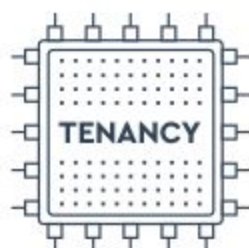


Design Report

Home Monitoring Technology

The case of a Mobile App for real-time monitoring



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(CI7820_A_TB2_19)

Link to the Online Portfolio Website: <https://samirdesign.myportfolio.com/>

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1. Introduction and Background

The project aims to offer home automation mobile application for helping the landlords start the journey to a better understanding of energy consumptions done by their tenants and the money it costs them.

It aims to monitor and control the usage of resources such as electricity, gas and water by an individual tenant or room and also get a cumulative consumption data of the whole house helping in cutting down the utility bills and avoiding any sort of misuse or leakage. The concept is made possible by securely accessing real-time data from electronic wireless utility meters (smart meters) using RTL-SDR device, and providing feedback to landlords via mobile application.

The report investigates and outlines all the issues that the landlords undergo and provide solutions using a case of a mobile application named “Tenancy”, for real-time home monitoring. The report also focuses on demonstrating the technical research done by the author, ensuring the possibility of the concept before implementation.

Managing home energy is all about tracking how much energy resources a house or apartment uses, then finding ways to save. However, monitoring and controlling energy consumption have never been easy. It sounds a bit obsolete that conventionally, landlords followed some old ways to monitor energy usage. Either visiting the house to record the meter readings or phone call their tenants to share readings or pictures of the utility meters. However, there are energy providers like Chameleon Technology and E.ON, which are known for installing in-home energy display monitors for real-time monitoring of the whole house.

The first big question that still comes to light in people’s mind is, “Can they see the consumption data for individual rooms and devices?”. The answer to this question is, No. Although these monitors measure and display accurate data, they restrict users from monitoring individual rooms or individual devices. Furthermore, the second big question that arises is, “Can they take these devices outside their houses?”. The answer to this question is, No. They are thereby, limiting users from monitoring their houses from a different location.

Therefore, these questions ground the motivation for the author to work on this project.

The report is produced in response to the secondary research done by the author on the need for controlling the wastage of energy resources.

According to the national statistics provided by the UK government’s Energy Consumption in the UK (ECUK) 1970 to 2018:

- Total energy consumption in the UK increased by 1.1 per cent in 2018 to reach 143 million tonnes of oil equivalent (mtoe), the highest level since 2013. •
- This increase was driven by the high contribution of the domestic gas consumption of over 1.6 mtoe; nearly three quarters of which was in the domestic sector because of the

severe weather conditions in the UK. As a result, a larger proportion of consumption is used for space heating.

Fig1.1: Change in consumption by fuel and sector (2017-18)

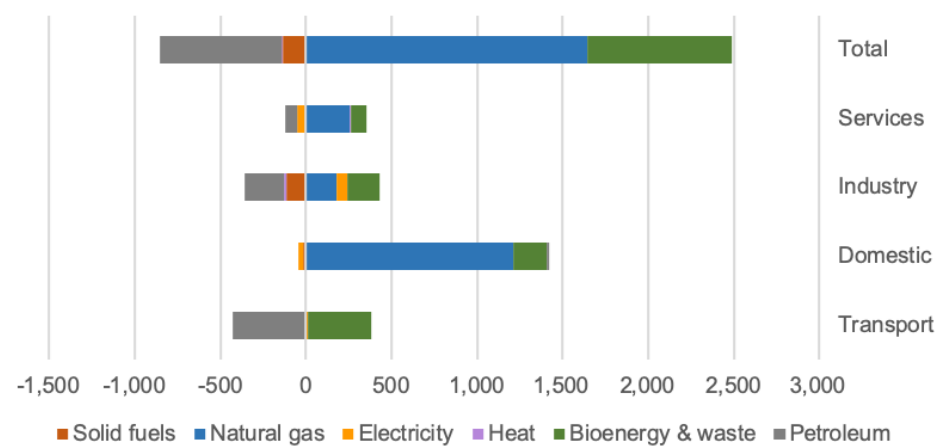


Fig1.2: Consumption by sector (1970)

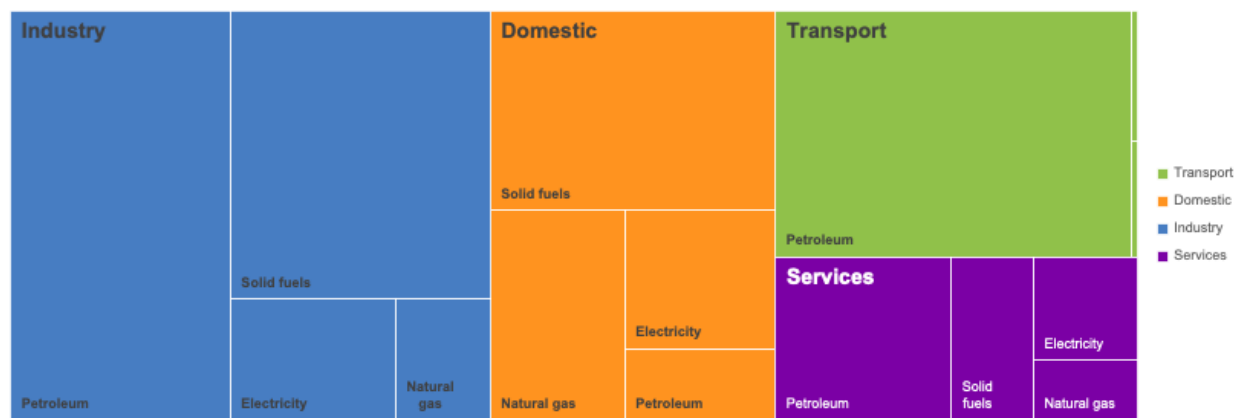
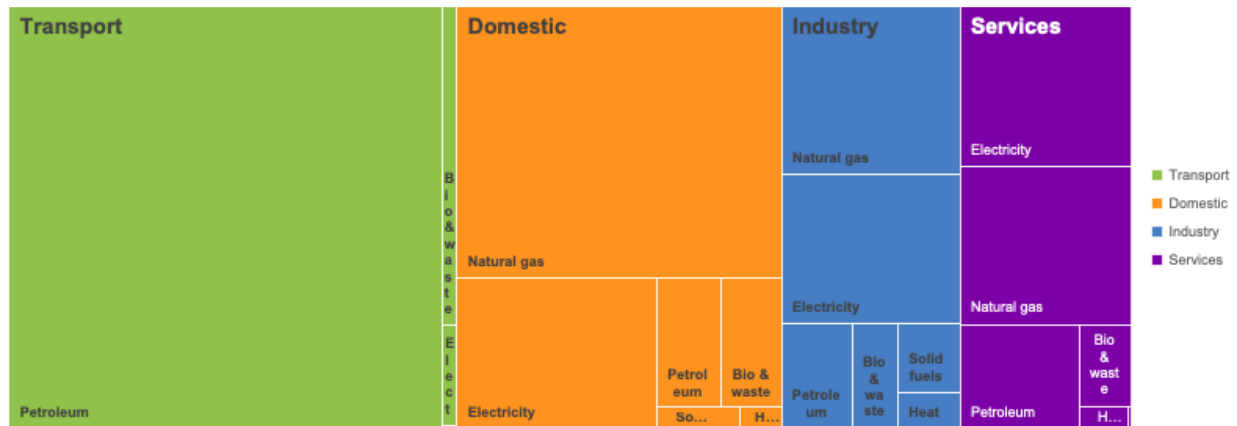


Fig1.3: Consumption by sector (2018)



Therefore, from figure 2 and figure 3 we can conclude that since 1970 the domestic sector has always been responsible for the highest consumption of:

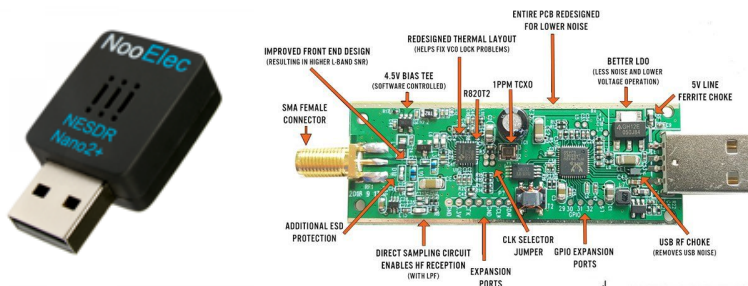
- natural gas with value 8922 being the highest out of all the other sectors in the year 1970 and value 26,584 being the highest out of all the other sectors in the year 2018;
- electricity with value 6622 being the highest out of all the other sectors in the year 1970 and value 9034 being the highest out of all the other sectors in the year 2018.

The obvious conclusion to be drawn from these facts is that there is an urgent need for the people to terminate the wastage of resources and save for future generations. Therefore, the key solution could be a Home Monitoring Technology that could help the users keep an eye on the energy consumption in real-time. (2020)

1.1 Home Monitoring Technology

RTL-SDR

The RTL-SDR nanochip is the backbone that makes the entire concept possible by functioning as a computer-based radio scanner for receiving live radio signals around them (no internet required). RTL-SDR is a very cheap USB dongle that could be bought from online shopping platforms like Amazon.com. The chip could also receive frequencies from 500 kHz up to 1.75 GHz. (About RTL-SDR, 2020)



1.2 Monitoring System Architecture Overview:

The fig 1.2.1 below depicts a blueprint of a house with a setup comprising of different components such as utility meters, electrical power outlets, and a master hub arranged in a random manner.

i) Utility Meter



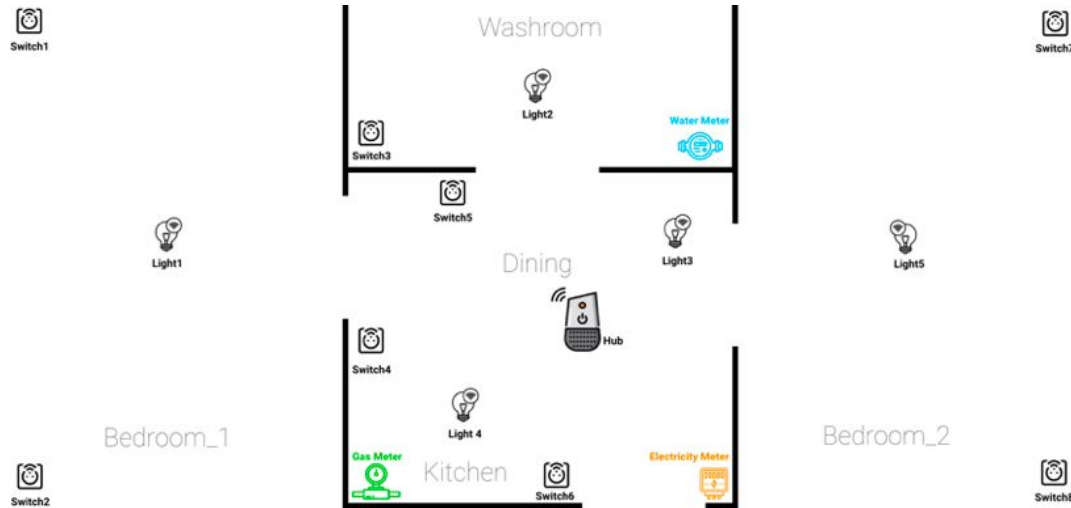
ii) Power Outlets



iii) Master Hub

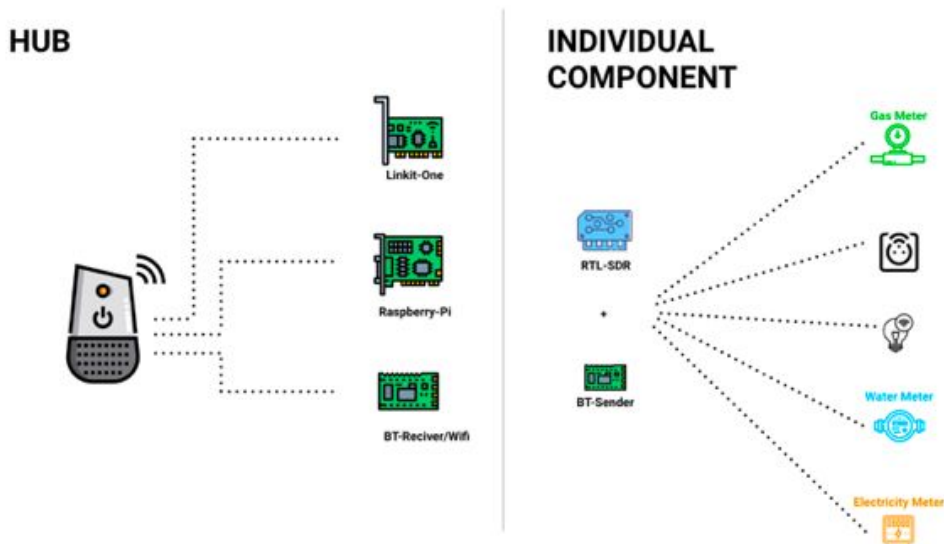


Fig1.2.1: Monitoring System Architecture Overview



The fig 1.2.2 below further elaborates on the components that a master hub and other components like utility meters, electrical devices and power outlets comprise of

Fig1.2.2: Hub and Individual components explained



The master hub comprises a Linkit-One kit, a Raspberry-Pi computer with the RTL-AMR decoder installed in it and a Bluetooth(Sender/Receiver) or Wifi.

1. LinkIt ONE



2. Raspberry Pi Computer

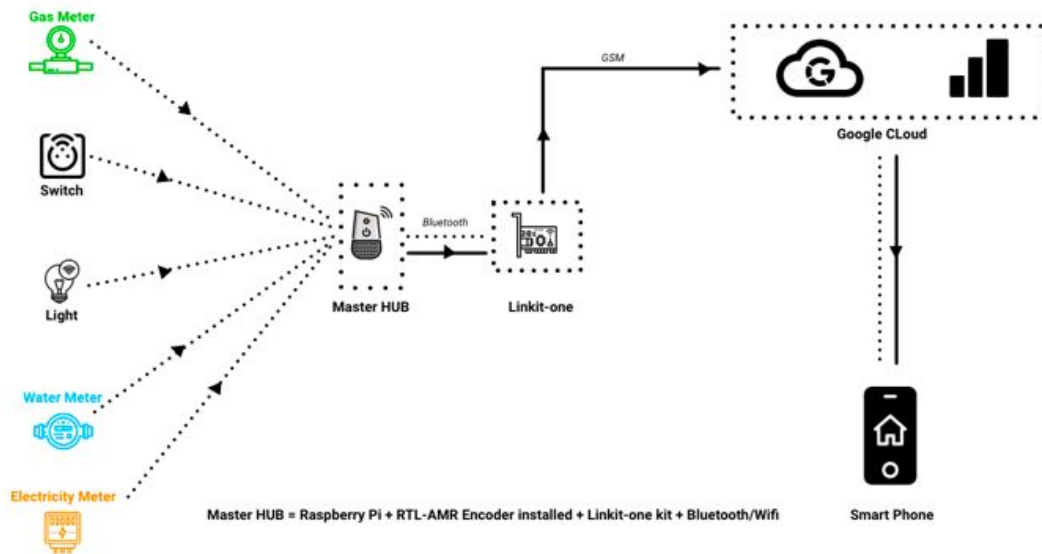


3. Bluetooth (Sender/Receiver)



The other individual components i.e. utility meters and power outlets comprise an RTL-SDR chip embedded on them with a Bluetooth Sender/Receiver as shown in fig 1.2.2.

1.3 Component Diagram / Mechanism



The mechanism starts right away from continuous emission of radio signals from the power outlets and utility meters. The RTL-SDR chips embedded on them capture these radio signals and transmit it further to the Master Hub using Bluetooth.

The Raspberry Pi computer has the RTL-AMR decoder installed which is able to decode the radio signal (via the ERT protocol) transmitted by the utility meters and the power outlets into some meaningful data and transmits it further to the Linkit ONE kit. (About RTL-SDR, 2020)

The Linkit ONE consists of GSM sim which further sends the data to the Google Cloud via GSM continuously.

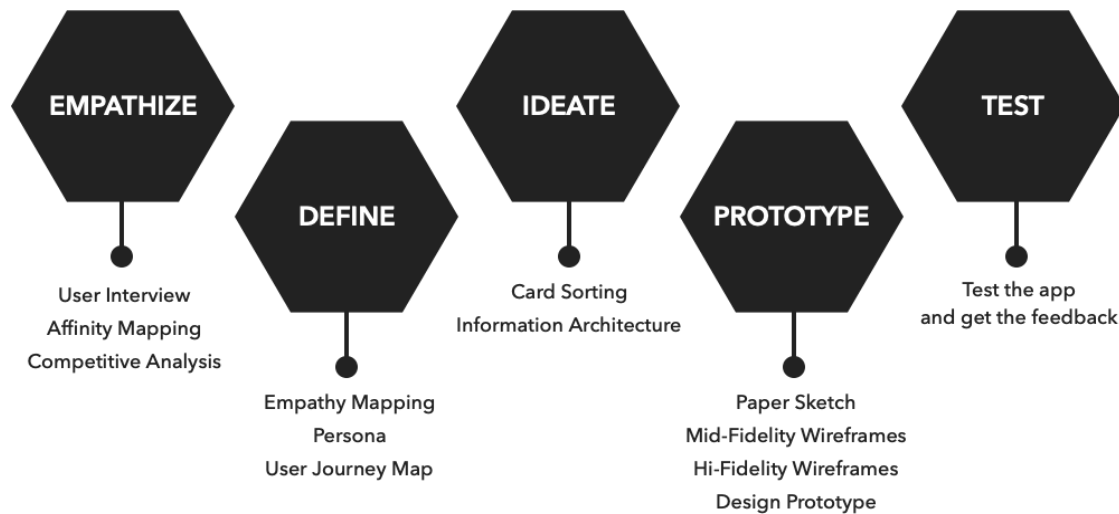
The Google Cloud stores the data in tabular form with column attributes such as time, location, RTL-SDR device ids and threshold data.

The stored data can be called from the database to Google Analytics that we want to visualize.

The analytics view can be embedded in the mobile application by calling the google analytics chart through APIs in real-time.

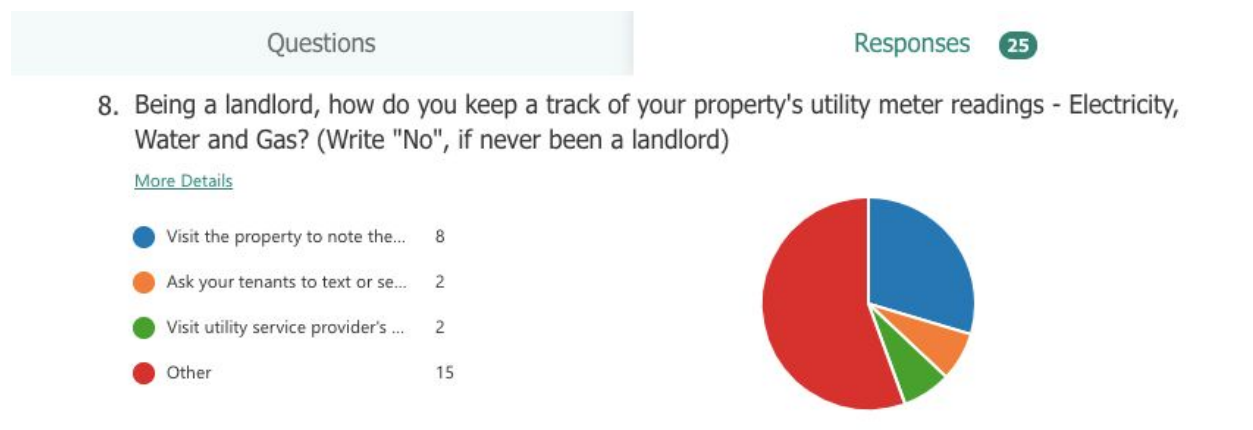
2. Project Process

The project process reports how the author conducted the entire project divided into several phases. Each phase describes the activities that were conducted, the product of these activities, and significant decisions that were taken as a result of those.

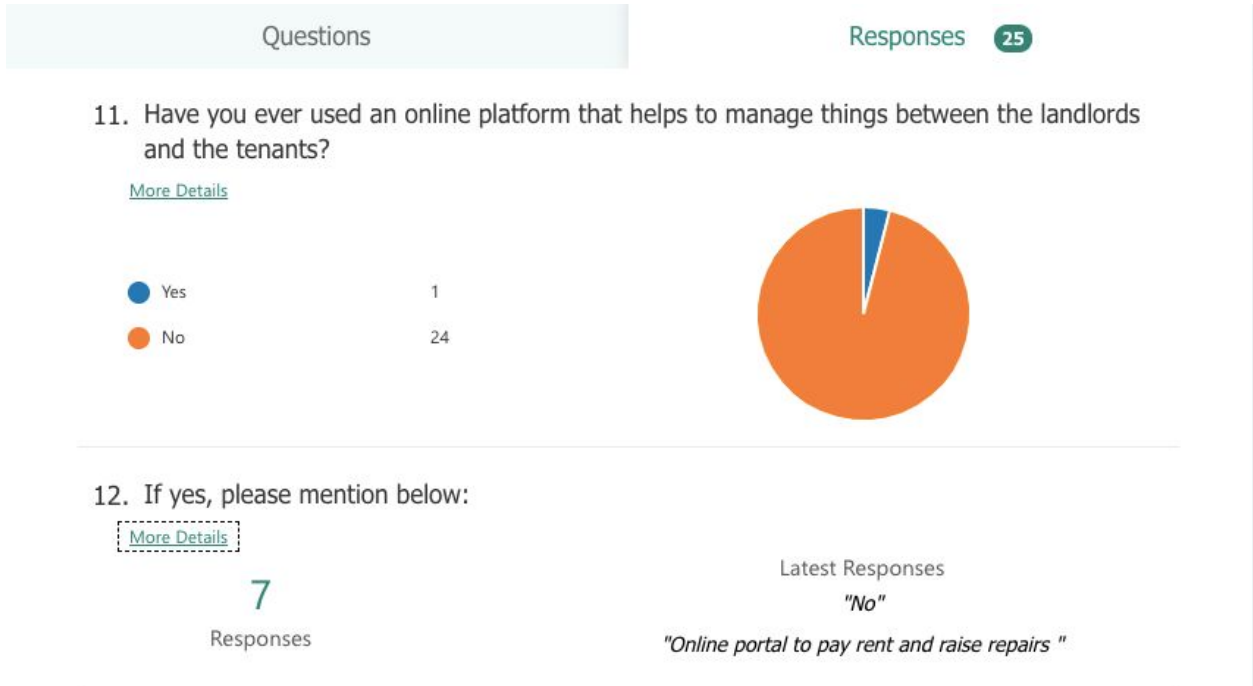


2.1 Empathize

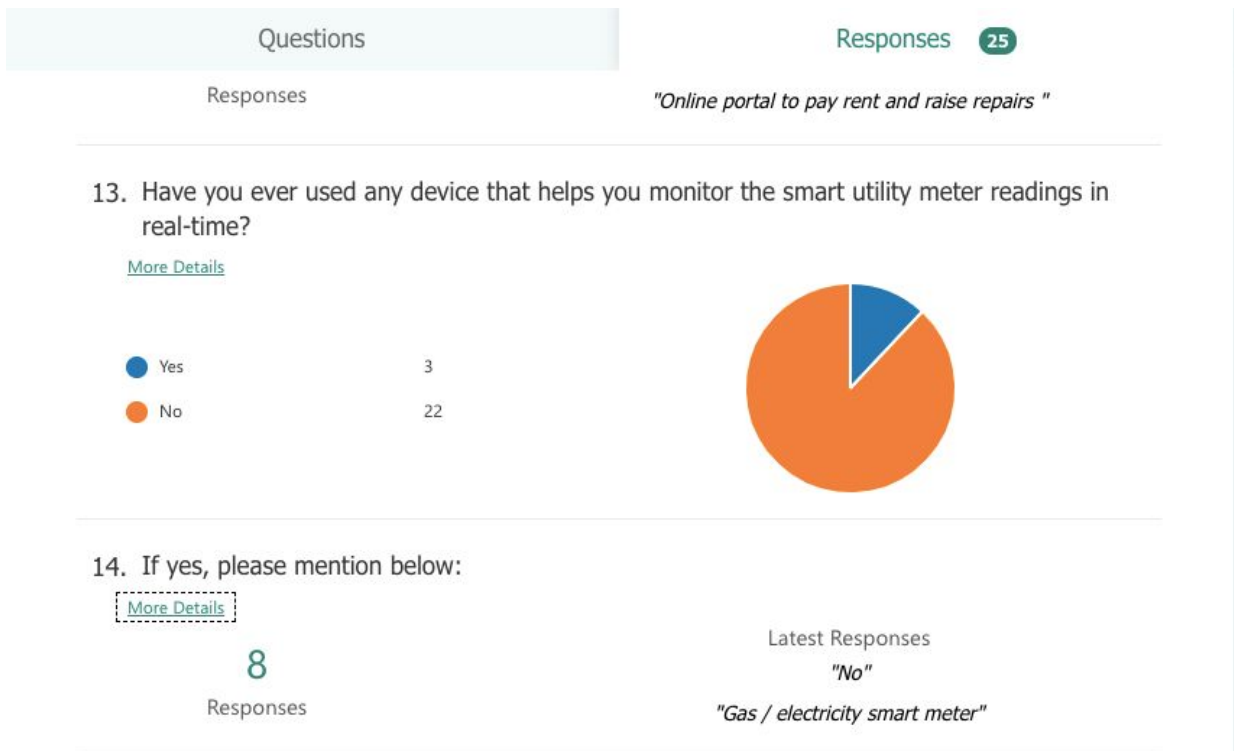
2.1.1 Surveys



- All of the surveyed users either visited the property to note the readings, asked their tenants to share pictures of the meters or visited the service provider's website.



- 96 % of the users have never used an online platform that manages businesses between landlords and tenants.



- 88% of the users have never used any device that helps monitor the smart utility meter readings, while 12% of the users have used the in-home display monitors.

2.1.2 User interviews

a) Table of Research Questions

The aim of the project would be covered by addressing the following Research Questions:

1	How many people have experienced renting their house?
2	What issues do the landlords have with their tenants?
3	Being landlords, how do they monitor utility meter readings?
4	What issues do the tenants have with their landlords?
5	Have they ever used any device that helped them monitor the smart utility meter readings in real-time?

b) Target Users

The process of recruiting the participants is one of the most vital steps if your user research is to get your design anywhere. It is crucial to find the users who represent your target group or are similar to your site users to ensure that the results translate into something that gives useful insights for your study. (Affairs, 2019)(The Interaction Design Foundation, 2019).

The most relevant target group for the research included people who are landlords. The landlords could be working professionals and retired senior citizens. They were the best people to approach to get insights on how they manage their tenants and properties, and how they monitor the utility meter readings of their houses. The main focus of the interview was to gather the issues they face when it comes to monitoring energy consumption and how they would want the solution to be.

Participants Recruited: 5

Males: 2

Females: 3

Age Range: 35-65

Table 2.1.2(b) : Participant's Demographics

User	Age Group	Gender	Have Tenants?	Profession	Participated in user research before?
1	40-45	Male	Yes	Executive Manager	No
2	35-40	Female	Yes	Professor	No
3	45-50	Female	Yes	CA	No
4	50-55	Female	Yes	Retired	No
5	60-65	Male	Yes	Retired	No

c) Mode: Contextual Inquiry

The author performed face to face contextual inquiry mode of interview, moderated in-person. The aim of using this method was to get in-depth insights and investigate the reasoning behind user pain points by directly interacting with the participants.

It was much of an explorative and open-ended interview as the participants were asked to give opinions, suggest solutions, and express emotional impressions about ideas and concepts. Keeping it open-ended helped the author to learn from the users as he is a novice to London and was eager to learn about the relationship between landlords and tenants in London and what do the landlords do to monitor and control the energy consumptions.

d) Some Key Findings from the Users

User 1: Usha Patel

"It is a sad reality I have to travel from Hayes to Kingston just to note down the utility meter readings every month."

"It is crucial to stop your tenant from wasting resources."

"I wish there was a way I could know the consumption of different rooms or tenants and devices individually."

"I charge 100 pounds from my tenants for the utility bills. However, the amount comes out to be more than that most of the times. Hence, I have to pay for it."

"The tenants never follow the house rules."

"I use different platforms for different purposes, like WhatsApp for communication, service providers website for keeping a check on utility bills and bank applications for transactions."

User 2: Jade

"I sometimes call my tenants to send me pictures of the utility meter readings."

"It does not make sense to travel just to note down the readings."

"I think it is difficult to manage your work and your properties simultaneously."

"Some of the tenants never pay on time. I have to follow them up every time."

"I have e.ON energy monitor at my properties but there is no way I could carry them around and get those readings on my mobile phone."

2.1.3 Affinity Mapping:

The following project activity was performed to cluster and bundle all the key findings from the user interviews at one place.



- Difficult to monitor energy consumptions.
- Regular house visits for note down the meter readings.
- Asking tenants to send texts or pictures of the meter readings.
- Visit the service provider's website to keep a track on consumption data.
- Tenants misusing energy resources.
- Can not track the usage of a specific room or a tenant.
- Tenants do not pay on time.
- No direct debit payment method.
- Can not keep a record of the utility bills or any other invoices.

2.1.4 Competitive Analysis

a) Competitors

According to the research, **Tenancy** has no direct competitors. However, there are some in-home energy display monitors and one of them which I found to be the best is **Chameleon SMETS2**.



b) Analysis Table

The table below shows the comparison of the competitor with **Tenancy** on the basis of some key features of the product.

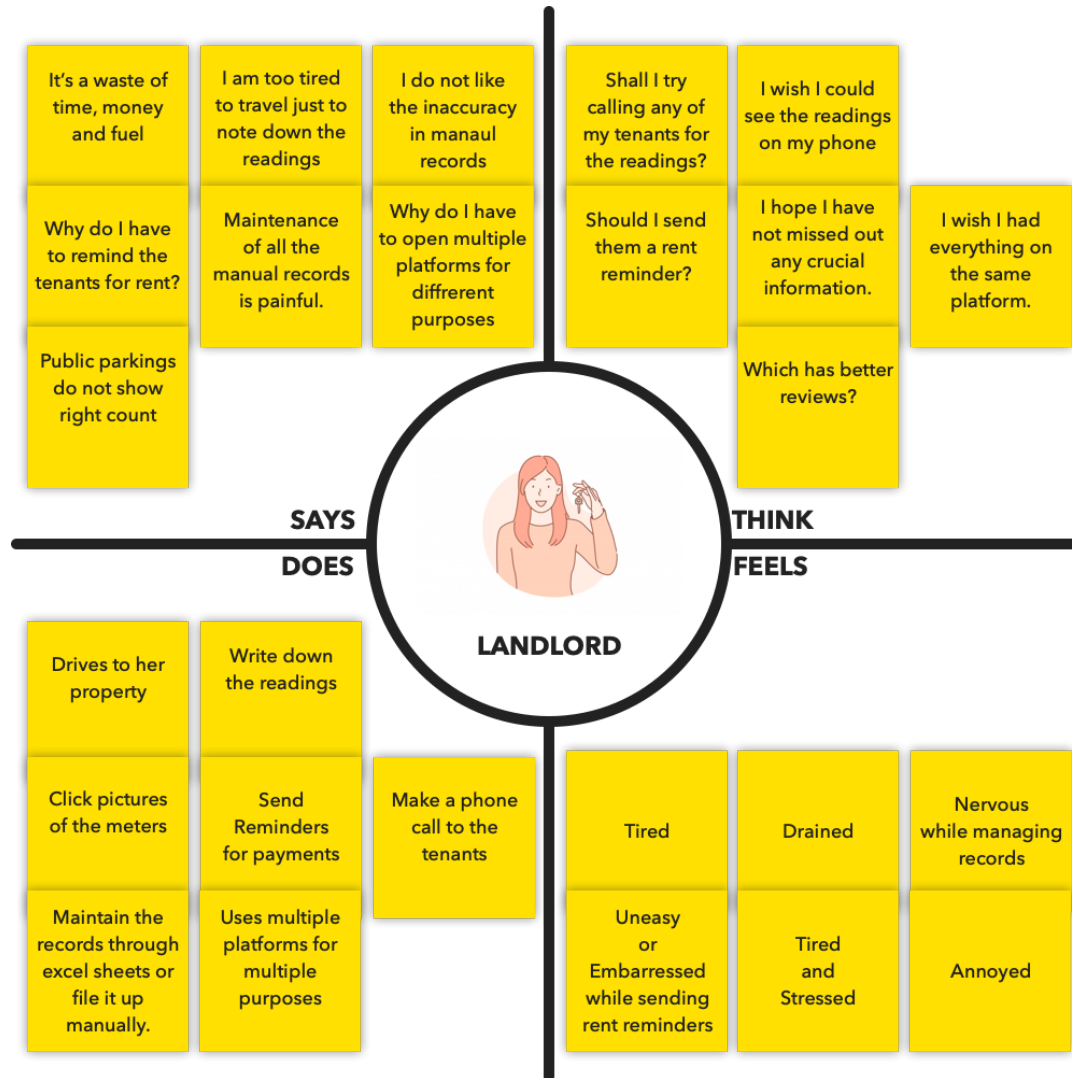
Table 2.1.4(b) : Competitive Analysis Table

	Chameleon SMETS2	Tenancy
Electricity	Yes	Yes
Gas	Yes	Yes
Water	No	Yes
Consumption Data	Yes	Yes
Bill Amount	Yes	Yes
Set Budget	Yes	Yes
Meter Reading	No	Yes
Daily Usage Data	Yes	Yes
Monthly Usage Data	Yes	Yes
Annual Usage Data	Yes	Yes
Bill Payment	No	Yes
Payment History	No	Yes
Record of Utility Bills and Invoices	No	Yes
Send Reminders	No	Yes

Individual Room Usage Data	No	Yes
Individual Tenant Usage Data	No	Yes
Device's Usage Data	No	Yes
Comparative Analysis Graph	No	Yes
Add Tenants	No	Yes
Chat	No	Yes

2.2 Define

2.2.1 Empathy Map



Takeaway

Empathy map was created to visualize user attitudes and behaviours in order to align on a deep understanding of the end-users or stand-in their shoes. The map had four quadrants: says, thinks, does and feels. The aim of the exercise was to stand-in the users' shoes and align on what they say, think, do and feel while they are stuck in the problem.

2.2.2 Personas

Based on the qualitative data gathered from the user research, character profiles or personas were created.

Takeaway

The user research helped in classifying different user types having similar behaviour. These user types are further described in the personas with their attributes. Creating personas helped

understand users needs, behaviour, goals, personality, values, opinions and expectations thus making the design process much easier.



Usha Patel

Chartered Accountant / 50 years old / Married

PSYCHOGRAPHICS

Owns two private student accomodations
Loves helping her tenants
Concerned about saving enery for future
Also an Environmentalist

TECHNOGRAPHICS

Uses Smarthphone
Uses Online Payment Methods for most of the transactions
Uses WhatsApp for conversations
Uses Service Providers Website to keep a track on energy consumption

NEEDS

Wants an easy way to monitor the energy consumption and utility meter readings
Wants to track the usage of rooms and tenants specifically
Want an easy way to manage property related records (utility bills, invoices, etc.)
Wants her tenants to pay on time

PROBLEMS

Tenants Misusing the energy resources
Do not like visiting the property just to note down the consumption data
Do not like asking tenants to share pictures of the meter readings
Existing in-home energy monitors does not let me monitor the property from my house

"I really don't like travelling from Hayes to Kingston just to note down the utility meter readings every month."

Stefan T.

Retired Officer / 63 years old / Married

PSYCHOGRAPHICS

Owns one private student accomodations near his own house
Loves to help children
Prefer to keep students as his tenants
Believes in saving money

TECHNOGRAPHICS

Uses Smarthphone
Uses Online Payment Methods for most of the transactions
Uses WhatsApp for conversations
Uses In-home energy monitors to keep a track on energy consumption

NEEDS

Wants an easy way to monitor the energy consumption and utility meter readings siting at home
Wants to manage his tenants while sitting at home
Want an easy way to manage property related records (utility bills, invoices, etc.)
Want an easy payment method
Wants one platform to solve all the purposes

PROBLEMS

Paying for utilities from my pocket because of misuse of energy
Old age does not allow him to make regular house visits
Using mulitiple platforms for different purposes turns out to be tricky
Existing in-home energy monitors does not let me monitor the property from my house

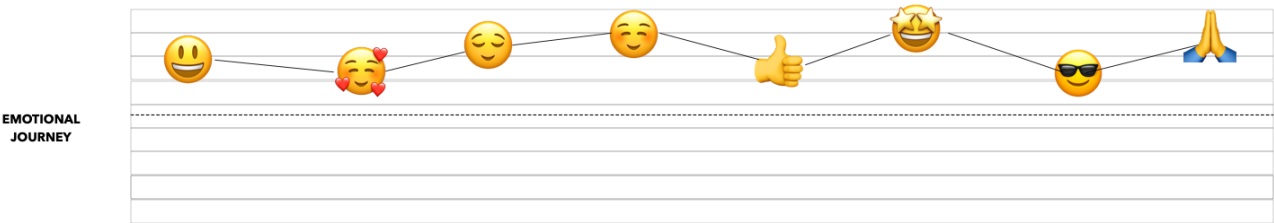


"Old age does not allow me to go out and make regular visits to my nearby property"

2.2.3 User Journey Map

The journey map below describes the experience of a landlord trying to monitor the energy consumption of her house, starting from choosing the type of utilities she wants to monitor and creating a floor plan until seeing all the relevant usage data for her house.

Stages	ONBOARDING	DASHBOARD	HOME	ADD BUTTON	TENANTS	CHAT	NOTIFICATIONS	HAMBURGER
THINKING	This looks neat and easy	Wow. This look mesmerising	Great way to visualize data for different rooms and devices individually	Lovely! Looks like a complete package for me.	Now I do not have search through my files to look for their details	This app is really a complete package for landlords. Now they won't have to user other apps.	Great way they to stay updated	Pleased to see all the other features in the hamburger
DOING	Register Property, Select Utilities, Enter Meter Details, Create Floor Plan, Add No of Power Outlets	Reading through the energy consumption data and visualizing through radial and line graphs	Horizontally scrolling through data of different rooms and devices	Try adding utility bills and invoices	Reading through user-profiles and their payment histories	Try exploring it and discover what all a landlord can share with their tenants	Reading through all different types of notifications	Try exploring all the secondary features.
FEELING	INTERESTING	MESMERISED	PLEASED	BLESSED	EASY	EXCITED	CONFIDENT	EXCITED



2.3 Ideate

Problem Statement: To monitor and control the usage of resources such as electricity, gas and water by an individual tenant or room and also get a cumulative consumption data of the whole house.

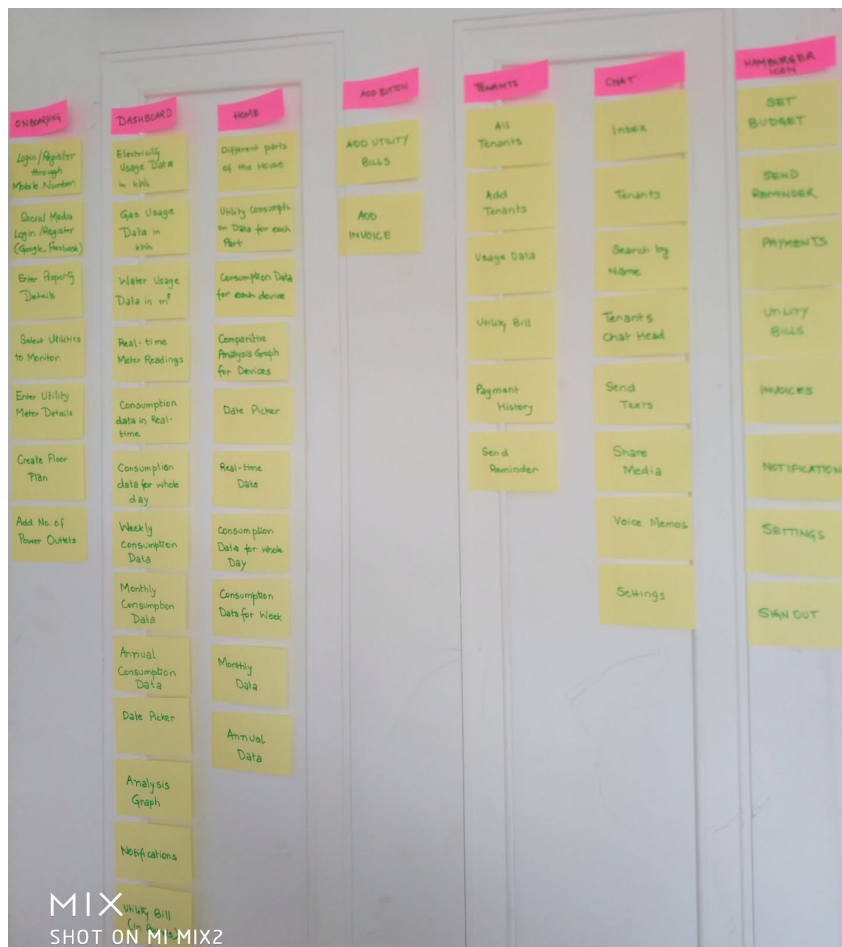
The Solution

- Cumulative energy consumption data of electricity, gas and water for the entire house in real-time, weekly, monthly and annually.
- Energy consumption data of specific rooms, tenants and devices in real-time, weekly, monthly and annually.
- The landlords can view their Utility Meter Readings in real-time
- The landlords can set their budgets to ensure they do not go beyond a limit.
- The applications show the amount of money the tenants would have to pay for the energy they have used.
- The landlords can see the difference in their usage activities with the help of graphs.
- The landlords can view all their tenants and their details at one place and can even add as many as they want to their account.
- The application provides a direct debit payment method ensuring the payment of rent on time.
- The landlords can check the payment history of their tenants.
- The landlords can send payment reminders to the tenants.

- The landlords can chat with the tenants, share media and create groups.
- The application notifies the landlords on important occasions.
- The landlords can add the utility bills and repair and maintenance invoices ensuring easy management.

2.3.1 Card Sorting

Card Sorting activity was performed with some recruited participants to understand their attitudes, values, preferences as they relate to the domain under study. The activity helped the author to develop a deep understanding of the audience's mental models or conditioning. In simple words, it helped the author to figure the way individuals break down a problem, concept or task in their head, and sort them based on their priorities and relative value of breakdown items. As a result, the features and the Information Architecture for the application were discovered.



Takeaway: The features that came out as a result of the activity are:

- i) **Onboarding**
 - Login / Register
 - Register Property

- Select Utilities to Monitor
- Enter Utility Meter Details
- Create a Floor Plan
- Add the number of Power Outlets

ii) Dashboard Tab

- Electricity, Gas and Water Consumption Data
- Real-time data
- Data for today, week, month and year
- Date Picker
- Analysis Graph
- Notifications
- Utility Bill Amount in pounds

iii) Home Tab

- Different parts of the House
- Consumption Data for each part
- Consumption Data for each Device
- Comparative Analysis Graph
- Date Picker
- Real-time Data
- Data for Today, Week, Month and Year

iv) Add Button Tab

- Add Utility Bills
- Add Invoices

v) Tenants Tab

- All Tenants
- Add New Tenants
- Usage Data
- Utility Bill Amount
- Payment History
- End Reminder

vi) Chat

- Inbox
- Tenants
- Search by Name
- Tenants Chat head
- Send Texts
- Share Media
- Share Voice Memos
- Chat Settings

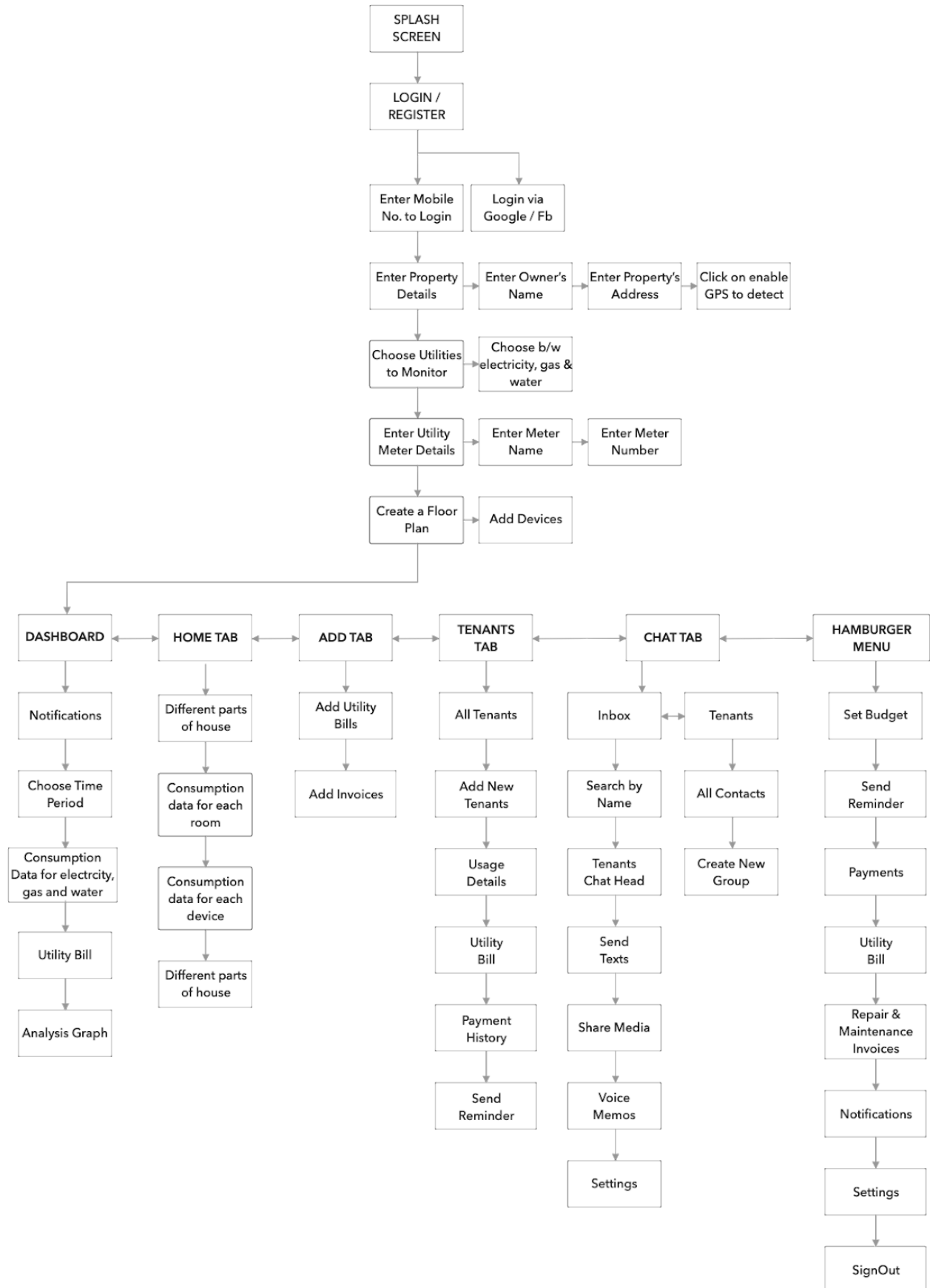
Hamburger Menu

- Set Budget

- Send Reminder
- Payments
- Utility Bills
- Invoices
- Notifications
- Settings
- Sign Out

2.3.2 Information Architecture

The architecture below depicts how the information is going to flow within the application. This flow came out as a result of a card sorting activity.

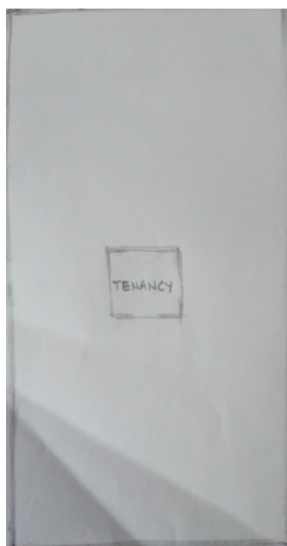


2.4 Prototype

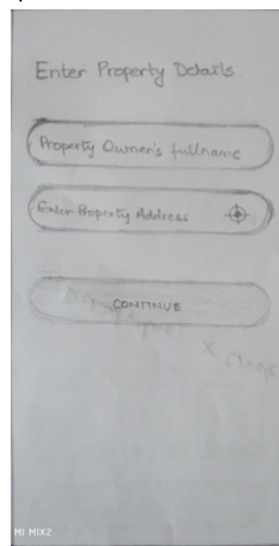
2.4.1 Lo-Fidelity Prototype

Lo-fidelity prototypes were created as a first attempt to get a rough visualization and testing of the ideas gathered. It turned out to be helpful during the early-stage conceptualizing- when the author wanted to explore a variety of different concepts and choose the right ones that will be used before jumping on to the hi-fidelity prototypes. Doing so fixed many usability problems before avoiding the wastage of time and money invested in implementing something that does not work. (Paper Prototyping: Getting User Data Before You Code, 2020); (The Magic of Paper Prototyping, 2020)

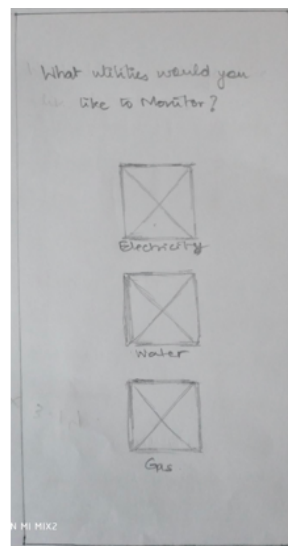
Tools used: Pencil and Paper



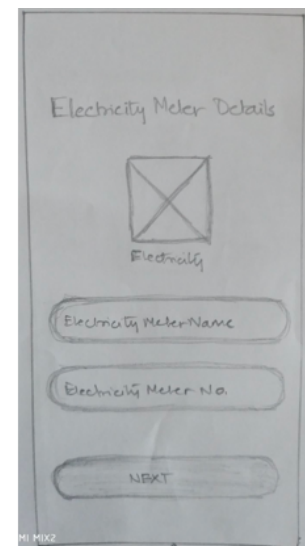
1. Splash Screen



2. Property Details



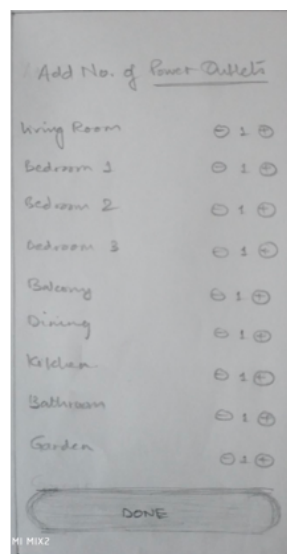
3. Choose Utility



4. Meter Details



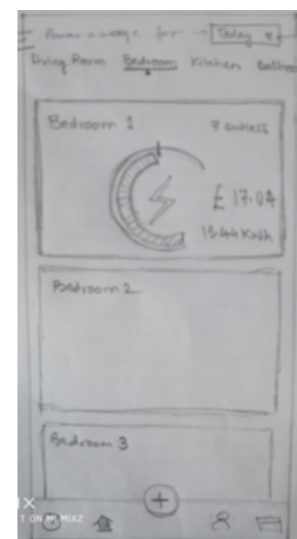
5. Floor Plan



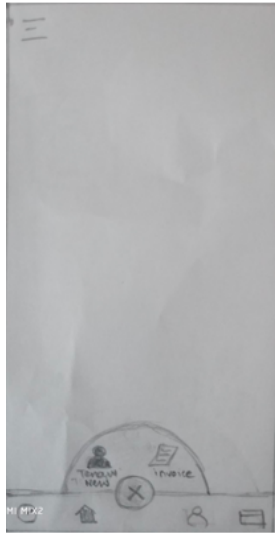
6. Power Outlets



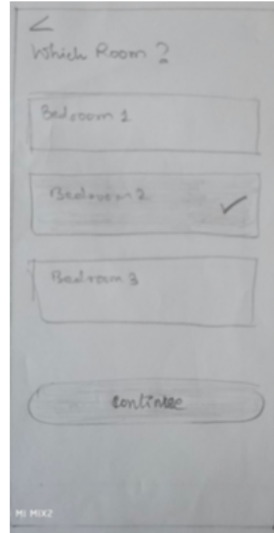
7. Dashboard



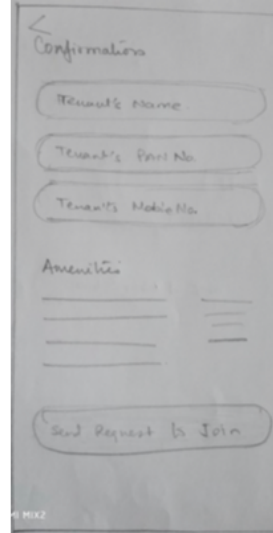
8. Individual Rooms



9. Tabs



10. Which Room?



11. Tenants Details

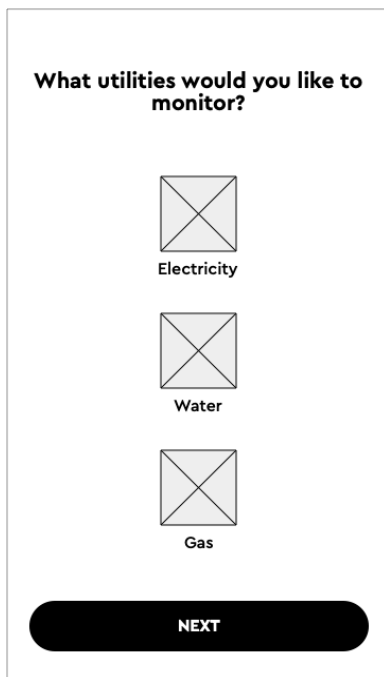


12. Tenants

2.4.2 Mid-Fidelity Prototype

After feeling a bit confident and comfortable with what was visualized on paper, next, the author tried creating the mid-fidelity prototypes.

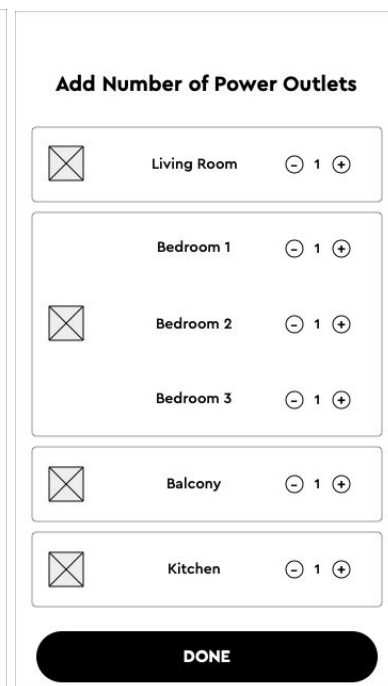
The Tool used: Sketch



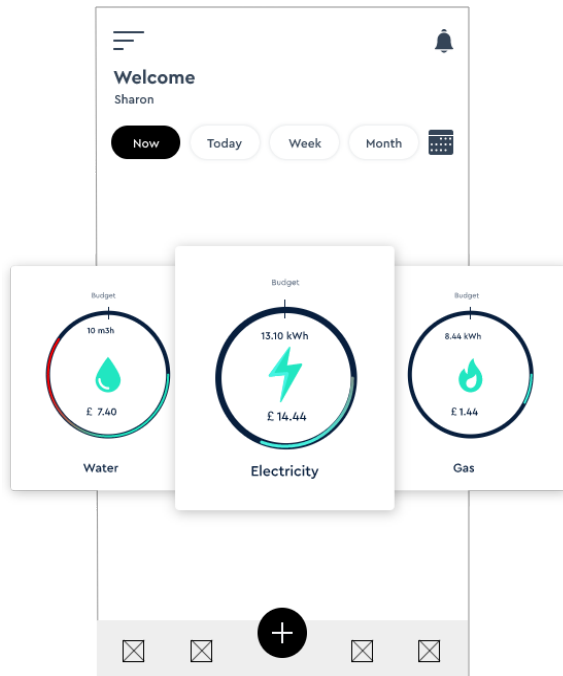
1. Select Utilities



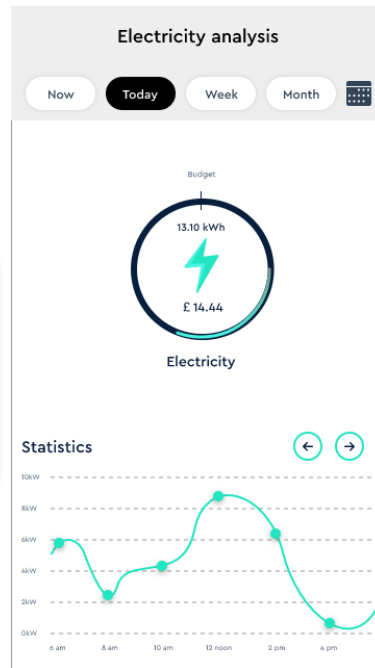
2. Create Floor Plan



3. Add Power Outlets



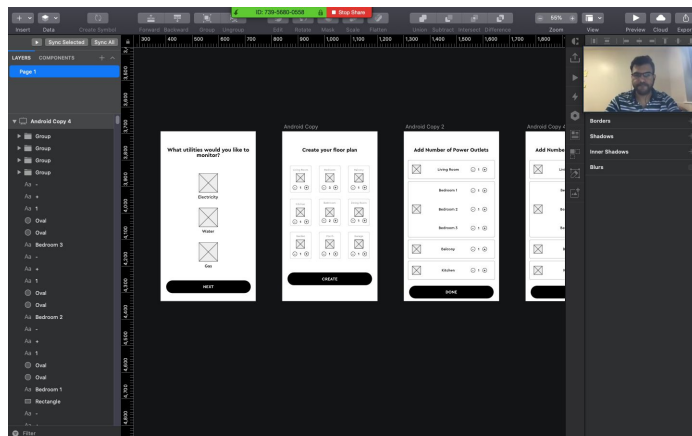
4. Dashboard



5. Analysis Graph

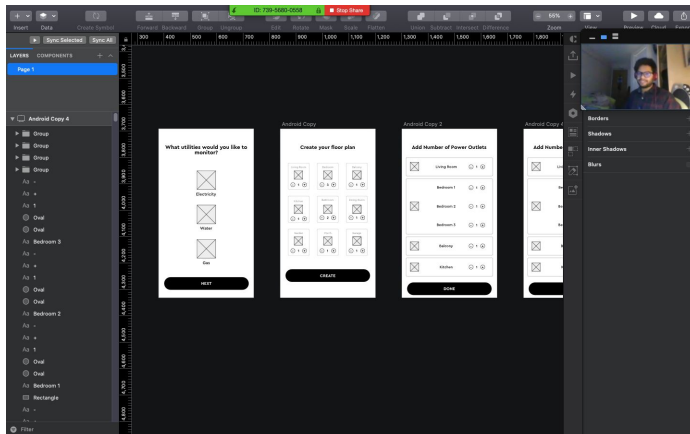
2.4.3 Formative Feedback

User 1:



- The user found the application simple and easy to use.
- The user was impressed with the minimalistic design approach.
- The user suggested making the data visualisation clearer by allotting more space to each type of utility for data visualisation.
- To visualise energy consumption data for each of the rooms.

User 2:

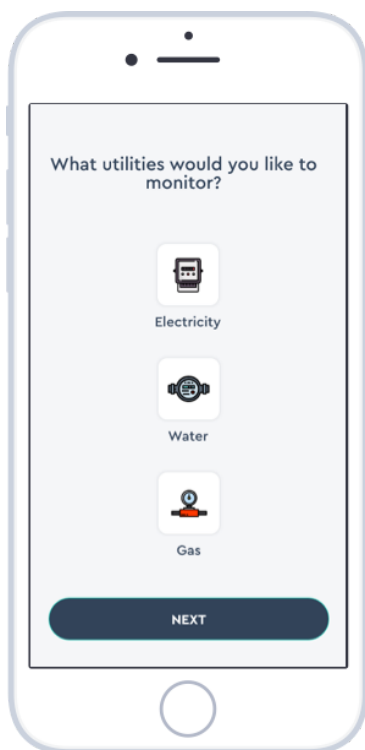


- The user wanted to see the data visualisation of energy consumption for all the devices in the house individually.
- The user suggested providing a comparative analysis graph, comparing the energy consumptions of individual devices.

2.4.4 High-Fidelity Prototype

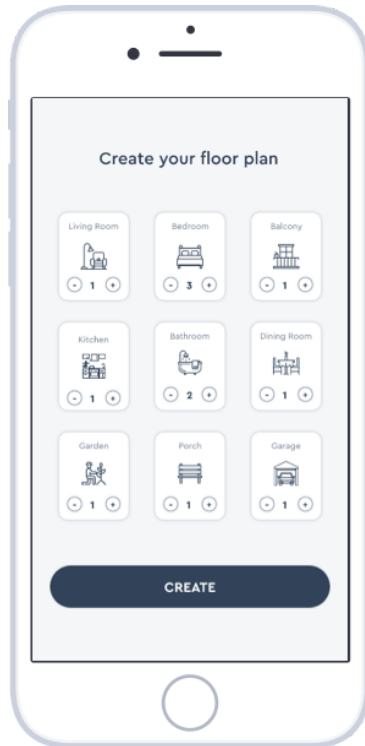
(Tool used: Sketch)

1. Select Utilities



- The landlords can select the utilities they would want to monitor. (Electricity, Gas or Water)

2. Create a Floor Plan



- The landlord would need to create a floor plan of their house mentioning the number of rooms with their types.

3. Dashboard



- The Dashboard Tab provides all the relevant energy consumption data, meter readings and bill amount for the landlords.

Discussion

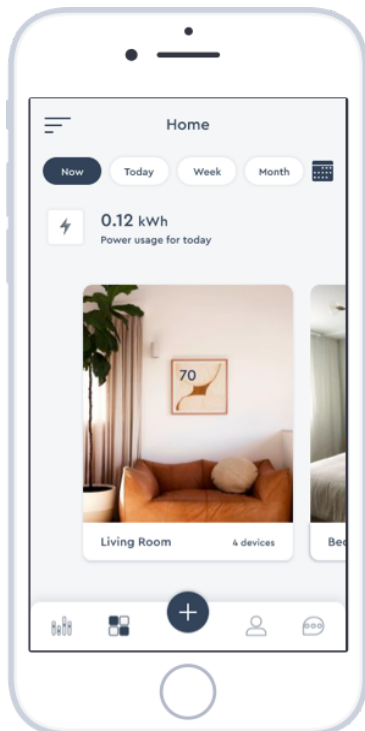
The reason behind choosing Line Graphs Data Visualization Format was the continuous flow of data from the cloud. In that case, there was no better choice than a line graph. This is often the clearest way to show trends, and it's often a much quicker visual read than a bar graph.

4. Analysis Screen



- The Analysis Screen provides a lines graph describing energy consumption in an easier way.

5. Home



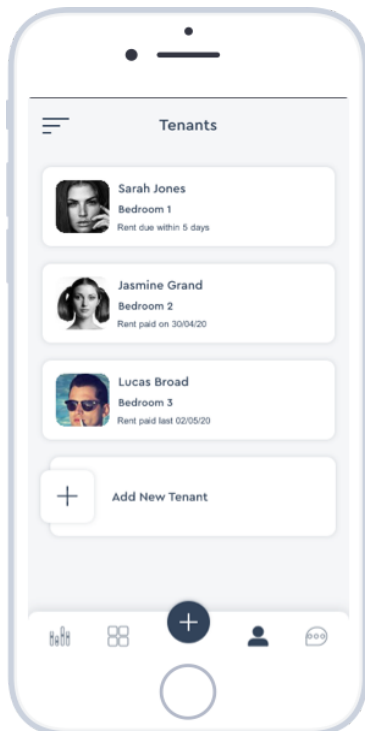
- The Home Tab consists of the different types of rooms in the house with the number of devices and their consumption data.

6. Consumption Data for Individual Rooms



- This screen visualizes the consumption data of different devices specifically.

7. Tenants

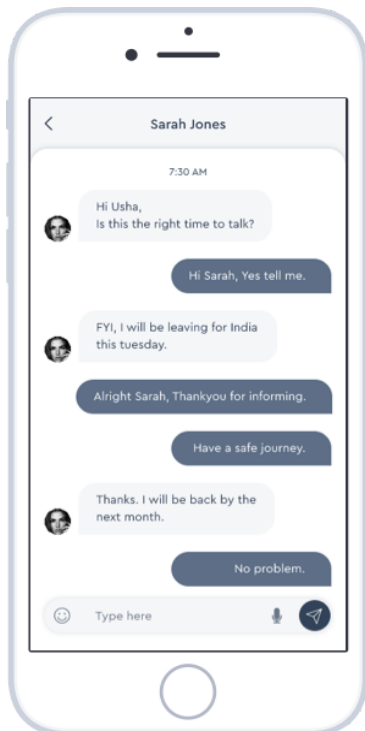


- The Tenants Tab consists of all the Tenants living in the house with their user-profiles and payment histories.

8. Chat

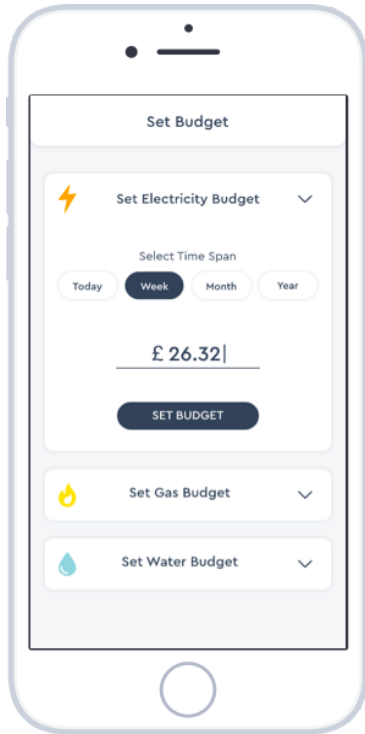
- The Chat Tab provides a feature for the landlords to communicate with their tenants via sending texts, sharing media and voice memos.

9. Conversation



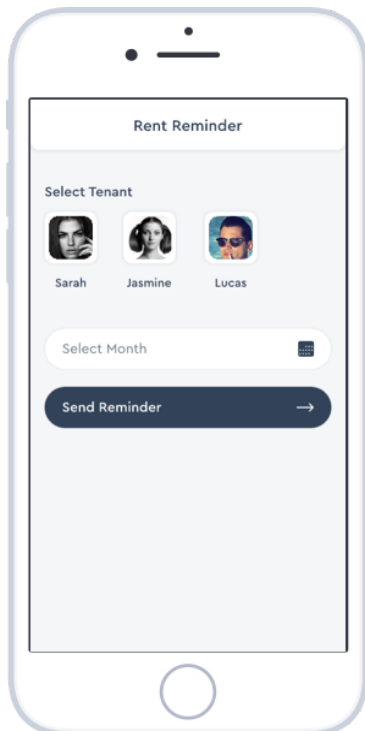
- This screen depicts a private conversation between a landlord and a tenant.

10. Set Budget



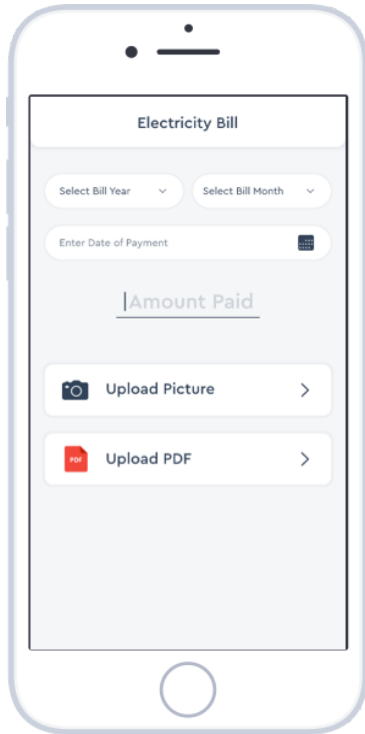
- The application provides a feature for the landlords to set daily, weekly or monthly budgets for the energy consumption.

11. Send Rent Reminder



- The application also lets the landlords send rent reminders to their tenants ensuring rent payment on time.

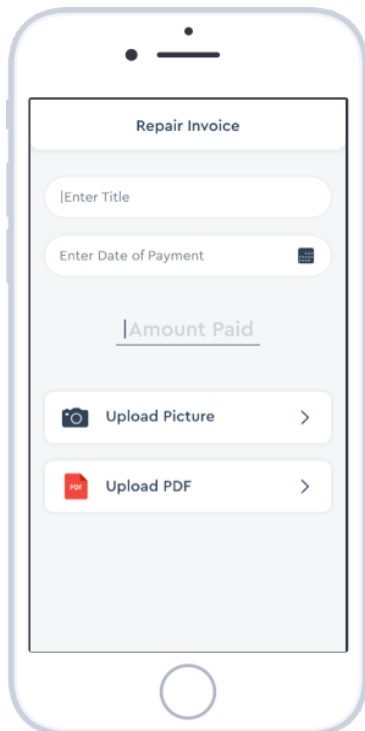
12. Add Utility Bill



The screenshot shows a mobile app interface for adding a utility bill. The title is "Electricity Bill". Below the title, there are two dropdown menus: "Select Bill Year" and "Select Bill Month". Below these is a text input field labeled "Enter Date of Payment" with a calendar icon. Below that is a text input field labeled "Amount Paid". At the bottom, there are two buttons: "Upload Picture" with a camera icon and "Upload PDF" with a PDF icon. Both buttons have a right-pointing chevron.

- The landlords can also upload any utility bills to the application ensuring easy management of the records.

13. Add Invoices



The screenshot shows a mobile app interface for adding a repair invoice. The title is "Repair Invoice". Below the title, there is a text input field labeled "Enter Title". Below that is a text input field labeled "Enter Date of Payment" with a calendar icon. Below that is a text input field labeled "Amount Paid". At the bottom, there are two buttons: "Upload Picture" with a camera icon and "Upload PDF" with a PDF icon. Both buttons have a right-pointing chevron.

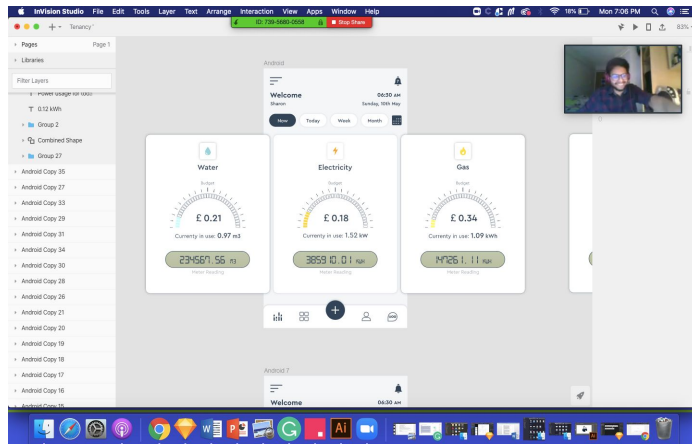
- The landlords can also upload repair or maintenance invoices to the application ensuring easy management of the records.

2.4.5 Link to Prototype

<https://projects.invisionapp.com/prototype/cka4blg71003s4o01cpyjyk91/play>

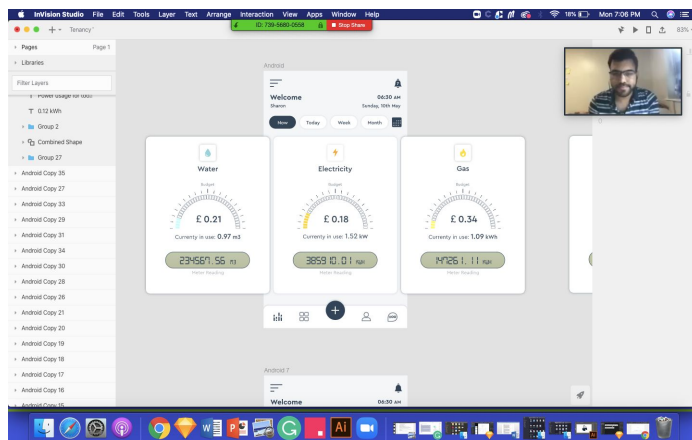
2.5 Test

User 1:



- The user was highly impressed by the user experience and the look and feel of the application.
- The user could easily visualise the energy consumption data for electricity, gas and water separately.
- The user especially liked seeing the real-time meter readings.
- He really liked seeing the real-time, daily, weekly and monthly consumption data separately.

User 2:



- The user was glad to see the energy consumption data for different rooms and devices individually.
- According to the user, the colours used were the best fit for data visualisation.
- The user also liked additional features such as setting daily, weekly or monthly budget and sending rent reminders to the users.

3. References

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4. Appendices

System Architecture Artefacts:

https://drive.google.com/drive/folders/1mJTgXZTJU-5At0SleZGS0_MeKNDN4Kdn?usp=sharing

Research Artefacts:

https://drive.google.com/drive/folders/1_-81iBKCnj7iZfTsINwpeBi7qfeRv7oo?usp=sharing

Define Artefacts:

https://drive.google.com/drive/folders/1O_e1SWmBrnbQ9MmANS_h61wkYeXVfwwB?usp=sharing

Ideate Artefacts:

https://drive.google.com/drive/folders/1_DtV9s2Ap5fDJQvkZnAt9FCKA95pMmCf?usp=sharing

Prototype Artefacts:

<https://drive.google.com/drive/folders/1hiSemg1rIm7K15xqVyqiMHnFr30qT1lM?usp=sharing>

Test Artefacts:

<https://drive.google.com/drive/folders/1wCb-K9oae9MkSM27sJLY1ZkLMROLZ9W4?usp=sharing>