Food Emission Visualisation

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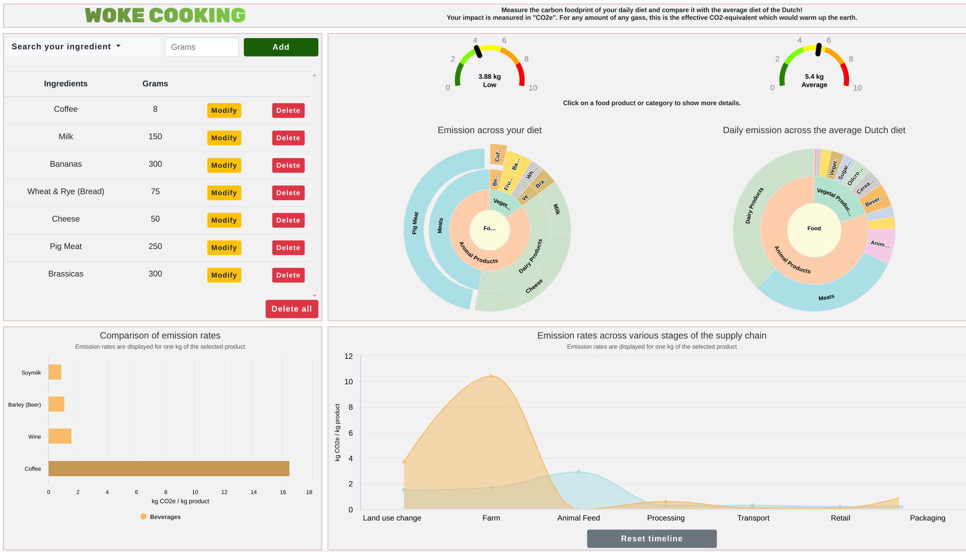

Figure 1: Woke Cooking Dashboard

Abstract

This Information Visualization project attempts to give users insight into their dietary emissions footprint. In order to achieve this, multiple complementary visualizations are shown on an interactive dashboard. Users can compare their diets to a Dutch average diet, and see how switching certain foods change their footprints. They can also select a food and see its emissions across the supply chain timeline, to gain understanding about how certain foods are contributing to the total emissions footprint. While not all foods are in the database, we believe that the dashboard can be a viable way to give insight to users and to help them change their diets to a more sustainable alternative. The project code can be found at `https://github.com/avd94/vizteam11` and the website at `http://co2score.herokuapp.com/` (best viewed in fullscreen).

1 Introduction

Sustainability is a hot topic in most developed countries. Efforts are made to make energy production more sustainable and to reduce the emission of greenhouse gasses. Stocks in “green” companies like Tesla are skyrocketing; a signal that people are jumping on board the sustainability-train. However, one aspect often gets overlooked. Food systems are responsible for 34% of anthropogenic greenhouse gas emissions [3]. Yet people often are not aware of the impact of their diet on the climate. Research suggests that, while sustainable diets are available, most people have diets that are beyond the limits of sustainability [7]. The biggest problem is that most diets contain way too many animal products. This food category causes most emissions, mostly because of land use, animal waste and the food that is required to feed the animals themselves.

Switching to a diet with less or no animal products can prove to be hard though, mostly since the supply of some micronutrients like calcium and vitamin D is not guaranteed in a plant-based diet [4]. The researchers suggest a move away from beef and veal to replacements like poultry and protein-rich meat replacements might lead to a more sustainable diet. But how can the average consumer decide such things without any prior knowledge?

Research shows that ecologic footprint calculators are an efficient tool in giving people insight into how their activities impact the environment [2]. This paper proposes a method to combine an ecological footprint calculator with intuitive visualizations to give people insight into their diets and to hopefully help them in shaping a more sustainable way of living.

In this design study we contribute:

- Different visualizations to help users grasp the ecological footprint of their specified diets, and the influence of specific ingredients.
- A way for users to visually compare their diet’s footprint to the footprint of an average (Dutch) diet.
- A visual explanation of the factors that contribute to the footprint of individual ingredients.

1.1 Dataset

The data were taken from *“Reducing food’s environmental impacts through producers and consumers”* by Poore et al. [6] and *“The foastat database of greenhouse gas emissions from agriculture* [8]. The dataset from Poore et al. provides a sample of different food categories and includes their detailed CO_2 emissions, land use and

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water use. The FOASTAT database contains detailed information about the food supply in each country, from which we derived the average Dutch diet. In this way, the average diet and emission data were aggregated to depict how much CO_2 the average diet emits per kg. Since not all specific food products overlapped between the two datasets, in some cases the average emission was taken from the food emission dataset [6] to provide the CO_2 per kg emission per food product in the average diet [8].

In literature on emission and CO_2, there are multiple terms used, such as "greenhouse gases" (GHG), CO_2, CO_2e and carbon. Greenhouse gases refer to any gas in the atmosphere that absorbs and re-emits heat, such as water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oixide (N_2O) and ozone [1]. Carbon dioxide (CO_2) is the most common GHG emitted by human activaties and is the main cause of global warming [5]. The term CO_2 is sometimes used interchangeably for all greenhouse gases, which might be confusing. The term "Carbon dioxide equivalent", or abbreviated "CO_2e", is the term for describing different greenhouse gases in one common unit, such that CO_2e signifies the amount of CO_2 which has the equivalent global warming impact. The CO_2-equivalent can therefore be used to measure the emission of food products, and be used to compare the emissions of food products to one another, such that the potential effects on global warming can be measured.

2 GOALS AND TASKS

This application is designed for users that want more insight into the carbon footprint of their diet. For example, students who wants to know their carbon footprint or a father who is doing groceries for his family and wonders if he can be more CO_2 neutral. The application should be visually pleasing, easy to use and understand and the application must be accessible to all layers of society. The overall goal of this application is to give more insight into the user's diet and also providing substitute products that are more eco friendly. It is important that all food products in the user's diet can be visualized in an uncluttered manner. The application should be intuitive to users without any domain knowledge about this subject, and it should be able to provide insights into the user's diet in a high- and low-level way. The following high- and low tasks are identified as important for the users of the application:

Task 1: Analyze diet. The users should be able to analyze the emission across their diet, based on their input. For example, after a user enters their dietary data, they want to analyze this by exploring the distribution of emission across their diet and investigating specific categories. They should be able to view their data on a high en low level. This way, users can be provided more insight in their consumptive carbon footprint and the key food products or categories can be identified.

Task 2: Compare diet. This task is focused on comparing the users emission to an average daily diet of people in the Netherlands. The users want to compare their total emission, and the distribution of emission across their diet, to a reference point. By comparing user data to an average, the users can acquire new insights, such as finding out that their diet contains a very skew distribution of emission among food categories.

Task 3: Find suitable substitutions. Users might include food items that produce CO_2e at a high rate in their diet, which can increase their emission greatly. In this case, users want to reduce their total emission, so they need to find suitable substitute products with lower emission rates.

Task 4: Inspect emission across the supply chain. For the production of one food product, different levels of CO_2e emission are produced at different stages in the supply chain. The final emission is the sum of those. The users want to be able to investigate a product's emission at the various stages to gain insights. For example, when users identify high emission products in their diet, they want to find out what stages in the supply chain contributed most to the emission. Additionally, users want to compare emission rates in the supply chain between products.

Most of the tasks are focused on giving insight in an user's diet, and showing the data without increasing the intrusiveness of the application. Also this project wants to make clear that not only certain products are high in CO_2 emission but also the less obvious examples, such as chocolate or cheese.

3 VISUALIZATION DESIGN

Woke Cooking is an online interactive visualization framework that enables users to analyze the carbon footprint of their diet. The goal of Woke Cooking is to let users compare between individual components of their diet and support them in making judgements about their own consumption footprint.

The main interface is shown in Figure Fig. 1 and consists of: (A) a hierarchical overview of the emission across the user's diet and the Dutch average diet, (B) indicators of the carbon emission level, (C) a detailed view of food products' emission across the supply chain, (D) a comparison of products within a category and (E) the diet input form. The users are first prompted to add food items and the consumed amount in grams to their diet before the visualizations are fired.

The first prototype of Woke Cooking used a vertical layout, where the visualization components were stacked on top of each other in the center. However, in this approach, parts of the visualization were pushed outside of the window size (1920x1080 pixels). While users could scroll through the visualization, it still caused a diminish of direct attention towards the obscured component. To resolve this, a dashboard layout is implemented in the final framework, where visual components are presented more compactly and fitted to the window size as shown in Fig. 1. This process was also part of our attempt to minimize the cognitive costs associated with multiview visualizations. One of the goals in creating the dashboard was to make each visualization complementary to another, keeping the eight rules of multiview design in mind.

3.1 Hierarchical overview

The hierarchical overviews play a central role in the application, integrating the Dutch reference diet and the users' diet to support comparison and further analysis based on food categories and products **(Task 1 and Task 2)**. On a high-level, it aims to help users identify areas in their diet that contribute largely to the total emission and to put it in context by comparing it with the reference diet. More specifically, it can help users locate outliers.

To best encode the hierarchical dietary data, the sunburst visualization is used. It shows the hierarchy in a screen-efficient way while being capable of encoding the emission and class information. A downside of using space-filling radial plots is that nodes at the outer ends of the hierarchy become large in number, causing cluttering. Additionally, since the rate of emission differs greatly between and even within categories, small nodes tend to vanish. However, the Sunburst alleviates these disadvantages by supporting strong user interaction, enabling users to view smaller nodes in detail while maintaining the hierarchical context. Moreover, a bar chart is chosen to visualize the varying emissions of products within a food category, because it excels at showing values for a small number of items.

The overview shown in Fig. 1 incorporates a chart containing the users' diet on the left, and a chart for the reference diet on the right. The former contains four hierarchical layers, while the latter contains only three. This is because the data for the latter is a generalization of the Dutch population, and thus only shows the aggregated food categories.

In both sunburst charts, food categories are encoded with different colors to distinguish between groups. Matching categories between charts are encoded using the same color to convey similarity and enable quick comparison. In the users' diet chart, food products lowest in the hierarchy inherit the color of their parent category to signal grouping. Category and product names are also shown in each node if there is available space. In addition to node names and color-coding, we also experimented with varying brightness to make food products within a category more distinct. However, we quickly realized that this would cause users to perceive brightness as a scale of the emission, which creates confusion across categories with dissimilar ranges of emission. Hence, no brightness variation within a category was used.

The relative size of a node encodes the amount of emission in kg CO_2e produced by the users consumed amount. This size is relative because it is compared to the total emission of the user. A mouseover tooltip for each node shows the absolute kg CO_2e emitted and also its percentage of the total emission.

Cluttering of nodes at the lowest hierarchical layers is alleviated by implementing effective user interaction. When a category is clicked, the sunburst filters the data and shows only the selected category and its child nodes in the same view (Figure Fig. 2). The user can move back to the unfiltered view by clicking on the return button or the parent node in the center. Smooth animations are implemented to benefit user experience. Thus, users can easily navigate throughout the hierarchy.

Users can interact with the sunburst visualizations and select categories. This will reveal all food products within a category on a bar chart, together with their rates of emission (kg CO_2-eq per kg product). This component explained in the Section 3.2. Additionally, users can select specific food products. When clicked, the product is highlighted using a **pull-out** effect (Fig. 1) to connect this point to the other views, and its emission rate across the supply chain is visualized on the timeline. The latter is further explained in Section 4.2.

The visualization components of the hierarchical overview and its features support users at viewing their diet, analyzing its structure and gathering insights about their dietary composition (**Task 1**). After inputting their diet, users can inspect the composition of CO_2e among their diet at each hierarchical level. They may start off by scanning the overview of the hierarchy and identify key insights, such as the proportion of emission from vegetable or animal products. They could further identify important categories and food products that contribute most to the emission by scanning and comparing the node sizes. If they are interested in a certain category, they can dive into this by interacting with the visualization.

Additionally, it allows users to compare their diet to the Dutch average (**Task 2**). Users may analyze the reference diet and its composition, in order to identify proportions of emission from different categories. They could put their emission patterns into perspective by comparing relative proportions to the reference diet, and can further identify key categories. This can support users in making judgements about their own emission composition. See Fig. 2 and Fig. 3.

3.2 Viewing substitute products

When users identify a spike in emission that originates from a specific food product, they might want to find suitable substitutes with a lower emission to reduce this (**Task 3**). To support this task, we used a vertical bar chart to visualize emission rates of food products within one category. The bar chart excels at displaying proportions of multiple items and it enables quick identification of key values. Also, food categories do not contain more than eight products at once, so the displayed chart will not be packed.

When the user filters or selects a category in the hierarchical overview, all food products of that category are visualized in the chart, as shown in Figure Fig. 3. Contrary to the quantities in the Sunburst visualization, the bar chart shows the rate of emission in CO_2e per kg food product, instead of the amount of emission produced by the users consumption. We chose to visualize the rates to

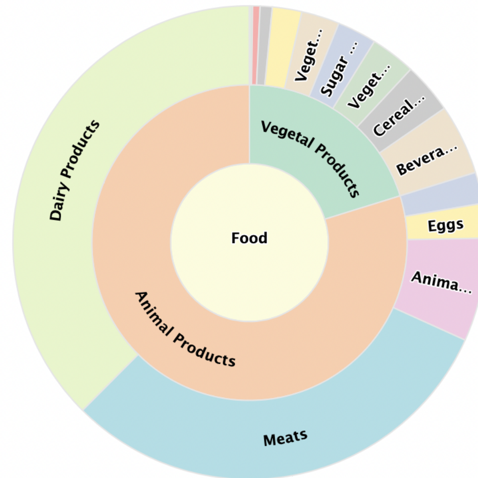

Figure 2: Dutch diet Sunburst visualization

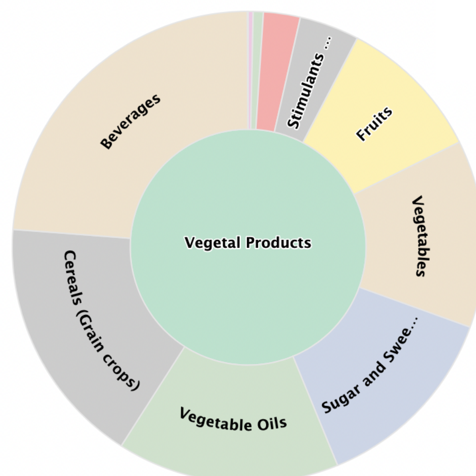

Figure 3: Sunburst visualization for "Vegetable Products" in Dutch diet

allow sensible comparison between food products. This circumvents the dependency of a product on the amount of consumption, which was previously the case. For example, if a user consumed high amounts of one product, then this would account for a large amount of the total emission, even if this product would have a low rate of emission. Also, it enables the comparison between products not included in the diet.

The bars use the same color as the selected category in the sunburst visualization, which visually connects the displayed items to their category. In case a specific food product was selected, the respective item in the bar chart will also be highlighted, as shown in Figure Fig. 4. A darker shade of the color was used since Woke Cooking utilizes a light color pallet. When the user hovers over a bar, a tooltip will pop up, showing the emission rate.

Since the range of emission rates can differ between two categories, the x-axis is dynamically updated to fit the values when displaying a new category. Additionally, food items are sorted in descending order, which adds a logical and more continuous structure to the graph. This could aid users in identifying low emission foods quickly.

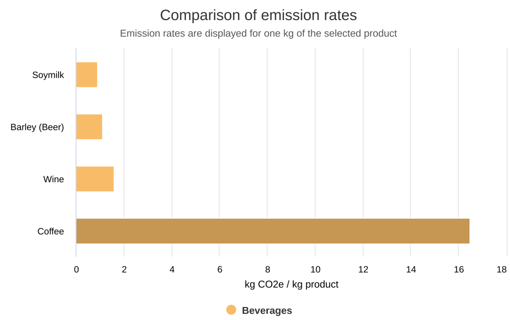

Figure 4: Barchart visualization for “Beverages” category, with the “Coffee” products highlighted

3.3 Supply chain timeline

Users should be able to analyze the emission of a food product across different stages of the supply chain and to understand those (**Task 4**). To visualize emission across the stages, we used a spline area chart. This visualization method is well-suited for uni-variate quantitative data that changes over time. While our dataset did not contain explicit timestamps, it is structured sequentially, going from stage to stage. This can be used to visualize changes in emission rate between stages in an intuitive manner. Hence, we decided to visualize the change in emission rate as a quantitative timeline. This is presented in Fig. 5.

We decided to use the emission rate (kg CO_2e per kg product), instead of the raw amount of CO_2e emitted from the user’s consumption, for similar reasons as outlined in Section 3.2. By visualizing the rates, users get a less biased view and are able to compare between stages and even between different products. Each datapoint then represents a product’s emission rate at the corresponding stage.

After the user selects a food product in the hierarchical overview, a corresponding line is drawn on the timeline that captures the emission rate across stages. The first time in a user session that a line is plotted, its animation will pause shortly after each stage to display a description of the emission causes. This can give users a better understanding of each stage in the supply chain. The animation of subsequently drawn lines will not pause to improve the user experience. In case that a user wants to read the descriptions again, the stage labels on the x-axis can be hovered to reveal its description.

The color of the line is kept equal to the color of the food product in the hierarchical overview. Additionally, the area underneath the line is filled with the same color for legibility but uses a decreased opacity to show all occluded lines. Users can plot multiple food products on the timeline, and previous lines can be removed using the *Reset* button. Additionally, when the user hovers over a line, it will be highlighted so that users can see occluded areas. A tooltip is also shown when a datapoint is hovered, revealing the emission rate of the current stage. The timeline visualization and the described features aid the users’ understanding of emission across the supply chain and enable them to further analyze a product’s emission (**Task 4**). They can identify key stages that contribute the most to the emission for a product. Users may gather insights when inspecting the timeline. An example is that nuts can have a negative emission rate at a stage because of their positive influence in biomass growth. Users can also compare the emission timeline between products, which helps them judge their own diet.

3.4 Gauge

Since CO_2e values might not give a clear, tangible indication, we wanted users to be able to compare their emission to some reference

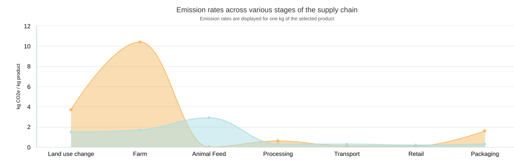

Figure 5: Timeline visualization for “Coffee” and “Pig meat” product.

point (**Task 2**). That is why we decided to use gauge charts. This visualization method is easy to understand because it is intuitive and related to physical gauges. Two gauge charts are used: one to display the user’s total emission Fig. 6, and another one for the emission of the Dutch average diet. Fig. 1 displays the user’s emission on the left and the reference emission on the right. The average Dutch diet emits 5.4 kg CO_2e per day, as found in the FOASTAT data. A cultural color sequence from green to red is adopted as emission increases, which is intuitive to understand for users.

In this way, we try to create a reference point from an average diet, to which the user can compare. The text indication, ranging from ”Very Low” to ”Very High”, shows a comparison to the average Dutch diet.

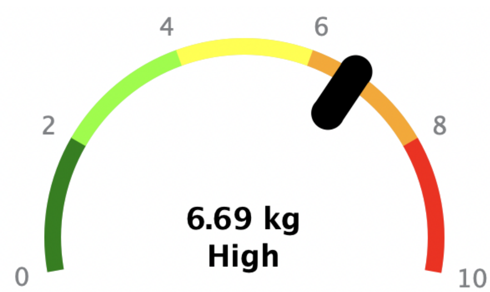

Figure 6: Gauge visualization

4 Discussion & Conclusion

The dashboard can help users in reducing their diet’s ecological footprint, by analyzing, comparing, and adapting individual parts of their diets. The cause for those emissions can also be individually analyzed, which helps to gain a deeper understanding of the emissions across the supply chain.

One weakness might be that the user has to take their time to individually fill in the ingredients of their diet or meal themselves. Maybe a plugin for importing recipes from a cooking website would be helpful but that is outside the scope of this project. Furthermore, the database used was limited in scope so not all foods are in the database. This is perfect for a proof-of-concept but not so perfect in a real-life use scenario.

This project was an interesting learning experience. Creating and combining all the different elements and thinking of details that would have never crossed our minds before this course was very insightful. The guidance of our supervisor Gjorgji Strezoski was also very helpful. He was very supportive of the global idea for this project and gave us great pointers and advice. The team was also very easy to work with. There was a clear common goal, and having multiple visualizations made it quite easy to divide the tasks among the team members. We take pride in how the dashboard turned out, especially since none of us had prior experience creating a dashboard from scratch with JavaScript.

REFERENCES

[1] M. Brander and G. Davis. Greenhouse gases, co2, co2e, and carbon: What do all these terms mean. *Econometrica, White Papers*, 2012.

[2] A. Collins, A. Galli, N. Patrizi, and F. M. Pulselli. Learning and teaching sustainability: The contribution of ecological footprint calculators. *Journal of cleaner production*, 174:1000–1010, 2018.

[3] M. Crippa, E. Solazzo, D. Guizzardi, F. Monforti-Ferrario, F. N. Tubiello, and A. Leip. Food systems are responsible for a third of global anthropogenic ghg emissions. *Nature Food*, 2(3):198–209, 2021. doi: 10.1038/s43016-021-00225-9

[4] S. González-García, X. Esteve-Llorens, M. T. Moreira, and G. Feijoo. Carbon footprint and nutritional quality of different human dietary choices. *Science of The Total Environment*, 644:77–94, 2018. doi: 10.1016/j.scitotenv.2018.06.339

[5] J. G. Olivier, J. A. Peters, and G. Janssens-Maenhout. Trends in global co2 emissions. 2012 report. 2012.

[6] J. Poore and T. Nemecek. Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392):987–992, 2018. doi: 10.1126/science.aaq0216

[7] E. Röös, H. Karlsson, C. Witthöft, and C. Sundberg. Evaluating the sustainability of diets–combining environmental and nutritional aspects. *Environmental Science & Policy*, 47:157–166, 2015. doi: 10.1016/j.envsci.2014.12.001

[8] F. N. Tubiello, M. Salvatore, S. Rossi, A. Ferrara, N. Fitton, and P. Smith. The faostat database of greenhouse gas emissions from agriculture. *Environmental Research Letters*, 8(1):015009, 2013.