



Final Product – Stage 2 Report

Github link : <https://github.com/HomeSpace3/HomeSpace-Release> (clean version of the web app, without the api key, with no commit history for security).

Group 3 – Software One

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1. Introduction

The HomeSpace app is a smart home system designed to promote energy efficiency and sustainability in households. The system enables users to add smart devices within their home and monitor the energy consumption of devices in the home, through an intuitive interface. The project aims to deliver a functional, user-friendly and enjoyable solution that encourages sustainable energy practices in homes.

The application was developed and tested locally using a localhost development server. The public GitHub repository serves as the primary reference for the application as we did not deploy the system.

1.1. Purpose

The purpose of this report is to present the final development, evaluation, and demonstration of HomeSpace, a smart home system designed for managing smart devices and promoting energy-efficient practices in sustainable homes. Stage 2 focuses on delivering a user-friendly and robust application that enables users to monitor energy consumption and manage smart devices within their homes.

This report is structured into several key sections, including the final application design and implementation, marketing strategy, the usability evaluation, and overall project assessment. In this stage, the team completed the development of the HomeSpace application, ensuring its functionality and usability. A final usability evaluation was conducted to assess user experience and user-friendliness, gathering insights into the system's effectiveness and areas for improvement. Additionally, the report includes an overview of the project's outcomes, details on the development process, limitations, setbacks faced, and potential enhancements to improve the product in the future.

1.2. Intended Audience

This report is intended to be read by:

Client: this report should provide a comprehensive overview of how the project meets the system requirements and delivers value.

Line Manager: this report should help the line manager track project progress, ensure alignment with project expectations and review accomplishments.

Software One Development Team: this report should serve as a reference for the development team to review system requirements, design details and usability findings for further improvements.

2. Final System Design and Implementation

2.1. High-level Overview

HomeSpace is a smart home application, designed to help users manage their energy consumption efficiently while also giving them control to all their devices/smart devices. Users can manage their homes by remote access and manage user permissions. The system has real-time monitoring, automations, and gamification features to encourage users to save more energy. We developed the front end of our smart home system using React.js and the back end, authentication, and database using Firebase as well as Node.js for two-factor authentication. These were selected because of their smooth integration, scalability, ease of development, and real-time capabilities. These ensure that the system is responsive and efficient on both mobile phones and desktops.

Purpose

The goal of HomeSpace is to help users reduce their energy consumption and automate tasks to make it more convenient. Many households waste energy unnecessarily due to limited control and a lack of real-time energy insights. HomeSpace helps with these issues by providing:

- **Real-time energy monitoring.**
- **Scenes and automation.**
- **Remote device control.**
- **Gamifications and rewards.**
- **Home management.**
- **Cross-platform compatibility.**

The Scenes is our key feature which helps the users with automation based on predefined conditions or schedules allowing users to create a scene by selecting multiple devices (e.g., lights, plugs), they define conditions or triggers for when the scene should be active, once the scene is triggered, all selected devices will automatically turn on or off based on the users

conditions. Scenes enhances convenience by allowing users to configure settings such as "Morning Routine" (turning on lights and adjusting the thermostat) based on either a schedule or the user manually triggering the scene on the app. With HomeSpace, users can also access their consumption data and device status so that they can monitor their energy usage. Energy monitoring is a key feature, so users have real-time tracking of their energy consumption to have knowledge on their usage patterns. The system also provides users with energy saving tips for each device, this helps users track their progress, get points and become higher up in the leaderboard.

2.1.1. Core technologies & components

Component:	Technology:	Reason:
Frontend	React.js	Provides a fast and interactive UI for smooth user experience.
Backend	Firebase	Provides a serverless, scalable solution for real-time data management.
Database	Firestore (NoSQL)	Ensures real-time synchronization of user data and smart device status.
Authentication	Firebase Auth	Provides secure user authentication with google and email login options.

Figure 1: Core technologies & components

Interaction flow between components

- The user logs in through the React frontend, which sends authentication requests to Firebase Authentication.
- The frontend shows device status and energy consumption by retrieving real-time data from Firestore.
- A request is made to Firebase Functions when a user interacts with the user interface (such as turning a device on or off), and Firebase Functions updates the database and initiates actions on linked devices.
- Changes in Firestore trigger automatic UI updates to ensuring a real-time experience for users.

- The Scenes feature allows multiple devices to be controlled simultaneously based on predefined rules (e.g., "Night Mode" turns off all lights and lowers the thermostat).

Energy monitoring and device management

- Real-Time Tracking: The system continuously receives power consumption data from smart devices.
- Analytics & Insights: Users receive personalized reports and notifications about excessive energy use.
- Device Scheduling & Control: Users can schedule devices to turn on/off at specific times.
- Scenes Automation: Users can set predefined automations for multiple devices, such as "Morning Routine" (lights on, thermostat set to 22°C).

2.2. System Design & Data Flow

2.2.1. System Architecture Diagram

The system architecture diagram below shows how the components in HomeSpace interact with each other, providing a high-level overview of the system. The diagram helps visualise the technologies used in our application.

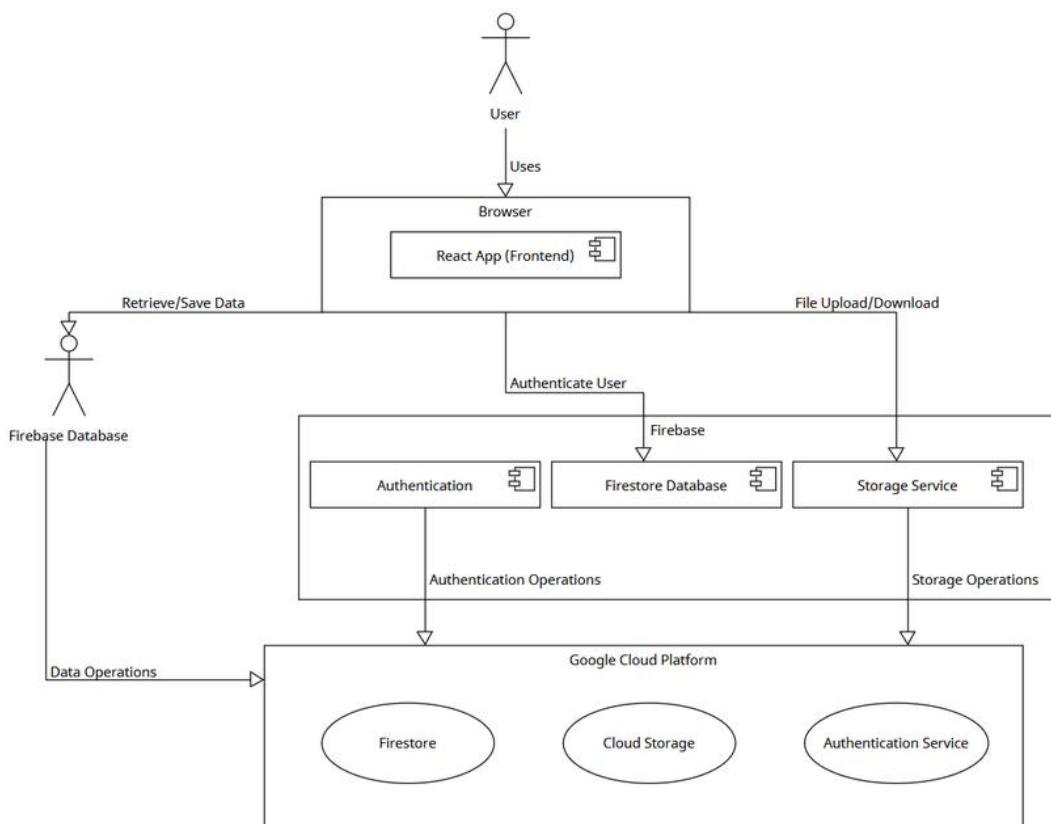


Figure 2: HomeSpace system architecture diagram

2.2.2. Frontend

React.js was used in the development of the interactive, responsive, and modular user interface. Because of its component-based architecture, which guarantees that UI elements are scalable, maintainable, and reusable, we went with react.js. This enhances user experience by making it simpler to update the interface elements without having to reload the entire page.

- o **Component-Based Architecture:** The UI is divided into components that are reusable. This makes the system scalable and maintainable.
- o **Responsive Design:** Tailwind CSS was used to create flexible consistent designs across different screen sizes making the app is responsive and ensuring usability on desktops, tablets, and mobile devices.
- o **Navigation & Routing:** React Router provides smooth page transitions without reloading the entire app.
- o **Private Routes & Authentication:** Secure private routes ensured that only signed-in authenticated users can access protected pages.

The navigation and frontend user-interface are discussed further in more detail in **section 3.5**.

2.2.3. Firebase

For our application backend, we used Firebase to handle authentication and implement our database. It is a backend-as-a-service platform provided by Google, commonly used in app development (*Cloud Computing Services | Google Cloud*, n.d.).

Firebase provides a fully managed backend which allowed us to focus on the main app requirements and features without worrying about server infrastructure. Compared self-hosted backend databases such as MongoDB or PostgreSQL, Firebase is fully managed, removing the need for manual setup and maintenance. Furthermore, it also integrates well with our frontend framework ReactJS.

- **Firebase Authentication:** We used Firebase authentication to manage user registrations, logins, and session handling. This enabled secure access control, ensuring that only authorized users can access app features. Firebase Auth supports email/password authentication, and its seamless integration with Firestore allowed us to associate users with their respective homes.
- **Firestore database:** We used Cloud Firestore as our NoSQL database to store and manage *users, homes, devices, scenes, and energy consumption data*. Firestore stores data in collections, with each collection containing documents that hold key-value pairs and data in various data types. **Section 3.2.3.** goes into more detail about our database implementation including the database structure.

2.2.4. Firestore Database

Our NoSQL database is structured around two root-level collections: *Homes* and *Users*. The *Homes* collection stores information about homes that are created by users. Each home is stored as a document within the collection and each document stores information about the home including its members, devices, energy records and more. Each home document has sub-collections for devices, energy records and scenes. This enables us to keep an organised structure for the database and use efficient queries for writing and retrieving data.

The *Users* collection holds individual user details. A user document is created when a user signs up, sensitive information including passwords are not stored and handled securely by Firebase authentication. User documents store user specific details including name, email address, phone. The documents also have a field ‘homeld’ which is used to associate a user with the home they are in, empty when a user is not part of a home.

Below is the schema description for the HomeSpace database:

Homes collection (*homes*/):

```
Document (string - autoid)
    createdAt (timestamp)
    homeld (string)
    homeName (string)
    ownerId (string)
    members (array)
    membersPermissions (map)
        {userId (string)} (map)
            addDevice (boolean)
            removeDevice (boolean)
            manageScenes (boolean)
            viewAnalytics (boolean)
```

devices sub-collection (*homes/{homeld}/devices*/)

```
lastUpdated (timestamp)
manufacturer (string)
model (string)
name (string)
powerRating_kW (number)
status (Boolean)
```

energyConsumption sub-collection

```
daily (document)
Date (timestamp)
Sessions (array)
```

- Start (timestamp)
- End (timestamp)
- Energy (number)
- Total (number)
- monthly (document)
 - date (timestamp)
 - total (number)
- yearly (document)
 - date (timestamp)
 - total (number)

energyRecords sub-collection (**homes/{homelId}/energyRecords/**)

- daily (document)
 - date (timestamp)
 - total (number)
- monthly (document)
 - date (timestamp)
 - total (number)
- yearly (document)
 - date (timestamp)
 - total (number)

scenes sub-collection (**homes/{homelId}/scenes/**)

- createdAt (timestamp)
- devices (map)
 - deviceld (string -> map)
 - action (string)
 - homelId (string)
 - name (string)
 - type (string)
 - user (string)

Users collection (users/):

- Document (string - autold)
- createdAt (timestamp)

```
userId (string)
firstName (string)
lastName (string)
email (string)
phone (string)
dateOfBirth (string)
twoFactorEnabled (boolean)
twoFactorVerified (boolean)
homeId (string)
isAdmin (string)
```

Device Management and Energy Tracking

Devices are added to a home via QR code scanning, which provides the model, manufacturer, and power rating (kW). A new document is created in the devices sub-collection (e.g., homes/{homeId}/devices/{deviceId}), initializing an energyConsumption sub-collection with daily, monthly, and yearly documents. When a device is toggled on/off, a session is recorded in the daily document's Sessions array, with start, end, and energy (kWh) calculated as powerRating_kW × session duration (hours). Daily, monthly, and yearly totals are updated by summing session energies, and the energyRecords sub-collection aggregates these totals across all devices for home-level metrics, enabling real-time monitoring and analytics.

Firestore database class diagram

Since Firestore is not a relational database, it does not use tables and foreign key relations. Instead, it structures data in collections where a collection can contain documents and sub-collections. Documents can also have sub-collections within them. To effectively visualise the hierarchical structure and associations between different entities in our database, we have chosen to use a generic UML-style class diagram. Although class diagrams are typically used for Object-oriented programming, we have decided to use one as it provides a clear way to visually represent associations between our different Firestore documents.

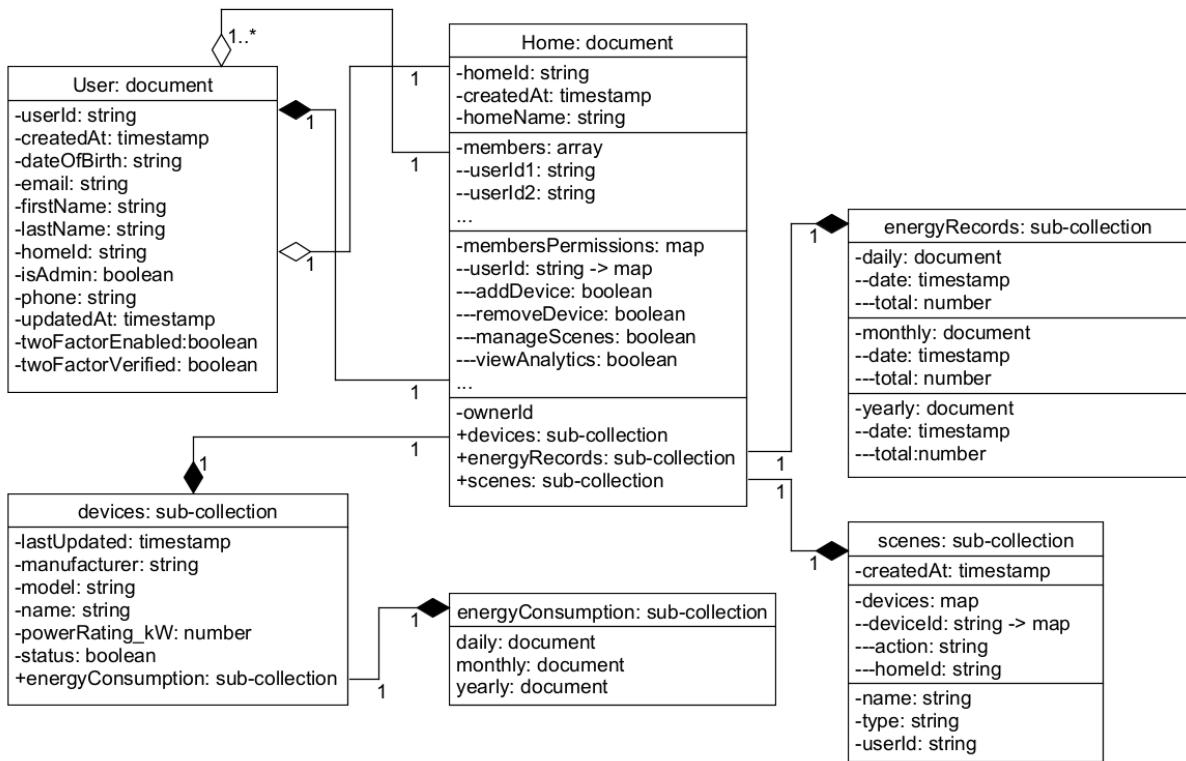


Figure 3: Generic class diagram representing the database structure and hierarchy

2.2.5. NodeJs and Express

To implement two-factor authentication (2FA), we built a custom solution using Node.js with Express, as Firebase Authentication did not fully meet our 2FA requirements. This system integrates with the Google Authenticator app to generate and verify one-time passwords (OTPs), adding an extra layer of security to user authentication.

The Express server handles 2FA enrolment and verification. When users enable 2FA, a secret key is generated and stored securely in Firestore. A QR code is also provided for easy setup with Google Authenticator. During login, users must enter an OTP, which the server verifies before granting access.

Our backend uses:

- Speakeasy – Generates and verifies OTPs.
- QRCode – Creates QR codes for users to scan.
- Axios – Handles API requests between the frontend and backend.

Currently, the Express server runs locally due to budget constraints, requiring manual execution using a local IP address. While we explored cloud hosting solutions like Firebase Functions and Vercel, they were either cost-prohibitive or did not provide the flexibility required.

For security, the 2FA secret is securely stored in Firestore using a merge update strategy to prevent data loss. To mitigate abuse, we enforce a verification window and plan to implement rate-limiting for OTP verification attempts in the future.

2.3. Final State of Project Requirements

In the final application, we have successfully implemented a fully responsive design, real-time energy tracking with consumption updates, user account and home management, and automation through customizable scenes. We made significant changes to our initial design plan after conducting usability testing on our prototype. The feedback revealed that the application was somewhat confusing to navigate and lacked clear explanations, particularly regarding the scenes feature. As a result, we refined the design by adding more descriptions to improve user flow and provide more guidance on how to use the features in our system.

The improvements we made primarily focused on refining the layout and components of the application. We redesigned the navigation bar and added more buttons, each clearly indicating its purpose or destination. While these updates significantly enhanced usability, we acknowledged that not all desired features could be implemented within the time frame, so some were postponed for future updates. The features that were postponed include gamification and privacy & ethics. For gamification, we implemented initial elements to signal to users that it's a feature to look forward to in future updates. Regarding privacy and ethics, while this is a key aspect that we discussed while making the system, we weren't able to fully implement it at this stage. However, it will be prioritized in future updates.

2.3.1. Implemented Features

This overview highlights the key features implemented in HomeSpace based on our requirements, detailing their functionality:

- **Energy Tracking and display:** The system monitors and records energy consumption in kilowatt-hours (kWh) for each device, ensuring up-to-date insights about their energy usage. Additionally, it updates consumption data daily, providing users with a real-time understanding of their usage patterns. Also, the system enables users to track their energy consumption on a daily, monthly, and yearly basis, allowing them to make informed decisions based on their usage.
- **Graphical display:** We implemented graphs to represent energy consumption data, this allows users to easily track their progress over time. Additionally, the system uses graphs to compare the user's energy consumption, offering insights on how their usage varies from time to time. This feature helps users pinpoint areas of improvement they can manage their energy use efficiently.
- **Account & home creation:** We designed a secure account creation process that allows users to sign up and log in with their email and password. Once logged in, users must either create a new home or join an existing one using a home ID. If they choose to create a home, they simply enter a name, and the system generates a unique home ID that they can copy and use to join their home.

- **Profile settings:** Users can edit their personal details, including name, email, and password, directly from the profile settings page.
- **Device management & remote access:** Users can add or remove smart devices within their home environment. They can manage all connected devices, monitor their real-time status, and control them remotely as long as they have a Wi-Fi connection.
- **Scenes and automation:** We developed scenes that lets users group multiple devices and set their status (on/off) either manually through the app or automatically at a scheduled time.

2.3.2. Unimplemented Features

One of the main features that remains unimplemented is the gamification elements and the rewards system due to time constraints and being a lower priority feature.

- **Gamification & Rewards System:** Planned features including points and badges were meant to encourage energy-efficient habits through rewarding users for maintaining low energy consumption and utilising devices efficiently. However, since due to our system design energy consumption data was tracked per home rather than per user implementing personalised rewards was not feasible.
- **Community Leaderboard:** Another gamification feature to compare energy usage with similar homes or friends was considered to encourage efficiency through friendly competition but was not implemented due to the same reasons above. However, in future iterations of the project, energy usage per home could be considered for a home-based leaderboard within communities, to enhance engagement.
- **Notifications & usage alerts:** A feature to send alerts based on consumption trends (e.g. "You are using 40% more energy this week than last week! ") was not implemented. This would have provided timely feedback to users and can be implemented in future iterations of the project to improve user experience.

Future iterations of HomeSpace can incorporate these features to improve user engagement and encourage energy-efficient habits. Implementing per-user energy tracking would enable personalised rewards and point-based leaderboards for homes. These improvements would make the app more interactive and enjoyable, motivating users to be more sustainable.

To view the list of all functional requirements for HomeSpace and a complete breakdown of how many requirements were achieved please check **section 5.3.** of Project Evaluation.

2.4. UML diagrams

2.4.1. Updated Use Case Diagram

Provided below is the updated use case diagram for the HomeSpace app. It has been adapted from the stage 1 use case diagram and updated accordingly to highlight the key changes from our planned version of the App. One of the features we were not able to implement in this stage due to time constraints was the gamification features and the rewards system. This has been removed from the diagram to reflect the change.

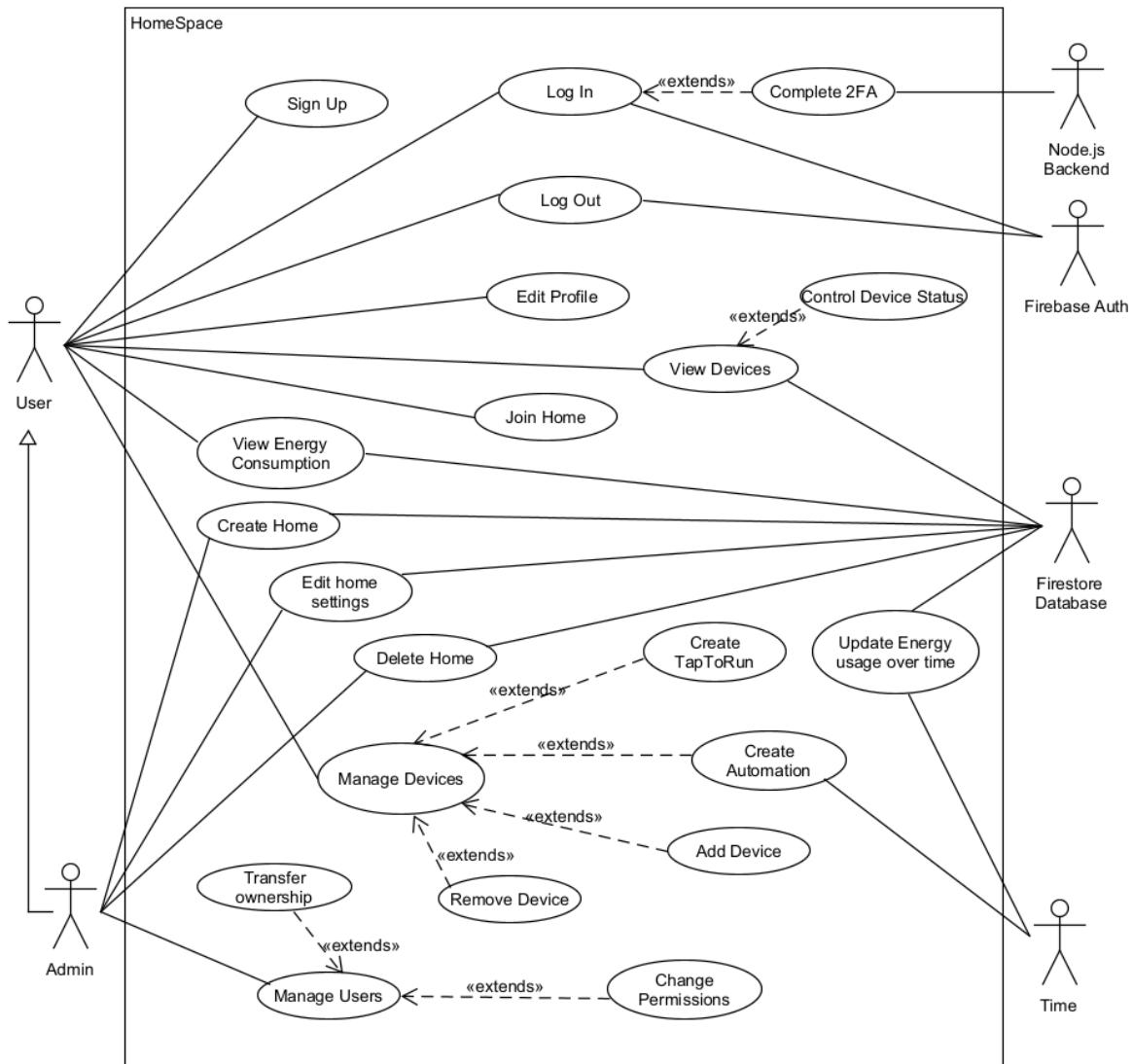


Figure 4: Use Case Diagram (stage 2)

2.4.2. Activity Diagram: User Sign In

The activity diagram provided below illustrates the system's workflow for user sign-in and authentication, depicting the user's actions and interactions. This diagram shows how the user logs in and how authentication is set.

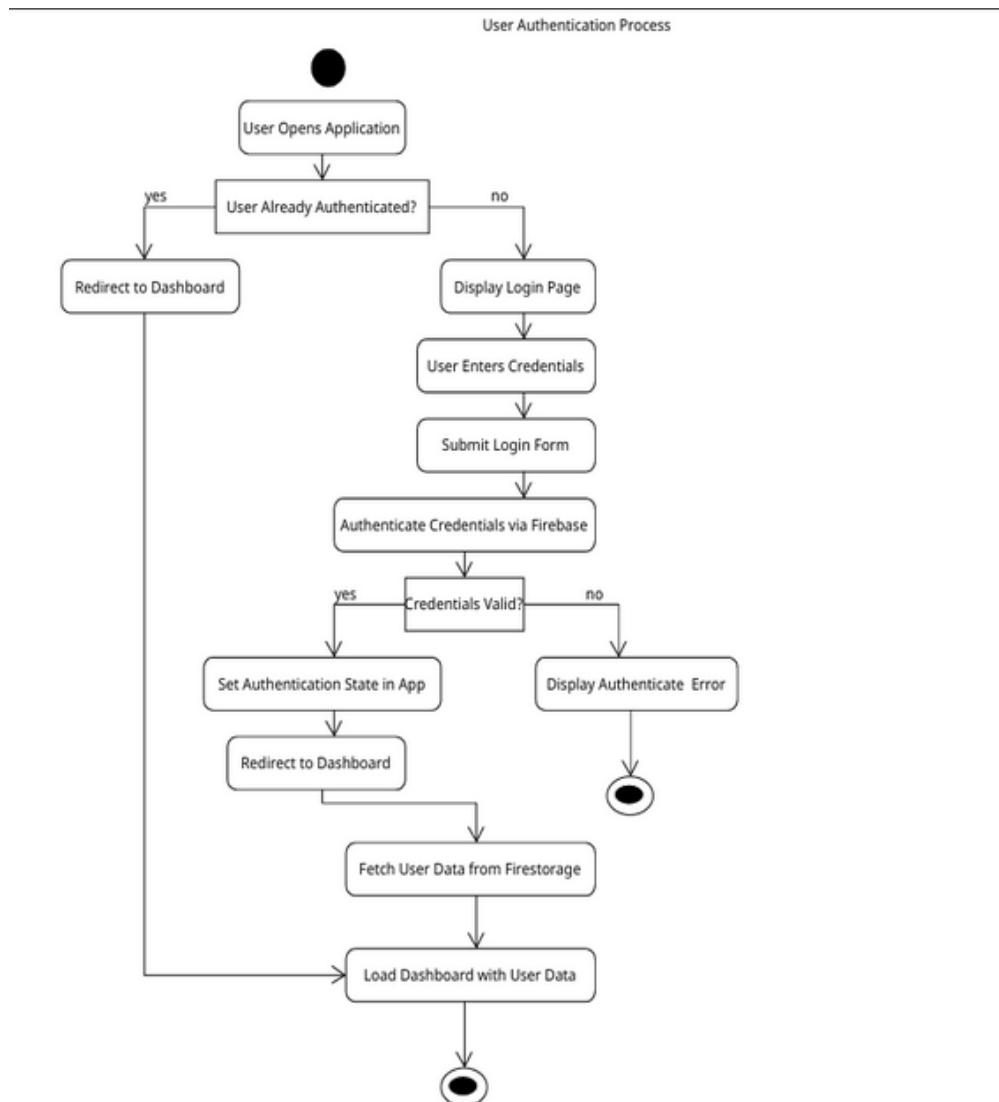


Figure 5: Activity diagram for user sign-in

2.4.3. Sequence Diagram (Authentication)

This sequence diagram shows the HomeSpace React App authentication flow. The user logs in, and Firebase validates credentials using Google Cloud Platform. In the case of an unsuccessful authentication, an error message is displayed.

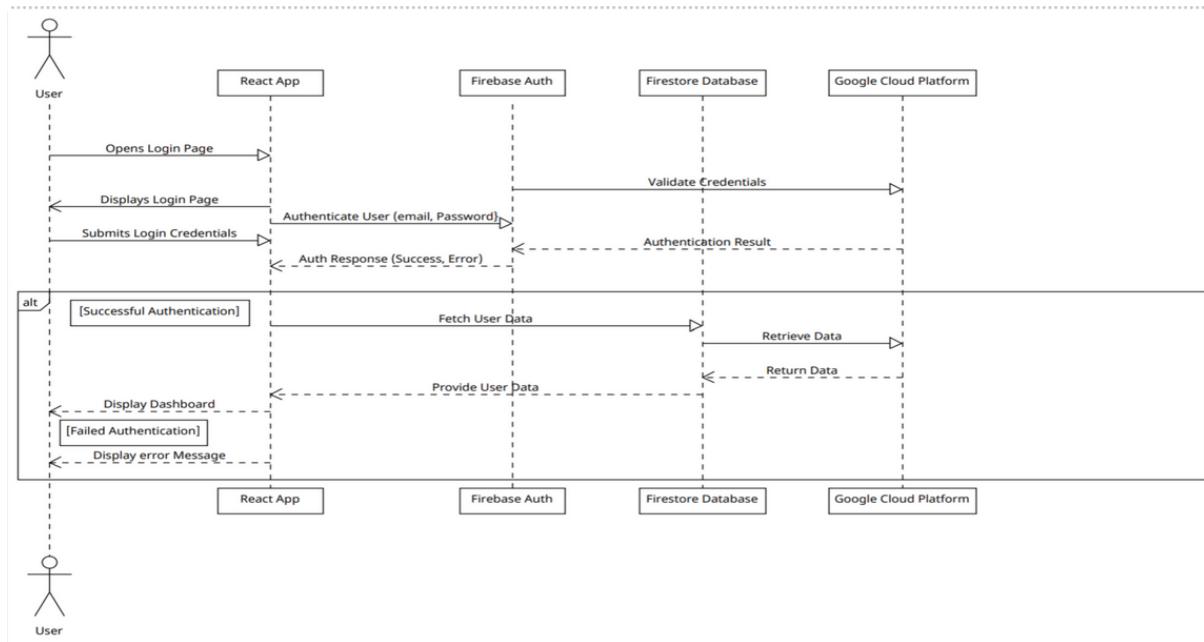


Figure 6: Sequence diagram for user authentication

2.5. Final Interface Design

HomeSpace app is made to present a cohesive user experience for the control of smart homes. Navigation and layout are designed to enable users to simply access the core functionalities such as energy monitoring, device control and scenes. The final design of the interface is a balance of aesthetics and functionality. Also, it is responsive on both phones and desktop. Navigation is smooth, easy to navigate between different sections of the app. This gives users easy access to all their data. Through this design approach, HomeSpace provides users an easy way to monitor their homes with good user experience.

2.5.1. Sitemap Diagram

A sitemap diagram has been provided below to clearly illustrate the navigational structure of the HomeSpace app. The sitemap represents how users move between pages, the pages in the diagram are categorised based on user access levels:

- Publicly accessible pages: available to everyone.
- Restricted to signed-in users: only visible to authenticated users setting up a home after signing up or leaving an existing home.
- Accessible to home members: restricted to signed-in users who are part of a home.
- Admin-only pages: accessible only to homeowners (admins) who have full control over home settings and member management.

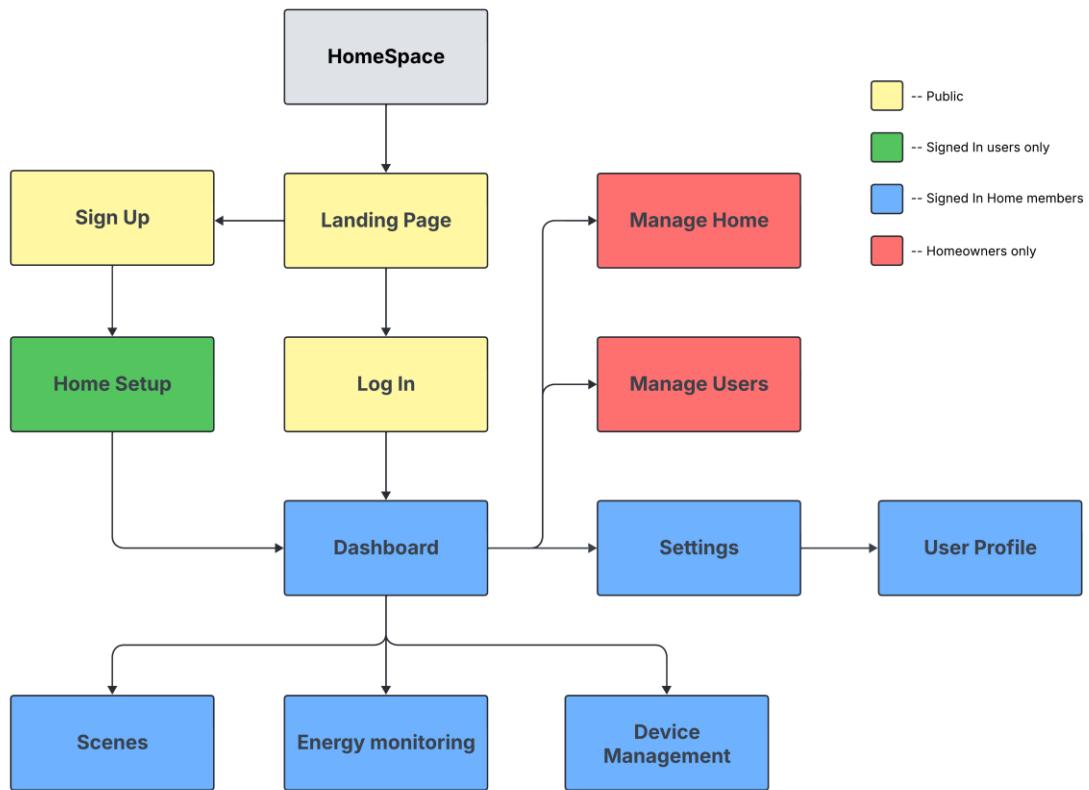


Figure 7: Sitemap diagram showing app pages and navigation

2.5.2. Frontend Interface Designs

Navigation

HomeSpace has 2 navigation bars on desktop, each designed to enhance the user experience at different stages of interaction. providing easy access to information about the app and allowing users to learn more before creating an account. the second navigation bar is displayed, granting users access to the full range of features, including Energy Monitoring, Device Management, and Scenes.



Figure 8: App header and navigation bar

On mobile devices the first navigation bar changes pages as you scroll, serving as the landing page, while the second navigation bar transforms into a footer bar.

Landing Page

The landing page is designed to introduce users to our application, featuring a navigation bar that allows users to scroll through various sections of the page. As users scroll, the content changes dynamically, or they can use the navigation bar to directly access specific sections of the page.

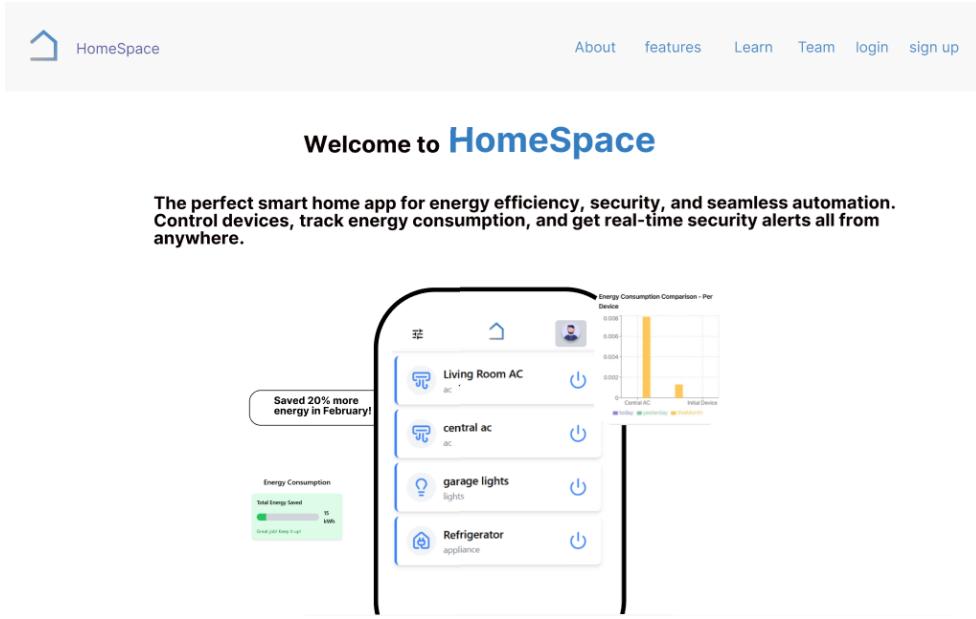


Figure 9: HomeSpace Landing page

Login/Signup

This is the sign-up popup, where users can create an account while ensuring they meet the required age criteria. Once registered, they must log in to proceed with setting up their home.

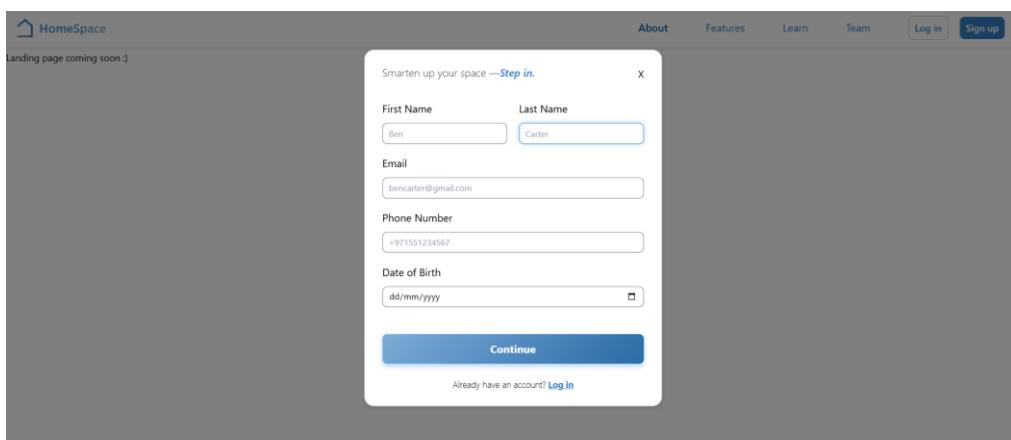
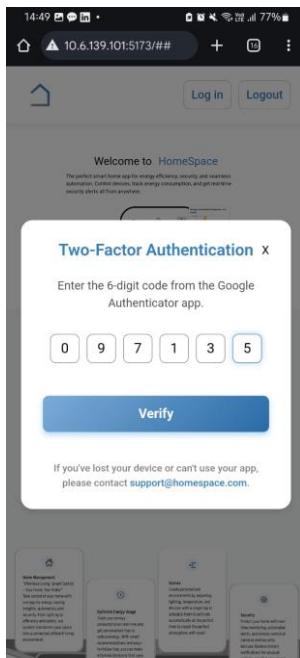


Figure 10: User Sign-up and Log-in

2-factor authentication

We implemented 2-FA as an extra security layer, it requires the user to verify their identity by a temporary code sent to their email, this is to prevent unauthorised access.



Join/Create home

After creating an account, the user is directed to this page. If they already have a home, they can join by entering their **Home ID**. Otherwise, they can create a new home, choose a name, and join.

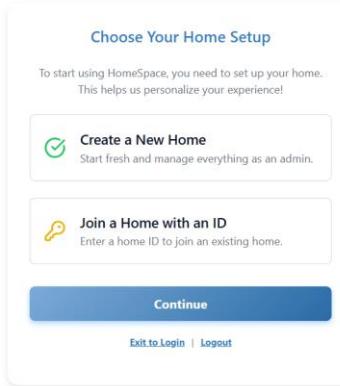


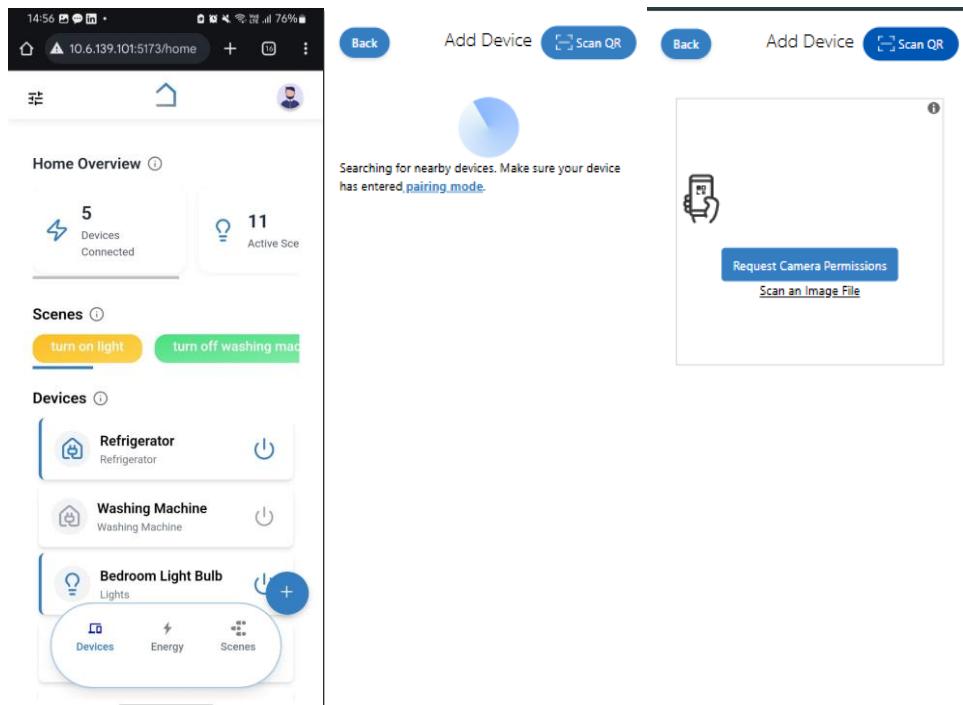
Figure 12: Home setup page

Dashboard

After creating an account, the user is directed to this page. If they already have a home, they can join by entering their Home ID. Otherwise, they can create a new home, choose a name, and join.

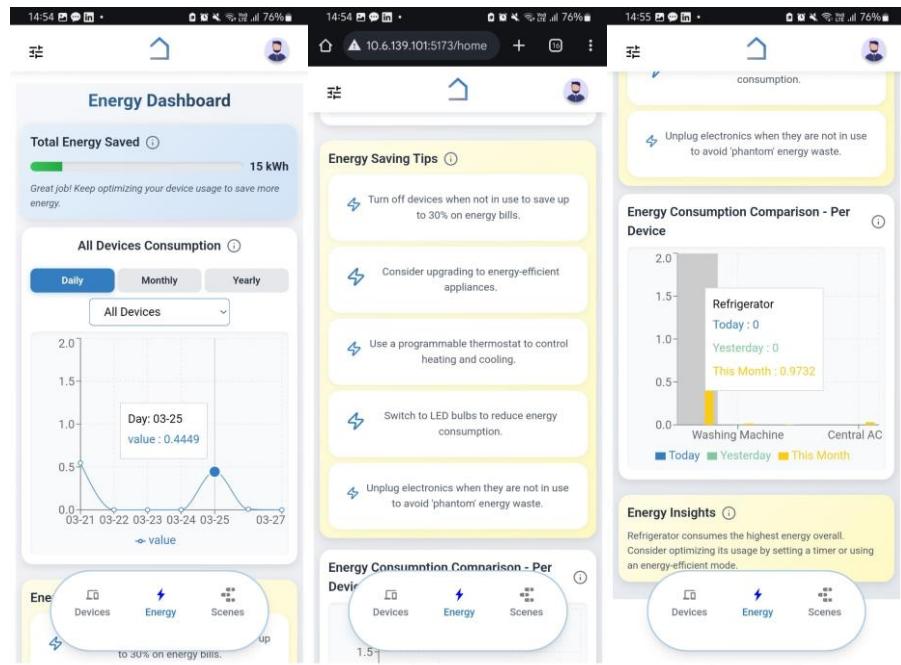
Adding devices

When users click the Add Device button, they are taken to this page, where they can scan their device's QR code to complete the setup. Home overview displays the number of connected devices and how many scenes are active.



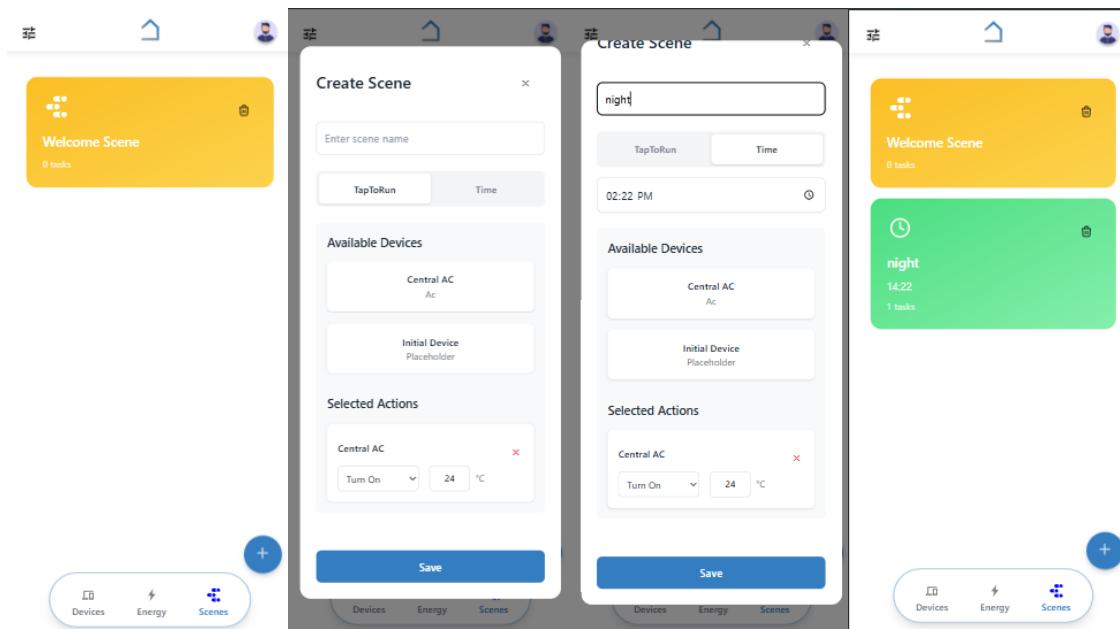
Energy

After adding devices, users can track the exact energy consumption of each device daily, monthly and yearly, while the system provides personalized tips to help them save energy.



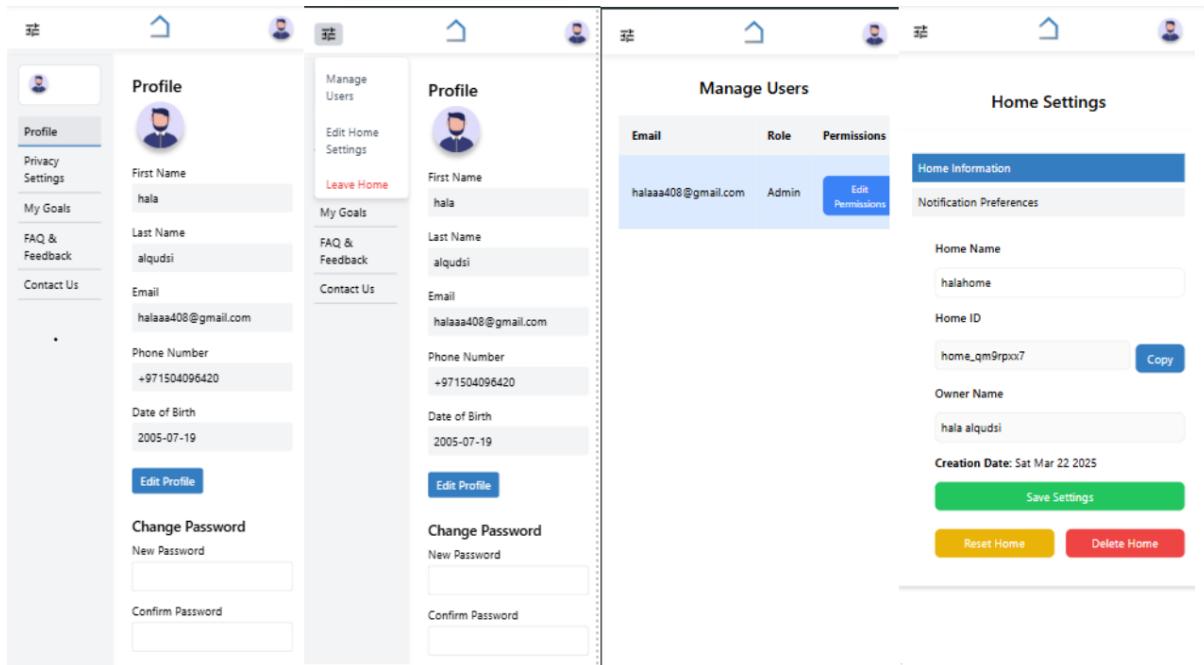
Scenes

The Scenes page allows users to control multiple devices simultaneously by creating a scene, including turning them on or off or setting the AC to a specific temperature. Users can manually activate or deactivate a scene with a tap or schedule it to turn on and off at a set time.



Settings/Home management

The first page shown is the Settings page, where users can update their profile details, including their name, password, and other account information. Additionally, the button at the top left of the navigation bar provides access to Home and User Management. In the Manage Users section, the admin can modify user permissions, while the Edit Home Settings section allows users to change the home name, reset the home, or delete it. The sidebar also enables users to manage their privacy settings and preferences, ensuring they have full control over their account and home environment.



2.5.3. Implementation Methodology

During the development of HomeSpace, we used Scrum framework. Scrum was chosen because it is an adaptable and iterative methodology, enabling us to gradually enhance the system.

The project was broken up into several sprints, each of which concentrated on deliverables and features. Among the essential Scrum elements, we implemented:

- **Sprints:** The project was divided into multiple sprints, each with distinct objectives and results.
- **Sprint Planning:** We held meetings prior to each sprint to plan and organise in order to create the sprint backlog and prioritise the work.
- **Weekly Stand-ups:** The team held weekly stand-up meetings to talk about progress, challenges, and future goals. This ensured that the development process was going according to plan and that the problems we were facing had been fixed.
- **Sprint Reviews:** We held a sprint review at the end of each sprint to show the newly added features to get feedback from our group members and line manager.
- **Sprint retrospectives:** At the end of each sprint, we held a retrospective to evaluate what we have done and identify areas of improvement. This helped improve our workflow for future sprints.

Our group's work was better organised thanks to the Scrum process, and we were able to complete many crucial features, such as scenes, energy monitoring, device management, and gamification elements, at the end of each sprint. The implementation schedule has been provided in **section 5.2.** which goes into more detail on the structure of the sprints and what was achieved

2.6. System Testing

The testing process was conducted within the framework of the Scrum methodology, integrating testing into each sprint. Initially, testing was informal, but as development progressed, we refined our approach to align with industry-standard practices. The primary objective was to ensure that core features were stable, functional, and met expected requirements, with a focus on usability, scalability, security, and performance.

The testing process followed a structured approach tailored to our development cycle while incorporating essential software engineering test planning principles. This approach ensured that testing was efficient and aligned with sprint timelines.

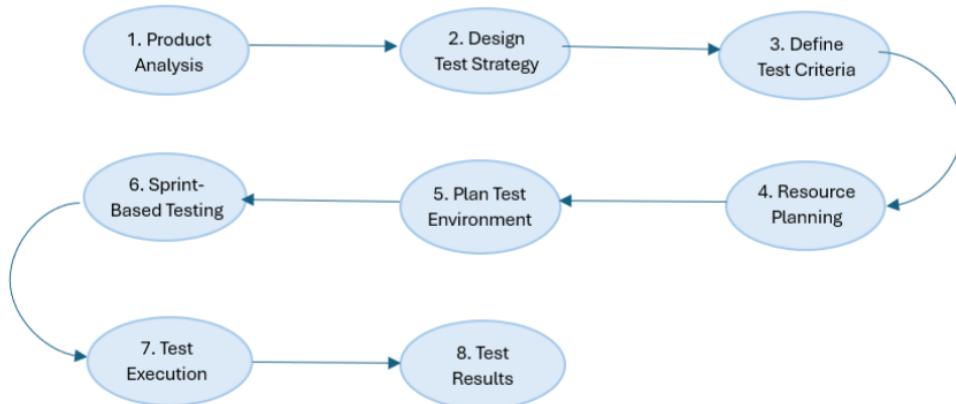


Figure 11: Testing structure

2.6.1. Product Analysis

Before development began, we identified key stakeholders, software and hardware requirements, and the overall purpose of our application (as briefly mentioned in the previous sections). This foundational understanding enabled us to establish a clear test strategy and maintain an efficient development pace.

2.6.2. Test Strategy

Initially, testing was conducted informally as features were developed. However, we refined this approach by implementing structured testing at the end of each sprint in line with Scrum principles. Balancing comprehensive testing with sprint deadlines proved challenging, requiring significant effort and time. To manage this, we prioritized key features for testing purposes and appropriate testing types.

Scope

The primary features tested included:

- User signup and login
- Create and join home
- Add and manage devices

- View real-time energy data
- Manage scenes
- Edit user profiles
- Manage user permissions
- Manage home settings
- Logout and leave home functionality.

Lower-priority features such as managing home preferences and energy-based permissions, as well as late-implemented features like two-factor authentication (2FA) could not be tested extensively due to time constraints.

Testing Types

The primary testing methodologies used were:

- **Functional Testing** – Ensuring core functionalities worked as expected.
- **Regression Testing** – Checking that new changes did not break existing features.
- **Integration Testing** – Validating seamless interactions between different components.
- **Usability Testing** – Evaluating user experience and responsiveness.

Security testing was limited due to the late implementation of certain security features, as noted in the limitations section.

2.6.3. Test Criteria

Testing followed **exit criteria**, marking a sprint's testing phase as complete when most test cases passed successfully. Any failed test cases were documented and prioritized for resolution in the subsequent sprint, ensuring continuous improvement. This can be depicted by the table in **2.6.6**.

2.6.4. Resource Planning

Testing required both human and system resources. Due to inconsistent attendance at meetings, only a limited number of members were available for testing at the end of each sprint. This sometimes led to overlooked issues, which were later identified during usability testing.

System resources played a critical role in testing success. A stable network, properly configured development environments, and installed dependencies were essential for running the application. Some testers encountered challenges in setting up the system, which affected testing progress at times.

2.6.5. Test Environment

The test environment was designed to simulate real-world conditions, ensuring that the application performed consistently across different platforms and scenarios.

- **Browsers Tested:** Chrome, Firefox, Edge
- **Devices Used:** Windows PC, MacBook, Android Smartphone, iPhone
- **Network Conditions:** Stable network, slow-speed testing for resilience
- **Database:** Firebase Firestore
- **Backend:** Firebase Authentication & Node.js functions

2.6.6. Sprint-Based Testing

Testing was integrated into the Scrum sprint cycle, ensuring that major functionalities were validated within their respective sprints. Each sprint incorporated feature testing alongside development, allowing for iterative improvements.

This table gives an overview of what was tested in each sprint (in relation to the Implementation Schedule section - 5.1.8), how long testing took, and key issues found.

Sprint	Features Tested	Testing Duration	Issues Found	Resolution Status
Sprint 1	-	-	-	-
Sprint 2	User signup and login Edit user profiles	4 days	3 Minor Issues	Fixed in Sprint 3
Sprint 3	Create and join home Add and manage devices	3 days	2 Minor Issues	Fixed in Sprint 4
Sprint 4	Manage scenes	2 days	1 Critical Issue	Fixed in Sprint 5
Sprint 5	Manage user permissions Logout and leave home	2 days	1 Minor Issue	Fixed in Sprint 6
Sprint 6	Real-time energy data	5 days	2 Major Issues	Ongoing Fixes

2.6.7. Test Execution

Testing was conducted manually by team members using different test accounts and simulated real-world interactions within the application. The process involved:

- Executing manual feature tests using multiple accounts with different roles.
- Identifying issues based on expected vs. actual behaviour.
- Tracking and addressing bugs during subsequent sprints for continuous improvement.

Each feature was tested under various scenarios, including different user roles, home IDs, and device configurations.

2.6.8. Test Results

The testing process across six sprints was conducted to validate the development of key features for a smart home energy management application. Features tested included repository setup, frontend UI components, user signup/login, device management, energy consumption tracking, scenes, rewards, user permissions, and two-factor authentication. Testing was

performed manually using specified accounts (user@gmail.com, admin@gmail.com, johntest@gmail.com, leressa018@gmail.com, =johnben@gmail.com) as well as other made-up accounts to simulate real-world scenarios with admin and user roles across various devices (Windows PC, MacBook, Android, iPhone), browsers (Chrome, Firefox, Edge), and network conditions.

Key Metrics

- **Total Test Cases Executed:** 184
- **Total Passed:** 167
- **Total Failed:** 17
- **Overall Pass Rate:** 91%

The application demonstrated strong reliability, with a 91% pass rate across all sprints. Most features, such as user signup/login, home creation, and device management, performed well.

Future improvements would focus on network resilience, complex logic testing, and expanded security validation to ensure robustness in production.

2.7. User Guides & FAQ

Installation & Setup Guide:

1. **Visit the App:**
 - Go to the HomeSpace web App URL
2. **Create an Account:**
 - Click Sign Up on the landing page
 - Enter your details: Name, Email, Phone number, Password
 - Set up Two-Factor Authentication
3. **Create or Join a Home:**
 - After finishing Signing Up you will be asked to create a new Home or join an existing home using its ID
4. **Start using HomeSpace:**

- Add devices and setup scenes to track energy usage and manage your smart home from anywhere

User Guide:

1. Login/Create Home:

- After logging in Create or join a Home using an existing ID

2. Add Devices:

- Navigate to "Devices" and click on the "Add Device"
- Scan the QR code to input the Device data

3. Track Energy Usage:

- Go to "Energy" to view the energy consumption stats per device and home
- Use the graphs to view usage over daily, monthly and yearly intervals

4. Create Scenes:

- Under "Scenes" group devices and set automation conditions
- Set tap-to-run or scheduled automation like "Morning Routine"

5. Manage Home Settings:

- Admins can manage users and change home name or assign permissions under "settings"

Maintenance:

1. Backup Data:

- Data is stored in Firebase Firestore which handles backup Automatically

2. Security Tips:

- Enable Two-Factor Authentication
- Limit permission for non-admin users
- Regularly review user access from the Manage Users page

Frequently Asked Questions:

Q1: How do I reset my password?

- use the "Forgot Password?" link on the login page to receive a reset link via email.

Q2: Can I add multiple users to a home?

- Yes, once the home is created, share the Home ID so other users can join.

Q3: Why isn't my Scenes working/Triggering?

- If a scene isn't working, common reasons would be:
 1. Incorrect scheduling
 2. Devices not properly added
 3. Permissions not granted

Q5: Does this work on Mobile?

- Yes, HomeSpace is fully responsive and works on both desktop and mobile browsers.

End of Final System Design & Implementation

3. Usability Evaluation

3.1. Overview

This document provides an evaluation of the usability for the final implementation of the HomeSpace web application. The data collected from usability testing will be used to identify any issues or areas for improvement in the app's design and functionality.

Based on feedback from earlier usability testing, the system has been enhanced to better meet user preferences. Additionally, the system is responsive and optimized for performance across both desktop browsers and mobile devices.

The system is designed to fulfil the following key objectives:

1. Visual elements should effectively convey information and be tailored to meet the specific needs of users.
2. The system must ensure consistent and reliable performance under all conditions.
3. All user data will be securely stored and maintained, adhering to the privacy standards.

The following section contains 4 parts:

Test Plan: The test plan outlines the testing process to be implemented, detailing the methods used, the criteria for analyzing collected data, and the objectives we aim to achieve.

Test Protocol: The test protocol is a structured set of questions we will use to measure how effectively users can navigate and use the system.

Test and Questionnaire Findings: The findings from pre-test, post-test questionnaires, and protocol testing will be analyzed based on the metrics and participant feedback received. This will inform potential changes to be made to the system.

Conclusions: To summarize the test findings and finalize the changes to be made based on the user feedback results.

3.2. Test Plan

3.2.1. Objective

The primary objectives of the testing phase are:

- To collect feedback from users participating in the testing process, which will inform future updates and improvements to the software.
- To assess the overall user experience when interacting with the system.
- To allow users to interact with the system and ensure it meets functional and non-functional requirements.
- To gather qualitative and quantitative data based on test findings.

The platform will be tested on both mobile devices and web browsers to detect interface issues and ensure optimal responsiveness across various screen sizes.

We predict that the users will find the application's interface to be intuitive, aesthetically pleasing and the features to be helpful.

3.2.2. Participants

We anticipate approximately 6-9 participants for the testing phase, all of whom will be from Heriot-Watt University. To participate, individuals must be at least 18 years old.

Before the testing session began, participants are provided with an informed consent form explaining the purpose and nature of the study, the risks and benefits of participation. Their personal information will be kept confidential and securely stored.

During the session, participants will be asked to complete a series of tasks within the application. They will also have the opportunity to ask questions and may choose to stop at any time if they feel uncomfortable or no longer wish to continue.

The feedback collected will be used to assess system performance, evaluate its effectiveness, and identify any overly complex or redundant aspects of the system.

3.2.3. Task Scenarios

Tasks	Related Requirements
1. Sign-up /Login	F-SR 6.1: The system must allow users to create a new account using form validation and Two-Factor Authentication. F-SR 6.3 : The system must allow users to login using their email and password, with Two-Factor Authentication if they have it enabled.
2. Create Home	F-UR 7.1: The system must allow users to create a home environment where they can add smart devices and view energy usage statistics.
3. Join Home	F-UR 7.2 : The system must allow users to join an existing home by using the home ID that was shared by the homeowner.
4. Profile Settings	F-UR 8.1: The system must allow users to edit their personal credentials, by allowing them to change their name, email address, phone number.
5. User Permissions	F-SR 9.2: The system must provide the homeowner/manager (user whom created the Home) the ability to set and manage different access levels for various users.
6. Device Management	F-UR 10.1: The system must allow users to add new smart devices to their Home.

	<p>F-UR 10.2: The system must allow users to remove smart devices from their Home.</p> <p>F-UR 10.3: The system should display real-time updates on the operational status of each device, including connection status and current operational state (e.g., light bulb on/off).</p>
8. Energy Consumption Display	<p>F-UR 3.1: Individual Devices</p> <p>The system must display energy usage for individual devices and robots for comparison.</p> <p>F-UR 3.2: Consumption by Time Periods</p> <p>The system shall allow the user to view energy consumption over different time periods (daily, weekly, monthly and yearly).</p>
9. Graphical Display	<p>F-UR 4.1: Time periods</p> <p>The system must use graphs and charts to display the consumption through different time periods</p> <p>F-UR 4.2: Individual Devices</p> <p>The system must use graphs and charts to display the consumption of individual devices</p>
10. Scenes	<p>F-UR 11.1: The system shall allow users to create “Scenes”, where multiple actions can be set-up for easier control of multiple smart devices.</p>

Participants' performance during each task scenario is accessed based on the following values:

- Successful: Participant successfully completed the task with no assistance required.
- Unsuccessful: Participant was unsuccessful in completing the task.

- Required Assistance: Participant required assistance from the investigator to complete the task.

The values outlined above help categorize each task, allowing us to identify those that frequently require assistance or result in failure, which may indicate potential system flaws. The investigator monitors each step taken by participants observing how easy or difficult it is to the participant.

During testing, participants will navigate various screens to evaluate whether the system's functionality is intuitive and meets user expectations.

Additionally, subjective data will be collected through questionnaire forms, including Likert scale questions. Participants will also be encouraged to provide additional feedback or suggestions.

3.2.4. Metrics

The metrics observed from the usability testing are as follows:

- Completion rate: Measures the percentage of tasks successfully completed by the participant with or without assistance.
- Assistance required: Number of participants that required assistance to accomplish a task.
- Subjective Data: Collecting qualitative/quantitative data through questionnaires to gain insight on the user experience of the platform.
- Rate of errors: Indicates the number of times an error occurred during testing. This provides an understanding of areas that need improvement.
- UEQ usability score: The User Experience Questionnaire (UEQ) is used to assess the overall usability and user experience of the system. The results provide a quantitative measure, where higher scores indicate a more positive experience and better usability.

3.3. Test Protocol

3.3.1. Consent Form

Tester: _____

Date: _____ **Time:** _____ **Location:** _____

Participant No.: _____

Aim

This test aims to learn how users interact with the HomeSpace app. The app allows users to control various aspects of their home automation system, such as managing

devices, monitoring energy usage, and setting up automated scenes. The goal is to assess usability and gather feedback on the overall user experience.

Introduction

You're now asked to carry out the following tasks and provide feedback regarding the ease of usability. Additionally, you can provide feedback regarding each task or note anything about the functions that may be of any use. Your responses are anonymous and will not be used to identify you. After the test, we would like you to complete a short anonymous questionnaire. There are no correct or incorrect responses, and your interpretation of the presented information will greatly aid in refining the design. If, at any point you wish to stop feel free to inform the facilitator.

3.3.2. Questions

Testing protocol Questions

1. Register Page
 - a. Please create an account
 - b. How easy or difficult was it to make an account?
 - c. Did you encounter any difficulties in this task? if so, please describe them.
2. Login Page
 - a. Please login to your created account.
 - b. How easy or difficult was it to login?
 - c. Did you encounter any difficulties in this task? if so, please describe them.
3. Create Home
 - a. Please create a Home
 - b. How easy or difficult was it to create a home?
 - c. Did you encounter any difficulties in this task? if so, please describe them.
4. Profile page
 - a. Please indicate how you would view your profile.
 - b. Please edit any of the fields for your profile.
 - c. How navigable did you find the page?
 - d. Is there any design elements you found confusing? If so, please describe them.
5. Devices page
 - a. Please indicate how you would add devices using the QR code provided to you.
 - b. Please indicate how you would view device settings and toggle to turn on/off a device.
 - c. How easy or difficult it was to add a device?
 - d. Are there any design elements you found confusing? If so, please describe them.

6. Energy page
 - a. Please indicate how you would view the energy consumption based on daily, monthly and yearly for a particular device.
 - b. Are the graphs visually appealing and easy to understand?
 - c. Based on your observation, do you think anything can be improved?
7. Scenes Page
 - a. Please create a tap to run scene for a device.
 - b. Please create a scene triggered by time for a device.
 - c. Is the representation for creating a scene clearly convey its purpose and functionality?
 - d. Did you encounter any difficulties in this task? if so, please describe them.
8. User Permissions page
 - a. Please indicate how you would edit your user permissions.
 - b. What are your first impressions of the screen?
 - c. Did you encounter any difficulties in this task? if so, please describe them.
9. Logout
 - a. Please indicate how you would log out from the application.

3.4. Usability Testing Results

3.4.1. Usability Test Findings

1) Signup page

Participants' initial impressions of the page were positive, though some felt it was plain and required aesthetic improvements.

"Efficient but very functional, needs aesthetic improvements."

"Straight forward and simple"

Users successfully completed the registration, but some struggled to get their accounts approved.

Recommended Changes:

- o Enhance the UI design to make it visually appealing.
- o Optimize two-factor authentication for seamless and efficient functionality.

Task Scenario Result:

- 1) Please create an account.

Completion rate	86%
Rate of errors	14%
Successful	5/7
Unsuccessful	0/7
Assistance Required	2/7

2) Login Page

Participants found this page intuitive and easy to navigate. None of them experienced difficulties when logging into the application.

"Was good, easy to know where to input everything"

"Easy to navigate and use."

Recommended Changes:

- Enhance the UI design to make it visually appealing.

Task Scenario Result:

- 1) Please login with the account you have created.

Completion rate	86%
Rate of errors	14%
Successful	6/7
Unsuccessful	1/7
Assistance Required	0/7

3) Create Home Page

Some participants found the page clear and easy to understand, while others suggested adding more indicators and incorporating colors to enhance the UI.

"very clear in its function"

"good as well but at first didnt know where to press and was kinda lost"

All participants completed this task without difficulty, indicating that creating a home was straightforward.

Recommended Changes:

- Enhance the UI design by incorporating better colors.
- Add indicators to help users easily recognize the functionality and purpose.

Task Scenario Result:

1) Please indicate how you would create a home.

Completion rate	100%
Rate of errors	0%
Successful	7/7
Unsuccessful	0/7
Assistance Required	0/7

4) Profile Page

Most of the participants were able to easily navigate to the profile settings, though one mentioned that its location was not immediately obvious.

"very easy to navigate and all text is very clear"

"not clear that profile in the settings field so wasnt obvious where to go to"

Recommended Changes:

- One participant noted that it wasn't clear whether profile changes were saved after editing. Additionally, they suggested closing the fields on the settings page to reduce visual distraction.

Task Scenario Result:

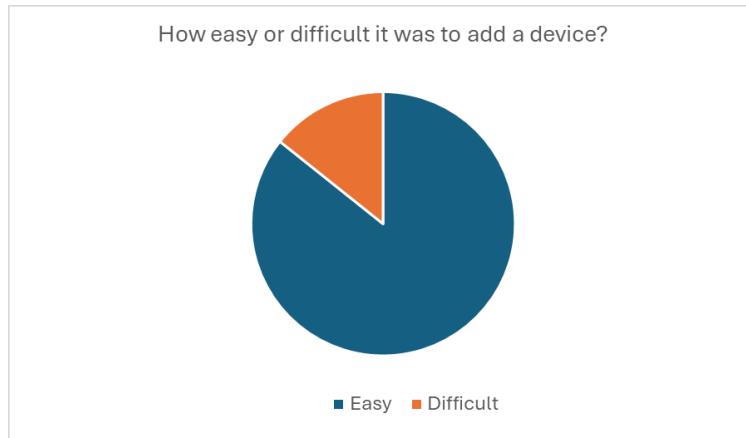
1) Please indicate how you would view your profile.

2) Please edit any of the fields for your profile.

Completion rate	86%
Rate of errors	14%
Successful	6/7
Unsuccessful	0/7
Assistance Required	1/7

5) Devices Page

Most participants found adding a device via the QR scanner to be easy and straightforward.



One participant mentioned that turning all devices on or off simultaneously could be challenging. However, our application offers a useful feature called "Scenes," allowing users to control multiple devices using Tap-to-Run or automated triggers.

Recommended Changes:

- Enhance the UI design to better indicate when a device is turned on/off.

Task Scenario Result:

- 1) Please indicate how you would add devices using the QR code provided to you.
- 2) Please indicate how you would view device settings and toggle to turn on/off a device.

Completion rate	100%
Rate of errors	0%
Successful	7/7
Unsuccessful	0/7
Assistance Required	0/7

6) Energy Page

All the participants found the graphical visualization of the energy consumption to be visually appealing and understandable.

"yep, it was pretty clear"

"Yes, they are cool"

Recommended Changes:

- Adjust the layout to place graph-related buttons (e.g., daily, monthly, yearly) in a single row or a dropdown menu for the mobile version.
- Add a note informing users that the device must be turned off to view graphs.
- Make the "Total Consumption" value clearer to prevent confusion.

Task Scenario Result:

1) Please indicate how you would view the energy consumption based on daily, monthly and yearly for a particular device.

Completion rate	86%
Rate of errors	14%
Successful	6/7
Unsuccessful	0/7
Assistance Required	1/7

7) Scenes Page

While some participants found this page clearly conveyed its purpose and functionality, a few others struggled to understand its function and layout.

"Yes, it clearly conveys the purpose."

"Visible but does not convey the functionality directly"

Some participants experienced issues with scenes not working on all devices and the inability to edit existing ones. Additionally, there was no clear feedback when a scene is pressed, so adding alerts and status messages would improve clarity.

Recommended Changes:

- Fix the issue where scenes don't work with all devices.
- Allow editing of existing scenes instead of recreating a scene.
- Provide clear success/failure feedback when triggering a scene.

Task Scenario Result:

- 1) Please create a tap to run scene for a device.
- 2) Please create a scene triggered by time for a device.

Completion rate	100%
Rate of errors	0%

Successful	7/7
Unsuccessful	0/7
Assistance Required	0/7

8) User Permissions Page

Most participants found this page clear and functional. However, many had difficulty navigating to it, as they expected it to be in settings under the user profile rather than home management settings.

"Visible and easy to change the permissions"

"Not clear to navigate to but, easy to use."

Recommended changes:

- Relocate the user permissions page to settings under the profile, where users naturally expect to find it.

Task Scenario Result:

1) Please indicate how you would edit your user permissions.

Completion rate	57%
Rate of errors	43%
Successful	3/7
Unsuccessful	1/7
Assistance Required	3/7

9) Logout

All participants successfully logged out after using the application, indicating that the process was easy to navigate.

Recommended changes:

- None

Task Scenario Result:

1) Please indicate how you would log out from the application.

Completion rate	86%
Rate of errors	14%
Successful	6/7
Unsuccessful	0/7
Assistance Required	1/7

3.4.2. Participant Demographics

To evaluate the initial user expectations and familiarity with smart home applications, we provided the participants with a short demographics questionnaire. This aimed to understand user demographics, prior experience, and perceived gaps in existing smart home management systems.

1. Demographics & User Background

Gender: All participants identified as Male.

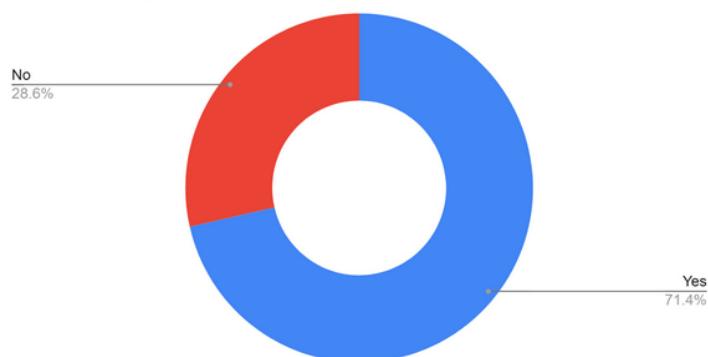
Age: All participants were aged 18–24.

2. Prior Experience with Smart Home Tools

Yes: 4 participants (71.4%)

No: 3 participants (28.6%)

Count of Have you had any prior experience utilizing smart home management tools?



3. Perceived Gaps in Current Smart Home Applications

Participants identified the following shortcomings in existing smart home tools:

- Aesthetics (e.g., UI design, visual appeal)
- Layout and overall design (e.g., navigation, intuitiveness)
- Obviousness for tasks (e.g., managing profiles)
- Ease of use and device connectivity
- Security features
- Scheduling functionality

4. Competitor Awareness

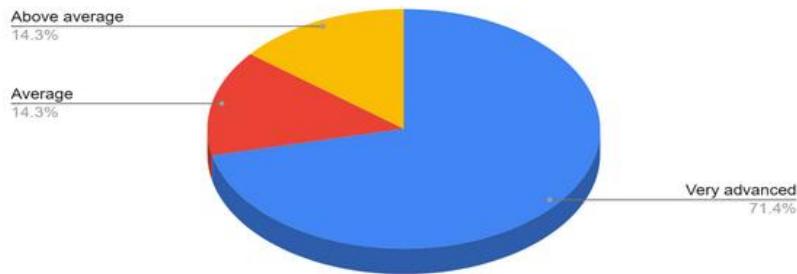
When asked about competing smart home tools, participants mentioned:

- Google Nest/Home
- Amazon Alexa
- Phillips Hue
- Unspecified "apps for smart devices"

5. Key Insights

Technical Proficiency: Most participants had high computer literacy, suggesting they could navigate the app effectively.

Count of How would you articulate your level of computer literacy and proficiency?



Design-Centric Feedback: Aesthetics and usability were recurring themes, highlighting the importance of intuitive UI/UX.

Security Concerns: One participant noted security as a gap, aligning with HomeSpace's focus on secure authentication.

Fragmented Market: Mentions of multiple competitors (e.g., Alexa, Google) indicate a competitive landscape where differentiation (e.g., energy efficiency) is key.

6. Implications for HomeSpace

UI/UX Focus: Address design gaps (e.g., clearer navigation, visual appeal).

Security Highlight: Emphasize HomeSpace's encryption and 2FA in marketing.

Competitive Positioning: Leverage energy monitoring and automation as unique selling points.

7. Overall User Expectations

Based on responses, participants expected a seamless, easy-to-use, and secure smart home application. The main priorities for users were:

- Simplicity & Intuitive Design – Users preferred minimal learning curves.

- Reliable Device Integration – The system should support a wide range of smart devices.
- Better Energy Monitoring – Users wanted real-time tracking and actionable insights.

3.4.3. Post-Questionnaire (UEQ) Results

To evaluate the usability and user experience of the HomeSpace app, we used a post-questionnaire using the *User Experience Questionnaire (UEQ)*. The UEQ is a standardised questionnaire designed to assess the subjective user experience of a product's interface across the following quality aspects:

1. **Attractiveness** - Overall impression of the product.
2. **Pragmatic Quality** – How effectively users can complete their tasks including:
 - **Perspicuity:** Is it easy to use and easy to learn how to use.
 - **Efficiency:** Can users complete tasks quickly without unnecessary effort.
 - **Dependability:** Does the user feel in control of the system.
3. **Hedonic Quality** – Emotional and motivational aspects that make the interface enjoyable, including:
 - **Stimulation:** Is the product exciting to use.
 - **Novelty:** Innovation and creativity in design.

(*User Experience Questionnaire (UEQ)*, n.d.).

We chose the UEQ as it provides a quantitative measure of user experience, provides benchmarking metrics against other products and it is adaptable as it can help provide insights for user-centered design improvements. Our aim with HomeSpace is to provide a seamless and user-friendly experience for a smart home app therefore, this method was well-suited to identify strengths and areas for improvement.

After completing the test protocol and interacting with the HomeSpace system, participants were asked to complete the long-form UEQ questionnaire. The responses were then transferred into the UEQ Excel analysis tool, which computed scale means, confidence intervals, answer distributions, and consistency scores.

Results and Analysis

Provided below is the table with the Mean and Variance of the UEQ. The values range from -3 to +3, where higher positive values indicate a better user experience, and lower or negative values suggest usability issues.

UEQ Scales (Mean and Variance)		
Attractiveness	↑ 1.262	1.29
Perspicuity	↑ 1.536	1.40
Efficiency	↑ 1.286	1.34
Dependability	→ 0.786	0.82
Stimulation	↑ 0.821	1.56
Novelty	→ 0.321	0.54

Figure 12: UEQ Scales mean results

Based on the UEQ scales, the app achieved a 1.26 in *Attractiveness*, indicating a positive impression and that users found the app appealing.

Pragmatic Quality

- **Perspicuity (1.54)** highest scoring quality, suggesting that users found the app intuitive and easy to learn.
- **Efficiency (1.29)** also received a positive rating, meaning users felt they could complete tasks easily and the app was fast.
- **Dependability (0.79)** had the lowest score, indicating concerns regarding system predictability, and suggesting that users did not feel in control of the app.

Hedonic Quality

- **Stimulation (0.82)** showed moderate engagement, suggesting that the app was somewhat enjoyable but not highly exciting to use.
- **Novelty (0.32)** was the lowest-scoring dimension, implying that users did not perceive the app as particularly innovative or unique.

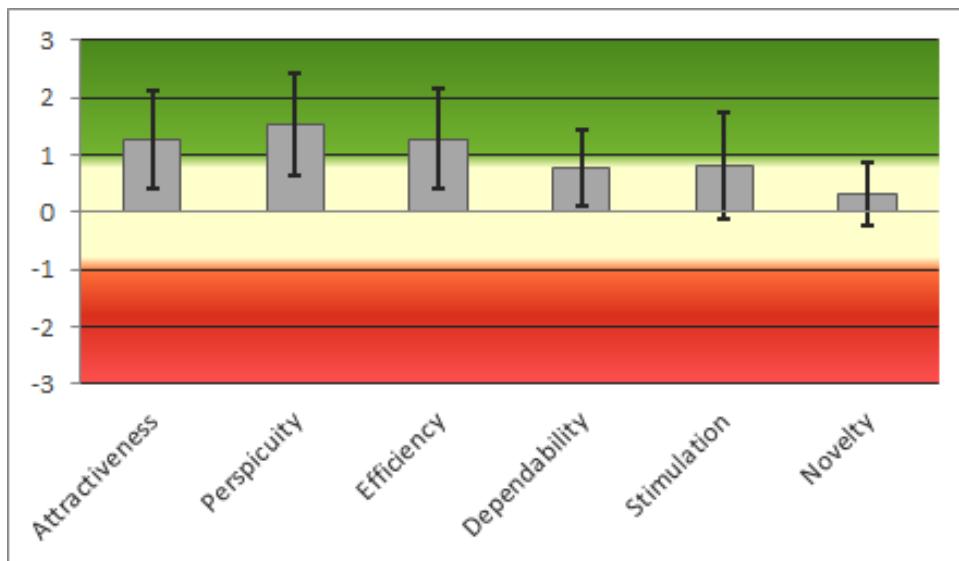


Figure 13: UEQ Qualities scores (+3 to -3)

Overall results

Pragmatic and Hedonic Quality	
Attractiveness	1.26
Pragmatic Quality	1.20
Hedonic Quality	0.57

Figure 14: Pragmatic and Hedonic Quality scores

The overall results show that users found the system to be visually appealing, functional and easy to use. However, the Hedonic quality score suggests that the system lacks innovative features. This is likely because we were unable to implement our ambitious gamification features and rewards system, which could have enhanced user engagement and made the application more exciting and enjoyable.

Detailed user responses

Provided below is a diagram highlighting the mean values for each individual question in the UEQ offering a detailed view of user responses.

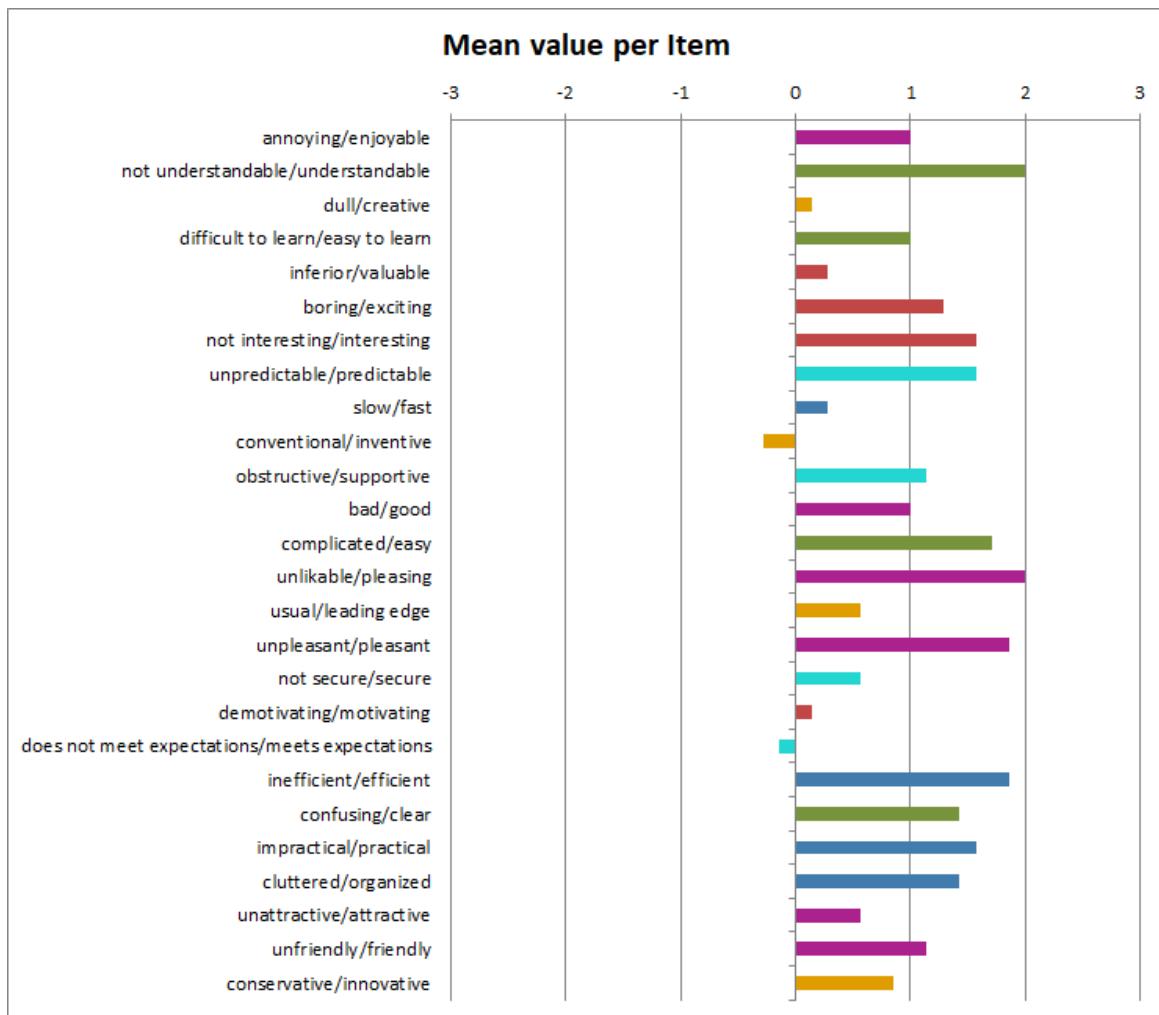


Figure 15: Mean response value for each UEQ question

Usability Benchmarks

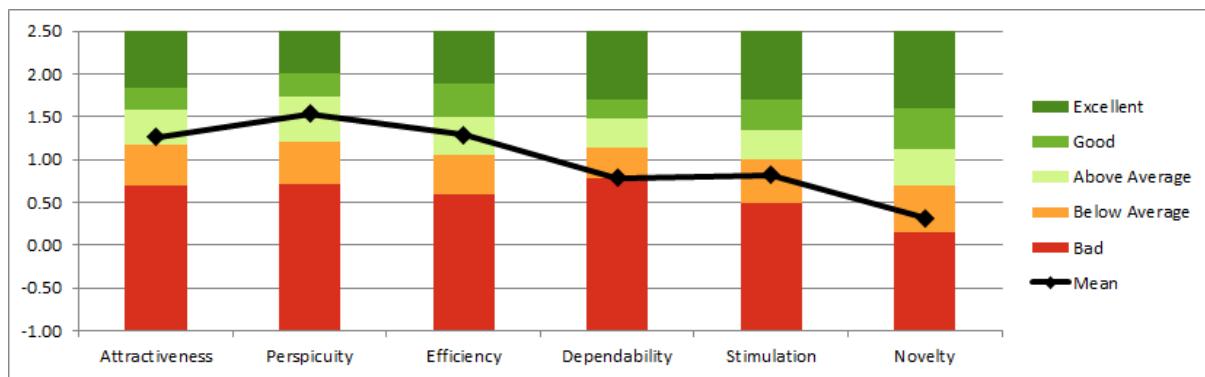


Figure 16: HomeSpace UEQ scores benchmarked

The bar chart above shows a benchmark comparison of the HomeSpace app's UEQ scores compared with a dataset of various products, including business software, web pages, web shops, and social networks. Although the benchmark does not specifically include smart home

systems, it still provides a useful reference for evaluating HomeSpace's usability and user experience in a broader context (*User Experience Questionnaire (UEQ)*, n.d.).

The benchmark comparison allows us to assess how HomeSpace performs in terms of attractiveness, pragmatic quality (efficiency, perspicuity, dependability), and hedonic quality (stimulation, novelty) compared to other digital products.

This diagram helps further visualise the strengths and weaknesses of HomeSpace's user experience and identify areas for further improvement.

Conclusions and Areas for improvement

Based on the usability testing results and the data collected over a sample of 7 participants. The app shows strong usability in terms of ease of use and efficiency, making it effective for users to navigate and complete tasks. However, the low Dependability score suggests that users may have concerns about reliability and do not feel in control of the system.

Furthermore, the Hedonic Quality scores (Stimulation & Novelty) are also relatively low, indicating that although the app is functional and efficient, it does not strongly engage or excite users. This indicated areas for improvement including:

- Implementing the originally planned gamification features to drive user engagement and make the app more enjoyable.
- Introducing more unique features that differentiate the app from similar systems.

By addressing these areas, HomeSpace can improve both its usability and user engagement, making it a more exciting product for users.

4. Marketing Strategy & Materials

4.1. Executive Summary

The marketing report gives an overview of HomeSpace, which is a smart home automation management application. It is designed to provide users with a better experience of automating their homes while promoting sustainability and efficient use of energy. This report outlines the objectives, which include a smooth user experience while keeping in mind the security and privacy of the user and integrating new features such as gamification and rewards.

According to projections, the worldwide smart home market will increase from USD 199.4 billion in 2025 to USD 414.2 billion by 2034 due to rising consumer demand for convenience, technical developments, and a greater emphasis on sustainability. By providing real-time energy tracking, intelligent automation, and tailored suggestions, HomeSpace sets itself apart from rivals like Google Nest, Amazon Alexa, and Apple HomeKit and positions itself as an environmentally responsible and user-focused option.

A SWOT analysis identifies HomeSpace's advantages in terms of sustainability-focused features, user-friendliness, and energy efficiency. Low brand awareness, few third-party integrations, and fierce rivalry from well-known businesses are obstacles, nevertheless. The PESTLE study also looks at outside variables that have an impact on HomeSpace, such as government subsidies for smart home technology, shifts in the economy, and tightening data privacy laws.

Approach to Strategic Positioning and Marketing

- Through intensive digital marketing efforts, consumer interaction programs, and smart alliances with IoT device makers, HomeSpace hopes to develop a significant market presence. Important tactics consist of:
- Value-Based Marketing: Stressing the application's financial and environmental advantages.
- Gamification & User Rewards: Rewarding energy-saving achievements to promote sustained user participation.
- SEO & Social Media Presence: Using online advertising, influencer partnerships, and content marketing to increase brand recognition.
- Offering tiers of pricing to draw in a large clientele while guaranteeing recurrent income is the goal of subscription and freemium business models.

4.2. Objectives

1. User Experience and Satisfaction

- To design a clean and responsive user interface which ensures that the users of the application are able to easily manage their smart home devices without facing any difficulties.
- There will be a low learning curve and clear navigation for the users to easily adapt to without facing any issues.
- The program will load and run smoothly.
- Smart home devices and the application will have reliable connectivity.

2. Security and Privacy

- The application will be equipped with a multi-factor login authentication system.
- Data of the users and applications are encrypted via strong encryption mechanisms and stored for maintaining the privacy of the user.
- The application adheres to data protection laws such as GDPR to protect the user privacy.

3. Sustainable and Energy Efficiency

- The system allows users to also create automation which helps save energy and reduce energy waste.
- The application provides real time energy usage tracking and also provides live update as a device notification.
- This focus on sustainability aligns with the growing demand for eco-friendly solutions, as companies that prioritize environmental strategies can innovate, create value, and build competitive advantage (Esty and Winston, 2009).

4. Increase Brand Awareness

- The application will have regular feature updates so new functionalities can also be introduced to the application.
- The app will also provide recommendations based on the user's behavior and preferences.
- The application also provides in-app gamification and rewards which helps the users stay motivated by rewarding them for energy saving milestones. This approach not only motivates users to reduce energy consumption but also fosters long-term engagement (Nir and Raz, 2016).

4.3. Product and Market Background

4.3.1. Background

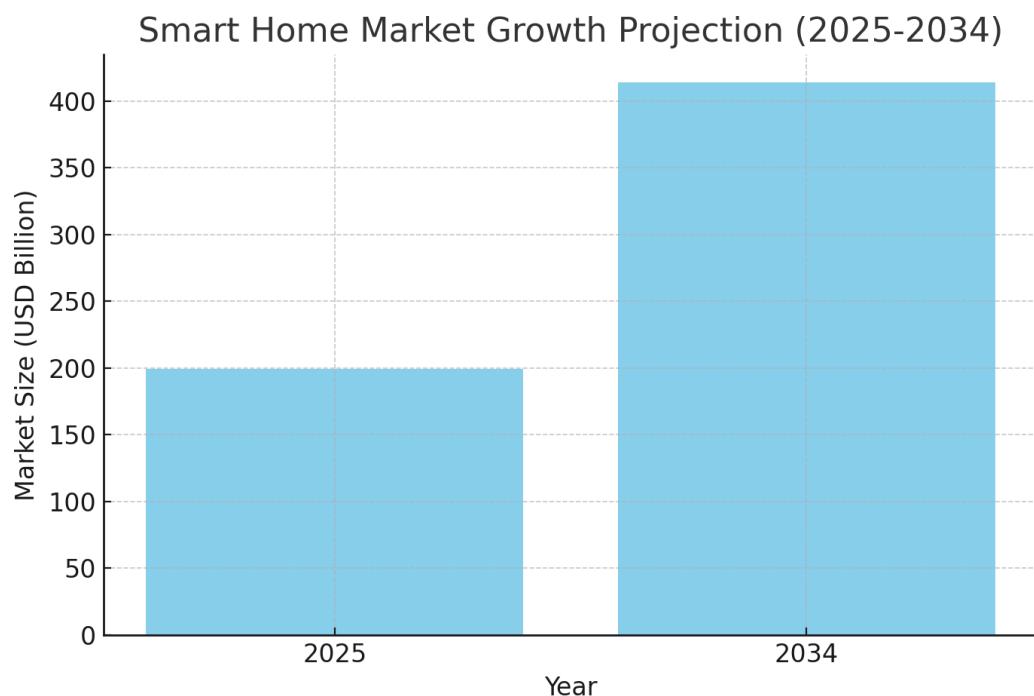
The need for effective, user-friendly smart home management solutions is growing in an era where smart technologies are drastically changing modern living. HomeSpace was established with the goal of encouraging sustainable energy use and streamlining smart home device administration. We created a web application and a mobile application to provide smooth management over a variety of smart home devices in response to the increasing need for integrated solutions.

What distinguishes Home Space is its twin focus: it offers sophisticated energy use data in addition to simple smart device control. With the help of this function, customers can track their energy usage trends in real time, spot inefficiencies, and put customized energy-saving strategies into practice. Home Space seeks to improve the smart home experience while promoting ecologically responsible living by fusing sustainability and convenience.

HomeSpace's primary objective is to build a steady and increasing client base and an excellent reputation in the market as an organization.

4.3.2. Product

The lack of seamless interoperability in today's smart home management application has left the users with different difficulties in owning and maintaining a smart home device. As a result, HomeSpace has designed an application for smooth running and maintenance of smart home devices by allowing the users to easily add and remove devices from their smart home system, having an interface that allows the users to view energy usage details and track the trends of different devices. For a better understanding, the application will also make the use of different charts and diagrams to inform the user of the amount of energy being consumed by a particular device. The application also helps the users in saving energy by providing them with tips and suggestions which are tailored to the user and his needs.



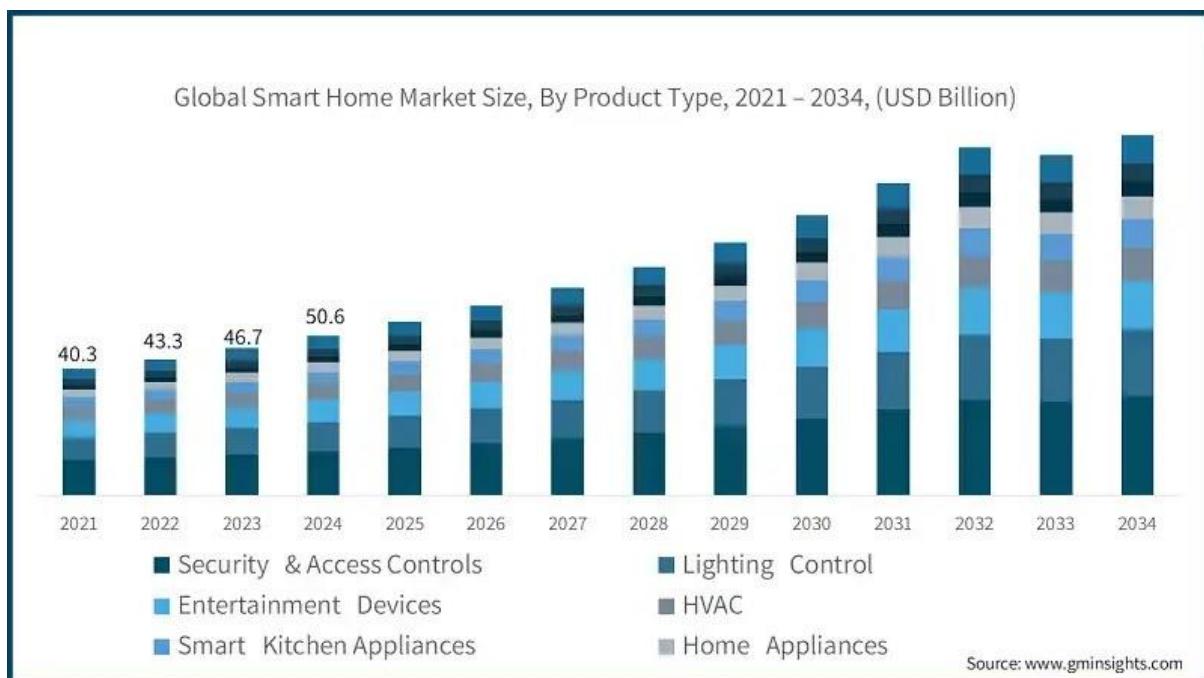
4.3.3. Market

As technology is advancing, the desire of the customers for convenience and a focus on energy conservation is also increasing which leads to the growth in the need of smart home management applications. The market for the global smart home was estimated to be worth USD 183.2 Billion in 2024 and is also expected to grow from USD 199.4 Billion in 2025 to USD 414.2 Billion in 2034 with a compound annual growth rate of 8.5% (Singh and Singh, 2024; Global Market Insights Inc., 2024).

In 2022 the global smart home market was worth around USD79.16 billion. The demand for smart home gadgets has only been increasing which has been possible as a result of increasing usage of mobile phones and high speed of the internet. AI and IoT have also merged which

leads to enhancement of device interoperability and experience of the user using the application.

To conclude, because of growing consumer demand and technological advancements, it would lead to a large expansion in the market for smart home management applications. On the other hand, fixing the user interoperability and experience would also be necessary for long term success of the application.



4.3.4. Trends

Automation and smart technology are major industry trends that will only get bigger, impacting a wide range of sectors including home security and consumer electronics. The growing usage of artificial intelligence is one significant advancement in smart home technologies. Artificial intelligence can observe and anticipate significant behaviors from a sensor before the homeowner thanks to machine learning. For instance, Google enabled voice input for message typing in October 2022. Additionally, Google Assistant lets users add emojis to texts for an improved messaging experience (Singh and Singh, 2024).

These internet technologies are becoming more and more popular. Smart wearables, smart cities, and smart homes are just a few of the IoT gadgets that are currently flooding the market. Convenient and safe gadgets like Amazon Alexa, smart locks, smart thermostats, smart lighting systems, and security systems are especially available in smart homes (Singh and Singh, 2024).

4.3.5. Competitors

The market for smart home automation is quite competitive, with both well-known companies and creative entrants. There are a few that have been listed below:

1. Abb Ltd: Company based in Switzerland that brings in the market a variety of electrical and automation technologies which also includes smart home solutions (MarketsandMarkets, 2024).
2. Honeywell International Inc: An American company that focusses on selling air quality monitors, security systems and stat thermostat under the name Honeywell Home Brand (MarketsandMarkets, 2024).
3. Legrand SA: A businessman from France providing a range of home connected solutions such as energy management (MarketsandMarkets, 2024).

4.4. Marketing Analysis

This SWOT analysis takes into account HomeSpace's internal strengths and weaknesses, as well as external opportunities and threats. It will determine how HomeSpace leverages its unique strengths like green-focused features and simplicity of interface and how it is mitigating challenges like brand initial unawareness and harsh competition from industry players. Awareness of these internal and external variables provides HomeSpace with a strategic blueprint for strengthening its market positioning and growth potential.

4.4.1. Swot Analysis

Strengths: HomeSpace's competitive edge is its product value proposition of home automation with simplicity combined with energy savings and security features that set it apart from others. The green color scheme of the app also arrives at the opportune moment when consumer and regulatory push to offer eco-friendly solutions has increased. Its strong online presence, its partnerships with IoT device makers and property developers, and its big data-driven insights to craft customized user experiences all contribute to its competitive advantage. They make HomeSpace a distinctive and appealing option in the smart home automation market (MarketsandMarkets, 2024; Singh and Singh, 2024).

Weakness: Despite its strengths, HomeSpace has weaknesses too. The market of smart home automation is very competitive in nature and therefore it is difficult to differentiate from existing brands like Google Nest and Amazon Alexa. The company's third-party integration strategy, i.e., IoT devices, can compromise control over the user interface. As a new entrant, HomeSpace also lacks high brand awareness and trust like incumbent players. In addition, resource constraints, i.e., fewer funds to invest in large-scale marketing and R&D, can possibly restrict its growth (MarketsandMarkets, 2024; Singh and Singh, 2024).

Opportunities: HomeSpace is on the verge of vibrant expansion over the next few years. The market for smart homes is flourishing because of the rapid growth of Internet of Things technologies, which brings an enormous and waiting customer base knocking at its doors. Simultaneously, expanding awareness for sustainability and energy efficiency both from customers and authorities finds a perfect fit with what HomeSpace can bring to the table (Singh and Singh, 2024; Grand View Research, 2024).

Threats: HomeSpace also has its own set of challenges that need to be taken into consideration. HomeSpace is up against industry giants such as Google Nest, Amazon Alexa, and Apple HomeKit, which could potentially make it more difficult to establish a niche within the market. Increased fears over data privacy and enhanced data security regulations could also discourage potential users from embracing the platform. Economic recessions may also affect spending by consumers, lowering demand for discretionary smart home products (MarketsandMarkets, 2024; Singh and Singh, 2024).



SWOT Analysis for HomeSpace and its Competitors.

Category	HomeSpace	Google	Amazon Alexa	Apple HomeKit
Strengths	- Strong energy-saving features - User-friendly interface - Sustainability focus	- Established brand - Advanced AI integration - large ecosystem	- Seamless voice assistant - Extensive smart device compatibility - Amazon ecosystem integration	- High security & privacy - Strong Apple ecosystem - Seamless iOS integration
Weaknesses	- Lower brand recognition - Limited third-party integrations	- High cost - Limited compatibility outside Google ecosystem	- Privacy concerns - Dependence on Amazon services	- Limited device compatibility - High entry cost

	- smaller market share			
Opportunities	<ul style="list-style-type: none"> - Growing smart home market - Partnerships with IoT manufacturers - Sustainability demand 	<ul style="list-style-type: none"> - Expansion into new smart home categories - Integration with more third-party apps 	<ul style="list-style-type: none"> - Expansion into business/home automation - Enhanced AI capabilities 	<ul style="list-style-type: none"> - Increasing focus on security & privacy - Growth in premium smart home market
Threats	<ul style="list-style-type: none"> - Competition from big brands - Data privacy concerns - Economic downturns 	<ul style="list-style-type: none"> - Competition from Amazon & Apple - Dependence on Google services 	<ul style="list-style-type: none"> - Competition from Google & Apple - Growing regulations on data use 	<ul style="list-style-type: none"> - Competition from Google & Amazon - Dependence on Apple ecosystem

4.4.2. PESTLE Analysis

The PESTLE analysis identifies the external macro-environmental forces influencing HomeSpace's operations and strategic path in the market for smart home automation. This involves evaluating Political support for sustainability and privacy legislations, Economic influences on consumers' purchasing ability, social movement towards smart living, Technological advancements in IoT and AI, Legal compliances in terms of data privacy, and Environmental demands calling for environmentally friendly solutions. Understanding these external drivers helps HomeSpace grasp more market complexities, anticipate more industry shifts, and effectively respond to more pervasive economic and regulatory changes.

Political: Policy supports from the government for energy efficiency and smart home technologies, i.e., subsidies and tax credits, can be advantageous for HomeSpace. Conversely, compliance with data protection regulations such as GDPR can be expensive. Political stability in target markets is also important to guarantee smooth operations and expansion (Singh and Singh, 2024; Grand View Research, 2024).

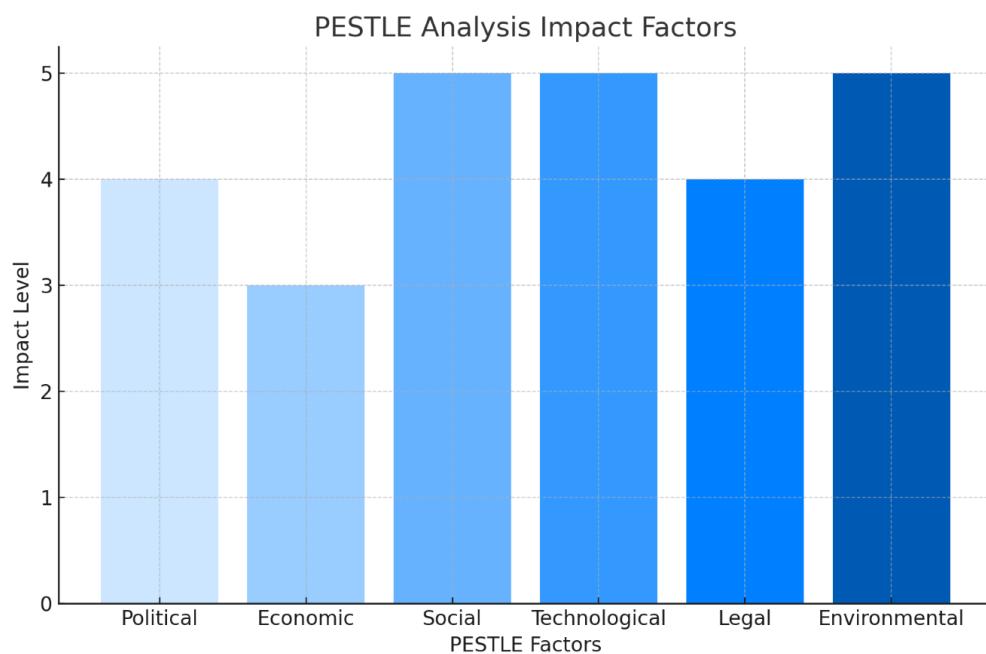
Economical: Growing disposable incomes in developing markets generate potential for the adoption of smart homes, especially in countries with expanding middle-class consumers. Economic slumps or instability, though, may dent consumer expenditure on high-end smart home solutions, affecting HomeSpace's top-line growth (MarketsandMarkets, 2024; Singh and Singh, 2024).

Social: Growing consumer consciousness of energy efficiency and sustainability fuels demand for HomeSpace's products. The increasing popularity of smart home technologies among homeowners and tech-conscious consumers also fuels market expansion. Moreover, the movement toward convenience and connected living increases the attractiveness of HomeSpace's app (Singh and Singh, 2024; Grand View Research, 2024).

Technological: Improvements in IoT, AI, and data analytics increase the functionality and usability of HomeSpace's app. Nevertheless, the fast pace of technological change demands ongoing innovation to remain competitive. HomeSpace must spend on R&D so that its app stays up-to-date and at the forefront in a rapidly changing industry (MarketsandMarkets, 2024; Singh and Singh, 2024).

Legal: Compliance with data protection and privacy laws, such as the GDPR, is paramount to maintaining customer trust and escaping expensive legal penalties. Intellectual property law protects HomeSpace's innovations, yet the firm must be vigilant in order not to let competitors replicate its proprietary technology. Finding equilibrium between these regulatory and legal requirements is the route to continued growth and beating the competition (Singh and Singh, 2024; Grand View Research, 2024).

Environmental: The international thrust for sustainability and climate change activities resonates with the value proposition of HomeSpace. The rising need for energy-saving products provides a big opportunity for the firm. Yet, HomeSpace should also see to it that its operations and supply chain comply with environmental regulations and standards (MarketsandMarkets, 2024; Singh and Singh, 2024).



PESTLE analysis Structured Table

Factor	Description
Political	Government incentives for energy efficiency, GDPR compliance
Economic	Growth in disposable incomes, impact of economic downturns

Social	Rising consumer focus on sustainability and convenience
Technological	Advances in AI/IoT, rapid innovation demands
Legal	Data privacy laws, intellectual property regulations
Environmental	Demand for eco-friendly solutions, compliance with green policies

4.4.3. Competitive Analysis

Direct Competitors: HomeSpace has direct competition from industry titans such as Google Nest, Amazon Alexa, and Apple HomeKit. These titans offer full-integrated smart home solutions with brand presence, big ecosystems, and the latest features. Competing with these Goliaths translates to HomeSpace having to emphasize its unique value proposition, i.e., affordability, sustainability, and simplicity (MarketsandMarkets, 2024; Singh and Singh, 2024).

Indirect Competitors: Home security firms like ADT, which are part of the security business but do not provide the automation feature, and energy monitoring software like Sense and Smappee, which provide only energy monitoring but not the entire smart home experience. Indirect competitors can be accessed through HomeSpace because HomeSpace can provide a more complete solution to their niche (Singh and Singh, 2024; Grand View Research, 2024).

Market Positioning: HomeSpace is a high-end, budget-friendly smart home automation solution with a specialization in energy management, security, and user-friendliness. HomeSpace will appeal to a diverse range of clients, from residents and renters to property developers and techies, with its concentration on sustainability, data analytics, and strategic alliances. It will enable the company to stand out in the market of highly competitive smart home automation (MarketsandMarkets, 2024; Singh and Singh, 2024).

4.5. Marketing Strategies

The marketing approach used focusses on selling on value based, involvement of the customer and the difference needed in order to establish a strong market presence. The main goal of our marketing strategies is to position our smart home automation software as a cost effective and easily usable choice prioritizing security and efficiency of energy (Kotler and Keller, 2016). To ensure long-term user engagement, HomeSpace incorporates gamification and reward systems, which are proven to build habit-forming behaviors among users (Nir and Raz, 2016).

4.5.1. Market Segmentation

The market we are targeting is divided into the following segments:

1. **Homeowners and Renters:** Individuals or companies that specialize in holiday homes that are looking to enhance their or the customer's experience with smart automation.

2. **Property Developers:** Smart solutions are being included in new buildings by builders and real estate developers.
3. **Tech-Savvy Consumers:** enthusiasts that actively look for new developments in smart homes.

By ensuring that marketing initiatives are customized to meet demands, our segmentation strategy raises adoption rates among a wide range of user populations (Chaffey and Ellis-Chadwick, 2019).

Product Positioning

Our app is marketed as an intelligent, safe, and energy-saving home automation solution that works in unison with current IoT networks. It is promoted as a high-end yet reasonably priced system that offers data-driven energy insights, easy-to-use controls, and improved security features, making it a great option for both companies and homes (Kotler and Keller, 2016).

4.5.2. Marketing Channels and Tactics

To reach our target market effectively, HomeSpace has decided to market the product not only through internet but also taking the advantage of the traditional marketing strategies as this would allow the application to have a higher exposure and visibility in the market. we will utilize the following as our marketing channels and tactics:

1. **Digital Marketing:** As the use of internet platforms grows, digital marketing is becoming a more affordable and focused way to connect with potential clients (Chaffey and Ellis-Chadwick, 2019).
 - a. **Search Engine Optimization (SEO):**
 - i. This includes optimizing the web application and content of the blogs with keywords that include smart home automation such as “best smart home app” or “energy saving automation”.
 - ii. To increase organic traffic to the website, google search ranking will also be increased as it also helps in bringing the application to the spotlight.
 - b. **Social Media Marketing:**
 - i. Creating a relationship with the audience and potential customers over social media such as Facebook, Instagram, Linkedin and Twitter by posting demos of the product, stories of customer success and tips on how one can save energy.
 - ii. Running ad campaigns which are also interactive to engage with the audience to provide high quality leads which can be turned into potential customers at a later stage.
2. **Strategic Partnerships:**
 - a. HomeSpace would also collaborate with IoT device manufacturers for cobranding and integration.
 - b. HomeSpace would also partner with real estate developers as this would allow our application to be pre-installed in the smart home projects.

3. Marketing Products:

- a. Flyers and Posters: Placing flyers and posters in real estate offices, maintenance companies and technology expos would help HomeSpace gain exposure and visibility and also be seen in the market. An example of a poster and flyer is also attached below.
- b. Stickers and QR Codes: Distribution of stickers of QR codes which would lead to the landing page of the HomeSpace website which would from there allow the customers to know about the product and download the application.

4. Direct Sales and Live Demonstration:

- a. Live demonstrations will be held at real estate and technology expos, trade shows and smart city conferences.
- b. Offering one on one personalized in person or virtual demonstration for clients such as businessmen or real estate developers.

4.5.3. Competitive Advantages

HomeSpace's goal is to build smart home management software that provides the users with seamless, energy efficient and a smart way to manage their devices connected to the home. The competitive advantages based on functional and nonfunctional requirements are listed below:

1. Energy Monitoring and Optimization: The systems track and store the energy consumption data in real time in kWh which is done for every single device, and it updates the statistics and the data every day.
2. User Friendly Interface and Accessibility: The application has accessibility features, works well across different screen sizes and is user-friendly and easy to use.
3. Cross Platform Accessibility: The system ensures that a single user can run the application on different platforms such a mobile and a laptop.
4. Secure Authentication: Users also have the benefit of Two Factor Authentication when logging in to make sure all their data is kept safe and private.

4.5.4. Stakeholders

Stakeholders of HomeSpace really play a important role in different departments of the application like development, usage and deployment. The crucial stakeholders include the homeowners or residents who directly have the benefit from the smart home management application, efficiency of the energy and the security features. For the development and maintenance of the application, developers and system administrators are responsible who also ensure security, privacy, scalability and make sure that the application works within the regulatory standards. The key collaborators are the smart device manufacturers as they are the ones with whom HomeSpace would integrate their application into the devices. Lastly, investors and business partners also have an important role in funding and expanding the reach of HomeSpace in the Smart Home Management Software Industry.

4.6. Marketing Goals

Building brand awareness: HomeSpace would like to become a leading brand in the smart home management market. To achieve this, focused digital marketing campaigns on social media platforms, search engines, and display ads will be launched by the company. HomeSpace will also collaborate with influencers and tech bloggers for the app's promotion, along with participating in smart home and sustainability-based events and trade shows to get further exposure (MarketsandMarkets, 2024; Singh and Singh, 2024).

Drive User Acquisition: The end objective is to obtain a huge and growing base of customers for the HomeSpace app. This will be done through short-term incentives, such as free trials or reduced premium features, and referral programs to encourage existing customers to invite their friends. App store listing optimization (ASO) will also be a significant objective to improve visibility and drive downloads (Grand View Research, 2024; Singh and Singh, 2024).

Enhance User Engagement: HomeSpace will try to involve the users to a larger extent with the application and build long-term loyalty. It will do this by sending user-specific energy-saving advice and reminders, making the application experience an exciting one by rewarding the completion of milestones, and continuously updating the app with fresh content based on the feedback of the users to make the experience exciting and fascinating.

Enhance User Engagement: HomeSpace will try to involve the users to a larger extent with the application and build long-term loyalty. It will do this by sending user-specific energy-saving advice and reminders, making the application experience an exciting one by rewarding the completion of milestones, and continuously updating the app with fresh content based on the feedback of the users to make the experience exciting and fascinating (MarketsandMarkets, 2024; Grand View Research, 2024).

Improve Market Penetration: HomeSpace will localize the app to regions and languages, partner with smart home hardware companies to deliver the app as part of their product shipment and target under-served yet highly growth-inducing markets for smart home technology (MarketsandMarkets, 2024; Singh and Singh, 2024).

Increase Customer Retention: Reduction and user retention on the platform is a priority. HomeSpace will achieve this by providing excellent customer support and onboarding procedures, having loyalty programs or subscription models with special rewards, and conducting regular surveys to identify and address pain points (Grand View Research, 2024; MarketsandMarkets, 2024).

Establish Thought Leadership: HomeSpace will concentrate on becoming an expert in smart home management and energy efficiency. It will release whitepapers, research papers, and industry reports, host webinars and workshops, and engage in industry forums in an effort to share knowledge and insights (Singh and Singh, 2024; Grand View Research, 2024).

Achieve Revenue Growth: To be profitable, HomeSpace will provide premium price schemes with improved functions to high users, co-promote with electric companies to have the app part of efficiency saving plans, and sell added value services such as expert energy audits or appliance upkeep (MarketsandMarkets, 2024; Singh and Singh, 2024).

Leverage Data-Driven Marketing: HomeSpace will leverage analytics to maximize marketing effectiveness and enhance ROI. This involves monitoring user behavior and preferences to

enhance targeting and messaging, A/B testing campaigns, and monitoring market trends and competitor activity to remain ahead (Grand View Research, 2024; MarketsandMarkets, 2024).

Community Building: Establishing a loyal user base of HomeSpace users and enthusiasts is a priority. The company will seed online forums or social media groups in which users can share tips and experiences, encourage user-generated content through contests and incentives, and highlight community achievements and energy-saving milestones (Singh and Singh, 2024; Grand View Research, 2024).

4.7. Unique Selling Point

HomeSpace is distinctive in the smart home management competitive space as it is energy efficient, human-centered, and secure. Below are some of the distinctions:

Real-Time Energy Monitoring: HomeSpace allows monitoring of real-time energy consumption, along with detailed statistics and graphical analyses. This transparency notifies consumers of energy-guzzling devices and recommendations on how to maximize the usage habits, making it energy-efficient usage.

Easy-to-Use Interface: HomeSpace has an easy-to-use interface and fewer navigations, leading to a learning curve of very low magnitude to facilitate use by individuals of any age group and technical aptitude. Basic configurations also play their part in the user experience.

Cross-platform compatibility: This software is designed to work originally on both desktops and mobile devices, making it super convenient and flexible. Thanks to its cross-platform compatibility, users can easily manage and control their smart home equipment anytime, anywhere.

Personal automation and scenes: Users can create customized scenes and automation conditions according to their specific requirements. For instance, lights can be switched off automatically at a chosen time, many devices can be controlled through a single click, and the house can be rendered energy-efficient and convenient.

Secure Data Protection: HomeSpace employs multi-factor authentication and advanced encryption algorithms to safeguard user data. The system complies with global data protection standards, such as GDPR, to ensure user privacy.

Gamification and Incentives: For the encouragement of energy consumption through sustainable means, HomeSpace employs gamification elements such as energy-saving competitions and incentives. As a result, not only are the users incentivised to save energy but are also motivated for the long run (Nir and Raz, 2016).

IoT Integration: HomeSpace offers a vast number of IoT devices, which means it is now easy to operate lighting, heating, security, and appliances all from one location. Interoperability enhances the convenience factor as well as easy management of a smart home.

4.8. Implementation

To implement and grow HomeSpace effectively, there needs to be a comprehensive product, strategy, and marketing implementation plan in place.

Marketing Implementation:

Digital Marketing: SEO, social media, and Google advertisements will help HomeSpace promote its online visibility. Direct consumers, homeowners, and property developers will access targeted advertising technology (Chaffey and Ellis-Chadwick, 2019).

Traditional Marketing: Disposable paper traditional marketing (flyers, posters) will be distributed to real estate offices and technology expos, while QR code stickers will introduce potential users to the HomeSpace website.

Strategic participation: HomeSpace collaborated with property programmers as well as the IoT brands; this will facilitate market recognition in which smart residence development consists of an app in pre-installation.

Live performance: Interactive performance applications in fairs and conferences will show resources that will lead to potential practical experience for users.

Customer Retention: Both personal notifications and tips on how to save energy, as well as Mark Rewards, will keep the user engaged. Frequent updates and new features will keep interest peaked.

HomeSpace aims to create stability and convenience through smart habitat management by combining smart innovation product development with an overall marketing strategy to develop HomeSpace as the smart habitat management go-to and stable solution.

5. Project Evaluation

5.1. Organisation

5.1.1. Group Structure and Roles

Our team was organised with roles and responsibilities to ensure clarity and accountability. The following are all team members and their primary role and responsibility:

Member		Role/responsibility
Muhammad Idman Barghoob	<i>MB</i>	Developer/Organisational Manager
Leressa Britto	<i>LB</i>	Developer/Reporter/Technical Manager
Mehak Shameer	<i>MS</i>	Developer/Usability
Hala Alqudsi	<i>HA</i>	Developer/Liaison
Joao Bianchi Labriola	<i>JB</i>	Developer
Mostafa Abdelnabi	<i>MA</i>	Usability
Pratik Dutt	<i>PD</i>	Marketing
Kabir Bhatia	<i>KB</i>	Marketing
Mohammed Qarmout	<i>MQ</i>	Marketing

Our team was originally structured with 6 members to work on developing the app, and 3 members to work on marketing. While the original structure was effective, not all members were effectively contributing, leading to a need for redistributing tasks and roles. We decided to move forward with having 5 members developing the app, 3 members working on marketing and 1 member to begin the report sections in order to maintain progress.

5.1.2. Collaboration

To effectively communicate and work as a group, we used several collaboration tools to facilitate teamwork including the following:

- **Jira:** In this stage we continued using Jira to assign and track individual tasks and monitor progress which was useful for our agile development method. Further discussed in section 5.1.4.
- **GitHub :** We used GitHub as our main platform to store our project's repository and codebase. We also used it to collaborate and develop the app together. Further discussed in section 5.2.4.
- **SharePoint:** We used Microsoft SharePoint as a centralised storage space for storing all our project files including notes, designs and the report.
- **Microsoft Teams:** To hold online team meetings, we used Microsoft Teams which is a common platform for video conferencing and group communication.
- **WhatsApp:** To communicate regularly we used WhatsApp to handle all main communication outside of in person and online meetings.

The tools we used for collaboration were useful however team engagement varied, requiring more check-ins to maintain consistent communication.

5.1.3. Meetings

We set a requirement as a team to have a meeting at least once a week to monitor progress and assign new tasks. During each meeting our team discussed tasks that were completed from the previous meeting and brainstormed ideas and tasks for the upcoming week. By the end of every meeting, we set goals to have some specific tasks done which were assigned and tracked in Jira. The Project Diary for this stage is provided in **section 7.3.** Appendix C.

5.1.4. Jira

Since the beginning of the project in stage 1, our team primarily used Jira to view and keep track of tasks and timelines. Continuing into this stage, Jira remained our primary tool for:

- **Sprint planning:** Adding tasks to the backlog and assigning individual members tasks for every sprint. Planning each sprint for a specific timeframe (1 to 2 weeks).
- **Progress tracking:** Jira's Sprint board allowed us to track tasks that were marked as (To do, In progress or Done) enabling us to monitor progress.

Overall, Jira was an effective tool as it displayed all necessary tasks that needed to be completed for each member (Atlassian, n.d.).

5.1.5. Project Plan and challenges faced

Our initial plan aimed at completing the app's frontend interface within the first 3-4 sprints by the end of week 7 and have the complete application done by the end of week 9, to allow us time for usability testing and the project deadline, however due to some unforeseen technical challenges and inconsistent participation within the group these milestones were delayed. To overcome this, we quickly reprioritised our tasks and decided to focus on the core functionality of the app by making sure that we implement our 'Must-have' priority requirements by the end of week 9.

One of the setbacks that we faced earlier in the project was that some members were inexperienced with using GitHub, which led to some challenges with code collaboration and merging completed tasks. To solve this problem, we decided to set a clear work structure for our repository by:

- Ensuring that members worked on either a fork of the main repository or a separate branch.
- Ensure any features implemented were pushed to a new branch to be tested first.
- Assigned tasks between members to different sections of the app, to reducing overlapping changes and avoid merge conflicts.

These changes greatly improved code collaboration within the team as everyone quickly got familiar with Git Version Control and we were able to efficiently develop the app.

The Gantt Chart for stage 2 is provided below.

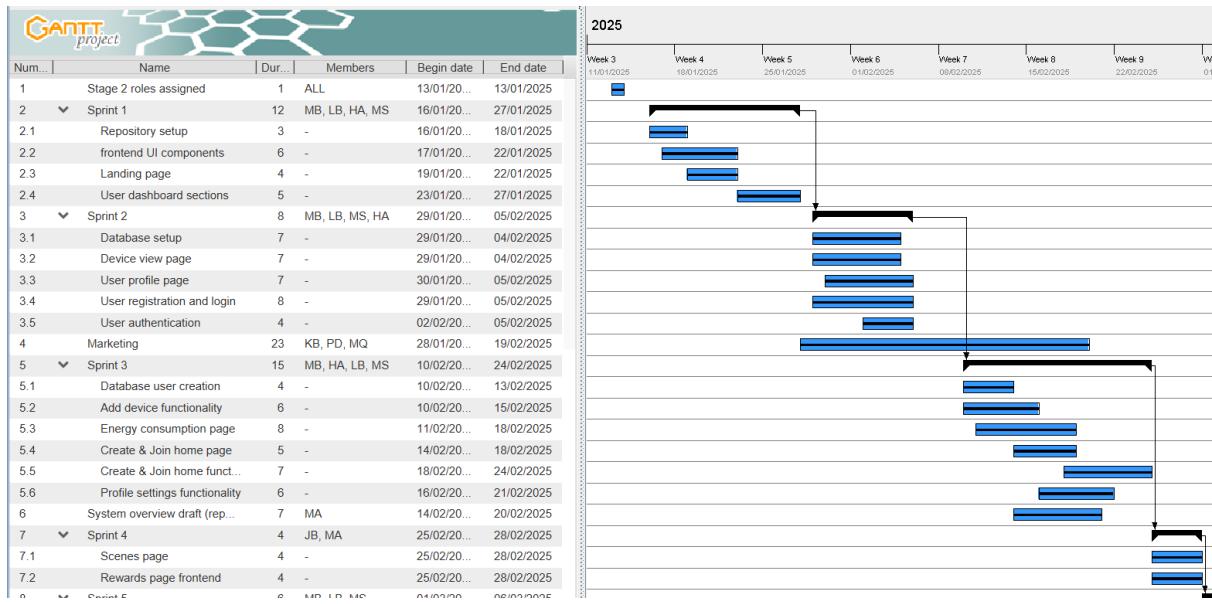


Figure 17: Stage 2 Gantt chart (January - February)

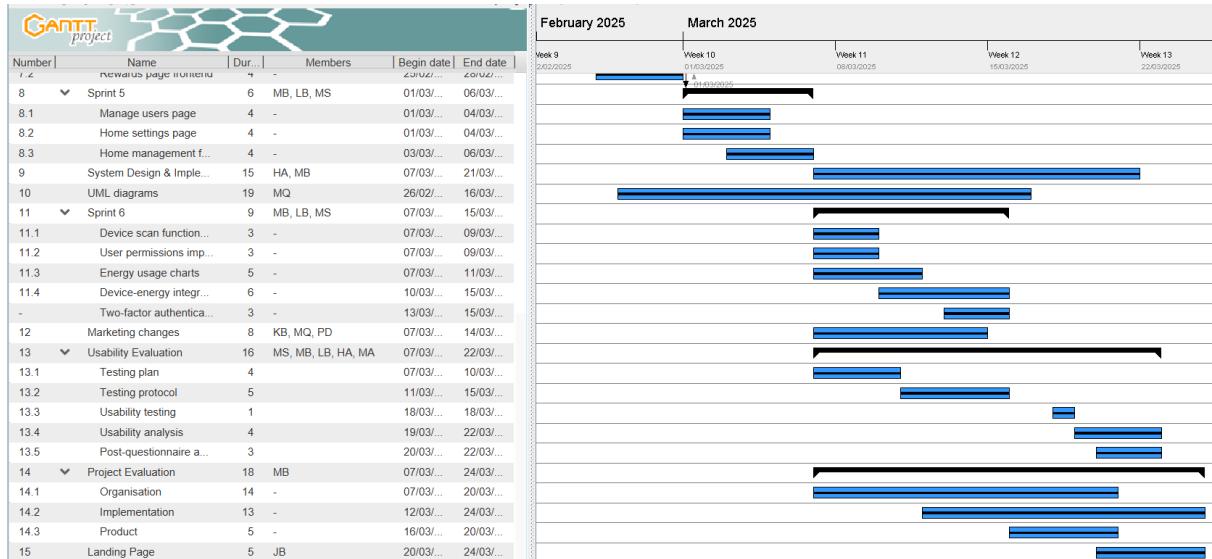


Figure 18: Stage 2 Gantt chart (March)

5.1.6. Implementation approach

Our project followed an Agile scrum development approach where developers on our team worked on implementing a certain set of functionalities and features chosen from a backlog before each sprint. The sprints lasted approximately anywhere from 1 to 2 weeks depending on everyone's schedule and other modules. Any tasks that were unable to be completed within a sprint were moved to the following sprint. By keeping sprint lengths varied and distributing different parts of the app to different members for each sprint we were able to successfully meet our Must-have requirements for the app.

5.1.7. Tools and frameworks used

For implementation we used the following technologies including open-source libraries and frameworks to streamline development:

- **ReactJS:** Open-source frontend framework used for our frontend interface (*React*, n.d.).
- **Firebase:** Used as our fully managed backend platform for the database and authentication (*Firebase*, n.d.).
- **TailwindCSS:** Open-source CSS framework we used for developing responsive styling for frontend components (*Tailwind CSS - Rapidly Build Modern Websites Without Ever Leaving Your HTML.*, n.d.).
- **Recharts:** Open-source JavaScript library used for developing the energy usage graphs and charts (*Npm: Recharts*, n.d.).
- **Lucide React:** Open-source collection of customizable icons used across the interface (*Lucide Icons*, n.d.).
- **html5-qrcode:** Integrated to enable QR code scanning for adding device functionality (*Npm: Html5-qrcode*, n.d.).

The tools we used for implementing HomeSpace were very suitable for our needs especially React which provided a modular way to build our frontend interface and TailwindCSS which enabled us to keep all pages responsive. However, Firestore's NoSQL structured required additional restructuring as our app evolved during development.

The implementation of the app and how these tools were used is discussed in more detail in **section 3. Final System Design & Implementation**.

5.1.8. Implementation schedule

Provided below is the table representing our stage 2 implementation schedule. This includes the development sprints, and all major tasks completed during the stage. When we couldn't finish tasks in a sprint we moved them forward to the next sprint. Throughout the project we also reimplemented certain pages and functionalities of the application that were either partially completed or had to be redesigned to better meet our requirements. There were other tasks including marketing which also needed some changes after review.

Key: (Completed -) (Partially completed -) (Not completed -)

Task	Start	End	Members	Progress
Stage 2 roles assigned	13/01/25	13/01/25	ALL	
Sprint 1	16/01/25	27/01/25	MB, LB, MS, HA	
- Repository setup	16/01/25	18/01/25		
- Frontend UI components	17/01/25	22/01/25		
- Landing page	19/01/25	22/01/25		
- User dashboard sections	23/01/25	27/01/25		
Sprint 2	29/01/25	05/02/25	MB, LB, MS, HA	

- Database setup	29/01/25	05/02/25				
- Devices view page	29/01/25	04/02/25				
- User profile page	30/01/25	04/02/25				
- User registration and login	29/01/25	05/02/25				
- User authentication	02/02/25	05/02/25				
Marketing	28/01/25	19/02/25	KB, PD, MQ			
Sprint 3	10/02/25	24/02/25	MB, LB, MS, HA			
- User creation	10/02/25	13/02/25				
- Add device functionality	10/02/25	15/02/25				
- Energy consumption page	11/02/25	18/02/25				
- Create & Join home page	14/02/25	18/02/25				
- Create & Join home functionality	18/02/25	24/02/25				
System Overview (report)	14/02/25	20/02/25	MA			
Sprint 4	25/02/25	28/02/25	JB, MA			
- Scenes page	25/02/25	28/02/25				
- Rewards page	25/02/25	28/02/25				
- Rewards system						Red
Sprint 5	01/03/25	06/03/25	MB, LB, MS			
- Manage users page	01/03/25	06/03/25				
- Home settings page	01/03/25	04/02/25				
- Home management functionality	03/03/25	06/03/25				
Final System Design & Implementation	07/03/25	21/03/25	HA, MB, LB			
UML diagrams	26/02/25	16/03/25	MQ			
Sprint 6	07/03/25	15/03/25	MB, LB, MS			
- Add device scanning functionality	07/03/25	09/03/25				
- User permissions implementation	07/03/25	09/03/25				
- Energy usage charts	07/03/25	11/03/25				
- Device-energy integration	10/03/25	15/03/25				
- Two-factor authentication	13/03/25	15/03/25				
Marketing changes	07/03/25	14/03/25	KB, MQ, PD			
Usability Evaluation	07/03/25	22/03/25	MS, MB, LB, HA, MA			
- Testing plan	07/03/25	10/03/25				
- Testing protocol	11/03/25	15/03/25				
- Usability testing	18/03/25	18/03/25				
- Usability analysis	19/03/25	22/03/25				
- Post-questionnaire analysis	20/03/25	21/03/25				

Landing Page	20/03/25	24/03/25	JB	
Project Evaluation	07/03/25	20/03/25	MB	
- Organisation	07/03/25	14/03/25		
- Implementation	12/03/25	24/03/25		
- Product	16/03/25	20/03/25		

5.1.9. GitHub

To effectively develop the application on the same codebase, we used GitHub for version control and code collaboration. After we faced some setbacks early on in the project as discussed in 4.1.5. where we faced code collaboration challenges as we were working on separate forks and everyone's repositories were not in sync leading to merge conflicts, we decided that each team member will develop on separate feature branches, ensuring that new functionalities were tested before merging into the main branch.

We implemented a feature-based branching strategy, where each feature or bug fix was developed in an isolated branch and reviewed before integration. We used pull-requests for code review and testing before merging into our main branch.

By leveraging GitHub's version control capabilities, we were able to streamline collaboration and maintain a structured development process (*GitHub · Build and Ship Software on a Single, Collaborative Platform*, 2025).

5.2. Product

5.2.1. Overview of Functionality Achieved

By the end of stage 2, we successfully managed to implement nearly all of our *Must-have* requirements defined using the *Moscow* prioritization method, ensuring that the core functionality of the HomeSpace application was met. Additionally, we also nearly achieved all should-have requirements, including the tap-to-run scenes and automated scenes, which enhance user control over their devices. However, due to time constraints and limited developers, we were unable to implement any of the gamification features, which were classified as *Could-have* (lower priority). These features remain potential improvements for future iterations of the project.

5.2.2. Functional Requirements

Provided below are the functional requirements for HomeSpace that were defined in stage 1. A column has been added to reflect if the corresponding requirement has been met, partially met or not met within stage 2.

ID	Description	Priority	Implemented
User Interface and Experience Needs			
1	Accessibility Features		
F-UR	Responsive Design	Should	Yes
1.1	The system shall allow users to adjust font sizes without breaking the applications design.		
F-UR	High Contrast Modes	Could	No
1.2	The system could provide different contrast modes to assist the visibility of users with visual impairment.		

UI and UX

Making use of CSS media queries and TailwindCSS we were able to develop pages that were responsive and maintained the app's design on a phone browser. Some user interface components such as the navbar and device cards were designed differently for phones and larger screens to ensure responsiveness.

	Energy Monitoring and Analytics	Priority	Implemented
2	Energy Tracking		
F-SR	Track and Store Consumption	Must	Yes
2.1	The system must track and store the consumption of energy in kWh of each device connected to the home.		
F-SR	Daily tracking	Must	Yes
2.2	The system must update energy usage of devices daily.		
3	Energy Consumption Display		
F-UR	Individual Devices	Must	Yes
3.1	The system must display energy usage for individual devices and robots for comparison.		
F-UR	Consumption by Time Periods	Should	Yes
3.2	The system shall allow the user to view energy consumption over different time periods (daily, weekly, monthly and yearly).		
4	Graphical Display		
F-UR	Time periods	Must	Yes
4.1	The system must use graphs and charts to display the consumption through different time periods		
F-UR	Individual Devices	Must	Yes
4.2	The system must use graphs and charts to display the consumption of individual devices		
F-UR	Benchmarking	Should	No
4.3	The system should provide insights on how a user's energy consumption compares to average or efficient usage standards.		
5	Recommendations for Energy Saving		
F-UR	Personalized Recommendations	Should	No
5.1	The system should generate suggestions tailored to the user's habits to improve energy efficiency.		

F-UR	Alerts	Should	No
5.2	The system should notify users of spikes or anomalies in energy usage.		

Energy monitoring and analytics

Since we used mock device data to simulate device activity, we calculated energy usage per device based on the device's power consumption rating which was researched. Through this we made use of timestamps that were adjusted based on the device's status that allowed us to keep track of a device's energy consumption. Our energy consumption page also displays updated energy consumption for the home as a whole and for individual devices using graphs. However, we were not able to implement the personalised recommendations as these would be linked with the gamification features which were also not implemented.

	Account Creation and Customisation	Priority	Implemented
6	Account registration and login		
F-SR	Sign-up	Must	Yes
6.1	The system must allow users to create a new account using form validation and Two-Factor Authentication.		
F-SR	Account Details	Must	Yes
6.2	When creating an account, the system shall request the user's: - E-mail - Phone Number - First Name - Last Name - Password - Date of Birth		
F-SR	Login	Must	Yes
6.3	The system must allow users to login using their email and password, with Two-Factor Authentication if they have it enabled.		
F-SR	Reset Password	Must	Partially
6.4	The system must allow users to reset their password if they have forgotten it, by sending them a reset link to their registered email.		
7	Create and Join Homes		
F-UR	Create Home	Must	Yes
7.1	The system must allow users to create a home environment where they can add smart devices and view energy usage statistics.		
F-UR	Join Home	Must	Yes
7.2	The system must allow users to join an existing home by using the home ID that was shared by the homeowner.		
8	Profile Settings		
F-UR	Edit credentials	Must	Yes
8.1	The system must allow users to edit their personal credentials, by allowing them to change their name, email address, phone number.		

F-UR	Change password	Must	Yes
8.2	The system must allow users to change their password if they are already logged in.		
9	Custom Accesses and Permissions Handling		
F-SR	Age-Based Access	Must	Yes
9.1	The system must allow users under the age of 18 to only join existing Homes; they cannot create new Homes.		
F-SR	User Permissions	Must	Yes
9.2	The system must provide the homeowner/manager (user whom created the Home) the ability to set and manage different access levels for various users.		
F-SR	Permission Types	Should	Yes
9.3	The system shall provide the homeowner/manager the option of customizing the following permissions: - Add device - Remove device - View device status - Create scene - Create automation - View analytics - Share analytics		
F-SR	Default Permissions	Should	Yes
9.4	By default, the system should give the homeowner/manager permission for all functions mentioned in F-SR 9.3, and other users the permission to add device, view device status, create scene, create automation and view analytics.		
F-SR	Change Admin	Should	Yes
9.5	The system should allow the homeowner/manage to transfer all admin rights and privileges to another user in the home, allowing that user to become the new homeowner.		

Account creation and home management

For account creation and management, we have working user sign up and login. The user is also able to change their password and edit their profile information. For Home creation and home management the create and join home functionalities are also implemented as they are essential to the app's functionality. Furthermore, homeowners (admins) are also able to set permissions for other users.

	Smart Device and Robot Control Needs	Priority	Implemented
10	Device Management		
F-SR	Centralized Home Device Management	Must	Yes
10.1	The system must allow users to create a "Home" as a centralized platform to manage all connected smart devices and robots, and to connect multiple users for access and control.		

F-UR	Add Device Functionality	Must	Yes
10.1	The system must allow users to add new smart devices to their Home.		
F-UR	Remove Device Functionality	Must	Yes
10.2	The system must allow users to remove smart devices from their Home.		
F-UR	Real-Time Device Status	Should	Yes
10.3	The system should display real-time updates on the operational status of each device, including connection status and current operational state (e.g., light bulb on/off).		
11	Automation and Scheduling		
F-UR	Scenes	Should	Yes
11.1	The system shall allow users to create “Scenes”, where multiple actions can be set-up for easier control of multiple smart devices.		
F-UR	Conditional Automation	Could	Yes
11.2	The system could allow users to automate device actions based on triggers like time, sensor input, or user location.		
12	Remote Access and Control		
F-UR	Remote Access	Must	Yes
12.1	The system must allow users to control their home devices through the application regardless of their location, by using an internet connection.		
F-SR	Multiple Users	Should	Yes
12.1	The system shall support multiple users to "join" a Home, providing access to functionalities relative to each user's permissions.		

Smart device and scenes management

All planned requirements for device management have been implemented, additionally this stage we went a step further with the add-device functionality. The user can now scan a QR code of a device to add a device to their home. This was not a part of the original requirements, but we decided to implement it as it works well with our model of working with the mock devices and enhances ease of use.

We also implemented the tap-to-run and automated scenes allowing the user to create preset configurations for device actions that activate based on either user toggling a scene (tap-to-run) or at a time of day set by the user (automations).

	Gamification and User Engagement Needs	Priority	Implemented
13	Incentives for Energy Saving		
F-UR	Energy Consumption Goals	Could	No
13.1	The system could allow users to set weekly, monthly and yearly goals for energy consumption.		

F-UR 13.2	Device Gamification Ownership The system could allow homeowners/managers to assign devices to different users (i.e parents can assign their children's devices to their accounts).	Could	No
F-UR 13.3	Rewards System The system could implement badges, points and rewards for achieving energy-saving goals.	Could	No
F-UR 13.4	Social Media Integration The system could allow users to share their achievements and energy statistics on social media platforms.	Could	No

Rewards and gamification elements

Due to time constraints and design complexities, we were not able to implement the gamification functionality and the rewards system. This still remains a key feature to improve the app that can be considered in future work and iterations.

	Support and Training Needs	Priority	Implemented
14	Help Centre and Tutorials		
F-UR 14.1	Interactive Guides The help centre of Home Space should contain interactive guides to help new users understand the application.	Should	Yes
F-UR 14.2	FAQ The help centre of Home Space should maintain a comprehensive repository of common questions and solutions.	Should	Yes

5.2.3. Special Features and Improvements

Beyond the requirements that cover the core functionality of our application, we also implemented some new features and made improvements to originally planned features to enhance overall user control.

Adding device by scanning QR code

Throughout this stage as we developed the app, we made use of mock data to simulate the behaviour of reading device data and adding it to a home environment. After research and many revisions, we decided on a format to store device data in JSON objects and implemented functionality to allow the user to add a device by scanning a device QR code that contains the JSON data. The app uses the device's camera to capture the QR code, reading the device data object and adding the device to the home.

Improved user permissions

In stage 2, we revised the permissions functionality and changed it to the following:

- Add device
- Remove device
- Manage scenes
- View analytics

This revised format ensures that essential permissions are clear and simplified the user experience for homeowners when managing permissions.

Tap-to-run and Automated scenes

The scenes is one of the unique features of HomeSpace and was implemented successfully, enabling users to create device management configurations that controlled multiple devices. The *Tap-to-Run* scene enables users to manually trigger a scene with a single tap, providing a quick and easy way to execute predefined actions for selected devices.

For *Automated Scene*, we implemented a time trigger-based system where users can choose a time of day to activate certain device actions. When the time is met the system automatically executes the scene, improving home automation.

5.2.4. System Robustness and known bugs

The overall system is functional and reliable, supporting the key features including device management, home and user management and energy monitoring.

Authentication and Security

User authentication and security is a crucial part of our system and Firebase's authentication handles this by providing a fully managed authentication system with built-in security features. Firebase handles user credentials securely using encryption, enforces authentication best practices and uses token-based authentication making it a more secure option compared to self-hosted authentication. Firestore security rules also ensure that users can only access data they are authorised to view, minimising unauthorised access risks.

To enhance user account security, we implemented two-factor authentication using NodeJS and Express. Our 2FA system integrates with Google Authenticator, requiring users to enter a one-time password during login.

Bugs and limitation

However, there are a few minor issues and limitations that can affect user experience and could be fixed in future iterations:

- **Firestore update latency:** Some updates, such as loading scenes or newly added devices take longer than expected to reflect in the user interface due to Firestore's real-time sync delays. This could be improved in future iterations by using indexes.
- **User based energy consumption:** One of the limitations of HomeSpace is that energy consumption is not based on an individual user but the home. This is a design feature that can be incorporated to improve the application in future work.

Despite these issues, the system remains reliable and functional for regular use and no issues have been found so far that cause the app to crash. Future optimisations could focus on improving database queries, using indexes and enhancing system responsiveness for larger homes.

5.2.5. Usability Summary

Pragmatic and Hedonic Quality	
Attractiveness	1.26
Pragmatic Quality	1.20
Hedonic Quality	0.57

The UEQ results indicated that HomeSpace is functional and stable scoring well in attractiveness and pragmatic qualities. However, it also showed that the app lacks features that drive excitement and joy as the app scored lower in hedonic qualities. In summary, the app provides a reliable but slightly less engaging user experience. For a comprehensive analysis of the app's usability including the testing protocol results, see **section 4.4.3.** in Usability Evaluation.

6. Conclusions & Future Work

This report has outlined both the implemented features and the limitations of HomeSpace. While some planned requirements were not achieved, we successfully implemented nearly all *Must-have* and *Should-have* requirements to deliver a functional system. Using HomeSpace users can manage smart devices, monitor energy consumption and use scenes to set device configurations and schedule automations, providing a seamless smart home experience.

However as previously mentioned, the system also has a few limitations and areas for improvement. Firestore update latencies occasionally causes delays in real-time updates and changes. Furthermore, a major limitation that we had in our overall design for the system was that energy consumption tracking was implemented per home rather than per user, which means that although users can view energy consumption for each device individually and for the entire home as a whole, they cannot track their individual energy consumption. This also restricted our ability to develop the gamification and user rewards system as initially planned. This is reflected in our usability evaluation with participants finding the system less engaging and the hedonic qualities scoring lower in the UEQ questionnaire.

Future iterations of HomeSpace can improve system performance and expand on functionality by addressing these limitations. User-based energy tracking would enable personalised insights and usage details allowing for a more engaging gamification system that can encourage energy-efficient behaviour. Additionally, optimising Firestore queries with database indexes would reduce latency and improve responsiveness. Implementing these improvements would make HomeSpace a more interactive and enjoyable smart home solution.

7. Appendices

7.1. Appendix A: Usability Testing

7.1.1. Sample Consent Form

Future Homes - HomeSpace
Heriot-Watt University

Consent to Act as a Subject in an Experimental Study

Principal Investigators: Muhammad Idman Barghoob, Joao Bianchi Labriola, Mehak Shameer, Leressa Britto, Hala Alqudsi, Mostafa Abdelnabi, Pratik Dutt, Mohammed Qarmout, Kabir Bhatia

Description: The purpose of this study is to evaluate the user interface and the user experience of the HomeSpace application.

There are minimal risks for you to participate in this study. All personal information will be kept confidential in a secure filing cabinet or in password-protected computer directories. Your participation will not affect how well you do in your courses (if you are a student) or affect your relationship with the university in any way.

You are free to decline to participate in this study. Should you decide to participate, you are free to end your participation at any time. Such a decision by you will not adversely affect or alter your status with the university in any way.

Voluntary consent: I certify that I have read the preceding and that I understand its contents. Any questions I have pertaining to the research have been and will be answered by the team. My signature below means that I have freely agreed to participate in this study, and that I agree to the publication of the results for scientific purposes and to the distribution of the recordings and transcripts of the sessions for research purposes so long as my identity is not revealed.

Date

Subject Signature

Inv. Initials

Investigator's certification: I certify that I have explained to the above individual the nature and purpose, the potential benefits, and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature.

Date

Investigator Signature

Figure 19: Usability testing consent form

7.1.2. Post-Questionnaire (UEQ)

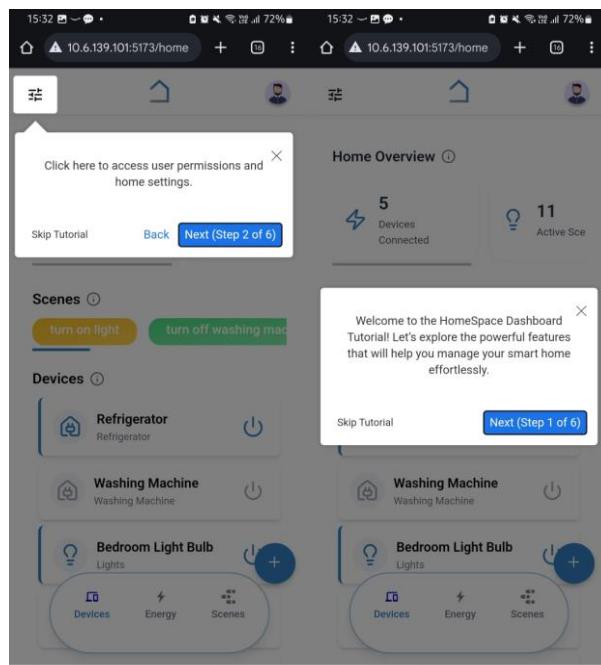
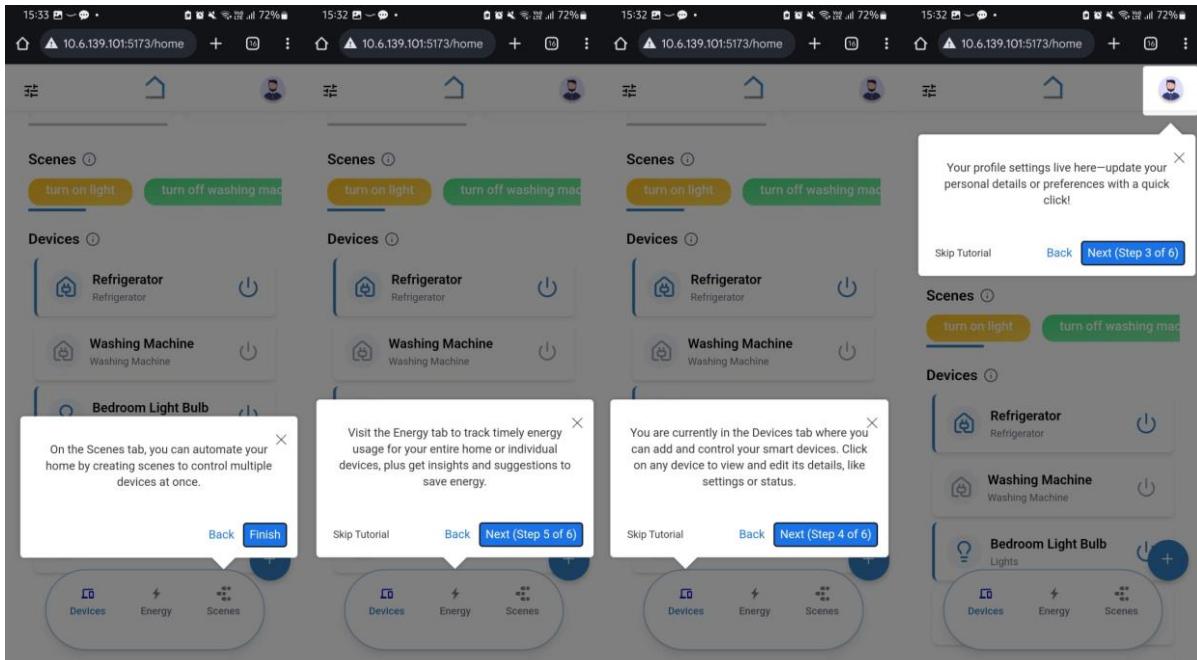
	1	2	3	4	5	6	7	
annoying	<input type="radio"/>	enjoyable 1						
not understandable	<input type="radio"/>	understandable 2						
creative	<input type="radio"/>	dull 3						
easy to learn	<input type="radio"/>	difficult to learn 4						
valuable	<input type="radio"/>	inferior 5						
boring	<input type="radio"/>	exciting 6						
not interesting	<input type="radio"/>	interesting 7						
unpredictable	<input type="radio"/>	predictable 8						
fast	<input type="radio"/>	slow 9						
inventive	<input type="radio"/>	conventional 10						
obstructive	<input type="radio"/>	supportive 11						
good	<input type="radio"/>	bad 12						
complicated	<input type="radio"/>	easy 13						
unlikable	<input type="radio"/>	pleasing 14						
usual	<input type="radio"/>	leading edge 15						
unpleasant	<input type="radio"/>	pleasant 16						
secure	<input type="radio"/>	not secure 17						
motivating	<input type="radio"/>	demotivating 18						
meets expectations	<input type="radio"/>	does not meet expectations 19						
inefficient	<input type="radio"/>	efficient 20						
clear	<input type="radio"/>	confusing 21						
impractical	<input type="radio"/>	practical 22						
organized	<input type="radio"/>	cluttered 23						
attractive	<input type="radio"/>	unattractive 24						
friendly	<input type="radio"/>	unfriendly 25						

Figure 20: UEQ Questionnaire (User Experience Questionnaire (UEQ), n.d.-b)

7.2. Appendix B: HomeSpace Interface Screenshots

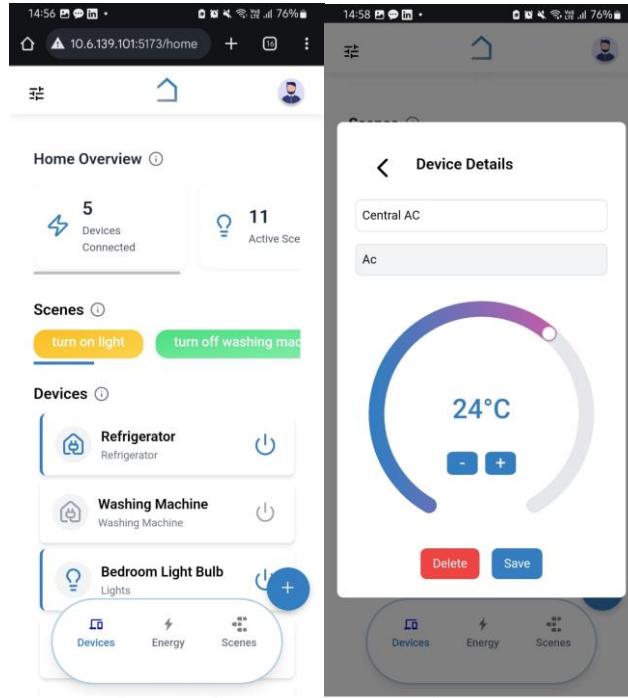
User guide

The system gives a tutorial for the user when they first log in.



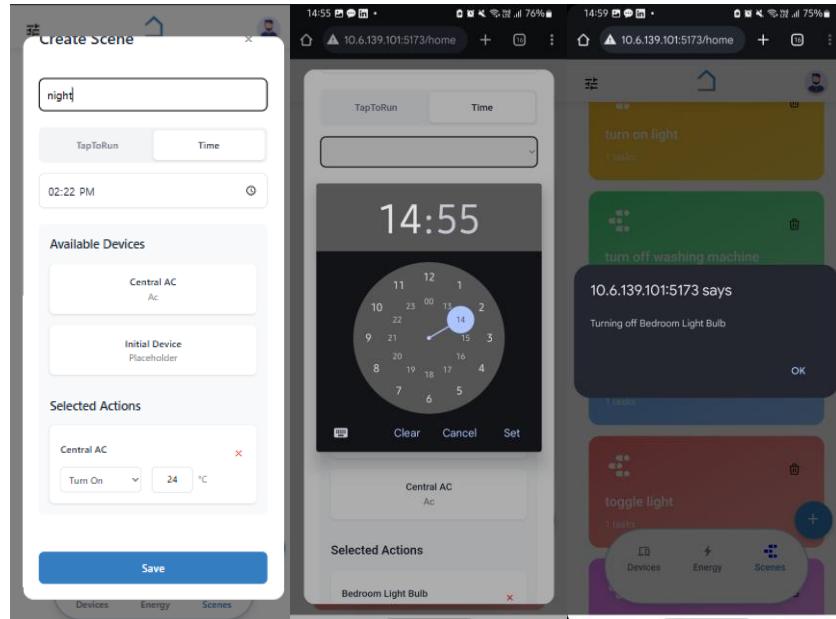
Devices

In the dashboard the user can click on some of their devices such AC and adjust the temperature.



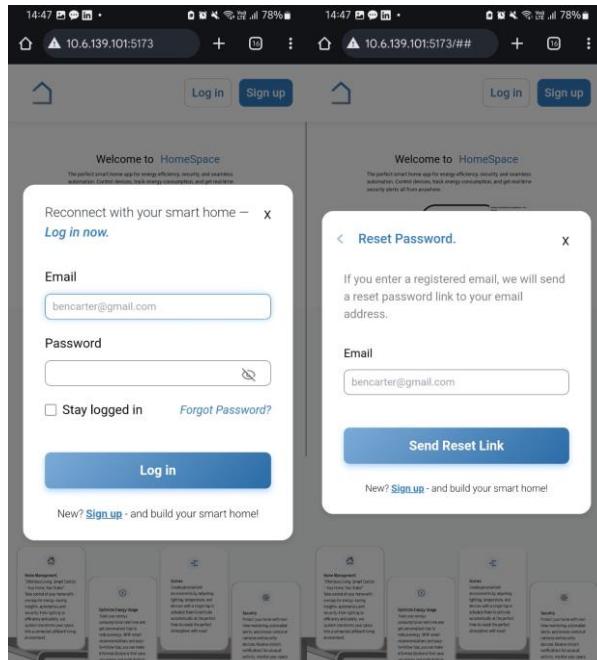
Scenes

In tap-to-run users can pick a time to schedule the scene and once they save, they get a message/alert that the scene has been saved.



Reset Password

The user has the option to reset their password.



User Management Page

A screenshot of the HomeSpace User Management page. At the top, there are navigation links for 'Home Management' and the 'HomeSpace' logo. On the right, a user profile for 'testing testing' is shown. The main area is titled 'View Users' and displays a table with three rows. The first row shows 'john ben' (Owner), 'john@gmail.com', 'Admin', and a 'View Permissions' button. The second row shows 'testing testing', 'test12@gmail.com', 'User', and a 'Hide Permissions' button. A context menu is open over the second row, listing 'Add Device', 'Manage Scenes', and 'View Analytics'. The table has columns for 'Name', 'Email', 'Role', and 'Permissions'.

User Management Page: Admin View

Home Management		HomeSpace			john ben Admin	
Manage Users						
Name	Email	Role	Permissions	Action		
john ben <small>Owner</small>	john@gmail.com	Admin	Edit Permissions			
testing testing	test12@gmail.com	User	Edit Permissions	Remove User	Transfer Ownership	

Home Settings Page: Admin View

Home Management		HomeSpace			john ben Admin			
Home Settings								
Home Information		Home Name						
Notification Preferences		testing_devices						
		Home ID						
		home_k1z5r5w8						
		Copy						
		Owner Name						
		john ben						
		Creation Date: Fri Mar 07 2025						
		Save Settings						
		Reset Home						
		Delete Home						

User Profile Page

Profile

john ben
john@gmail.com

Privacy Settings

My Goals

FAQ & Feedback

Contact Us

First Name
john

Last Name
ben

Email
john@gmail.com

Phone Number
+97150567432

Date of Birth
2005-10-11

[Edit Profile](#)

Change Password

New Password

Confirm Password

[Change Password](#)

Scenes Page

Home Management

HomeSpace

Leressa Admin User

Devices Energy Scenes

turn on light (1 tasks)

turn off washing machine (1 tasks)

turn off light (1 tasks)

toggle light (1 tasks)

turn on ac (1 tasks)

turn off ac (1 tasks)

time test (00:43 | 2 tasks)

goodnight (4 tasks)

+ Add Scene

Devices Page

Home Management

HomeSpace

Leressa Admin User

Devices Energy Scenes

Home Overview ⓘ

5 Devices Connected 8 Scenes

Devices ⓘ

Refrigerator

Washing Mac...

Bedroom Lig...

Initial Device

Central AC

+ Add Device

Energy Pages

Energy Dashboard

Total Energy Saved ⓘ



15 kWh

Great job! Keep optimizing your device usage to save more energy.

All Devices Consumption ⓘ

[Daily](#) [Monthly](#) [Yearly](#) [All Devices](#) ▾


Energy Saving Tips ⓘ

⚡ Turn off devices when not in use to save up to 30% on energy bills.

⚡ Consider upgrading to energy-efficient appliances.

⚡ Use a programmable thermostat to control heating and cooling.

⚡ Switch to LED bulbs to reduce energy consumption.

⚡ Unplug electronics when they are not in use to avoid 'phantom' energy waste.



7.3. Appendix C: Project Diary

PROJECT DIARY

F29SO GROUP 3

Group 3 Members: Hala, Joao, Kabir, Leressa, Mehak, Mostafa, Mohammed, Muhammad, Pratik

Line Manager: Dr. Drishty Sobnath

Project Coordinator: Dr. Ali Muzaffar

Roles and Responsibilities:

- **Reporter - LB**
- **Liaison – HA**
- **Organisational Manager – MB**
- **Technical Manager - LB**

STAGE 2

Meeting Number : 1

Date: 18/12/24
Time: 25 mins (4:15pm – 4:40pm)

Time: 25 mins (4:15pm –

Attendees:

- Online: LB, MS, MB, MQ, KB, HA, MA

Meeting Description:

Read through stage 2 specifications. Discussed about maintaining sprints and creating a GitHub repository as a common working space.

Decisions Taken:

- We would take time to learn React, create a github repository and then proceed.

Next Steps:

- Start developing frontend by next week.

Next Meeting: Scheduled for 28/12/24.

Meeting Number : 2**Date:** 28/12/24**Time:** 30 mins (5pm – 5:30pm)**Attendees:**

- Online: LB, MS, MB, MQ, HA

Meeting Description:

Discussed development progress made, looked through basic layout developed.

Decisions Taken:

- We would use Vite for React development.
- Create

Progress Against Milestones:

- The usability experiment was successfully conducted, and data collection is complete.
- The questionnaires and testing protocol are ready for analysis.

Next Steps:

- Review and analyse the collected data to gain insights into the prototype's usability.

Next Meeting: Scheduled for 19/11/24 (1pm – 2pm).

Meeting Number : 7**Date:** 29/01/25**Time:** 120 mins (1pm – 3 pm)**Attendees:**

- Onsite: HA, LB, MA, MB, MS, JB, KB

Meeting Description:

Discussed progress on the web app development as well as the marketing section. Discussed on better layout designs for the web app. Created a sprint on jira and split tasks to speed up development.

Decisions Taken:

- We would require 9-10 participants.

Progress Against Milestones:

- The usability experiment was successfully conducted, and data collection is complete.
- The questionnaires and testing protocol are ready for analysis.

Next Steps:

- Review and analyse the collected data to gain insights into the prototype's usability.

Next Meeting: Scheduled for 19/11/24 (1pm – 2pm)

Meeting Number : 8

Date: 05/02/25

Time: 120 mins (1pm – 3 pm)

Attendees:

- Onsite: HA, LB, MQ, MA, MB, MS

Meeting Description:

Finalized the questionnaires and testing protocol, conducted the usability testing, and gathered responses from participants.

Decisions Taken:

- We would require 9-10 participants.

Progress Against Milestones:

- The usability experiment was successfully conducted, and data collection is complete.
- The questionnaires and testing protocol are ready for analysis.

Next Steps:

- Review and analyse the collected data to gain insights into the prototype's usability.

Next Meeting: Scheduled for 19/11/24 (1pm – 2pm).

Meeting Number: 9

Date: 11/02/25

Time: 120 mins (1pm – 3pm)

Attendees:

- Onsite: HA, LB, MB, MS, MA, MQ

Meeting Description:

Closed Sprint 2 (all tasks completed by 05/02/25). Started Sprint 3: User creation, Add device functionality, Energy consumption page, and Create & Join home page. MA provided an update on the System Overview report (due 20/02/25). Marketing team discussed progress (60% complete).

Decisions Taken:

- Assign MS to lead Energy consumption page development.

Progress Against Milestones:

- Sprint 2 fully completed.
- Sprint 3 tasks (User creation, Add device functionality) 20% complete.
- System Overview report 50% complete.

Next Steps:

- Continue Sprint 3 tasks, focusing on Create & Join home functionality.

Next Meeting: Scheduled for 18/02/25 (1pm – 3pm).

Meeting Number: 10

Date: 18/02/25

Time: 120 mins (1pm – 3pm)

Attendees:

- Onsite: HA, LB, MB, MS, KB, PD

Meeting Description:

Reviewed Sprint 3 progress: Energy consumption page and Create & Join home page completed; Create & Join home functionality in progress (due 24/02/25). Marketing team finalized their work (completed 19/02/25). Discussed Sprint 4 tasks (Scenes page, Rewards page) starting 25/02/25.

Decisions Taken:

- Assign JB and MA to focus on Scenes and Rewards pages in Sprint 4.

Progress Against Milestones:

- Sprint 3 tasks 80% complete (Create & Join home functionality pending).
- Marketing section fully completed.

Next Steps:

- Finish Sprint 3 and start Sprint 4 tasks.

Next Meeting: Scheduled for 25/02/25 (1pm – 3pm).

Meeting Number: 11

Date: 25/02/25

Time: 120 mins (1pm – 3pm)

Attendees:

- Onsite: HA, LB, MB, MS, JB, MA

Meeting Description:

Closed Sprint 3 (all tasks completed by 24/02/25). Started Sprint 4: Scenes page and Rewards page (due 28/02/25). MQ presented initial UML diagrams (26/02/25 start). Discussed upcoming Sprint 5 tasks (Manage users page, Home settings page, Home management functionality).

Decisions Taken:

- Prioritize Rewards system planning for Sprint 5.

Progress Against Milestones:

- Sprint 4 tasks 20% complete.
- UML diagrams 10% complete.

Next Steps:

- Complete Sprint 4 tasks and prepare for Sprint 5.

Next Meeting: Scheduled for 04/03/25 (1pm – 3pm).

Meeting Number: 12**Date: 04/03/25****Time: 120 mins (1pm – 3pm)****Attendees:**

- Onsite: HA, LB, MB, MS, MQ, KB

Meeting Description:

Closed Sprint 4 (Scenes page, Rewards page completed by 28/02/25). Started Sprint 5: Manage users page, Home settings page (note: end date 04/02/25 seems incorrect, assuming 04/03/25), and Home management functionality. Discussed Sprint 6 tasks (Add device scanning, User permissions, etc.) starting 07/03/25. Reviewed Marketing changes progress (due 14/03/25).

Decisions Taken:

- Assign LB to lead Add device scanning in Sprint 6.

Progress Against Milestones:

- Sprint 5 tasks 30% complete (Home settings page done).
- Marketing changes 50% complete.

Next Steps:

- Finish Sprint 5 tasks and begin Sprint 6.

Next Meeting: Scheduled for 11/03/25 (1pm – 3pm).**Meeting Number: 13****Date: 11/03/25****Time: 120 mins (1pm – 3pm)****Attendees:**

- Onsite: HA, LB, MB, MS, MA, PD

Meeting Description:

Closed Sprint 5 (all tasks completed by 06/03/25). Progressed on Sprint 6: Add device scanning, User permissions implementation, and Energy usage charts completed; Device-energy integration in progress. Usability Evaluation team (MS, MB, LB, HA, MA) reviewed Testing plan and Testing protocol (both completed). MB updated on Project Evaluation (Organisation, Implementation in progress).

Decisions Taken:

- Schedule usability testing for 18/03/25 as planned.

Progress Against Milestones:

- Sprint 6 tasks 60% complete.
- Usability Evaluation 40% complete (Testing plan, protocol done).

Next Steps:

- Complete Sprint 6 tasks and conduct usability testing.

Next Meeting: Scheduled for 18/03/25 (1pm – 3pm).**Meeting Number: 14****Date: 18/03/25****Time: 120 mins (1pm – 3pm)****Attendees:**

- Onsite: HA, LB, MB, MS, MA, MQ

Meeting Description:

Closed Sprint 6 (all tasks completed by 15/03/25). Conducted usability testing as planned (18/03/25). Discussed initial feedback from testing. Reviewed Final System Design & Implementation progress (HA, MB, LB) and UML diagrams (MQ, 80% complete). JB updated on Landing Page redesign (started 20/03/25).

Decisions Taken:

- Begin usability analysis immediately (due 22/03/25).

Progress Against Milestones:

- Usability testing completed.
- Final System Design & Implementation 60% complete.

Next Steps:

- Analyze usability data and finalize system implementation.

Next Meeting: Scheduled for 25/03/25 (1pm – 3pm).

Meeting Number: 15

Date: 25/03/25

Time: 120 mins (1pm – 3pm)

Attendees:

- Onsite: HA, LB, MB, MS, MA, JB

Meeting Description:

Reviewed usability analysis and post-questionnaire analysis (completed 22/03/25). Finalized Final System Design & Implementation (completed 21/03/25). JB confirmed Landing Page redesign completion (24/03/25). MB presented Project Evaluation (completed 20/03/25).

Planned for project submission and final review.

Decisions Taken:

- Set project submission date for 31/03/25.

Progress Against Milestones:

- Usability Evaluation fully completed.
- All sprints and major tasks (including Landing Page) done.

Next Steps:

- Prepare final submission materials and conduct a retrospective.

8. References

Smart Home Market Size, Share & Trends Analysis Report by products (Lighting Control, security & Access Controls), by application (New Construction, Retrofit), by protocols (Wireless, wired), by region, and segment Forecasts, 2023 - 2030. (n.d.). <https://www.grandviewresearch.com/industry-analysis/smart-homes-industry>

MarketsandMarkets (2024). Home Automation System Market Size, Share, Industry and Growth Analysis [Latest]. [online] MarketsandMarkets. Available at: <https://www.marketsandmarkets.com/Market-Reports/home-automation-control-systems-market-469.html> [Accessed 18 Feb. 2025].

Singh, S. and Singh, A. (2024). Smart Home Market - By Type (Security & Access Controls, Lighting Control, Entertainment Devices, HVAC, Smart Kitchen Appliances, Home Appliances, Smart Furniture, Home Healthcare, and Others Device), By Connectivity, By Price, By Application, By Distribution Channel Forecast 2024 – 2032. [online] Global Market Insights Inc. Available at: <https://www.gminsights.com/industry-analysis/smart-home-market> [Accessed 18 Feb. 2025].

Chaffey, D. and Ellis-Chadwick, F. (2019) Digital Marketing: Strategy, Implementation, and Practice. 7th edn. Harlow: Pearson.

Nir, E. and Raz, T. (2016) Hooked: How to Build Habit-Forming Products. New York: Portfolio.

Esty, D.C. and Winston, A.S. (2009) Green to Gold: How Smart Companies Use Environmental Strategy to Innovate, Create Value, and Build Competitive Advantage. New Haven: Yale University Press.

Provost, F. and Fawcett, T. (2013) Data Science for Business: What You Need to Know About Data Mining and Data-Analytic Thinking. Sebastopol: O'Reilly Media.

Kotler, P. and Keller, K.L. (2016) Marketing Management. 15th edn. Boston: Pearson.

Grand View Research (2024). Smart Homes Industry Analysis. Available at: <https://www.grandviewresearch.com/industry-analysis/smart-homes-industry>

Global Market Insights Inc. (2024). Smart Home Market Forecast 2024 – 2032. Available at: <https://www.gminsights.com/industry-analysis/smart-home-market>

GM Insights. (n.d.). Smart home market size, share & industry analysis, 2024-2032. Available at: <https://www.gminsights.com/industry-analysis/smart-home-market>

Cloud Computing Services | Google Cloud. (n.d.). Google Cloud. <https://cloud.google.com/>
React. (n.d.). <https://react.dev/>

Firebase. (n.d.). Firebase. <https://firebase.google.com/>

Atlassian. (n.d.). Jira | Issue & Project Tracking Software | Atlassian.
<https://www.atlassian.com/software/jira>

GitHub · Build and ship software on a single, collaborative platform. (2024). GitHub. <https://github.com/>

Safely collaborate and share content | Microsoft SharePoint. (n.d.). <https://www.microsoft.com/en-us/microsoft-365/sharepoint/collaboration>

Video Conferencing, Meetings, Calling | Microsoft Teams. (n.d.). <https://www.microsoft.com/en-us/microsoft-teams/group-chat-software>

Tailwind CSS - Rapidly build modern websites without ever leaving your HTML. (n.d.). Tailwind CSS. <https://tailwindcss.com/>

npm: recharts. (n.d.). Npm. <https://www.npmjs.com/package/recharts>

Lucide icons. (n.d.). *Lucide*. <https://lucide.dev/guide/packages/lucide-react>

npm: html5-qrcode. (n.d.). *Npm*. <https://www.npmjs.com/package/html5-qrcode/v/2.2.7>