Software Frontend Design: Utilizing HCD for Home Power Usage Web Apps

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ABSTRACT
To enable users of all experience levels to calculate stats on their home appliance power usage, *WattBuild,* a solar solution web app, needs a tool that is intuitive and easy for novices to use, as well as powerful and complex enough for advanced users. To ensure the most user-friendly design, I utilized different Human Center Design techniques and patterns to create a design that resulted in the most consumer satisfaction and quickest completion times. Using Figma, I created tens of different wireframes so I could compare designs on a broad, component level and get a feel for organization. Then I narrowed my choices to two or three designs programmed using SvelteKit. I took my measure for comparison by conducting beta testing with a handful of testers. They gave verbal or written accounts of each design and were timed on completion of a basic task. The results showed that a design that made more use of modals and collapsible divisions was more favorably received as it was easier to view and use. Users also had an easier time using designs that didn't require dragging over single button presses. I could further build on my research by conducting more in-depth testing interviews.

1. INTRODUCTION

As renewable energy adoption increases, more homeowners are seeking accessible tools to understand and optimize their power consumption. However, many existing energy calculators either oversimplify data, making them ineffective for advanced users, or overwhelm novices with excessive complexity. This usability gap is particularly problematic in the solar energy sector, where clear, data-driven decision-making is crucial for consumers transitioning to solar power. To address this, WattBuild, a solar solution web application, aims to develop an energy usage calculator that is both intuitive for beginners and powerful for experienced users. Achieving this balance requires a structured approach to design, one that prioritizes user needs at every stage.

Human-Centered Design (HCD) is a problem-solving methodology that focuses on optimizing products and systems by deeply understanding users' behavior, needs, and limitations. Originating from cognitive psychology and human-computer interaction (HCI) research, HCD has been widely adopted across various industries, from software development to product engineering. The core advantage of HCD is its iterative approach, which incorporates continuous user feedback to refine and improve designs. This process typically follows a structured lifecycle: understanding user needs through research and requirements elicitation, ideating and prototyping potential solutions, testing designs with real users, and iterating based on feedback.

2. RELATED WORKS

My development of a user-friendly energy usage calculator was influenced by prior research focused on building effective interfaces using techniques similar to HCD. Several studies emphasize the importance of intuitive interfaces for improved user performance. For instance, Barron, et al. (2004) examined the impact of response delay and interface richness on user performance in graphical user interfaces (GUIs) for engineering design. Through an I-beam design experiment, the authors measured design efficiency using completion time and design effectiveness using the error from the optimal design. Their findings indicated that response delays as short as 1.5 seconds significantly reduce user performance, increasing workload and decreasing efficiency. Meanwhile, to examine interface richness they constructed three different interfaces of differing richness based on a scale motivated from principles of visual attention and object perception. They found that "perceived workload of the users increased as delay increased and as the richness of the design interface decreased." The study highlights the importance of optimizing interface responsiveness and visual richness for effective engineering design tools.

Beyond individual interface elements, Tarkhov, et. al. (2024) explore in their study the assessment of software interface quality within human-machine interaction systems. The research introduces a methodology based on Shannon's information entropy to quantify interface complexity. To enhance assessment precision, the study integrates Ishikawa diagrams to visualize and analyze cause-and-effect relationships affecting interface quality. Functional suitability criteria include problem-solving capability, manageability, and error resistance, while usability is measured in terms of informativeness, intuitiveness, learnability, and customization. Through statistical ranking and data visualization, the study highlights the most influential indicators impacting user application performance and advocates for continuous evaluation throughout a product's lifecycle to enhance usability and reliability.

For tools that are specifically for renewable energy systems, a study by Rozmi, et al. (2019) researched the role immersive visualization (IV) tools play in the development of hybrid renewable energy systems (RESs). This review examined 41 software packages and 163 research articles to assess the accessibility, complexity, robustness, and adaptability of IV tools in RES development. Findings suggest that IV tools enhance decision-making by improving data representation and user interaction, though challenges remain in terms of complexity and integration. The study highlights the growing role of IV tools for optimizing renewable energy system design.

While these studies provide valuable insights into interface design, usability assessment, and visualization tools, gaps remain in their application to energy usage calculators. My research will build on these findings by focusing on how interface responsiveness, evaluation methods, and visualization techniques can be specifically tailored to improve user engagement and decision-making in renewable energy tools.

3. PROJECT DESIGN

I followed an iterative design process for my project, starting with wireframes and progressing to functional prototypes built in SvelteKit.

3.1 Wireframes and Mockups

I sketched 10-15 low-fidelity wireframes on my notebook to begin. After presenting these to my project manager and debating the benefits and drawbacks of each, we narrowed them down to six designs from which I made high-fidelity mockups (Figure 1). The process of narrowing down to these six involved removing the wireframes we believed were obviously inefficient or unorganized.

Figure 1: Power Usage Calculator Wireframes

Using SvelteKit, these six were programmed into functional software to prepare for beta testing.

3.2 Testing

Beta testing was conducted with a group of 30 users to evaluate usability, performance and feature effectiveness. They were divided into six groups of five where each group was given a design to complete the same set of predefined tasks using the Power Usage Calculator. These tasks differed from information collection which involved browsing the site and recording a specific metric to using specific features like the "add device" button. When creating the list of tasks, we aimed to cover a wide range of activities to ensure a comprehensive experience that reflects a typical use case. Testers were only timed on a single design because they would become faster and understand their task list much better after the first run. User feedback was also collected and recorded through written or verbal accounts and direct observation.

4. RESULTS

Design 6 had the fastest average completion time with an average time of 2 minutes 8 seconds and Design 1 had the slowest with an average of 4 minutes 6 seconds (Figure 2).

Design	Average Completion Time
Design 1	4 minutes 6 seconds
Design 2	3 minutes 2 seconds
Design 3	2 minutes 46 seconds
Design 4	4 minutes 34 seconds
Design 5	3 minutes 32 seconds
Design 6	2 minutes 8 seconds

Figure 2: Average Completion Times for each Design

Of the qualitative feedback provided by testers, a few notable patterns emerged as well. A few participants noted that the later designs with collapsable cards were easier to view and use than Design 1, which did not include collapsable cards. Many testers also believed that the filter devices' feature was better as a modal than a widget used directly above the device list.

5. CONCLUSION

By applying HCD principles, my design shows how different interface patterns impact user experience, task efficiency and overall satisfaction. Through iterative design cycles—starting with wireframing in Figma and progressing to functional prototypes in SvelteKit—various layouts were tested to identify the most user-friendly and efficient interface. Usability testing, including timed tasks and qualitative feedback, provided key insights into which design elements improved accessibility and engagement. This research not only informed the development of WattBuild's energy calculator but also contributed to broader discussions on how intuitive interface design can drive consumer adoption of sustainable energy solutions.

6. FUTURE WORK

While my work is built on extensive and well-covered literature on user-centered design, one shortcoming is the generalization of my software tool. In the future, work could be conducted that tests features that are unique to solar solutions, such as interactive visualizations of energy savings, rather than the common features dropdowns and text containers. Additionally, conducting long-term user studies could provide insights into how interface design influences sustained engagement and decision-making in adopting solar solutions. Further refinement of accessibility features and adaptive UI components could also enhance usability for a broader range of users, ensuring that energy tools remain both intuitive and inclusive.

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