COMP2213: Interaction Design
Hand-In # 3:
Problem Statement and Ideation

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Potential Concept Design for Renewable Energy for Residential Use

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1. PROBLEM STATEMENT

The prime objective of this problem statement is to address the issues related to clean energy waste caused by insufficiencies in domestic solar power energy systems. This is important, since the lack of perceived utility could hinder the continued adoption of residential renewable energy, more specifically the usage of photovoltaic (PV) panels (Faiers & Neame, 2006). There are already several barriers to the adoption of renewable energy for residential use, of which many relate to the financial aspect of the system, perceived relative advantage, and aesthetic characteristics (e.g., visual intrusiveness) (Faiers & Neame, 2006). While, for instance, in the UK all new house builds are by law required to have PV, the lack of adequate installation space has been identified as an impediment in adopting PV to pre-existing homes (Karjalainen & Ahvenniemi, 2019). This indicates that the existing challenges related to PV systems not only impact the current costumers but could potentially also discourage future adopter. As such, it is essential to explore potential solutions to some of the main limitations in order to encourage ongoing implementation of solar energy sources and reduce the energy waste among the existing users.

Interestingly, many of the above issues could be addressed by the implementation of smart home energy management systems. Yet, the results of our literature review (i.e., Hand-In 1) indicate a considerable lack of home-automation systems readily available for residential usage of PV technologies. This is a notable omission, particularly since the implementation of monitoring devices, such as these that inform the user about energy outputs, is known to have a positive impact on the user energy awareness and their energy consumption (Keirstead, 2007). The results of our thematic analysis revealed that the diminished usability of PV was related to energy waste, lack of insight, and monitoring.

Home automation has been widely adopted across domestic sector (Abide & Sona, 2017; Pyae & Joelsson, 2018). In particular the use of automated scheduling, such as Google or Alexa routines, are used to automate the activity of household devices in a way to conserve energy (Vandome, 2018). This highlights a clear need for integration where capabilities of home monitoring could be utilised to also manage domestic energy sources. The standard PV installed as part of new builds face several critical user-design issues which reduce their perceived utility. The evidence from our interviews suggests that the only way a user knows that a solar panel is working is a button which blinks to indicate they are "on". For instance, Participant 2 (excerpt 4, line 116) stated that "*We've got a box in the cupboard, and we have to go and open the door and stand and watch it. If the red light is blinking, the solar panels are working*". Secondly, the PV may not be used efficiently as constant monitoring is required to ensure the users are able to take advantage of them when they are "on". For example, Participant 2 (excerpt 3, line 83) mentioned "*if I want to run the dishwasher, I've got to remember to put it on the right time*" or (excerpt 2, line 66) "*you have to actively think about when you're doing things*". The general sentiment of the respondents suggested that trying to make an efficient use of the PV was seen as "*a little bit of a faff* " (excerpt 1, line 132).

While both the existing literature (see: Chouaib et al., 2019; Kofler et al., 2011; Patil et al., 2019) and participant responses reflect the need for a wider implementation of smart home technologies in home energy management, the key issues appear constrained to two specific factors. The first difficulty reported by the interviewees concerned the lack of insight into the ability to effectively use the PV. For example, Participant 2 (excerpt 5, line 133) stated "*I don't know if [panels] are producing more energy at some times and other times*". The second was a lack of automation, which they already use for their other household appliances. For instance, Participant 1 (excerpt 1, line 138) reported using an air dehumidifier that "*learns.*

So it basically registers the humidity at certain times". This functionality can apply further to numerous daily activities, such as "*dimming the lights which uses less electricity as well*" (excerpt 6, line 85).

As a result, creating an app that would intuitively integrate home automation with the usage of artificial intelligence to manage domestic PV systems would both address the issues faced by the participants and equally address the gap in the availability of home automation as evidenced by the literature. An adoption of such technology may even further increase the perception of the utility of renewable energy for residential use.

2. IDEATION PROCESS

Our group has organised the ideation process as a two-phase brainstorming activity followed by a prioritisation round inspired by the workshop activities throughout the semester. We opted for Lucidchart.com as the environment for building the resulting artifacts at the end of each phase for easy sharing and record keeping. The ideas were logged as sticky notes entries on the chart with each suggestion being discussed by the whole group but not debated in detail as feasible solutions.

In the first phase of our ideation process (see Fig. 1, Ideation: Phase 1) we decided to start with the main themes identified in the problem statement as the starting points. Under the "Automation" label we grouped the smart-home devices that, as we pointed out in our problem statement, would address the energy waste concerns. The "Monitoring" label has ideas centred around ways to interface with the user as several interview participants complained about the lack of insights and feedback received from their solar panels. Finally, we added the "Efficiency" label to encompass ideas meant to cut on energy costs and make the most of the surplus energy available during PV peak times with the goal of increasing the value delivered by the panels outside powering appliances which is the standard use case of solar panels. Some ideas at this stage did not fit in any category but we recorded them as potentially being part of an idea in the second phase. Besides grouping elements, we have drawn some connections between ideas that we think work particularly well when combined. The only constraint we imposed was to avoid ideas using solar panel battery storage as two interview participants did not have them and were not planning on getting them due to high cost (excerpt 3, line 72; excerpt 7, line 88) and we wanted our system to accommodate a wide range of PV owners.

The second phase (see Fig. 2, Ideation: Phase 2) expanded on the first one's ideas by combining them into PV systems able to satisfy all the needs outlined in the problem statement. Each group member was given the time to meditate and propose a solution using the first phase ideas as building blocks with the freedom to add any missing elements. Every concept proposed was then explained and discussed as a group to decide if the idea could be a viable solution and to make any changes needed to improve it (each concept also received a title for easy reference). The result was 6 concepts (one is an offshoot of two other ideas) with varying degree of complexity and "finish". The second phase ended with a vote in which each member assigned three ideas 3, 2 and 1 points respectively in favour of further developing the concept. At the end of this phase, we have selected the top three most promising concepts for refinement.

Note that colour coded boxes indicate the theme of the ideas inside for better readability and concept understanding.

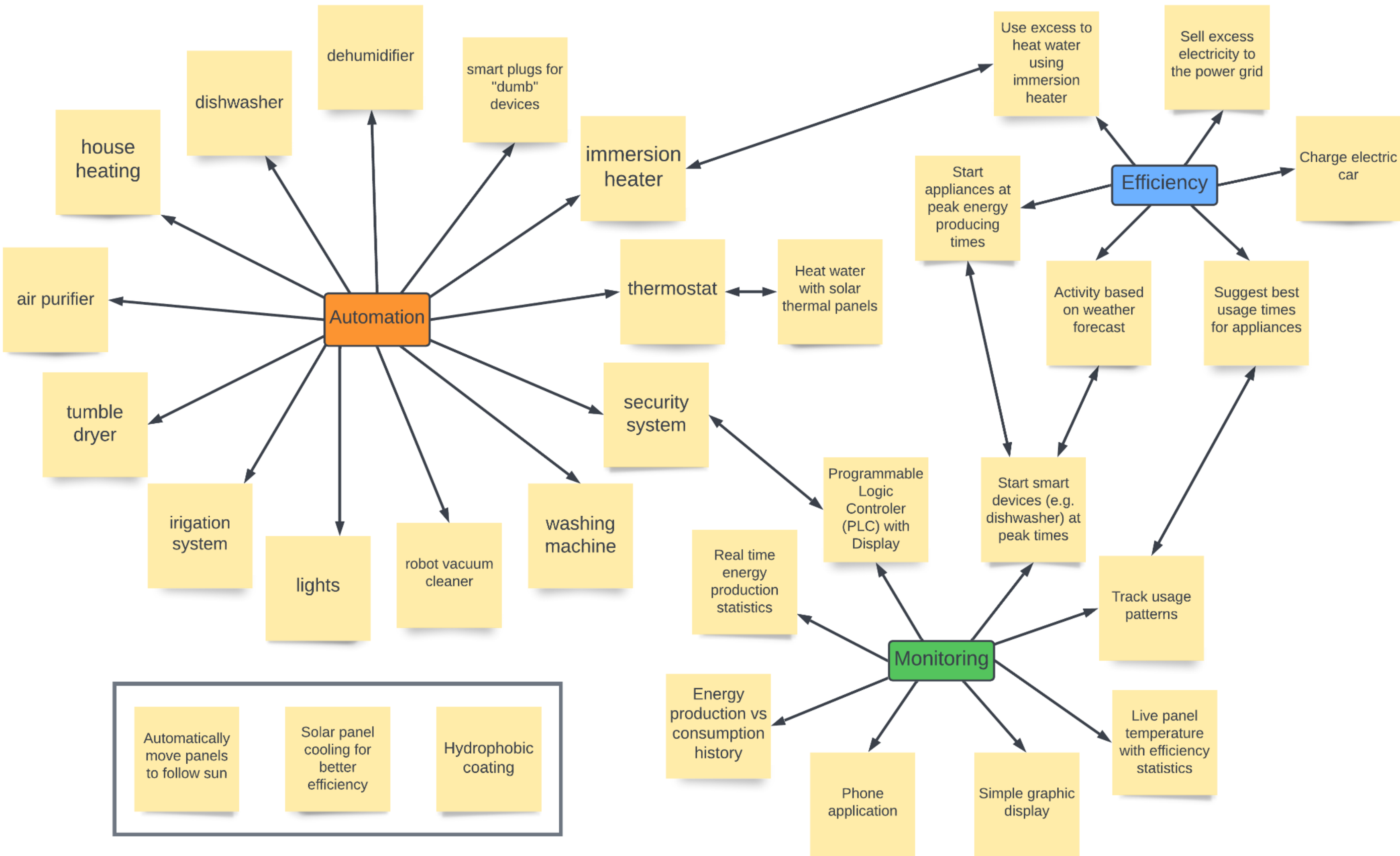


Figure 1. Ideation: Phase 1 artifact. Ideas grouped according to problem statement themes after first brainstorming phase.

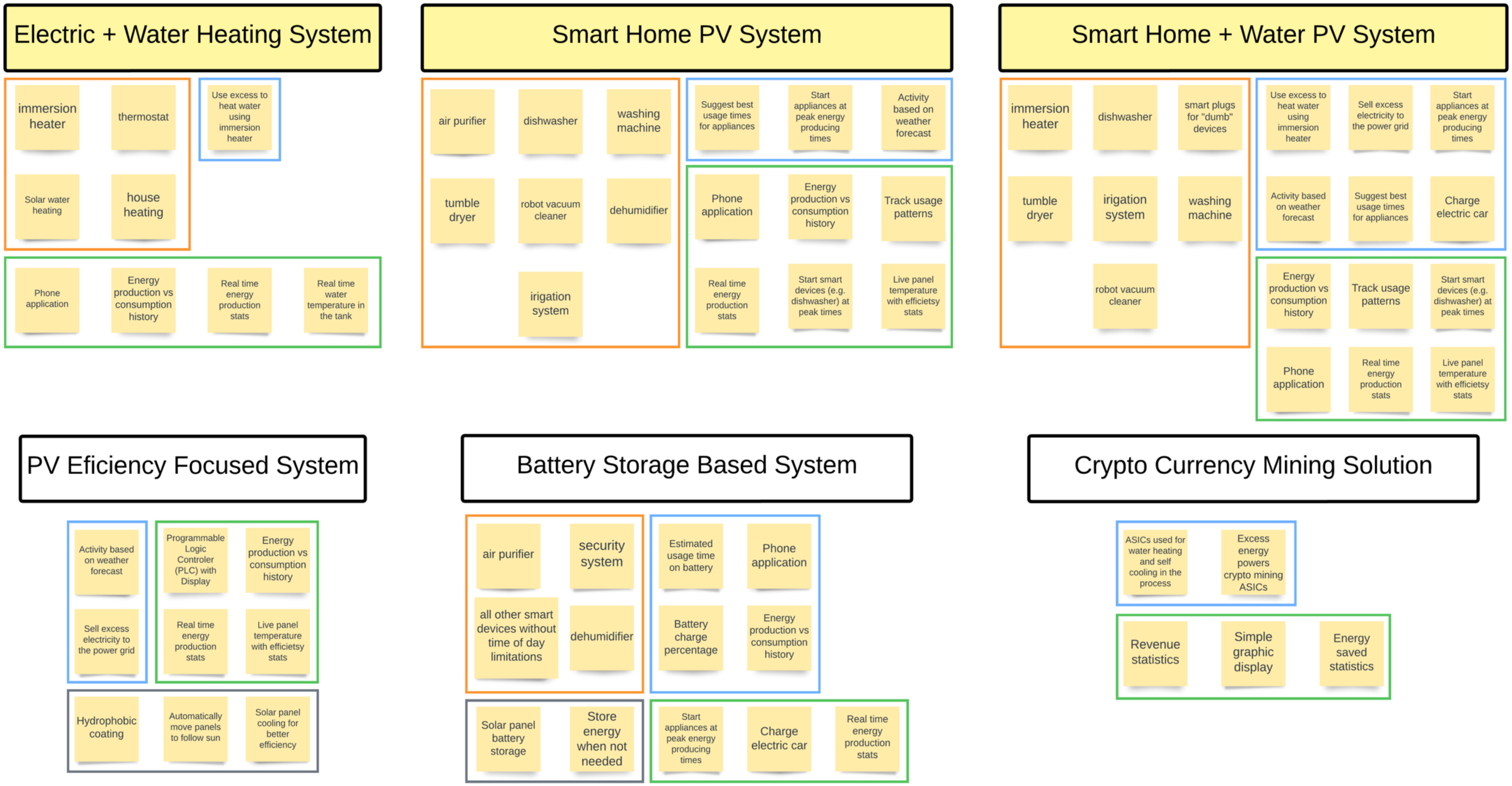


Figure 2. Ideation: Phase 2 artifact. Concepts and their component ideas from Phase 1. Selected idea titles are highlighted in yellow

3. DESIGN CONCEPTS

Design Concept 1: Electric + Water Heating

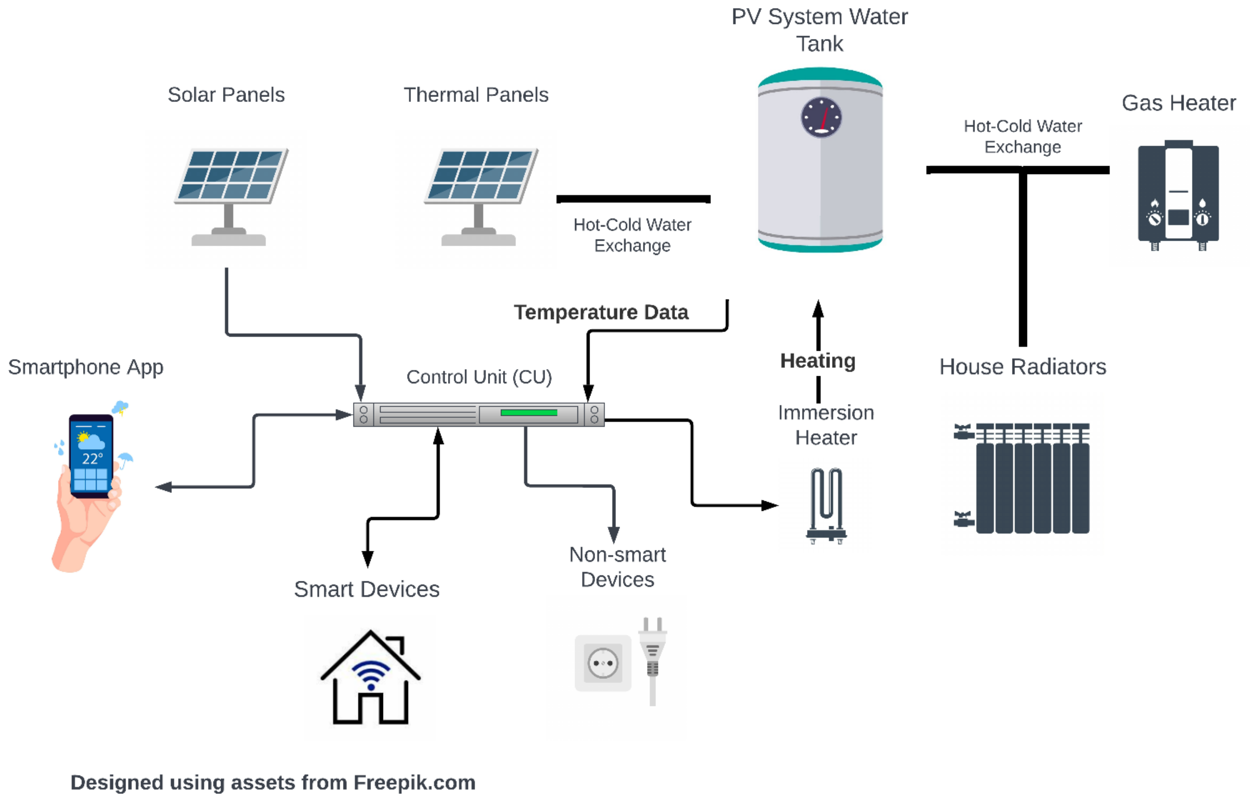
A good use of excess solar energy be it thermal or electrical, would be the heating system of the house. That is why Solar Thermal Panels in combination with regular Solar Panels would be a good choice for a battery free household.

Solar Thermal Panels have a simple but effective system of heating water which can later heat the whole house. The way it works is: there exists a close loop of water between the said thermal panels and a water tank which initially contains cold water, the liquid in the closed loop travels from the tank to the panel where it heats up from the sun and then returns to the tank passing through a second coil to heat up the stored water. The stored hot water can then be used in certain appliances or for heating your house.

In case of failure, the regular solar panels come into play, by having an immersion heater. Any excess energy from the solar panels can be used for the immersion heater for later or emergency use. Generally, good insulation on the water tank, would mean that even if it is night and there isn't any energy converted anymore from the solar systems, the water in the tanks is still hot or warm depending on how much time passed since the last cycle. Whilst there exists a backup system already, it can be lifesaving to additionally have a gas heater to protect you from multiple cloudy days in a row in which case the solar panels become ineffective.

To have absolute control over your heating system, you can use a smartphone app with details of energy converted, water temperature, what system is currently used for heating and other statistics of your choice.

By using such methods, we are addressing a common problem of households that do not have solar battery storage units and most of the time are contributing to clean energy waste due to lack of usage in their home.



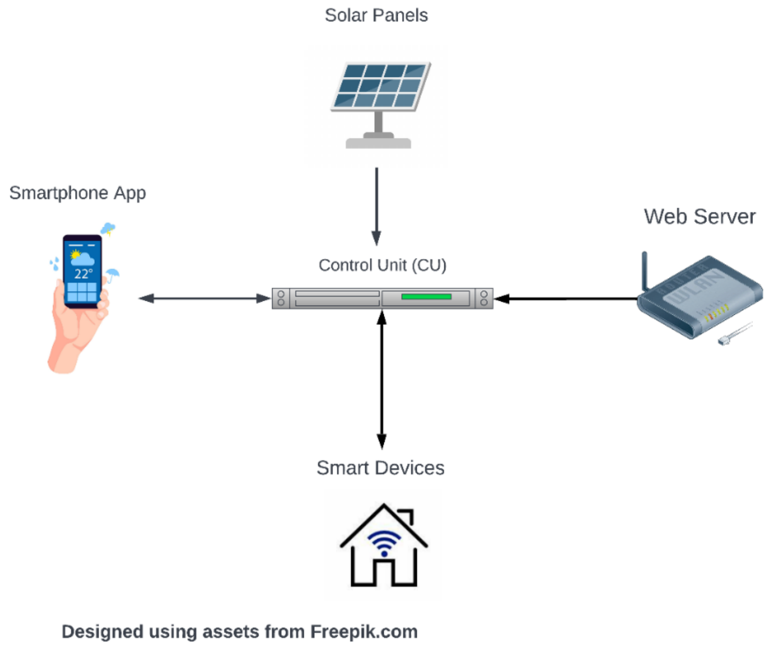
Design Concept 2: Smart Home PV System

Solar panels would need to be connected to the internet where it can collect the data of the cloud level from several reliable weather forecast providers. Based on that data, it will make a prediction on how much energy it is expecting to generate at particular time. The data then gets filtered and matched with the energy home appliances it can run at the time. Next, this information is sent to the app and smart home devices, where user will have option to choose how they would like the energy to be distributed.

There are several ways user can interact with the system. They will be able to use the app by itself or link it to the smart home devices like Alexa or Google assistant. The user will get the notification on their devices with the suggestion on when they should run their appliances. They can either accept it or amend the suggested time to alternative time. If they don't do anything it will automatically start at the suggested time.

All the appliances would need to be loaded in advance, so it can be turned on at suggested time. If the user doesn't load their appliances for scheduled time the appliance won't start. This system would be beneficial to the whole market, as it can be used both manually and automatically. If the user doesn't have smart home devices, they can still use this technology as a guideline on when they should use their appliances.

On the other hand, if the user is using the smart home technology, they can link all their devices with the app which will automatically turn the devices on at the best time. To test if the technology will work, we can build a prototype of a small solar panel which would need to be connected to the weather forecast providers where it can collect the required data. The solar panel will be connected to the energy level recorder where we can collect separate data of actual energy generation. Then we can compare two data sets and calculate the level of accuracy. If the accuracy is between 70 – 100% , the technology is good enough to be released to the market. We would also need to develop the app which can be linked to the smart home technology. Once the system is set and all devices are linked, the user would need to maintain the system to make sure it always up to date and the internet connection is uninterrupted.

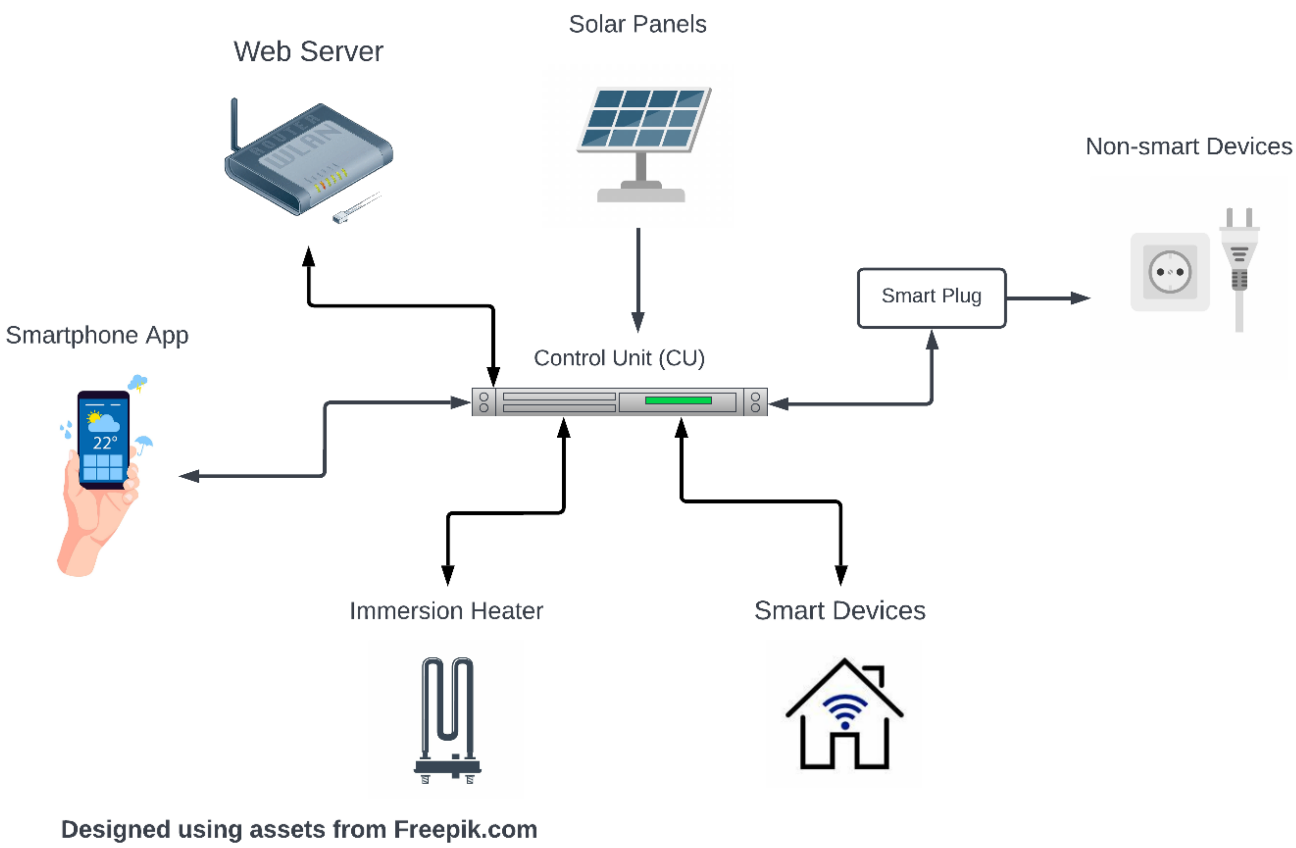


Design Concept 3: Smart Home + Water PV System

In the ideation phase, our group identified this concept as an integration of the previous two ideas that would best address the literature gaps and user concerns, we have surfaced in our problem statement. To address the lack of insight provided by current PV setups, the system includes an application connected to a Control Unit (CU) that will manage all the smart home capabilities of the system. Our group opted for an application as interface instead of a Programmable Logic Controller (PLC) with its interface to increase the affordability of the system.

This idea assumes the availability of smart home enabled devices to communicate with and uses weather forecast data and user usage data to assist in optimizing their behaviour to take advantage of their PV's energy. For non-smart home enabled devices, we provide smart plugs which offer the simple ability for devices to be turned on and off remotely and their status. Besides this smart home functionality, the CU redirects excess energy generated to an immersion heater to heat up water.

With this system, the user is empowered with absolute control over their house at the tip of their fingers by using a smartphone app. It can show various statistics on consumption/production, recommendations and give users the ability to schedule appliance runtime.



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5. APPENDICES

Appendix 1 – Excerpts from transcribed participant interviews

Excerpt 1. Participant 1

Participant 1: Yeah, yeah, like kind of important. Having to run everything during the day is a little bit of a faff to be honest.
Interviewer: Especially because like, I guess your usage of your consoles and sophists were
Participant 1: Yes. The sun especially nowadays, it's kind of sick. That's true.
Interviewer: Okay, question eight. Right. So what do you think you could do to improve the energy consumption in your home?
Participant 1: So, our home's pretty well insulated, because obviously, as a new building, it comes as kind of a standard. So we're pretty conscious about that. I, I bought a smart dehumidifier. Okay, specifically for that purpose. So we have a small dehumidifier that runs on a smart circuit in the room that stores my common books, right? . And we have a large scale dehumidifier outside which purifies the air, but the principle behind that is that it learns. So it basically it registers the humidity at certain times. Okay, so when you first buy it, it will have to learn when you are most likely to say, shower or hang your washing and then it will switch itself onto a higher level at that period of time. . And then it will go into overdrive and then it will switch back just based off the humidity it serves to pre-emptively.

Excerpt 2, Participant 2

Participant 2: Yeah, so I think overall, I think it's, it can be done. And I think it will, it can have an impact can have an impact on your individual energy consumption. Then in terms of fossil fuel energy, but I also think that it's not necessarily the easiest because you have to actively think about when you're doing things.

Excerpt 3, Participant 2

Participant 2: We don't have a battery. So how's it when you have a solar panels that have to come with the battery, in fact, the majority of solar panels to my understanding don't, because the batteries are very pricey and take up a lot of space. So instead, the energy goes back to the grid. Now, that's really good for other people and the energy companies because there's energy going back. But what it means for us as individuals is that if we're not using it, at the time it's being produced. So minute by minute, then we essentially lose access to that energy. And instead, we withdraw from the grid. And so the energy we use in the evening isn't from our solar panels, it's from from the grid. So to make the most of them, you've got to be thinking, okay, when do I need to consume energy, and make sure that you're doing it in the hours of daylight? So for example, if I want to run the dishwasher, I've got to remember to put it on the right time. If I get to the end of my working day, in the winter, it's going to be dark. So then it's a case of deciding, do I wait till tomorrow? Is there enough space? You know, we only run it when it's full? So can I leave the staff on the surface until tomorrow, because it won't fit in the dishwasher and run the dishwasher tomorrow and reload? Or do I run the dishwasher in the evening, in which case I'm not using the solar panels are not being less efficient. Yeah. Same with clothes washing, and with clothes washing, because you want to do the drying, we use a heated era, again pulling the energy from the solar panels, well, that takes longer. So if you don't do your washing kind of in the morning, or lunchtime, you're getting less time drying it using the solar energy coming through the panels.

Excerpt 4, Participant 2

Participant 2: It's fine, it's okay for us, because we work from home, we didn't work from home, it'd be much harder because we wouldn't be at home at the time was when it would be most useful to do the additional energy consumption. It's not just the constant underlying, you know, appliances going on in the background that kind of fit. So in order to use that, to have that discretionary usage, we would need to be home. And you know, we work full time who can work from home now, before the pandemic? Yeah, we probably didn't optimise the solar panels at all, because we weren't there to do so. So I think it would be useful if there was, you know, if you could say, programme, your washers and things like that, and we we've got decent appliances, we don't have high tech appliances, and those, they're really smart appliances possible for money. So to you know, to replace everything with them, one in terms of the ecological efficiency and environmental efficiency, you would be getting rid of perfectly good appliances, that's wasteful. There's energy consumption in the production of those appliances. So in terms of net zero, you're not going to get that that way. So we have the appliances we have till they break, we won't replace them. So that means that we have to actively keep doing it. If you forget you forget that's human, there's no way Oh, we don't set an alarm to get the dishwasher on. Yeah. And there's nothing smart to say, hey, the solar panels are on. In fact, sometimes, to go and check. We've got a box in the cupboard, and we have to go and open the door and stand and watch it. If the red light is blinking, the solar panels are working. If the red light is on permanently, then they're not they're not working, because there's not enough light. So on a cloudy day, you might find yourself having to go and stand in your cupboard and stare at a box to find out if your solar panels have enough light to actually be producing solar energy at that time.

Excerpt 5, Participant 2

Participant 2: The lack of affordable storage options, I understand why the batteries are pricey. But at the same time without the battery, you are going to have a lot of energy running off now it is going back to the grid. So it's not is helping the country overall, I guess but it's still helping the individual. I think another challenge will be I have no idea how to maintain them. And I wouldn't know if there was something wrong with them. And so I went and stared at the box. So actually, knowing that they're not work when they're on and when they're off is a bit of guesswork. So it'd be it'd be good to have a way of understanding on the LA optimise it. You know are they working? I don't know if they are producing more energy at some times and other times whether there's more energy on a sunny day than a cloudy day I guess there might be and actually

Excerpt 6, Participant 3

Participant 1: Yes. Because it has to convert the solar energy into, into power for the house. Okay, so there's like, almost like a dynamo, I guess, that converts it and then feeds it back to the grid. That's where the battery would go if you had five grand to spare.

Interviewer: Right.

Participant 1: And they're about five grand. They are not cheap. We did look into them. Because objectively, it will be a really good idea. But it was that we're getting a lot boarded. Unfortunately, we have too much crap to not have that last boarded.

Excerpt 7, Participant 1