Bilkent University

Department of Computer Engineering

Senior Design Project

Project short-name: SolarUpp

Analysis Report

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Analysis Report
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1 - Introduction

Each day our world is becoming polluted due to the usage of fossil fuels as an energy source. World Wide Fund for Nature also known as WWF specifies fossil fuels as the biggest cause of climate change. Average global temperatures have risen almost 1°C since the industrial revolution [1]. As long as passing to renewable energy sources will not come true, levels of carbon dioxide and heat-trapping greenhouse gases in the atmosphere is going to increase. Renewable energy sources ensure reliable, sustainable, environmentalist and cost efficient solutions rather than fossil fuels. Communities and governments has increasing tendency to escape the impacts of fossil fuels and to build a livable world for the future.

Renewable Technologies are considered as clean sources of energy. Their usage will drop the negative effects of fossil fuels regarding to social needs and future economics. The sun is counted as one of the biggest energy sources. It has the capability to provide more energy than we need to power everything in the world. The sun generates energy from a process called nuclear fusion. The generated energy radiates out to space by solar radiation. Solar Energy technologies are used to convert the power from solar radiation. The productivity of Solar Energy Systems are not the same everywhere around the world. However, there is a solar map for every position, time, location, and temperature. Therefore our thought as a group was “Why don’t we make a feasibility study on Solar Energy Systems to keep our world cleaner”. Our project SolarUpp will be based on energy production and efficiency on rooftops of building to increase the productivity. Moreover, it proposes tracking built solar panel systems with a cloud based system. Information such as energy production, profit estimation, statistics etc. will be tracked with this system. We are planning to make a notification system to inform users on emergency

situations, and needs for care. Briefly, our project won't be a single use software only. We are offering a software as a service.

In this report, there will be a brief description of our project in terms of analysis. Subsequently, project constraints will be listed under the titles of maintainability, implementation, reliability, and economic. The professional and ethical issues will also be discussed for the requirement. A detailed proposed systems can be found in this report. Additionally, other analysis elements such as consideration of various factors, risks and alternatives, project plan, ensuring proper team-work, ethics and professional responsibilities, and new knowledge and learning strategies is available in the following sections. Lastly there is a references part at the end of the report.

2 - Proposed System

2.1 - Overview

SolarUpp aims to have a feasibility study on solar energy production and efficiency on building rooftops in order to increase usage of green energy. In this web application, solar ratings of rooftops will be calculated by gathered information from images of rooftops. The users will easily find their building's images by entering their addresses. After finding their buildings, users will be able to choose spaces to plant solar panels on their rooftops. In order to calculate solar energy production, users will have the chance to compare different solar panels and inverters to find optimum solution on their rooftops in terms of cost, size and efficiency.

Beside a feasibility study on energy production, SolarUpp will also provide 3D model of rooftop by visualization to show user's rooftops final state after plantation of solar panels and inverters by regarding real size of solar components and chosen free space on rooftops. To calculate solar energy production in best way SolarUpp will be able to

determine distinct obstacles on rooftops such as pools and air conditioning components to calculate free space on roofs .

After solar panel plantation, generated solar energy amount will be gathered from registered users's inverters in time intervals like one week. Gathered information will be uploaded to our system to compare expected and generated value of solar energy. Recent weather conditions in the area of specified building will be checked to see if there are any additional reasons which cause low energy production than expected rather than unexpected weather conditions. For example, if a rooftop have great difference between expected and produced energy level in optimum weather conditions, registered users will be informed with a warning message about the need of maintenance check or an unexpected problem.

SolarUpp is a green field project which aims to increase solar energy usage by gathering information from rooftop's images which are taken from above. Using images of rooftops to have a feasibility study is an essential point for large scale using by users

2.2 - Functional Requirements

2.2.1 User Specific Requirements

- Users able to register to our application by providing their personal email addresses or company email addresses.
- There will be 2 main service type within the system. First of this is feasibility estimating of solar panels. In other words, this is a calculation of the amount of solar energy production that the given rooftop is capable of. Second main service of this project is maintenance alarm system for solar panels. For now every verified user is able to see the feasibility estimation of solar panels and is able to use maintenance alarm system but for future work, maintenance alarm system service might be only for premium users.

- Users should be able to notified by maintenance notification system from multiple platforms such as email, SMS or from the web application itself.
- All users should be able to model their solar panels on the top of their houses in 3D.
- All users should be able to compare different solar panels and inverters to find optimum solution on their rooftops in terms of cost, size and efficiency.
- All users should be able to enter their addresses and find these addresses in the google earth. They also should be able to see their buildings' picture from the top.
- Users checking feasibility of solar panels on a building should be able to see how the expected cost and electricity generating capacity are calculated. The variables used in the calculation should be presented clearly to the user.
- In Solar Panel systems, if the amount of solar energy produced is larger than the electricity needed, then solar panel users are able to sell the excessive solar energy to government. Therefore users are able to see the expected profit if his expected solar energy production that is calculated by SolarUpp is larger than needed electricity.
- If a user has multiple building, he is able to compare the feasibility of Solar Panels to each of the building with their prices, estimated profit and 3D solar panel plan models.
- If user cannot find a specific parameter that is for calculating feasibility and cost of the solar panels, he is able to enter all of the parameters manually.
- A user is able to view suggestions of solar panel plans in the SolarUpp system that is similar to his building and panel plans that is in the neighborhood.
- Each user is able to see the tutorial of SolarUpp and learn how to use the system.

2.2.2.Data Sources

- Archive of all generated electricity and their estimated electricity generation from tracked solar panels will be held in the database.
- Information of registered users such as address, email, phone number will be stored.
- Properties like size, price, efficiency, mass and energy production for different solar panels and inverters will be stored.
- The data about generated solar energy amount of verified users which is gathered from their inverter will be stored for distinct time intervals in the database.
- Solar maps and solar rating of different regions will be provided to users before feasibility study.

2.3 - Non-functional Requirements

2.3.1 Reliability

- Users with installed solar panels should be notified if there is a problem in their solar panels, or the system. It should not take more than a week for anyone to learn about a malfunction in their solar panels.
- The values accumulated from the APIs should be accurate enough for expected cost and electric generating capacity.

2.3.2 Performance

- The application should run smoothly while browsing the map or checking for potential solar panel locations on a roof. The FPS rate should be 30 at minimum for the most part.

2.3.3 Extendability

- In case of the application reaching a critical level of user base, the system should be able to make great use of the gathered data.

2.3.4 Scalability

- The system should be able to serve to several different users at the same time.
- The system should be usable wherever used APIs are supported.

2.3.5 Usability

- Users should be able to find their desired building in a short time.
- The interface of the webpage should be easy to understand for users. The features of the application should be presented clearly.
- There should be a tutorial on how to use the application.
- The notification system of the application should be convenient for the users. For example, there should be more than one way to notify users.
- A user who had installed a solar panel prior to using the application should be able to use the application to track their solar panels.

2.4 - Pseudo Requirements

A numbered list is below:

1. Weather API: https://openweathermap.org/api This weather API provides current and forecast weather data collection. This API can be used for maintenance service that SolarUpp provides. This is necessary for turnable solar panels, In cloudy weather it should not work. [2]
2. Solar Map API: https://globalsolaratlas.info/map This API provides how much a specific region gets solar energy. This is a global solar map. This API will be used for calculating expected solar energy. [3]
3. Google Maps and Google Earth Engine:Google Earth engine and Google Maps provides visualization of buildings and streets. We will use Google Earth for identifying slope and surface area of rooftops. Also Google Earth services will be used for a user to find address of his building and demonstrate it on the map. [4]

4. Solar Calculation API: https://solcast.com/ Solcast API provides solar radiation data, historical time series solar irradiance, utility scale solar forecasts, rooftop solar forecasts, grid aggregations and utility scale wind forecasts. This API will be used for our predictions to be more accurate. [5]
5. PSMA Building API: https://www.programmableweb.com/ This API provides data about 8.8 million Australian buildings that includes 2D and 3D building footprints. This API also contains average roof height, roof materials and addresses. This API can be used for testing our prediction about expected solar energy production. [6]
6. Reality Capture API: https://forge.autodesk.com/api/reality-capture-cover-page/ This API will be used to create viusalization of user's rooftop after having a feasbility study for selected solar panels as a final state.[7]

2.5 - System Models

2.5.1 - Scenarios

2.5.1.1 Scenario 1

Use Case Name: SignUp

Actors: Alp

Entry Conditions:

- Alp is on the Sign Up Screen

Exit Conditions:

- Alp is on the Sign Up Screen

Main Flow of Events:

1. Alp clicks the "SignUp" button.
2. SolarUpp navigates to SignUp Screen.
3. Alp enters name, surname, email.

4. Alp creates a password which complies to password rules.
5. Alp clicks "Submit" button.
6. SolarUpp checks if email is legitimate.
7. SolarUpp creates a new account for given name, surname, email and password.
8. SolarUpp navigates to Home Screen.

Alternative Flow of Events:

1. Alp clicks the "SignUp" button.
2. SolarUpp navigates to SignUp Screen.
3. Alp enters name, surname, email.
4. Alp creates a password which complies to password rules.
5. Alp clicks "Submit" button.
6. SolarUpp checks if email is legitimate.
7. SolarUpp displays an error message about password rules are about mail address is incorrect.

2.5.1.2 Scenario 2

Use Case Name: ViewMaintenance

Actors: Alp

Entry Conditions:

- Verified user Alp is on the Home Screen

Exit Conditions:

- Verified user Alp is on the View Maintenance Screen

Main Flow of Events:

1. Verified user Alp clicks on the "View Maintenance" button.
2. SolarUpp navigates Alp to View Maintenance Screen.

3. SolarUpp displays information about the amount of produced and expected solar energy of verified user Alp's rooftop.
4. Alp displays produced, expected solar energy and check for need of maintenance for solar panels.

2.5.1.3 Scenario 3

Use Case Name: ViewStatistics

Actors: Alp

Entry Conditions:

- Verified user Alp is on the View Maintenance Screen.

Exit Conditions:

- Verified user Alp is on the View Statistics Screen.

Main Flow of Events:

1. Verified user Alp clicks on the "View Statistics" button.
2. SolarUpp navigates to View Statistics Screen.
3. Alp selects one of his own addresses to learn about statistics.
4. SolarUpp displays properties of Alp' solar panels for selected address, electricity consumption and solar energy production in recent months.

2.5.1.4 Scenario 4

Use Case Name: FindAddress

Actors: Alp

Entry Conditions:

- Verified user Alp is on the Home Screen.

Exit Conditions:

- Verified user Alp in on the Find Address Screen.

Main Flow of Events:

1. Verified user Alp clicks "Find Address" button on the Home Screen.
2. SolarUpp navigates to Find Address Screen.
3. Verified user Alp will enter his address and it will be displayed on map visually by location on a map.
4. After address is chosen, verified user Alp will select this address as new address.
5. Verified user Alp will enter information about building in selected address.
6. SolarUpp displays building's roof which is the new address.

Alternative Flow of Events:

1. Verified user Alp clicks "Find Address" button on the Home Screen.
2. SolarUpp navigates to Find Address Screen.
3. Verified user Alp will enter his address and it will be displayed on map visually by location on a map.
4. After address in entered Alp will change this address with one of his previous address if there is an address change for user.
5. Verified user Alp will enter information about building in selected address.
6. SolarUpp displays building's roof which is the new address.

Alternative Flow of Events:

1. Verified user Alp clicks "Find Address" button on the Home Screen.
2. SolarUpp navigates to Find Address Screen.

3. Verified user Alp will use his location services of his device to find his current location as his address by clicking "Use Location" button.
4. After address is determined by global position of device, verified user Alp will adjust this address as new address or change with one of the previous addresses.
5. Verified user Alp will enter information about building in selected address.
6. SolarUpp displays building's roof which is the new address.

2.5.1.5 Scenario 5

Use Case Name: ComparePlan

Actors: Ege

Entry Conditions:

- Verified user Ege is on the Home Screen.

Exit Conditions:

- Verified user Ege is on the Compare Plan Screen.

Main Flow of Events:

1. Verified user Ege clicks on the "Compare Plan" button.
2. SolarUpp navigates to Compare Plan Screen.
3. Ege selects of his own addresses to learn about statistics.
4. SolarUpp navigates to the selecting of second building
5. SolarUpp displays the solar feasibility of each building side by side
6. SolarUpp suggests to invest on the most efficient solar panel plan

2.5.1.6 Scenario 6

Use Case Name: Login

Actors: Ege

Entry Conditions:

- Verified user Ege is on the Home system.

Exit Conditions:

- Verified user Ege is on the Home Screen.

Main Flow of Events:

1. Verified user Ege fills the email address and password sections in the login box.
2. Verified use Ege clicks on the Login button.
3. SolarUpp navigates user to Login Screen.
4. SolarUpp checks whether the entered email address exists in the database.
5. SolarUpp checks whether the entered email address matches with entered password.
6. SolarUpp confirms if credentials are correct.
7. SolarUpp navigates to the Home Screen.

Alternative Flow of Events:

1. Verified user Ege fills the email address and password sections in the login box.
2. Verified use Ege clicks on the Login button.
3. SolarUpp navigates user to Login Screen.
4. SolarUpp checks whether the entered email address exists in the database.
5. SolarUpp checks whether the entered email address matches with entered password.
6. SolarUpp displays an error message that indicates the credentials are incorrect.

2.5.1.7 Scenario 7

Use Case Name: ChooseSolarPlan

Actors: Ege

Entry Conditions:

- Verified user Ege is on the Calculate Feasibility Screen.

Exit Conditions:

- Verified user Ege is on the 3D Model Plan Screen.

Main Flow of Events:

1. Verified user Ege clicks ChooseSolarPlan button.
2. SolarUpp navigates user to ChooseSolarPlan Screen.
3. In ChooseSolarPlan screen, SolarUpp demonstrates 3 different SolarPanelPlan which are the most feasible, the cheapest and the most latest with their detailed features.
4. User selects one of the plans.
5. According to Solar Panel Plan, SolarUpp navigates user to 3D Model Screen.

Alternative Flow of Events:

1. Verified user Ege clicks ChooseSolarPlan button.
2. SolarUpp navigates user to ChooseSolarPlan Screen.
3. In ChooseSolarPlan screen, SolarUpp demonstrates 3 different SolarPanelPlan which are the most feasible, the cheapest and the most latest with their detailed features.
4. If the user does not select one of the plans, SolarUpp checks one of the plans automatically.
5. According to Solar Panel Plan, SolarUpp navigates user to 3D Model Screen.

2.5.1.8 Scenario 8

Use Case Name: EstimateProfit

Actors: Ege

Entry Conditions:

- Verified user Ege is on the Calculate Feasibility Screen.

Exit Conditions:

- Verified user Ege is on the View Profit Screen.

Main Flow of Events:

1. Verified user Ege clicks on the Estimate Profit button
2. SolarUpp navigates user to View Profit Screen
3. SolarUpp demonstrates user's solar energy consumption in View Profit Screen
4. SolarUpp demonstrates the expected solar energy production annually
5. SolarUpp demonstrates the expected excess solar energy of the user
6. SolarUpp demonstrates users' expected profit if he sells his excess solar energy to the government.

Alternative Flow of Events:

1. Verified user Ege clicks on the Estimate Profit button
2. SolarUpp navigates user to View Profit Screen
3. If SolarUpp system has not got the consumption information of the solar panel, user enters consumption information manually.
4. SolarUpp demonstrates the expected solar energy production annually
5. SolarUpp demonstrates the expected excess solar energy of the user

6. SolarUpp demonstrates users' expected profit if he sells his excess solar energy to the government.

2.5.1.9 Scenario 9

Use Case Name: CalculateFeasibility

Actors: Ege

Entry Conditions:

- Verified user Ege is on the Find Address Screen.

Exit Conditions:

- Verified user Ege is on the Home Screen.

Main Flow of Events:

1. Verified user Ege clicks on the Calculate Feasibility button
2. SolarUpp navigates user to Calculate Feasibility Screen
3. In this screen SolarUpp calculates the feasibility of the solar panel system by analyzing the roof of the building.
4. The SolarUpp system derive all parameters of the solar energy production formula by analyzing the picture of the roof of the building.
5. SolarUpp demonstrates the estimated annual solar energy production.

Alternative Flow of Events:

1. Verified user Ege clicks on the Calculate Feasibility button
2. SolarUpp navigates user to Calculate Feasibility Screen
3. In this screen SolarUpp calculates the feasibility of the solar panel system by analyzing the roof of the building.

4. If SolarUpp system cannot derive some of the parameters, user enters the lacked parameters manually.
5. SolarUpp demonstrates the estimated annual solar energy production.

2.5.1.10 Scenario 10

Use Case Name: ViewSuggestions

Actors: Fatih

Entry Conditions:

- Verified user Fatih is on the Find Address Screen.
- Verified user Fatih has selected a building

Exit Conditions:

- Verified user Fatih is on the Find Address Screen.
- Fatih's interface stays on the same building

Main Flow of Events:

1. Verified user Fatih clicks on the view suggestion button
2. An overlay panel will pop up and ask for parameters that could not be accessed from 3rd party applications.
3. Verified user Fatih manually enters the parameters.
4. The SolarUpp system demonstrates a suggested solar system plan with potential benefits. If this suggestion is derived from other similar houses, those houses with their statistics are shown.

Alternative Flow of Events:

1. Verified user Fatih clicks on the view suggestion button
2. An overlay panel will pop up and ask for parameters that could not be accessed from 3rd party applications.
3. Verified user Fatih manually enters the parameters.

4. The system fails to make a suggestion and notifies the user.

2.5.1.11 Scenario 11

Use Case Name: ViewTutorial

Actors: Fatih

Entry Conditions:

- Fatih is on the Welcome Screen.

Exit Conditions:

- Fatih is on the Welcome Screen.

Main Flow of Events:

1. Fatih clicks on the view tutorial button.
2. A short video showcasing the features of the SolarUpp will begin.
3. The video teaches Fatih how to start using the SolarUpp and how to make use of the features.
4. Fatih finishes the video.

2.5.1.12 Scenario 12

Use Case Name: EnterParametersManually

Actors: Fatih

Entry Conditions:

- Verified user Fatih is on the Find Address Screen.

Exit Conditions:

- Verified user Fatih is on the Find Address Screen.

Main Flow of Events:

1. Verified user Fatih clicks on the enter parameters manually button.

2. An overlay panel will pop up and ask for parameters that could not be accessed from 3rd party applications.
3. Verified user Fatih enters the parameters.
4. The SolarUpp system continues to calculating feasibility with the given parameters.

Alternative Flow of Events:

1. Verified user Fatih clicks on the enter parameters manually button.
2. An overlay panel will pop up and ask for parameters that could not be accessed from 3rd party applications.
3. Verified user Fatih enters the parameters.
4. Parameter values are incompatible, system asks them again.
5. Verified user Fatih checks the parameters again and enters right values.
6. The SolarUpp system continues to calculating feasibility with the given parameters.

2.5.1.13 Scenario 13

Use Case Name: Logout

Actors: Fatih

Entry Conditions:

- Verified user Fatih is on the Home Screen.

Exit Conditions:

- Fatih is on the Find Address Screen.

Main Flow of Events:

1. Verified user Fatih clicks on the Logout button.
2. A popup question asks if Fatih is sure.
3. Fatih verifies his decision, logouts safely.

2.5.1.14 Scenario 14

Use Case Name: ViewPanelStatistics

Actors: Fatih

Entry Conditions:

- Verified user Fatih is on the View Statistics Screen.
- Fatih has existing panels in the system.

Exit Conditions:

- Verified user Fatih is on the View Panel Statistics Screen.

Main Flow of Events:

1. Verified user Fatih clicks on one of the solar panels in the statistics screen.
2. SolarUpp demonstrates past performance and analysis of the specific panel.

2.5.1.15 Scenario 15

Use Case Name: Add Panel

Actors: Fatih

Entry Conditions:

- Verified user Fatih is on the View Maintenance Screen.
- Panel to add has an inverter connected to the internet.

Exit Conditions:

- Verified user Fatih is on the View Maintenance Screen.
- Fatih's profile is updated to include the added panel.
- SolarUpp actively tracks the energy produced from added panel now on.

Main Flow of Events:

1. Verified user Fatih clicks on add panel button in the maintenance screen.
2. Add panel screen opens.
3. Fatih chooses the desired way to export his inverter's data.
4. Fatih enters properties of the panel to add.
5. Fatih presses finish adding panel.

2.5.1.16 Scenario 16

Use Case Name: Remove Panel

Actors: Fatih

Entry Conditions:

- Verified user Fatih is on the View Maintenance Screen.
- Fatih had already added the panel to delete to system.

Exit Conditions:

- Verified user Fatih is on the View Maintenance Screen.
- Fatih's profile is updated to exclude the removed panel.
- SolarUpp stores the tracked energy production from removed panel, and Fatih is able to see it.

Main Flow of Events:

1. Verified user Fatih clicks on remove panel button in the maintenance screen.
2. A popup notification asks if Fatih is sure.
3. Fatih presses yes.

2.5.1.17 Scenario 17

Use Case Name: Enter Power Usage

Actors: Fatih

Entry Conditions:

- Verified user Fatih is on the View Maintenance Screen.

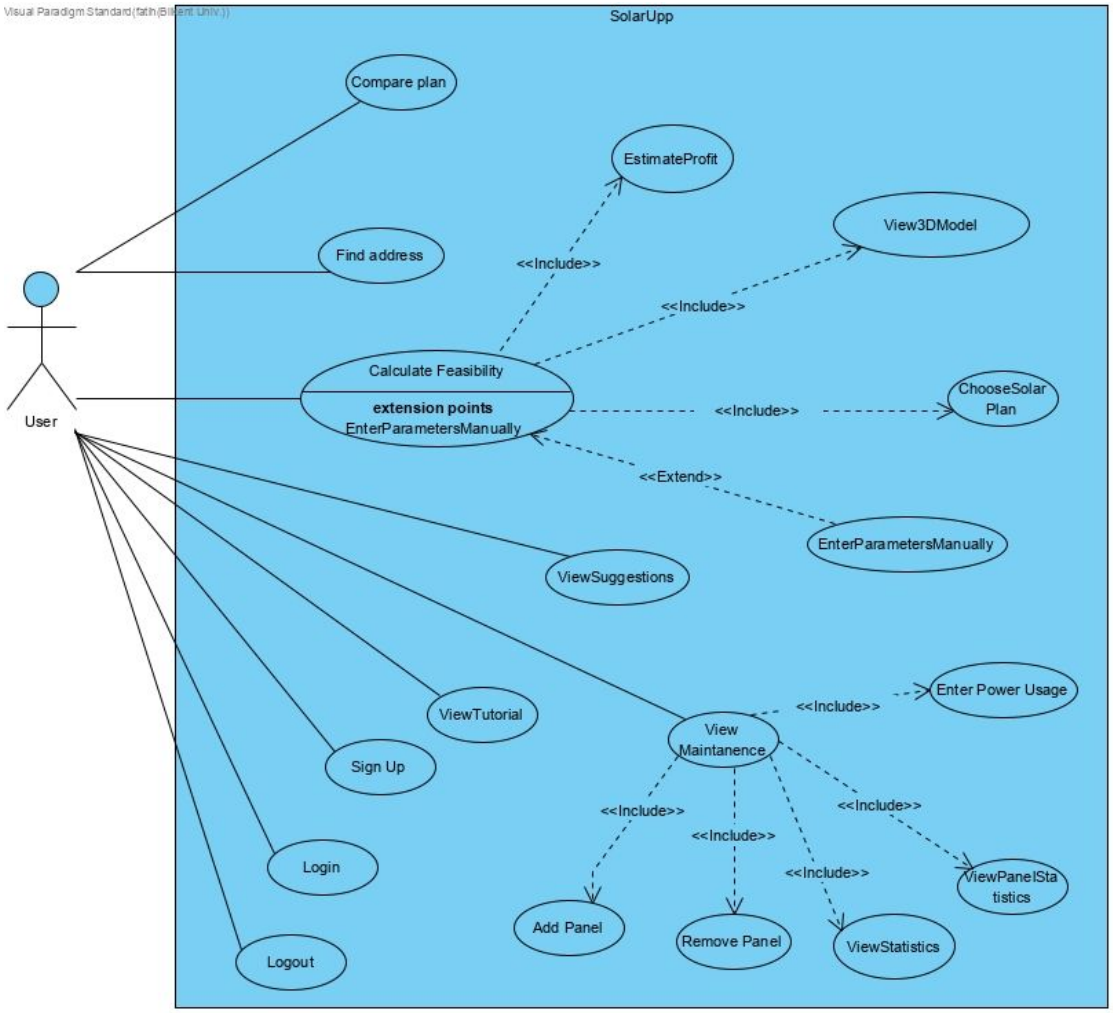
Exit Conditions:

- Verified user Fatih is on the View Maintenance Screen.
- Fatih's profile is updated to include the power usage.

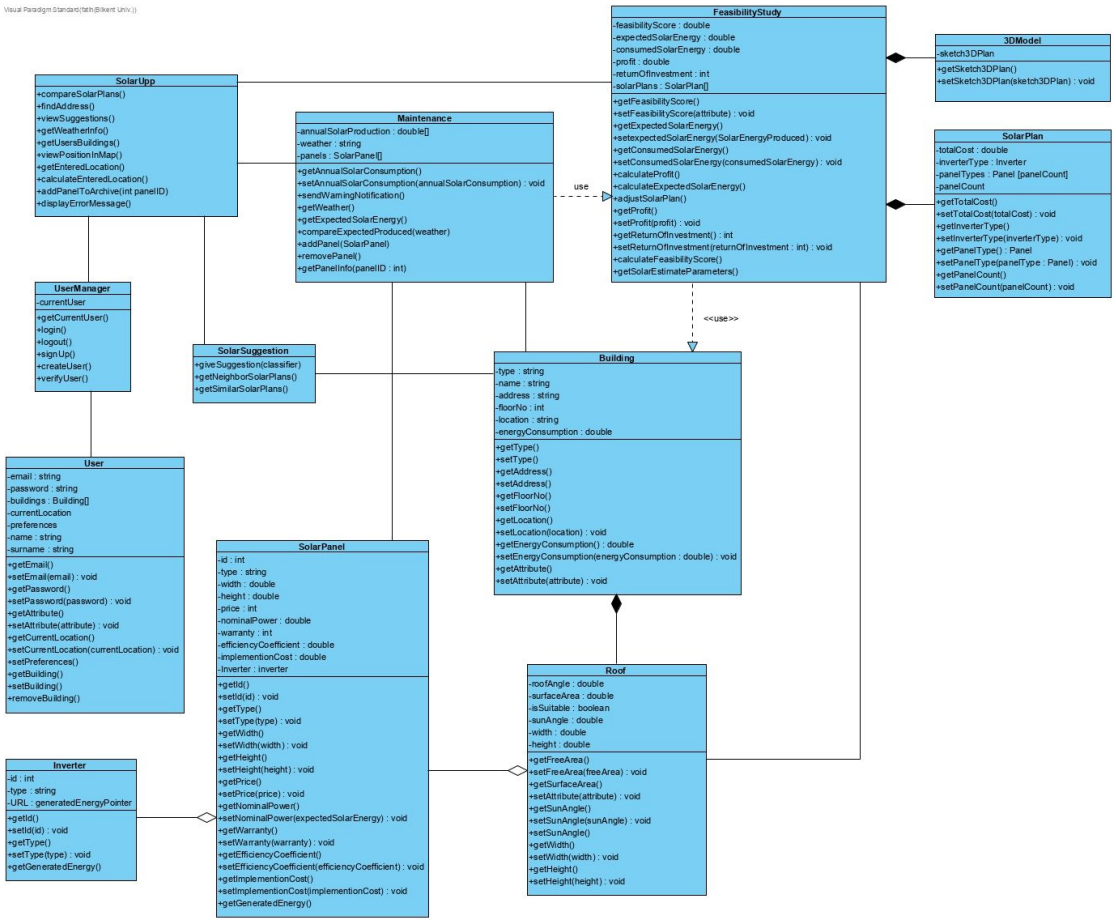
Main Flow of Events:

1. Verified user Fatih clicks on update power usage button in the maintenance screen.
2. Enter Power Usage screen opens.
3. Fatih selects the month he wants to update.
4. Fatih enters the power usage and bill.
5. Fatih presses finish button.

2.5.2 - Use-Case Model



2.5.3 - Object and Class Model



2.5.3.1 - Class Descriptions

2.5.3.1.1 - SolarUpp

SolarUpp is the main class of our project. It basically controls data fetching from Solar APIs. Also the communication between the Google Earth and Google Maps will be provided by this class.

2.5.3.1.2 - Maintenance

Maintenance class provides the maintenance operation of SolarUpp. It controls the solar panel continuously and send a notification report if panel is producing solar energy smaller than the expected solar

energy production. It gets the consumed solar energy by Building class.

2.5.3.1.3 - FeasibilityStudy

FeasibilityStudy class is the main class that provides feasibility service of SolarUpp. It calculates the feasibility score by analyzing solar panels feasibility to the given roof. This class calculates expected solar energy and provides the expected annual solar energy production. FeasibilityStudy also calculates the estimated profit to provide profit if there exists excessive solar energy production. Moreover, it can adjust solar panels for sketching 3D model of the preferred solution.

2.5.3.1.4 - 3DModel

3DModel class will be used for showing the 3d model of the roof and a model of the solar panel. The 3d model will be sketched on the roofs. Feasibility study will call this class with the parameters of the solar panels and the given roof.

2.5.3.1.5 - SolarPlan

SolarPlan will be used to provide the asked solar panel solutions for the FeasibilityStudy class. Total cost, inverter types, panel types, and the total number of panels will be the variables for the SolarPlan. SolarPlan class will hold the

2.5.3.1.6 - Building

This class is responsible for holding information about buildings which user have. Building class will have roof objects because single building may have several roofs. This class also stores information on building’s address and user’s energy consumption for further use.

2.5.3.1.7 - Roof

Roof class contains all of the features of the roofs such as roof angle, sun angle, width, height and surface area. These features will be used for parameters of calculating feasibility score of the rooftops and estimated solar energy production.

2.5.3.1.8 - SolarPanel

SolarPanel class is used for identifying each possible solar panel in the market. It has some variables such as id, type, width, height, price, nominal power, warranty, efficiency coefficient, implementation, cost, and inverter type which will be used for the maintenance service.

2.5.3.1.9 - User

This class used to hold information about user and letting access to this information. User class information is not requested directly by other classes, rather than User Manager class is used to access information of User class. Name, email, password and buildings that user have, can be an example for User class information.

2.5.3.1.10 - Inverter

This class holds general information and properties of inverter. This class also used to upload generated electricity to cloud for our project.

2.5.3.1.11 - UserManager

UserManager class is a controller class for User class instances. Checking for credentials while logging in will take place in this class with verifyUser() method.

2.5.3.1.12 - SolarSuggestions

This class responsible for presenting solar suggestions to user based on similar roof and building types of user's. SolarSuggestions is also used to recommend solar plans to user by regarding implemented solar panels which are in the same neighbourhood with user.

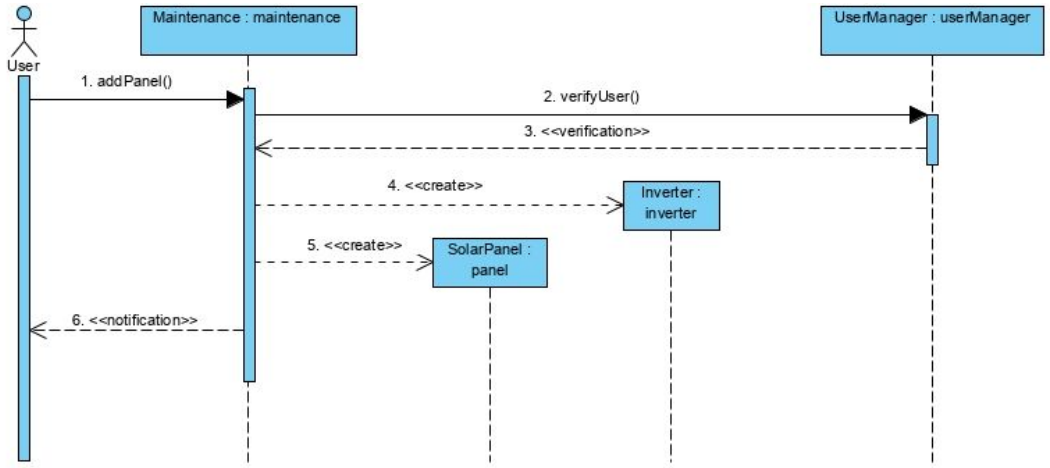
2.5.4 - Dynamic Models

Here are the dynamic diagrams, these demonstrate the relationships between the objects.

2.5.4.1 - Sequence Diagrams

Here are the sequence diagrams, these simply depict interactions between objects in a sequential order i.e. the order in which these interactions take place.

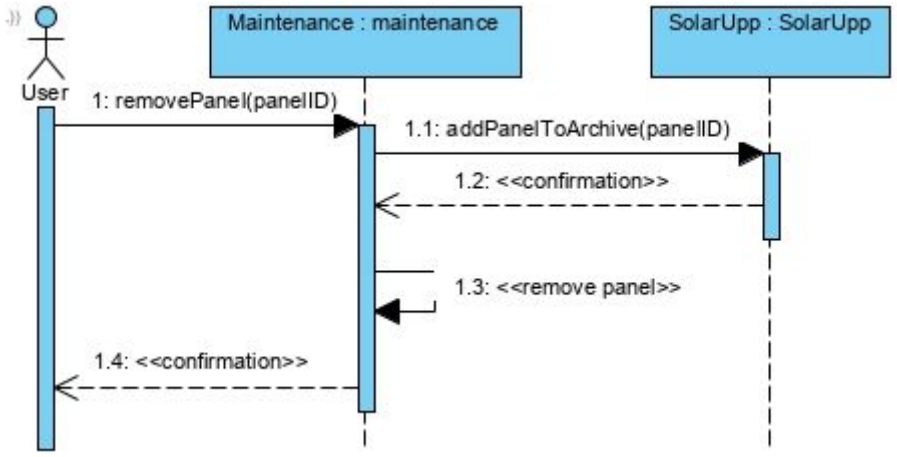
2.5.4.1.1 Add Panel Sequence Diagram



Add Panel Sequence Diagram Description: The user initiates addPanel() function from his client with the parameter values for inverter and solar panel

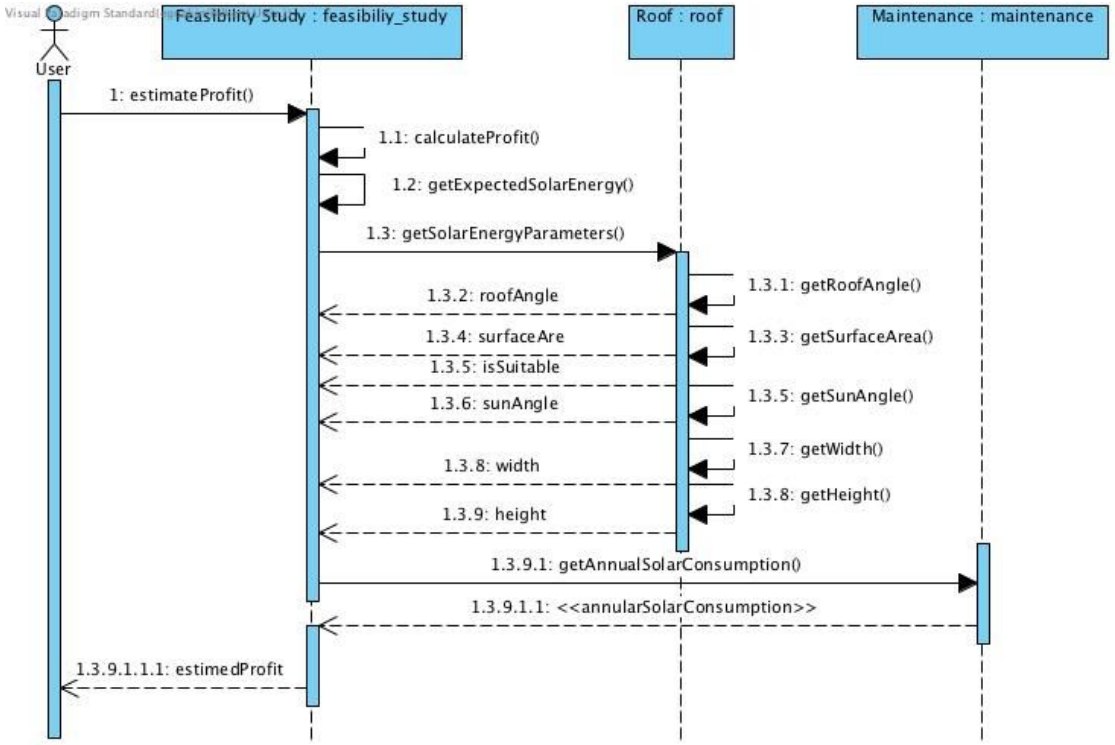
entered. Then the maintenance object verifies the user and creates inverter and solar panel objects.

2.5.4.1.2 Remove Panel Sequence Diagram



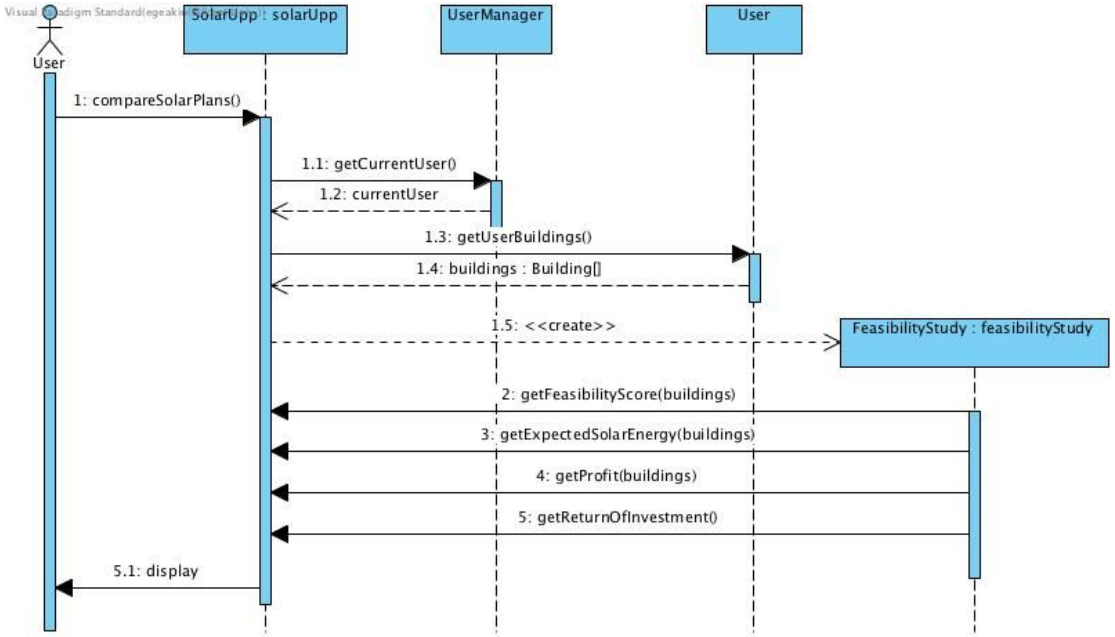
Remove Panel Sequence Diagram Description: The user initiates removePanel() function from maintenance screen with selecting the panel to remove. The panel information is archived to database, managed by SolarUpp class, and then the active link between panel and the user is deleted.

2.5.4.1.3 Estimate Profit Sequence Diagram



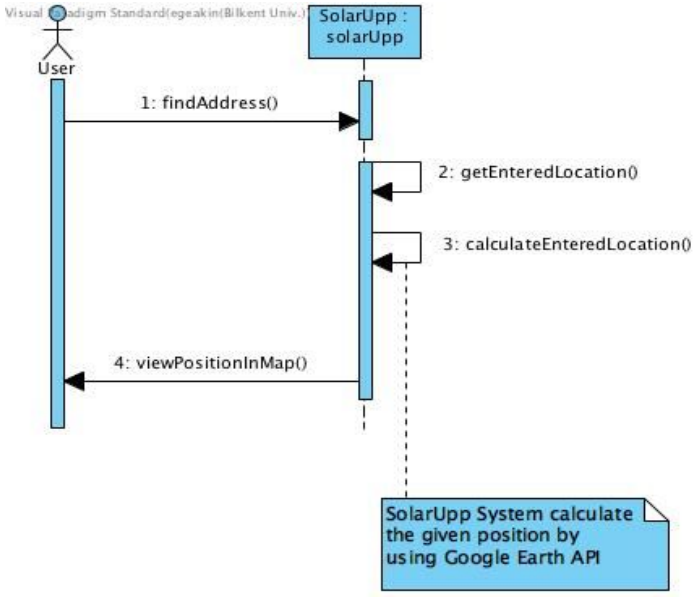
Estimate Profit Sequence Diagram Description: When user want to view the estimated profit, estimateProfit() function is called. Estimation of the profit is done in Feasibility_Study class. Feasibility Study takes annual solar energy consumption by the Maintenance class. Calculating expected solar energy is done at Feasibility_Study. The parameters of calculating expected solar energy comes from the Roof class. After getting annual solar energy consumption and expectedSolarEnergy, profit is calculated in Feasibility Study class.

2.5.4.1.4 Compare Plan Sequence Diagram



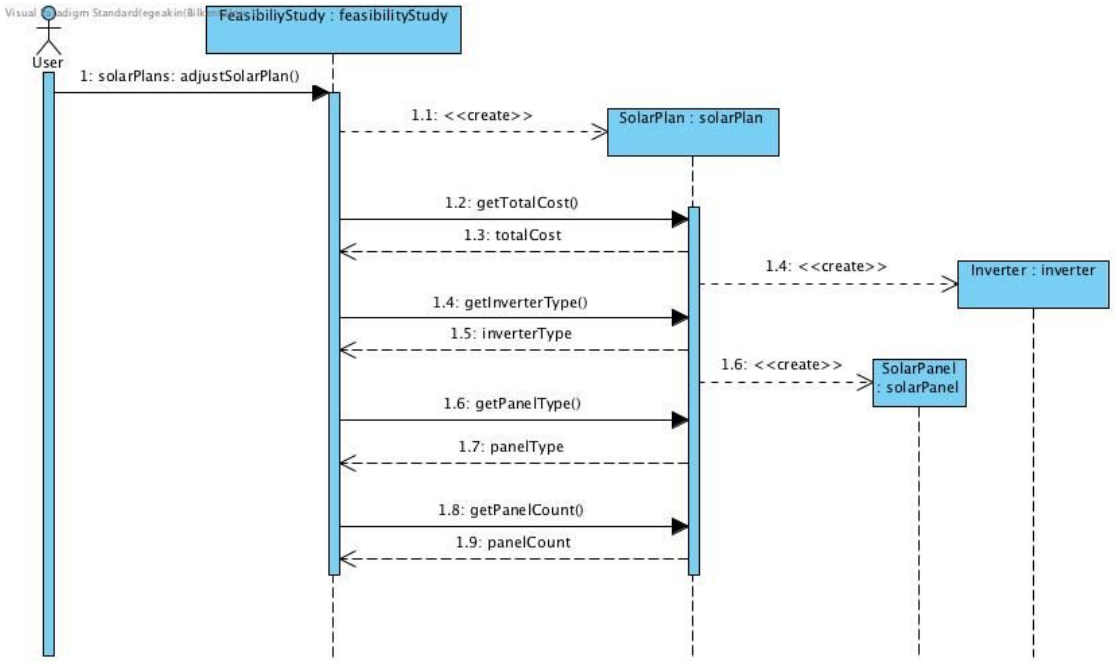
Compare Plan Sequence Diagram Description: If a user has more than one building and wants to compare the feasibilities of solar panels to each of his buildings, compareSolarPlans function is called. SolarUpp class gets the current user from UserManager and then according to currenUser, buildings array of user comes from the User class. Then for every building of user, feasibilityScore, expectedSolarEnergy, getProfit and returnOfInvestment is calculated by creating feasibilityStudy class.

2.5.4.1.5 Find Address Sequence Diagram



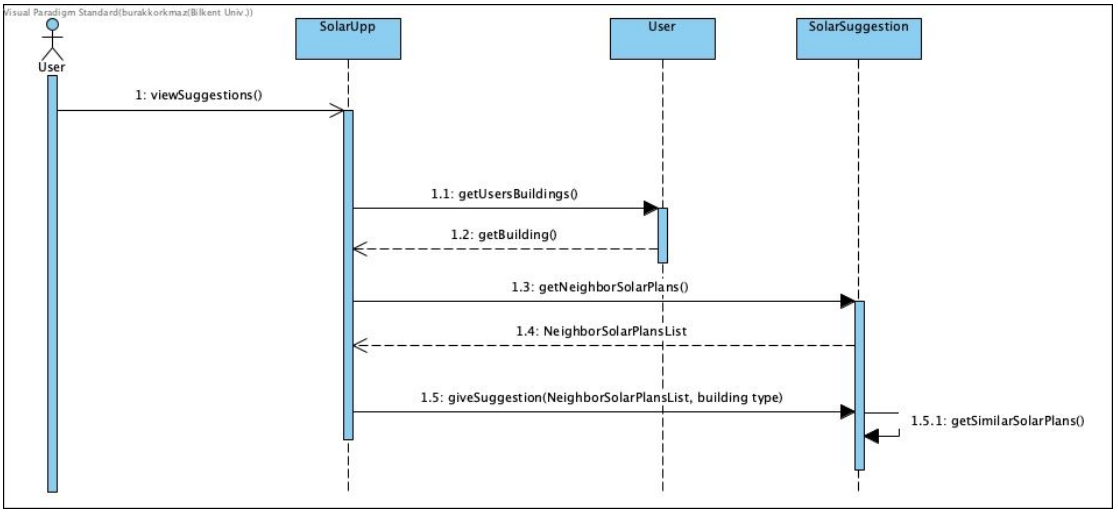
Find Address Sequence Diagram Description: Finding given address is done at SolarUpp class. First SolarUpp gets the location by the user. After getting location parameters, it calculates the entered location by using the services of Google Earth and Google Maps. After that it views the position in the map by viewPositionInMap function.

2.5.4.1.6 Choose Solar Plan Sequence Diagram



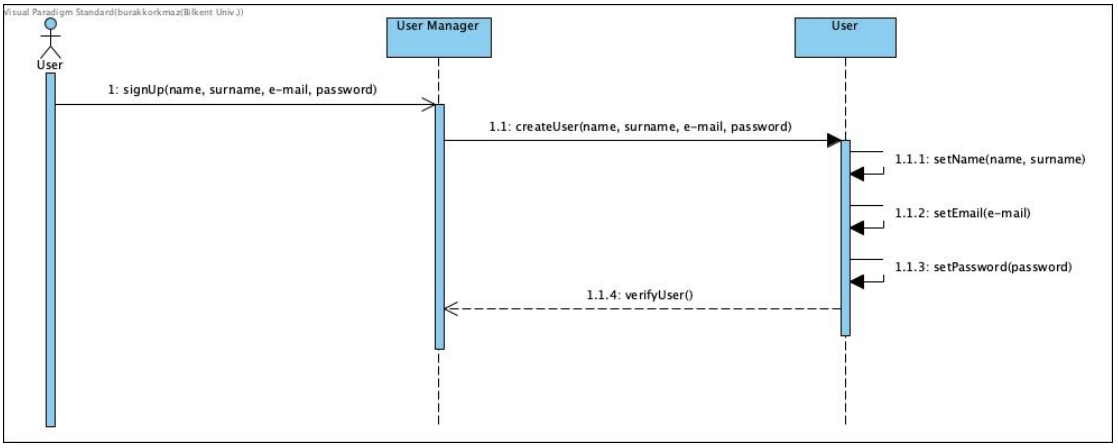
Choose Solar Plan Sequence Diagram Description: When user completes his feasibility study, he will get solar plans. Feasibility Study will create an array of SolarPlan objects and user will be able to see various solar panel plans by calling adjustSolarPlan function.

2.5.4.1.7 View Suggestions Sequence Diagram



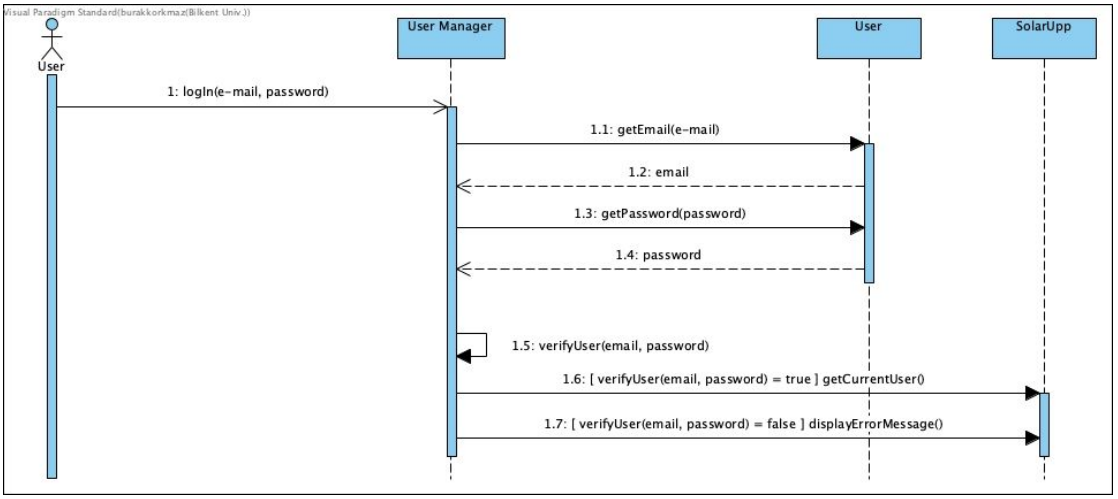
View Suggestions Sequence Diagram Description: In this diagram a user can view possible suggestions around the selected building, and the building type. SolarUpp, User, and SolarSuggestion classes will be used to obtain suggestions. A user will call viewSuggestion() method as the initial step. Then, SolarUpp class will call getUsersBuilding() method to the User class to get the buildings of the users. Later on, solar plans of the neighbors will be get from SolarSuggestion class. For the final step, SolarSuggestion class will return the similar solar plans according to the similar solution plans around the building and the type of the building.

2.5.4.1.8 Sign Up Sequence Diagram



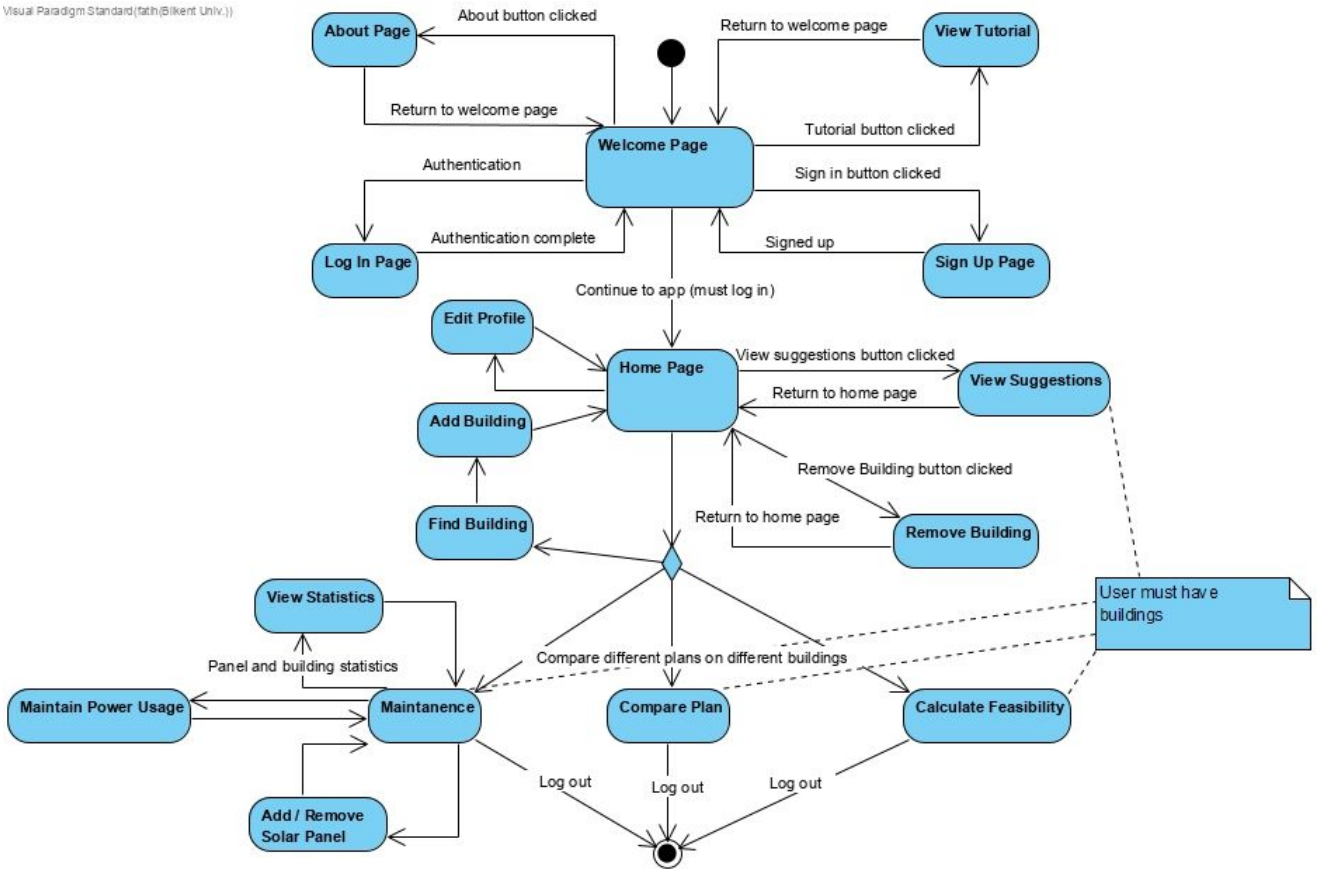
Sign Up Sequence Diagram Description: User firstly clicks on sign up button then enters her name, email address and password for registration. If her email and password are legitimate for rules her account is created and user is navigated to home screen.

2.5.4.1.9 Login Sequence Diagram



Login Sequence Diagram Description: Verified user fills input for email address and password for signing in then clicks the login button. User credentials are checked by SolarUpp, if they are correct verified user navigated to home screen. If credentials are wrong error message will be displayed.

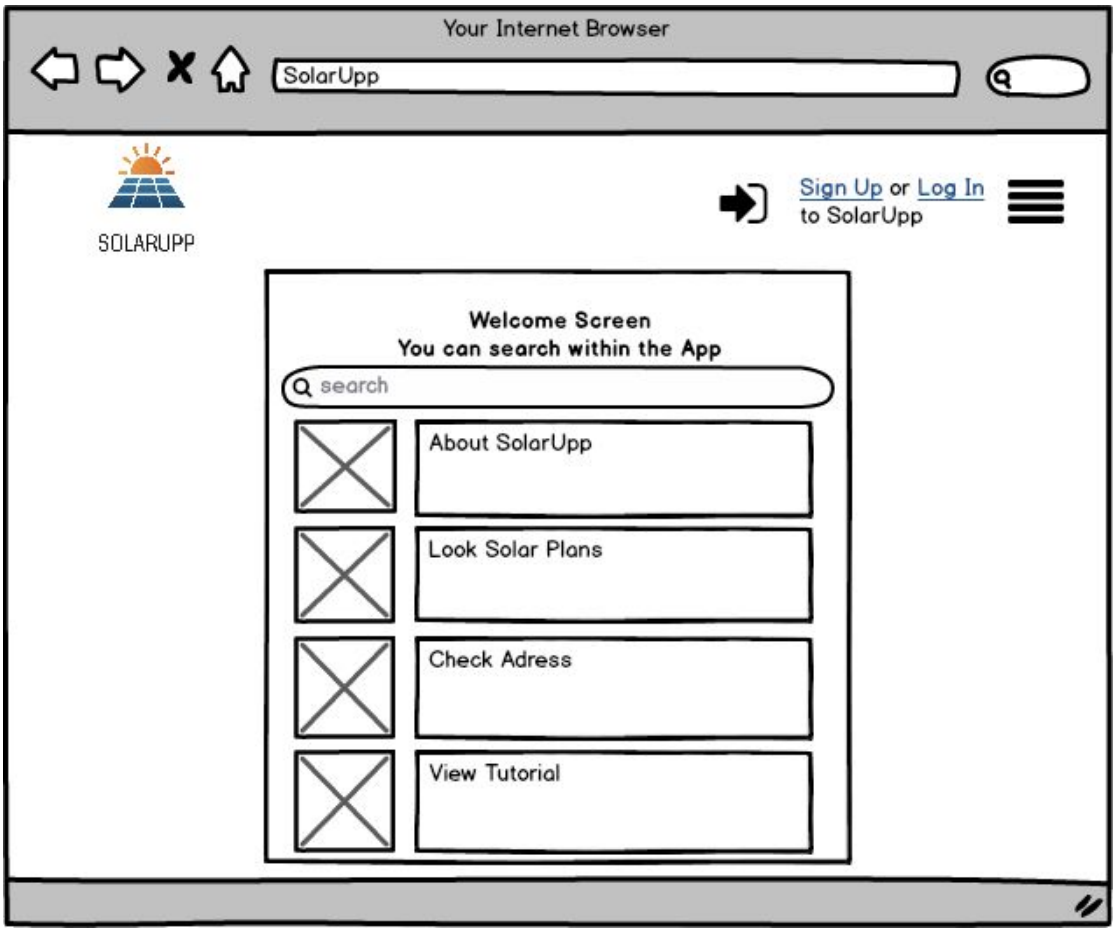
2.5.4.2 Activity Diagram



2.6.5 User Interface

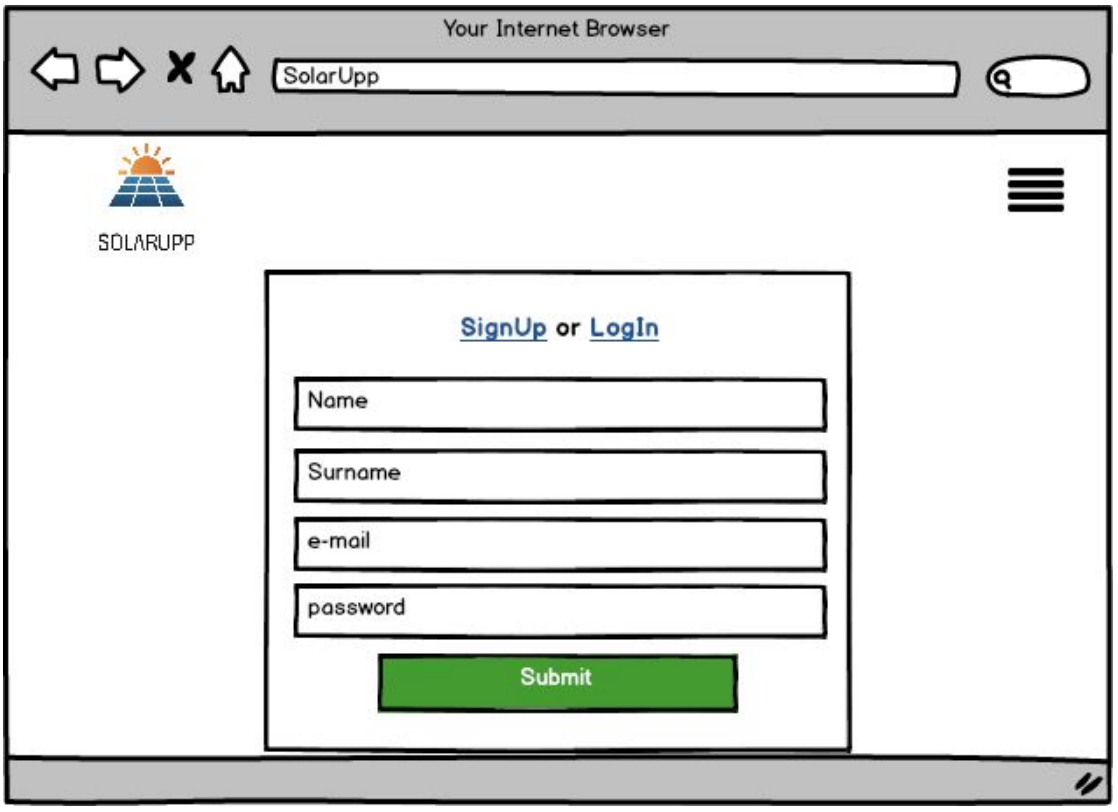
In this section, User Interface(UI) of the Solar Upp will be presented as mockups. The description of the pages will be provided with brief descriptions. The UI of the project is based on the use case diagram which was presented in 1.1.2 section. All the UI mockups were created by using Balsamiq Mockup 3[2].

2.6.5.1 - Welcome Page



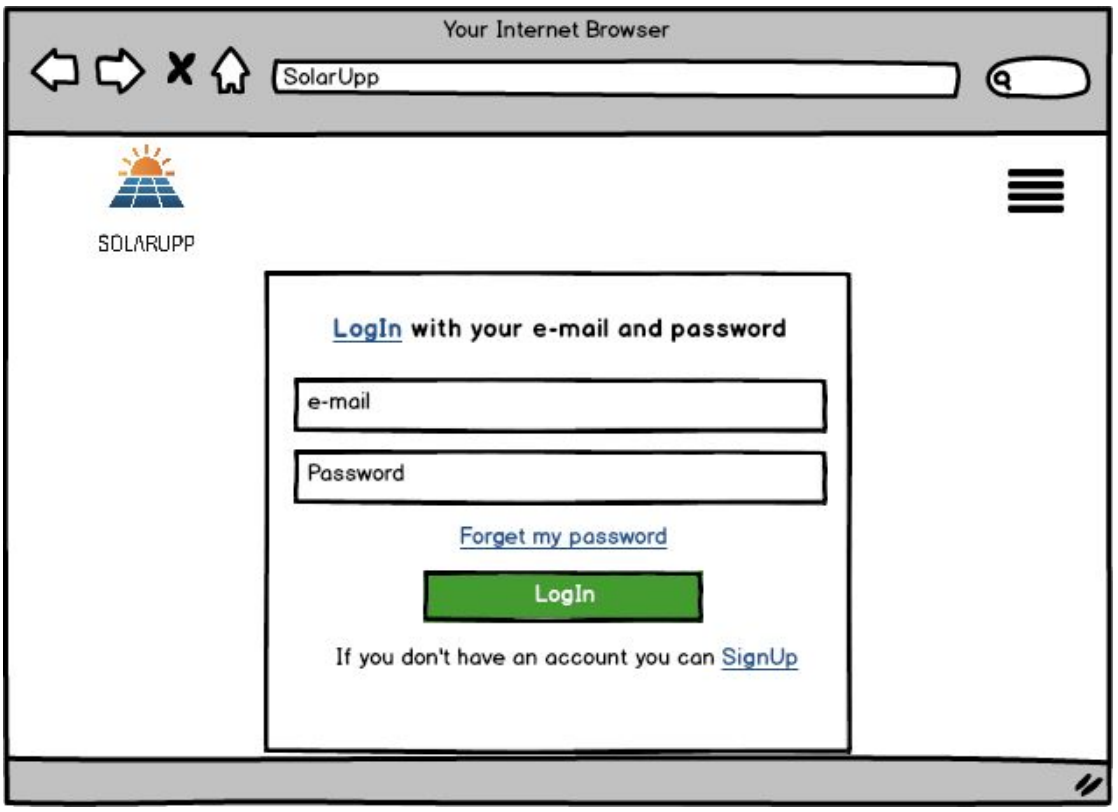
The UI of the welcome page is the initial screen when users come across first. It has a simpler design for users and potential users. Since the SolarUpp has a software as a service idea, users will not spend much time on the first screen. It will be used for login purpose for users. Additionally, there will be some information about the services. The search box will help users on whatever comes to mind. Moreover, a tutorial for the SolarUpp will be available in the welcome page. It will provide a general knowledge about the system.

2.6.5.2 - SignUp Page



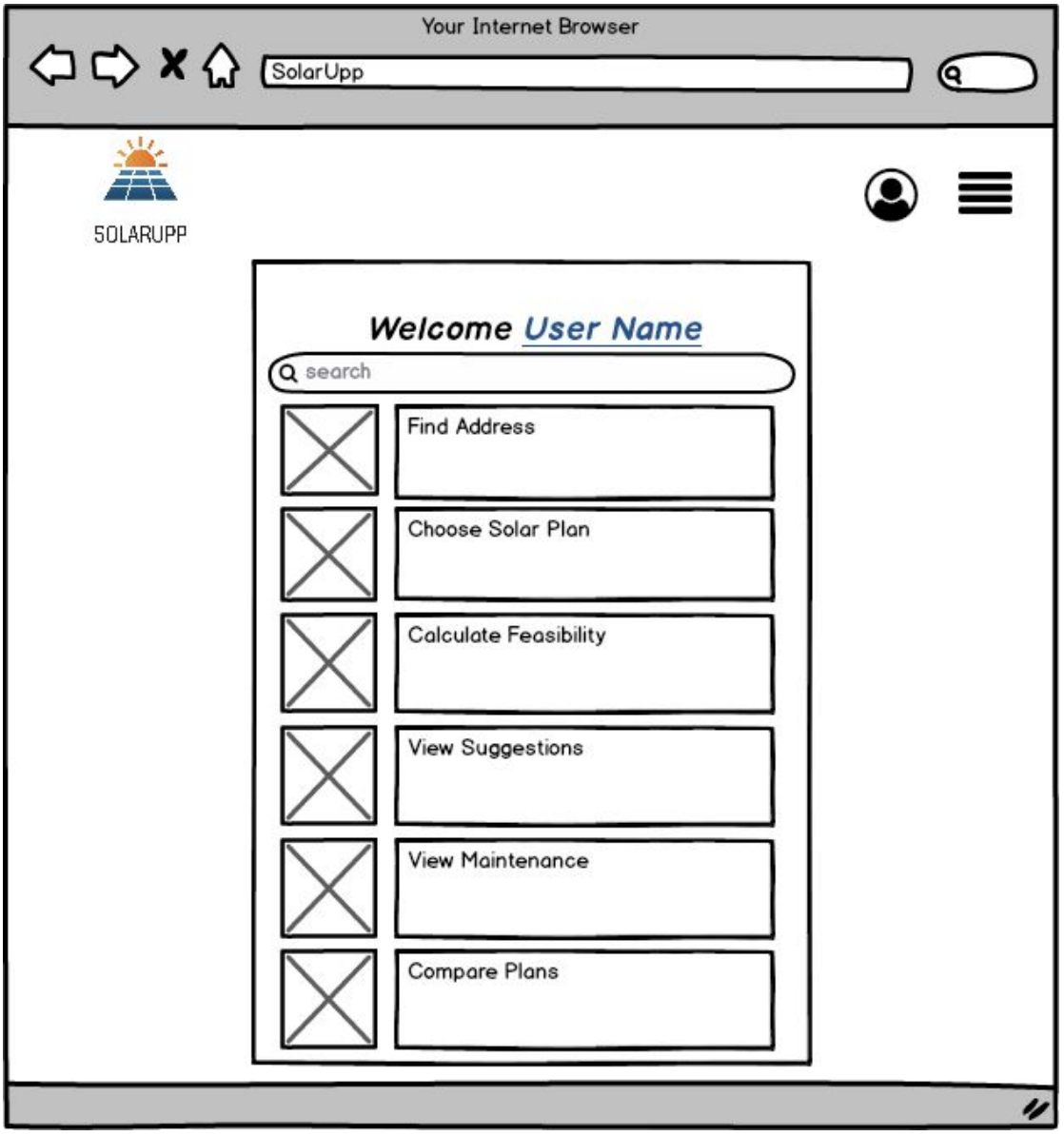
In Registration, there will be two screens for LogIn and SignIn purposes. For the SingIn, potential users will register to the SolarUpp by entering basic information such as Name, Surname, e-mail, and password. After registration to the system, more detailed information will be desired from users in order to learn their intentions. But for the first step, these information will be expected from users in order to make things easier. If a user enters registration page by mistake, by clicking LogIn the page turns into LogIn Page.

2.6.5.3 - LogIn Page



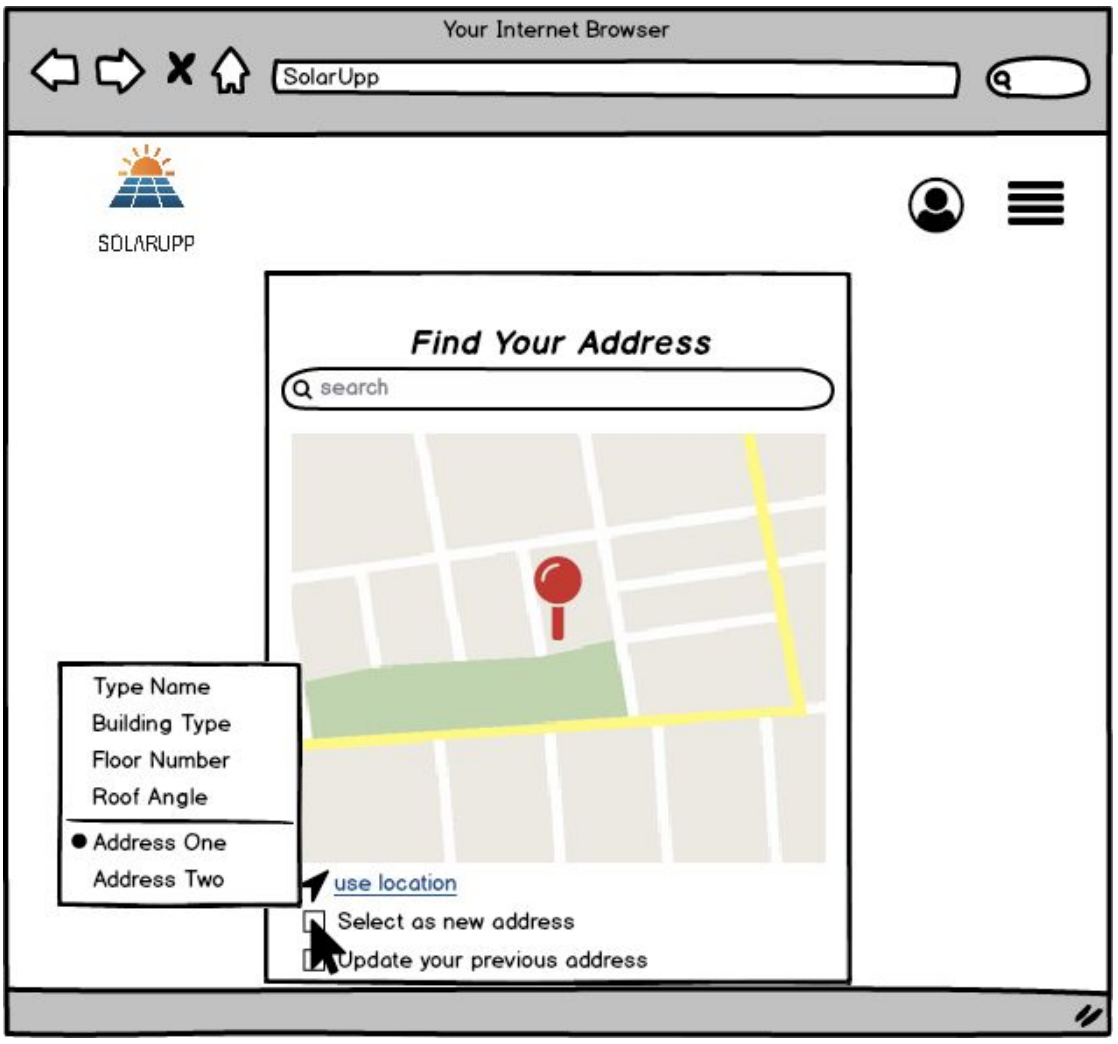
In the LogIn page, users can log in by entering their e-mail and password. If users forget their passwords, a new password will be provided to their e-mail addresses. If a user enters registration page by mistake, by clicking LogIn the page turns into LogIn Page.

2.6.5.4 - Home Page



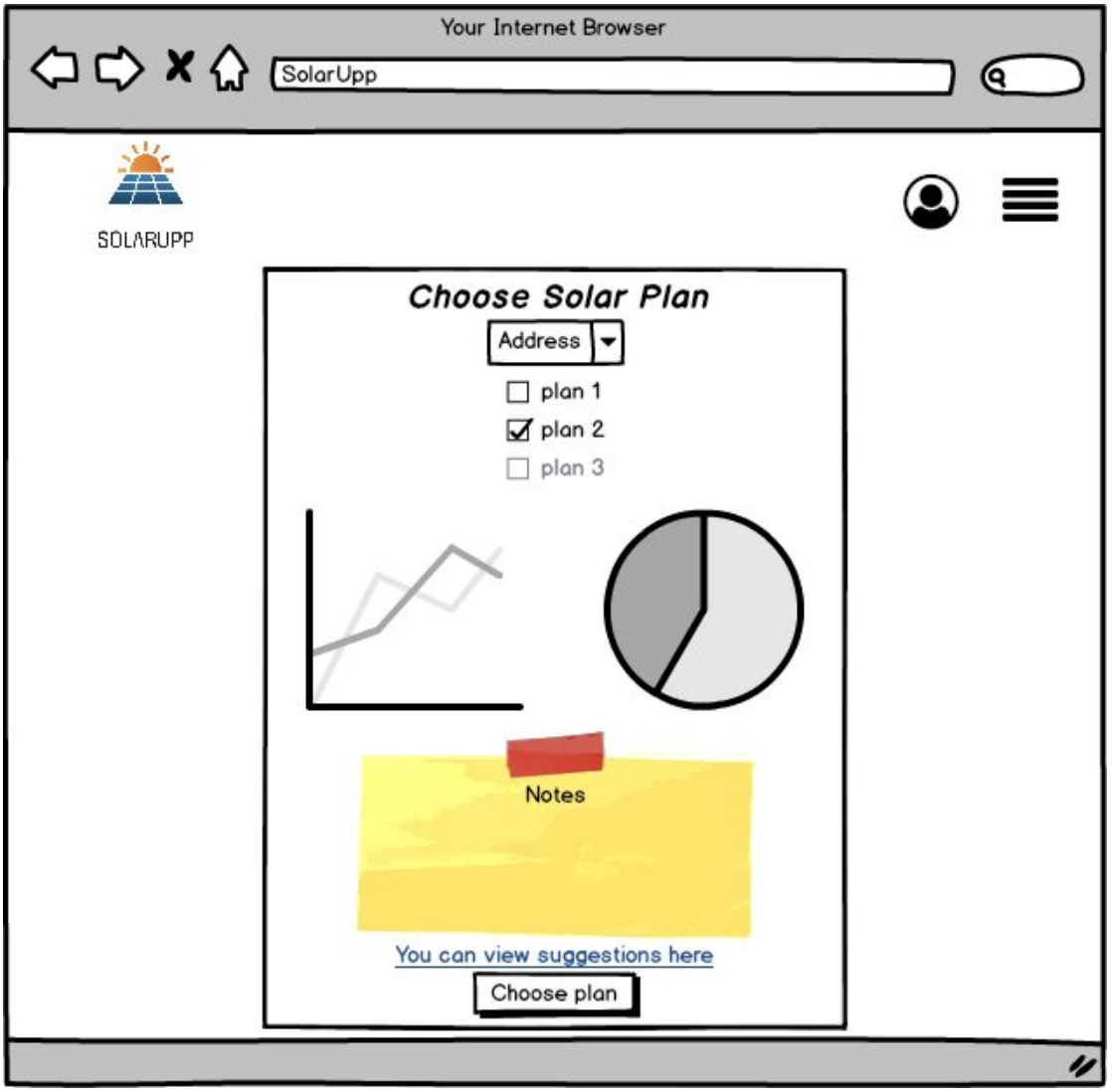
The home page will be designed to offer users a quick access to the content of the SolarUpp. The goal of the design is provides simplicity to users. With this purpose, users can access 'Find Address', Choose Solar Plan', 'Calculate Feasibility, 'View Suggestions', 'View Maintenance', and 'Compare Plan' pages easily. Also, the search box on the page will help users to find their needs by typing keywords.

2.6.5.5 - Find Address Page



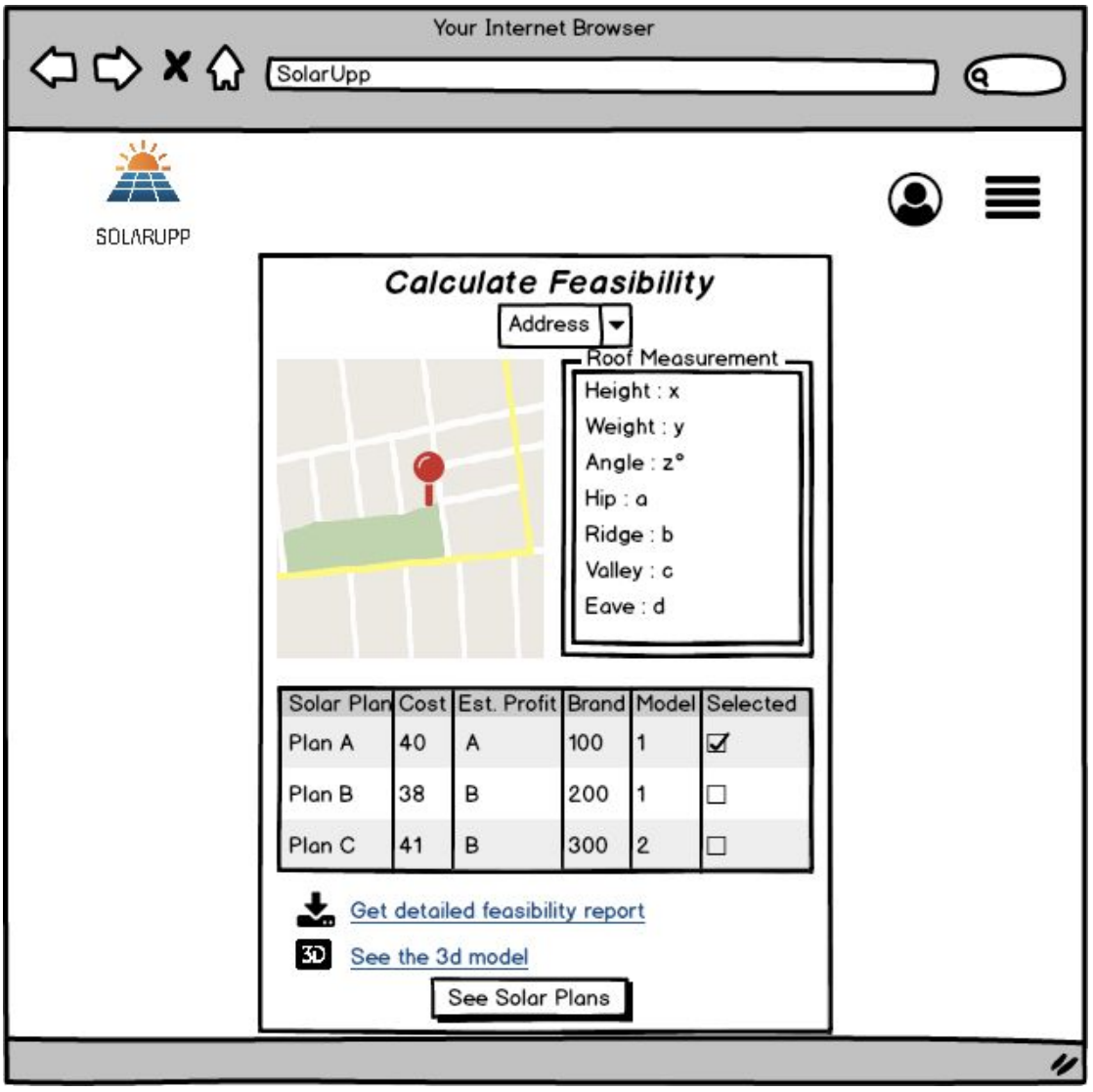
In the find address page, users can add their addresses to the system to locate their facilities. When an address box is selected, customizing the selected address can be possible. Users can type their addresses, or use their location to locate facility. The update checkbox enables to change a previous access easily.

2.6.5.5 - Choose Solar Plan Page



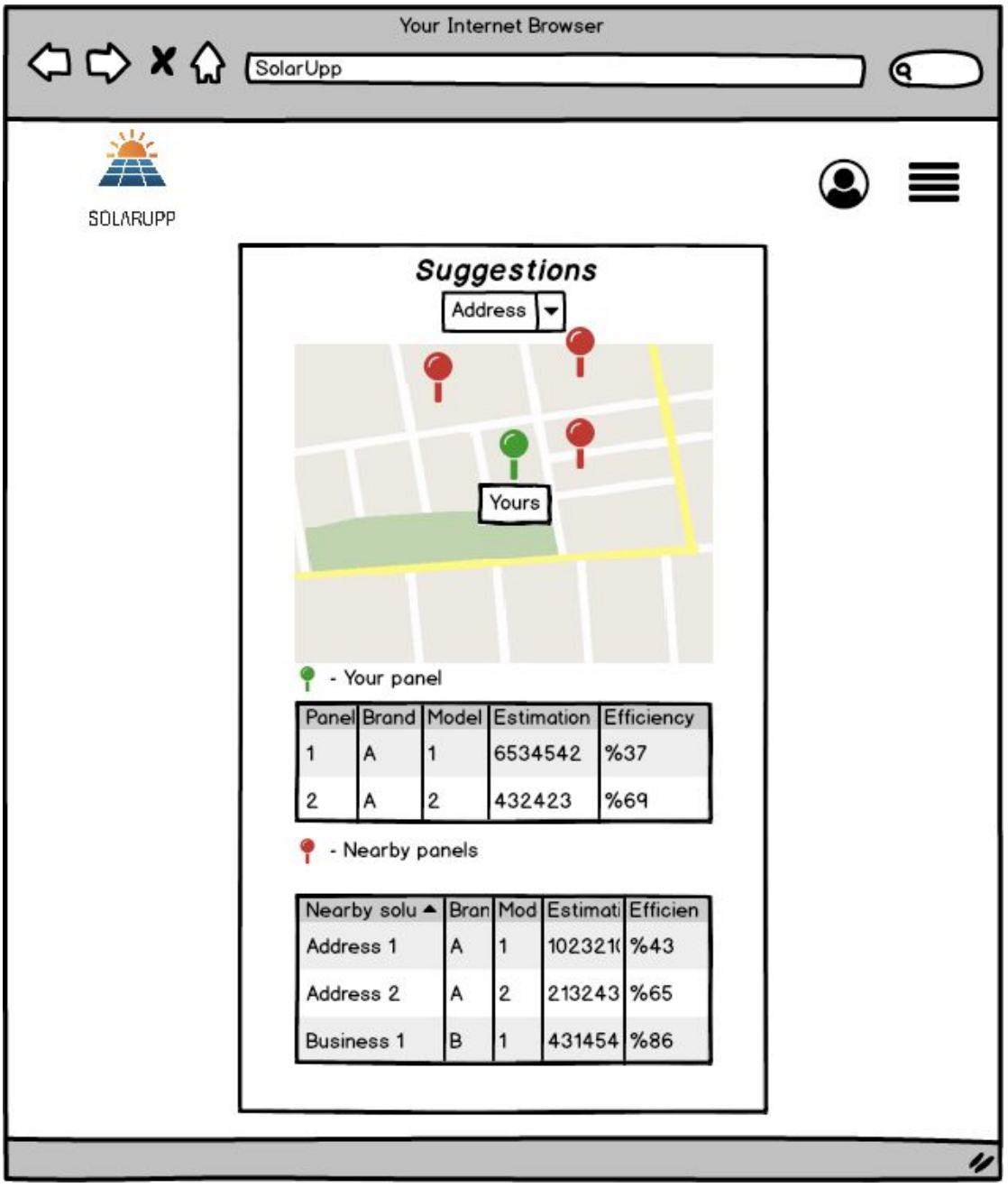
The choose solar plan page will provide all available plans for selected address to the users. Pie charts, Line charts, side notes etc. about available solar solutions will be given to the users. Users can see the differences by selecting plan on the checkbox. Some plans will be available, and some of them will not according to the area and facility. Unavailable plans will not be selectable in the menu. Users can find all necessary information on the notes section. Moreover, users will view suggestions for requested addresses. Chosen plan will add to the users solar plans.

2.6.5.6 - Calculate Feasibility Page



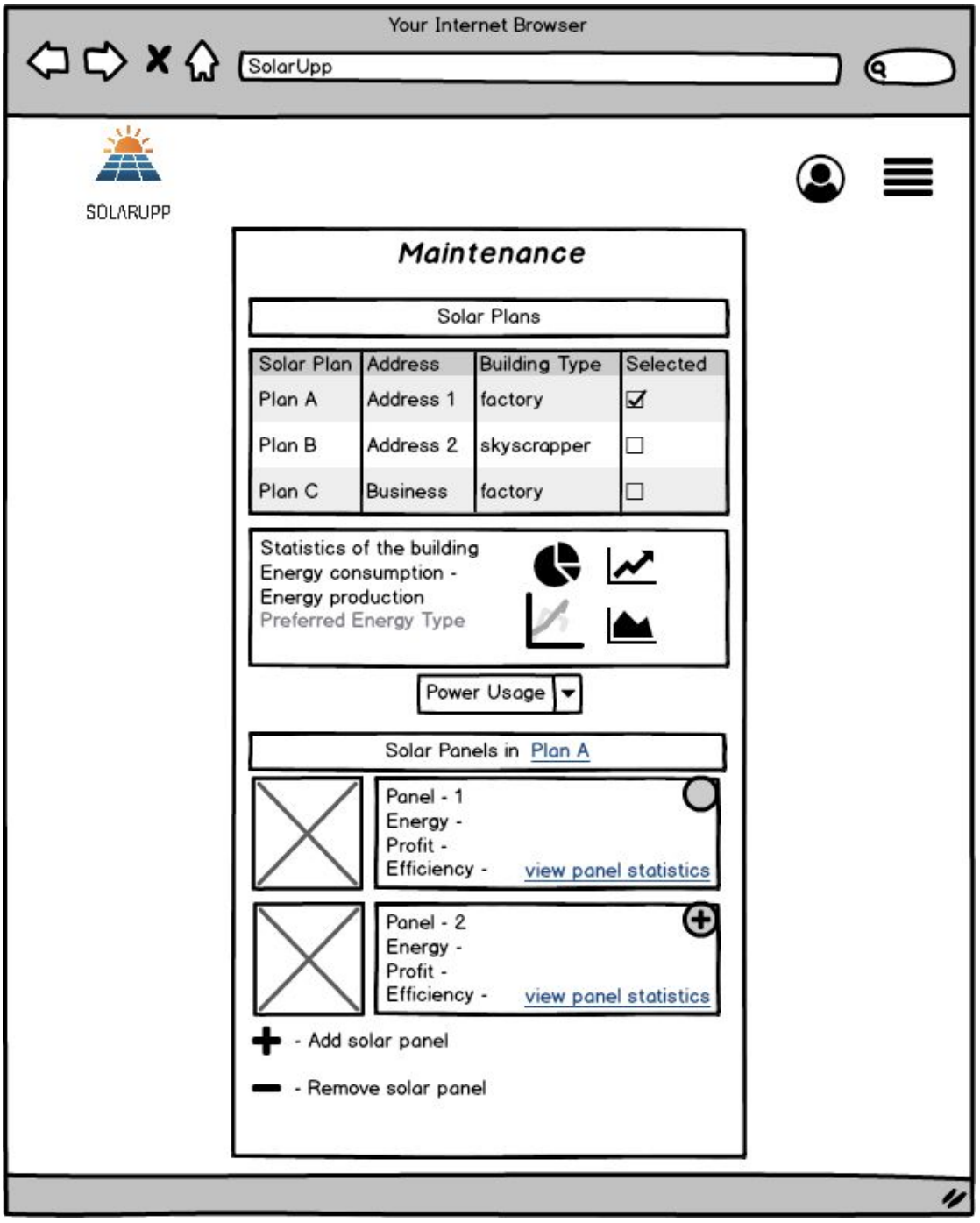
In this page users can see their selected building and its roof measurements in the same table view. Roof measurements will be automatically reflected on the Roof Measurement section. Besides, users can edit the measurements by themselves for accuracy. Apart from that, Solar Plans will be listed according the parameters such as cost, estimated profit, brand, model. Users can get more detailed feasibility report by a link. Moreover, 3d model of the selected plan will be available. Solar plans for the selected address will be seen by the "See Solar Plans" buttons.

2.6.5.7 - View Suggestion Page



View suggestion page will provide nearby solutions to the users. Nearby solutions will be evaluated by the building type and location of the building. Users can see the information of other solar panels and make comparisons among their panels. By this way, a user can see the possible trends and efficiencies of the available solar panel solutions in nearby areas.

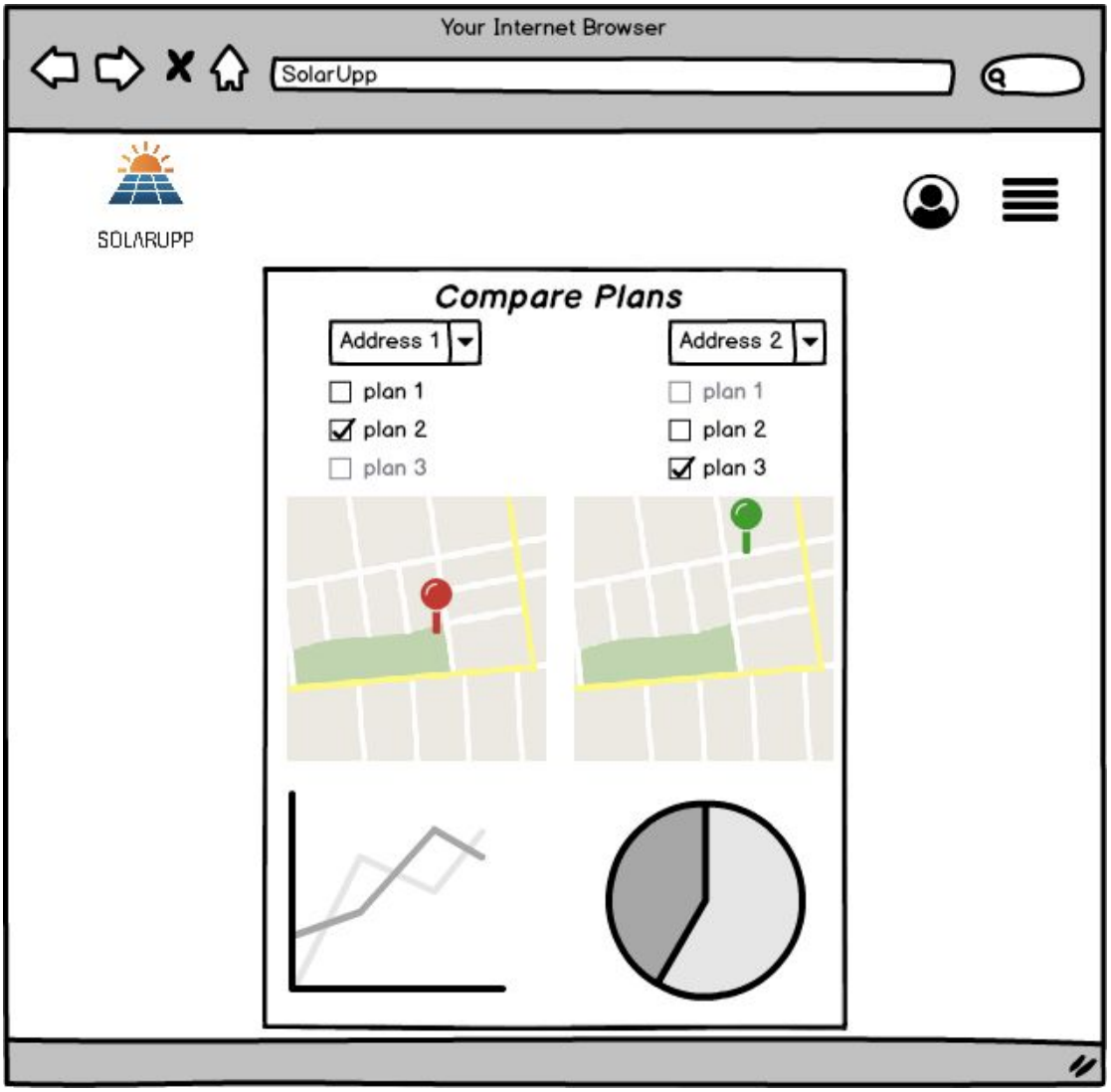
2.6.5.8 - View Maintenance Page



In the maintenance page, solar plans of the user are listed. Solar plans and their properties such as address, type of the building etc. is displayed. Statistics about the selected building is available in the statistics sections with pie charts, graphs,

tables, and related information of the building. Users is going to enter the power usage of their building in order to analyze the power usage of the building. After the selection of a solar plan, solar panels of the plan will be listed. Users can add and remove solar panel to the system. In the add solar panel section, users are able to include their pre implemented solar panels to our system to use our maintenance service. Apart from that, statistics about solar panels will be available in the "view panel statistics" section.

2.6.5.9 - Compare Solar Plans Page



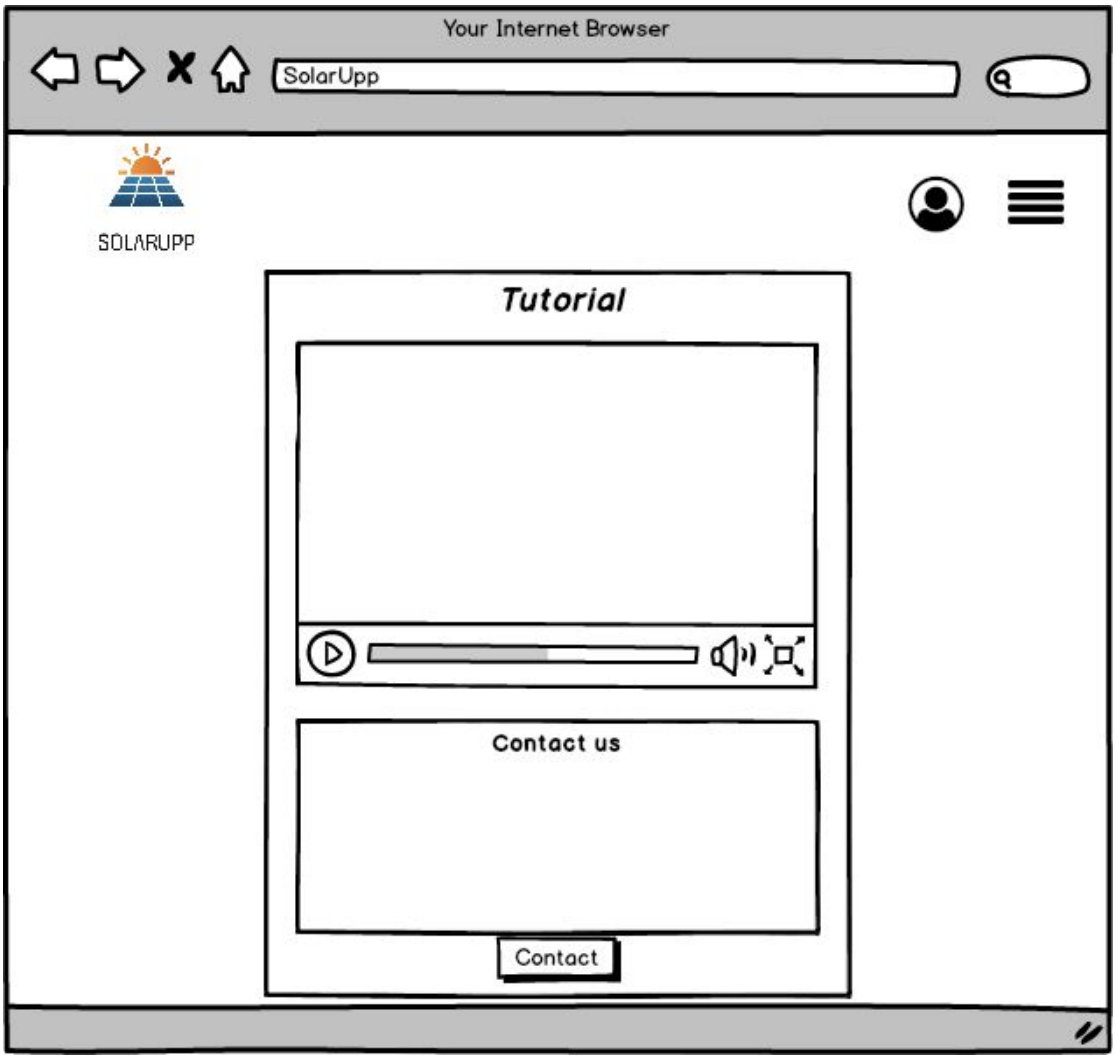
Users can compare their solar plans in the Compare Plans page. Some plans will be available, and some of them will not according to the area and facility.

Unavailable plans will not be selectable in the menu. Location of the plans are shown in the map. Statistics of the plans are listed under the maps.

2.6.5.10 - Profile Page

Users can edit their properties in the "Profile" page. Users can change their password, add/remove their address in terms of properties. Address demonstration on a map, full address, building type, roof information, briefly essential information about the building will be listed.

2.6.5.11 - Tutorial Page



There will be a tutorial of the application in this page. Contents, and properties of the application is processed in the tutorial video. Additionally, users can type any questions, and suggestions with the "Contact Us" option.

3 - Other Analysis Elements

3.1. Consideration of Various Factors

Feasibility study for solar energy production for buildings requires multiple technologies and access to different datasets. In order to have a feasibility study for

a roof, first you need available space on that roof by considering width, length and roof angle which is important for solar panels to calculate solar radiation. Roof angle is an essential element to calculate solar productivity of a building, solar angle can not be calculated from images which are taken from satellite. To gather roof angle there will be two options. First option is, accessing 3D model of that building which is available publicly for some regions around the world. If modelling is not shared publicly for some regions it can be modelled by technology called Lidar. For the second option, if 3D modelling can not be accessed or available for a specific building properties of that roof which are width, height and roof angle can be entered manually to have a solar productivity calculation.

Regions around the world may vary largely in terms of the amount of solar radiation (sunlight). Solar maps are available and shared for common use and they are categorized as city, state and country to get information about how much a certain piece of land, building, or home experiences a certain amount of sunlight. After getting information about roof such as free space and global position solar map of that building's region will be checked and solar radiation will be used to feasibility study. Another factor for having a solar plan for a roof is that components used such as solar panels and inverters. Solar panels and inverters vary because there are many companies which have different solar panel types and each panel can have different properties about solar efficiency and they also vary in terms of cost which is important for a solar investment. These information about solar components will be added manually to SolarUpp and will be updated in further determined time intervals.

Later on gathering information about roof properties and regions specific information such as solar radiation and weather SolarUpp will be able to have study on solar productivity of the roof. After having feasibility study produced solar energy by solar panels should uploaded to our system in order to achieve maintenance service. Inverters planted on roofs are able to upload amount of solar energy produced to cloud. Different technologies and data will be used to provide feasibility study service to user before plantation of solar components and maintenance service in the long term after solar panel implementation.

3.2. Risks and Alternatives

Calculating the feasibility of solar panels to a specific building, we have various parameters and factors. For example sun angle is very important for efficiency of solar energy production. But sun angle is a dynamic factor. We cannot basically calculate sun angle to each building by looking address' latitude and longitude. If a building that gets a feasibility study from SolarUpp, a building that is near of the studied building affects the sun angle of studied building. For example if the neighbor building is a skyscraper, then it will overshadows studied building. The risk is in this point. We might not be able to consider all of the relational position of buildings. An alternative to solving this problem is to prevent a building's feasibility study if its height is on average smaller than neighbor buildings since the efficiency of solar energy production will be inefficient.

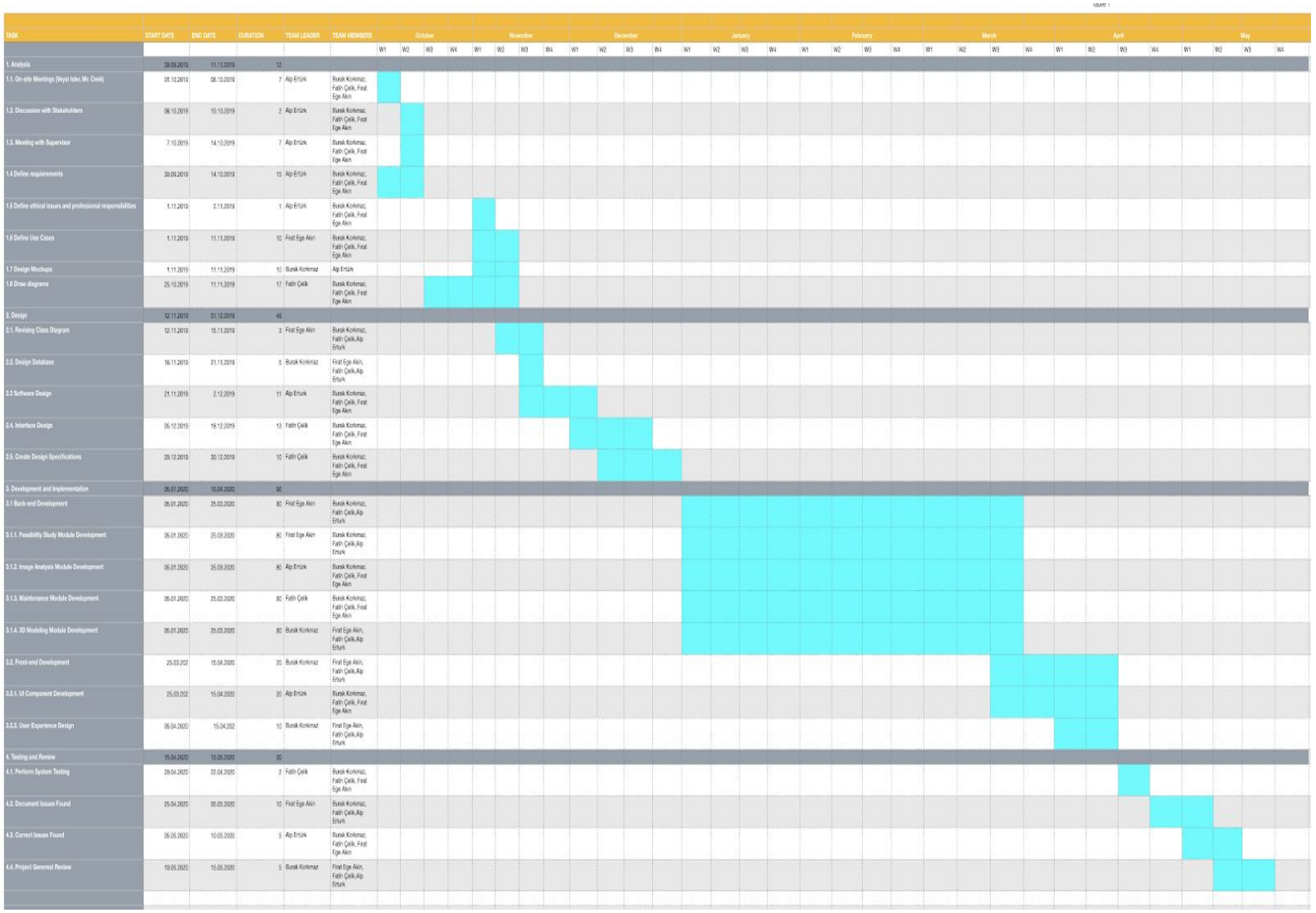
Another risk is problems that might occur in retrieving data from databases and APIs. While we were researching databases and APIs that we are going to use we observed that the accuracy of data is not homogenous. In other terms, for example Google Earth provides 3D images of countries accurately such as USA, Spain etc. But for Turkey, the 3D views of buildings and streets is not available. Since we should consider the rooftops of buildings and slope of them, we might not correctly measure the feasibility of solar panels to the buildings if we do not have 3D views of buildings. This is a significant risk. An alternative that solves this problem is proving SolarUpp services to specific regions that have accurate data.

There is another risk in the service of estimation profit that SolarUpp provides. When we researched about selling the excessive solar energy produced to government, we observed that some governments is not permitting selling excessive solar energy produced from panels. For example in the USA, excessive solar energy can be sold to government and in this way the estimation of profit that SolarUpp is meaningful. But in Turkey selling excessive solar energy is not permitted. Therefore our service in this case is not meaningful. An alternative to solving this problem is add the sell permission information by research this law for various regions and if there is no sell permission for a specific country, we should alert it and say that this

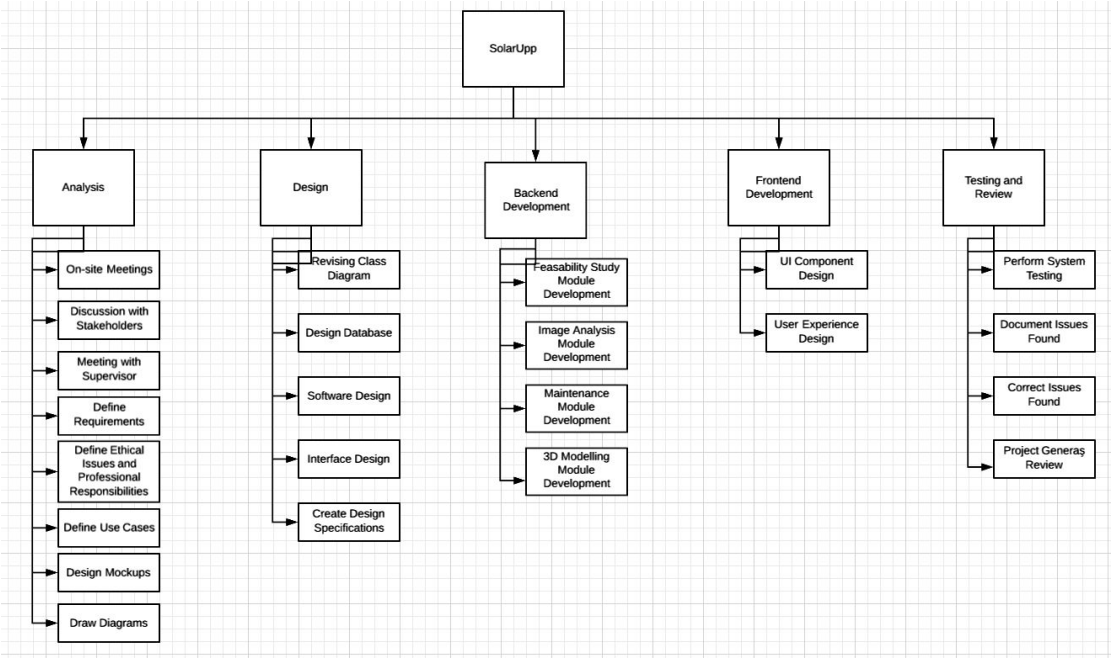
building cannot get profit from selling excessive solar energy produced from solar panels.

3.3. Project Plan

3.3.1. Gantt Chart



3.3.2 Gantt Chart Diagram



3.4. Ensuring Proper Team-work

Effective teamwork is essential in order to develop a project which satisfies requirements and deadlines. Without teamwork, unnecessary disruptions may occur and strategic failures are expected. Having a proper teamwork relies on several aspects. Distributing workload to team members based on their acquired skills is important while ensuring proper team work. Working on frontend to develop user interface, storage functionalities, cloud usage, backend development and more can be examples of acquired skills to share workload among team members in our project. Different team members will have different tasks to achieve but also developed parts have to work correctly together in specified deadlines. In order to achieve this, it is also important to specify subteams and tasks for these smaller teams.

3.5. Ethics and Professional Responsibilities

The professional and ethical issues related to SolarUpp discussed in terms of data retrieval and storing user specific information. Some amount of data required for our project are not stored as a database. In order to use these data such as properties of solar panels or inverters data should be copied to our application by hand which will not have a legal limitation because solar panel properties are shared publicly. Solar maps of different areas around the world are distributed without any restriction so it will not have a legal concern. Users private information such as address, email or phone number will not be distributed or shared.

3.6. New Knowledge and Learning Strategies

SolarUpp will be a web application developed on React framework, which is JavaScript based. Our application structure will follow client-server model; hence, we will need to learn database management with React as well as developing the necessary features our application require with React and JavaScript. We will follow online tutorials for the most part. We will also examine other projects that are similar to ours done with React framework.

We will also need to work with different kinds of APIs; for example we will need to access weather and solar information in the run time of the application. We will have to learn interfaces of such APIs and how to implement their services in our application. We will review documentation of these APIs and learn how to access to their services using React framework.

Since our project is about solar panel implementation, we will need to improve our problem domain knowledge drastically. We will learn the process of both how solar panels are implemented and how they are maintained. We will interview with the experts in this domain, by the means of either face to face or online interview. Fortunately, our innovation expert Veysi İşler has some domain experience; we are planning to have interviews with him about the proper steps to take in our project. Furthermore, we will also make our own analysis based on online literature.

Although it will not be feasible without a critical mass of users, we want to use machine learning in our application to analyse the data gathered from users. Our

plan is to use machine learning algorithm to find similar buildings and pair those buildings with successful solar plans and buildings that need a solar plan. Three of us in the group are currently taking the introduction to machine learning course, and we plan to interview data scientists from Bilkent if we get to a critical mass of users.

Image analysis/map analysis/ APIs? TODO

- web application development / database
- javascript
- react framework
- Solar panel implementation / inverters
- Machine learning for finding similar houses
- Working with different APIs
- Image analysis
- Map analysis

4 - References

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