Wearable Carbon Footprints; An Exploration of How Data Visualization Garments Facilitate Behavioral Reflection

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ABSTRACT

This wearable data project aims to promote awareness and stimulate discussion about climate change through visualizing personal carbon footprint data on clothing. It explores placement of visualizations in the social sphere, as well as revealing unseen individual and systematic responsibility for carbon emissions. Through creating and wearing my personal footprint data on a fabric sash, I became intimately familiar with my own environmental impact. Through wearing it in public as a social and cultural probe, I also learned that conspicuous placement of intriguing visualizations can draw attention to issues, stimulate conversation, and leave individuals with a desire to learn how they can make a difference. This project shows how visualizing data on garments can facilitate these types of social interactions and increase intimacy with one's own personal data.

Keywords

Wearable Data, Carbon Footprint, Environmental Sustainability, Data Visualization, Physical Visualization, Persuasive Technology, Digital Media

1. INTRODUCTION

1.1 Statement of Problem

Climate change is a growing problem in the modern world, and is one of the most important issues my generation will face[32]. The causes of climate change have been in motion for decades, and the effects have the potential to last for thousands of years if allowed to proceed too far before intervention occurs[1]. In the worst case scenario, we are faced with the possibility of our planet becoming uninhabitable[2].

While large-scale environmental sustainability policies are being put in place to reduce emissions in some parts of the world, the question remains as to whether we are acting quickly enough[1]. In other cases[3], skepticism and differing philosophical and economic priorities make it difficult to agree on a global course of action. In addition, social and cultural differences[4] in how individuals interpret the threat of climate change has a large impact on what kinds of policies a nation agrees to implement and take part in. While awareness and communication of risk is important, individuals must also feel enabled to make a change and perceive that society is moving in a similar direction[4].

In the United States today climate change is an issue often placed on the backburner. In many ways, such as with the decision to reject the Paris Agreement, we as a nation have taken a stance that almost says "This issue is not important." However, due to the lack of prioritization, the United States is one of the highest greenhouse gas emitting nations in

the world. In 2014 we emitted 16.5 metric tons of CO_2 per capita, putting us at #11 in the world[31]. For context, the world average is 5.0 metric tons per capita. Given that climate change is a global issue, I believe there needs to be a shift in our nation's individual understanding and attitudes towards environmental impact.

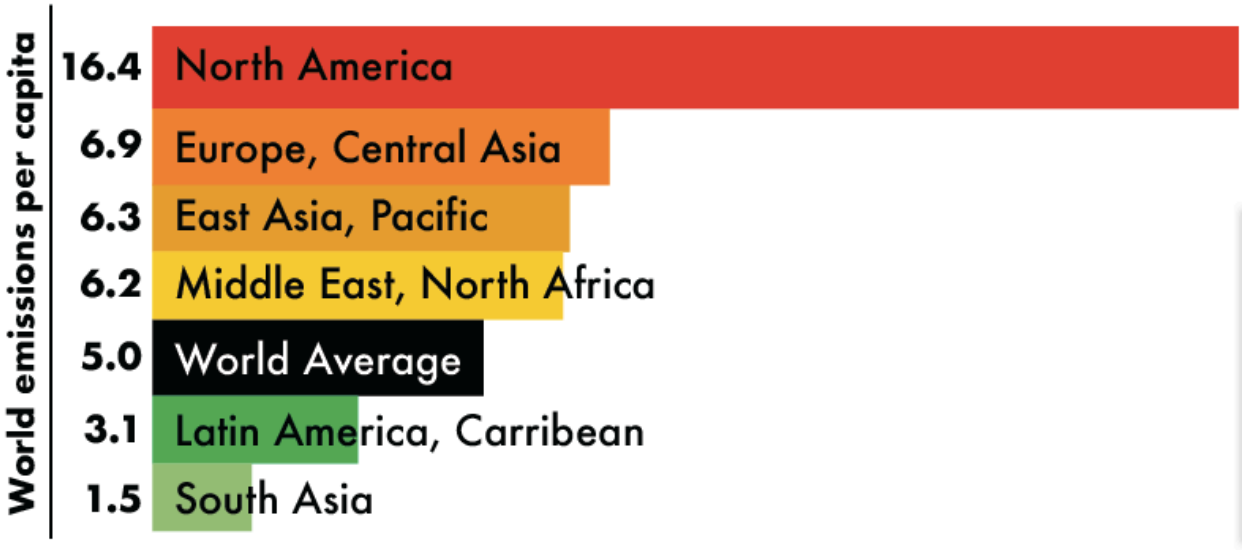


Fig. 1.1: Comparison of 2014 regional emissions per capita (in metric tons); This is the same graphic as used on the back of my sash to contextualize the size of the USA's national average

1.2 Solution

This project aims to improve awareness and the overall prevalence of discussion about climate change by providing a tangible wearable artifact that displays individual carbon footprint data. This awareness is achieved both on the individual level, by visualizing a detailed view of a single person's carbon footprint to inform them of where their emissions come from, and on a larger social level by promoting discussion around the object. The data is in the form of a wearable article of clothing such that it may be present with a person throughout their day and be a centerpiece for conversation and reflection, both to the wearer and those who encounter the artifact in public.

I have created a fabric sash visualizing my own personal carbon footprint data. The sash has colored bands coded to represent the various sources of emission data, as well as pins that display corporate logos of entities also involved in the production of these emissions. My individual total is compared to the United States national average, and a graph on the back contextualizes the individual footprint by displaying world carbon footprint averages.

Fig. 1.2: Finished fabric sash, displaying my carbon footprint data, secondary consumer sources on button pins, and a graph of global emissions per capita for contextualizing my footprint

I have explored my own data through the careful creation of this artifact, as well as provoked discussions with others by wearing it in public. I have gotten feedback on the design of the object and attempted to guide conversation into productive discourse by providing a multi-level view of the carbon footprint, as it is often a pitfall of modern environmental visualization to put too much emphasis on the responsibility of individuals alone. The artifact does not presume to be a cure-all solution to our cultural attitudes about climate change, but instead plays a role in the broader discourse of making the reduction of greenhouse gasses more socially, economically, and politically accessible.

Though this project has focused in-depth on only my own carbon footprint, I can certainly see the potential for it to be expanded and made available for others (see more in Future Work). The main outcome of this project was for me to gain an understanding of my footprint and be able to more easily engage in discussions by wearing the sash, and these are the two that benefits I could see driving an expansion of the work.

2. BACKGROUND

2.1 Perspectives on Climate Change

As mentioned above, climate change is a mounting concern for the modern age. There are many different attitudes about climate change currently, ranging from skepticism[26] to alarmism[2], though climate scientists generally agree that climate change is a real human-impacted phenomenon and has consequences for the habitation of our planet[6]. This is an important basis for the motivation of this project.

How different cultures and societies discuss climate change is another motivation for the project. I have experienced firsthand what it is like to be temporarily immersed in a culture that acknowledges and strives to improve long-term human impact on the environment. My greatest exposure to this was in Copenhagen, Denmark, and the overall environmental conscientiousness that I witnessed was a stark contrast to how the general population in the United States discusses (or does not discuss) climate change.

As part of my coursework in Denmark I did user research and developed an application to help Copenhagen toward its goal of becoming carbon neutral by 2025. The fact that the capital city of Denmark has such a progressive and lofty environmental goal speaks volumes about the national attitude towards climate change, and my research for the feasibility of our app seemed to echo this prevalent environmental mindset. While the United States has several cities now planning to become carbon neutral by 2050, Denmark is where The Carbon Neutral Cities Alliance was born[27] and has a far better political track record when it comes to actually implementing effective environmental policies[28,29].

In *Public Views On Climate Change: European and USA Perspectives*, Lorenzoni and Pidgeon discuss the underlying principles of the same phenomenon. They state that though most Americans are aware of climate change, it is generally considered less important than other issues, and people are not widely aware of the specific causes or solutions to climate change[4]. This attitude of considering climate change a distant and overly complex threat allows it to remain a “backburner” issue to many people.

Their suggestion to remedy this is to not only communicate risk and feasible actions, but to change the perception about climate change; “Successful action is only likely to take place if individuals feel they can and should make a difference.” Individuals must feel that they not only have agency, but that society is moving in the same direction. This affirmation of environmentalism as a social value can come in various forms, such as local or national level policy implementation, local initiatives, or media representations that frame climate change as an important and valid issue.

Further recommendations from Lorenzoni and Pidgeon are to situate addressing climate change in localized spaces to increase saliency[4]. By starting at an individual level and moving up to the larger scale, a movement can form without regard for the current state and national level of action. Additionally, as mentioned in their paper, local level

initiatives may in fact set the precedent and initiate wider-ranging activities[30]. This project also aims to instigate awareness in this way, starting at the most individual level but allowing for large-scale considerations and discussion to occur.

2.2 Carbon Footprints & Calculators

For this project, I have selected the carbon footprint as a metric by which individuals can measure the environmental sustainability of their activities and how they relate to the impact of global greenhouse gas emissions. Though the term "carbon footprint" mentions only carbon dioxide in its name, likely due to the fact that CO_2 makes up the majority of greenhouse gas emissions[9], it can often include more greenhouse gases. In this case, their total is expressed in the equivalent amount of carbon dioxide. This can make it effectively the same as a "GHG (greenhouse gas) footprint," depending on the methods of measurement. Despite the existence of this more specific term, however, I have chosen to operate under the terminology of "carbon footprint" due to its higher public familiarity and the fact that my chosen calculator only accounts for CO_2 and methane.

A wide array of carbon footprint calculators exist online to provide a digital analysis of user-provided emissions data. However, they tend to vary in their thoroughness, which types of activities they consider, and how their results are expressed. Throughout the course of the project, I tested various calculators and made a selection based on specificity, inclusion of activities that produce non-CO_2 greenhouse gases, and consistency. My final calculator selection was from The Nature Conservancy's official website[7].

The Nature Conservancy's carbon calculator seemed the most appropriate out of about 8 different calculators I tested. The main reason for this is that it factors in emissions from a broader range of sources than most; Inclusion of the food section is particularly good because I saw it in few other calculators, but food sources make a large contribution to national emissions[25] and diet is a choice for which people have a large amount of agency.

My next consideration was that this calculator breaks down the data in a decently understandable way. Though not as in-depth as it could be, it is possible to discern how much each category contributes to your overall total, which is an essential part of my project. Though I had to do this partially through going into the calculator and manually changing values within some sections (eg: if home energy use is 6 metric tons, what portion of that is just the water bill?), many of the other calculators I tested just spat out a single number at the end and would not have been suitable for further breakdown.

2.3 Carbon Offsets

Along with summary information of the carbon footprint, carbon calculators often provide prompts to take action in various ways, whether it be voicing desires for policy change, signing a petition, or purchasing a carbon offset.

Carbon offsets are of note because they are currently the only feasible way to attain a neutral emissions footprint. Purchasing a carbon offset is often expensive, generally $18.15 per metric ton[8]. The average emissions per capita of the United States is approximately 20 metric tons per year, meaning a typical offset for a year is at least $363.

An obvious issue with carbon offsets that I considered during this project is the issue of income inequality and the ability to purchase them. This became less of an issue once I adjusted the baseline expectation to be the national average rather than being as low as possible, but is still an issue in the discussion of lowering carbon footprints and keeping a sustainable lifestyle accessible.

Though my final artifact does not directly involve carbon offsets, I have included this background piece to explain them and their relationship to the current way carbon footprints are viewed – as something that must be financially negated. This is in contrast to the way that my project presents footprints as something that should be reduced, but with more realistic and comparative benchmarks than total negation. This project also extends the actionable step at the end of carbon calculators to focus on personal awareness and behavioral adjustments for improved sustainability, as opposed to simply buying a clear conscience.

2.4 Data

For the implementation of the wearable artifact, I used my own carbon footprint data. While I initially considered using emissions data for a large group of people, such as the city of Atlanta, I felt that reducing it to a more personal level was more appropriate for the form of a wearable and could potentially foster a greater personal connection to the data. Through doing this, I was able to discover and reflect upon my own sustainability practices in much more depth than if I had used general statistics or even another person's data.

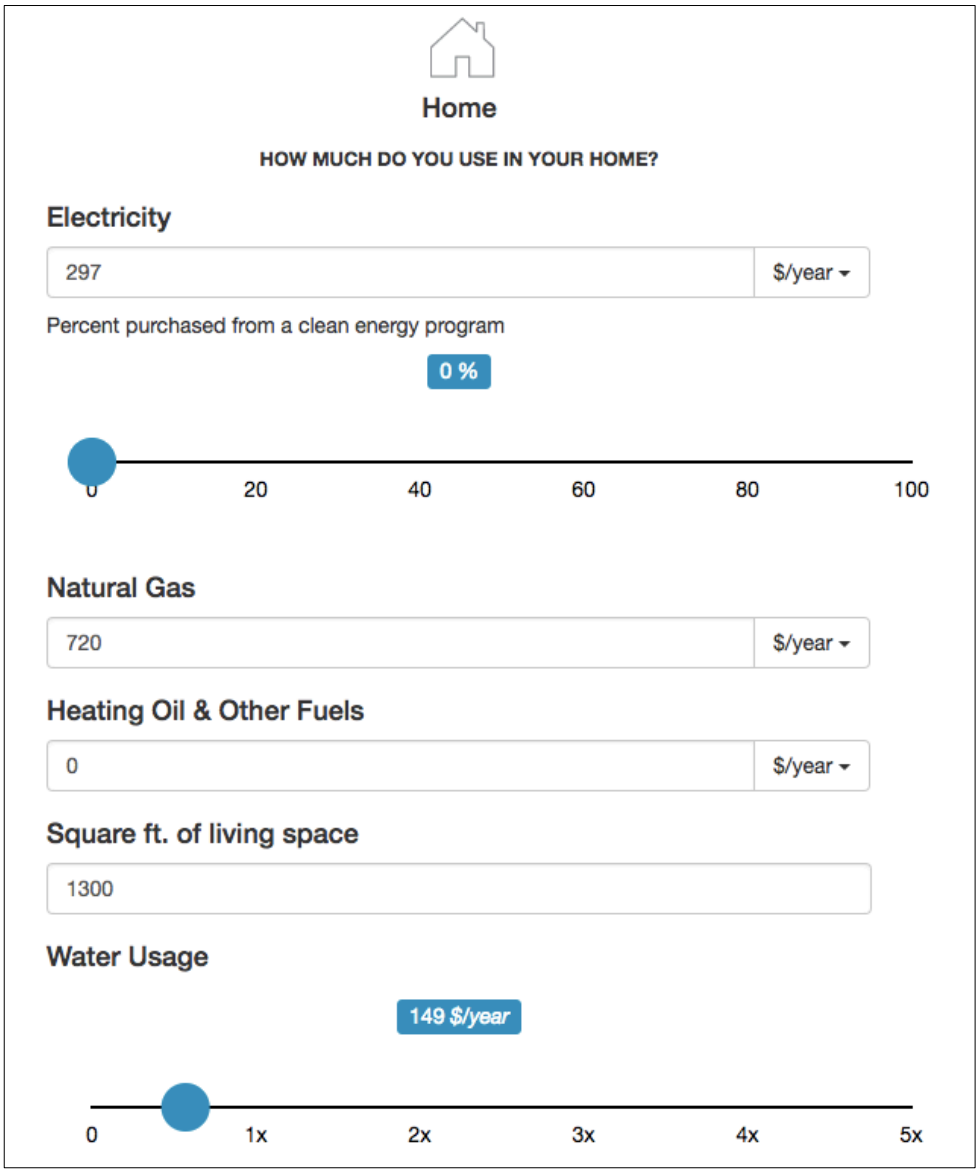
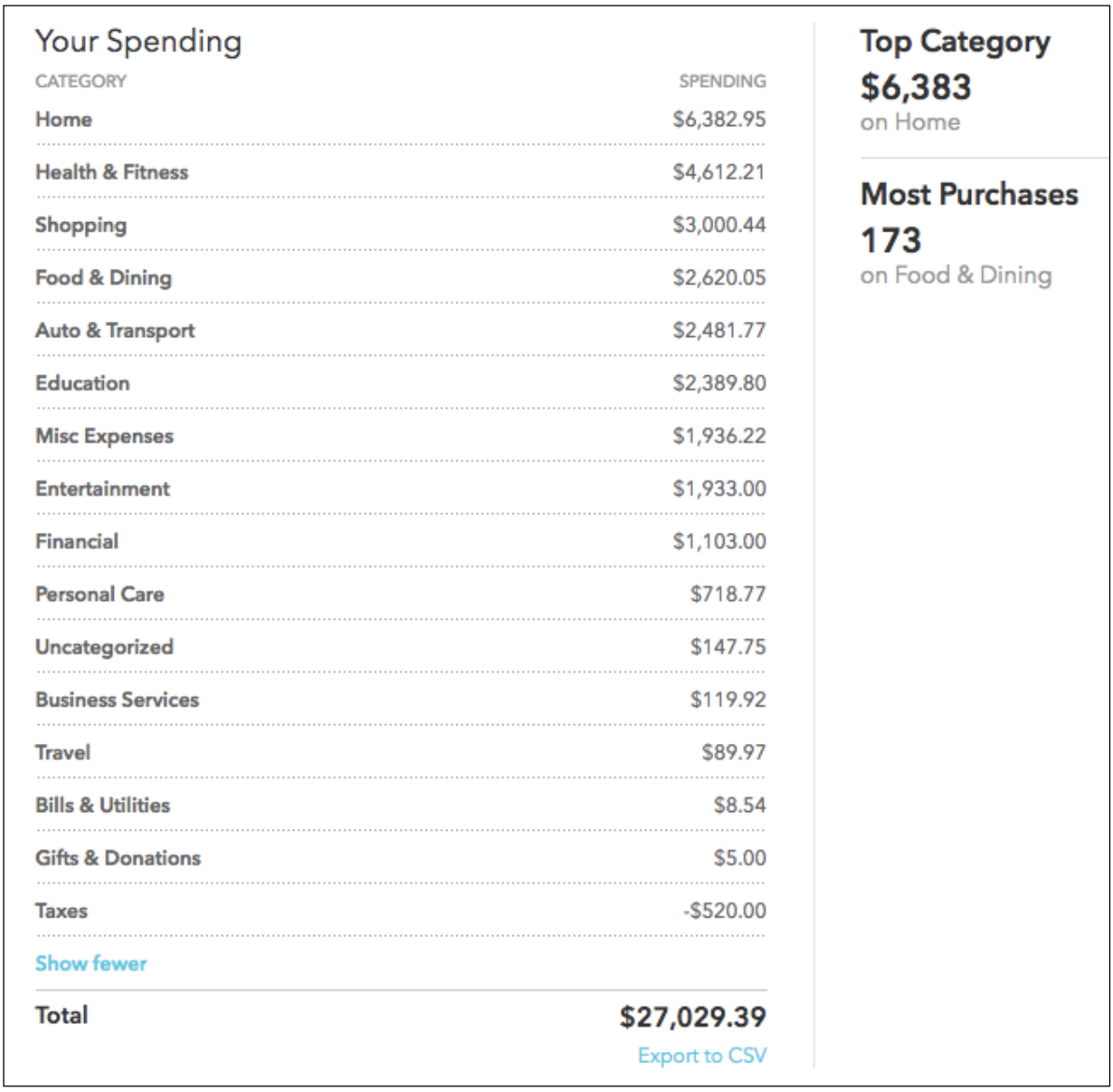


Fig. 2.1: The Nature Conservancy's calculator; Home utility section including water, natural gas, electricity

Using The Nature Conservancy's calculator, I collected emissions data from January 2017 to January 2018 in four categories: travel, home, shopping, and food consumption. Travel and home resource use are common categories among carbon calculators, but I made my selection of this calculator based partially on its inclusion of shopping and food. Shopping helps address corporate responsibility and the economic side of greenhouse gas emissions, while the food category is an easy area to demonstrate individual agency and to include non-CO_2 gases such as methane.



Your Spending

CATEGORY	SPENDING
Home	$6,382.95
Health & Fitness	$4,612.21
Shopping	$3,000.44
Food & Dining	$2,620.05
Auto & Transport	$2,481.77
Education	$2,389.80
Misc Expenses	$1,936.22
Entertainment	$1,933.00
Financial	$1,103.00
Personal Care	$718.77
Uncategorized	$147.75
Business Services	$119.92
Travel	$89.97
Bills & Utilities	$8.54
Gifts & Donations	$5.00
Taxes	-$520.00

Show fewer

Total $27,029.39

Export to CSV

Top Category

$6,383

on Home

Most Purchases

173

on Food & Dining

Fig. 2.2: Spending summary from Mint for January 2017-2018; This is part of the data I entered into the carbon calculator to get my final footprint size. I also looked within each of these categories to select the most common logos.

Travel data was based on the mileage of my current car, an estimation of my annual travel distance with some help from Google Maps, and plane ticket purchases in the last year. The home resource data was collected using utility bills at my new current residence,

including water, natural gas, and electricity. Shopping data was sourced from Mint, a financial software I have linked to my debit and credit card accounts which tracks and categorizes spending and income. I roughly divided which purchases fall under “goods” vs “services” for the calculator. Finally, my food data was estimated with the help of MyFitnessPal, an app I regularly use to track my diet.

Despite my comparison to other calculators and best efforts to get the most accurate data, there are some possible issues with the data I have collected. As mentioned previously in section 2.2, the calculator did not provide data quite as granular as I would have liked. As such, my totals for each category are whole numbers in the unit of metric tons.

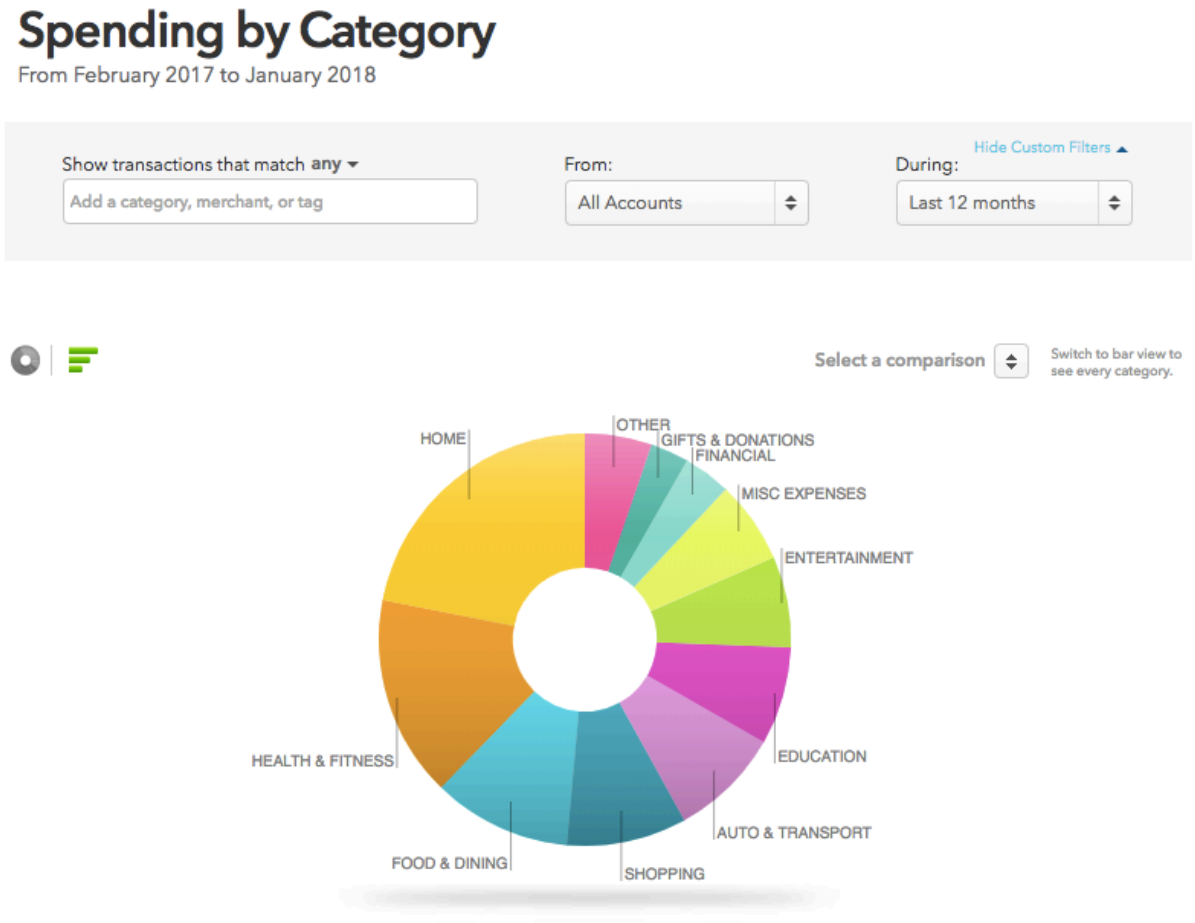


Fig. 2.3: Another view of Mint’s spending summary by category for January 2017-2018

I also collected a friend’s data using this same calculator, for comparison during the design process. His spending habits and diet were fully estimated, but his home resource use and travel data were collected in similar ways to mine. His data contrasts nicely with mine, as he is fairly below the national average, lives in a different state, and has a household size much larger than mine.

3. RELATED WORKS

3.1 Physical Visualizations

Immediately following my initial project proposal, a physical data sculpture, I researched various precedent projects. Through my exploration of precedents, I identified several key elements of successful visualization projects that I was interested in utilizing. These included the project's placement in the world and materiality.

Placement mixes the unique aspects of a location, whether that be a particular place with certain social associations or even a relative location such as in "the home", to content in order to create a more meaningful and complex interpretation of the work. Materiality is the quality of manifesting data in a new medium, often one that serves to highlight or reveal unseen aspects of the data.

A precedent that has keep its relevancy since my initial proposal is Loren Madson's District 5 piece[16], a collection of bent metal tubes representing charts of various types of violence on decline. This particular sculpture is of interest due to its shared location relevancy with the data it portrays, as well its allusion to charts as they would traditionally be displayed in 2 dimensions. This was the initial inspiration for the placement theme, which has evolved beyond the medium of data sculpture but remains important to motivating the project.

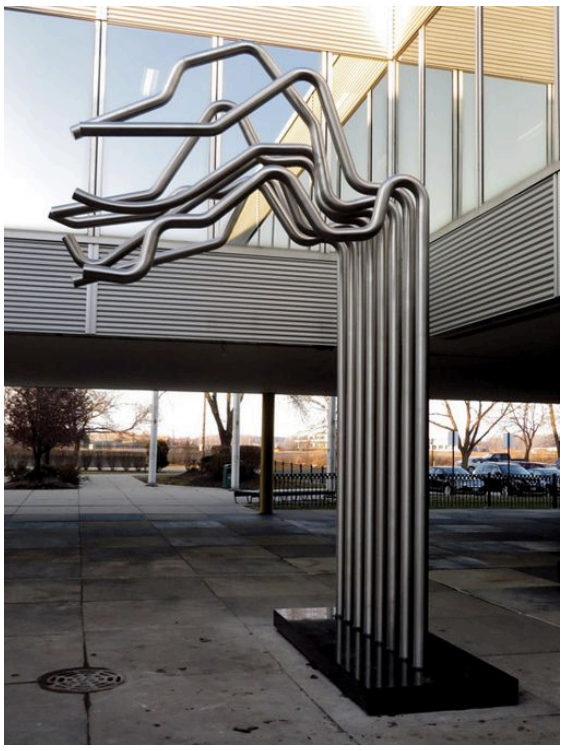


Fig. 3.1: Madsen's District 5; bent metal

We Were Strangers Once Too[17], a 2017 sculpture by Jer Thorp for display in Times Square, is another example of how placement can be used effectively in data visualization. The installation itself consists of various metal poles with national information on foreign-born occupants of New York. Physical placement is a large factor in the striking nature of the piece, as well as how it is socially positioned.

Fig. 3.2: Jer Thorp's We Were Strangers Once Too

The most obvious way in which physical placement is used here is the choice of city. As the principle entry point for many immigrants, New York is a sensible choice to tie location to content. Additionally, Times Square is known as an important cultural landmark, in many ways emblematic of American society at large, giving the display an air of speaking for the nation. However, the piece also utilizes even more local placement by altering the overall shape of the installation based on the observer's perspective. When viewed from the correct angle, individual data points on poles align to create a large heart shape.

Socially, the sculpture is designed primarily as a centerpiece for discussion on immigration and valuing diversity, taking a stance on an important topical issue of the times. The physical placement in a busy hub of such a large city helps stimulate this discussion, but is secondary to the artist's social intent. This project was my first inspiration to use data as a motivation for discussing important issues.

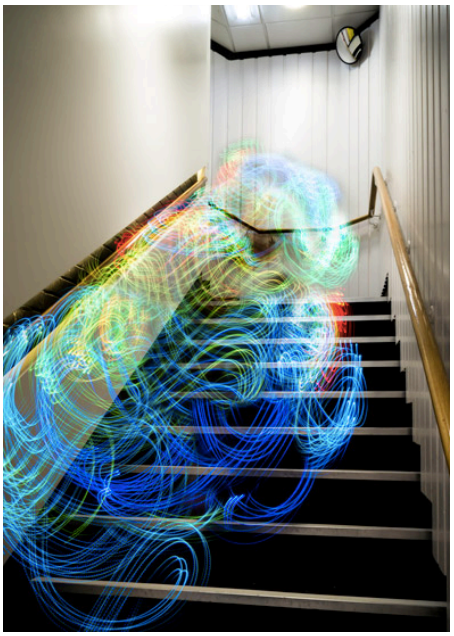


Fig. 3.3: Digital Ethereal; WiFi signals revealed through long exposure photography

Materials and representing data in various mediums was another strong element of the precedent projects at this stage. I explored visualizing data through sound, light, and performance. I found that a core feature of many successful visualizations is the ability to utilize the unique features of a particular medium to make unseen patterns of data more apparent.

Digital Ethereal[18], a project that visualizes WiFi signal as light, incorporates many of these elements. Long exposure photographyi is coupled with a device that registers WiFi signal and represents it as a color based on reception strength. This creative translation of unseen yet ubiquitous information into something visible was a strong motivation for exploring what types of information I would want my project to reveal, as well as an inspiration for using an unconventional medium.

Stacey Kuznetsov's air quality balloons[23] are an excellent example of a physical data visualization with environmental content. This project highlights how environmental factors are often invisible until purposefully show using the tangible materials of an installation or other visualization technique.

Fig. 3.4: Air quality balloons by Stacey Kuznetsov use sensors to change color and show various air pollutants

The air quality balloons use sensors to update the color of each balloon's LED in real time, indicating the detectable levels of pollutants in the air. Each balloon represents a different substance. While pollution is a complex and ever-changing environmental phenomenon, this project displays the environmental information neatly by providing a snapshot of the individual chemicals only within the current proximity of the balloon. This also serves as a model for how complex systems can be trimmed down to digestible, while still conveying enough information to give viewers an idea of what is occurring.

This installation also employs spectacle computing, a strategy by which information is "vibrantly projected into the social sphere using expressive and tangible media"[23]. This helps to draw attention to the project as people pass by, influencing them to stop and engage with the visualized content. In choosing to put my own data on a garment as uncommon as the sash, I also leveraged some of this novelty factor to draw attention to my project. I saw this many times while wearing it in public, as people would inspect me for much longer than if I were wearing normal clothing and would often start conversations by asking why I was wearing it.

3.2 Wearable Data

Using the two above-mentioned principles of placement and materiality as an anchor, my project evolved from planning a data sculpture into a wearable visualization. I considered a wearable artifact to be an alternate medium of visualization with high potential to explore placement both on the body as well as in social interaction. From here, I found various examples of wearable data to further guide my exploration of this data visualization space.

A precedent with a similar ecological focus, Dressed in Data[19], informed much of my early brainstorming. These dresses visualize air quality data with static pieces of lace and net clothing, mapping the number of chemicals detected to the number of squares, the relative amounts of chemicals to square size, and the potential sources to the type of fabric used. The dresses comment on the unseen yet very real environmental factors around us every day, as well as bring attention to the concept and importance of air quality. I also appreciated how, unlike many other projects that represent data collected by sensors, this artifact remained non-digital in its representation. The ways in which this project provokes thought about the environment while remaining effortless to use strongly motivated my wearable's final form.

Fig. 3.5: Dressed in Data; air quality data as fabric

Fig. 3.6: x.pose, a wearable sculpture that changes transparency in real time

On the digital side of wearables, x.pose[20] is an excellent precedent demonstrating how real time data can be shown on the body. The piece is a 3D printed flexible mesh fitted with electrochromic film panels that change transparency dynamically. This provocative piece reveals more of the wearer's body in accordance with how much of their personal data is being shared on their smartphone.

I found this project to be a great example of how to use and subvert the traditional function of clothing to make a point, as well as remind the wearer of the implications their data have. While I ultimately did not choose to make my project digital or real time like x.pose, this project did influence how I wanted my project to remind users of the impact their data has.

Another fabric based project that I found inspirational was Kristen Nutbrown's temperature scarf and afghan[21]. This project visualizes long term data in a simple yet beautiful way, creating a functional item. Similar to the data dresses, I enjoyed how the final product was tangible, informed by data, but not necessarily computational itself. The idea of interacting with data uncoupled from devices or technology struck me as a novel characteristic of this physical visualization that fosters intimacy with the data. This uncoupling allows the data to be present with the wearer throughout their day and in the midst of their daily activities, extending beyond the digital realm and into everything they do. This provides more opportunity not only for data-related conversations with others, but also for the object to spark reflection about its visualized content. Both of these are effects that I personally experienced through the process of crafting and wearing my own data sash.

Fig. 3.7: Scarf displaying 1 year of temperature data

While you could certainly read the data of the temperature scarf as a traditional bar graph, I also liked how the product itself does not necessarily declare itself as a visualization or complex artifact in the way that the dresses do. Additionally, the handmade nature of the scarf inspired me to consider the accessibility of my data wearable's materials.

Fig. 3.8: Kryzystof Wodiczko's alien staff in a public setting

Kryzystof Wodiczko's Alien Staff[24], among several of his other similar works, is an example of how physical components of an outfit can be used to display information about the wearer and shape discursive practices.

The Alien Staff is an electronic staff intended to be carried by immigrants as a tool for facilitating communication. It includes a small monitor and speaker at head level, which broadcasts the story of the staff bearer's journey. The base of the staff includes a transparent cylinder containing artifacts representing the life of the carrier, such as letters, visas, and objects from their home country.

Through both the monitor and the collection of items, the staff acts as a form of visualization for the person's complex and unfamiliar background, bringing it to the forefront of observation. It also acts as an intermediary object to communication, drawing

the attention of strangers and establishing a dialogue where one might otherwise not be present. The establishment of this dialogue is intended to decrease space, both physically and psychologically, between native people and the immigrant.

On both of these fronts, there are parallels to the how the carbon footprint data sash presents information socially. Much like the Alien Staff, it is intended to be an intermediary object representing unseen information about the wearer and facilitating a dialogue about that information. Similarly, the sash also aims to increase public familiarity with what it represents.

3.3 Carbon Footprint Data Walk & Field Guide

As part of Dr. Yanni Loukissas's LMC 6312 studio course, I also collaboratively designed a relevant project to the topic of visualizing emissions. My work on this project provided a helpful additional perspective to exploring environmental data and influenced me to introduce a larger focus on carbon footprints in my master's project. The assignment was to create a data walk experience on the Atlanta BeltLine using at least one of several local datasets. My role included dataset research, creating a field guide, and collaborating with my partner to mockup and present several iterations of ideas for the structure of the walk.

My partner and I chose to use a Trees Atlanta plantings dataset, tree removal and building permits from the Accela citizen access database, and general research on Atlanta's carbon production and emissions sources. For the former two datasets, I created a field guide[11] detailing the context of the data sets. This field guide includes an overview, access information, standards and practices of the data's collection, possible errors or issues with the data, visualizations, and a summary of interviews with individuals who are familiar with how the data is handled. This field guide also touched on the primary target content for my data sculpture project at that time, which was the Atlanta tree canopy, and built on previous interviews with arborists and Trees Atlanta that I had conducted during the summer.

While the walk itself was initially based on the idea of introducing walkers on the BeltLine to the makeup of Atlanta's tree canopy, it shifted into using the canopy as part of a narrative of Atlanta's environmental sustainability. Atlanta boasts an impressive number of trees for a city of its size, and is often referred to as the "city in a forest." However, through myself and my partner's research in the carbon negation effects of trees, we found that Atlanta's huge population of trees in no way makes up for emissions we collectively produce. The BeltLine seemed like an apt place to counter the false idea that having so many green spaces makes Atlanta ecologically "green" as a whole.

Fig. 3.9: Mockup of the carbon footprint data walk where it would be located on the BeltLine, along with Trees Atlanta plantings

The walk itself was framed around the question “Do trees negate our carbon footprint?” For a short 100 foot span of the BeltLine, a graph of Atlanta’s CO_2 production and negation, stylized to look like a tall tree, would be drawn on the pavement. The segments are broken down by source of emissions as well as commercial, residential, and industrial sources where applicable. Totals are given underneath each. The city-wide production figure is approximately 16 times higher than Atlanta’s total negation by the tree canopy, and the visualization is to scale. A short blurb about the purpose and message of the installation is written at the end in the illustrated tree’s branches.

This stretch of pavement is adjacent to several Trees Atlanta plantings of various species. For each unique tree species, a small label on the pavement points to it and givens information about their estimated yearly CO_2 negation based on their species and maturity. Paired with this, a common activity that produces an equivalent amount of CO_2 is mentioned. The desired result is the realization that each individual tree alone does not negate very much carbon at all, so we must be mindful of how much we produce.

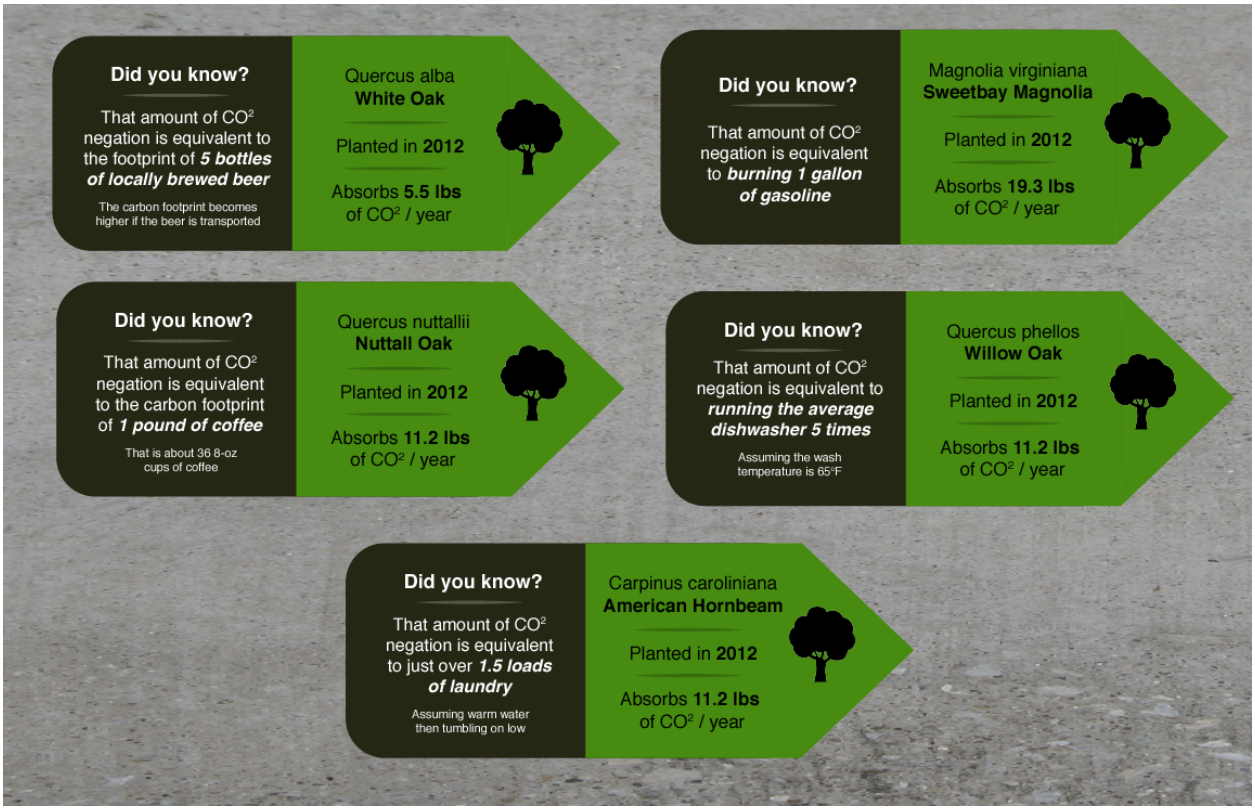


Fig. 3.10: List of tree species and activity labels

This project allowed for an exploration of physical data visualization using both the tree canopy data I had been considering for my final implementation, as well as a perspective about carbon emissions. Ultimately, this project aided in my understanding of the datasets I was working with (through the field guide and their use in a real design implementation), as well as helped me to identify characteristics that worked particularly well.

The tree labels in particular were something that sparked the idea of moving to a personalized view of carbon emissions in the final wearable data artifact. Similar to how the tree labels provide unseen context for the environmental function of the trees, I wanted a wearable that indicates the personalized environmental information about people. I felt that the strongest and most intriguing aspect of the tree labels were that they were highly specific to the tree in question, and this individual specificity seems to go hand in hand with the format of a wearable.

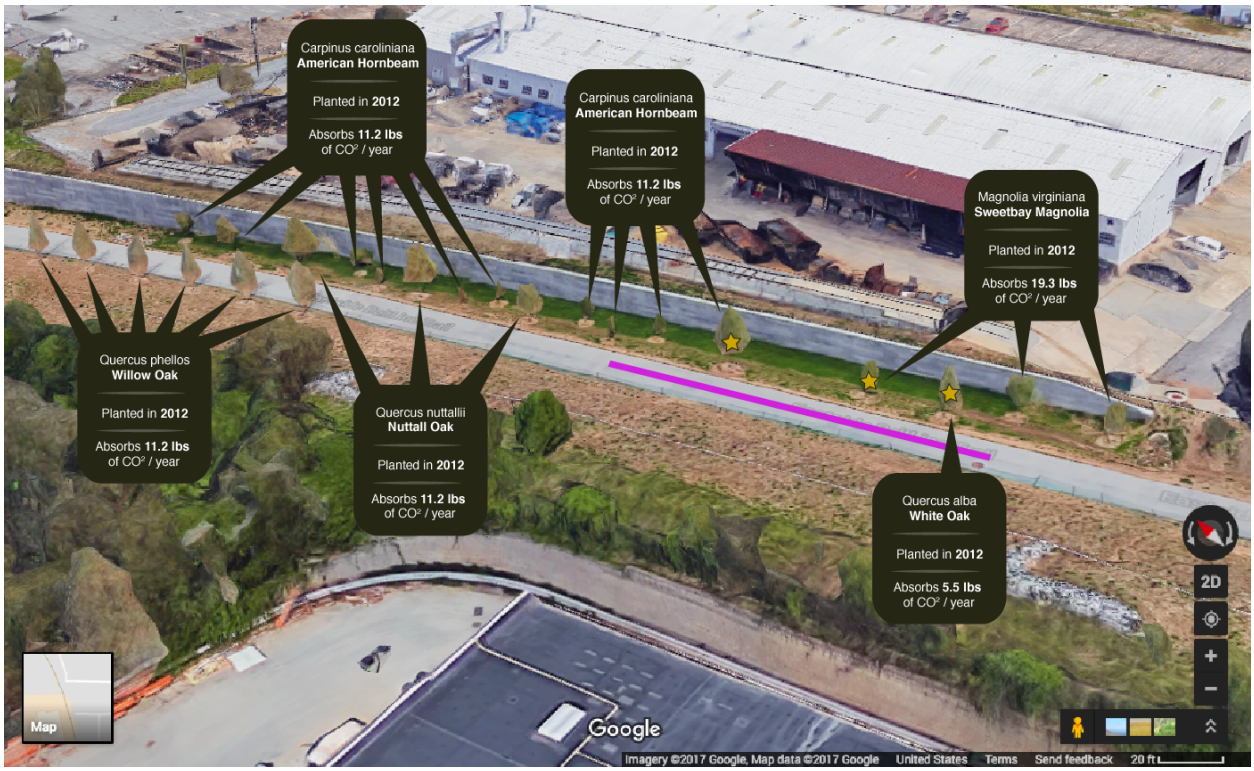


Fig. 3.11: Diagram of various tree species and negation values, with markings for the final trees that appear labeled in the data walk

3.4 Green Guide Copenhagen

Green Guide Copenhagen, a previous carbon footprint project of mine, was also an inspiration for the direction that the data garment took. During the spring semester of 2015, I studied on an exchange program at IT University of Copenhagen. There I worked with a group of Danish students to design an app that would help Copenhagen meet its goal of becoming carbon neutral by 2025[12].

The app itself helped individuals and businesses alike by listing restaurants, shops, and services around Copenhagen that are making an effort to reduce carbon emissions. The businesses listed in the app would be reviewed and rated on how environmental they are, as well as listing a short description of how they are making these efforts. All businesses in the app met a baseline level of environmental sustainability, so users could feel they are making a good choice no matter which places in the app they choose. Shops would see an increase in business and recognition for their sustainable choices, further promoting the individual store itself as well as the general idea that running a green business is more profitable.

On the consumer's end, the app assumes a desire to be an environmentally conscious individual, as well as to be seen as such. The app includes a social media element that

allows users to see where their friends have gone and what reviews they have of these businesses. It is designed with a prominent locally centered map feature to aid in exploration and promotion of businesses that are around you now but you may not have heard of or considered visiting before. This feature is also intended to pair well with the bicycle-centric travel style in Copenhagen.

Aside from the benefits of research about carbon footprints and gaining a more specified idea of what is considered ecologically friendly, this project also opened my eyes to a new way of viewing cultural perspectives on environmental sustainability. As mentioned previously in section 2.1, it was a bit of a culture shock to realize that so many Danish citizens had, on average, a much higher regard for the environment that I was used to. It took a detailed look at the culture of the city (in addition to our regular interview process) to realize that such an app could work and is something that people would use. It was new information to me that this was an initiative that could succeed somewhere in the world.

I found myself thinking “What if people in the US could be convinced to care this much about helping the environment?” Now, with this project, I am finally able to address ways that design can attempt to shift our culture and public perspectives in such a direction through the localized initiative of the data sash. Through the creation of the sash, I have already felt a shift in what it is like to begin evaluating my daily decisions in terms of sustainability.

4. DESIGN PROCESS

4.1 Initial Proposal

My initial proposal was for a physical data visualization sculpture, so much of my early work focused on that. My intention was to use Atlanta tree canopy data and create an installation that would inform viewers about various aspects of the canopy, as it is a unique and often underappreciated feature of our city.

Over the summer, I conducted informal interviews with Trees Atlanta representatives and the city arborist to gain a better understanding of the canopy and datasets I had. I identified the datasets I had been given Dr. Loukissas, and acquired the Downtown Tree Inventory as an additional resource. I learned about tree removal permits, ordinances, and an overview of how Trees Atlanta plantings occur.

I also accessed the Urban Tree Canopy Assessment and used it as inspiration for my ideas. I created a Fusion 360 model of a preliminary idea that represented tree density by neighborhood planning unit (NPU) in the form of a printed sculpture, drawing from concepts and materials in the researched precedent projects.

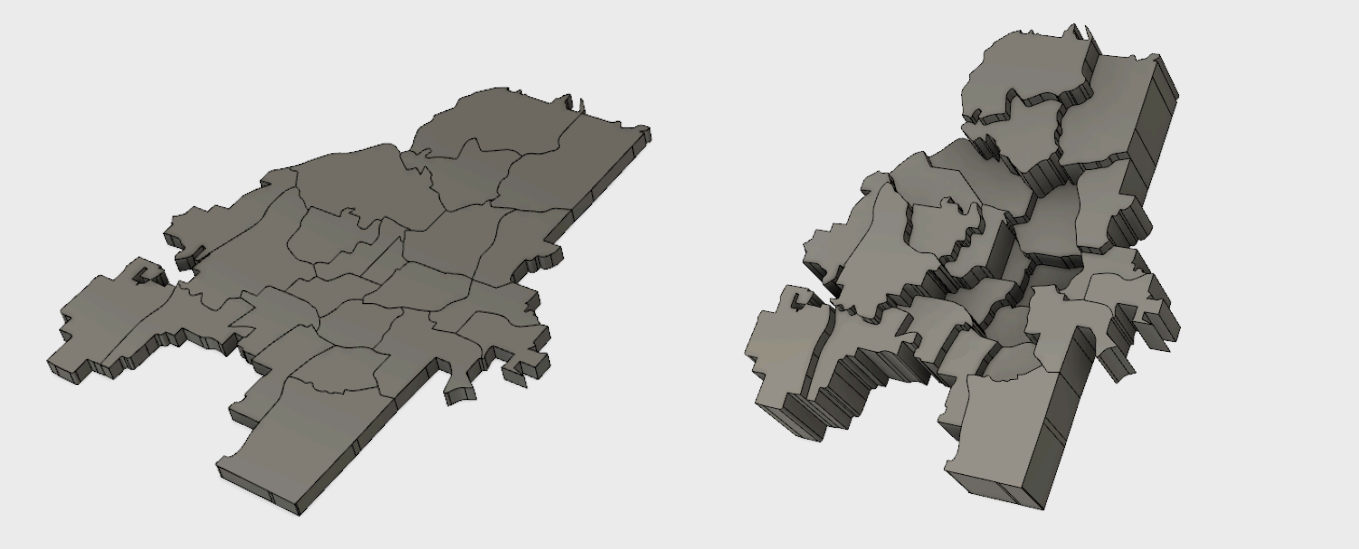


Fig. 4.1: 3D model of Atlanta broken down by NPU; In the 2nd image, height extrusions represent overall canopy density

4.2 Shift To Wearable Data

As mentioned above in Related Works, my project soon shifted from data sculpture into a data wearable. This shift occurred between completing the data field guide and carbon footprint data walk. Initially I wanted to retain the tree canopy as the content of the visualization, creating garments that are based on both negative and positive effects of having such a large urban tree canopy. Examples include articles based on pollen, urban heat index, Atlanta's uneven tree density spacing, and carbon negation. I soon realized, however, that using carbon for the content of the entire project would be a stronger conceptual choice, tying it to relevant current events and allowing for a more personalized context. I chose to retain the originally identified principles of placement and materiality from my data sculpture research.

Rather than creating a static work, I found the idea of dynamic placement intriguing. The benefits of mapping data on the human body were manifold, including making data more personal, organically displaying the artifact in multiple locations, and an exploration of the social interactions that go along with wearables, clothing, and data.

Combining the personal aspect of wearable data with the habits and behaviors of the wearer, I found the materiality principle could also remain a very strong motivator for the project. By making unseen personal data visible, I predict that the project can inform and motivate certain attitudes in the wearer.

On the most general level, the subject of the data will be more apparent and therefore contribute to a greater scale discussion of that subject (in this case, carbon footprints).

More personally, the wearer will be able to become more intimately familiar with their own practices and involvement in the creation of the data. They will be informed about the existence and particular details of their carbon footprint. Finally, they will experience their data as it pertains to real world interactions through wearing it. The data may stimulate and be the subject of specific conversations around it, as well as a broader cultural conversation.

Through testing the sash with my own data, I have noticed several of these effects. Upon discovering my footprint data and familiarizing myself with it during the creation of the sash, I have developed a higher awareness for my highest emission activities. For example, I will often think of my carbon footprint as I adjust the thermostat in my home or look at plane tickets. By wearing the garment in public and being prompted to explain it, I have also cemented in my mind the short analysis of which sources are the highest and that my footprint is above average.

4.3 Paper Iteration #1

The context for the sash was, at this point in time, a speculative object. In my chosen design fiction, the sash would be a government regulated garment that all citizens would be required to wear. This made several aspects of the design easier, such as how large-scale and accurate data collection may work and why people would be motivated to wear the sashes. I also felt that the resulting familiarity with the design, considering that all people would own one and have an idea of how to read it, could justify the use of only color families to distinguish emission sources, rather than needing to include labels that might cause visual clutter.

However, based off of feedback from conversations I had while wearing these prototypes, I decided to shift from this pseudo-dystopian design fiction to one in which the sash is part of a voluntary awareness campaign. This would remain true up until the 3rd paper prototype, at which point I shifted the context to its final position as a cultural probe for conversations.

For the first data sashes, I used a familiar bar chart style to make it very apparent that the garment is a data visualization. I chose to use color families to indicate emission sources, but limit explanatory text to the back of the garment.

Fig. 4.2: Color legend for sections and 1st iteration of paper prototypes, testing use of saturation to signify a lower total dataset, added pieces (tassels & pins), and various bar orientations

As indicated above in Figure 4.2, the warm yellow and red regions represent the travel category, with vehicles being yellow to orange (depending on the number of vehicles) and air travel being shown in red. The blue family is home energy use, with natural gas being the lightest shade, followed by water and electricity usage. The purple is total spending habits, including both goods and services. Though my carbon calculator initially separates the two, I chose to combine them due to the calculator's vagueness in what distinguishes them. Finally, the green group is diet. The first vibrant hue is plants and vegetables, followed by dairy, meats in the darkest shade (somewhat indicative of it being the worst section for emissions), with breads, snacks, and miscellaneous items at the end. The off-white section is for other estimated emissions, which are included in the calculator based on zipcode and household size.

This round of prototypes used my data, which is above the national average for greenhouse gas emissions, as well as a friend's data, which is lower than the average. I explored differentiating totals by saturation level, as seen in the first sash in Figure 4.2. The choice to indicate total emissions based on color originated from the desire to keep all sashes a consistent total length.

I also experimented with adding extra pieces to the sashes, such as pins and tassels. The tassels were another approach towards signifying total footprint size, in the absence of a visual benchmark. The tassel length was meant to show the size of one's carbon footprint, with longer tassels indicating a larger environmental impact. Feedback,

however, indicated that adornments such as tassels were generally viewed a positive sign, so I decided to approach this representation differently in the next iteration.

The second adornment present in this round of prototypes was a pin for each year that the wearer's carbon footprint was below average. The required nature of the sash allowed the assumption that a multi-year track record of past greenhouse gas emissions exists, and that a "bad year" can be contextualized with the presence of objects indicated good past performance. Feedback indicated that this representation worked, though the idea that the wearable was standardly issued and required to be worn was not immediately apparent without first asking why anyone would wear it.

4.4 Paper Iteration #2

In the 2nd round of prototypes, I tested other visualization methods for representing total carbon footprint size on a sash of a consistent length, while keeping emission source sections relatively sized to each other. Once again, I printed a garment with both my data and one with a smaller footprint for comparison. Throughout this process, I kept in mind that the total size of the footprint should be readable by someone passing by on the street, without having to sit and analyze the details closely.

Fig. 4.3: 2nd iteration of paper prototypes, testing use how to compare total size of footprints and the inclusion of data over time

In the first set in Figure 4.3, I indicated the average with two white lines. The area between the lines is the national average for carbon emissions. A chart smaller than that is lower than the national average, as shown in the top prototype. If the total emissions are higher than the national average, they spill over up to a maximum of two times larger. It is my estimation that this maximum should work for most carbon footprints, as the difference in my data and my friend's is not very much despite our very different lifestyles.

In the second set, the total footprint size and relation to the national average baseline is indicated in its own special section. This section is in grayscale to distinguish it from the emission source groups, and it includes a ranking system on the side. White is for carbon neutral to ¼ the national average, light grey is for just less than the average, darker grey is slightly higher, and the darkest shade is for up to twice the national average. A black bar is placed at the location of the wearer's current total amount, and the background is colored according to that to increase readability from a distance.

Feedback on these indicated that the first method in Figure 4.3 is more effective than the second, due to the totals section in the second set looking too visually close to the emission source groups. For the next iterations, I decided to continue the design scheme of marking the national average within a fixed area and scrapped the vertical gradient displays.

4.4 Cultural Conversation

When shifting to an awareness campaign context for the wearable, I adopted the idea of shifting social attitudes and perspectives about climate change. I was inspired partially by the social nature of clothing, my experience with cultural differences in environmental conscientiousness outlined in sections 2.1 and 3.4, and Goffman's *Presentation of Self in Everyday Life* .

For persuasive technology projects such as this one, which aim to provide a platform for reflection and intervention, it is an often made mistake to put too much responsibility solely on the individual[13,14]. Instead, HCI projects would benefit from a larger scale focus on the political, economic, and social context for environmental responsibility.

By raising social awareness and emphasizing the need for a culture shift to a nation demanding emission reductions, this approach to the project could address this large-scale need. Additionally, it could serve as a useful vehicle for political and economic motivations. By making citizens more aware and desirous of agency in policy, and by acknowledging the boundaries of individual vs corporate responsibility in essential and optional consumerism, this project generates conversation about various levels of the climate change issue. When discussing the final artifact, many people reflect and ask what it is that they can do to reduce emissions, and what types of large-scale action would be needed to affect greater change.

Further support for the social aspect of shifting our culture's view on climate change can be found in Goffman's *Presentation of Self in Everyday Life*[15]. As mentioned previously in section 2.1, *Public Views On Climate Change: European and USA Perspectives* mentions how Americans often do acknowledge climate change but consider it to be less important than other issues[4]. This is a societal value that varies by country and culture. In Goffman's book, he speaks to how social rituals an represent and affirm current social values, as well as reaffirm them in the continual practice of those rituals[15]. He states that "to the degree that a performance highlights the common official values of the society in which it occurs, we may look upon it… as a ceremony - as an expressive rejuvenation and reaffirmation of the moral values of the community." Drawing from this, one could conclude that to perform a ritual, such as wearing a climate change sash, with certain values encoded in it, such as a sense of duty in preservation of the environment, reinforces those values to society.

A practical application of this approach could yield promising results for how we discuss climate change. Increasing the visibility of climate sustainability and normalizing adjusting habits to reduce emissions may begin a positive feedback loop of raising concern for this issue. While such a result does rely on how widespread and successful an awareness campaign would be, the potential for such effects makes it a great motivator for the design of the project. Hence, further iterations from this point are designed with the promotion of larger-scale discussion and a shift from solely individual responsibility in mind. This is a secondary goal to the personal understanding of data one achieves by wearing the sash, but I certainly feel that there is room for both the individual and socially-focused levels of discussion on the garment.

4.6 Paper Iteration #3

For the 3rd iteration of paper prototype, I added corporate logos to each section. The logos show representative companies that I purchase the goods or services of and are meant to show the collaborative nature of how individual carbon footprints meld with the larger systems that people live within. I gathered these by looking at different spending categories on Mint and choosing the most frequently occurring companies.

This was added after reading articles by Paul Dourish[13] and Dr. Carl DiSalvo[14] on how environmental sustainability projects often put too much pressure on the individual themselves to change their lifestyle. In reality, much of what we do is shaped by the political, social, and economic contexts we live in. Being inspired by this insight, I sought to use the corporate logos as a way for the carbon footprint visualization to be interpreted at a different scale. The logos also happen to function as negative advertisements for these entities, attaching the notion of enabling emissions to the brands of each company represented.

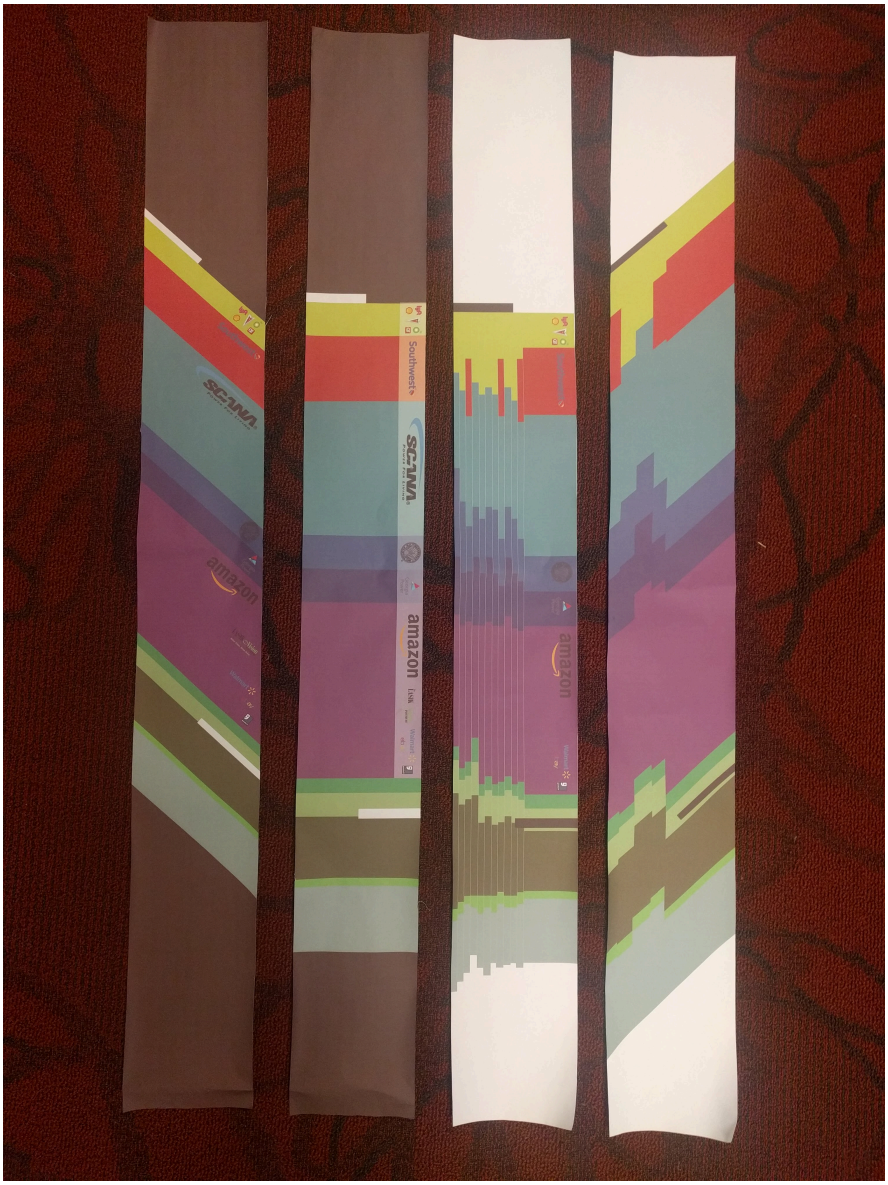


Fig. 4.4: Paper sashes including logos (left two) and experimenting with displaying data over time and angled for visual appeal when worn

I formally recorded feedback on the design and readability of the sash from two friends. They both enjoyed the fact that the data is visualized in a tangible garment, noting that the wearable felt like a novel way to show information. It was suggested that I add more icons and logos to the sash, as they help to identify what each section is about without needing to be told. Both interviewees also suggested possible large-scale contexts for the sash, such as being able to buy it and donate money to an emissions reduction project or using the sash as a way to spread political information related to environmental policy.

Finally, both interviewees also wanted to know what more can be done to reduce carbon footprints in general.

I also presented my design for feedback during Dr. Loukissas's weekly Local Data Lab meeting, as well as to my committee in individual meetings. Various other options for materials were suggested, such as making data scarves, shoes, or t-shirts. Crafting options such as bead-making, screen-printing, and heat transfer vinyl were suggested as well. I ultimately decided to keep the sash format due to its unique attention-drawing factor and the associations of civic duty that skill sashes for scouts have. I adopted heat transfer vinyl as a way to put text on the sash and improve readability. Feeling comfortable with the design after the small tweaks suggested to me in the various feedback sessions, I then moved on to creating a fabric version.

4.7 Fabric Sash

I began by crafting a plain white base using Adafruit's skill badge sash tutorial[22] and the facilities at Georgia Tech's Paper and Clay. I slightly increased the length, as this tutorial is meant to make a child size garment, and the width in order to fit larger printed logos.

I intentionally allocated the space on the front of the sash to equal the national average of emissions (16.5 metric tons), similar to what I found effective for conveying relative footprint size in the 2nd round of paper prototypes. The individual's total is made up of color vertical bars, measured to scale along the seam of the sash, which will fill up this space and spill over onto the back if larger than average. The seam line is also labeled with a vinyl heat transfer piece explaining this.

Playing on the civic responsibility associations of scout sashes, I also created a large badge to be displayed in the white space at the top corner of the sash. For my data, it is red, indicates that I am above the average, and lists my total emissions number (19.0 metric tons). Were the sash total to be below average, this badge would have a green background and display the same types of information.

While I originally intended to create large white logos on sash using heat transfer vinyl, I discovered that the constraints of that material meant I would need to cut out the curves of each individual logo that I did not want to have a white background. Instead of this method, I continued the idea of badges by gluing print outs of logos to removable 1.2" diameter button pins. This size was chosen because it fits in the smallest of the vertical bars in the food section but remains relatively readable. I matched the background color of the paper to the fabric color they correspond to for better visual cohesion.

Finally, I added a full sheet of heat transfer vinyl to the back depicting global averages for emissions. This contextualizes the national and individual averages, as well as invites another level of large-scale reflection. This section is especially important to have because it highlights how much higher the United States' (and all of North America's) average footprint is than the world average, or even the 2nd highest region. This

contextualization seems to help convey the importance of focusing more on this issue, based on several of the conversations I have had while wearing the sash. People tended to realize that we as a nation need to do better when shown the statistics, and combining that with my personal data was humbling.

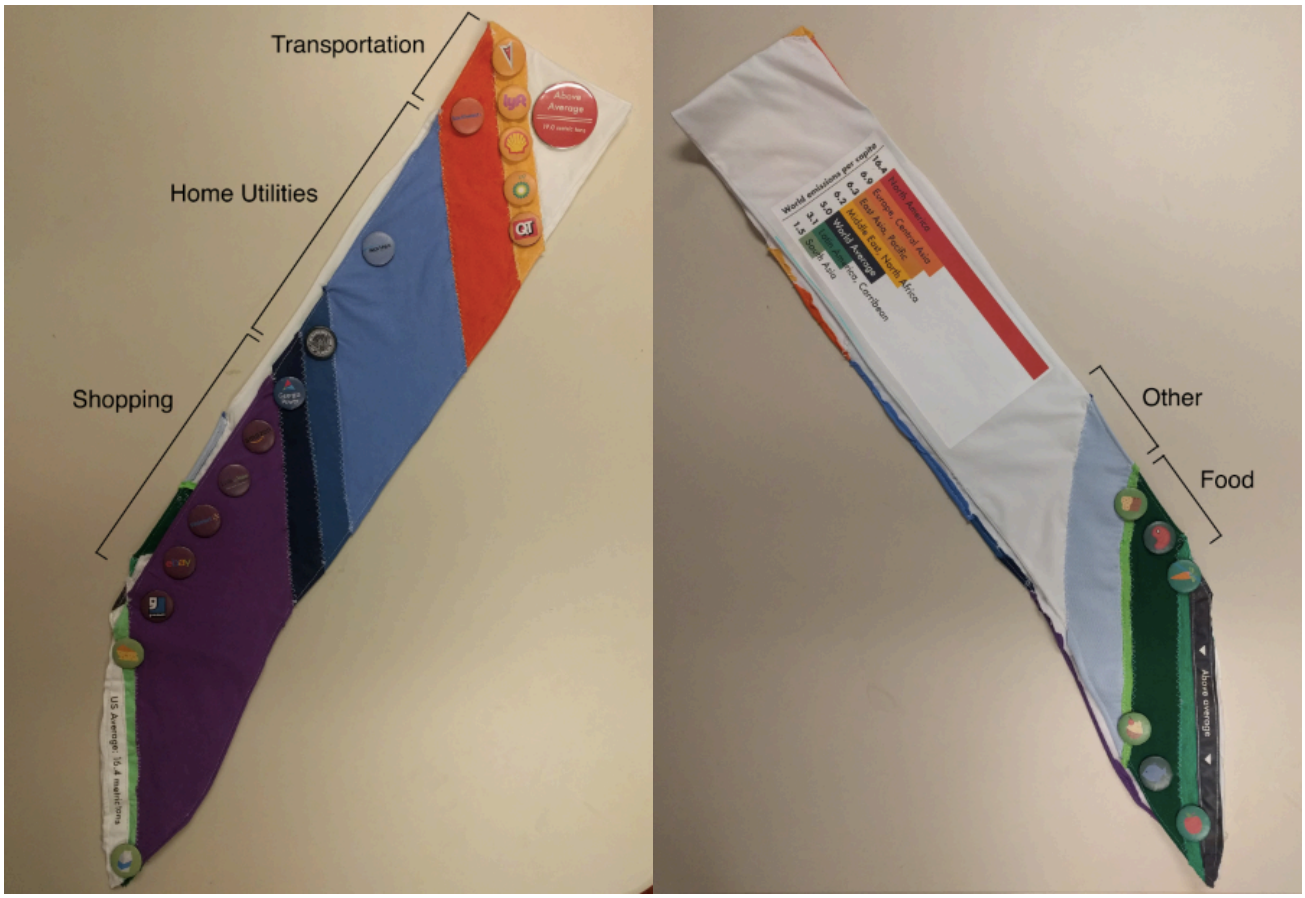


Fig. 4.5: Front (left) and back (right) of the fabric sash with labels for each category grouping

By wearing the finished product I have gained a lot of new insights and personal experiences around my footprint data. The fabric sash seems to gather more attention (or at least approachability) than the paper versions, and I have had many small casual conversations explaining its purpose. More details and quotes from these conversations can be found in the next section, Testing.

I have noted that I sometimes feel an element of shame in explaining how my footprint is much higher than average, especially with the global context on the back. I had previously thought of myself as a relatively environmentally minded person, often recycling and not being overly wasteful. In this way, the sash revealed surprising information about myself and I have had to come to terms with it. By explaining it time and time again to strangers,

I have ingrained in myself a solid short analysis of where my problem areas are and I think of them often when performing my daily activities. This is a useful way to become intimately familiar with my data, what it means, and have its presence continually refreshed in my mind as new people ask me about it. In a way, this highlights how the carbon footprint is always present, and I am glad to have the sash help me inspect it. Without seeing the details like I have in this project, I would not have the knowledge or motivation to improve.

That being said, much of my desire to improve could still use direction. Even after meticulously compiling the emissions data, I did not do much research as far as the best ways to lower it. The most important next step for the sash would probably be to highlight the easiest sections to lower so that people know where to start reducing their footprint. For example, I know that my shopping section is higher than average and makes up a huge portion of my total. However, I already try to not spend much more than I need to, and much of last year's total came from unavoidable expenses such as medical bills; This is not an area that I felt I had much leeway. My diet, on the other hand, is completely under my control. I know I could reduce my footprint by eating less meat, and I could definitely adjust temperature control in my house to try and lower the natural gas section. As for the other areas though, I am not sure how feasible it is to reduce them. This personal observation on a clearer path of action is also consistent with what I found others to say during testing.

5. TESTING

To test the effectiveness of each iteration, I began by making quick paper prototypes. I first tested these in social interactions by wearing the paper sash in public to elicit responses, but found that I received more detailed initial feedback from friends who I asked to converse with me about the project.

For the 1st and 2nd iteration, I took notes during the conversations in a notebook, then compiled and analyzed them afterwards. The discussions were unstructured and I mostly sought to hear first impressions and questions about the garment.

On the 3rd paper prototype iteration, I began recording some discussions surrounding the garment for later review. The primary motivation for this was to have a more detailed record of the conversations so that I could assess different ways in which the conversation could be guided by design changes. The recordings also serve as documentation of my progress and processes. These conversations were extremely helpful in assessing the effectiveness of my design, such as whether certain elements were of interest or readable, as well as how the object guides people into discussing climate change. I noted that most people I talked to enjoyed the wearable nature of the visualization, often stating that it was a unique way to represent the data.

There was a slight increase in questions about the artifact once rendered in its final fabric form, which I attribute to it being read as more of a purposeful garment than piece of paper. Often people would begin with “Why are you wearing a sash?” or take a guess at what it is for (“Is that a graduation stole?”) Strangers passing by would often stare for slightly longer in order to try and understand what they were seeing. In this way, I feel it was an effective promotion of carbon footprint awareness, so long as the wearer is willing to explain and discuss the artifact when conversations occur.

Many people told me “You look like a girl scout” or “Oh, its kind of like what scouts wear.” On the day of the GVU research showcase, I spoke to three different people (including two grade school teachers) who mentioned that the sash would be great for teaching children about environmental impact. One person spoke with me for a while about the pitfalls of carbon calculators and how it would be nice if there were more rigorous and trustworthy ones available.

Some people suggested that they would have a hard time wearing the sash if their footprint was, like mine, “bad.” A group of men I was speaking with began by saying that the form of the sash definitely evoked feelings of being proud of what it displays, but if they have a footprint they are not proud of it might be strange or difficult to wear it. On the other hand, they could see the case for trying to have a good footprint so you can display it proudly.

Many people, after I explained the sash, questioned what their footprint might be. Two women I spoke with even said something to the effect of “Mine is probably even worse than yours!” and said that they might be nervous to see it. This makes me wonder if people would buy into the sash awareness campaign, knowing that they will likely get an unsatisfactory initial answer once they look into their carbon footprint size.

In general, I received many positive comments praising the sash, ranging from appreciation for the design to the way it provokes thought on an important issue. One person stated “That’s actually a really cool visual. It’s super simple, but incredibly compelling.” Another began our discussion with “What if everyone had to wear these? We might be a lot more mindful of what we’re doing.”

Some of the less productive conversations were ones in which people either did not ask for further explanation of the sash or were seemingly overwhelmed when I explained what it was about. This could, however, have just been the reaction of people who were curious enough to ask what it is but simply did not want to have a long conversation.

I noted in my extended discussions that many people wanted to know what can be done to reduce their carbon footprint. While the individual footprint source data itself is helpful, along with the economic, national, and global contexts included in the sash’s design, people want next steps. One person suggested selling the sashes and donating a portion of that money to promoting emission reduction projects. Another suggested

adding a political layer to the sash in order for people to learn how they can promote better environmental policies.

The prevalence of this question feels like a large success, revealing that there is an interest in reducing emissions and that the sash can act as a guiding force to help people consider what actions are available to them. However, it also confirms much of what Lorenzoni and Pidgeon mentioned about agency in their paper; Individuals must not only be informed of the problem and possible solutions, but also believe that they have the power to make a difference[4]. A digestible source of relevant actions would be a powerful addition to the design going forward.

Finally, after a while I noted some practicality pain points in the sash design that impacted most of my conversations at some point. First of all, it can be awkward to discuss the back of the sash. I feel it is important to show the graph on the back when I mention the US average, but turning around and trying to still talk to someone is quite difficult and not something that I initially accounted for. Additionally, probably the worst part, is that the crucial area where my footprint overflows the national average is situated on the lower back of the sash. This essentially results in me asking people to direct their attention to an area of my body that is somewhat taboo to stare at, and this may impact the critical examination and discussion of the data. However, this location issue could be relieved by shifting the overflow area to be over the shoulder seam rather than the bottom seam.

6. FUTURE WORK

To be of real societal impact, the project could be launched as an awareness campaign for greenhouse gas emissions. The manufacturing of wearable data garments could be paired with an improved carbon calculator than can automatically pull data from paired application such as food and finance trackers, similar to how I manually gathered my own data. If sold, the garment itself could be a carbon neutral product by including a carbon offset in its price and funding a variety of carbon emission reduction initiatives.

An alternative to selling the garment, which requires a large-scale manufacturing scheme, would be to make a free website and calculator that provides a template for a printable sash. This would be more feasible and in line with a grassroots style of movement. The success of such a campaign would likely depend largely on attention. I could envision the campaign launching and encouraging people to print and wear their data garments for Earth Day in particular, or perhaps as an awareness campaign by girl and boy scouts, who already wear sashes and focus on civic responsibility (I actually received the comment that I looked like a girl scout many times when I wore the sash in public.) Additionally, two grade-school teachers that I spoke with also mentioned how it seems like a great way to help kids learn about what a carbon footprint is and means.

Regardless of how the sash is distributed, the most important element of future work on this project would be the inclusion of actionable steps in reducing emissions. This could be by informing people about how to help environmental policies pass, organizing a campaign for certain corporations to lower their footprints, or even creating a carbon calculator with a very personalized breakdown of which emission sources an individual can have the most impact on. As indicated in my various interviews, people want to know how they help once the emissions problem is brought to light.

7. REFERENCES

1. Solomon, S., Plattner, G., Knutti, R., Friedlingstein, P. “Irreversible climate change due to carbon dioxide emissions”. PNAS. 2008. Accessed Feb 26 2018. http://www.pnas.org/content/pnas/early/2009/01/28/0812721106.full.pdf

2. Wallace-Wells, David. “The Uninhabitable Earth, Annotated Edition”. New York Magazine. July 2017. Accessed Dec 27 2017. http://nymag.com/daily/intelligencer/2017/07/climate-change-earth-too-hot-for-humans-annotated.html

3. Romo, Vanessa and Miles Parks. “Confusion Continues: The United States' Position On The Paris Climate Agreement”. NPR. September 2017. Accessed Feb 27 2018. https://www.npr.org/sections/thetwo-way/2017/09/16/551551083/u-s-still-out-of-paris-climate-agreement-after-conflicting-reports

4. Lorenzoni, Irene and Nick Pidgeon. “Public Views on Climate Change: European and USA Perspectives”. August 2016. Accessed Feb 26 2018. https://link.springer.com/article/10.1007/s10584-006-9072-z

5. Hulme, Mike. “Why We Disagree About Climate Change: Understanding controversy, inaction and opportunity”. Cambridge: University Press, 2009. https://books.google.com/books?hl=en&lr=&id=DWMkb4ondbQC&oi=fnd&pg=PT1&dq=climate+change+significance&ots=s0wsq3KFlT&sig=zRLze5WxrKCZorc3ETHTiU1K5DA#v=onepage&q=climate%20change%20significance&f=false

6. Houghton et al. “Climate Change 2001: The Scientific Basis”. New York: University Press, 2001. http://pubman.mpdl.mpg.de/pubman/item/escidoc:995493/component/escidoc:995492/WG1_TAR-FRONT.pdf

7. The Nature Conservancy. “Free Carbon Footprint Calculator”. Accessed Jan 20 2018. https://www.nature.org/greenliving/carboncalculator/index.htm

8. Conte, Mark and Matthew Kotchen. “EXPLAINING THE PRICE OF VOLUNTARY CARBON OFFSETS”. 2010. Accessed Feb 26 2018. http://environment.yale.edu/kotchen/pubs/explain.pdf

9. EPA. “U.S. Greenhouse Gas Inventory Report: 1990-2014”. April 2016. Accessed Feb 27 2018. https://www.epa.gov/ghgemissions/us-greenhouse-gas-inventory-report-1990-2014

10. EPA. “Climate Change Indicators: U.S. Greenhouse Gas Emissions”. August 2016. Accessed Feb 27 2018. https://www.epa.gov/climate-indicators/climate-change-indicators-us-greenhouse-gas-emissions

11. Dykes, Stephanie. “Data Field Guide: Atlanta Tree Canopy”. October 2017. https://docs.google.com/document/d/1Nia326gnt5gr4ocsEQnjuRksscy9vFcywqqDJn-YrOU/edit?usp=sharing

12. Gerdes, Justin. “Copenhagen’s ambitious push to be carbon neutral by 2025”. The Guardian. April 2013. Accessed Feb 28 2018. https://www.theguardian.com/environment/2013/apr/12/copenhagen-push-carbon-neutral-2025

13. Dourish, Paul. 2010. “HCI and Environmental Sustainability: The Politics of Design and the Design of Politics“.

14. DiSalvo, C., Sengers, P., and Brynjarsdottir, H. 2010. “Mapping the Landscape of Sustainable HCI”.

15. Goffman, Erving. “The Presentation of Self in Everyday Life.” Garden City, N.Y.: Doubleday, 1956. https://monoskop.org/images/1/19/Goffman_Erving_The_Presentation_of_Self_in_Everyday_Life.pdf

16. Dragicevic, Pierre and Loren Madsen. “2014 – District 5: Tube Charts Reveal Decline in Violence“.List of Physical Data Visualizations and Related Artifacts. Accessed Mar 6 2018. http://dataphys.org/list/district-5-tube-charts-reveal-decline-in-violence/

17. “We Were Strangers Once Too”. Times Square Arts. Accessed Mar 6 2018. http://arts.timessquarenyc.org/times-square-arts/projects/at-the-crossroads/we-were-strangers-once-too/index.aspx

18. Hernan, Luis. 2014. “Digital Ethereal“. Digital Etheral. Accessed Mar 6 2018. http://www.digitalethereal.com/

19. Perovich, Laura. “2014 – Data Clothing: Dresses Show Air Pollution“. List of Physical Data Visualizations and Related Artifacts. Accessed Mar 6 2018. http://dataphys.org/list/data-clothing-dresses-show-air-pollution/

20. Chen, Xuedi. “X.POSE”. Behance. Accessed Mar 6 2018. https://www.behance.net/gallery/17256769/xpose

21. Nutbrown, Kristen. “2013 – Temperature Scarves and Afghans“. List of Physical Data Visualizations and Related Artifacts. Accessed Mar 6 2018. http://dataphys.org/list/temperature-afghans-and-scarves/

22. Stern, Becky. “Skill Badge Sash”. Adafruit. Accessed Mar 15 2018. https://learn.adafruit.com/skill-badge-sash/overview

23. Stacey Kuznetsov, George Noel Davis, Eric Paulos, Mark D. Gross, Jian Chiu Cheung. “Red Balloon, Green Balloon, Sensors in the Sky.” Accessed Apr 19 2018. http://www.paulos.net/papers/2011/BalloonSensingUbicomp2011.pdf

24. Wodiczko, Krzysztof. “Alien Staff.” Accessed Apr 14 2018. https://www.macba.cat/en/alien-staff-2515

25. Kling, M.M. and I.J. Hough (2010). “The American Carbon Foodprint: Understanding your food’s impact on climate change,” Brighter Planet, Inc. http://brighterplanet.com

26. Mooney, Kevin. “Climate Change Alarmism Is ‘Garbage In, Garbage Out,’ Retired NASA Physicist Says.“ Daily Signal. November 2017. Accessed Apr 15 2018. https://www.dailysignal.com/2017/11/22/climate-change-alarmism-is-garbage-in-garbage-out-retired-nasa-physicist-says/

27. United Nations Climate Change. “Carbon Neutral Cities Alliance.” November 2015. Accessed Apr 15 2018. https://unfccc.int/news/carbon-neutral-cities-alliance

28. Sustainable Government Indicators. “Denmark Environmental Policies.” 2017. Accessed Apr 15 2018. http://www.sgi-network.org/2016/Denmark/Environmental_Policies

29. Sustainable Government Indicators. “United States Policy Performance.” 2017. Accessed Apr 15 2018. http://www.sgi-network.org/2017/United_States

30. Hassol, S. J. and Udall, R.: 2003, ‘A Change of Climate’, Issues in Science and Technology 19(3), 39–46.

31. World Bank Group. “World Development Indicators.” Accessed Apr 15 2018. http://databank.worldbank.org/data/reports.aspx?source=2&series=EN.ATM.CO2E.PC&country=#

32. Yona, Leehi. “Climate Change is the Issue of My Generation.” The Nation. August 2017. Accessed Apr 18 2018. https://www.thenation.com/article/climate-change-is-the-issue-of-my-generation/