

COMP 2213 - Report — Group 28

Smart appliances for home electricity

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1 Literature Review

1.1 Introduction

This Literature Review looks at how people use energy in their homes, the different methods used to incentivize people to be more efficient with their energy consumption styles and how effective these methods are.

1.2 Incentivising household involvement

A key theme in the literature was an emphasis on study participants not being fully committed to changing their habits in order to reduce energy costs. Many solutions proposed and tested to increase reliance on renewable energy as an alternative to fossil fuels have merit on paper, and the potential to have an impact on energy usage, however they are less effective in practice due to people not being able or even willing to make changes in their routines to make use of these solutions. Relating this to our solution, we could explore methods to incentivise people to reduce their energy consumption, or alter it, to consume energy at more optimal times. An example of this was [?]. In this study a mobile game was used to track electricity and water usage throughout the day, with efficient usage being rewarded with in game customisation. This idea would be on the right track, but the rewards were not sufficiently enticing to encourage a real effort to use energy efficiently.

1.3 Benefits of household involvement

A crucial part of designing an interactive tool will be incentivising household involvement, because, if implemented effectively, it could have a huge effect on the efficacy of the tool. When all users are motivated to make best use of renewable energy, they can align their energy usage with the most efficient times in the day, and also can actively reduce unnecessary energy usage. Encouraging long lasting changes could be altogether another issue [?], implementing an interactive tool usually leads to a reduction in energy usage short term, but savings may wane long term.

1.4 Energy forecasting

Energy forecasting covers many different metrics, but relevant ones include the cost of energy throughout the day, the amount of green energy available and the load on the power grid. Making these metrics available to people in an easy to understand manner, gives them the tools to make smart decisions on their energy usage, so they can manage how and when they use high amounts of energy. This gives people more control over how much their energy bills are, and makes it easier to align energy usage with renewable energy supply levels. Svangren et. al [?] studied the challenges related to aligning renewable energy production with electric vehicle charging, this raises the issue of how

feasible it actually is for accurate energy forecasting to have an effect on energy efficiency. Renewable energy production is often at its peak during the day, so many people, especially commuters, would have to make significant changes to keep their EV at home at that time. This is an example of a wider issue, in that sometimes energy efficiency can't just be improved by people knowing the best time to use energy.

A potential application of energy forecasting is the use of a home battery storage coupled with IoT enabled ambient displays as discussed in [?]. This study explores the use of ambient displays to indicate the capacity of a home battery storage and its effect on a households renewable energy consumption. The study includes five households and monitors their monthly energy consumption before and after installing the device. Households involved in the study were able to improve the percentage of renewable energy used. Although conclusions about cannot be made by just the data of five households it can prove to be effective approach.

1.5 Smart Charging

Over the last decade there has been a big shift in how consumers are aware about where their energy is sourced from and how they are using it. This is due to increasing energy demand, finite natural resources and rising electricity prices [?]. As more people move away from internal combustion engines to electric vehicles, there is great attention on electric vehicle smart charging and how it can be used to reduce the strain put on the grid [?]. This increase in demand can negatively impact the power grid as many cars will charge at night so that they will be ready for the morning which can coincide with a reduced power supply to the grid [?]. Smart charging is not only used for electric vehicles. Uncontrolled charging and overcharging electronic devices, such as mobile phones, negatively affects the batteries. A recent study developed a smart charging mechanism that eliminated these problems, however it also identified that if the mechanism was to be integrated with other components such as a timer and display, it would need more power and could become “economically unreasonable” [?]. Another study developed a smart charging hardware and software solution for EVs charging at lower rates and is actively being assessed inside of a business. It created an inexpensive system that can be built from readily available components which can offer smart charging in vehicles that would normally not enable it [?]. This shows great promise, however further evaluation needs to take place once the data is available to assess if the system works as well as the study suggests.

1.6 Smart Interfaces

User experience is a significant factor in whether a product will be adopted by consumers or not. This is especially seen in smart devices used inside homes. To determine if a different home-control interface would be more positively interacted with than the existing systems, a study took place using a voice-controlled

speaker, wall-mounted screen, mobile application and an embodied social robot [?]. It found that even though the voice-controlled speaker and robot were more enjoyable, they were not as usable as the mobile app and wall-mounted screen. However, the mobile app was the most distracting and the mounted screen gave the users the greatest sense of control as it was more familiar to them. This highlights how consumers prefer systems that they are used to as they feel more in control and have more privacy. Currently a “Digital Twin” is being developed which enables users to monitor their energy consumption around the home [?]. It will support simulations so that users can check what their energy usage would look like in advance of using an appliance. This will help increase user awareness about the amount of energy being used and could be used to show the amount of money that the consumer is spending on different appliances’ energy consumption. This is only in the early stages though, so there is still a long way to go before it can be seen as a potential solution to lack of energy awareness, but the plans look promising.

1.7 Conclusion

The literature has given a valuable insight into the different ‘levels’ people are willing to change their current routines to benefit from existing products and services that make better use of the energy supplied to their homes. The papers consistently raised the issue of the load on the power grid from the increase in energy consumption due to smart homes and most deemed smart charging as a potential solution to this problem. However, this uses energy forecasting which was also identified as being unreliable and sometimes inaccurate. Overall, these papers have demonstrated the potential for many different solutions in using energy more efficiently in homes, however, lots of the research is in its infancy and requires more data and tests to understand the problem further.

2 Interview Analysis

For the interview analysis we started off by assigning 2 interviewees to each member, aside from Luke who was finalising and editing the literature review. We each read through our interviews, writing codes as we went. We then met up and set up a canva whiteboard so we could group the codes. We put all of our codes into sticky notes on a canva whiteboard, and grouped them together based on ones that we found covered similar ideas, and the ideas we were already developing from the literature review (See Appendix 3). The themes that we decided on are:

2.1 Challenges

Many of the respondents detailed their challenges when using smart energy solutions, this theme covers a wide range of findings relating to their struggles with reducing their energy usage. This theme allows us to attempt to solve some problems with our own design.

2.2 Needs

This theme outlines the suggestions and ideas that respondents had for improving the energy reduction systems they were using. This also encompasses respondents' thoughts on how they think they could be helped in lowering their energy usage. This gives us valuable information to work off as we can use these notes as starting points for our solution.

2.3 Solutions

This theme groups the more specific idea respondents had about what they thought would help them cut down on energy costs and usage.

2.4 Cost Saving

Many respondents wrote in detail about the aspect of saving money with their energy. This can be a great motivator for people to make efficient use of energy saving systems in their homes, they see tangible savings in their energy bills. This theme encouraged us to think about including money saving trackers in our solutions, as a way to show results.

2.5 Environmental Care

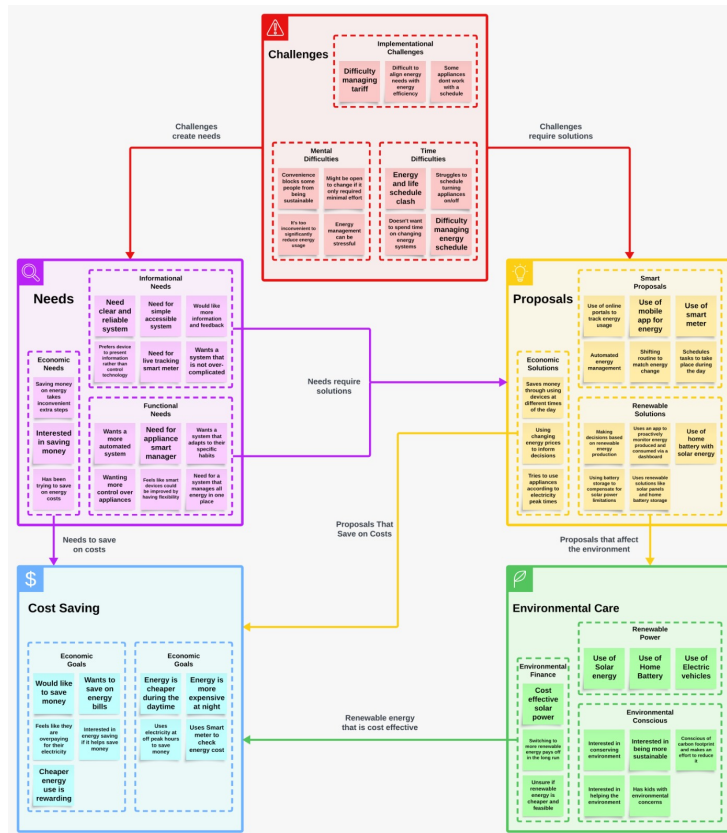
The second prevalent motivator for saving energy is environmental care, being the awareness that consuming energy from the power grid consumes fossil fuels and that renewable energy produced at home is better for the world.

2.6 Energy forecasting

Renewable energy production is not constant throughout the day, and neither are energy costs. Respondents wanted to be more aware of these factors, so that they could alter their energy consumption habits in correspondence with these trends.

3 Affinity Diagram

Having got the codes down, we looked at the general ideas that they covered and made a first draft of the themes that popped. Based on these initial themes, we started a refinement process; removing duplicate or irrelevant codes, linking codes that were relevant to each other, and deciding on overarching themes and how they relate to each other. Iterating again, we found more concise names for the themes, removed the energy forecasting theme, and identified codes that linked themes together. This process resulted in the final affinity diagram.



4 Problem Statement

Our primary goal is to encourage households to use energy in a sustainable manner, and through our initial conducted research we have noticed a number of challenges faced when trying to achieve this goal that need addressing. From the interview analysis we have observed that most people are in fact interested in managing their energy better for either environmental or economic reasons, however often this task is complex and time consuming for many, dissuading people from actually implementing energy saving behaviours.

In the interviews, a number of participants mentioned features that they would ideally want in a system. These can be broadly summarised as follows:

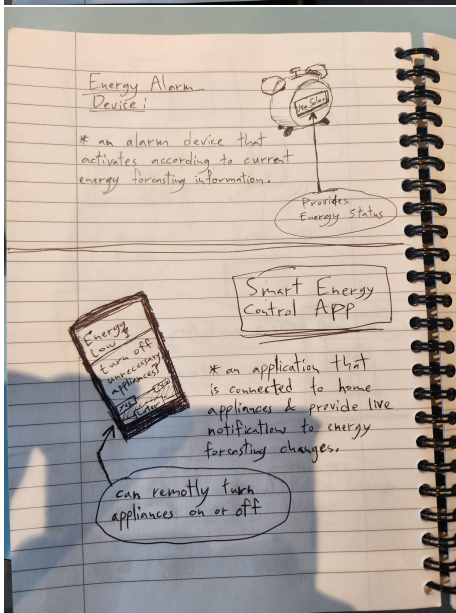
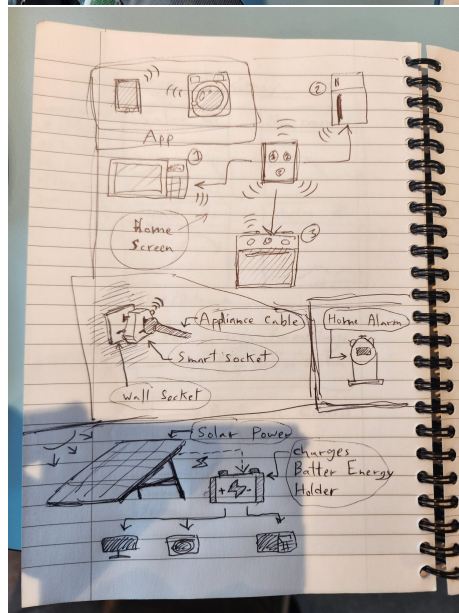
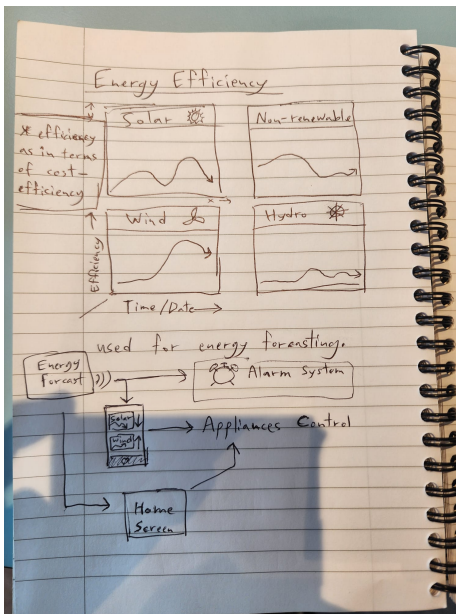
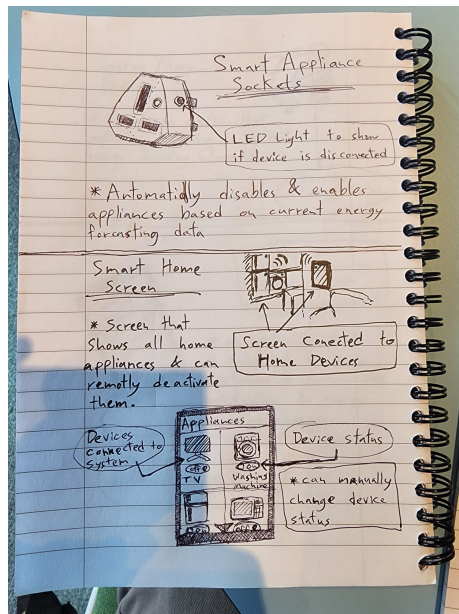
- Need a more automated solution..
- Need more information and feedback from the system.
- Need greater control over their energy usage.
- Need a solution that is more personalised to them.

From the literature review, we also identified couple of challenges that need addressing. That is that often people lack the motivation to use power more sustainability and that often this motivation wanes over time. It is hence important that we design a solution that means users are motivated to change their habits and that this motivation is maintained.

5 Design Concepts

We put together multiple design concepts on paper to visually represent our ideas. These are:

- Smart appliance socket
- Smart home screen
- Energy alarm device
- Smart energy control app

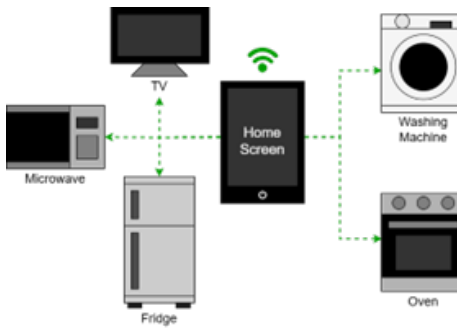
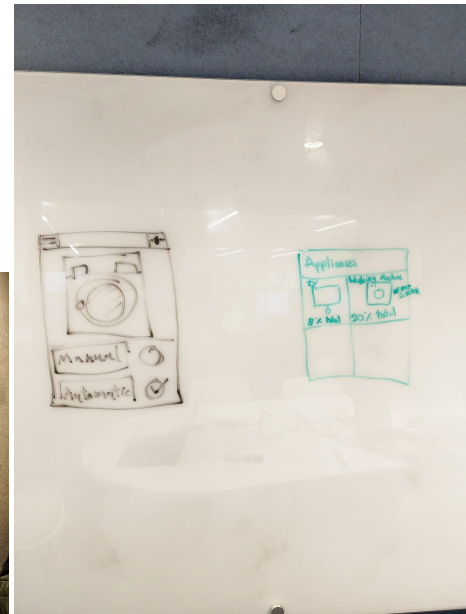
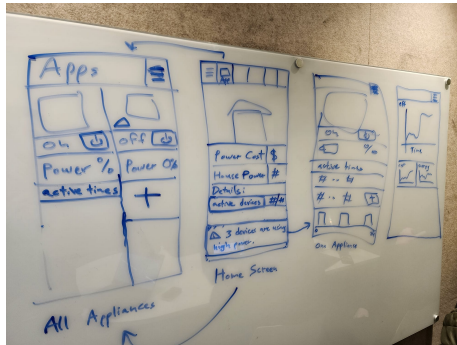


Each design concept was developed to address a specific issue identified in our problem statement. The smart appliance socket aims to enhance user control by enabling the management of appliances. The smart home screen offers increased personalisation and provides more information for the user. The energy alarm device introduces automation and reminder features, which users felt were lacking in existing models. While similar to the home screen, the app provides additional feedback on the user's energy usage, offering suggestions to increase

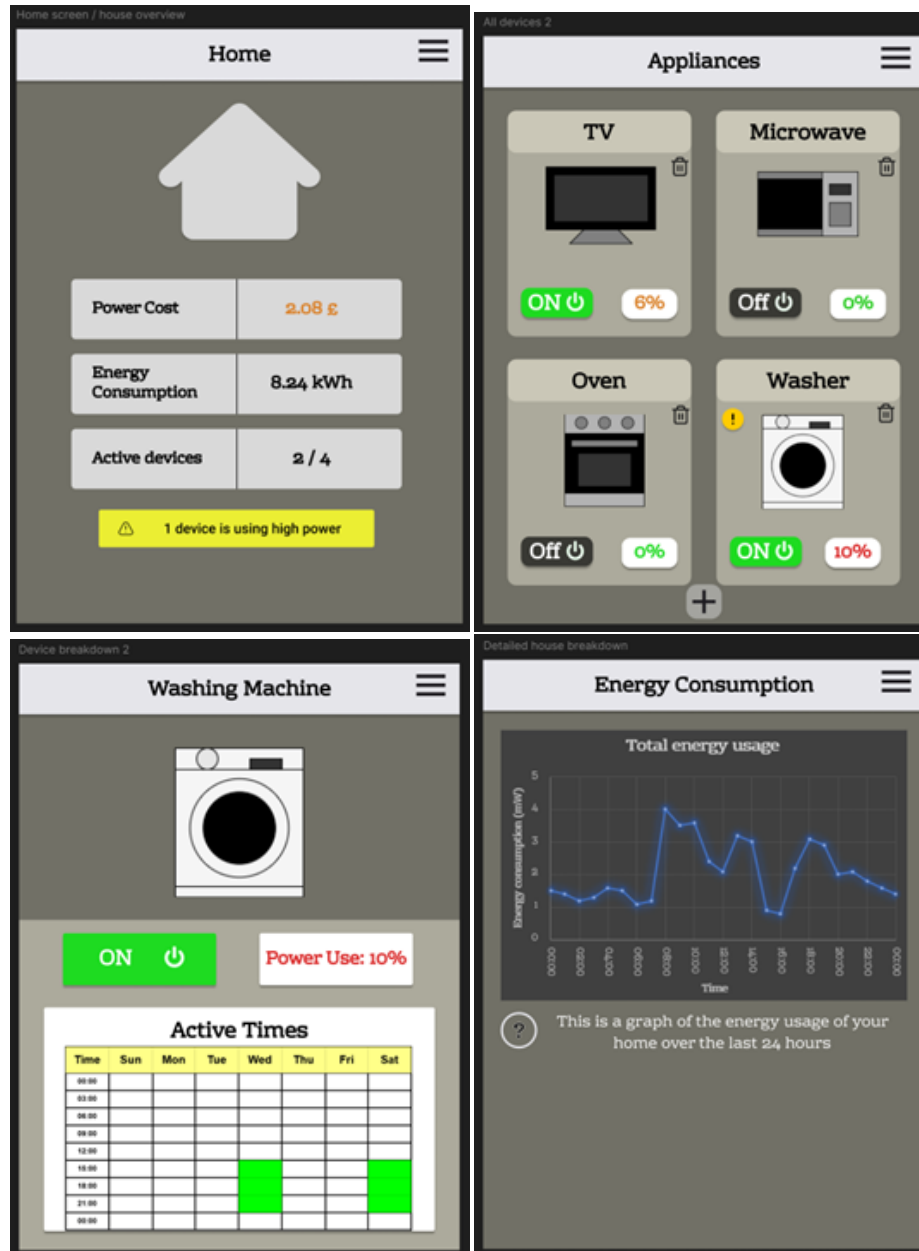
their energy performance. Ideating on these concepts, we settled on the smart home screen, and drew up rough ideas on how it would function (See appendix 9) We selected the smart home screen concept as it resolves multiple issues like the lack of personalisation and information whereas our other concepts focused on addressing a single issue. The smart home screen is a mounted display that primarily shows all the user’s current appliances in their home, along with their energy usage and status (on/off) . This concept offers a lot of flexibility, as it can easily be expanded to include new features as we progress through the design process. For this home screen, we are assuming it is possible to control the on/off status of plugs via the screen within the home.

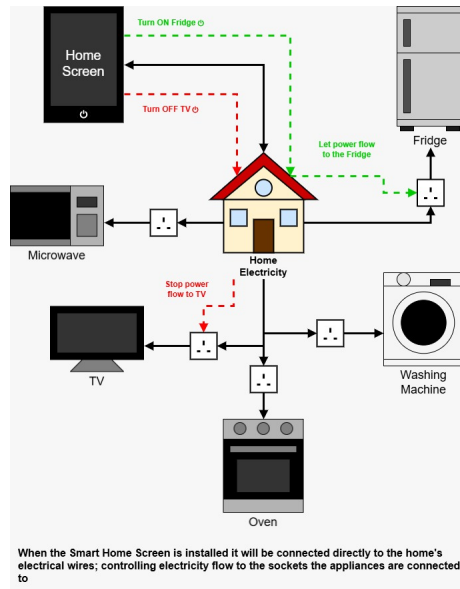
6 Low Fidelity Prototype

Appendix 9 shows our iterative process of working on the smart home screen, putting together our ideas on how it would function, and the features that it would have that would assist potential users in cutting down on their energy costs. We used Figma, whiteboards and paper to create various designs, mapping out how systems would look aesthetically, and interact with people’s home electricity networks. Once we had worked through this process, we used a whiteboard to summarise this into 4 screens of the smart device’s UI. Having all of our ideas down, we could take these screens and implement them in Figma, to create the final UI prototypes. The Smart Home Screen was selected out of all the other design concepts made since it best fit all the requirements needed, it also provided solutions to most of the needs and challenges provided by interviewees: it is a simple and compact solution that can be used by anyone at home, it is customizable and personalised to the users home appliances, it also shows clear details of the users energy data. The Home Screen was also a good choice in that since it is a physical part of the house it will help connect and make family members more aware of energy usage as opposed to using an app.



7 Medium Fidelity Prototype





Our prototype is a design for a mounted screen in a home which gives users more freedom and information regarding their energy usage. Our home screen gives an overview of the current cost ,energy usage in the last hour / any time chosen and the number of active devices in the household. From the home screen you can access the Appliances and Energy Consumption screen. The Appliances screen shows you all your current appliances and their current usage as a percentage of the total energy currently being used. It also gives you a unique option to turn the devices on/off from the home screen so that users can choose to not waste energy on unnecessary appliances. The energy consumption screen gives the user a graph of their energy usage in the last 24 hours allowing them to see their peak energy usage times. From the Appliances screen, the user can access a page for a specific device which shows the active times of the device.