The Future of
Renewable Energy
Storage

Are We There Yet?

Capstone Project 2017

In collaboration with the Electricity Company of Madeira and

Madeira Interactive Technologies Institute

CONTENTS

Two Semesters Of Research, Design, And Prototypes

Executive Summary

Riberio Frio

One of Madeira's beautiful levada walks, showcasing a landscape built for hydro energy.

Our client, the Electricity Company of Madeira, has asked us to create a new, interactive experience for the Electricity Museum, located in Funchal, Madeira. This museum experience should emphasize the uniqueness of Madeira's energy system, while engaging a broad demographic in an educational, immersive experience.

During the first three months of the project, we conducted extensive research into museum visitor experiences, interactive exhibits, energy, and Madeira's unique energy system. From this research and our subsequent research synthesis, we discovered an array of visitor needs and desires as well as exhibit and experience opportunities. We then spent a month in a process called "Visioning" in which we immersed ourselves in design opportunities that came out of the research and brainstormed design concepts. After developing dozens of these concepts and with ongoing input from our client, we narrowed down to three. When we returned from summer break in the Fall, we aggregated the most desired design elements and teaching moments from each concept and continued to iterate until we were left with one concept.

Our final prototype is the result of multiple design iterations and user tests. The exhibit guides a museum visitor through a question and answer game about renewable energy and storage. If the museum go-er is successful, they will receive a promotion from Engineer-in-Training to Engineer. This report details the human-centered design process for the exhibit, aptly named The Renewable Energy Storage exhibit.

Project Manager

Christyne Tyler

My education and experience in Social Work inspired my desire to address pressing human needs with technology in order to develop comprehensive intervention approaches. I worked with various under served populations in the non-profit and government sector for several years. Pursuing a graduate degree in Human-Computer Interaction was a pivotal step towards a career in User Research. I enjoy advocating for individuals to ensure that human needs are transformed into design implications.

UX Designer

Stephanie Liao

My interest in user experiences stem from the different reactions users have when presented with the same interfaces. This drives me to better understand users through research to design custom tailored experiences. I worked previously as a full stack developer in the San Francisco Bay Area but soon realized that I wanted to do more on the earlier side of product development. My background in technology began in my undergraduate studies of Computer Science at Carnegie Mellon University and have continued through my professional work and graduate studies.

Prototype Lead

James Budday

I am a programmer gone UX designer whose love for learning is surpassed only by his love for teaching. I aim to use my skills in research, programming, and design to create experiences that educate, broaden perspectives, and create new opportunities for others in the way that technology has for me. As an alumnus of the Levine Scholars Program at UNC Charlotte I have a strong sense of civic duty and an international perspective afforded by opportunities for meaningful community service work and study abroad experiences respectively. When I'm not working, you might find me making music, proselytizing for open source, or competing in tournaments for a 15 year old video game.

Research Lead

Bria Best

I received a B.A. in Anthropology and B.A. in Comparative Religions from the University of Washington. My educational background firmly grounded me in ethnographic methods, and inspired a deep appreciation for human centered design thinking. Previously, I worked at the Pacific Northwest Ballet a leading performing arts institution that embodies beauty and dedication. I am passionate about creating artifacts to improve the human experience and believe technology is a catalyst for positive change.

The Museum of Electricity "Casa da Luz" is owned by EEM, and is installed in the space of the old Power Station of Funchal.

Client Brief

The Electricity Company of Madeira (EEM), started in 1897, then called Madeira Wood Electric Lighting Company, Ltd., the first electric utility in Madeira. EEM is responsible for transport and distribution of electricity in the archipelago of Madeira. The Museum of Electricity "Casa da Luz" is owned by EEM, and is installed in the space of the old Power Station of Funchal. The Power Station of Funchal was decommissioned in 1989 and has since upheld the Museum of Electricity "Casa da Luz. The Museum presents an exhibition on various subject areas.

The project will respond to the following objectives identified by the EEM for the Museum of Electricity in Funchal, Madeira:

01

A Dynamic Museum

Make the existing museum more dynamic, currently composed mostly of historical equipment, on static display, adding the experience of the future.

02

Multi Generational

To attract the attention of the target public, from age 8 to 80.

03

Educational and Interactive

Through interactive technologies to spread the concept of "SMART GRIDS", Intelligent Energy Networks.

04

Regional Context

Through interactive technologies provide visibility on the role of renewable energies at the regional level, and the impact of shared power production components.

05

Fossil Fuel Free Island

Through interactive technologies explain to the visitor the concept of the project for a sustainable Porto Santo Island: "Smart Fossil Free Island"

Research

- *Interviews*
- *Literature Reviews*
- *Observations*
- *Case Studies*
- *Concept Map*
- *Affinity Diagram*
- *Exhibit Graph*
- *Experience Mapping*

Design

- *Personas*
- *Value Testing*
- *Ideation*
- *Iterate*
- *Prototypes*
- *User Test*
- *Wireframes*

Develop

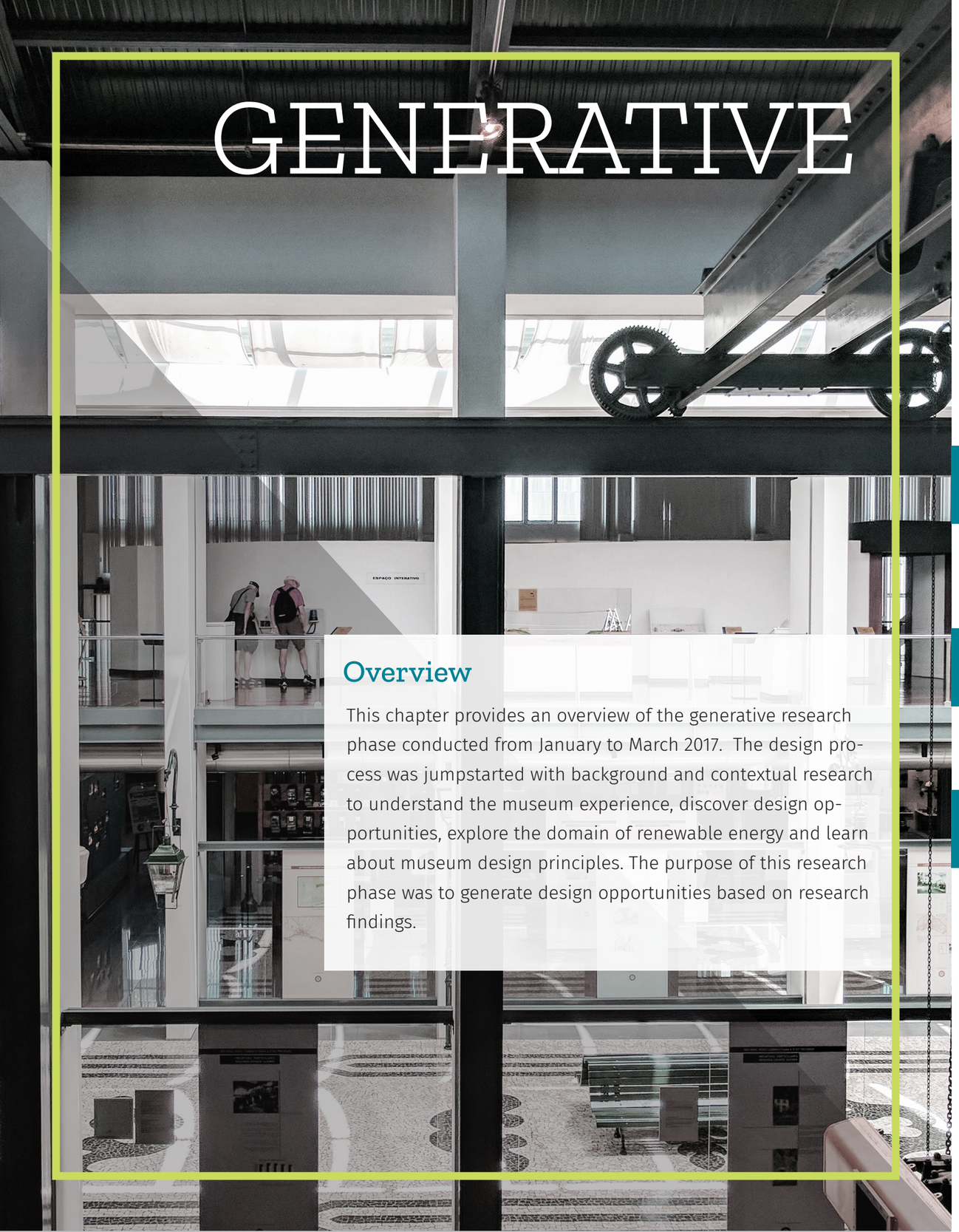
- *Programming*
- *High Fidelity Design*
- *Animation*

Human Centered Design

Human-centered design is a framework that incorporates human needs and desires during the design process. This framework involves research, ideation, designing, prototyping, and development. The process begins with contextual research to discover attitudes, behaviors, and problems. The design is tested with target users to assess usability and satisfaction. When testing is complete, it is time to develop the prototype.

Current Collective's Take

Current Collective utilized a human-centered design approach to learn more about museum design, museum visitors, and attitudes about renewable energy in Madeira. User-centered design can be at odds with traditional museum experiences, so we encountered some challenges with our design.



GENERATIVE RESEARCH

Overview

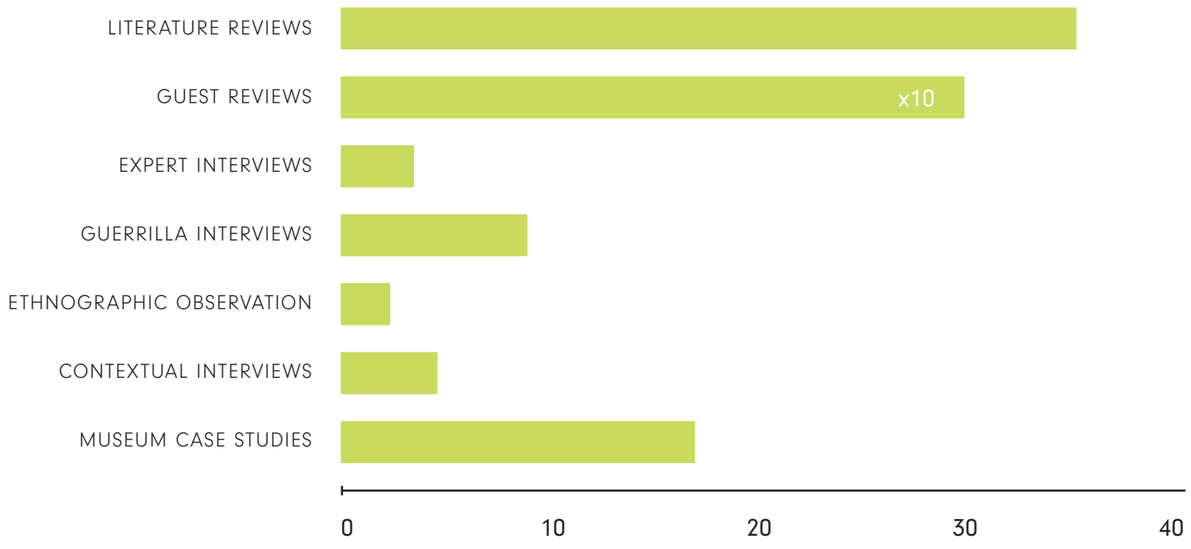
This chapter provides an overview of the generative research phase conducted from January to March 2017. The design process was jumpstarted with background and contextual research to understand the museum experience, discover design opportunities, explore the domain of renewable energy and learn about museum design principles. The purpose of this research phase was to generate design opportunities based on research findings.

01 *How do museum visitors experience the Electricity Museum? And, how might they?*

02 *How are experience and exhibit design principles successfully implemented in museums?*

03 *What is the relationship between the Madeiran community and sustainable energy/technology?*

Methods



Showing how often these methods were in the context of Current Collective's project.

Conducting an interview with our colleague Carolina.

Literature Reviews

A survey of relevant, credible research is conducted through the reading of reports, articles, and books. Categories of relevance are developed based on the problem space and project goals.

Expert Reviews

Interviews with experts allow researchers to gain a deeper understanding of subject matter by probing beneath the surface of what the experts have published. Guerrilla interviews are more flexible and brief

Museum Case Study

Researchers explore, experience, and analyze similar and varied museums to gain insight into exhibits and experiences.

Guerrilla Interviews

Using a flexible question guide, researchers conduct brief interviews with members of a target population.

Ethnographic Observation

Using this non-intrusive strategy, researchers observe participants to gain insights into normal behavior.

Contextual Interviews

Using pre-determined questions and flexible additions, researchers conduct brief interviews with a target population in the experiential context they are seeking to explore.

Guest Reviews

Researchers evaluate information about the target organization by exploring social media and guestbook reviews

Synthesis

This chapter provides an overview of our research synthesis for the methods in the previous chapter. Each synthesis approach is explained, and the key findings are noted. The key findings are demonstrated in graphic models. In the next chapter, we will present how the synthesis was used to inspire and guide the visioning process.

Concept Map

1. Stimulate curiosity with maker spaces, free choice learning, and a non-evaluative nature.

2. Create focus, integrate the community, and have a positive impact.

3. Use drawings, models and sketches to capture key research insights.

Exhibit Engagement Graph

1. There is a positive correlation between Learning and the combination of Emotional Response and Unpredictability.

2. There is very little correlation between Emotional Response and Unpredictability.

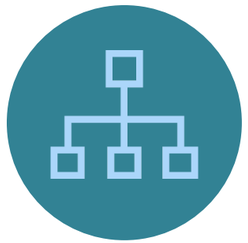
3. There is a positive correlation between Learning and Unpredictability.

Personas

The personas guide the design process by serving as archetypes. They represent the attributes of common visitors by outlining their needs, goals, desires, and background as revealed by our research. They guide the design process by keeping the user in the forefront of the project.

Experience Diagram

The diagram visually represents where the pain points occur in the museum, and traces visitor's emotions. As such, this diagram serves as a quick reference guide as well as aid in understanding complex visitor experiences as drawn from data.



Affinity Diagram

After those brief synthesis sessions, we combined all of our data and analyzed it using an affinity diagram. We categorized our findings according to Local Needs & Interests, Social Responsibility, Museum Flow & Layout, Sensory, and Relevancy. The interviews, observations, social media reviews, guestbook feedback and literature reviews were collectively synthesized in this affinity diagram. The following are the core themes that emerged from our data.

1. People enjoy walking down memory lane.
2. Energy professionals relate to exhibits.
3. Women expressed disinterest in the museum.
4. Students appeared to enjoy sharing the exhibits by experiencing them together.
5. The pacing of the tour may affect the visitor experience.
6. Allowing breaks during immersive experiences can prevent cognitive strain.
7. Multi-sensory components contribute to an immersive experience.
8. Museum layout and arrangement have a significant effect on the experience.
9. Signage and materials would be useful in more languages as this would enhance inclusivity.
10. Contextual exhibits elevate understanding of the topic.

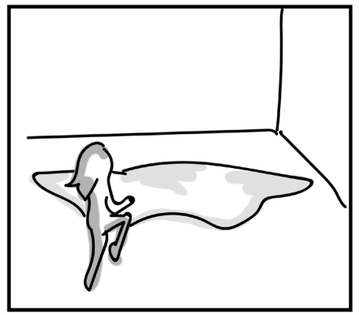
Visioning

Let's Get Creative

During the visioning phase of the project, the team engaged with key research insights to develop design ideas that addressed museum needs and opportunities. This process was facilitated by ideation strategies common in user experience design and was adjusted to target a museum experience. Each team member created personas, a behavioral lens, and a variety of storyboards to build conceptual models to envision a preferred future. As a team, we used group ideation methods to generate multiple ideas. We conducted two "speed dating" sessions with our client in which we pitched five concepts. We received feedback from the client and subsequently narrowed down our ideas to the three following concepts:

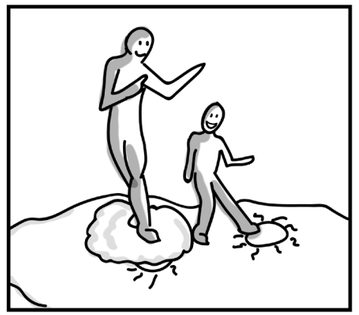
Microclimates Stomp

How might we make a family moment and learning experience all in one?



Aileen spots a bright floor map of Madeira with shifting colors. She runs over excitedly with her parents, Lindsay and Gordon, at her heels. It's time for a great family game!

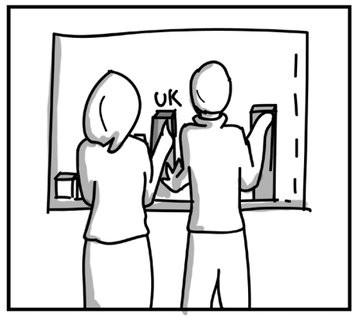
Aileen jumps and stomps around the map trying to catch solar energy as it becomes available. She is the grid capturing energy in Madeira's microclimate system, trying to keep the grid running on renewable energy.



Her father sneaks in as the dastardly storm cloud, and begins blocking the sunlight while making the Levadas fill with water for hydropower. Shrieking with glee, Aileen rushes around to capture sun and water as it shifts quickly, illustrating rapid shifts in Madeira's microclimate system.

Race to 100%

How might we make connections across borders?



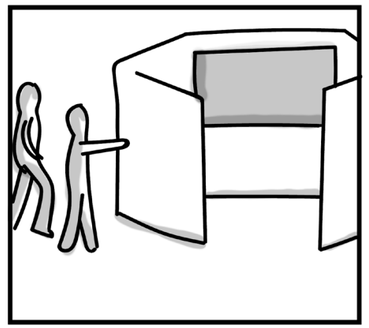
Emily and Rupert are drawn to a colorful graph featuring many countries, including their own. The UK is ahead of some countries and behind others in the race to 100% renewable energy.

They explore the many countries, and are curious to know more about why the UK isn't doing even better than it is. They click the "Why?" button next to the UK's position to learn more.

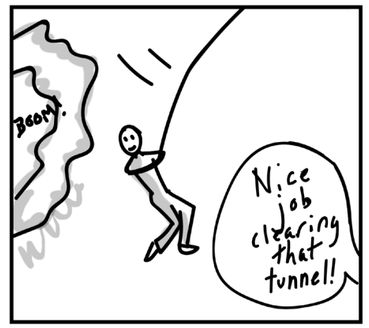
Emily and Rupert are delighted by a positive and encouraging message about what the UK is already doing to accelerate their progress and opportunities to do even more. They are excited to support these opportunities, and get the UK in first place!

Levadas: Adventure in Time

How might we experience the Levadas through time?



Maria and her classmate get curious about the Time Machine enclosure, and decide to go check it out.



They are transported through time in an immersive game. While exploring the past, they take part in the great, perilous, and heroic adventure of building the Levadas to bring needed water to the south of Madeira Island.

They travel to the present next, exploring how the Levadas are being used for hydropower. Maria is excited to discover the Levadas in this new, personal way, and learn about their many uses.

After a brief 3-month hiatus, we returned in the Fall with a renewed perspective on the previous three concepts. The team reviewed the concepts and research insights to refresh our minds and inform our design strategy. As we move forward with iterative designs, we realized that we would inevitably distance ourselves from the raw data we discovered in the Spring. With this reality in mind, we developed 4 Experience Principles.

ITERATIVE DESIGN

Experience Principles

Hunt Statement

We strive to create an educational, interactive exhibit that inspires agency and curiosity about the future of renewable energy storage through a relatable, understandable, approachable, and Madeira-specific experience.

Relatable

We want our exhibit to be relatable to the visitors. If they're local students, we want them to see the exhibit subjects and be able to relate them back to their lives on Madeira.

In Context

We will present our information in context. With context, visitors will be able to better understand and therefore learn and become more curious about the subject.

Approachable

Visitors should want to approach the exhibit with an open mind. We want to garner interest from both people we have a background in energy and also those we don't know as much.

Understandable

The subject matter that we introduce in our exhibit needs to be presented in a way that is understandable for our audience.

Once we defined our experience principles, we were ready to explicitly define the what we wanted the museum visitors to learn.

Why They Matter?

We created experience principles to help guide our exhibit design. The principles are not only reflective of key research insights, but they define the core values of our exhibit. Our principles articulate the fundamental goals that all decisions can be measured against and based off of that, keep the pieces of a project moving toward an integrated whole. These principles provide a consistent vision of the project for our team.

Showing research findings to our classmates.

Instructional Content

Stephanie and Christyne prototyping.

Learning Development

To guide the design process, Current Collective identified a major and minor learning takeaways for students. By addressing one dominant learning takeaway a museum exhibit is more likely to have an impact upon viewers and change their mentality and mental viewpoint.

Current Collective learned this through an interview with the Oregon Museum of Science and Industry's design team. If a student is going leave the museum after interacting with your exhibit what one thing would they take home with them.

Key Takeaways

From these two takeaways the team selected one, and generated richer content and learning takeaways for students.

1

An Island in Motion would showcase the levadas and how they provide energy, food, and water to Madeira. The team would dive into the history of levadas and a show how EEM is planning to expand electrical capacity around the levadas.

2

Madeira is made for energy demonstrates how the steep landscapes and the micro climates, make an unusual ecosystem that is difficult to manage a renewable energy system without energy storage.

Main Takeaway

Energy storage can provide a constant in a world of ***variable renewable energy*** availability, especially in an **isolated grid** like Madeira's.

Value Testing

Content

- Hydro is Madeira's largest and most reliable source of renewable energy The levadas generate energy by carrying water from North to South. Energy is harvested above 600 meters The water flows to agriculture and drinking water
- In Madeira, there are two wind farms in Canical and Calheta. At night the wind farms are used to carry water up the mountains preparing to generate energy in the morning. Wind speeds on Madeira can blow up to X km/h. When the wind blows stronger than X km/h, the wind turbines must be shut off because of X and unable to produce any energy
- Photovoltaic generates energy when people need it most. The sunshines during the day and energy peaks on Madeira during 12 pm and 8pm. However, solar energy is not always reliable because Madeira's micro climates produce many clouds that partially cover panels which reduces the efficiency of the panels.
- Storage is a missing piece of renewables. Energy can be stored in the forms of water reservoirs for longterm storage. Batteries can only offer short burst of energy to help a power plant transfer from one energy source to another.

Design Description

We iterated on the flow of our exhibit and focused on the story we wanted our exhibit to tell. For this testing session, we wanted to make sure that each part of the story was essential to the final ending of storage.

Goals for Value Test

1. Understand what young Madeirans are proud of and how they relate to the island.
2. Establish a baseline knowledge for renewable energy and storage.
3. Did our story improve knowledge around renewable energy and energy storage

Findings

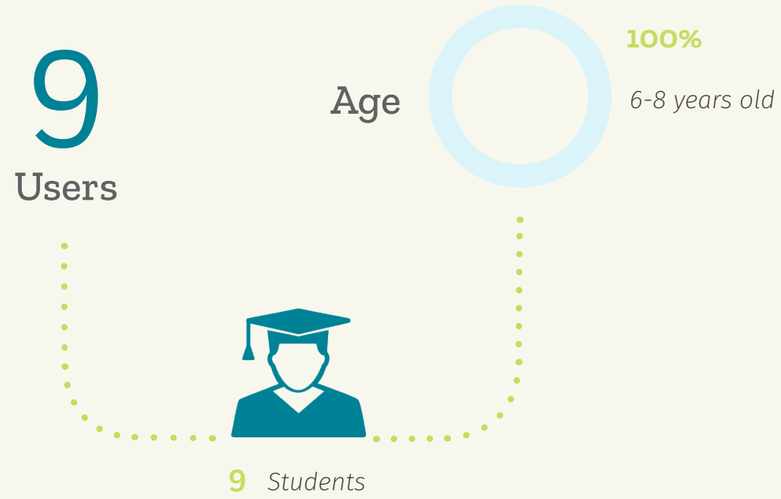
The students had a common understanding of levadas.

The students expressed an appreciation for the natural beauty of Madeira.

Implications

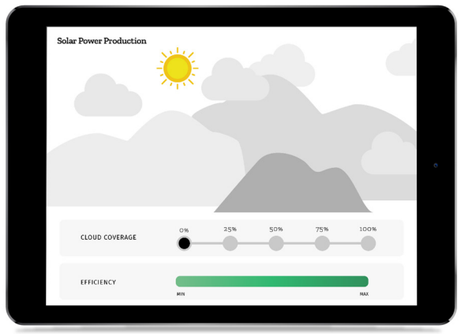
Transition from Renewables to Storage

Storage Takeaway



User Test 1

Tablet



Touch Screen

Findings

Students needed more feedback to understand why wind speed dropped to minimum

Many students thought the exhibit was teaching that more rain equals more energy.

Students, who noticed the clock, realized that energy is wasted without storage.

The appliances generated a lot of interest, but people jumped to reduce energy consumption

Implications

Added feedback to wind screen explaining why turbines are turned off at 90 km/h

Re-design of hydro exhibit to help students

Moved time to a more prominent position in the design.

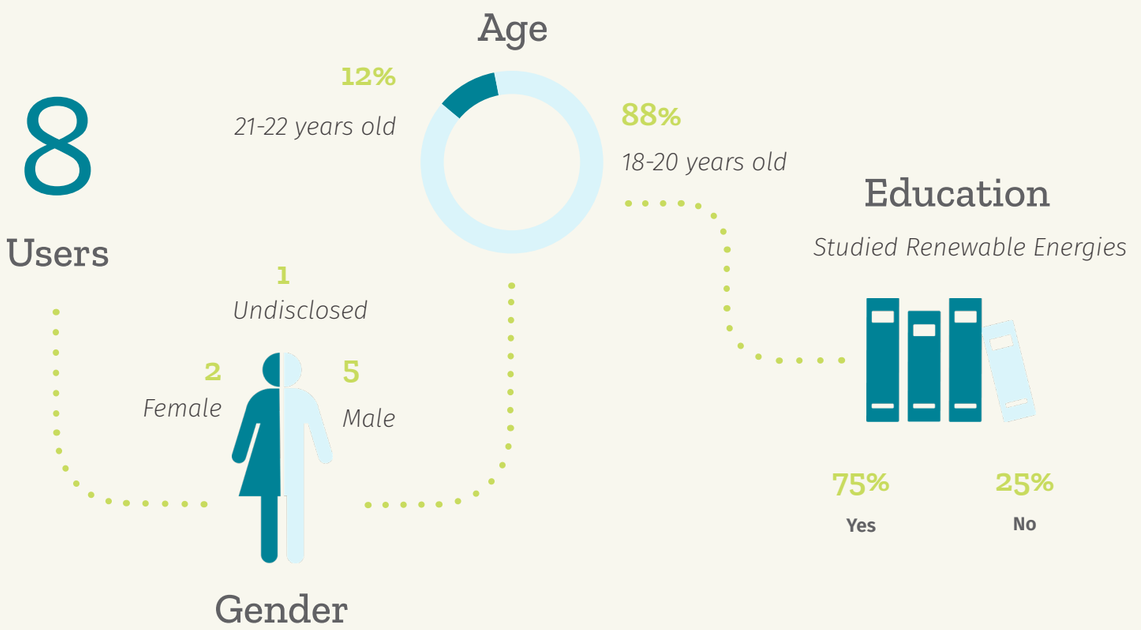
Removed appliances to mitigate confusion over behavior change.

Design Description

The designs that we tested were built to the fidelity needed to test the concepts we had envisioned. We included designs of controllers that had information that responded directly and indirectly with participants choices. To teach the concept of fluctuating consumption and production, we had a fluctuating animated graph that updated from day to night. We decided to design this prototype with animations to better understand what participants could take away from this experience.

Goals for Value Test

1. Measure learning for individual stages of the prototype.
2. Determine user's satisfaction with the experience.
3. Measure learning and key takeaways for the entire experience.



User Test 2

Tablet

Touch Screen

Findings

Hydro exhibit caused confusion and lead to more rain creates more energy.

Individuals focused on the controller and showed little curiosity on large.

As the experience continued people adapted to two screens with prompting.

Implications

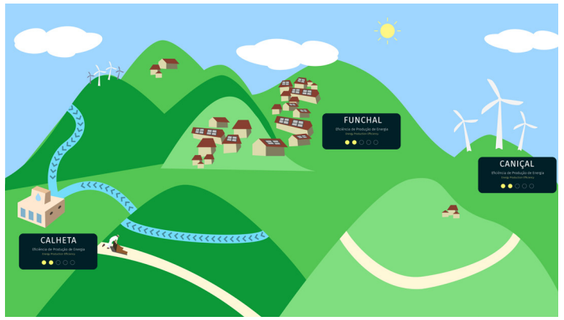
Re-design of hydro exhibit to help students

Direct user's attention with pause screens on the controller as well as the projection.

Design Description

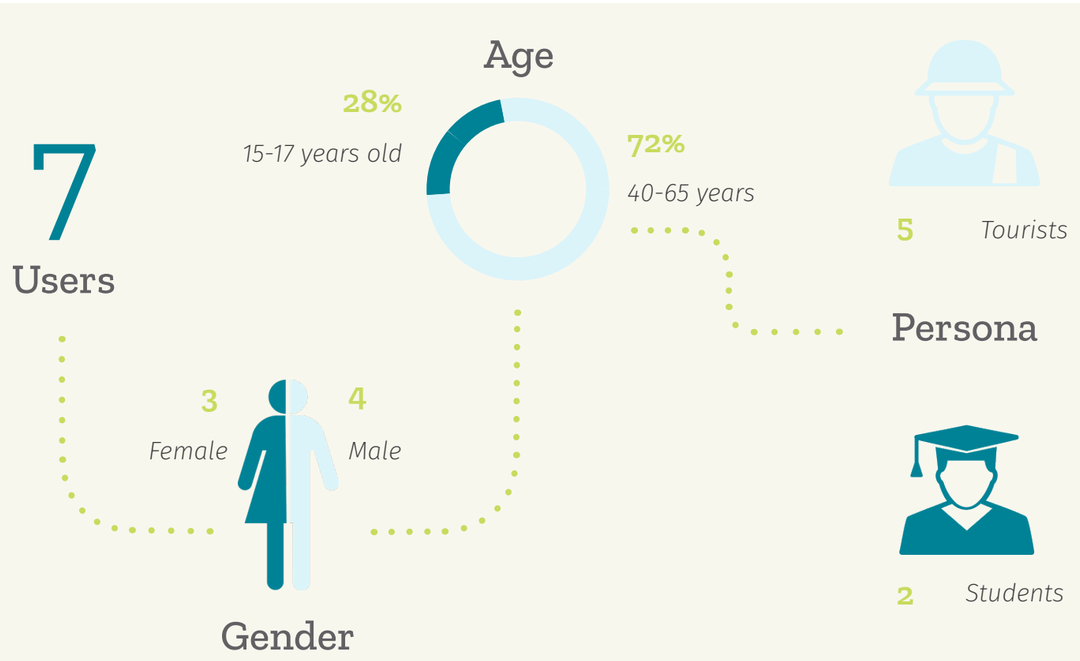
As our idea was becoming more flushed out, the fidelity of our prototype become higher. Since we wanted to better understand the interaction participants had between a big screen and a tablet, we made sure that the fidelity of both parts matched. We included some basic animated interactions to help match the fidelity we were aiming for.

Projection



Goals for Value Test

1. Determining how users respond to a dual focus interface.
2. Measure learning for the hydro exhibit.



Revisiting Our Content

Creating meaning and encouraging engagement

Visiting the Hydro Power Plant.

Restructuring the Exhibit

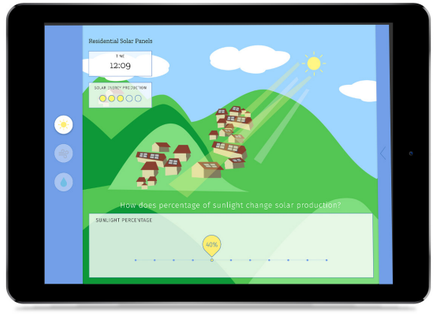
The team created an information architecture that marries our content with the screens. To keep track of the game show format and the user's progress we made a decision tree that dictates the progress based on each individual question. This format also allows for ambiguity in our answers, whereas our earlier designs had difficulty addressing the complexity.

Creating a Cohesive Experience

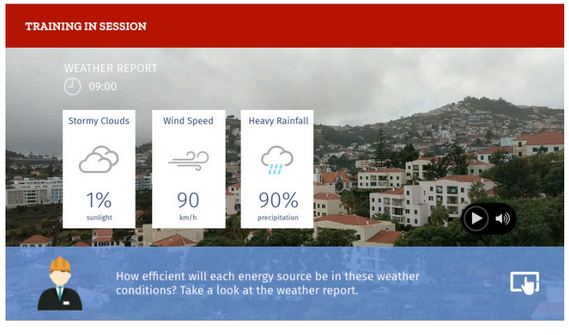
After the last prototype iteration, we debriefed on the research findings and discovered that our overall experience felt fragmented. The team focused on directing users attention, and used a game show format to build focus and pauses into the information of the exhibit. User's answer questions based on their knowledge. Their knowledge is then reaffirmed or dismantled depending on the correct answer.

User Test 3

Tablet



Touch Screen



Findings

Consumption factor on intermittence section created confusion.

Increased surprise and excitement upon learning correct answer.

Storage section created confusion and individuals were unsure of the takeaway.

Implications

Changed consumption factor to estimate energy production for solar, wind, and hydro.

Adding sound and engaging question feedback

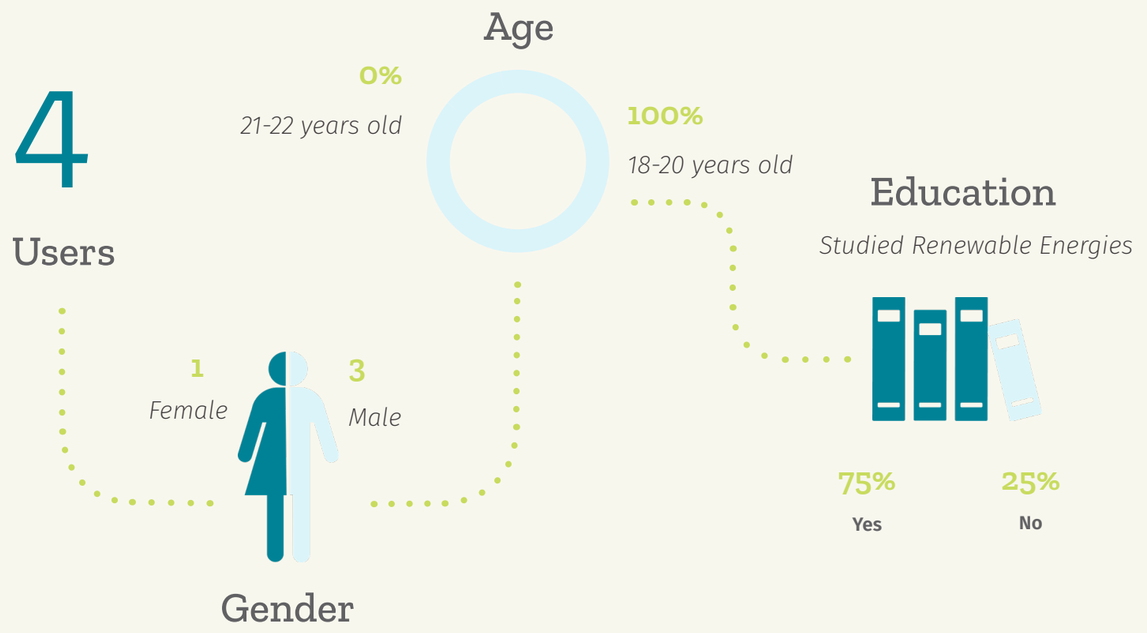
Rearrange the order of storage to create a climatic ending.

Design Description

Because of our new design direction, we returned to a lower fidelity prototype. Since we were focused on testing the concept idea, we believed we could accomplish that through paper prototyping. We wanted to reuse interactions we had tested in earlier concepts so we kept elements like sliders, weather related visuals, and bar graphs.

Goals for Value Test

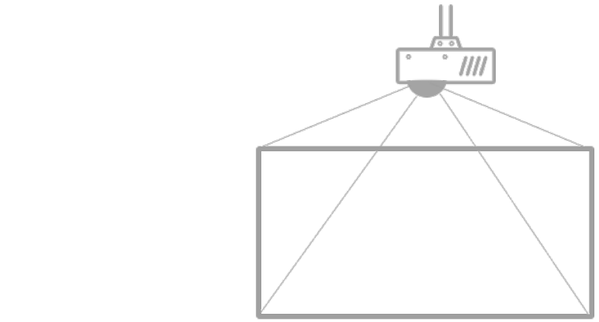
Understand whether the game show format created user goals that encouraged engagement. Determine whether the game show format increased learning and curiosity.

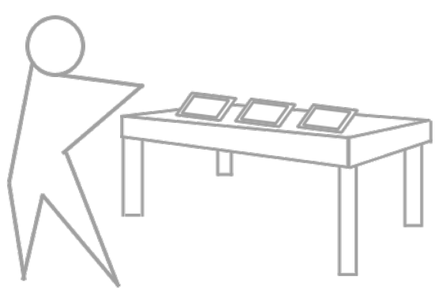


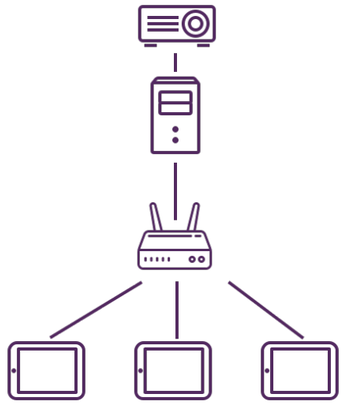
Final Prototype

System Design

The final design is a three player gameshow that directs user's attention through an engineer training session. Users learn through trial and error about the difficulties of managing an isolated electrical grid. The game culminates with teaching users the short comings of energy storage.

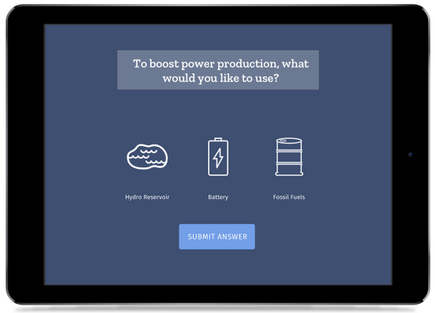






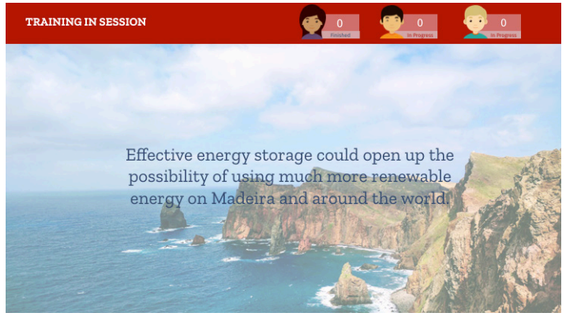
Technical Design

Three tablets prompt users for input, which is connected through a small computer and wireless router. The computer signals to the projector when a video should play.



Tablet Interface

Users respond to questions on the tablet and are provided with more opportunities to gain a deeper understanding of the subject presented.



Projection Interface

The projection moves the story along and cues action from the players with dialogue and animation.

Next Steps

Implementation

Current Collective presented a working prototype to the Casa da Luz, However it will require high fidelity programming. Specifically, if a user leaves in the middle the game will need to be reset.

Learning Objectives

Students have difficulty grasping the nuances of the storage message. One concept that may help them arrive at storage is that energy must be produced for instantaneous consumption. Although the prototype discusses the balancing act of production and consumption several students failed to grasp the impact of this.