ADU Home Display Design: Final Report

ENG 100D Fall 2022 | Instructor: Anh-Thu Ngo Ph.D.

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D1

Team D2: User Interface

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Table of Contents

Executive Summary

Our partner organization is **Triton Solar Decathlon (TSD)** which is a group of undergraduate UC San Diego students involved in developing ADUs for sustainable and affordable housing amidst the California housing crisis. They are currently working on their project to be submitted to the Orange County Sustainability Decathlon Build Challenge in 2023 and are in partnership with the Greater Victory Church in Logan Heights as a community partner.

Our users can be identified as low-income Latinx families who reside in Logan Heights. Residents in this community need a smart home display to inform them of their energy usage in real-time and to be aware of their consumption in relation to costs. Currently, they are paying their electricity bills without knowing the specific consumption of their appliances or parts of their house.

In our design approach, we went through the stages of secondary research, and ideation by brainstorming features and information architecture on paper, sketched out possible concepts for our display user interface, and created wireframes and low-fidelity prototypes on Figma. After creating our low-fidelity prototype, we communicated with D2 (the backend team) to understand what was feasible in our design or not and iterated with a high-fidelity prototype. We conducted four usability tests to gain feedback on the user experience behind our design and made iterations based on our testing insights. Over this time, we continuously communicated with D2 as well as with our assigned point of contact from TSD (Anne).

Our final design prototype can be found through this link here. The prototype starts at the homepage, where we have a navigation bar to the left (users can go to the different pages in one click whichever page they are on for easy access) and a card layout on the right. The cards include one for rooms where the user can either go to the full 3D ADU model by clicking on it or to each room right away instead. Another card is for the net energy usage which users can click to expand the graph and see it in two filters: time and room. On the room-specific page (i.e. Living Room), users can choose which graph to see through the four different button tabs on the top. They can also filter through time (hour, day, week, month). Then, on the appliances page, users see through a room and/or time filter the amount of energy and cost of such energy per appliance. This visualization is done by the size of circles; the larger the circle is, the more energy the appliance consumed. Due to time constraints, these are the four main pages we have designed (homepage, rooms, net energy usage, appliances).

1. Project Management

1.1 Goals and Objectives:

One of the most important social outcomes we want to achieve is to provide affordable housing for everyone and end poverty. These goals align with goal 1 in SDG:

“Goal 1. End poverty in all its forms everywhere.”

1.4

By using our product, we want to let users monitor their daily energy usage and be aware of excessive energy use. Thus, they can take action and start reducing their energy use. These actions will collectively result in positive changes to the environment. Users can also identify which appliances or which section of the house consumes the most energy. Therefore, these objectives align with goal 7:

“Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.”

7.1

7.2

One of the main objectives of our product is to create ease in daily life by increasing user comfort for everyone. We aim to give all people access to adequate, safe, and affordable housing services. The data collected by our product can also help sustainable urban planning in the future. These objectives align with goal 11:

“Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable”

11.1

11.3

Objectives:

- **Specific** - Team D1 is responsible for designing the user interface of the home display. We are also responsible to communicate with team D2 who is in charge of the back end of our display.
- **Measurable** - Create a low-fidelity prototype of the user interface with essential functions and aim to create a hi-fi demo.
- **Attainable** - We will work on the project to the best of our ability as time allows.
- **Relevant** - Team D1 will focus solely on the front-end development and UX/UI design of the Triton Solar Decathlon project.
- **Time-Bound** - We will finish our work by the end of the quarter for our final presentation.

1.2 Approach:

We plan to approach the design challenge with a focus on **user-centered design**. This places research at a core foundation where our ideas will stem from finding out what the users need/their goals and their current pain points. We also plan to follow the design process of researching, defining the problem and mission statement, ideating, prototyping, and user testing, but we understand that there may be constraints. This may include time and feasibility constraints where we may have to shorten the time for a task or take it out. We may also have to continue reiterating to ensure the prototype can be developed. Therefore, the stages are ultimately a rough outline and not exhaustive of what we may consider throughout the project. Aside from understanding and empathizing with our users, approaching this challenge with **strong and continuous communication between D2 (backend team) and project co-leads from TSD** is important. In other words, we will work in parallel not only with each other in our internal team but with others as well. We also want to make sure our design is feasible to develop in addition to ensuring that we add what TSD wants on our final prototype. A strategy to maintain good communication is to ask any questions we may have and to share our progress during the entire project process (i.e. asking D2 what their next steps are or what their progress so far is, asking TSD for any resources they have, or other clarifying questions).

Tools: Discord (Communication w/ team & D2), Email (With TSD Project co-leads), Google Drive/Docs, Google Slides, FigJam (Brainstorming, Processing Info from Research), Figma (Prototyping)

Methods

We plan to approach user research through three methods: (1) online secondary research (i.e. scholarly articles, web articles, websites, videos), (2) primary research by interviewing people, and (3) usability testing. A few qualitative points that we want to delve into during our early stages of research include: determining what makes a smart home display user-friendly, what appliances people use, if people have motivations to use such technology and if so what would they want on it. When we start prototyping, we would like to test its usability to make improvements to the experience and ensure it is user-friendly.

Currently, we do not have research participants and have asked TSD if they have any resources or people we can reach out to interview. In terms of interviewing in the soon future, we would like to hold it remotely through Zoom however it may depend on the technological fluency or accessibility of the interviewees as well.

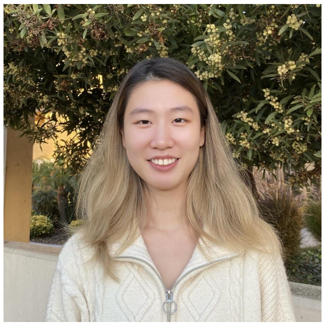
Project Management Strategies

- Communication: share any ideas and concerns, ask questions and clarification if needed, use our discord channel to communicate
- Participation: attend meetings on time, actively participate and listen
- Schedule: follow and meet deadlines
- 1st violations = reminder, repetitive = contact TAs and professor

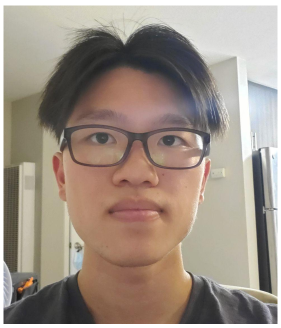
1.3 Schedule:

Link to Gantt Chart with steps of what we need to do: [Schedule]

1.4 Team Bios:



Annie
Role: Project manager
Responsibilities: set up and lead meetings
Major: Cognitive Science with a Specialization in Design and Interaction
Graduation year: Spring 2024
Relevant qualifications and experience: Figma, design coursework
Contact information: a1ye@ucsd.edu (415)747-9618

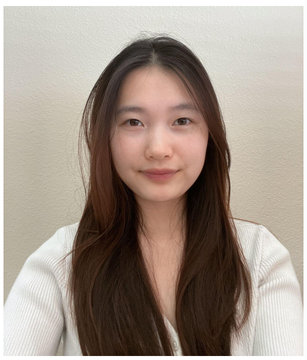


Austin
Role: Documentarian
Responsibilities: Documenting class and meeting activities
Major: Cognitive Science
Graduation Year: Spring 2024
Relevant Qualifications and Experience: Figma, CS coursework, design coursework
Contact Information: auy001@ucsd.edu (415)830-2446

Jana Melina
Role: Creative Director
Responsibilities: Responsible for the accurate implementation of the results of the research into the UX and UI design
Major: Interaction Design
Graduation year: Summer 2023
Relevant qualification and experience: Interaction Design, UX UI Design, Figma, Sketch, Adobe CC, Frontend Development
Contact information: hallo.jm@web.de +49 1732778255

Longtian
Role: Researcher
Responsibilities: Conduct research and help the team to communicate with the backend team
Major: Computer engineering
Graduation year: Summer 2024
Relevant qualification and experience: Figma, React, html, css, javascript
Contact information: lobao@ucsd.edu (858)319-5017

Bella (Jiayang)
Role: Researcher
Responsibility: Conduct research that is essential for the product design and final report
Major: bioinformatics
Graduation: Spring 2023
Relevant Qualification and experiences: Coding (html&css&sql&python&java&c++), CS coursework
Contact Information: j1bao@ucsd.edu (510)513-2529



Hillary
Role: Communication Liaison
Responsibilities: Being the point of contact with TSD and D2 group through email and Discord
Major: Cognitive Science w/ Specialization in Design & Interaction
Graduation: 2024
Relevant Qualifications: Design courses, Figma, Basic HTML/CSS
Contact Information: hmma@ucsd.edu (510) 599-9489

1.5 Stakeholder Analysis:

Families
Family members are people who are related to us. We can use our families as potential stakeholders and get their opinions during our design process. Although their opinion may be biased due to their relation to us, their feedback may still be important to know because their opinions span from different age groups (i.e. parents come from an older age range and may have a different perspective from those who are younger). Their matrix location should go more along the y-axis as we want our families to stay informed but we should not take in too many opinions from them due to potential bias. They fall into the keep informed section.

Investors
Investors are one of the most important stakeholders because they are people who give us the money needed to develop the interface. Therefore, we should approach them carefully and make sure they are informed whenever we have a major update. The investors can give us guidance on the budget we have and the directions on the project we will be developing for them. For the matrix location, we think it should be placed in management closely.

Suppliers
They are the product providers for us. Suppliers can help us produce the exact product we want, so we have to keep them always informed about the design changes and make sure the product fulfills our design. The suppliers can also be used to give us information about the cost of the product. They would be further down the y-axis and a bit lower on the x-axis, keeping the informed area.

Environment
This refers to the general environment around us and how it is taken into consideration when developing our project. The project development stage must understand that Logan Heights already faces immense pollution and therefore we need to make sure we maintain a sustainable approach to our design thinking. Thus, the environment can be put in the monitor area. We don't need to keep it informed or satisfied but will need to take care of it.

Orange County Sustainability Decathlon (OCSD)
The OCSD competition has guidelines that must be followed for successful participation, implementation, and realization. These guidelines cannot be modified, but they are very important. Therefore, the OCSD would have to be further left on the x-axis and relatively high on the y-axis.

Engineers
Engineers, specifically the D2 team who is in charge of the back-end, are stakeholders who we need to collaborate with. They depend on our work and we depend on theirs which makes exchanging information very important. They should be placed further to the right on the x-axis and further up on the y-axis.

Instructor
The instructor guides us to establish the design. The instructor helps us improve the quality of the product and may give advice during the project phase. The instructor should be put as managed closely because we would want the instructor to frequently check whether we are going in the right direction or not.

2. Problem Statement

2.1 Problem Statement:

Low-income Latinx families who reside in Logan Heights need a smart home display because they pay their electricity bills without knowing specific consumption and real-time information about their energy usage.

2.2 Background & Context:

While discussing questions we had about our target audience, Albert Chang from TSD mentioned how the people who live in Logan Heights fall under the San Diego Promise Zone (SDPZ). The SDPZ ranges from Barrio Logan to Encanto with a population that is **predominantly Hispanic (73.5%) and Black (12.9%) as of 2020** (ENG 100D Triton Housing Market Research).

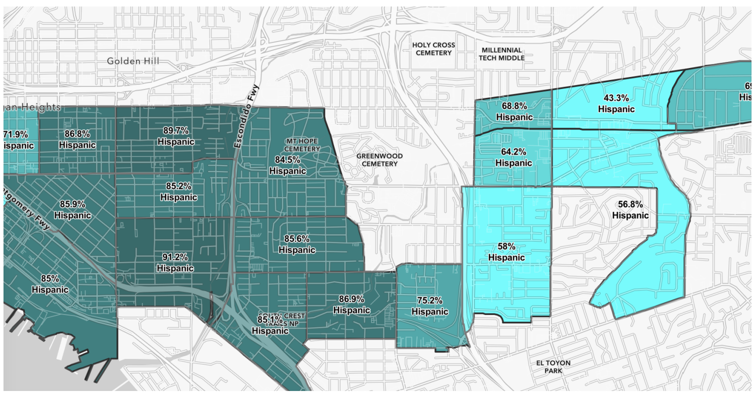


Figure 1. The map above shows how SDPZ is predominantly Hispanic through different areas (shaded in blue and teal) (SDPZ Website).

It marks as one of the 22 federally-designated Promise Zones in the United States because of the relationship between a high concentration of people who fall under low income and is one of the places with the least affordable housing in the nation (ENG 100D Triton Housing Market Research). The history behind this is due to **redlining**, a housing segregation practice, which prevented BIPOC people from owning homes in the past. Therefore, there is a higher amount of renters compared to owners because redlining ultimately caused a generational wealth gap for BIPOC people as compared to white people who *were* allowed to be homeowners.

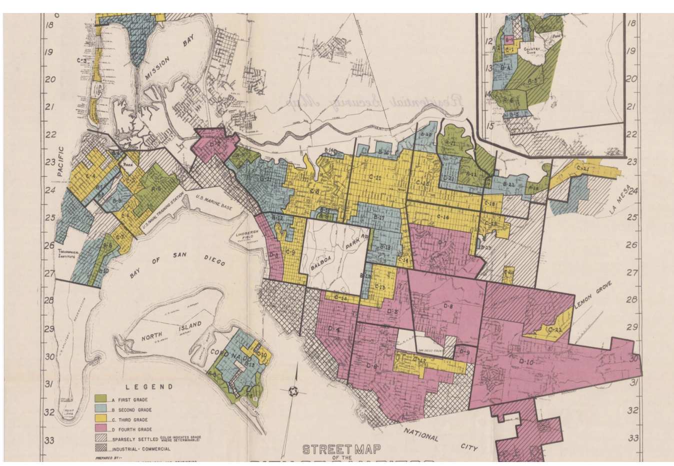


Figure 2. The picture to the left shows a 1936 map of how La Jolla and Coronado are blue which is “second grade” versus much of southeastern San Diego in pink which is the lowest grade – this latter region includes the SDPZ. This color coding is what has come to be known as redlining now (Cavanaugh). Areas in blue such as La Jolla were favored in getting the maximum amount of loans for

residents and builders because of the high grade (Lopez-Villafana and Schroeder).

We can see the impact of redlining in the present time. In Logan Heights specifically, there is a **74.06% rate of renters** which means they are directly impacted by the low amount of affordable housing available (ENG 100D Triton Housing Market Research). Therefore, in addition to the ADU that Triton Solar Decathlon is building, this smart home interface will support low-income Latinx families in understanding their energy usage and knowing how to reduce their electricity bill costs as well.

What is the problem? Who or what is impacted (where, how many, and in what ways)?

The problem is that many families residing in Logan Heights are low-income and face low affordable housing rates. In addition, they do not know how much energy they consume in real-time or how to reduce their electricity bill cost. For example, there is no real-time and specific information about how much their microwave is using or how much electricity the living room uses. Thus, we want to create a smart home display that allows family members to find transparent data and be more aware of their energy usage.

Describe the relevant context of the affected community (e.g., political, economic, sociocultural, technological, legal, geographical, environmental, and educational).

Building an ADU and the smart home display that allows residents in Logan Heights to be more in control and aware of their energy usage is particularly important because they are faced with extreme environmental issues such as air pollution. As a port-side community with toxic diesel particulate matter emitting from shipping trucks and equipment, many family members in Logan Heights face high rates of asthma and lung cancer compared to other locations in the nation. For example, residents in neighboring Barrio Logan have an **85% to 95% higher risk of developing cancer compared to the rest of the nation** (Environmental Health Coalition). Air pollution is also exacerbated by the neighborhood's close proximity to Interstate 5 (Smith).

What is the history of the problem, and how has it changed over time? What is the projected scope of the challenge in the future?

The issue of high concentration of poverty intertwined with low affordable housing in Logan Heights is due to redlining as mentioned above. Over time, the effects of redlining such as the generational wealth gap for BIPOC people from not being able to own homes remain to this present day. The emphasis on building ADU in Logan Heights provides a solution to the lack of affordable and sustainable housing in the neighborhood. Our smart home display interface in particular can also empower families to be more aware of their energy consumption so that financial capabilities and improving the environment do not have to be a tradeoff but rather work together. Therefore, there is work being done to counter this challenge but it needs to be implemented in a just way and in the genuine interests of those who live in Logan Heights. There is also a **Promise Zone Initiative** where the federal government works closely with local organizations and residents to provide resources (San Diego Government).

What are the underlying causes of the problem? Consider both immediate drivers as well as structural conditions (i.e., the "rules of the game").

The underlying causes of this problem are the lack of recognition and genuine initiative to help Logan Heights both in the lack of affordable housing and the immense amount of air pollution they face. Identifying the problem is a step but there also needs to be actively implemented in the interests of the residents themselves. The national and local governments should also properly "promise" the residents they will provide help rather than taking back their word. For example, The City of San Diego promised neighboring Barrio Logan residents that the land beneath the bridge would be used to build a park but they instead tried to build a highway patrol station (Intersectional Health Project San Diego). There can also be more publicity to make people outside of Logan Heights and even beyond San Diego county aware of the problems the neighborhood face and how to help out. With more publicity, there can be more pressure on the local and national governments to ensure their promising changes.

What resources and capacities does the community/organization possess that could be leveraged in addressing your design challenge?

Resources and capacities that TSD possesses and could be leveraged in addressing our design challenge include the demographic information and community engagement data provided to us. They answered our questions in a timely manner which assisted us in deciding what direction we should take. In the future, we hope that TSD can continue to answer our questions while we work on our design challenge and provide us with feedback on what we need to improve throughout the time.

2.3 User Profile(s):
Link to Figma

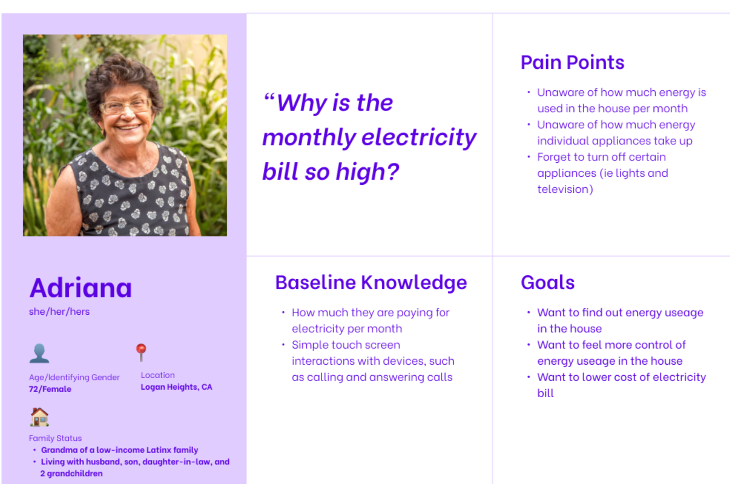


Figure 3. User profile of Adriana who is an example of a resident in Logan Heights who may use our smart home display

Figure 4. Empathy map for Adriana showing what she would say, feel, think, and do.

Journey Map

1. Wake up at 6am
2. Make breakfast for family
3. Eat breakfast while watching television with husband after everyone else left
4. Go get groceries with husband after breakfast
5. Come home realize the television is on and turn it off
6. Clean the house
7. Pick up grandchildren from elementary school
8. Prepare dinner for family
9. Watch television
10. Go to bed at 9pm

Figure 5. The above shows the journey map or an example of a day in the life of Adriana.

2.4 Design Requirements:

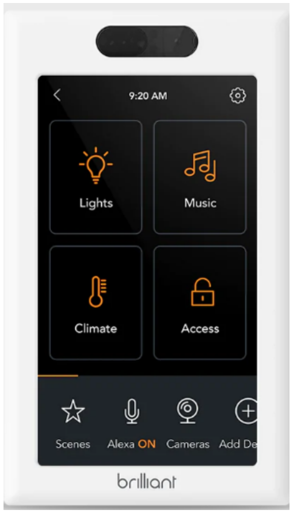
Criterion	Requirement

Functional	1. Our smart home device will use an electricity sensor to help determine energy usage. 2. Our smart home device monitor will allow users to monitor energy usage. 3. Our smart home device monitor will allow users to turn on or turn off the electric applicants. 4. Our smart home device will allow users to track energy use and calculate the estimated cost based on the current energy efficiency.
Usability	1. Our smart home device will allow users to easily see the current home energy usage in the 3D rendering 2. Our smart home device will allow users to set goals for their home electricity usage. 3. Our smart home device will allow the user to easily understand their energy use as well as cost savings.
Affordability	1. Our smart home device will be cheap enough so that every user can afford it ($100). 2. Our smart home device will be cheap to maintain.
Feasibility	1. Our smart home device will have a WiFi connection. 2. Our smart home device will be easy to install and work with any existing home energy usage systems. 3. Our smart home device will be able to update if it has a WiFi connection available.

Table 1. Above shows how our smart home display meets the criteria of functionality, usability, affordability, and feasibility.

3. Concepts

3.1 Existing Solutions Analysis



Pros:

- The interface is clean and easy to use.
- Includes a light switch for multiple lights
- Smart lighting, turn on and off lights using different methods
    - e.g touch, voice, built-in motion detection
- In wall sonos, ring & smart lock control
- Climate check, camera check provided

Cons:

- Doesn't address different language needs for different users
- The text may be too small for senior citizens or people with visual impairment to read

Figure 6. Brilliant smart home interface

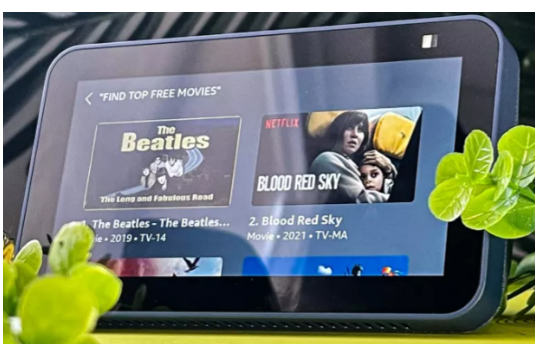
Pros:

- Edgeless glass display
- Accurate sleep tracking
- Youtube and Google programs integration
- Temperature display

Cons:

- Air gesture could work better
- No camera

Figure 7. Google Nest Hub



Pros:

- Cute compact design for kids
- Sounds decent for its size
- Kids edition has good privacy and warranty options

Cons:

- Low-quality camera
- Not so many features being displayed

Figure 8. Amazon

Most of the current solutions don't have a camera view or the view is not really great, it could be one of the gaps we can approach. Another weakness is the small text size which may affect elders and people with viewing disabilities who will use the system. We should also try to make it portable instead of having something that sticks to the wall. If we can have it on the phone, the system can become much more convenient. Also, water and gas leaks can also be addressed in the smart home display, but none of the smart home displays are doing that right now. The gaps within the existing solutions are that the camera display is not very high and the wireless connection doesn't seem to be stable. The screen is not portable and not very convenient as users have to be around the smart home display to use it. Some of the unaddressed obstacles are the unstable connection between electronic devices and the smart home display. Wifi is not very stable and as more and more features would need to be added to the smart screen in the future, we might need a much more powerful device.

3.2 Concept Generation

<u>Concept 1: Room-Oriented</u>

Navigation and information architecture by rooms

The need that is met by this concept is to see in which room what consumption is. This is solved by simply viewing each room on the left side.

A strength of this concept is that users can easily find the space they are looking for. The rooms are listed on the left-side navigation and are easy to find. Thus, the user can quickly see which room has which consumption and adjust his/her behavior accordingly.

A disadvantage of this concept is that equipment such as solar power is not applicable to just one room, but affects the whole house.

In this concept, we considered using icons in addition to text in the navigation bar.

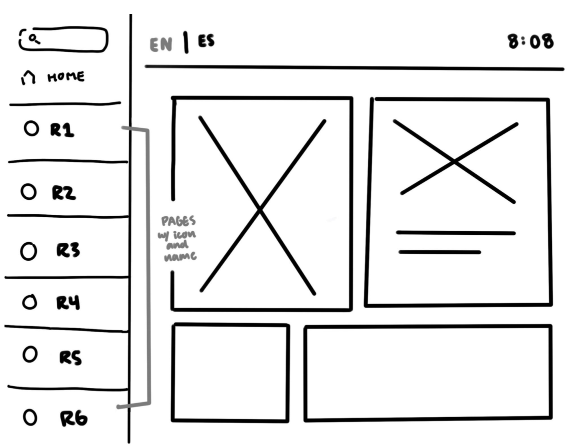


Figure 9. Above shows a rough sketch of the homepage for our smart home display with icons as circles and "R#" denoting different rooms.

<u>Concept 2: Utility-Oriented</u>

Navigation and information architecture by utility

The user's need is to see how much energy is being consumed and where in the house. This need is met by giving the user a 3D overview of the house to get an insight into individual rooms, but also an overview of the equipment.

The strength of this concept is that the user can use two different ways to view energy demand and usage–once via the 3D model of the house and once via the equipment directly.

A disadvantage of this concept may be that the user is overwhelmed with different ways to reach the goal, which we will have to find out through testing.

In this concept, we decided not to use icons in the navigation bar and only text labels. This way, we have more space for the text and it can be set larger for people with a visual disability. Another component we use here is cards. On these cards, you can find different information such as the 3D model, the rooms, net energy usage, and 3 main lighting controls.

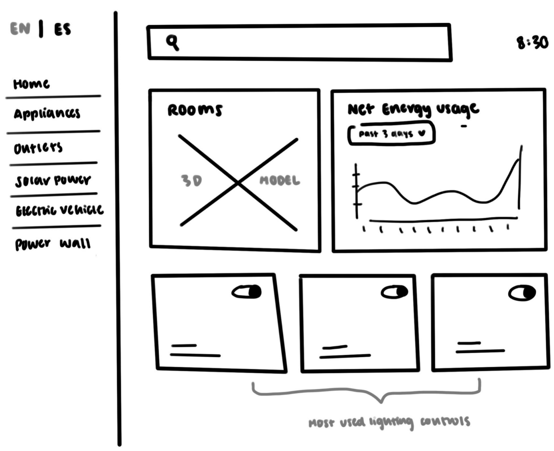


Figure 10. Above shows a sketch of the homepage with a more specific navigation bar (added labels without the icons) and the different cards on the right (rooms, net energy usage, light controls).

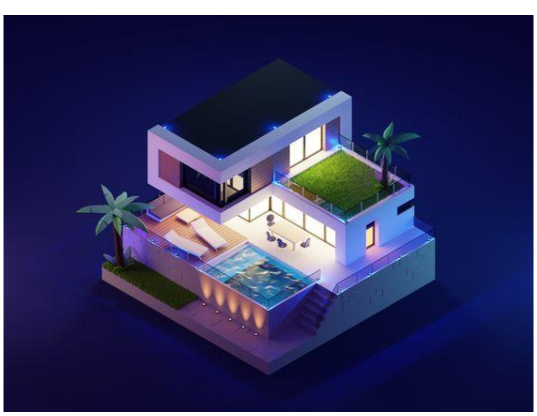


Figure 11. Image on the left shows an example of a 3D model. We are looking to incorporate a similar 3D model style of the ADU house onto our prototype as per the design brief requirements.

Concept 3: Visualizing through Text and Icons

Support the user through text and imagery and provide cognitive relief

The user should have to find his way around a software again and again. Through both text and visual language, the user can be optimally supported to achieve their goal and does not have to think for a long time.

A strength of this concept is that the user can learn the meaning of the icons and over time mean what it says and quickly recognize the icon when looking for something.

One weakness is that both consume a lot of space. For a person with vision problems who relies on large fonts, it could become difficult here.

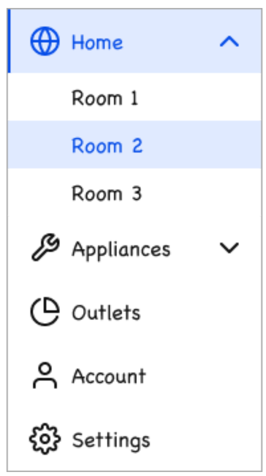


Figure 12. An example of how icons support visual learning when accompanied by labels. However, it may also take up space that can be used to increase the text size for higher accessibility.

3.3 Concept Evaluation & Selection

We decided to elaborate on the utility-oriented concept (concept 2) because we believed the information is presented most intuitively in this sort of format using the 3D model and that there were necessary features that could not be presented as well in other formats.

According to our initial design requirements, it is necessary for the user interface to display appliance electricity usage, outlet electricity usage, built-in light electricity usage, solar power electricity generation, EV charging electricity usage, power wall storage levels, net energy consumption, thermostat controls, and water heater controls. In addition to what it will display, other necessary features include a 3D model of the home with a heat map, the ability to zoom on the 3D model, a search bar, brightness adjustment, wifi compatibility, and a manual on how to use this device, though most of this is beyond the scope of the lo-fi mockup.

Our primary focus was on the best way to present energy consumption, generation, storage, and controls. We also have our own self-imposed requirements which are an intuitive navigation and accessible text and icons. We used a decision matrix to help us make our decision, however, we currently do not have insights from key stakeholders and experts on our concepts to help us make our decision. Concept 1 will be the baseline.

Criteria	Weighting	Concept 1	Concept 2	Concept 3
Displays energy consumption	1	0	0	0
Displays energy generation	1	0	+1	+1
Displays energy storage	1	0	+1	+1
Displays controls	1	0	0	0
3D model	1	0	+1	0
Intuitive navigation	2	0	+1	-1
Quick navigation	2	0	-1	0
Accessible text and icons	2	0	+1	+1
Multiple ways to view energy information	1	0	+1	0
Total		0	+6	+2

Table 2. Above shows how each concept is evaluated.

4. Analysis & Testing

4.1 Overview:

Approach:

Our approach towards prototyping and iterating the interface revolves around the fact that we are restricted by the time that we have, our own ability to design, and the biggest bottleneck of all, whether it can be implemented by team D2.

Method:

Using Figma, our team made 2 iterations of prototypes. In order to measure feasibility, every aspect that is unfeasible with each iteration counts as 1 towards the number of unfeasible aspects. This is the metric that is used to quantify feasibility with the target of 0 unfeasible aspects.

First Iteration:

Our first iteration was a lo-fi prototype containing barebones features. This included all the main pages such as the home page, appliances page, 3D model page, and rooms page. We brought this first iteration to our meeting with D2 where we talked over each feature.

First, our intended platform was a home display as it was suggested on our prompt. However, D2 had chosen to implement the interface on a website due to time constraints. We decided on the website and changed the dimensions of our interface. Additionally, while every page we have is essential, we may not have enough time, so it was decided that the Rooms page would be the priority to be implemented.

Next, we went over each feature in the interface with D2 in which they could ask clarifying questions. One such feature was toggling switches which would allow the user to toggle the lights.

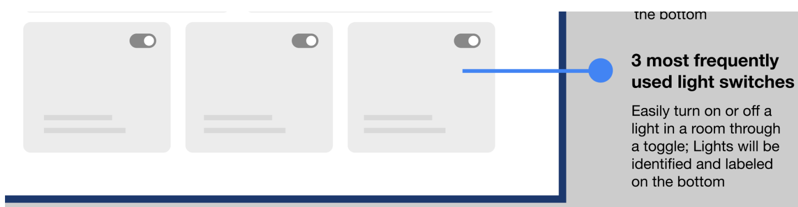
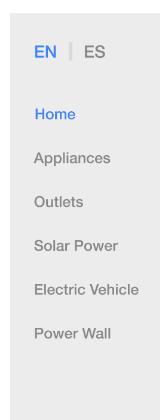


Figure 13. The above shows the feature of controlling light switches on our initial wireframe.



It was decided that this feature was possibly not feasible as team D2 were unsure if they could send information back into the sensors.

Though these were requirements on our prompt, D2 mentioned that they were unfamiliar with the outlets, solar, and electric vehicle tabs on our navigation bar and were only aware of implementing appliances and outlets. Our main focus would be on implementing the appliances and outlets page.

Figure 14. The image to the right shows our navigation bar and the outlets, solar, and electric vehicle page labels that D2 was unfamiliar with.

One last point that was discussed was whether team D2 would need to purchase Sense Energy Monitor. We were unsure whether we would have to purchase it ourselves or would be provided it. We decided it was not within our timeframe.

Second Iteration:
In our now hi-fi prototype, we began designing a style guide. We primarily focused on designing the hi-fi for the rooms page only first. We began testing our hi-fi with different color combinations. We also updated our dimensions to fit a monitor. In the meeting with Anne, further discussion was had to get feedback on our lo-fi prototype and new hi-fi prototype. There was a discussion about whether apps would be embedded to which Anne mentioned that for some of the pages we have a tab for, such as for outlets, we could redirect users from our app to their app so that we do not need to design our own interface.

We had addressed all the feasibility issues with our first iteration of the interface. In terms of the feasibility of implementation, we wouldn't have any issues, though we have talked about some user issues such as selecting a color palette with color blindness in mind.

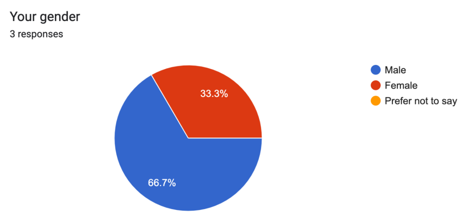
Iteration	Criterion	Metric	Target Value	Resultant Value	Method
1	Feasibility	# of Unfeasible Aspects	0	5	Analysis
2			0	0	

Table 3. The above shows a summary table used to measure the implementation feasibility of our design.

4.2 Desirability & Usability:
Introduction:
We have conducted smart home device user testing. Our testing question is: will users be likely to use our product? Our hypothesis is that our users have steady access to the internet and know how to use smart devices. We also assume that our users need to pay electricity bills as part of their monthly expenses.

Method: We made a Google Survey Form and would like the user to submit feedback regarding the product they evaluated and including feedback on product design, usability, and desirability.

Results:
The user's personal information is shown below:



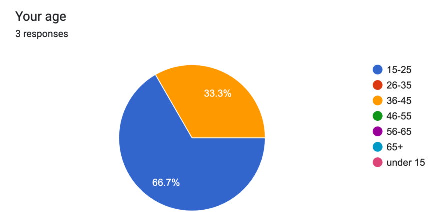
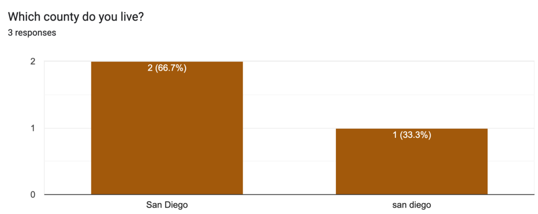


Figure 19 (left). The above shows a majority of participants (66.7%) identify as male whereas 33.3% identify as female.
Figure 20 (right). The above shows how the majority of participants (66.7%) fall between 15-25 years old while 33.33% of participants are between 36-45 years old.



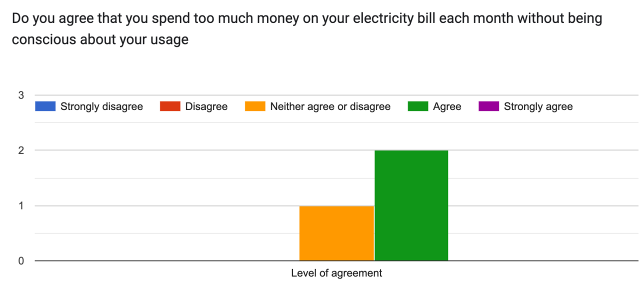
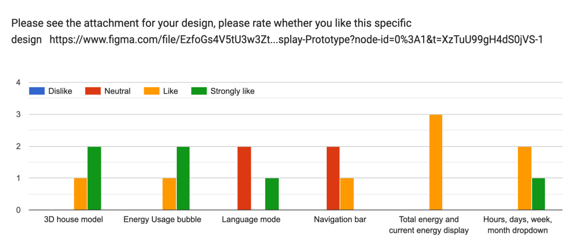


Figure 21. 100% of participants live in San Diego County.
Figure 22. Above shows a bar graph with one participant neither agreeing or disagreeing with the statement above. 2 participants agree with the statement.
Analysis:
All of our three users come from San Diego County. 2 of them are male and 1 of them is female. They are young users and 2 of them agree that they spend too much money on electricity bills without being conscious about the usage. We can see that usability is their primary concern. Users who share the electricity bill are more likely to use our product due to a more fair splitting mechanism.



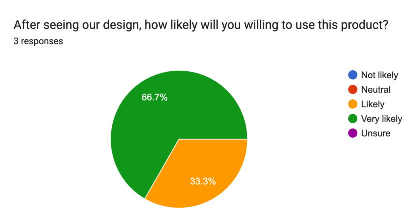


Figure 23. Above is a bar graph displaying how many participants (y-axis) felt neutral, liked, or strongly liked the various features of our design (x-axis).
Figure 24. Above is a pie chart showing how 66.7% of our respondents would be very likely to use the product whereas 33.3% are likely.

From this chart, we can see that users like the 3D house model and energy usage bubble the most. The users also state that the interface looks clear and user-friendly, and one user states that she hopes the language mode can integrate more languages. After seeing our product demo, 100% of the users state that they will likely use this product. This indicates that our product has high desirability and usability. From the advice that users propose, most of them hope this product will be cheap enough for them to give it a try.

4.3 Feasibility & Suitability:

We utilized design like this and developed further with corresponding to the scenario we are given for the Latinx families to come up with our own design. Considering the people that are using our design may vary from different ages, we added a search bar to provide some convenience if the user is not able to locate the data that he/she is looking for. In addition, we added the room name to show the user which room they are in so that the data is more specific. The resources required to create the display are available in any market as we only need a monitor to display the data. To measure the data in the room, we are going to use a chip to help us with the measurements. The rest of the wireframe can be coded with HTML and CSS. It should perform as expected because we believe that our design has some improvements from other designs such as the search bar and the different tabs with their interactive containers. Based on the feedback from 4.2, we are confident that the product will go well.

We think our solution is feasible in terms of the Latinx homes because it provides the data that the user desires (temperature, light, electric vehicles, etc.), quite a simple wireframe to learn and use, feasible as it is easy to build and install, and very sustainable as most of our design lies only in a monitor and a small chip. The product language can be either English or Spanish to suit the language preference.

We used the S.M.A.R.T goals-based evaluation to evaluate the product, the result is the smart home display and data are measured correctly. The product is doable, simple, and relevant to the requirements. It can also be done in the quarter which satisfies the time-bound. The product would be a good fit for the requirements, although it may not contain all the features that are visible in some of the other similar products, it's still a good design that's interactive, simple to use, and doable. We found out that it's important to show the energy usage of all possible energy to let people be aware of how big the energy consumption is. Also, the greenhouse effect is taking place which can be noticed as we have much hotter summers and colder winters. It's a good idea to get a smart home display at home to both lower power consumption and save some expenses on utility bills.

4.4 Sustainability:

<u>Economic Sustainability</u>

- **Is the cost to implement, use, and maintain the solution affordably?**

This question is difficult to answer. The following article gives a good overview of the costs https://maddevs.io/customer-university/software-maintenance-costs/ .
It shows that the highest costs come from implementation and maintenance. Since you need a Designer and a Developer, we will need both. But it depends on the scope of our solution later and if someone wants to resign for some reason. But the user should be affordable, since it is just a small device.

- **Does the solution improve user financial security and self-sufficiency?**
  Yes, the user interface allows the user to get an overview of his/ her consumption at a glance. Because of this she/he can see where she/he can improve her/his behavior regarding consumption and save money.

Socio-Cultural Sustainability

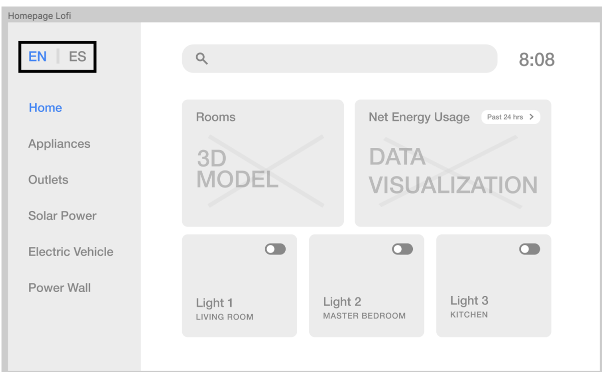
- **Is the solution culturally appropriate?**
  It is culturally appropriate for the culture of the target users. For instance, it has the constraint that the tab bar is located to the left.
- **Did the community play a determinative role in the design process?**
  Yes, the community plays a determinative role, we took into consideration the community and decided to offer it in Spanish as well.
- **Can the solution be harnessed, replicated, and improved on by the user?**
  During the development, the user helps us with feedback to improve the solution. Afterward, there can be improvements, by asking users for feedback and turning it into a better user experience. But for now, this is not planned,
- **Does the solution promote social justice?**
  Because our solution is installed in an affordable and sustainable home, it gives low-income society the opportunity to become aware of their energy consumption. Sustainability not only saves resources but also money. Sometimes in order to save, you have to buy things that harm the environment simply because they are cheaper. As someone who is financially a little better off, he does not need to "worry" about such things.

5. Design

5.1 Overview:

After creating the low-fidelity prototype, we showed it to team D2 and Anne from TSD. After discussing the design with them, we switched to prototyping a website to display energy usage in the house instead of home displays on the wall so it would be easier for D2 to code in the remaining two weeks. Through our design, users would be able to see the energy usage for the appliances, outlets, and electrical vehicles. Users can also see how much solar power and power wall are stored. Some typical use case scenarios include:

01. If the users want to change the home display website from English (EN) to Spanish (ES), they would do so by clicking on the ES in the box below.



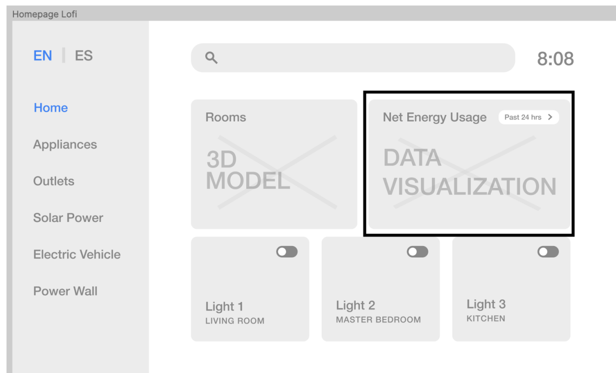
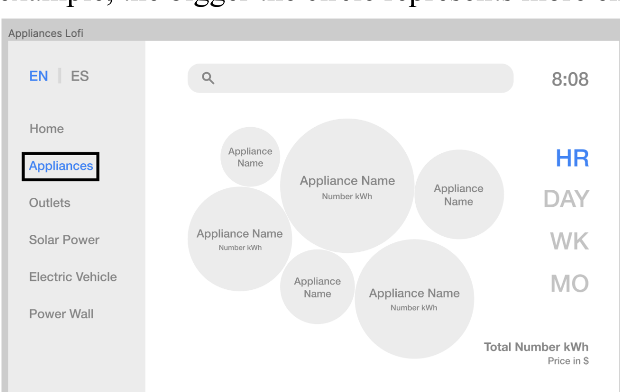


Figure 26 (left). Outlined in the black box is the language toggle on our low-fidelity prototype.
Figure 27 (right). Outlined in the black box is our net energy usage graph on our prototype.

02. If the users want to know how much energy they used for the past 24 hours, the graph in the black box below will tell them the information. The users can also click on the drop-down in that box to change the time range to 3 days, 1 week, or a month.

03. If the users want to know how much energy each appliance is using, they can click on the "Appliances." The size of the circle represents the % of energy usage of that appliance. For example, the bigger the circle represents more energy usage.



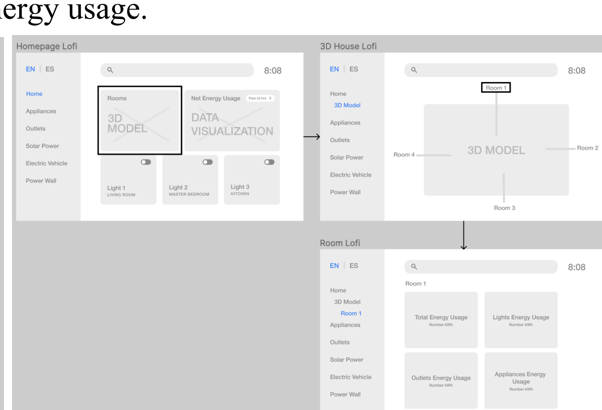


Figure 28 (left). Outlined in the black box is the appliances page on the navigation bar.

Figure 29 (right). The above shows the user journey to get to the room-specific page from left to right to the bottom.

04. If the users want to see energy usage by the room, they can click on the black box with the name "Rooms" in the upper left. They will be brought to a new page, upper right, with the 3D model of the house. Users can click on the name of the room. This will bring them to another page with detailed information on energy usage in that room, which is the page in the lower right.

5.2 Detailed Design:

User Flow ([link to FigJam file for better readability]())

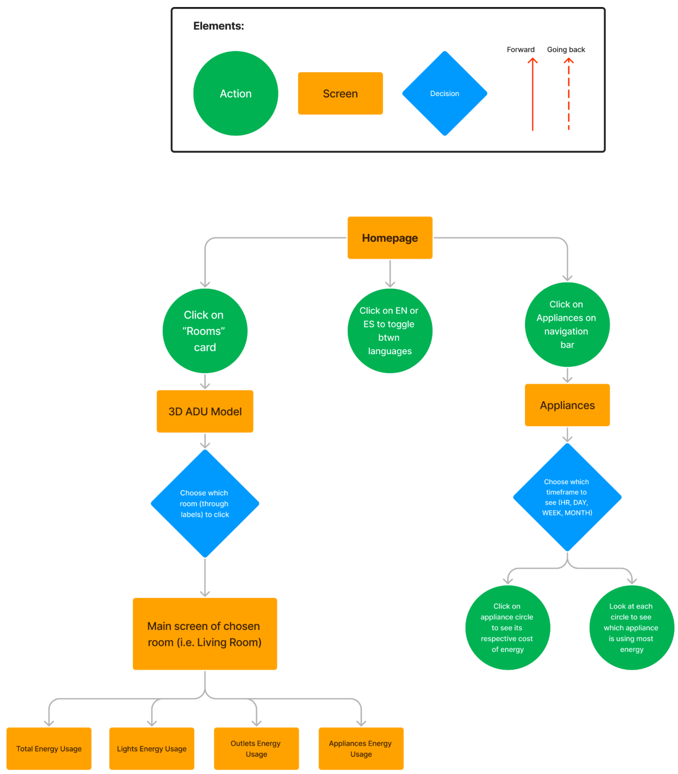
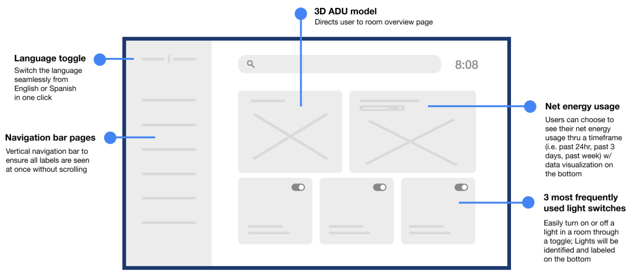


Figure 30. The above shows the user flow that the prototype follows, outlining the possible actions, screens, and decisions users may interact/come across.

Wireframe & Lofi Diagrams ([link to Figma file](#))

Homepage:



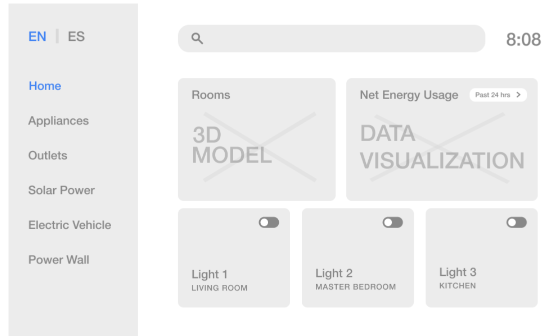


Figure 31 (left). Wireframe of the homepage

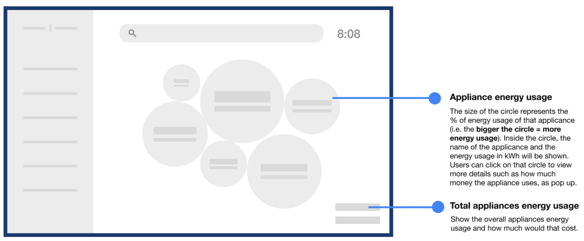
Figure 32 (right). Low-fidelity prototype of the homepage

On the homepage, we decided to go for a **card-based layout** because it was the most commonly seen in other home displays out on the market (i.e. Google Nest Hub & Amazon Echo Show). We also made this design decision because it allows the general interface to feel organized and thus clean, adding to the usability and user-friendliness of the display (as users will be able to find clearly what they are looking for due to this organization). The card layout also draws upon the **Law of Common-Region** from Gestalt Principles in UX where each card creates a specific region of information even if other information that may differ from the card is placed in close proximity. Thus, this ultimately distinguishes different information from one another when displayed on the same page.

We also added a **language toggle** on the top left-hand corner, where users can switch seamlessly between English and Spanish in one click. Because this home display will be used in a home located in Logan Heights where the majority of the population are Latinx families, we made this design decision to allow users to use the display in a language they're comfortable with. This adds to the usability and desirability of our display. If users can easily understand the interface in their own language, they will be able to navigate through the display and want to use it continuously because it may address their personal needs.

We also placed a **vertical navigation bar** instead of the horizontal one that we saw in many smart home displays out on the market. A usability issue with horizontal navigation is that users had to swipe through the navigation bar to see which pages the display offers (some are hidden unless the user knows they have to swipe right to see them for example). Since there is no clear signifier that allows users to know to swipe, we decided to go for a vertical navigation bar that does not need to be swiped. It shows all of the pages a user can navigate to right at once without the user having to think, thus increasing usability. Inspired by home displays on the market, we initially added mini-cards in users can click on as a toggle to turn off or on a specific light in the house. However, this was not feasible because we spoke to D2 and realized that the data they have may not support this function. Therefore, it is something we would not include in our high-fidelity prototype.

Appliances:



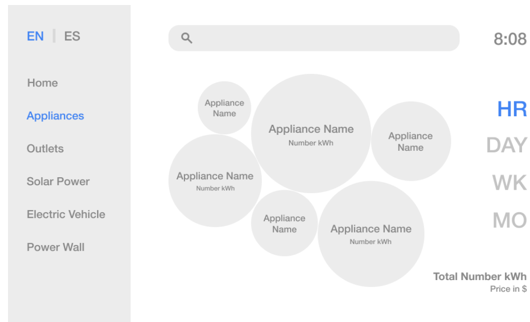
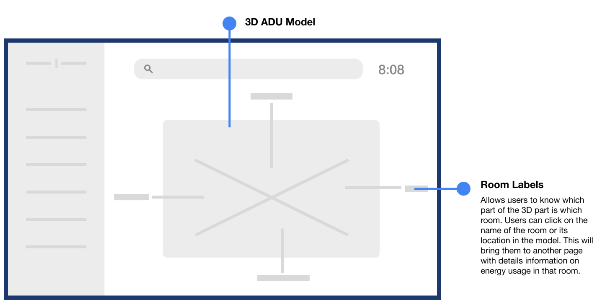


Figure 33. Wireframe of appliances page **Figure 34.** Low-fidelity prototype of appliances page

The interface design of appliances was heavily inspired by an app that TSD wanted us to incorporate into our display: Sense Energy Monitor. While conducting secondary research, we realized how they showed their appliances usage was visually-straightforward and appealing as well. The bigger the circle is, the more energy the appliance uses. This design also draws on the **Law of Focal Point** from Gestalt Principles in the sense that the larger circles are, the more noticeable it is and holds the user's attention first. Therefore, users don't have to think about which appliances are using the most energy; Rather, it is visually shown to them quickly and thus increases the usability of our interface design. We also included different timeframes on the right to allow users to view their energy consumption in multiple ways and see how they can more sustainably use their appliances.

3D ADU Model:



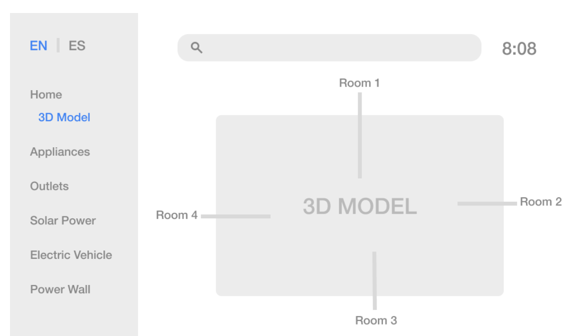


Figure 35 (left). Wireframe of 3D ADU Model page
Figure 36 (right). Low-fidelity prototype screen of 3D ADU model page

We added **room labels** onto the 3D model of the ADU house that TSD wanted to include on the display in order for users to understand which room is which. This also allows them to easily navigate to the specific room they want to find information for as they can click on the label to get more information regarding the certain room.

Rooms:

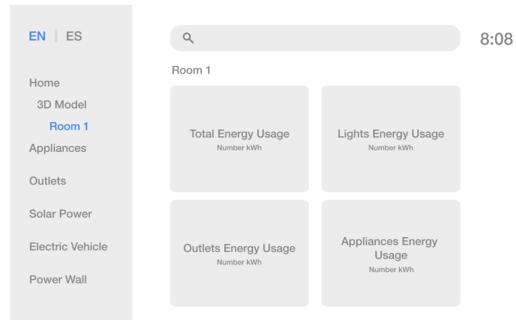


Figure 37 (left). Wireframe of room-specific page
Figure 38 (right). Low-fidelity prototype screen of room-specific page

On the specific room page (i.e for the Living Room), users can see graphs for the room's total energy usage and its specific usage of lights, outlets, and appliances. For example, users can see how much energy the TV in the living room is using by clicking on its corresponding card (appliances energy usage). We maintained the card layout as we used for the homepage to maintain consistency and thus usability. Users are familiar with the layout of the homepage and we did not want them to think of another mental model behind our design display.

6. Implementation & Impact

6.1 Implementation:

Our energy display prototype will be implemented by the backend team, D2. For the backend team to use as a reference when coding the display, we created a number of distinct screens with their flows on Figma. For simpler access by the team, we also produced a style guide that specified the typeface, its weight, and the colors we're utilizing.

In order to construct our prototype, we begin by sketching out the user interface and related flows on paper. Once we had a broad notion of the layout and appearance of the display, we used Figma to develop wireframes and a low-fidelity prototype. After meeting with the backend team, we learned that a website will be developed in its place as opposed to the home display on the wall. Before starting the high-fidelity prototype for the larger website screen, we created the style guide. The high-fidelity prototype will next be put to the test through user testing with those who have prior knowledge of home displays. At the same time, the backend team will be coding the screen that displays the total, of lights, appliances, and outlet energy usage in a room. While we do the user testing, the backend team will program the screen that displays the total energy usage in a room as well as the energy usage for lights, appliances, and outlets. Finally, based on the feedback we received from the people, we will iterate the prototype of other screens.

6.2 Failure Analysis:

Potential Failure Mode	Potential failure effect	Severity	Potential Causes	Occurrence	Detection	Risk Score	Action
Fail to show or incorrectly show the current usage	Dissatisfied users, annoyed customers, additional charge	8	Energy monitor is disconnected or broken	4	7	224	Annually hardware check and maintenance is required
Fail to turn on or off the electric appliances	Annoyed customers, a potential waste of energy	4	The Bluetooth connection between the electric appliances and the smart home device is unstable	3	8	96	Instruction for how to reconnect with the Bluetooth and wifi is needed
Fail to switch	Dissatisfied	2	The smart	2	2	8	Instruction for

language mode	users		home device system is down				how to update the system is needed
3D house model does not display the usage heatmap as desired	Dissatisfied users	3	The smart home device system is down, or the hardware connection is unstable	2	3	18	Annually hardware check and maintenance is required
Estimated monthly cost is incorrect	Dissatisfied users	4	The estimation algorithm is poor	8	4	64	The team need to redesign a better machine learning algorithm to estimate

Table 4. Above shows the failure analysis table.

6.3 Monitoring & Evaluation Plan:

The impact we hope to make should span all stakeholders that are involved in developing and implementing our solution. This includes people who will pick up our work at the end of our course, the people at TSD who will be receiving the work we have completed, and the other teams that we worked with. Additional stakeholders would include those that are influenced by our actions, but we do not have direct relations with, such as those responsible for hosting the Solar Decathlon Competition as a whole who may or may not see the fruits of our labor, the contractors who may or may not implement our vision into the ADU, and the beneficiaries of the ADU (the community living in Logan Heights) who may be interacting with the home display that is being developed in part by our group.

We hope that the home display designed by our group will be further developed by the next set of people that will be picking up the project. From there, hopefully some part of the home display designed by us will reach the final ADU plans and will be implemented into the actual ADU. We hope that the home display serves its intended purpose for its users by helping them understand their utility usage in real-time and what they can do about it.

Theory of Change

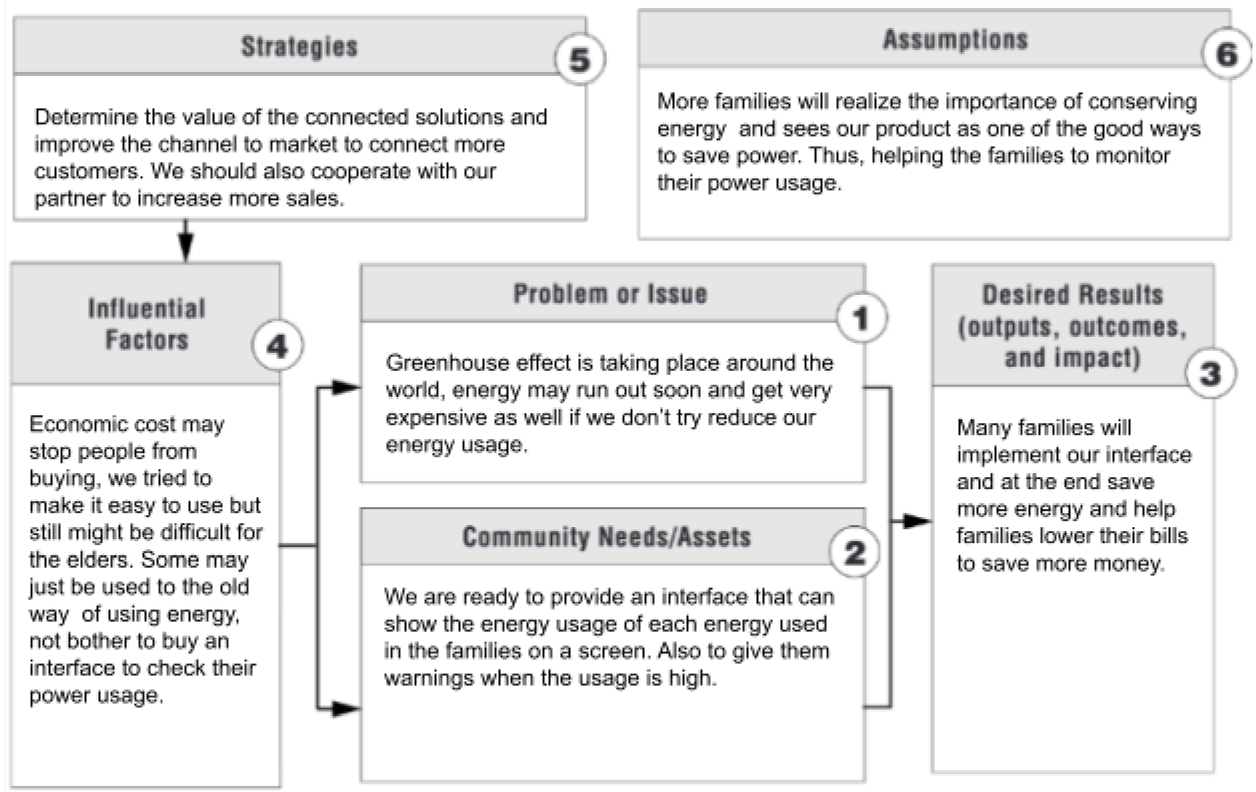


Figure 39. Above shows the theory of change in the context of our smart home display interface.

	Objectives	Indicators	Baseline	Target	Data Source	Frequency
Inputs	Lower cost of production	Cost of the design	$500	$200	Self	Once a month
Outputs	Families use our interface	Sales	0	1000	SMS survey	Once a month
Outcomes	Families lowered their bills	% of bill lowered	0%	25%	SMS survey and interviews	Once a month
Impacts	Energy consumption lowered overall	Graphs in the area	0% decrease	20% decrease	Government website stats	Once a month

Table 5. Above shows a monitoring and evaluation table that will be used to evaluate the effectiveness of our solution. Lower utility bills and energy consumption is the definition of “success”.

6.4 Ethical Analysis:

Our target audience, low-income Latinx families who reside in Logan Heights, may benefit from our solution of a sustainable and affordable ADU housing unit that our smart display is in. This is due to how residents in Logan Heights generally face high levels of poverty due to low affordable housing rates. They also face extreme pollution due to diesel particulate matter which has resulted in lung cancer and asthma for many people who live there. Thus, understanding their energy consumption through a display while living in an affordable and sustainable ADU can help them identify how to save on their electricity bills while using energy efficiently.

However, unintended consequences might include if residents want to use the smart home display in the ADU or not. This was a point of question we wanted to further delve into as a means of doing primary research, but it was hard to get in contact with residents from Logan Heights to gauge their interest. If they would not prefer to use the smart home display, it may affect TSD's envision apart from their submission in the competition that wants them to show this data.

7. Conclusions & Recommendations:

We worked closely together with the D2 team to get on the same page regarding our project. While they are coding the screen that displays the total energy usage in a room as well as the energy usage, we will conduct usability tests based on our high-fidelity prototype. For this, we created several flows and came up with a style guide. After the next usability tests, we will iterate our design and information architecture based on the outcome.

Our impact should span all stakeholders and we hope that the next team will pick up our project to bring it further. We hope that some part of our work will make it into the final design of the smart home device and that it serves its intended purpose by helping them understand their consumption.

In terms of future work, we recommend extending the user testing process and re-iterating the design based on testing feedback. Due to the time constraints of our project, we plan to conduct user testing through a convenience sampling of friends or family that we know who have prior experience in using smart home displays. Their prior experience will help give us useful feedback when testing our prototype because they have a baseline knowledge of how these displays work best and/or flaws in their experience. However, when there is more time and resources in terms of people to reach out to, it is recommended to extend the audience of the user testing process specifically to people who reside in Barrio Logan who will live in the ADU and use the smart home display. This is due to how they are more tied to the smart home display's target audience. With more user testing conducted, it is also recommended to reiterate the design using the feedback from interviewees (i.e. changing what users suggest or where users made errors, understanding what *did* work for the interviewees, and maintaining it on design).

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