DESIGNING A MULTI-LEVEL REPORTING SYSTEM FOR VISUALIZING GLANCEABLE AND CUMULATIVE DATA TO PROMOTE ECO-FRIENDLY BEHAVIORS

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ABSTRACT

Small-scale actions by individuals and communities, when clustered and added together, create a significant shift at the grand scale of climate change. The decision to address those small actions and prioritize sustainability starts with individual citizens and visual representations of how their contributions factor into overall impact. Designers have an opportunity to create citizen-centric visualization tools that not only offer environmentally-minded individuals the moments of clarity and understanding they need, but provide means by which individuals can identify — and 'see' precisely — where their contributions impact the larger system of climate change.

This project presents a multi-layer system composed of glanceable displays and a reporting dashboard providing users 'in-the-moment' and cumulative energy and water consumption data at scale. This multi-layer system intends to deliver influential information to motivate residents to make sustainable decisions in the moment and over time. By encompassing glanceable moments, incremental reports, community comparison, and goal setting into one multi-layer system, this project proposes how a home can be transformed into a motivational hub where citizens can understand how their sustainable efforts are contributing to mitigating climate change.

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PROBLEM AREA

Figure 1

List of human scale factors impacting climate change reported by "Detection Attribution of Climate Change-Climate Science Special Report"

CLIMATE CHANGE. WHO IS TO BLAME?

Recent media portrays climate change as a direct cause of human factors. For example, California Governor Jerry Brown addresses climate change to an audience in Stuttgart, Germany by saying "Unfortunately, no one's in charge—everyone is creating the problem, and unless everyone contributes to the solution, then the job won't get done." (1) The International Panel on Climate Change has concluded in its Fifth Assessment Report that there is more than a 95 percent probability that human-produced greenhouse gases such as carbon dioxide, methane, and nitrous oxide have caused much of the observed increase in Earth's temperatures over the past 50 years (2). Additionally, the Climate Science Special Report summarized by Friedman and Thrush states, "The global, long-term warming trend is "unambiguous," it says, and there is "no convincing alternative explanation" that anything other than humans — the cars we drive, the power plants we operate, the forests we destroy — are to blame." (3)

As media continues to place the blame on the public at large, the individual citizen is left confused and frustrated about how their individual contributions can make a difference in the wider, systemic problem of climate change. Citizens who are motivated to reduce their 'carbon footprint' seek to align themselves with other like-minded communities, such as carbonfund.org, COTAP.org, climatecare.org as well as 350.org and UCLA's Climate Lab. These citizens along with other associated communities need reinforcing tools to understand — and see — how their individual actions can make a difference.

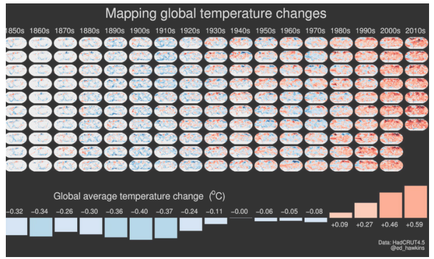


Figure 2

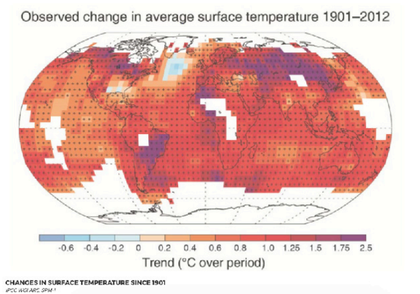


Figure 3

While the tactics of blame and fear work to an extent, the delivery of those tactics minimizes the complexity of climate change as a system. Small-scale actions by both individuals and communities, when clustered and added together, create a significant shift at the grand scale of climate change. The decision to address those small actions and prioritize sustainability starts with individual citizens and visual representations of how their contributions factor into overall impact. Current climate change visualizations in the media are unclear and too similar in comparison. For example, representations of large-scale maps portraying global temperature shifts and the loss of sea ice and glaciers over time, such as those from Ed Hawkins at weatherrescue.org (Figure 2) and the IPCC (Figure 3).

Individuals have limited visual offerings that provide an understanding of their personal impact on the larger climate change system, as the information provided in these media sources is often too broad and unengaging. It is difficult to imagine that citizens would willingly want to alter their behaviors when climate change information can, and should, create moments of awareness where citizens understand how their decisions and actions factor into the larger context. Designers have an opportunity to create citizen-centric visualization tools that not only offer environmentally-minded individuals the moments of clarity and understanding they need, but provide means by which individuals can identify — and 'see' precisely — where their contributions impact the larger system of climate change.

Designing visualization tools that help citizens gain a better understanding of their role within the larger climate change context offers designers an opportunity to design systems that communicate scale. Considering that every action has a ripple effect in the larger scheme, developing a representation of how small actions compare to collective efforts can offer both designers and citizens and understanding of the importance of cognitive scale. David McCandless's 2009 **Billion Dollar –o-Gram** *shows how the world spends money; how small amounts compare when placed alongside larger, more substantial, numbers laid out on the global scale. Allotting $147 billion dollars to developing nations to combat climate change is suitable until you notice that it cost $3000 to finance the Iraqi and Afghanistan wars together (Figure 4). To provide a representation of citizens' efforts at scale, designers should think about citizens as participants who value information delivery and how visuals can better inform the individual contribution within society. As typical visualizations of climate change capture problems at a distance, this lack prompts the design community to consider visualizing scientific and statistical data at a more close, human-scale range; something that is relatable to citizens.*

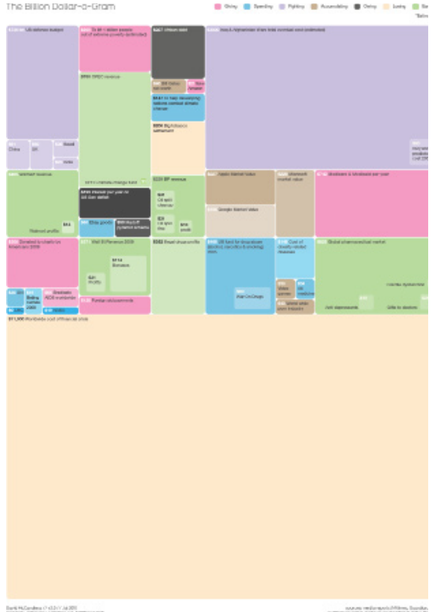


Figure 4

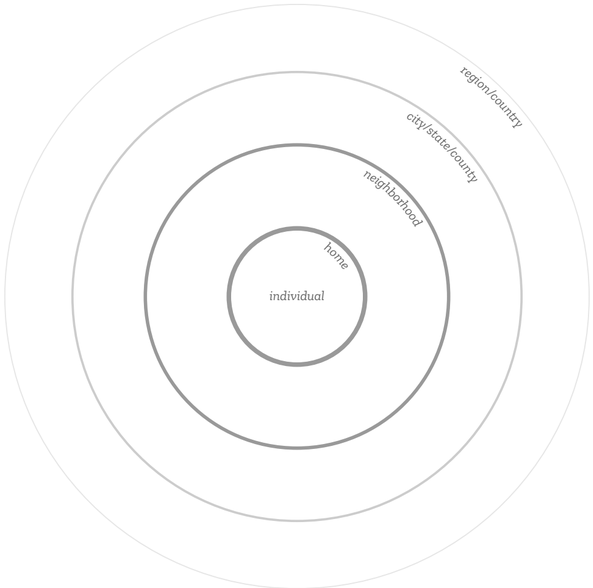


Figure 5

Diagram illustrating how an individual can impact the wider community and thus Climate Change.

JUSTIFICATION

"People increasingly adopt technologies to track their everyday behavior. Personal informatics tools rest on the assumption that people develop a better understanding of their habits through self-monitoring, which in turn promotes self-knowledge, reflection and ultimately change upon undesirable habits" (Ruben et al. 1). Glanceable displays offer users 'in-the-moment' information requiring low cognitive load while delivering visual consumption activity across household appliances. This form of information delivery provides individual residents with an opportunity to gain influential information regarding current energy and water consumption at a glance. This glanceable information is then translated into cumulative consumption data that is collected over time. This information is delivered to residents through a reporting dashboard allowing users to view aggregate and disaggregate consumption patterns at scale (daily, weekly, monthly, yearly), compare household patterns to patterns within their community, and set consumption goals for the future.

This project provides new opportunities for designers to consider visualization strategies at scale in various information environments. Murugesan et al. outline functional design requirements for visualizing household electricity consumption with the goal of bringing sustainable behaviors among end-users. Some requirements include User Interface Engagement, One-size-fits-all, Improve End-user Cognition, Avoid peak Pricing, Accuracy in Recommendations, and Easily Understandable Metrics (2726). Considering these requirements, designers can advance how visual language and communication approaches evolve to serve citizens with more clarity. This approach offers an opportunity for designers to integrate their work in more complex problems where they focus on communicating and visualizing how an individual person places themselves within a larger system.

Considering moments where design can intervene within a home system, this project serves as a road map for designers and citizens to visualize moments of interaction leading to sustainable behaviors within that home system. Looking closely at those moments to strategize where visual information delivery could serve as intervention equips designers to provide clarity to citizens who wish to place their individual efforts within a scalable system.

LITERATURE REVIEW

Scalable Systems

The scale of current wicked problems is complex and often includes several influential factors. Many designers approach complexity at the human scale with available tools. Presenting ideas on the future role and responsibility of designers, Paola Antonelli states, "The idea of human-scale has changed since Charles and Ray Eames's famous 1968 film Powers of Ten because perception has been expanded and augmented by technology. Distance is not what it used to be, and neither is time" (42). Considering today's views on climate change, citizens are left with few options to understand and impact this system of challenges. Hugh Dubberly describes this approach of accepting systems, with minimal control, and living within them as "Anti-planner" (2). He also states, "The difficulty is compounded because the systems at the core of challenges-that-really-matter may not appear as "wholes". Unlike, say, an engine or a dog or even a tornado, they may be hard to see all at once. They are often dispersed in space, and their "system-ness" is experienced only over time, often rendering them almost invisible. In some cases, we may live within systems, seeing only a few individual parts, making the whole easy-to-overlook" (2). The idea of the Anti-planner sparked my interest in how a designed system could offer a disruption from the norm and provide insight into how individuals efforts can scale to create and impact. Visualizing scale was an influential factor for my continued interest in understanding how the individual might be able to place themselves within a larger context.

Scholars have come to understand the many interconnected influences act upon a citizen's perception of complex environmental problems. Voinov et al. describe the control our genes and memes have on our judgments and actions. They describe how those controls "align best with our human interests when we are faced with situations that have been frequently experienced in the past and that require local, short-term, decisions and outlooks; and conversely, they align badly with trying to handle long-run problems spilling over into faraway places and future generation. Thus, those same controls do not necessarily prepare us well to manage our natural resources and environments in today's world, which is hyper connected and which often brings situations that we've never experienced before, at the level of individuals and of entire communities" (212). While our natural programming may not prepare us for understanding new complexities, we have developed approaches to clarify the influential factors acting upon our perceptions. Familiar environments hold the key to understanding the scale of individual impact. This idea reveals how an individual's journey through a multi-layer system can impact how they view and place themselves within complex environments.

Through a conducted analysis of circular economy, the Ellen MacArthur Foundation presents an executive analysis summarizing how technological advancements, guided by circular economy principles, create greater opportunities for society. "Information and industrial technologies are now coming online or being deployed at scale, which allow the creation of circular economy business approaches that were previously not possible. These advances allow more efficient collaboration and knowledge sharing, better tracking of materials, improved forward and reverse logistics set-ups, and increased use of renewable energy" (4). The idea of a circular economy initially influenced my thinking about how operational guidelines reinforce systems. Approaching my visual language, this idea helped shape how that language functions throughout the multi-layer system.

Behavior Change

Looking closer at current perceptions of climate change in the media and the impact of those perceptions on human behavior, O'Neill and Nicholson-Cole found that strong imagery, such as flooded houses, can be effective in capturing an individual's attention and increasing perceptions of the importance of the issue. They also found that impact imagery presents lower perceptions of efficacy for addressing climate change due to a boomerang effect (qtd. in Hart and Feldman 419). After conducting a study on the impact of climate change imagery in the news on public perceptions and behavioral intentions, Hart and Feldman found that images of renewable energy had the greatest potential to increase perceptions of efficacy and to indirectly increase individual behavior change through efficacy (435). To elaborate on the perception of self-efficacy with regard to complex systems, Stajkovic and Luthans define self-efficacy "as an individual's belief (or confidence) about his or her capabilities to execute a specific task within a given context (130). Considering citizens who are environmentally conscious and lead sustainable lifestyles, their perceptions of self-efficacy with regard to impacting climate change might be more positive due to their knowledge and previous experience. It would be interesting to explore how this multi-layer system might impact perception of sustainability among citizens who do not lead sustainable lifestyle and view self efficacy as low on the scale of impact.

While perceptions influence opinion and action, sustainable behaviors must repeatedly occur to produce effective impact. Asensio and Delmas state, "Conservation is not a one-time occurrence but requires repeated consumer effort and attention. Some responses may be immediate, others not; and currently, researchers have not been able to differentiate well between short- and long-run behavior change mechanisms in a framing intervention. A dynamic analysis of conservation behavior with real-time information strategies is lacking" (197). Focusing on repeated consumer effort and attention informed messaging and visual language within the multi-layer system that prompts citizens to behave sustainably.

Through an experiment focusing on behavioral research with advanced real time metering technologies deployed in at the appliance level in households, Asensio and Delmas found that a health-based framework influences energy savings more effectively (197). They add, "The emergence of real time consumer data should bring a shift in the research agenda on how to design and enhance the timing and duration of information framing approaches to meet energy conservation or policy goals" (209). Real time data holds value and helps reassure individual residents that this system is updating and tracking consumption data. A continuously updating system helps readily offers insight to users who are reliant on this information.

Considering behavior change in detail, Fogg's Behavioral Model introduces three combining elements, Motivation, Ability, and Trigger, causing behavior to occur. This model outlines three Core Motivators, six Simplicity Factors, and three types of Triggers to identify what causes of prevents behavior change (Fogg). The FBM informs how these combining elements motivate residents to alter their behaviors toward making more environmentally conscious decisions. Similarly, Dan Ariely proposes his Building Blocks for Behavior change with the design of display-free Shapa Scale. This approach takes the best of behavioral science to combine Reminders, Knowledge, and Habits that prompt users to make healthy choices, understand the behaviors that improve health, and build long term healthy habits (Ariely). I incorporated this approach within my system to help citizens set more sustainable goals for the future as they receive nudges and reminders about their progress.

Glanceability

Vygotsky's Activity Theory describes activity as a specific level of subject-object interaction, i.e., the level at which the object has the status of a motive. A motive is an object that meets a certain need of the subject (Kaptelinin and Nardi, 59). Referring to glanceable displays that incorporate motivational moments for users to gain insight and assistance, Tara Matthews identifies the position of glanceable peripheral displays within Activity Theory: "Our Activity Theory analysis of peripheral displays explores their use, leading to a definition: peripheral displays are tools used primarily at the operation level (i.e., their usage requires relatively low cognitive cost)" (Matthews 2). This idea informs how a user may shift toward the reporting dashboard, however the motivational factor of the glanceable display does not lose its value.

To further illustrate glanceability offerings, Consolvo et al. defines "glanceability" as feedback that quickly and easily conveys information after catching a user's attention To accomplish high glanceability, feedback should be "reduced to the essence through a process of simplification and abstraction". Feedback should provide "just enough" to be perceived and processed. A further quality of glanceable feedback is its ability to be perceived at the periphery of one's attention. Feedback should be "working in the background while we attend to foreground activities ... [enabling people] to get the essence of the information with a quick visual glance" (Gouveia et al. 2). Glanceable information should not be obtrusive. Information about consumption should be delivered in stages that are easily understood by the resident.

Kuznetsov and Paulos conducted a study utilizing faucet and shower displays to show cumulative and individual water usage. They reported that displays significantly affected people's thinking about water and energy consumption. "Despite the fact that most participants were already environmentally conscious, results of the post-study survey suggested that they became even more aware of personal and collective water use. Some became conscious of their water consumption and noted publications about environmental issues, and most re-evaluated the primary challenges for sustainability to be human ignorance" (5). They found the persuasive "sweet spot" is situated between a design territory where users are informed by data details and view less distracting information about their energy and water consumption (9). When information is readily available and concise, users develop trust in the system and understand how their behaviors connect to consumption patterns. To understand the hybrid between glanceable displays and the user's perception of sustainability, Kazemifard et al., present a computational model showing the impact of emotion and personality on behavior control. By separating information processing into reactive, reflective, and rule-based levels this model analyses external information and offers insight on possible impacts of sustainable indicators on user behavior (Silva et al. 3). This computational model informs how I view the glanceable displays within my system advancing over time. The displays could optimize how they motivate and prompt residents to make more sustainable decisions.

Consumption

Considering the delivery of consumption information, users and researchers often question the usefulness of highlighting details like peak times or the amount of electricity appliances and devices consume. Kidd and Williams ask, "How does this information help them to make sense of which appliances are consuming the most electricity and what steps might be taken to reduce consumption?" They report, understanding electricity consumption from time-series data requires understanding power consumed over time, which is a difficult cognitive task for most people (Hermann et al. 239). Taking into account the growing adoption of smart home appliances, users and designer should consider the impact visual elements have on users. Hermann et al. argue, "For the success of smart home technologies, examining the cognitive sense-making process and the suitability of graphic feedback is highly relevant when confronting users with domestic energy data" (242). The development of a visual language incorporated within my multi-layer system helps clarify the correlation between consumption patterns and sustainable behaviors.

When presenting consumption data, Murugesan et al. identifies several researches who suggest incorporating both functional and non-functional requirements into visualization design. Functional requirements such as User Interface Engagement and Avoid Peak Pricing prompt users to achieve sustainable behaviors through user interfaces and messages alerting peak pricing for energy use (ibid. 2726). Easily Understandable Metrics such as cost, kilowatt (kW), kilowatt hour (kWh), CO2 offer clarity about consumption information not usually understood by novice users (ibid.). Affective Energy Consumption is a functional requirement motivating users by conveying environmental impact of waste activity and conservation efforts (ibid. 2727). Non-functional requirements include Understandability and Scalability which are defined as ease of recognition of information displayed in the visualization and the accommodation of future information within the visualization (ibid.). These requirements along with others influenced the structure of visual information within the system. Incorporating requirements within visual displays could provide meaningful experiences for users who seek to understand the scale of their household consumption over time.

With an intent to design a system that encompassed both visual and textual information that motivates and prompts household residents to make sustainable decisions, I gained an understanding of designed factors and their influences on users within a system. Through research on complex systems and citizens that become anti-planners in the face of complex scale, I understood how a multi-layer system could provide value for those who wish to understand the value of their efforts at scale. Through visual studies and research, the components of my multi-layer system are easily integrated into the home and offer residents motivational prompts to continue leading sustainable lives.

RESEARCH QUESTION

How can the design of **glanceable displays** *and* **reporting dashboards** *motivate individuals to engage in* **sustainable decision-making** *by visually communicating how incremental actions, taken over time, accumulate to produce meaningful contributions towards societal efforts aimed at mitigating climate change?*

SQ1 *How can the design of a glanceable display system in the home deliver user feedback and information* **in-the-moment** *to promote consumption awareness and sustainable decisions?*

SQ2 *How might the design of the reporting dashboard deliver messages to support sustainable behaviors and inspire* **community building***?*

SQ3 *How might the design of the reporting dashboard display progress over time for residents to track household patterns of consumption, set* **sustainability goals**, *and plan future goals?*

DEFINITION OF TERMS

Glanceable Display
Visual and textual cues allowing residents to process information with minimal cognitive load. The produced glanceable moments serve to motivate behaviors and support information delivered within the reporting system.

"In-the-Moment"
Information delivered at an opportune moment allowing the resident to can gain an understanding of consumption activity and status.

Reporting Dashboard
A three part system including a view of cumulative consumption information at scale, a community view where residents can compare their consumption patterns to those of their neighbors, and a goal setting view where residents can set goals for a future period of time.

Community Building
By sharing consumption information along with tips and suggestions about savings and conservation, members gain a sense of belonging within the local community. Thus, viewing consumption information can motivate members to behave sustainably.

Sustainable Decision-Making
By establishing an awareness of Eco-friendly energy and water consumption through the use of glanceable and reporting systems, residents are motivated to make better informed decisions about the behaviors impacting their household consumption.

Sustainability Goals
Through an understanding of consumption patterns, residents can set sustainable goals depending on their lifestyle or upcoming events. By setting realistic goals for the future, the glanceable and reporting systems calibrate to help residents maintain set limits.

ASSUMPTIONS AND LIMITATIONS

This project focuses on glanceable displays paired with a reporting dashboard that serves to inform residents about their water and energy consumption in the home. Designed for citizens who want to understand their household's consumption at scale, this ecosystem intends to influence user's behavior toward making sustainable decisions in the moment and over time.

The glanceable displays offer three levels of information regarding appliance utilization; before us, during use, and after use. The information available at each level include combinations of icons and colors representing eco-friendly, warning, or overconsumption zones as well as numeric consumption values, and messages and alerts that suggest savings in cost and better behaviors for future use. These levels of information offer residents a visual structure to understand the status of water and energy consumption in context and at-a-glance.

*Designed as an extension of the glanceable display system, the reporting dashboard offers in-depth views of household consumption. Along with a view of cumulative consumption over time; hourly, daily, weekly, etc., **residents have the ability to see how their home compares to their neighborhood with a possibility for expansion to wider communities**. Additionally, the dashboard offers a goal-setting option for residents to set future sustainability goals.*

Participants within this system would have the option to opt-in to this open network of shared information

"Understanding really is the key. When you understand something, you're able to perceive its structure; its connections, its relationships, its significance relative to everything else. How it fits. You see-feel-intuit the fit. You know it. You know?

Context, I'm realizing, is the field of these connections, the network we plug any new information into. That explains why, when something is contextualized, we can suddenly get it. It feels 'meaningful' to us because it fits into the network of what we already know and understand and can relate to. Our knowledge.

The more you understand information in this way, the more connected and contextualized it becomes, the more it starts to morph and grow into knowledge."

"Knowledge is Beautiful" David McCandless. 2014

Figure 6

Framework mash-up of Fogg's Behavioral Model and Dan Ariely's Building Blocks for Behavior Change illustrating a suitable environment for design interventions to prompt behavior change.

CONCEPTUAL FRAMEWORK

My interest for this project began with decision making. By trying to understand why people make sustainable decisions, I was specifically interested in how those decisions were supported within the home to prompt and motivate behavior change. The behavioral aspect of this project led me to Fogg's Behavioral Model which states, "Three elements must converge at the same moment for behavior to occur: Motivation, Ability, and Trigger" (Fogg).

To understand how better decision making occurs, I paired Fogg's model with Dan Ariely's Building Blocks for Behavior Change, which illustrates how reminders that prompt us to make better decisions lead to knowledge and habits that help improve our decision making (Ariely). By combining Fogg's Behavioral model and Dan Ariely's Building Blocks for Behavior Change, I created a framework that structures and outlines influential elements within the consumption ecosystem. This framework informs my approach to designing a glanceable and reporting ecosystem that motivates residents to engage in pro-environmental decisions within their home and communities.

INVESTIGATION METHODOLOGY

COMPARATIVE ANALYSIS

Analyzing the energy efficient appliances currently on the market, along with other products offering eco-awareness capabilities, I found that most products paired glanceable displays showing activity status with a reporting system collecting and tracking activity over time. These products are marketed as tools that provide users with more insight and control over household appliance activity, helping users develop an understanding of usage patterns and avoiding unnecessary consumption. Considering the current capabilities of these tools, I wanted to investigate the gaps where I could ground my studies.

	THERMOSTATS ecobee, Nest, and Suntouch	**TOYOTA PRIUS** HUD and Reporting System	**SAMSUNG** Fridge and App	**BOSCH** Appliances and App	**SMART THINGS** IOT	**AMBIENT** Energy Products
Glanceability	*Interactive Display*	*Activity Display*	*Interactive Management Interface*	*Interactive Display*	*Automated Products*	*Interface Display + Color*
Report	***Nest App and SunStat Connect App** keeps track of energy consumption over time*	*Report and suggestions for future behavior*		***Home Connect App** allows for more efficient use of appliances and monitoring in the home*		*Interface collects and reports energy consumption data from the home along with pricing and neighborhood comparison*
Features	***ecobee App and SunStat Connect App** allow for temp. adjustment from anywhere*		***Family Hub App** allows for entertainment, food management, scheduling, and family connection*		***SmartThings App** allows users to monitor and adjust connected devices within the home* *Sensors react to behavior and presence*	

Thermostats

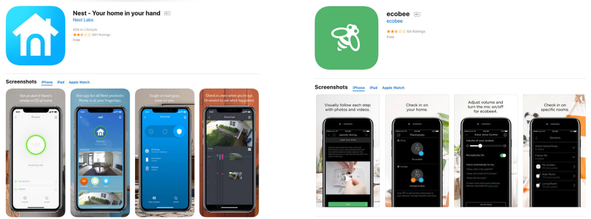


Figure 7

Learning thermostats like Nest and EcoBee adapt to household behaviors and adjust accordingly. They allow users to have more control over unnecessary energy consumption.

Smart Things

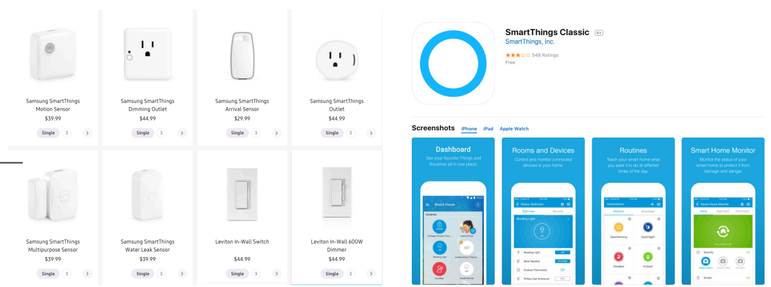


Figure 8

Connected objects like SmartThings offer security and automation within the home.

Toyota Prius HUD

Figure 8

The Prius HUD allows drivers to see how their driving impacts the car's eco-friendly status and delivering a brief message at the end of every driving session.

Ambient Energy Products

Figure 10

Ambient devices offer users in-the-moment information at a glance

Samsung Smart Home

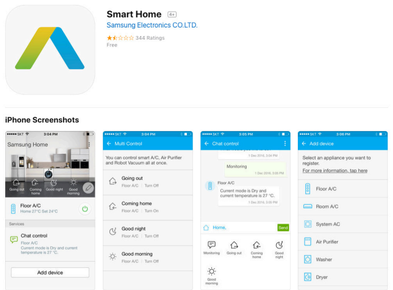


Figure 11

SmartHome offers users a way to monitor and control devices remotely as well as check the status of devices.

Bosch Home Connect

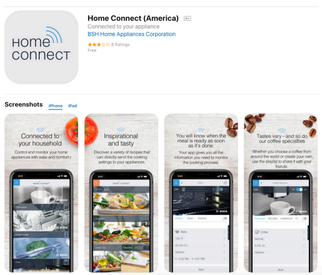


Figure 12

HomeConnect is similar to SmartHome by allowing users to monitor and control devices from their smartphone.

Physical appliances

Examining the physical affordances of these energy efficient appliances, many employ either glanceable interfaces or audio alerts to provide options for utilization. Many appliances have a display that allows users to adjust settings based on available options and gain information about activity duration (washing, drying, charging, preheating and time) and current activity status (idle, time, temperature, etc.). What was missing was a component allowing the user to visually understand water and energy consumption. The Prius Heads-Up Display illustrates a diagram indicating how blue, green, and red zones deliver in-the-moment information informing the user about their driving behaviors. This visual language influenced my approach to designing glanceable displays that provide current activity information to motivate behavior adjustment.

Mobile apps

The applications integrated with these appliances offer robust capabilities to residents who want more control over household consumption activity. Many applications afford users with options to adjust settings and communicate with their appliances remotely to check consumption over time and plan future use. While many applications collect and display consumption data, they lack the ability to prompt residents to change their behavior and place their sustainable efforts within a larger context. This missing motivational element led me to incorporate a Consumption, Community, and Goal view within my reporting dashboard to help residents understand the scalability of consumption patterns along with how their behaviors compare to their community and setting sustainable goals for the future.

FAMILY PERSONA

The Novaks are a young family that enjoys outdoor activities and family movie nights. They often go to the park on weekends, when the weather is nice, where they go on walks and have picnics to enjoy their family time. Ana and Boris have raised their children to understand the importance of being environmentally conscious and how precious the natural environment is to all of us. To teach their children about the value of sustainable decisions in the home and the ripple effect of those decisions in the world, they have integrated energy efficient appliances with glanceable displays that alert users of energy and water consumption status. Along with providing in-the-moment glanceable user feedback, these appliances gather consumption data and store it in a web-based dashboard that allows residents to view water and energy usage over time and in comparison with their community. This dashboard allows Ana and Boris to understand their cumulative consumption and make decisions about employing more sustainable behaviors in the home by setting sustainability goals.

Ana is a florist and has the opportunity to work on many events where she is in charge of arranging varieties of flowers and other plant life. She has always loved keeping plants and flowers around the house and has become very conscious of the duty to protect the environment. She takes pleasure in maintaining a vegetable garden in the backyard along with several types of flowers in the yard around their house. She also holds workshops about maintaining plant-life year round at the local farmer's market. Her husband Boris, works as a software developer without much connection to the natural environment at work. He loves outdoor activities and often takes his family on camping trips. Due to his passion for the outdoors, he advocates for creating and keeping parks safe and accessible in his local community.

Ana and Boris along with their two children like to volunteer in gleaning programs at local farms and food pantries. They also keep a small garden in their backyard along with a compost pile that allows the whole family to learn about natural processes associated with growing fruits and vegetables along with the benefits of composting. Gabriela and Nikolas both attend schools where they are exposed to many approaches to learning about the environment. Their schools keep gardens where students learn about various levels of Ecology. Gabriela and Nikolas both regularly participate in school activities that offer more immersive experiences about the natural environment.

Due to these activities, along with lessons they gain from their parents, both Gabriela and Nikolas have developed a passion for protecting the environment. Gabriela has become such a eco-friendly advocate that she has even started a recycling club at school with her friends. They collect rainwater and recyclable material to make DIY projects and water plants in their classrooms and library after school every Tuesday. Nikolas, on the other hand, is not so passionate about the subjects he learns in school but he does get really excited about recycling at home. He loves saving plastic bottles and empty boxes for DIY projects that he does with his dad and Gabriela. They both like to help their mom with flower arrangements whenever she is working from home or preparing for a workshop.

In the home, Ana and Boris both employ sustainable behaviors such as recycling, being mindful of peak hours for energy use, cutting down on water consumption by turning off faucets during teeth brushing and washing, taking shorter showers, and watering plants with collected rainwater. They have invested in appliances by Bosch that allow them to adjust settings for eco-friendly energy and water usage, which is a huge advantage for maintaining a sustainable lifestyle.

Figure 13

The Novak family is collectively passionate about environmental friendly actions. They identify as a family who is accepting environmentally friendly ideas and acting to adjust their behavior toward a more sustainable lifestyle.

David Rose's Audience Receptivity Gradient

ACTIVITY THEORY

Activity refers to a specific level of subject-object interaction, the level at which the object has the status of a motive. A motive is an object that meets a certain need of the subject (Kaptelinin and Nardi, 59). This theory looks deeper into what can motivate a citizen to engage in sustainable efforts as well as how their participation can alter their future goals.

Applying Vygotsky's Activity Theory (qtd. in Davis 229-230), the Novak family utilizes the glanceable and reporting system to establish and maintain sustainable behaviors within the home and their community. With an interest in making eco-friendly decisions, this two-part system allows the Novaks to gain information at various levels influencing their behavior in the moment and their long term decisions regarding water and energy consumption. By setting sustainable goals for the future, the Novaks are able to anticipate responses from the glanceable and reporting system that in turn motivates sustainable long-term behaviors.

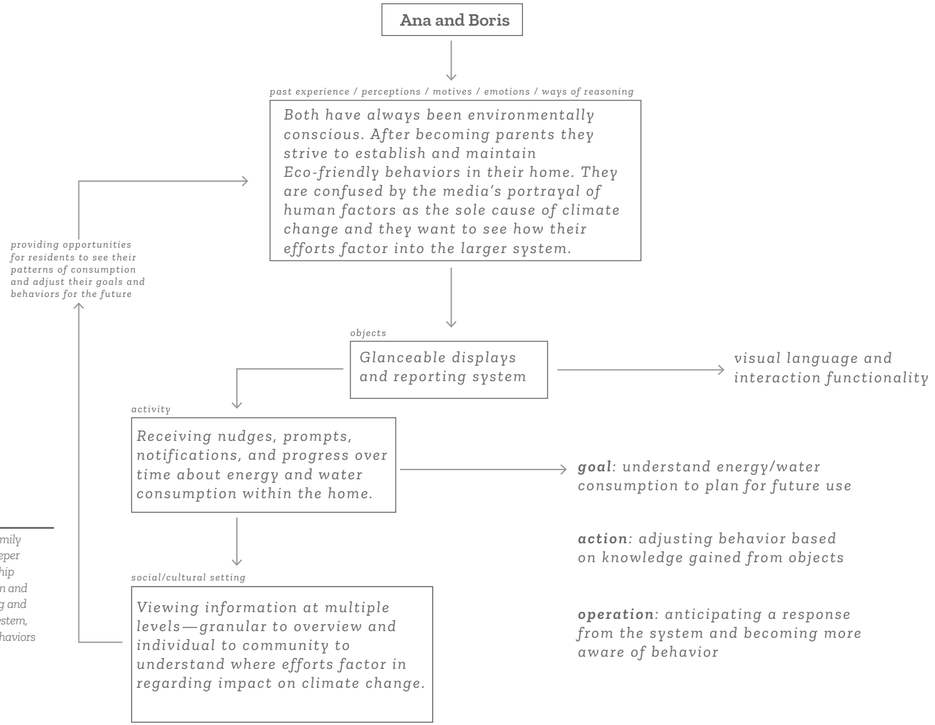


Figure 14

Through activity theory, the family members are able to gain a deeper understanding of the relationship between this multi-level system and their behaviors. By anticipating and gaining a response from the system, they are able to adjust their behaviors accordingly.

DESIGN STUDIES

My focus for this project centered on decision-making and sustainable behaviors in the home. I specifically wanted to investigate how a home system within could readily inform residents about their water and energy consumption while influencing short and long-term decisions that lead to sustainable behaviors. My design process consisted of many questions about what this home system could offer and how it could be scalable. My initial interest in interconnectivity and the communication of networked objects led me to question the possible visual offerings of home appliance displays and a central reporting dashboard.

Referencing the energy efficient appliances and applications currently available to users, my intent was to develop a visual language consisting of icons, color indicators, and messages that would be familiar to users. These visual studies explore how that development influences user's decisions and prompts sustainable behaviors. The following visual trials serve to provide and support eco-friendly options within a multi-layer system delivering information at scale.

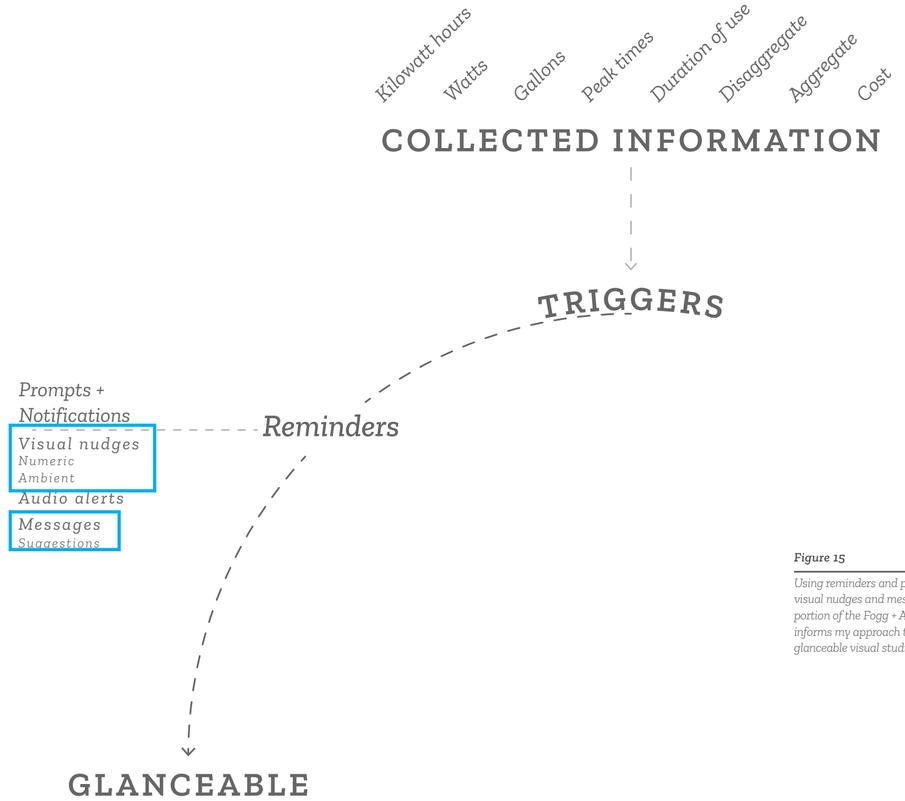


Figure 15

Using reminders and prompts as visual nudges and messages, this portion of the Fogg + Ariely framework informs my approach to developing glanceable visual studies.

GLANCEABLE DISPLAY

While I wanted the glanceable displays to deliver in-the-moment consumption information, I incorporated visual nudges such as numeric and ambient elements to understand consumption at a glance (this information was contingent on the affordances of specific appliances). While exploring iconography that could depict water and energy consumption, I utilized color and messages to indicate consumption zones. These zones signify a neutral (blue), good (green), warning (orange), and a bad zone (red), along with notification and alerting messages prompting consumption awareness.

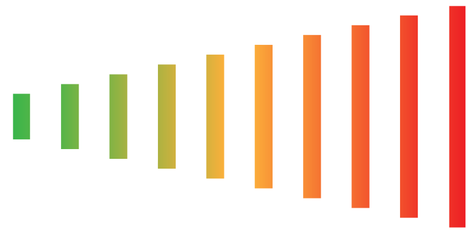
COLOR / ICON TRIALS

NEUTRAL / IDLE

GOOD / ECO

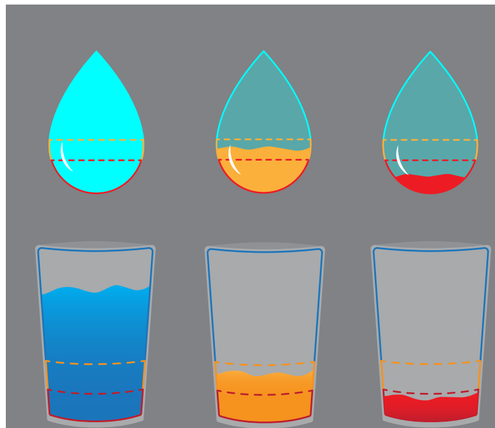
BAD / ALERT

Eco-friendly Warning Overconsumption



WATER CONSUMPTION

Eco-friendly Warning Overconsumption



ENERGY CONSUMPTION

Eco-friendly Warning Overconsumption

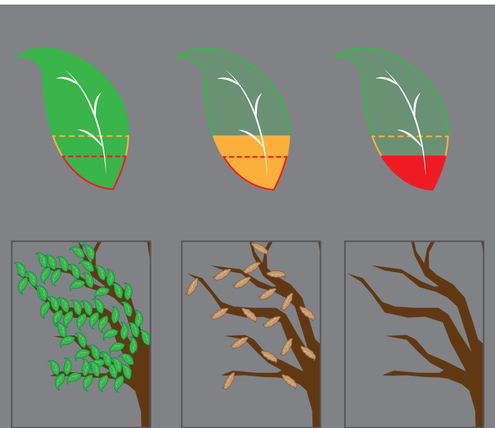
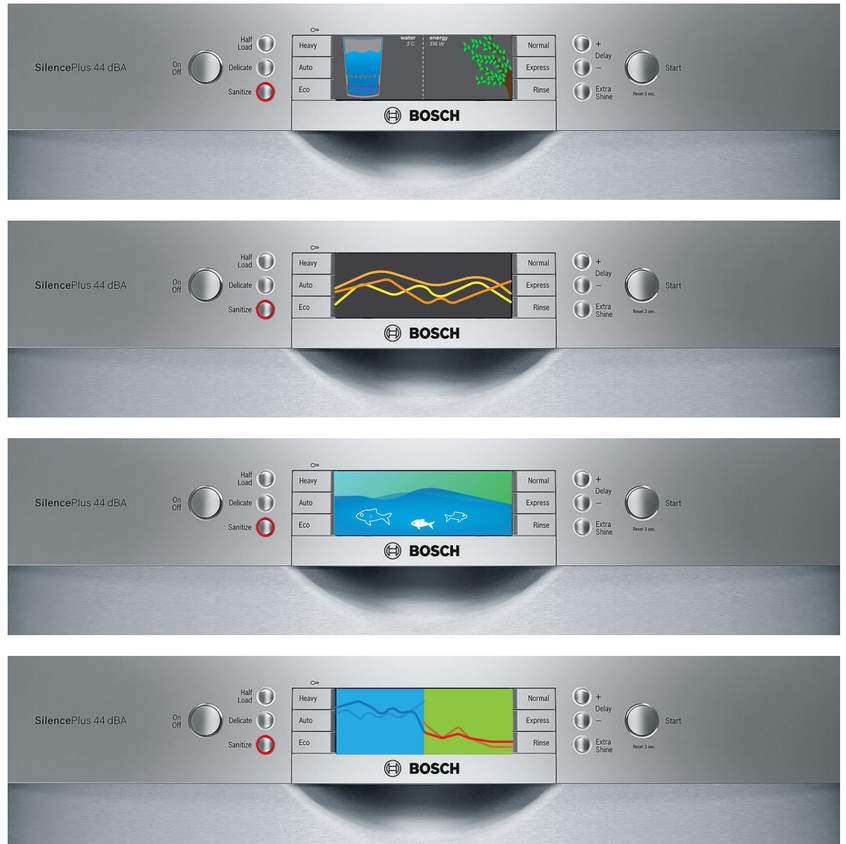


Figure 16

Along with color, I explored ways of capture the meaning of consumption by playing with levels of water in a glass, trees losing leaves, and a incorporating gradient showing good, warning, or bad zones based on consumption. I explored the use of abstracted lines to visually communicate current activity.



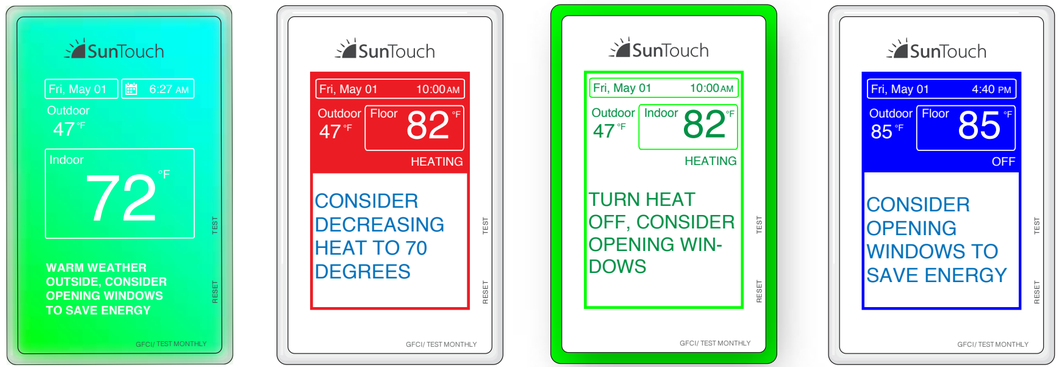
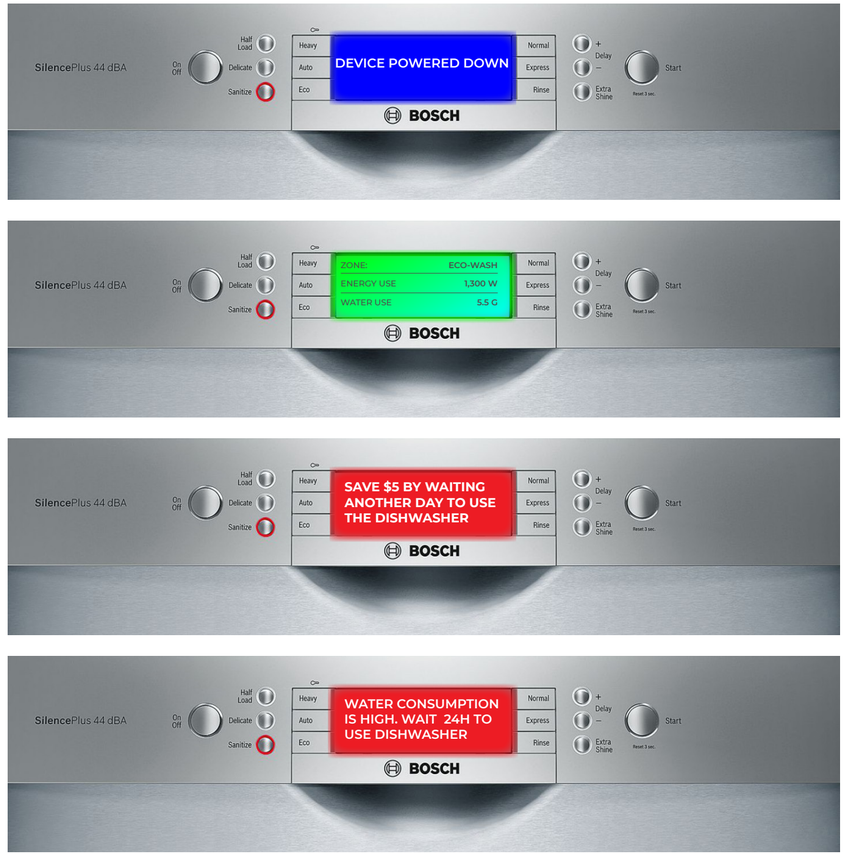


Figure 17

My early studies incorporated messages about saving money and prompting user action through a combination of messages and color indicating consumption zones delivering information at a glance.



REPORTING DASHBOARD

The design of the dashboard developed through iterations focusing on scale, overview, and granular information. Transitioning from glanceable reports on individual appliances to a proposed interface located in a central area within the home, I settled my studies within a web-based reporting dashboard accessible on any device. I explored how visual elements could help deliver a report on granular and overview content about household consumption. By exploring how to deliver consumption information over time (hourly, daily, weekly, etc...) I recognized an opportunity for additional layers of data visualization. By incorporating community and goal setting components to the dashboard, users could have a way to see how their household perform in their neighborhood, city, and wider community. This offers citizens a way to view where their contributions factor in as well as how they could set sustainability goals for the future.

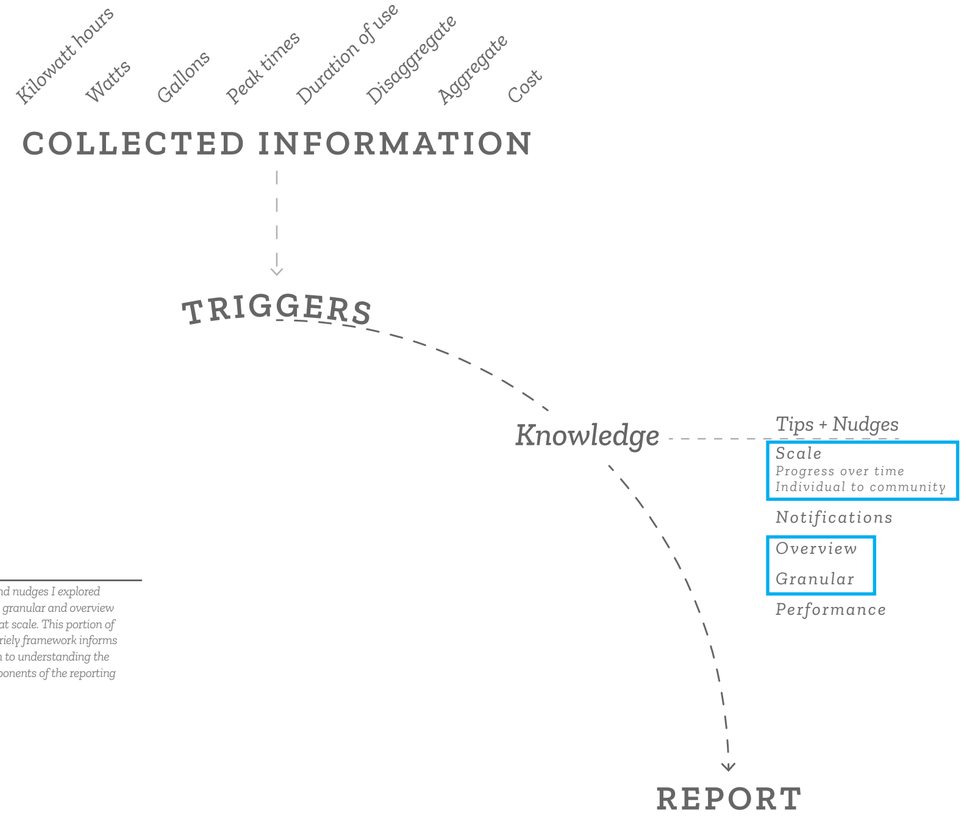
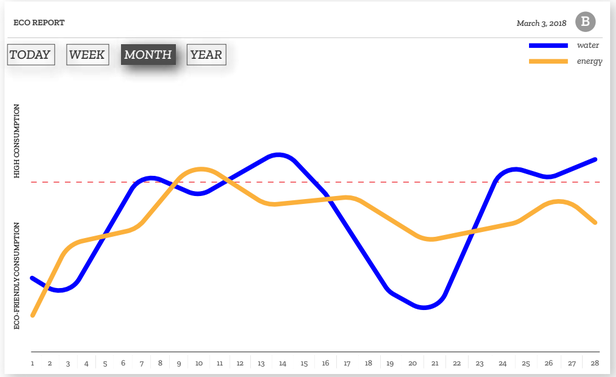


Figure 18

Using tips and nudges I explored how to show granular and overview information at scale. This portion of the Fogg + Ariely framework informs my approach to understanding the needed components of the reporting system.

CONSUMPTION OVER TIME



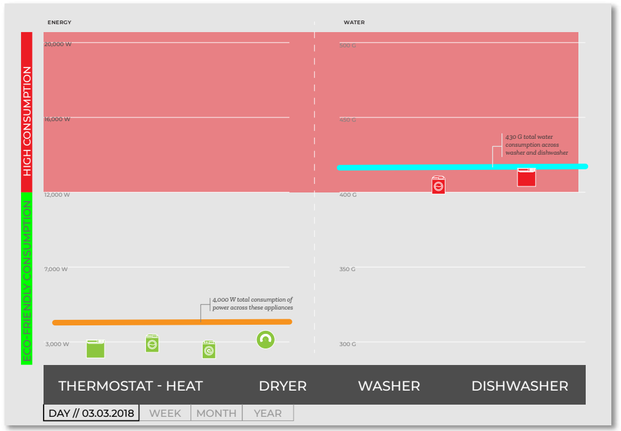
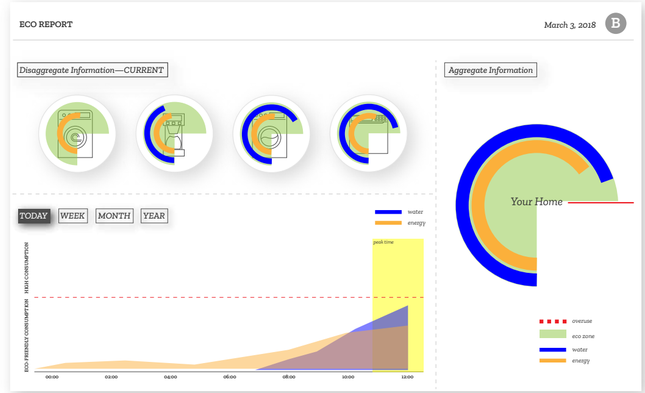


Figure 19

Most of my early studies of the reporting dashboard included the views of individual appliances and their role in consumption over time.

MULTI-VIEW



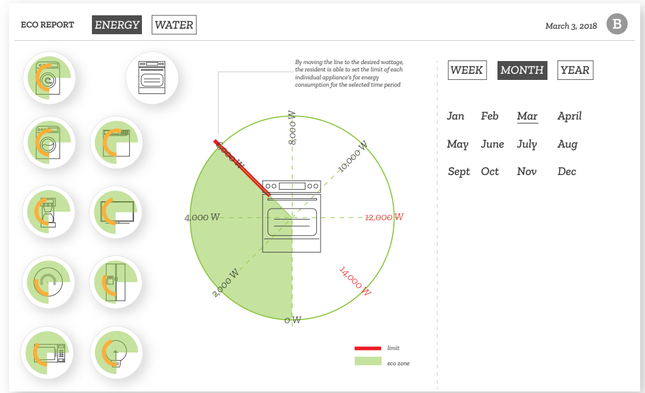
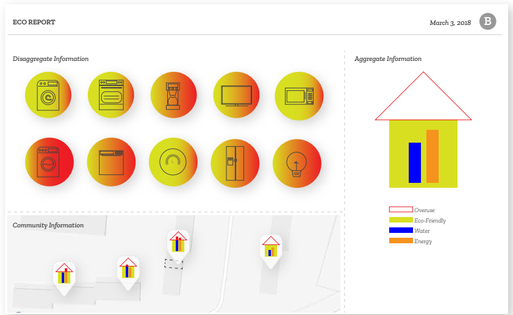
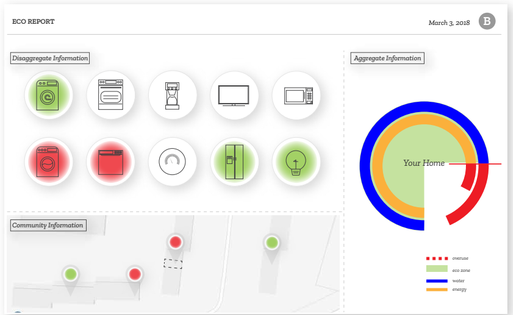


Figure 20

Separate views indicate sections where the user could view detailed information





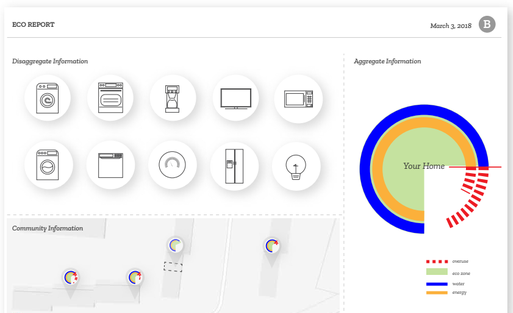
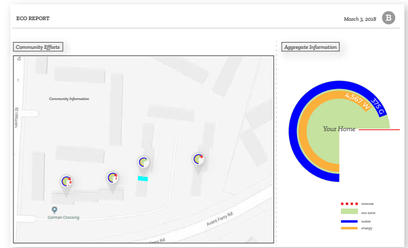
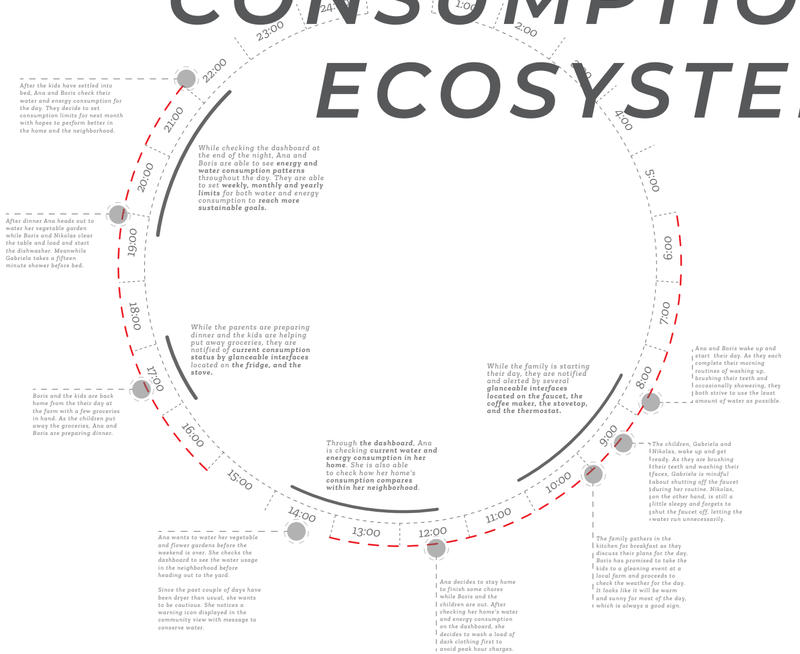


Figure 21

Showing views of community consumption offers a way for residents to compare their household performance to those of other community members. By neighbors sharing their consumption patterns, this system has potential to inspire community-building.



CONSUMPTION ECOSYSTEM



SCENARIO

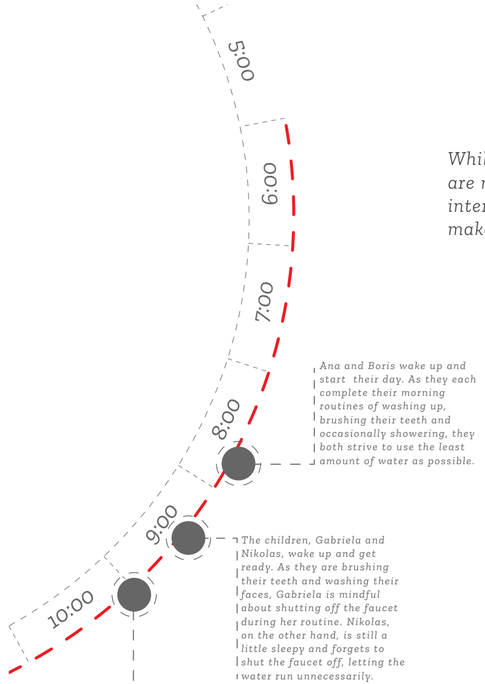
It's early spring and on this particular weekend the Novak family has planned some activities to enjoy the warm sunny days. As they start their Saturday, Boris and the children plan to go to a gleaning even at a local farm while Ana decides to stay home and take care of some chores. As she organizes her to-do list, she is assured when the glanceable system within her home informs her of peak and off-peak hours along with energy and water consumption status after she uses her household appliances. Ana is cognizant of the consumption goal her and Boris set the week before and knows the glanceable displays reflect that goal when she uses her appliances. She is confident when the reporting system indicates her current household consumption compared to her previously set goal and finds it helpful to compare how her home performs within her neighborhood.

It's late afternoon before Boris and the children return home with groceries in hand. As they prepare dinner in the kitchen and set the dining room table, the displays on the appliances are indicating peak times for energy consumption. It's worrisome when some appliances display warning and overconsumption icons for energy and water usage with messages suggesting tips for better behavior. This prompts Boris and Ana to set new consumption goals for the upcoming week with hopes to perform more sustainably within their household and their neighborhood.

A Day in the Life

*To view a **video** of this scenario, please visit:*
college.design.ncsu.edu/thenfinally/nedic/DayintheLifeJourney_ThesisSP18_DN.mov

enjoy!

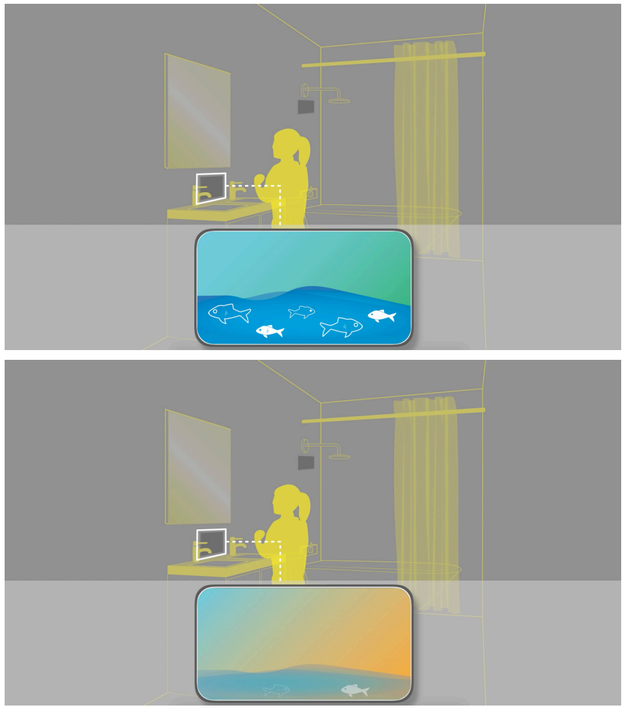


While the family is starting their day, they are notified and alerted by several glanceable interfaces located on the faucet, the coffee maker, and the stove top.

GLANCEABLE ALERTS

Figure 22

Referring back to an earlier idea of incorporating the increase and decrease of water levels along with fish, this idea taps into the emotion of keeping a fish alive. By not turning off the faucet, residents risk water depletion and losing fish.



DURING APPLIANCE USE

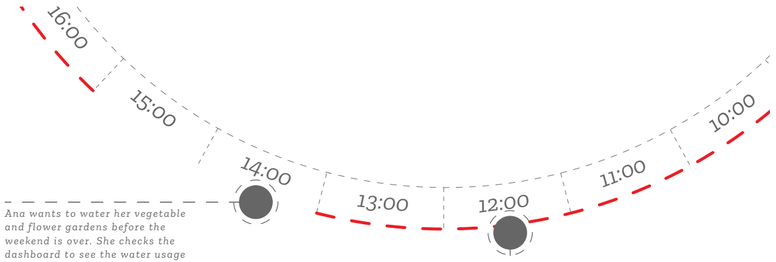
Figure 23

The glanceable displays offer household members in-the-moment information in the form of icon and color shift indicating consumption status while appliances are in use.

AFTER APPLIANCE USE

Figure 24

Glanceable moments display messages with consumption information indicating performance and possibly suggestion for future use.



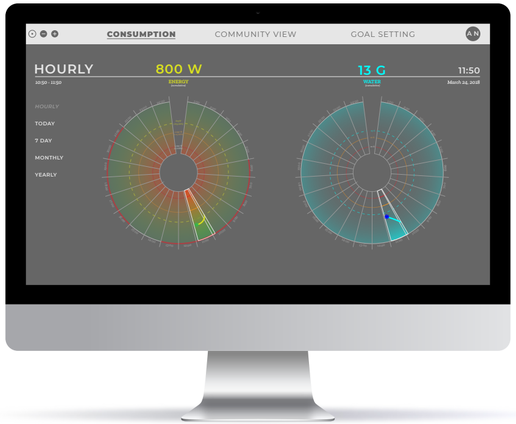
Ana wants to water her vegetable and flower gardens before the weekend is over. She checks the dashboard to see the water usage in the neighborhood before heading out to the yard.

Since the past couple of days have been dryer than usual, she wants to be cautious. She notices a warning icon displayed in the community view with message to conserve water.

Ana decides to stay home to finish some chores while Boris and the children are out. After checking her home's water and energy consumption on the dashboard, she decides to wash a load of dark clothing first to avoid peak hour charges.

Through the dashboard, Ana is checking current water and energy consumption in her home. She is also able to check how her home's consumption compares within her neighborhood.

CONSUMPTION VIEW



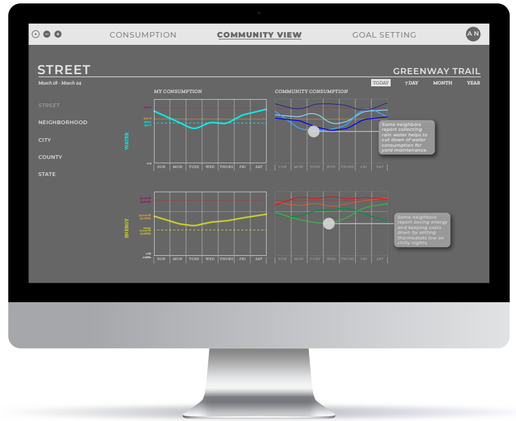


Figure 25

Checking daily consumption helps residents gain insight into how their daily consumption corresponds with their goals and their community.

Figure 26

Checking consumption of previous days helps residents make comparisons between their daily behavior and how it impacts current consumption patterns.

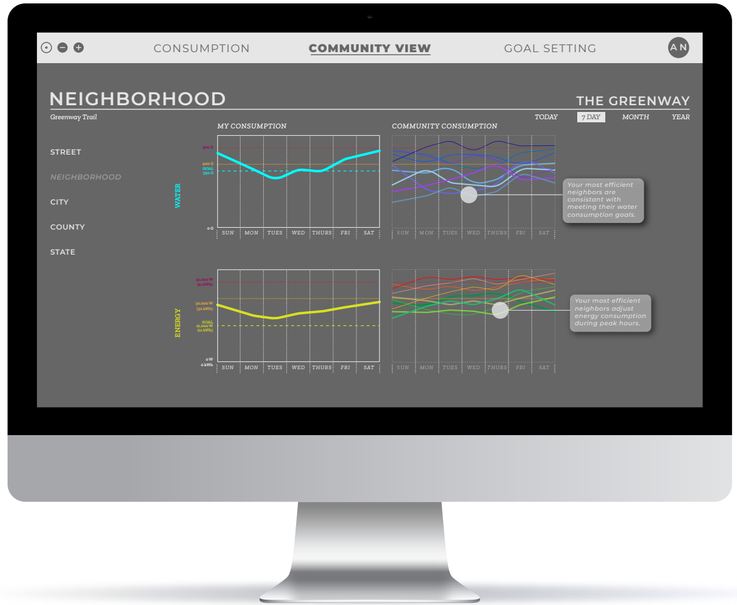


Figure 27

Community reports showing how efficient neighbors attain their sustainability goals is influential to residents who wish set and achieve their own goals.

DURING APPLIANCE USE

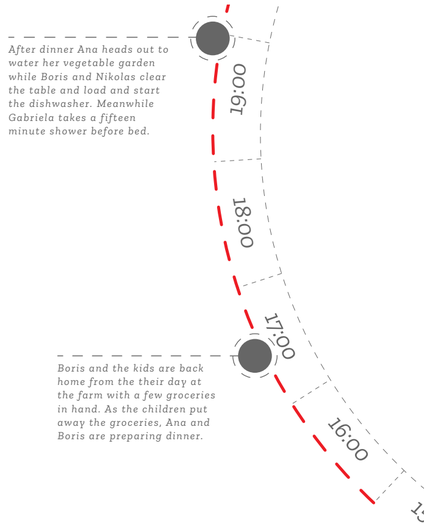
Figure 28

Displays on household appliances indicate peak times for energy use prompting residents to avoid energy consumption during that time.

AFTER APPLIANCE USE

Figure 29

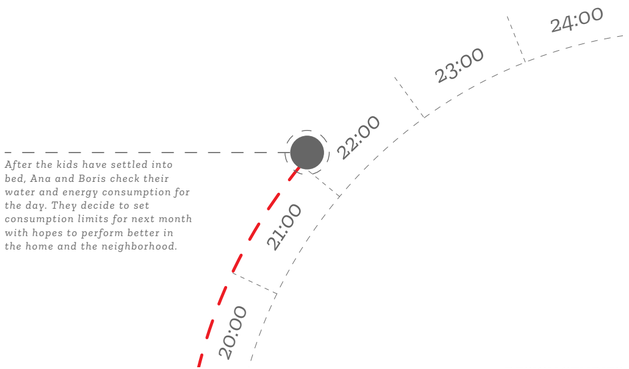
Messages that suggests better times for appliance use along with cost savings motivates residents to behave sustainably.



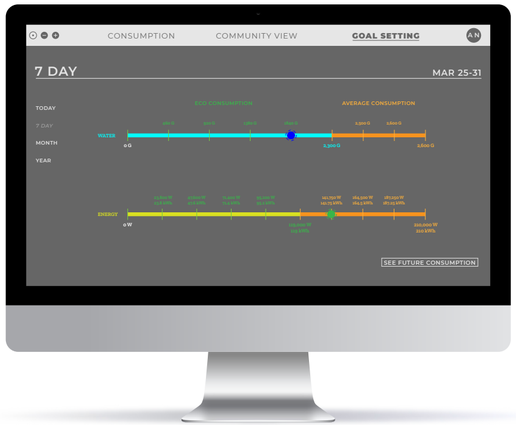
While the parents are preparing dinner and the kids are helping put away groceries, they are notified of current consumption status by glanceable interfaces located on the fridge, and the stove.

Figure 30

Displays offer both current and eco-friendly numeric values to help residents gain understanding of how consumption numbers relate to their behavior.



After the kids have settled into bed, Ana and Boris check their water and energy consumption for the day. They decide to set consumption limits for next month with hopes to perform better in the home and the neighborhood.



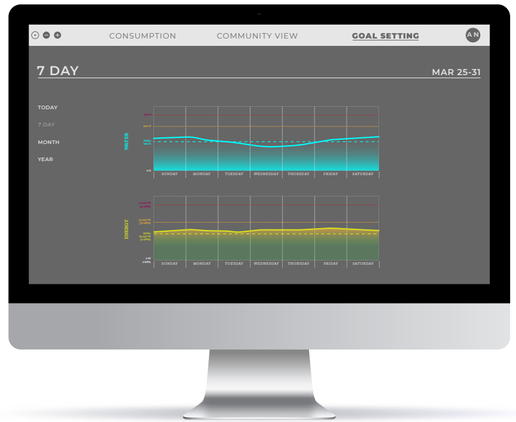


Figure 31

Setting goals motivates users to behave sustainable and set sustainability goals for the future.

DISCOVERED

CONCLUSION

My research suggests that a home can be transformed into a motivational hub where citizens can feel that their sustainable efforts are contributing to mitigating climate change. By considering that every action has a ripple effect, this integrated system offers citizens an understanding of how household energy and water consumption can be viewed at scale. While energy efficient appliances and eco-friendly mobile applications offer sustainable options for consumption, there are few options for citizens to gain insight how their consumption data compares over time and across a community scale.

My investigation shows that graphic designers play a significant role in communicating scale within complex systems. Not only focusing on developing a visual language but more importantly offering representations that help citizens identify their placement within a larger context. Graphic designers have an opportunity to develop a visual system that serves to prompt and motivate citizens to make environmentally conscious decisions and continue to behave sustainably. As scale continues to shift, designers and citizens can participate in a collective effort to communicate and understand how sustainable actions, taken over time, can accumulate to create an impact at scale.

Through designing a system encompassing glanceable moments, incremental reports, community comparison, and goal setting, I've found that each of these areas can and should be further developed. By establishing a cohesive visual standard along with guidelines by which to abide by, the design of these areas can be tested for efficacy and impact. While my research and design studies present a possible multi-layer system offering a view of individual citizens' sustainable efforts at scale, further exploration can be done to develop visual representations communicating water and energy consumption over time and within communities.

FUTURE IMPLICATIONS

This project leads to several areas for further investigation and development. To illustrate how individuals place themselves within larger contexts designers can explore how to integrate scale options to show where citizens' efforts create an impact. There is an opportunity to further develop a visual language that better communicates the impacts of sustainable behaviors across the glanceable moments and the reporting dashboard. Within this multi-layer system, further understanding is needed regarding the types of messages that aid to motivate and promote sustainable behaviors. Whether daily reports or momentary alerts and idle messages, further examination needs to be done on the benefits and effects of messages impacting sustainable decisions and behavior. Through further research, this system could serve to inform and motivate citizens not only in the residential environment, but also within commercial and public areas.

REFLECTION

Phew! Is it over yet?
No, just a few more thoughts.

I started this project with an intention to change the world. Yeah, I'm one of those people! However, what ended up changing was my view of the world. I learned that the world is made up of tiny little systems that work interdependently to create a large complex world of design opportunities. Through this project I had the opportunity to situate myself within a area of interest where I could gather information and design a system that expands upon that interest. My interest for this project and maybe the source for most of my work is decision-making. How people makes decisions? What motivates or prompts them to decide one way or another? And what options do they have to make sustainable decisions for themselves and their loved ones? By focusing on mitigating climate change my intention was not to solve this wicked problem but more so to locate a smaller system, a home system, and offer an approach where individual citizens could see where their contributions factor in.

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