The Carbon Consequences of Diet: A Visual Approach to Low-Carbon Diet Planning

Jennifer L. Cardona

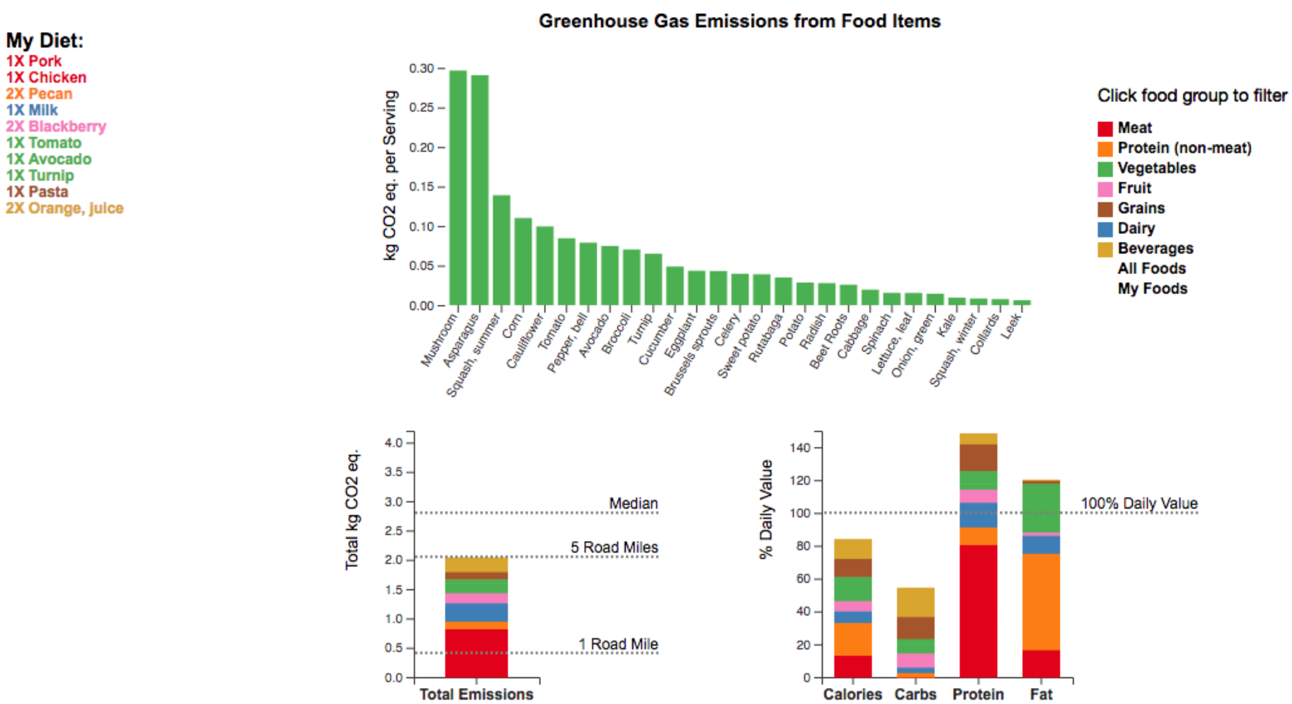

Fig. 1. View of interactive diet planner showing current diet nutrition and emission stats and comparison of choices in the vegetable group.

Abstract—An interacive visual explainer is put to use to guide users through greenhouse gas emissions related to food production. The visualization uses simple visual encodings in bar charts and scatter plots to compare various food items, and a color scheme to mark distinct food groups throughout the narrative. The narrative culminates in a low-carbon diet planner, allowing the user to put what the have learned about certain dietary choices to use and see how their diet compares with regards to emissions and nutreints.

Index Terms—Greenhouse gas emissions, diet

1 Introduction

The food industry accounts for a significant portion of world greenhouse gas (GHG) emissions [14]. An estimated 10-12% of world GHG emissions come from agriculture ignoring fuel use, fertilizers, and land changes [19], and accounting for these factors, the estimate grows to 30% [6]. This large quantity of greenhouse gas emissions due to food production demands the need for tools to educate the population on how their decisions can make an impact.

Although it is generally known that vegetarian and vegan diets are “more sustainable” than a conventional diet including meats, for those who have certain dietary restrictions or preferences, choosing a vegetarian lifestyle may not be a possible or appealing option. The nuanced details of how specific food choices affect greenhouse gas emissions is less talked about, but can still play an important role in the carbon footprint of an individual diet. Recent work has shown that almoust half of all food related emissions in the US come from only about 20% of the population [15]. Heller et. al suggest that if the 5th quintile of emitters were to reduce their diet related emissions to the median level, it would lead to an overall reduction of 9% of diet-related emissions.

The aim of this work is to create a visual explainer that will allow readers to understand how different food items contribute to GHG emissions. The explainer will feature a visual narrative meant to educate users on food choices that could have a large impact on their diet related emissions. The explainer will close with an interactive diet planner tool to show how different dietary choices contribute to both greenhouse gas emissions and nutrients.

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2 Related Work

Prior work has been done to visualize how food items stack up in terms of carbon emissions. There are a plethora of visualizations that show how various food types compare to one and other. Examples are shown in Figures 2 and 3 ([17], [5]). In these examples, the emissions from food items are compared with bar charts, and also put in context of

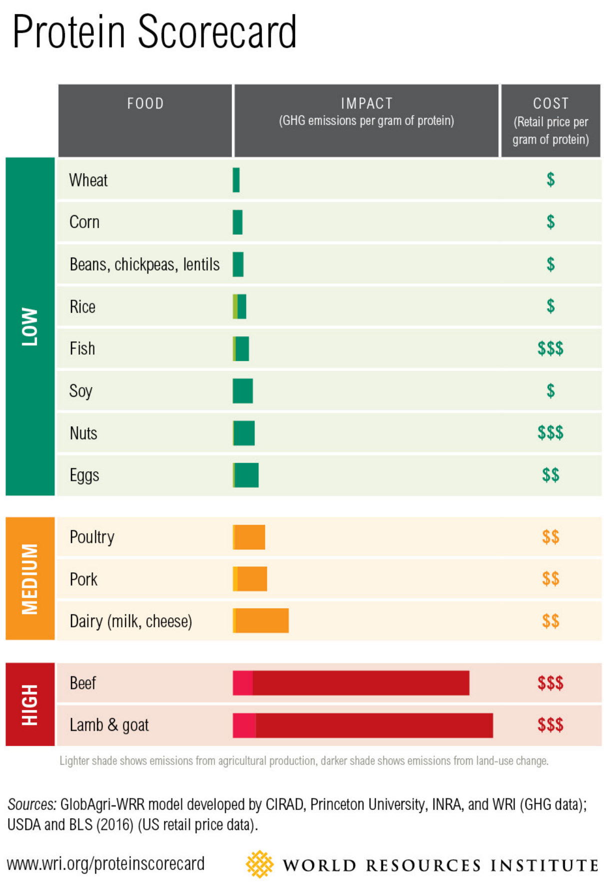

Fig. 2. Bar chart comparing foods [17]

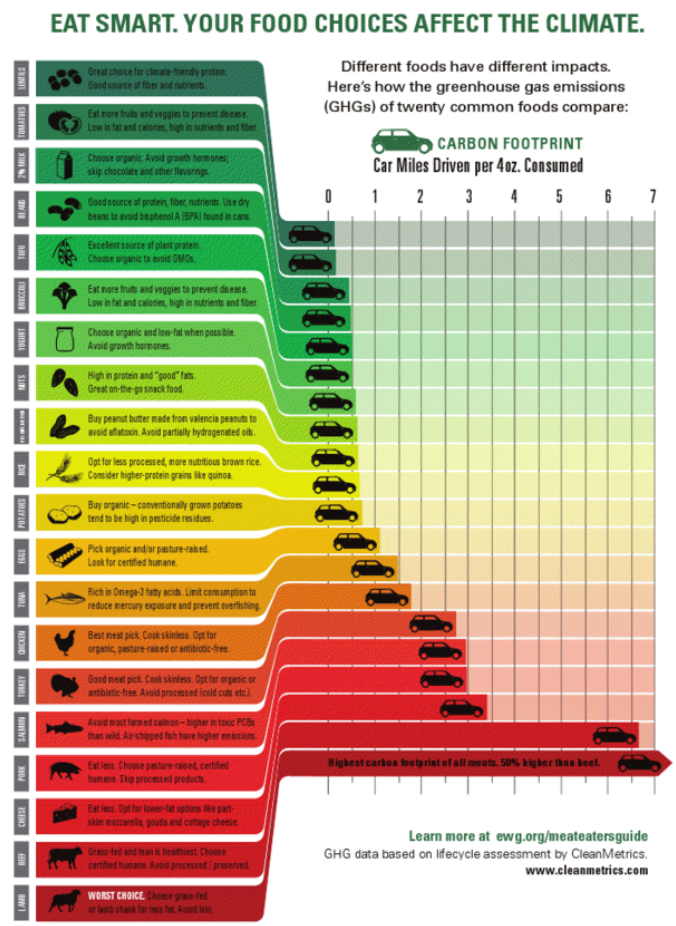

Fig. 3. Bar chart comparing foods [5]

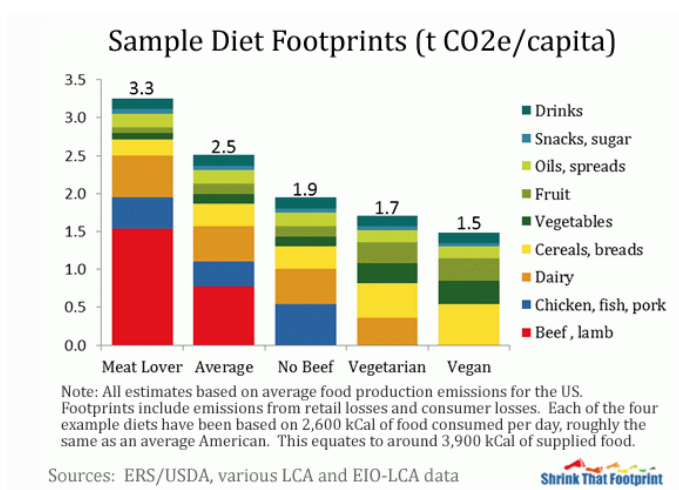

Fig. 4. Bar chart comparing diet types [1]

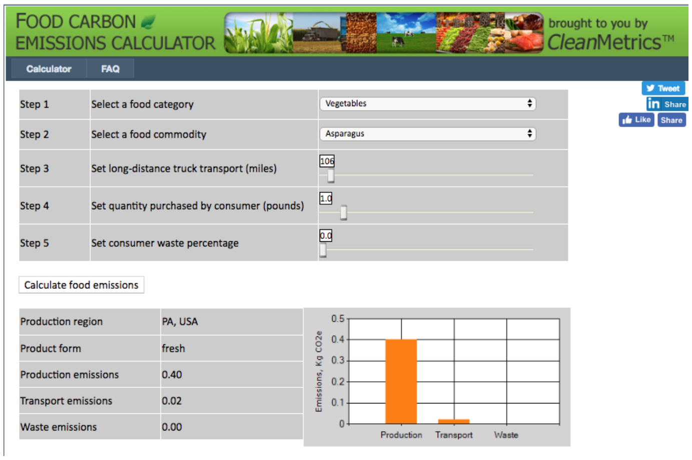

Fig. 5. Screenshot of food emissions calculator. [3]

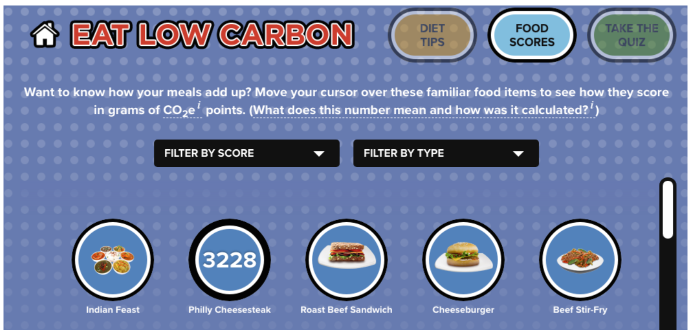

Fig. 6. Screenshot of food emissions sorter. [7]

other relevant data (price in Figure 2 and comparable car miles in Figure 3). These types of visualizations are good for giving the reader a broad sense of what food groups contribute to emissions, but lack specifics that may be important for diet customization.

Another type of visualization that is common within the literature is one that shows how different characterized diet types compare to one and other as in Figure 4 [1]. In this style of visualization, the reader can see how, for example, a meat eater diet compares to a vegetarian diet in terms of emissions, and which foods contributes the most to emissions. This is closer to a tool that could be used to make diet choices, but again lacks data about specific foods and customizability.

There are also some interactive tools that allow users to compare emissions from food items ([3], [7]. Screenshots of these tools are shown in Figures 5 and 6. These interactive offer the benefit of understanding the emissions from very specific food items that may pertain to an individual diet. However, they lack the ability to combine these food items together to see how an entire diet compares.

The present work combines elements inspired by the examples shown here to create a final product that first walks the reader through the broad strokes of how each food group contributes to emissions, and then allows them to visualize how their own diet choices compare.

3 Methods

3.1 Dataset

The dataset that used here to relate greenhouse gas emissions to food items is called dataFIELD, and was created by a Heller et. al based on a thorough literature review that applied lifecycle analysis (LCA) to food items [15]. This dataset contains the greenhouse gas emissions in kg of CO2 equivalent for different food commodities from the Food Commodity Intake Database (FCID) [22]. The FCID is linked to the What We Eat In America (WWEIA) database [20], which contains data regarding food consumption in the US. WWEIA can be linked to the Food and Nutrient Database for Dietary Studies (FNDDS), which contains portion and nutrition information for different food items. The commoditites listed in dataFIELD containing greenhouse gas emissions data were first matched with their WWEIA equivalent food identifications. The WWEIA equivalents were then linked to FNDDS to retrieve information about relevant portion sizes and the nutrition facts for each food item.

FNDDS offers multiple options for portion sizes. To choose appropriate portions to show in the present visualizations, ChooseMyPlate.gov was consulted [2]. Comparable portion sizes were chosen for each food item within a food group. For foods items with missing nutritional information in FNDDS, nutritiondata.self.com was used to fill in the dataset [4].

Because this work is meant to educate the user on daily diet choices, it was of great importance to include highly common food items. The original dataFIELD did not include bread or pasta. Greenhouse gas emission estimates for bread and pasta were included using other lifecycle analysis studies [13], [11].

Finally, each food item was manually assigned to one of the following food groups: meats, proteins (non-meat), vegetables, fruit, grain, dairy, and beverages. It is worth noting that while beverages are not always considered a separate food group, they were isolated as their own group in this because they have relatively high emissions levels compared to other foods.

3.2 Relatable GHGE References

The metric used for greenhouse gas emissions in the present work is killograms of CO2 equivalent (kg CO2 eq.). This is commonly used to compare emissions, and is calculated by tallying on all of the greenhouse gasses emitted normalized by their warming potential compared to CO2 [9]. The target user for this visual explainer may not be able to contextualize what 1kg of CO2 means. One way that this has been addressed in prior work is to compare the emissions in kg CO2 equivalent to the emissions that would be given off by an equivalent number of miles driving in a car [5]. Based on estimates from the EPA, one road mile translates to approximately 0.41 kg CO2 eq. [21]. Reference lines for one and five miles driven in an average internal combustion engine car will be used in the visualization to allow the average user to compare food related emissions to something more familiar.

3.3 Narrative Design

The present visual explainer takes on the "martini glass" narrative genre proposed by Segel et. al [18]. The user is guided through sever important points related to dietary choices step by step, and finally, the narrative opens up to allow the user to interact with the information in a much broader way.

The mechanism by which the user is guided through the narrative is scrolling. Using scrolling to move through a visual narrative (sometimes called "scrollytelling") has become a popular technique, and has been used by outlets such as The New York Times and pudding.cool.

Based on a throrough exploration of the data, one of the biggest takeaways from the dataset is that a few outlier foods (sheep, beef, and crustatceans) tower over the rest. All three of these outliers are meats, and there are many alternatives (both meats and other proteins) that could be used to substitute them. The narrative focuses around this point, since it has the greatest potential to impact diet-related emissions. The explainer will highlight these outliers as well as alternatives before opening up to the diet planner.

3.4 Implementation

This work was implemented using D3 (Data Driven Documents) [8]. D3 allows data to be bound to visual elements on a web page. This allows for implementation of highly interactive visualizations.

The scrollytelling functionality in this work was built off of an open source example using D3 presented at OpenVis by Jim Vallandingham available on github[1] [23].

[1] https://github.com/vlandham/scroll$_{d}$emo

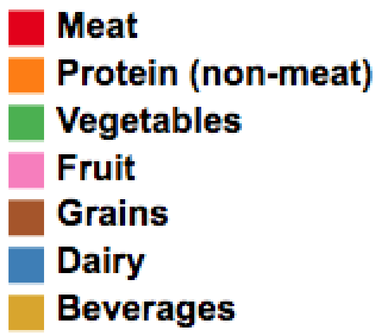

Fig. 7. Legend showing color choice for each food category.

3.5 Visual Encoding Selection

The quantitative data to be portrayed in the present visualizations includes greenhouse gas emission levels, and nutritional data. All quantitative data was encoded using either position or length, as these are known to be the easiest visual encodings for people to perceive quantitative information [16].

Two simple chart types are used throughout the narrative: bar charts, and scatter plots. These simple charts were chosen to ease the perceptual burden on the user in understanding what the visualization means. Complexities and details in telling the story were shown using interaction and step-by-step changes to these simple charts rather than choosing a more complex visual form.

Aside from emissions data and nutrition facts, the other main distinguishing data to be shown in the visualizations is the food group to which each food belongs. This is important information to show, firstly because there are large differences in emissions between food groups, and secondly because it is necessary for one to choose foods from several main groups in planning their diet.

The ordinal data of food group category was encoded using color. A distinct color was used for each of meats, proteins (non-meat), vegetables, fruit, grain, dairy, and beverages, as shown in Figure 7. ColorBrewer [10] was used in selecting these colors to optimize for colors that would be perceptually different from one and other. The palette generated in ColorBrewer was then slightly modified so that the visual elements were easy to see on a screen.

The same color was used for each food group throughout the entire narrative, and no other colors were shown except for black or gray. This choice of color continuity was meant to make it easier for the user to follow the story of each food group all the way through to their diet planning.

3.6 Animation

Animation is used to transition between plots when there is a scale change. Both the bars and axes are animated. This allows the user to see whether the scale is increasing or decreasing, and to get a qualitative sense of how much it is changing.

3.7 Interaction

3.7.1 Tooltips

Throughout the "martini glass stem" portion of the narrative, the main interaction mode is through mouseover. When the user hovers over a bar on the bar chart or point on the scatter plot, that point is highlighted, and the food name, portion description, and emissions per serving are shown with a tooltip. In order to show the outlier foods in the context of all other food options, several of the bar charts do not have x-axis tick labels to denote the name of the food item shown by the bar. For these information dense charts, the interactive tooltip feature is not a bonus, but a necessity for the user to be able to gather the details of a given data point.

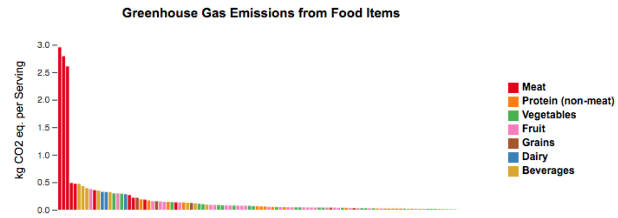

Fig. 8. Initial bar chart showing all foods.

3.8 Linking and Brushing

Linking and brushing is a technique that highlights the same subset of elements in multiple plots [12]. Brushing is used throughout the narrative to draw the user's attention to specific food groups and show where foods in a subset fall nutritionally and in terms of emissions. The brushing is also used as part of the interactive tooltips. When two plots are shown, if the user hovers over a food in one plot, that food is highlighted in both plots.

3.8.1 Diet Planner Design

In order to connect the diet planner to the story that was told in the explainer, the same bar chart that was used throughout the narrative is recycled in the diet planner. However, in the diet planner section, rather than being shown a specific food group, the user can select the food group they wish to view by clicking that group in the legend.

If the user clicks a bar connected to a food item on the original bar plot, one portion of that food item is added to their diet. It appears on a list on the right hand side of the screen in the color of its respective food group. Bar charts on the bottom of the screen show the emissions and nutrients present in their diet. These bars are updated as portions are added. The bars in these charts are stacked by the colors of the food groups so that the user can see how much of their nutrients and emissions are coming from each group.

To remove a serving of an item, the user can click on that item in their diet list. The tooltip highlighting functionality is extended so that the diet item is highlighted in the list when the user hovers over that food's bar, and vice versa. This allows the user to see the how the food item compares in terms of emissions before they click to remove it.

On the chart showing nutrients, a reference line shows 100% of the daily recommended value of each nutrient. On the bar chart showing total emissions, there are reference lines showing 5 road miles, 10 road miles, and the median daily emissions in the US. The line for the median emissions is shown at the same height as the 100% daily value reference line to encourage the user to keep their emissions bar below median.

Finally, The user can view how the foods in their particular diet compare by selecting the "My Foods" category, which filters the bar chart of emissions to only show their diet items.

4 Results

4.1 Narrative Explainer

Figures 8 and 9 show a an example of the type of progression that is seen throughout the narrative portion of the explainer. Figure 8 is the first visualization that is shown, which is a bar chart showing the greenhouse gas emissions per serving of all 106 food items. From this plot, the towering outliers are very apparent. Then, after a few steps, the narrative progresses to Figure 9. The same bar chart is still visible, but now the user also sees how the emissions are related to the calories in the foods (they are uncorrelated), and the meats are highlights to show that they make up most of the high emission foods. Text is used to explain what is going on at each step to link figures like these together in a cohesive way.

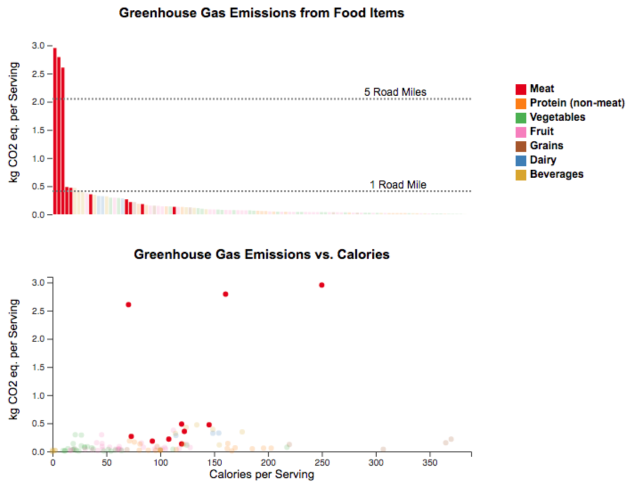

Fig. 9. Linked and brushed plots highlighting meats. Top: greenhouse gas emissions per serving for each food item. Bottom: greenhouse gas emissions per serving vs. calories per serving for each food item

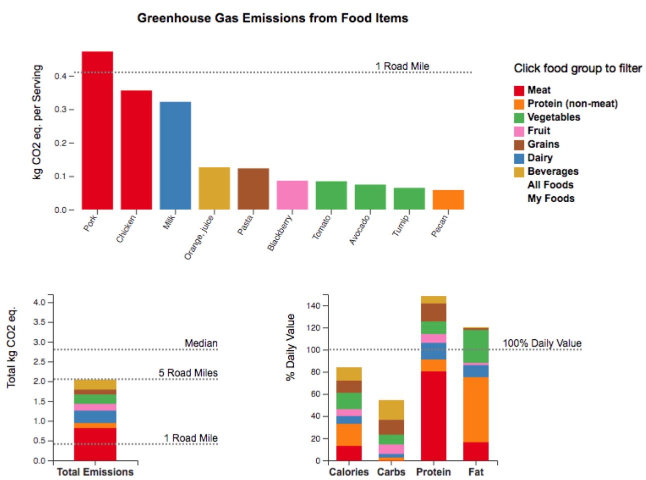

Fig. 10. Example of bar plots shown during diet planner visualization. Top: bar chart comparing emissions per serving of each food the user has selected in their diet. Bottom: Total emissions and nutritional data for the user's selected diet.

4.2 Diet Planner

Figure 10 shows an example of the bar chart visualizations present during diet planning. In this example, the top bar chart is showing only the foods that the user has chosen as part of their diet. The bottom charts show the total emissions for their diet the percent daily value of each macronutrient in their diet. In this case, the user might see that most of their emissions comes from meat (the red part of the stacked bar), and the food in their diet with the highest emissions level is pork. Thus, if they wanted to cut down on emissions, it eliminating pork might be wise. Furthermore, they are over 100% of their daily value of protein, so eliminating a serving of pork (which is a protein), would not be a bad nutritional choice. See Figure 1 for a full view of the diet planner including the diet item list.

5 Discussion

This work provides a tool that can be used to educate a user through a step-by-step scrolling narrative that walks through some of the most relevant choices that can be made to impact diet-related greenhouse gas emissions. The narrative visualization makes use of relatable references, a consistent color scheme, interactive tooltips, brushing and linking to the explanation as clear and engaging as possible.

After the explanation is complete, the user is led to a diet planner leveraging the same bar visualization for continuity in choosing low-carbon foods. The user can easily see which food groups are responsible for the emissions and nutrients in their diet, and compare their diet items against one and other, making it possible for them to remove items from groups that are negatively impacting their outcomes.

6 Future Work

This work begins to allow a user to visualize how certain foods and food groups impact emissions, but there is still work to be done to improve the diet planning portion of the visualization. One area where this work could be improved is in the interactivity of the stacked bar charts showing total emissions and nutrients. It would be useful if the user could see individual food items on those charts, or add their own reference lines for metrics that matter to them.

Another way the diet planner might be improved is by adding more specific nutrients. For sake of simplicity, this work focused only on the macronutrients (carbohydrates, proteins, fats), but depending on a specific user's needs, the ability to view certain vitamins and minerals might be important. An interactive feature to include nutrients of choice will be included in future iterations.

This visualization might also be improved through the inclusion of more processed foods and recipes that are common in people's diets (e.g. pizza, hamburger, etc.). These more complicated food items were not included in this work, as an estimation of their emissions would involve several layers assumptions that would need to be justified. This could be an excellent opportunity for collaboration between those who study, nutrition, emissions, and visualization.

Finally, this work focuses on *how* a user might be able to change their dietary choices to lower their carbon emissions, but one thing that is missing from the present work is *why* some of these foods are such outliers. One future direction should be to link the current dataset to other data that might tell the story of why some food items have such high emissions.

Acknowledgments

The following open source examples were used in the implementation of this work:

- Scrollyteller framework: https://github.com/vlandham/scroll$_d$*emo*
- Function to move items to front: https://gist.github.com/trtg/3922684
- Top of page on reload: https://stackoverflow.com/questions/3664381/force-page-scroll-position-to-top-at-page-refresh-in-html

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