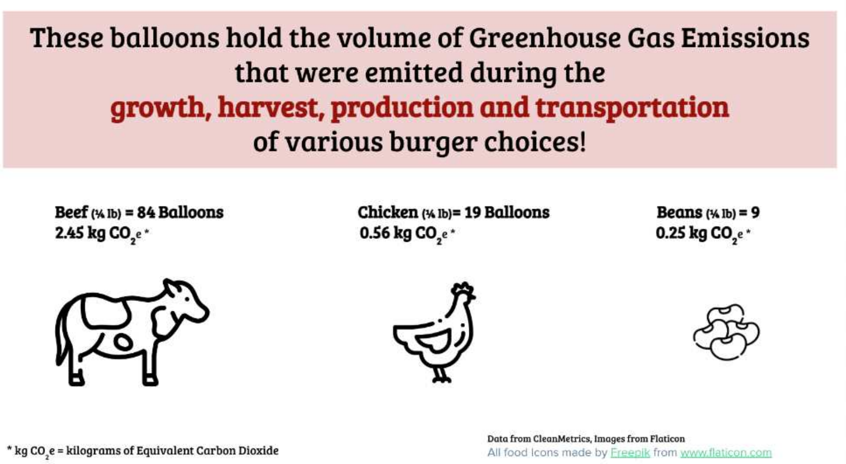

Figure 12: Example of a Display to Be Used for the Foodservice Distribution Method

Similar displays can be developed by the retailer based on their unique food offerings. The spreadsheet provided in the Appendix can be used to calculate the balloon volumes for other food options. Note that including foods from the animal (especially ruminant species such as beef and lamb) categories versus plants will yield the greatest difference and therefore yield the most impactful display.

It has been shown that social influences can impact food choices and lead consumers to choose more nutritious food options (Levy et al. 2021). The hope is that this commercial distribution method will help increase consumer literacy about environmentally friendly options as well as provide encouragement to make small changes to dietary habits for the sake of environmental sustainability.

Conclusion and Implications

This work stemmed from a need for a wide-reaching communication strategy to facilitate climate change discourse surrounding the topic of food. While there are many environmental impacts of our food system, this tool focuses on the GHG emissions of our choices of food. This is unique from what is more commonly discussed, such as farming practices, packaging, or transportation. The aim is to encourage the use of this tool both within the classroom and through outreach pursuits.

Framing CO_2e emissions in terms of a common, tangible object opens avenues of understanding that have scarcely been explored and removes the burden of excessive explanations or charts. Additionally, unlike fixed visualization tools currently in circulation, this calculator allows for adaptation to additional considerations as they appear. The flexibility to build upon the tool unlocks the imagination to the tool's potential and encourages future collaboration and feedback. The three distribution methods presented here range from classroom to STEM outreach events to commercial eateries. While these are impactful distribution methods, the possibilities of other distribution models are endless, and individuals are encouraged to adapt this tool to best suit their educational needs.

The authors hope that this visualization tool will help people, who may otherwise be unengaged or feel helpless in the face of the climate crisis, begin to care about and act in a way to contribute to the climate change solution. This tool provides empowerment for people to take control over their own food carbon footprints. Integrating low carbon-emitting foods can be implemented immediately, which is not a common trait among other sectors of climate change solutions. For example, it takes planning and commitment to purchase an electric vehicle or install photovoltaic (PV) panels; it is much easier to choose a bean burger over beef. This simple act puts people in control so that they can seek other sustainable actions in the future. Additionally, the clarity offered in this tool also helps those not engaged in the science of our food system to see the magnitude of the range of emissions from our food system choices. This could lead to increased activism resulting in policies that promote foods with lower GHG emissions.

Final Comments

Inclusivity and Food Education

While a single change will not solve all our problems, the authors hope that this tool will act as a catalyst for discussion and broaden the minds of our future makers of change. It is imperative that obstacles to such lifestyle changes are addressed. Educators often disseminate this type of information with the perspective of an 'ideal situation,' but many if not most people are not in an ideal situation. Worldwide food scarcity is a current problem that will continue to worsen as climate change worsens (FAO, IFAD, UNICEF, WFP, and WHO 2020; Ritchie 2020). This discussion may feel off topic, but you can be assured that someone in your class or participating group will have been touched in some way by food scarcity. One out of eight US citizens experience food insecurity even when food is available. One in three people globally experience food scarcity (Coleman-Jensen et al. 2019).

Availability of food and accessibility to food are two very different things that must be taken into consideration when broaching this subject. Availability is simply that there is food available to the public for purchase, but when individuals may not have the resources to purchase the food items, the available food is inaccessible. The authors acknowledge that this tool and many other studies encourage the incorporation of a plant-based diet (Sun et al. 2022; Shaw et al. 2022). Accessibility to these types of foods, especially for low-income households, is not as simple as it may seem. For a middle-class household, switching out proteins may be a cinch because such a socioeconomic status comes with the privilege of money, time, education, and a variety of food options.

As our society learns more about overcoming climate change, we must not operate in a vacuum of entitlement. It is our responsibility, as educators, to include all backgrounds in these discussions. In this way, we bring light to the many struggles we face as a society, bringing us closer to comprehensive climate solutions.

Caution Regarding Shaming Due to High-Emissions Food Choices

It is important to use caution when distributing these educational materials so as not to shame anyone based on their food choices. Many food preferences are based on cultural traditions that are part of a person's identity and these traditions are critical to acknowledge and protect.

One distribution method that may suffer from this negative comparison is in the classroom. Prior to launching this tool in a classroom, the teacher should proactively discourage this type of classroom communication. Comments such as "there is no right answer" or "everyone's food preferences are valid" need to be made before introducing the lesson. This activity simply helps us understand how to make changes to reduce GHG emissions. Also, participants can be challenged to be creative in modifying their traditional foods in ways that retain the flavors while reducing the emissions. Another venue where shaming could be a negative consequence of this tool is in the commercial setting. While this is more difficult to facilitate, it is important to ensure steps are taken to evoke positive discourse amongst participants.

Environmentally Friendly Food Choices Have Additional Sustainable Benefits

Sustainability is defined as the capacity or ability to endure (Merriam-Webster, n.d.). We talk about sustainability in many aspects of life, not just in terms of environmental stewardship. It spans our conversations on diet culture, economic strategy, exercise routines, agriculture, etc. Sustainability trickles down into every aspect of our lives. Choosing environmentally friendly options in our diets encourage sustainability across these facets. Increasing these protein swaps into our diet can decrease the likelihood of developing certain “first world” diseases and disorders (Drew et al. 2020; Hallström et al. 2017). Additionally, by law of supply and demand, increasing these swaps also increases demand for sustainable agriculture. Further, increased demand and supply for these environmentally friendly foods grants lower-income households access to better food, nutrition, and overall well-being (Naja et al. 2020). On a larger scale, these environmentally conscious swaps have the ability to have a great impact on the welfare of humans and our environment.

What This Tool Is Not

It should be noted that this paper presents an educational visualization tool. It is not a resource for explaining the source nor scientific explanations for the range of emissions from different food choices. There are other resources available to help people better understand the reasons for the GHG emission variations for different food options (Ritchie 2020).

Future Extension of this Work

This tool is in its preliminary stages and, as previously highlighted, has the potential to expand greatly. A hope for the future of this tool is to integrate it into a mobile application. Users will be able to easily record their food choices and receive instant feedback about their meal’s carbon emissions with accompanying graphics. Partnering with CleanMetrics to make such an application could be the next step for this tool. Additional features could include expanded food choices, impact of transportation, and organic agriculture.

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Conflict of Interest

The author declares that there is no conflict of interest.

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Appendix

Supplemental material described in this paper can be found and downloaded from: https://drive.google.com/drive/folders/1RoSgFZgqz2wDeBo3KGVET-wBDFjQcFR4?usp=sharing.

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