Specification of Interfaces for IoT Devices

Deliverable D3.3

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Technical References

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[1] PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

Document history

V	Date	Beneficiary(ies)	Author(s)
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Summary

The aim of the ebalance-plus project is to create an energy-balancing platform in order to unlock the flexibility of energy grids and increase their resilience. This platform will allow to minimize the energy costs, reduce the CO2 emissions, and increase energy efficiency. It will also enable interoperability of an array of energy sources. In order to support the energy balancing platform, IoT solutions are developed and enhanced for smart buildings within the ebalanceplus project.

The main objective is the development and implementation of devices to turn building facilities into smart, implementation of devices to monitor and control distributed energy resources, implementation of communication interfaces and implementation of building users' app (Android and iOS). Using the requirements from WP1 and the pilot characterization from WP6, the tasks related aim at design and developing IoT solutions and communication interfaces to operate with the energy balancing platform.

The tasks conducted related to this deliverable are mainly focus on the Smart Campus of the University of Calabria.

REE is the main developer, SOF is the supporter for communication interfaces, IHP is supporter for security and privacy and CEM is the supporter as demonstration leader.

Disclaimer

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1 IoT-based management of energy in buildings

Within the scope of the project's 3rd work package "Solutions Grid Flexibility Resilience" and its sub-task “T3.3 IoT Solutions for Smart Buildings", it is aimed to participate in grid flexibility applications with the smart use of energy assets of buildings together. In this respect, the main target is to create usage scenarios that can be used to participate in flexibility studies, especially through existing resources, and validate them in project pilots. The study conducted in at the University of Calabria aims to develop proof of stake usage scenarios that can be scaled to many kinds of buildings and households.

1.1 Existing Building Systems Study

T3.3 IoT Solutions for Smart Buildings work is carried out specifically for the University of Calabria demo. Demo site UNC, which is more fully described in **D6.1 Chapter 2.1,** is a public institution consisting of several buildings with several electric loads and production facilities. Among the university facilities, the focal point of the T3.3 study is the Monaci Residential Buildings located within the university. Residential Building (Monaci) consists of about 100 apartments. Generally, each apartment is used by two students; there is a bedroom, a single room between the living room and kitchen, and a bathroom. Since the Monaci building is the accommodation facility for the students at the university, it offers a very convenient demo area for residential use case examples.

Figure 1 Captions from MONACI Residential Buildings

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Within the scope of the study, it was worked with the UNICAL team. In the first phase of the study, the existing infrastructure of the building was evaluated. As the primary target, it was aimed to evaluate the existing infrastructure and assets in the building in flexibility solutions. In this respect, an evaluation was made with the UNICAL team regarding the building assets.

First of all, the assets in the building were listed and it was discussed which of these assets could be included in energy monitoring and what kind of monitoring methodology could be used. Then, the assets considered to be included in the building within the scope of the project were evaluated. At the end of the study, a list was prepared jointly by UNICAL, REENGEN and CEMOSA teams on which assets will be procured, which assets will be included in energy monitoring, and which assets should develop remote control solutions.

Table 1 presents existing and provided energy assets of the Calabria demo site. Within this study.

- Existing smart meter infrastructure will be utilized for main consumption data monitoring. These Smart Meters use HTTP as communication protocol; the data are accessible on the Amazon AWS MySQL database. Consumption of each building will be monitored by this infrastructure.
- Fridges already exist in each apartment. Although they are not capable of remote monitoring and control, it is planned to monitor their energy consumption and on/off control via smart plugs.
- LED-Lightning system does not have an IoT system. It is planned to monitor lightning consumption via meters.
- Existing temperature sensors do not have communicate capability. Therefore, smart thermostats for heat-pump control will have temperature measurement capability.
- For satisfying heating and cooling requirements, 5 Heat Pumps will be provided for 5 different locations. Heat-Pumps will be controlled via smart thermostats according to indoor/outdoor temperatures and flexibility requests. Data transfers will be provided via API. As a thermal load, heat pumps will participate flexibility use cases described in 1.2.
- Smart Dishwasher and Washing machines are planning to be provided for residents' usage. These appliances are connected to the cloud via wi-fi connection and appliances will be controlled remotely via API connection. The API structure has been shared by the product provider will be created as a library and integration will be provided to the devices. Both appliances will participate flexibility use cases defined in 1.2.
- There are several appliances, such as Fridge, does not have any communication interfaces. Smart plugs are quite practical devices for integrating conventional devices. Among these, smart plugs will be used to monitor and control the equipment selected for use cases.

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Table 1 Asset List of MONACI Residential Building Apartments

Asset	Existence	Location	Connection Type	Comment
Smart Meter	Exist	Each apartment	Amazon Database	UNC provides smart meters. Data is stored in Amazon Database
Temperature Sensor	Provided	Each apartment	Amazon Database	Modbus enabled sensors will be connected. Data is stored in Amazon Database.
Fridge	Exist	Each apartment	Via Smart Plug	Non-Controllable appliance. Needs switch
Led-Lightning	Exist	Each apartment	Via Smart Plug	Non-Controllable
Smart Plug	To be provided	For Selected appliances	Wi-Fi / API	For consumption monitoring and remote control appliances of the buildings
Smart Washing Machine	To be provided	In 3 apartments of the demo site	Wi-Fi / API	For appliance scheduling use case
Smart Dishwasher	To be provided	In 2 apartments of the demo site	Wi-Fi / API	For appliance scheduling use case
Heat Pump	To be provided	In 5 apartments of the demo site	Via smart thermostat	For appliance scheduling and demand response use case

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Asset	Existence	Location	Connection Type	Comment
Centralized water heater	Exist	-	-	Gas powered heating system is out of the project
Kitchen Electric plate	Exist	-	-	Out of the project prioritization scope
Smart Thermostat	To be provided	For each heat pump	Wi-fi / API	For controlling heat pumps

1.2 Calabria Demo Site Use Case Development

After evaluation of demo site facilities in energy flexibility perspective, the teams started to develop flexibility dedicated usage scenarios. In this phase of the study, equipment, primarily the electrical loads in the pilot site, that can be used as a source of flexibility has been determined. Applicable and scalable usage scenarios have been created for each specified equipment. In addition, new equipment's that will contribute to the project objectives has been listed and discussed. It is aimed that the determined equipment will be successful in creating flexibility reserves, transform conventional existing equipment into smart and participating assets. Particularly, the use cases have been designed as affordable and suitable for the user experience.

In the process of designing the use cases, the assets that are available and have been planned to be procured are listed first. Then, which of the monitoring (consumption or temperature) and remote-control options of the assets should be applied is listed in priority. Energy monitoring and control methods are also has been placed for each appliance. For instance, smart plugs will be used to monitor and control most of the existing appliances since it is an easy method and does not require additional device for communication. In addition, the use cases designed for each asset are listed in the table and the priority level is determined.

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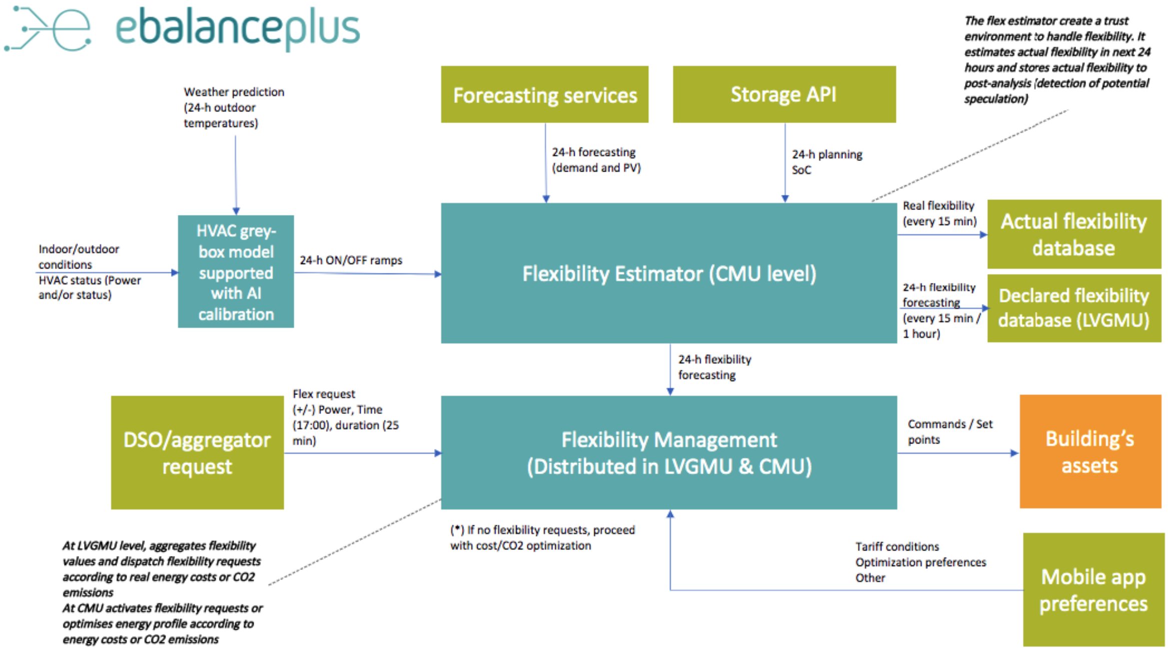

Figure 2 Hierarchal Model of Flexibility Management in ebalance-plus Project

Usage scenarios are aimed at creating flexibility reserve with direct demand control according to distribution grid needs, creating improved demand with the schedule of consumption loads or with awareness-raising user interfaces. Priorities between Use Cases are prepared as the use of existing devices, affordable prices if there is a need for new devices, the simple and scalable solution, and minimal impact on user comfort. In this respect, the distribution shared in Table 2 has emerged.

Table 2 Uses Cases for Calabria Demo

Asset	Monitoring (priority)	Control (priority)	Use Cases	Priority of Use Case
Main Consumption	Via Smart Meter (high)	-	Consumption monitoring and analysis	High
Temperature	Via Smart Thermostat (high)	-	Indoor air quality monitoring for residents. Thermal load consumption analysis	High
Fridge	Via Smart Plug (high)	Via Smart Plug (Low)	Consumption breakdown monitoring & analysis	High

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Asset	Monitoring (priority)	Control (priority)	Use Cases	Priority of Use Case
			Demand response actions according to the aggregator requests	
Lighting	Via Smart Meter (medium)	-	Consumption breakdown monitoring & analysis	Low
Kitchen Plug Loads	Via Smart Plug (low)	Via Smart Plug (Low)	Consumption breakdown monitoring & analysis Demand response actions according to the aggregator requests	Low
Heat Pump	Via Smart Plug (high)	Set-point and On/Off Control (high)	Thermal load consumption monitoring & analysis Energy efficient thermal comfort with HVAC Control Demand response actions according to the aggregator requests	High
Dishwasher	Via Smart Plug (medium)	Smart Appliance Control (medium)	Consumption breakdown monitoring & analysis Load flexibility by appliance scheduling	Medium
Washing Machine	Via Smart Plug (medium)	Smart Appliance Control (medium)	Consumption breakdown monitoring & analysis Load flexibility by appliance scheduling	Medium

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1.2.1 Smart Control of Fridges

As described in 1.1 there is a refrigerator in each student apartment in the Monaci building. It is possible to realize the energy consumption and control of all refrigerators with an affordable operation and infrastructure, as it is an asset currently available in all apartments. With this aspect, a study to be carried out on refrigerators addresses targets in terms of both scalability and utilization of existing devices.

Refrigerators are one of the most energy-consuming appliances, especially in residences. Therefore, it was decided that the apartments in the pilot study were a consumption subfraction worth watching. In the research, it was found that refrigerators can maintain their temperature for up to 4 hours in case of interruption. In this respect, short interruptions in refrigerators do not affect the comfort of users.

1.2.1.1 Usage Scenario Design for Smart Control of Fridges

First, it was decided to use refrigerators with smart sockets. Thus, using the existing Wi-Fi infrastructure, it will be possible to monitor the refrigerator load in real time and to cut its energy remotely without the need for an additional device. With this method, it is planned to add the refrigerator loads to the demand response application in case of an imbalance or load in the distribution network and to perform direct load control. The stages of the usage scenario are as follows.

i. The smart plug is installed to be connected to the refrigerator supply. Then, the building is connected to the internet via the wi-fi network. This process is performed for each refrigerator within the scope of the pilot.
ii. According to the API document shared by the device provider, cloud-to-cloud integration of the plugs is performed. At the end of the tests, the sockets are made ready for control.
iii. The residents of the apartment have access to the refrigerators, which are defined in advance through the Flexibility Participation Section, through the ebalanceplus mobile application developed and offered to them. Users may monitor the loads taken by their devices through the mobile app. In addition, they may enter the flexible times of their appliances as a weekly schedule via the flexibility participation module in the mobile app.
iv. All data reaches the Controller Management Unit (CMU) as well as the users. The CMU unit can take action according to the period constraints determined by the users.
v. CMU can monitor the aggregated level load of all available refrigerators in real time and calculate the flexibility reserve.
vi. In case of any ancillary situation, CMU sends demand reduction requests to the platform.
vii. Platform directly controls the smart plugs and sends turn-off command to the smart plug

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viii. Turn off time is constrained with one hour period. After one DR event, same fridge cannot be reused until 2 hours is passed. It is possible to use same fridge 3-4 times a day provided that it does not exceed 2 hours in total.

1.2.1.2 Hardware and Communication Requirements

Since the refrigerators in the Monaci pilot building are conventional products, there is no cloud connection. Smart sockets will be used for energy consumption monitoring and load control. Smart sockets have Wi-Fi communication and will connect to the building's Wi-Fi network and perform internet communication. With the API service shared by the smart plug manufacturer, cloud-to-cloud integration will be realized between the device and the ebalanceplus platform. The refrigerators will work according to the on/off housing sent by the CMU via the smart plug.

1.2.1.3 Data and Calculation Requirements

There is a need for some algorithmic calculations specific to the application. First, it is calculated whether the refrigerators can be included in the flexibility reserve at that time. There are two conditions for this; First, the current time must be in the available time slot shared by the user. Second, the time determined over the previous session must have passed. On the other hand, in order to calculate the available flexibility reserve by the CMU, the total load of the refrigerators that meet the condition must be calculated over the smart plug data. Apart from the device side, available time periods should be collected from users via mobile app. Finally, the participation time of the refrigerator loads participating in the load shedding operation should be calculated with time counting.

1.2.2 Smart Control of Dishwasher and/or Washing Machine

Washing machines and dishwashers are appliances that are operated for very short periods on a weekly basis but draw high power when they work. With these aspects, these devices are significant assets in demand management aspect. Shifting their loads from peak times to of-peak times would be quite effective for reduction of the peak demand of residential buildings.

With the increase in smart home concepts, many appliance manufacturers have developed modules to make their products connected and integrated them with different user experiences based on mobile applications. Smart home appliance solutions, which generally aim to create applications to increase user comfort, have also become a working area for demand management applications.

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1.2.2.1 Usage Scenario Design for Home Appliance Scheduling

Another usage scenario aimed to be developed for the Calabria Demo is a scheduling methodology that will enable the use of washing machines and dishwashers (to be provided to the student dormitory) in accordance with demand management. In this use case, it will be ensured that the load of both devices is shifted to the most suitable times according to the availability periods to be received from the users. At this point, it is important to protect the user experience and comfort. If the use of both devices is part of our usage habits, they are part of interconnected routines such as ironing. With all these aspects developed methodology addresses with targets in terms of user experience, impact, and scalability.

Developed smart control methodology as follows.

i. The communication setup of smart home appliances is completed over the wi-fi network in the pilot. No additional gateway is needed. With the API service shared by the application provider, the connection between the devices and the ebalanceplus platform is established. The system is thus ready for use.
ii. In the ebalanceplus mobile application, dormitory users can access both home appliances from the Flexibility participation section. Through this interface, the users may monitor the current status of the appliances and enter their preferences to participate in the flexibility application.
iii. When they are going to run a washing machine or dish washer, after selecting operating mode to run, through to mobile app, they select the device they have used through, select the delivery time, and confirm the session respectively. For example, a user who places his dishes in the dishwasher can create a session to determine the readiness of his dishes within 6 hours.
iv. After the session is confirmed and started by the user, the mobile application sends an operation command to the platform together with the user preferences.
v. CMU schedules the appliance to work in the most appropriate 1-hour period among the time period shared by the user, taking into account the distribution system load estimation based on the data it has obtained.
vi. The machine is in IDLE mode until the working time, during which the user can reschedule the appliance or add new laundry or dishes while it is on standby.
vii. Laundry or dishes are made ready within the time period determined by the user.

1.2.2.2 Hardware and Communication Requirements

The biggest obstacle encountered in the use case prepared for appliance control was integration with devices. Many household appliance manufacturers integrate smart solutions in their new generation products and offer them to users through their own cloud systems and mobile applications. However, as a 3rd party technology developer, it has been noticed that when it is desired to develop new features with these devices, manufacturers keep access to their devices extremely limited and many only allow

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access through their own applications. The applications they provide cannot provide a solution at the point of integration with the platform.

We were working on two alternatives as a solution. In the first alternative, it is considered to control some household loads with smart relay or smart plug on off commands. However, this solution is not applicable for every device particularly dishwasher and washing machine since these devices require more sophisticated remote setting features. Both appliances cannot be operated by simply cutting off the supply and re-energizing. Most of these devices do not resume their operating mode after they are de-energized. In addition, power cuts during operation adversely affect the user experience. Therefore, this alternative was abandoned.

As a second alternative, open-source studies and API servers were searched for connecting from household appliances to washing machines and dishwashers. As a result of the search, the Home Connect application, which is directly related to many brands and models, was found. Home Connect enables remote access to globally widespread home. As said, it is able to start and stop programs, adjust settings, read status and monitor events via Home Connect. Remote access via Home Connect is provided by the Home Connect API. Direct access to home appliances is not possible. The following graphic shows a high-level overview of the connections between the technical components. The system architecture of Home Connect is represented in Figure 3.

In addition to both alternatives, in the later phase of the project, in the meeting we held with the R&D team of a home appliance manufacturer, they stated that they could offer API service with their devices, so this problem has been solved by continuing with the device provider mentioned in the Calabrio Demo. After the device is procured, it is planned to connect the devices to the Calabria Wi-Fi network and to perform API integration of the devices to the platform.

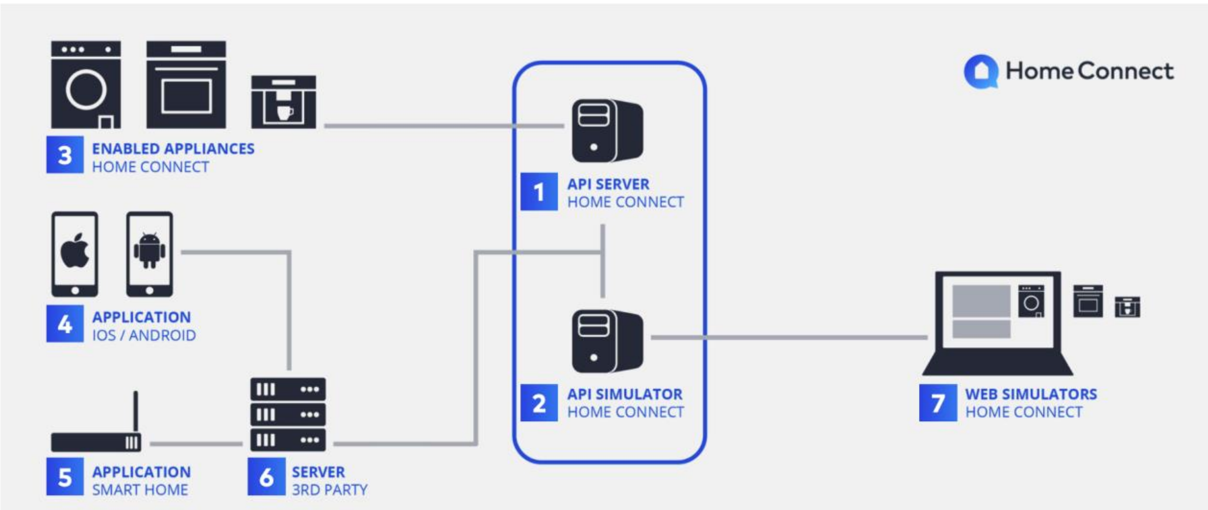

Figure 3 Home Connect System Architecture

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1.2.2.3 Data and Calculation Requirements

The usage scenario prepared for these two home appliances has similarities with smart electric vehicle charging. There is a need for various data and calculations to be collected from different points in the application. First of all, the data that should be provided as integrated with the devices are the open/close information of the device cover, the selections that give the operating mode (temperature and time). It is important to start the device whether the device cover is open or closed. On the other hand, the energy consumption and operating time of the device whose operating mode is learned are assumed.

Apart from the information received from the device, it is necessary to obtain information about the working time from the users. Here, the time interval that the user should complete the washing process will be received from the user via the mobile application. Besides, energy consumption of each device should be collected for validation of the use cases and assumption of energy consumption of each device in each mode. For these, additional smart plug will be used. In addition, since more than one device will be used by different students in the apartments, a mapping is required with the devices through the mobile application. Table 3.

Table 3 Smart Home Appliance Scheduling Use Case Data Requirements

Data Required	Data Source	Collection Method
Device ID	Assignment	Manuel
Door Status (open/closed)	Appliance	Appliance API Connector
Temperature Setting	Appliance	Appliance API Connector
Time Setting	Appliance	Appliance API Connector
Departure Period	Mobile App	Mobile App Connector
Energy Consumption	Via Smart Plug	Smart plug API Connector
Device Start Time	From CMU	Appliance API Connector

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In addition to data communication, data calculation and algorithms should be developed for this usage scenarios. The algorithm to be developed sends scheduling commands to the devices via the CMU. Algorithms decides appliances running periods according to the user preferences and distribution system availability. Priority target is shifting appliance loads to the periods when surplus renewable energy is exists as well as smart EV charging scheduling.

1.2.3 Demand Response Participation with Heat Pumps Control

Heating and cooling loads are generally the highest energy consumption groups in buildings. With this aspect, they are assets with high potential, which have high impact results in both energy efficiency applications and demand flexibility applications. For a healthy and comfortable indoor environment, it is sufficient for the temperature to be within a certain hysteresis range. In addition, the heat inside the building also provides a thermal storage and the internal temperature can be maintained for a certain period of time.

With this aspect, flexibility can be achieved in a significant amount of electrical load by load control of HVAC loads between the specified hysteresis. Another use case that is aimed to be developed in the Calabria Demo is the intelligent heat pump control. Usage scenario, which is designed around distribution system dynamics and user comfort, is explained below.

1.2.3.1 Usage Scenario Design for Heat Pumps Control

It is planned to purchase 5 heat pumps to be used in the Calabria pilot study. The heat pumps to be supplied will be made controllable with smart thermostats or air conditioning control units. In addition, energy consumption will be monitored via the smart plug, in order to calculate the mean load flexibility and monitor the total consumption of the heat pumps. Additionally, indoor air temperature sensor will be utilized for measurements.

i. The supplied heat pumps will be installed in the Monaci Building. Along with heat pumps, smart sockets and smart thermostat products will also be installed. The smart socket and smart thermostat will connect to the building's existing Wi-Fi network. The integration of both devices with the ebalanceplus platform will also be completed with the API service of the devices.
ii. It is planned to control the heat pump according to the preferences of the users. For this, there is a Heat Pump dedicated section in Flexibility Participation part of the ebalanceplus mobile application.
iii. Through this section users may enter their available periods and temperature hysteresis for flexibility participation.
iv. According to the user preferences and heat pump consumption, CMU calculates actual flexibility.

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v. In case of any ancillary situation, DSO or Aggregator sends flexibility requests to the CMU. Then, CMU sends demand reduction orders to the available heat pumps via smart thermostats.
vi. Heat pump control continues until the temperature drops below the hysteresis set by the user or until the flexibility request is completed, and then continues its normal cycle.

1.2.3.2 Hardware and Communication Requirements

For the smart heating scenario with Flexibility participation, it is aimed to purchase 5 heat pumps in the Monaci building. Aggregated level load creates a significant electrical load in this scenario. Smart thermostat will be used for remote management of air conditioners. The operating mode, temperature set point and on/off commands can be controlled in air conditioners by means of the smart thermostat. In addition, smart plugs capable of measuring load will be used to calculate heat pump consumptions and flexibility reserve. Both thermostat and smart plug have Wi-Fi communication. Therefore, both devices will be connected to the cloud via existing Wi-Fi network of Monaci Building. The manufacturers of both devices provide API service and the ebalanceplus platform will be realized with API integration with the devices.

1.2.3.3 Data and Calculation Requirements

In the designed usage scenario, there is a need to develop decision support systems over the collected data as well as the need for communication infrastructure. In the heat pump flexibility scenario, first of all, the data requirements have been studied. **Table 3** lists the required data along with the data source and collection method. At first, since more than one heat pump can be managed by different users, it is decided to assign an ID to each device. The device operating status (on/off), temperature setpoint, operating mode may be read with API requests via the smart thermostat. Likewise, with the commands sent to the relevant registers on the device, the air conditioner temperature setting and operating mode can be controlled remotely. In addition, indoor temperature data will be obtained from the temperature sensor to be provided in case it is not in the thermostat. Apart from access to devices, other important information to complete the usage scenario will be provided from users. Users will transfer the time periods and temperature ranges they are available for flexibility to the platform via the mobile application. Users will be able to enter temperature limits and available periods from the Flexibility Participation section in the mobile application.

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Table 4 Smart Heat Pump Control Use Case Data Requirements

Data Required	Data Source	Collection Method
Device ID	Assignment	Manuel
Device Status	Smart Thermostat	Thermostat API Connector
Device Consumption	Smart Plug	Smart Plug API Connector
Temperature Setpoint	Smart Thermostat	Thermostat API Connector
Operation Mode	Smart Thermostat	Thermostat API Connector
Indoor Air Temperature	Temperature Sensor	Thermostat API Connector
Max & Min Temperature Preferences	Ebalanceplus Mobile App	Mobile Application Interface
Available periods	Ebalanceplus Mobile App	Mobile Application Interface

In addition to data requirements, computational and algorithmic approaches are also needed. First of all, the real-time aggregated load created by the heat pumps and the total reserve of available flexibility should be calculated from CMU. Whether or not each heat pump load is flexible depends on two conditions. First, the current time must be within the available time interval that users share in the mobile application. The second is that the indoor temperature must be between the maximum and minimum temperature values shared by the users. In case both conditions are checked in the algorithm and the condition is met, the CMU can use the relevant heat pump load as a flexibility reserve. In the demand reduction period according to the DR request the indoor temperature continues to be monitored during this time period.

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2 ebalanceplus mobile app

An important goal of the project is improved demand flexibility through behavioral demand management applications, raising awareness and making them an active participant in the energy system. In order to engage end-users into the technologies, and service models developed in ebalanceplus project, a mobile application is being developed. In this respect, the mobile application acts as a bridge that delivers the project outputs to the end users and create a two-way interaction between them. The mobile application enables users to view all end-user-oriented technologies such as energy management, demand flexibility, smart charging, smart heating, etc., and enables users to actively participate in flexibility applications with management interfaces created.

The ebalance-plus mobile application, prototypes of which have been developed, includes majority of outcomes of the project. In the mobile application, household energy consumption is displayed on interactive screens, energy flexibility analyses are performed and presented. Besides, the users may create demand flexibility with their home appliances (explained in detail in 1.2) and may use the smart EV charging technology developed in T3.6. The mobile app provides interfaces of technologies developed in the project. With this, it is also fed from other technology outputs (for example, consumption forecasts) in the project. In addition, many parameters (eg EV departure time or temperature preference) along with preferences and restrictions are provided by the users through the mobile application.

While developing mobile application prototypes, care has been taken to design a user-experience that will engage users in accordance with behavioral science, and to be compatible and interoperable with ebalanceplus technologies. In this section, the mobile application design processes and the features and design requirements of the modules of the mobile application are shared.

2.1 Initial Design & Requirements

A comprehensive review was carried out before the mobile application designs were developed. Deliverables and discussions under **WP1**, D1.1 Guidelines and D1.2 Definition of use cases and specification of technical, market, and social requirements for electric flexibility and resilience, are references for understanding and defining the market requirements, ebalanceplus energy balancing approach, all related use cases and how they interoperate. Deliverables and studies under **WP2**, D2.1 Energy End User Behavior Characterization, D2.2 Methodology for user engagement in energy literacy and flexibility are references for understanding the user engagement side of the mobile app and systems design. Deliverables and studies under **WP5**, D5.1 Networking Layer specification, D5.4 Communication Platform are references for understanding systems communications and data exchange approach for the design and implementation. Deliverable D6.1 Evaluation Methodology from **WP6** has been

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utilized as a reference for understanding the demosite characteristic and requirements. Existing market solutions are also reviewed for research purposes.

The aim here is to design a mobile application that addresses both the project goals and the application target audience. For this purpose, working activities related to mobile application design are divided into four. These are:

i. Analysis of the requirements of the project pilots
ii. Requirement analysis of technologies developed in the project
iii. User engagement strategies
iv. Similar product analysis

2.1.1 Analysis of Requirement of Project Pilots

The mobile application will be used by the demosite users, including but not limited to the residents of the MONACI Building, in the University of Calabria demo. Therefore, the designed modules have been developed especially considering the needs of this pilot study. In **Section 1 IoT-based management of energy in buildings**, details about the Calabria Demo Building are given and the usage scenarios developed under the T3.3 IoT Solutions for Smart Buildings task are explained in detail.

In the Calabria pilot, a demo study will be carried out in a certain number of apartments in the MONACI Building. Within the scope of this study, a detailed energy measurement is realized thanks to the integration of smart sockets to the sub-loads of the apartment, especially to the appliances. In the light of these data, it is aimed to provide users with monitoring screens and detailed consumption analysis screens of the mobile application.

On the other hand, mobile application will be used in flexibility usage scenarios developed within the scope of the pilot. In this way, users will be able to view their consumption in detail and integrate them into a central flexibility platform with a mobile application. The data to be provided and transferred specific to the application are listed and their technical infrastructures are determined.

2.1.2 Requirement Analysis of Ebalanceplus Technologies

As shared, many software and products were obtained as intermediate outputs by technology providers and academics in the Ebalanceplus project. Some of these products are aimed directly at end-users, and at this point, mobile applications become a tool for technologies to reach users.

For instance, the Smart EV Charging Mobile Application, details of which are shared in Section 2.4, is an important component of the smart charging system. If the user preferences required for the algorithms to work, they can be collected as data from the users via the mobile application. In this respect, a mobile application has been designed in accordance with the requirements of the smart charging system, taking into account the user experience. A mobile application has been developed both as a

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part of the developed technologies and to be fed from the developed algorithms. For this, the requirements of each ebalanceplus technology have been determined and appropriate solutions have been designed.

2.1.3 Analysis of Similar Commercial Products

There are various commercial energy management solutions and mobile applications for end users to provide energy management in their homes. The majority of these are solutions that present their energy consumption with different monitoring interfaces and notification mechanisms. In addition, there are many different mobile applications developed by charging network providers or product manufacturers. The products on the market were examined considering their many different features and the best practices in them were analyzed. At this point, the points to be paid particular attention are:

- Users' initial login processes
- Adaptation process offered to the user at first use
- The way data is visualized, interface features
- Matching data and chart types
- Shared feedback patterns to users
- Performance indicators and calculations obtained from raw data, if any

During the design phase of the study, many commercial mobile applications were reviewed and compared. A lot of feedback has been obtained from these applications.

2.1.4 End-User Engagement Strategies

In order for end-user-oriented services and technologies to turn into a successful and sustainable application, a service design that prioritizes the user experience as well as the technical infrastructure is essential. Besides, flexibility applications for the energy grid, which is the subject of the project, and demand side management applications at the end user's pillar are complex and technical issues that end users cannot understand. Therefore, a sustainable and user-friendly application design is an important challenge. As such, behavioral science is involved.

The main goals of the mobile application are to improve the user experience of the mobile application, to raise awareness among the users who are mostly uninformed about the subject, and to motivate them for demand side participation. At this point, the work package outputs within the **WP2 - User Engagement and Requirements** work package were examined in detail. Especially in the first phase of the study, "**D2.1 - Energy end-user behavior**" deliverable was examined in detail. In the study, deliverable 2.1 outputs were examined in detail and designs and solutions were

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developed that addressed shared user behaviors and needs. The determinations obtained from D2.1 are as follows.

i. The first motivation behind energy efficiency applications is the reduction of expenses. *Also, individual education and lifestyle are powerful as well. After these, environmental concerns are also important. The best way to motivate users is to provide feedback based on their motivation patterns.*

ii. *The first thing that makes persons demotivated is the low return of effort and investments or the thinking it is.* Conversely, users are motivated when they see the benefits of their efforts. *Especially, it is quite effective to show the result of changes in consumption habits in monetary terms.*

iii. *Surveys show that most of the users are quite weak in terms of energy literacy. They are quite unaware of demand side management applications, especially energy efficiency and time of use policy. Awareness and information are two important issues. Therefore, the first thing to do is to offer users a learning process in the first place.*

After the first impressions and outcomes, interface ideas were started to be developed to meet the user expectations in the mobile application, and finally the first prototypes were designed. User requirements and solution design matrix is presented in Table 5;

Table 5 Mobile Application Interface User Requirements and Solution Design

Key Finding from D2.1	Designed Solution
Reduction of expenses is the first motivation. A majority of people want to control exactly how much spend on electricity. Almost %50 of them check their utility meters regularly.	Users can monitor electricity energy and power trend of any aggregated energy use in various time intervals. In this way they will be aware of the periods of abnormal consumption and compare them with the consumption of sub-breakdowns. They can also set budget goals.
One of the accelerators is the awareness and knowledge of root causes and consequences of energy usage. They need to be informed about their consumption details and breakdowns.	Users will be able to compare the aggregated energy usages of different groups. Module can show the % deviation of the aggregated energy usages groups compared to the previous same period. In addition, the cost and distribution of aggregated loads can be seen in the module
People have trouble reading their electricity	Monitoring energy consumption breakdowns

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Key Finding from D2.1	Designed Solution
bills. Mostly they cannot associate time tariffs and consequences. It has a good potential to empower citizens while integrating them in demand-side management applications	with different tariffs such as ToU tariff. It is possible to track development of consumption behavior by comparing different terms
Generally, users tend to turn off unused devices and they prefer efficient ones when purchasing new products.	Mobile notifications will be sent to users according to the energy consumption of the users and their load shifting potential. The following types of notifications can be sent; Price Based Notifications that inform users peak pricing times and give suggestions Abnormal Consumption Alarms according to their baselines Load Shifting Recommendations in case of users shiftable loads (heater, washing machine or oven etc) are online in high price interval Notifications to keep users in the app
The first thing that encourages people to participate in energy efficiency and flexibility practices is to show them how these practices affect their savings and carbon footprint.	Energy Performance Module shows the variation between the expected and actual consumption of buildings according to defined parameters. Impact of consumption behaviour change can be displayed as Money, saved trees or reduced carbon footprint
More than 50% of the respondents and 62% of the Italians pay attention to the unit price of energy. Also, many have trouble reading their bills. Furthermore, they need to be informed about their consumption status.	Energy Performance Indicators provides users with information about their energy consumption. The users are compared with common metrics among themselves and their current rankings can be learned.

Mobile application interfaces have been developed for energy monitoring, energy flexibility applications and Smart EV charging in line with the requirement analyses shared in the table and the solution suggestions addressed to them.

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In the second phase of mobile application designs, behavioral science techniques have been successfully applied, especially in interfaces for end users, with the participation of the IPI team. All interfaces and many contents are co-created with the IPI team. Two different templates were also prepared for the survey to be carried out by the IPI team with 4000 people. One of these templates uses the phonetic colors and logo of the ebalanceplus brand. In order to measure user impressions, an ECO Version with a dominant green color evoking nature has also been designed. In the next sections, mobile application prototype screens developed specifically for the application were given.

2.2 Energy Literacy

As described in the section 2.1.4 End-User Engagement Strategies, most of the users are quite weak in terms of energy literacy. They are quite unaware of demand side management applications, especially energy efficiency and time of use policy. Awareness and information are two important issues. Therefore, the first thing to do is to offer users a learning process in the first place. In the energy literacy module, users will have access to tutorials on energy efficiency and demand flexibility. Thus, the adaptation of users to demand management applications is ensured. The prepared notifications are as follows.

Energy Flexibility: You can contribute to reducing greenhouse gas emissions and the cost of energy production by shifting some activities that require energy to times of day when energy is produced from renewable sources. For example, doing laundry during the day (when the sun is shining) rather than in the evening (when energy comes from burning coal or gas).

Energy Balance: The amount of energy produced and consumed must always be in balance. We do not have energy storage, so it is important to use renewable energy when it is available (e.g., When the sun is shining or the wind is blowing), and on the other hand to limit our use of energy when it comes from burning fossil fuels. Try to use electricity efficiently when it comes from renewable sources, such as when the weather is sunny. This reduces energy costs and greenhouse gas emissions.

Smart Device: There are already smart home appliances that can automatically adjust their power consumption according to the current grid situation, so as to make the most of renewable energy, which is cheaper and produces lower greenhouse gas emissions. This way, you don't have to adjust appliances such as the fridge, air conditioner, washing machine, dishwasher, and boiler yourself; they will automatically take care to use energy in a smart way.

Peak Demand: Most of us start using a lot of electricity when we get home in the evening. This causes a big peak in demand for electricity from the grid, and supplying this energy is expensive and requires running large amounts of fossil fuel-powered capacity. Shifting the use of some appliances to a different time (e.g. Turning on the washing machine or dishwasher at a different time) reduces these voltages on the grid and causes us to use less fossil fuel, reducing the cost of energy production and greenhouse gas emissions.

Different Source of Energy: Electricity can come from different sources that have different environmental impacts. For example, when it is produced from coal it can be up to 20 times more damaging to the environment than when it is produced from hydroelectric power. By shifting your energy use to use more from clean sources (e.g. When there is sun or wind) you reduce the cost of energy production and the environmental impact.

Table 6 Energy Facts Module Design

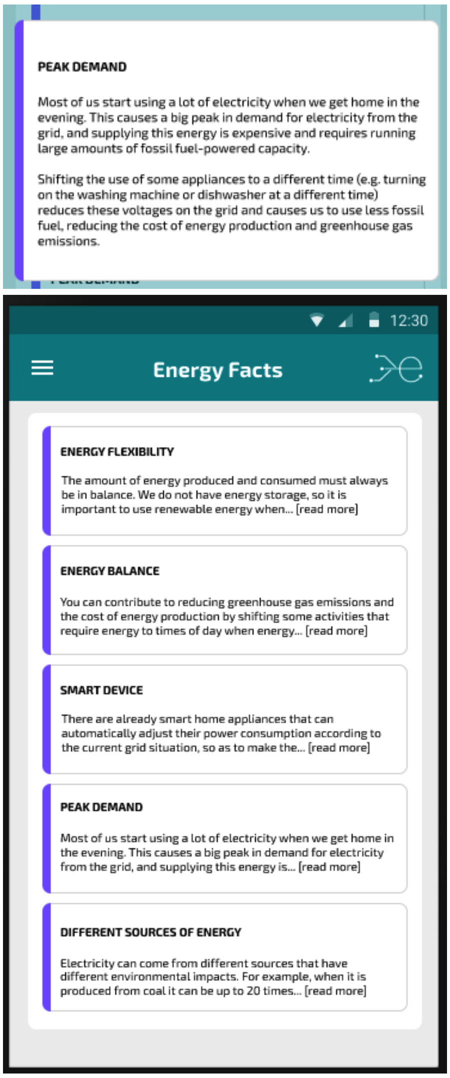
<table>
<tr><th colspan="2">Energy Facts</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="7">
</td>
<td>Energy facts module consists of several informative contents according to energy efficiency, renewable energy and demand side management topics.</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>Informative content prepared for standard users to adapt to project applications will enable users to understand the aims of the project and service models and associate them with their energy consumption.</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>No data required</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
<tr><td>No calculation required</td></tr>
</table>

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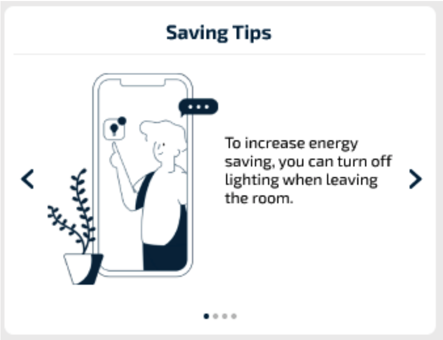
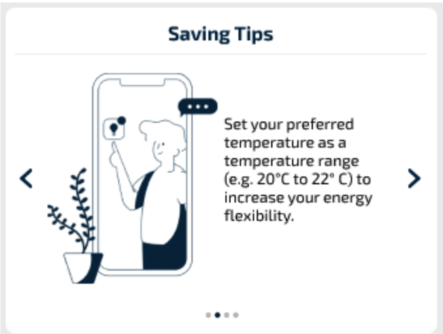
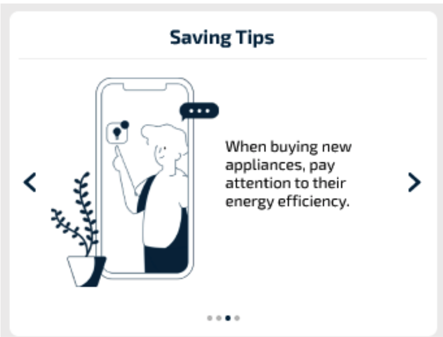
Table 7 Saving Tips Module Design

Saving Tips	
Module Mock-up	**Short Description**
  	*In this module, prepared saving tips in terms of energy efficiency and energy flexibility actions will be presented.*
	Benefit
	Saving tips educate users and guide them how they participate flexibility actions, reduce their cost / emission / consumptions. There are informative contents about smart energy management, sustainability, demand side management, energy efficiency and etc.
	Data Requirements
	No data required – text information to be generated and prepared
	Data Calculation & Algorithm Requirement
	No calculation required

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2.3 Household Energy Monitoring

The main goal of the household energy monitoring modules, which specifically targets household users, is to inform users about the energy they consume, to raise awareness, and to improve their energy consumption in terms of efficiency and demand flexibility, with a successful data visualization and feedback mechanisms. For this purpose, many different modules have been designed in the project for users to monitor their energy consumption. Each module is designed to increase the awareness of users by evaluating energy consumption through a different aspect. In the designs, different behavioral applications were used in order to create energy literacy in end users and to associate their consumption habits with their results.

For the success and sustainability of demand-side management applications targeting end-user electricity subscribers, it is important to correctly analyze and use the behavioral sciences in the developed application. From the perspective of the project, what data will be shared and how, text content and user experience are important, especially in the mobile application and alarm messages. Therefore, the first point of attention and the first point studied during the designs was the analysis of consumers. At this point, a literature analysis was also carried out. The study results show that even among consumers who use energy monitors and are motivated by it, several limitations emerge that undermine the ability of energy monitors to deliver significant and lasting energy savings. These obstacles are as follows.

i. The energy monitoring application does not have the analytical capability to 'make sense' of personal energy consumption and is just data display. One of the most important points in the project is to offer the user a feedback mechanism that can share refined implications and propose solutions.
ii. It is demotivating that users cannot see and monitor the financial value of the actions they take. The screens to be developed in the project should be emphasizing the savings to the users.
iii. It is beneficial to associate data about energy consumption with clear, concrete things that users can understand. It will be beneficial to pay attention to this in feedback and alarms.
iv. One of the biggest misconceptions is that the energy management system alone is sufficient for savings. It is important to share this misconception of users with suggestions to take action. Otherwise, the applications have a neutral effect. The more personalized the feedback shared with users, the more successful their effects will be.

In addition to the analyzes we carried out for consumer behavior analysis, many commercial household energy monitoring solutions and especially mobile applications were examined. Best practices were created by analyzing the display patterns and user flows of the data in the applications. Care was taken to use all these obtained outputs while designing the user experience and mobile interfaces. The following methods have been determined with the outputs obtained from user behavior models and commercial applications.

i. Enriching the user's data sources with web-sourced data (weather data)
ii. Creating baseline from past energy consumptions

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iii. Creating baseline from forecasting data
iv. Creating energy performance indicators by utilizing existing raw data
v. Presenting energy consumption breakdowns according to the household appliance consumptions. Distribution of each device is presented with energy use and cost of use
vi. Time of Use consumption monitoring with time breakdown details
vii. Energy performance reviewing according to the demand side improvements
viii. Diagnostic feedbacks on consumption habits
ix. Impact analysis

With these methodologies, users are expected to diagnose consumption errors and be motivated for improvements. With these methodologies, users are expected to diagnose consumption errors and be motivated for improvements. Mobile application designs will be tested on university residents, especially in the University of Calabria demo, in the Monaci Buildings pilot. Through the application, users will be able to view their household electricity consumption on many different analysis screens and follow the feedback.

In this part of the study, the modules of the prototype application developed within the scope of Household Energy Monitoring are given with explanations. General features, benefits, data and calculation requirements of each module are presented.

Table 8 Mapping Screen Module Design

Mapping Screen	
Module Mock-up	**Short Description**
	This screen presents the mobile app mapping. Users will be able to reach all products, services and educational contents with this mapping.
	Benefit
	These mapping provides users a practical interface to reach each module
	Data Requirements
	No data required
	Data Calculation & Algorithm Requirement

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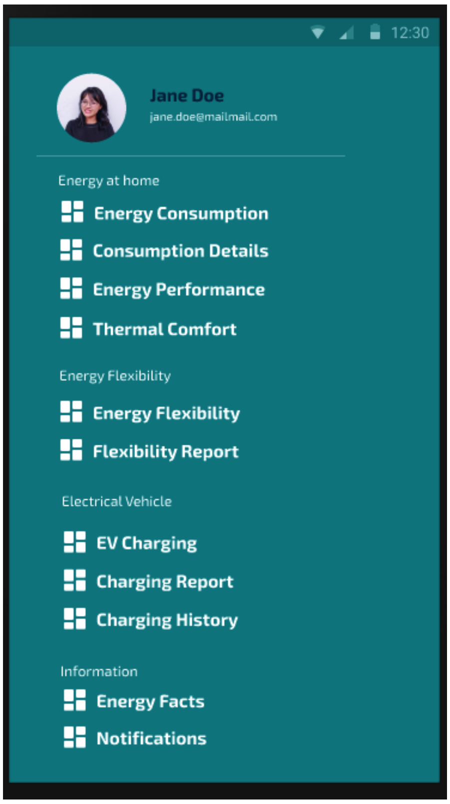	No calculation required

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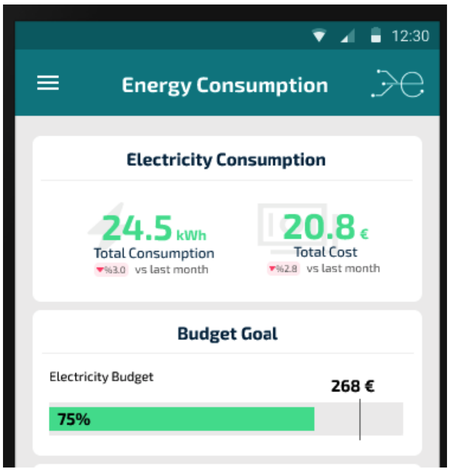
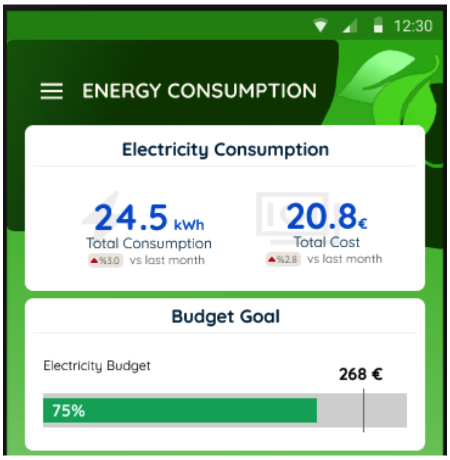
Table 9 Electricity Consumption Module Design

<table>
<tr><th colspan="2">Electricity Consumption</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="7">




</td>
<td>In this module, users may track their energy consumption and cost in desired period (monthly or yearly) as a summary.

For monthly selection, comparison with last month is also given below

Users may also set budged goals for tracking their bills with budged goal module</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>This module is designed for tracking their spends and motivate users by presenting them their savings according to their actions.</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>Saving calculation requires several data sources and calculations. To calculate actual savings involves both home usage and EV charging expenses, following data should be provided;
○ Actual electricity consumption of household (preferred with breakdowns)
○ Electricity consumption baseline according to the forecasting
○ Electricity tariff
○ Budget goal taken from user (via mobile app)
○ Cumulative cost (weekly, monthly or yearly request)</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
<tr><td>No calculation required</td></tr>
</table>

Table 10 Actual vs Baseline Module Design

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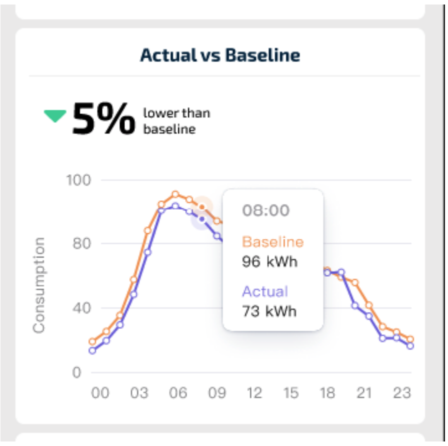
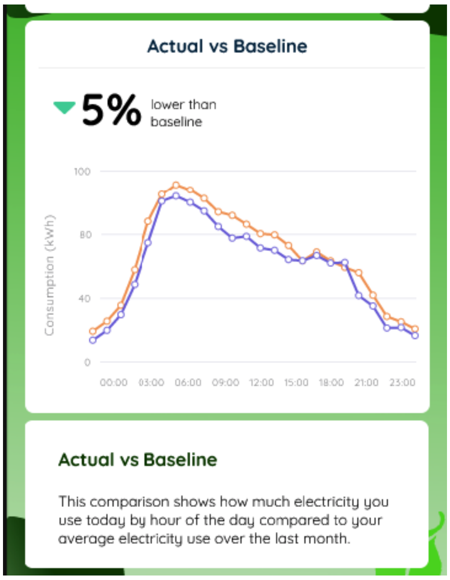
Actual vs Baseline Representation

Module Mock-up





Short Description

In this module, the baseline consumption of the users obtained from the energy forecasting algorithms is compared with the actual energy consumption. Energy savings are calculated by comparing the baseline and actual consumption.

Benefit

Users will be able to follow the improvement in their energy consumption.

Data Requirements

As seen on the screens, it is necessary to subtract the baseline to see the effect of energy flexibility applications. In the demand flexibility module, for example, we aimed to show the load curve at an hourly or 15-minute frequency and the result after load shifting. For this, consumption forecast within the building are needed.

- *Daily Energy Consumption Forecasting with at least hourly level*
- *Daily Actual Energy Consumption*

Data Calculation & Algorithm Requirement

%Change of energy or cost savings according to the past month can be calculated as:
%Change = (Last Month – This Month)/last Month Consumption or Cost saving

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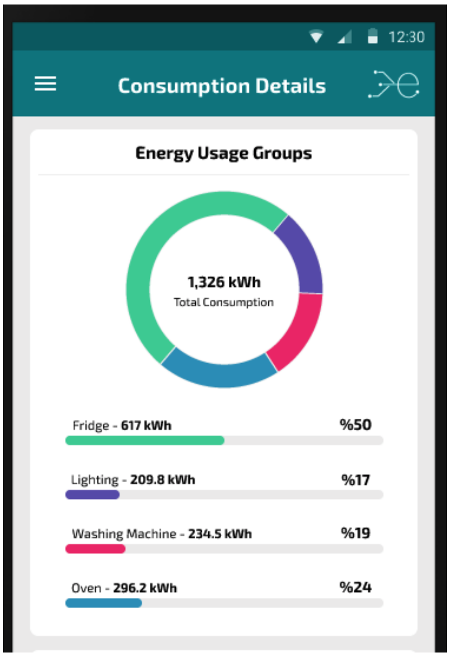
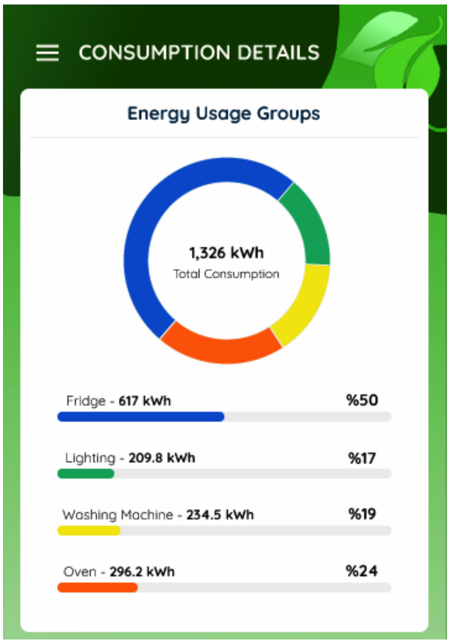
Table 11 Energy Usage Groups Module Design

<table>
<tr><th colspan="2">Energy Usage Groups</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="8">




</td><td>This module presents consumption breakdowns of the building or household and its distribution.</td></tr>
<tr><td>Benefit</td></tr>
<tr><td>Energy usage groups provides visibility for consumption groups and consequences</td></tr>
<tr><td>Data Requirements</td></tr>
<tr><td>The hierarchy between the consumption groups and the main point should be well established. Breakdowns should only be displayed under the relevant building and only to relevant users. It should meet the requests in this format.
○ Energy Consumption with sub-point levels (at least 15 minute periods)
○ Device ID</td></tr>
<tr><td>Data Calculation & Algorithm Requirement</td></tr>
<tr><td>Distribution of consumptions should be calculated</td></tr>
</table>

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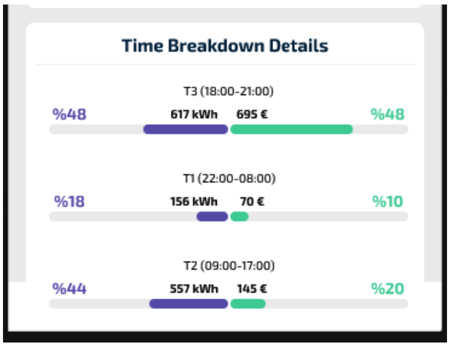
Table 12 Time Breakdown Details Module Design

<table>
<tr><th colspan="2">Time Breakdown Details</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="8">


</td><td>With this module, users will follow the periodic (daily, weekly, monthly or yearly) consumption distributions and the resulting cost according to fixed time tariffs. Different time schedules can be created</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>It is a useful module for users to associate time tariffs with cost savings.</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>This module is beneficial only for users whose consumptions are billed according to their time of use
○ Electricity consumption (daily, weekly, monthly or yearly) according to the tariff periods (such as monthly T3 consumption)
○ Time of tariff details
○ Consumption and cost distribution</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
<tr><td>Distribution of consumptions should be calculated as;
Percent = 100 * (ΣTime Period Cons / ΣTotal Cons) for desired period</td></tr>
</table>

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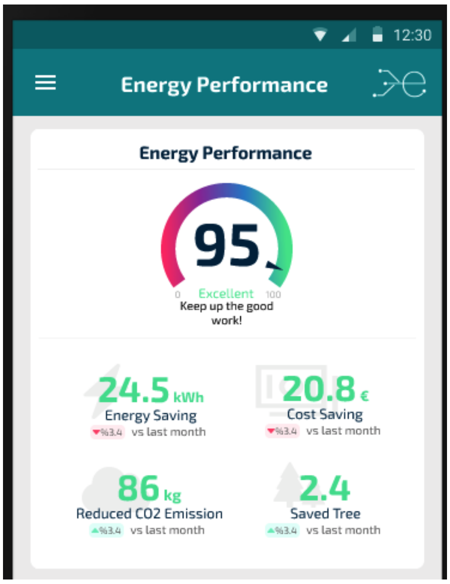
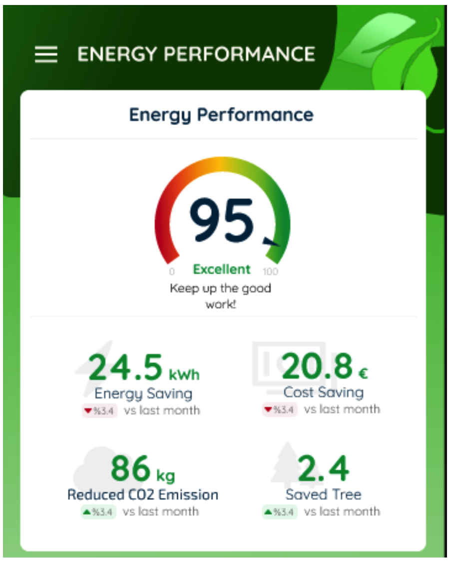
Table 13 Energy Performance Module Design

<table>
<tr><th colspan="2">Energy Performance</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="7">


</td>
<td>This module present users their energy performance according to their energy efficiency and flexibility performances. Users will be able to monitor the energy and cost savings they have achieved as a result of their own actions. Carbon emission reduction and related saving trees is also located in the module.</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>Users will be able to monitor their energy consumption performance and the results of their efficiency and flexibility actions. Seeing the positive effects of the actions and being able to follow their status will motivate the users.</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>Saving calculation requires several data sources and calculations. To calculate actual savings involves both home usage and EV charging expenses, following data should be provided;

Actual electricity consumption of household (preferred with breakdowns)
Electricity consumption baseline according to the forecasting (not displayed, but for calculation)
Electricity tariff (not displayed, but for calculation)
Reduced Cost compared to boost charging (calculated in smart charging side)
Cumulative cost (monthly or yearly request) (not displayed, but for calculation)
Total Cost Saving (monthly or yearly request)
Total Energy Saving compared to the baseline (monthly or yearly request)
</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
</table>

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	i. Users will be scored on Key Energy Performance Indicators, which are analyzed and designed on energy consumption data. Performance indicators may include Energy Saving, Carbon Reduction *ii. Total energy saving should be calculated. For this, baseline of energy consumption should be provided by forecasting them or alternatively calculated with historical consumption. This is the essential data coming from forecasting algorithms* *iii. Total cost saving should be calculated as :* *Total Energy Saving = ΣEnergyTariff(t)*[Baseline Energy Cons(t) - Actual Energy Cons.(t)]* *iv. Reduced Carbon Emissions should be calculated as: ΣCarbonIntensity(t)*[Baseline Energy Cons(t) - Actual Energy*

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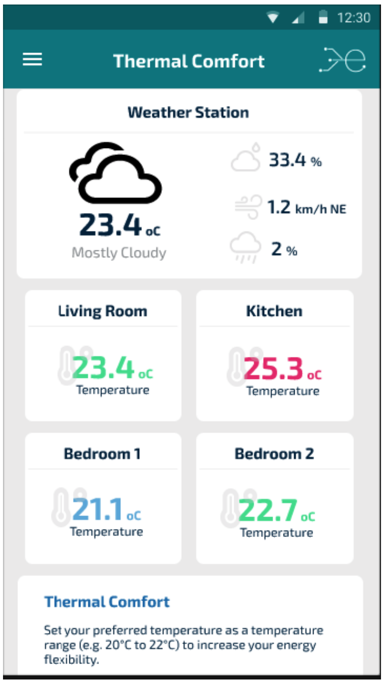
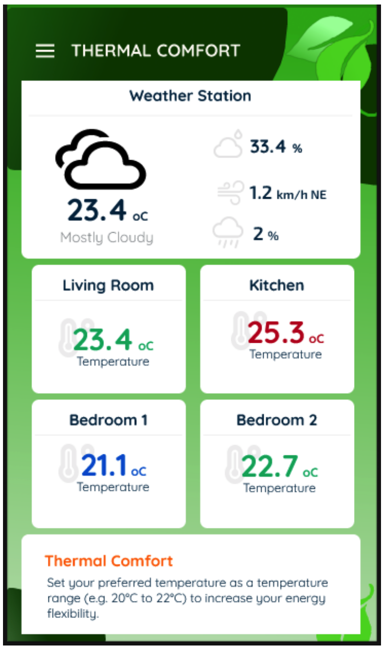
Table 14 Thermal Comfort Module Design

<table>
<tr><th colspan="2">Thermal Comfort</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="7">


</td>
<td>In this module, users will have a screen where they can get information about daily weather conditions. Weather info module consists outdoor temperature, humidity, wind speed, rain possibility.

Users will also access the temperature data received from the IAQ sensors in the houses they are in and will be able to follow the building temperatures.

Info block for managing heating and cooling requirement in efficient way.</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>It is one of the energy consumption groups with the highest heating and cooling needs. Therefore, it would be beneficial for users to be aware of the indoor air quality in their buildings. User will reach whether info via app.

It is one of the energy consumption groups with the highest heating and cooling needs. Therefore, it would be beneficial for users to be aware of the indoor air quality in their buildings.</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>○ Real time temperature data form relevant temperature sensors (5-minute period is enough)
○ Correct matching of IAQ data is important
○ Whether data (temperature, humidity etc.) obtained from 3rd party whether information services including;</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
<tr><td>No data calculation needed.</td></tr>
</table>

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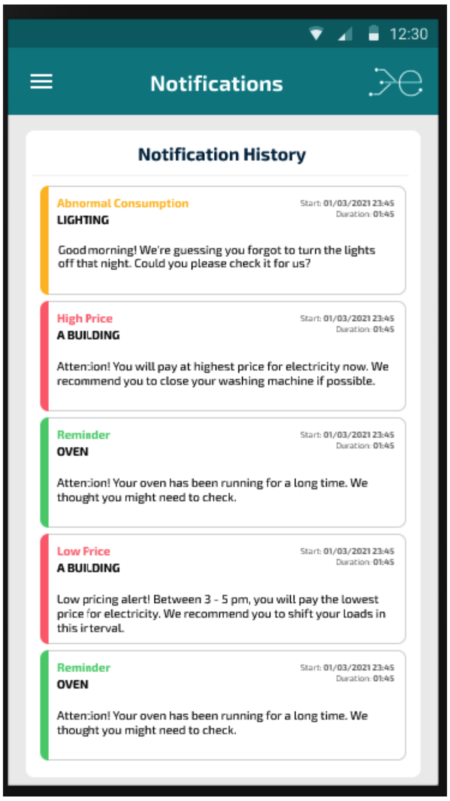
Table 15 Notifications Module Design

<table>
<tr><th colspan="2">Notifications</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="7">
</td><td>The list of mobile notifications sent to users through this module will be shared. Users will be able to review the details of the listed mobile notifications.</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>Mobile notifications will contain educational content aimed at providing flexibility to users and reducing energy consumption.</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>The messages of notifications in this module are planned to be static. It is planned to forward notifications to users from the created notification pool at the frequencies scheduled by the platform.</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
<tr><td>No calculation required</td></tr>
</table>

2.4 Flexibility Program

2.3.1. Smart Management of Household Appliances

In addition to household energy consumption monitoring solutions in the mobile application, mobile application management interfaces have also been developed for the integration of residential appliance clusters, the details of which are shared in D1.2, into flexibility applications.

The main goal in this part of the mobile application is to create management modules that will support the scaling of the created use cases, especially the University of Calabria demo, to residential applications outside the project. At this point, some of the modules developed aim to present the flexibility potential to the users by analyzing the energy consumption of the users. Another part of the modules is to analyze the demand-side improvement of the users and to present the gains achieved on the basis of savings and sustainability. For instance, baseline trends from users' past consumption are generated and compared with actual consumption. With this comparison, the improvements in the electricity demand of the user are calculated and presented to the users with different visual interfaces and feedbacks.

On the other hand, "Participation in Flexibility Practice" tool has been designed in order to benefit from the flexibility potential of the energy assets in the residence, apart from the monitoring and analysis of energy consumption. With this tool, users are provided with the opportunity to manage their energy assets, the details of which are shared in Section 1.2, with their own preferences.

In the continuation of the section, the explanations of the modules of the flexibility program and the requirements analysis are shared.

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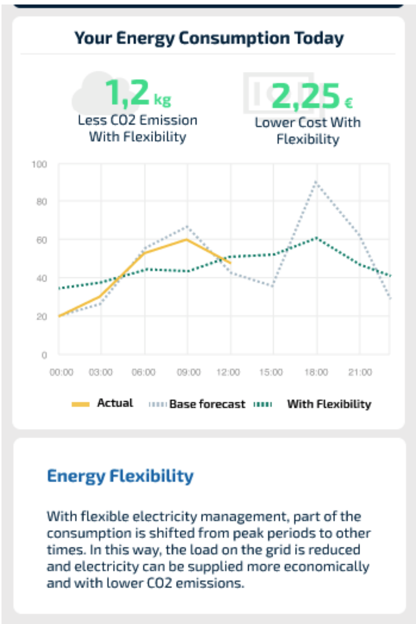
Table 16 Daily Energy Flexibility Monitor Module Design

Daily Energy Flexibility Monitor

Module Mock-up



Short Description

Daily energy flexibility monitor determines the energy consumption trends of users by calculating the historical consumption data and forecasting the consumption of the following hours. Then, it calculates the flexibility potential according to the current state of the flexible devices and generates the improved demand scenario. A screen with all three trends is displayed in the graph and then the elasticity scenario is calculated. In addition, a text describing energy flexibility has been prepared.

Benefit

With this module demonstration, users will monitor their current flexibility potential and the positive impact in return.

Data Requirements

The calculation in the module is based directly on historical and actual energy consumption data

Data Calculation & Algorithm Requirement

In this module, where quite sophisticated calculations are made, the following algorithmic calculations are needed;

- i. *Electricity demand forecasting*
- ii. *Baseline of previous consumption trends*
- iii. *Actual daily consumption trend*
- iv. *Calculation of emission reduction & cost reduction according to flexibility scenario*

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Table 17 Flexibility Preferences Module Design

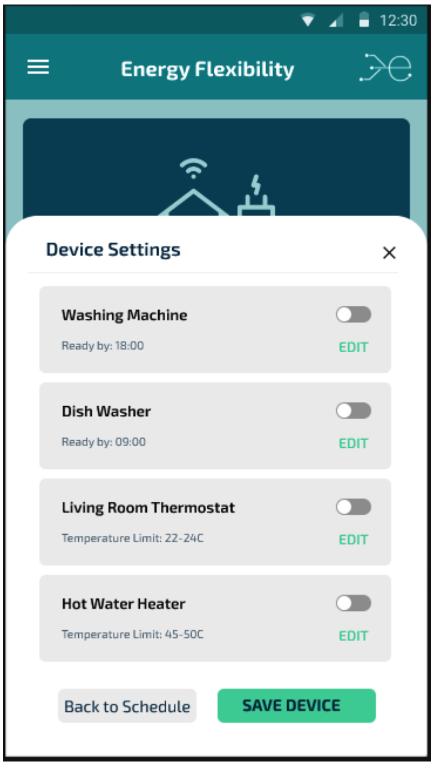
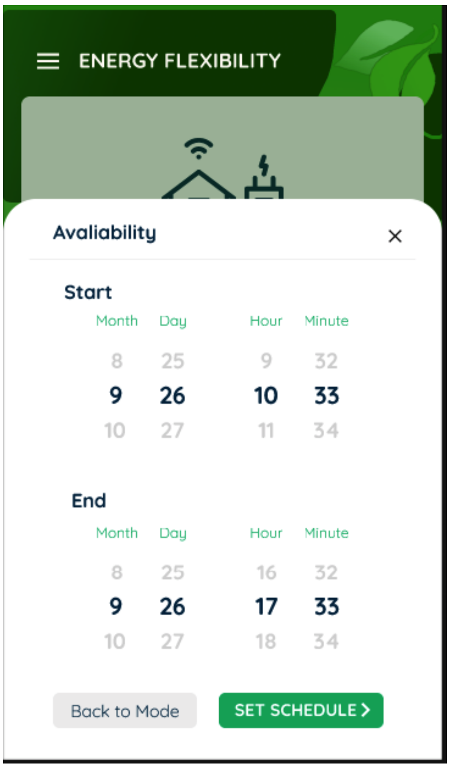
Flexibility Preferences	
Module Mock-up	**Short Description**
 	*Through two shared modules, users will be able to participate in the flexibility program according to their own preferences through the flexible loads defined in their residences. For example, users will be able to determine the temperature set values and time intervals in which they can include their heaters without disturbing their comfort zone.* **Benefit** *Modules offer users an interaction and governance interface for users to participate in the flexibility program.* **Data Requirements** *It is necessary to make preferences entries specific to the device. In addition, it is essential to identify devices and pair them with users.* **Data Calculation & Algorithm Requirement** *No data calculation required*

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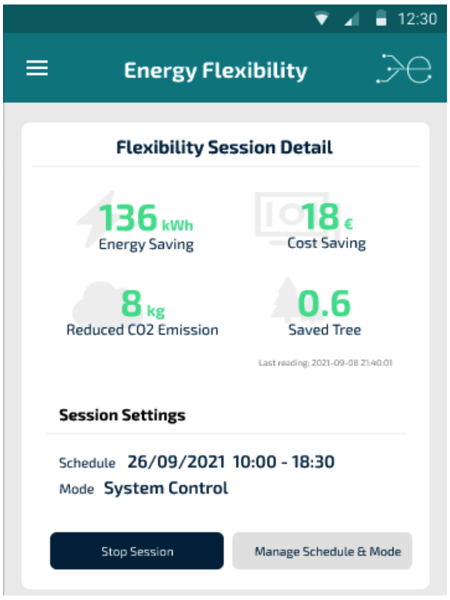
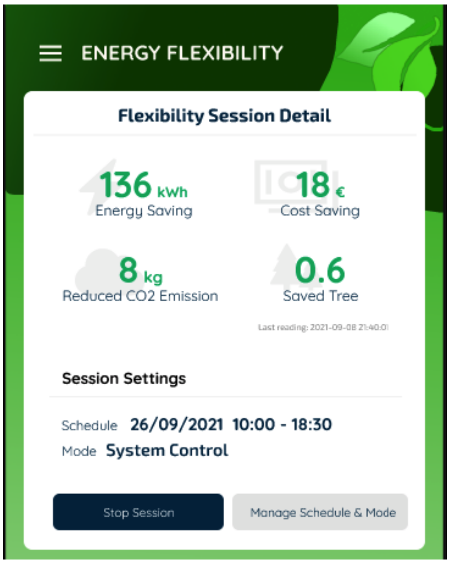
Table 18 Flexibility Session Details Module Design

Module Mock-up	Short Description





With this module, the predicted gains and effects of the participants who started the flexibility program at the end of the session are presented as a summary. Users may stop the session starting from this screen or set new preferences.

Benefit

With the summary screen, they will motivate users by sharing the impact and achievements they have created thanks to the program they have voluntarily participated in.

Data Requirements

Consumption history, actual consumption and current flexibility reserve are needed to calculate the summary.

Data Calculation & Algorithm Requirement

i. *Total energy saving should be calculated. For this, baseline of energy consumption should be provided by forecasting them or alternatively calculated with historical consumption. This is the essential data coming from forecasting algorithms*

ii. *Total cost saving should be calculated as :*
Total Energy Saving = ΣEnergyTariff(t)[Baseline Energy Cons(t) - Actual Energy Cons.(t)]*

iii. *Reduced Carbon Emissions should be calculated as:*
Σ[Baseline Energy Cons(t) - Actual Energy(t)]

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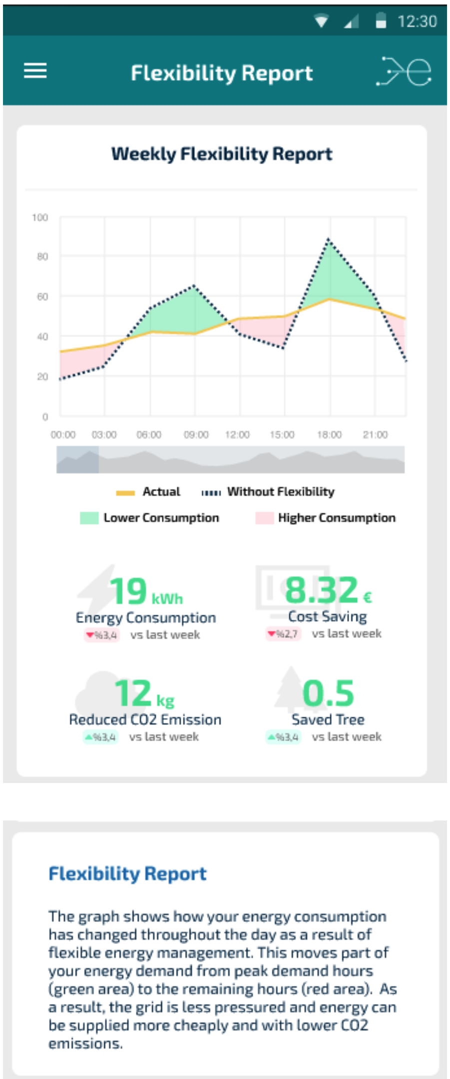
Table 19 Weekly Flexibility Report Module Design

Weekly Flexibility Report	
Module Mock-up	**Short Description**
	*In this report presented to the users, the effect of the flexibility reserve is calculated by comparing the average of the weekly load trends and the load trend of the past consumption. Additionally, an informative content has been also created.*
	Benefit
	Users will be able to monitor the effect they have achieved in individual electricity demand management thanks to the module.
	Data Requirements
	Consumption history, actual consumption and current flexibility reserve are needed to calculate the summary.
	Data Calculation & Algorithm Requirement
	i. Total energy saving should be calculated. For this, baseline of energy consumption should be provided by forecasting them or alternatively calculated with historical consumption. This is the essential data coming from forecasting algorithms *ii. Total cost saving should be calculated as :* *Total Energy Saving = ΣEnergyTariff(t)*[Baseline Energy Cons(t) - Actual Energy Cons.(t)* *iii. Reduced Carbon Emissions should be calculated as:* *Σ[Baseline Energy Cons(t) - Actual Energy(t)]*

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2.5 Electric Vehicle Charging & V2G

Electric vehicles are regarded as one of the advanced flexible load according to its power density and availability. The instantaneous power demand of an electric vehicle can be as much as the total power demand of an apartment. For distribution system designed for standard household loads, this seems to cause overload. From the perspective of the distribution network, increased EV use will trigger problems such as voltage imbalance, overloading of transformers, bottlenecks or inefficiencies in the system. To overcome these issues, coordinated charging methodologies have been developed.

Within the scope of the project, smart charging solutions are being developed and the mobile application is positioned as a part of the solution that offers an interface to the end user. The developed smart charging mobile application design is a structure that feeds the charging management algorithms with user inputs, as well as providing a monitoring interface for the smart charging use case of the project. The application designed in this way has a structure that covers the project needs. Through the mobile application, users can manage and monitor the charging process according to their needs and thus participate in smart charging and flexibility applications. The mobile application offers end users a simple, understandable and encouraging user flow for smart charging. In Figure 4, the user flow of the smart charging application is shared from the perspective of the users.

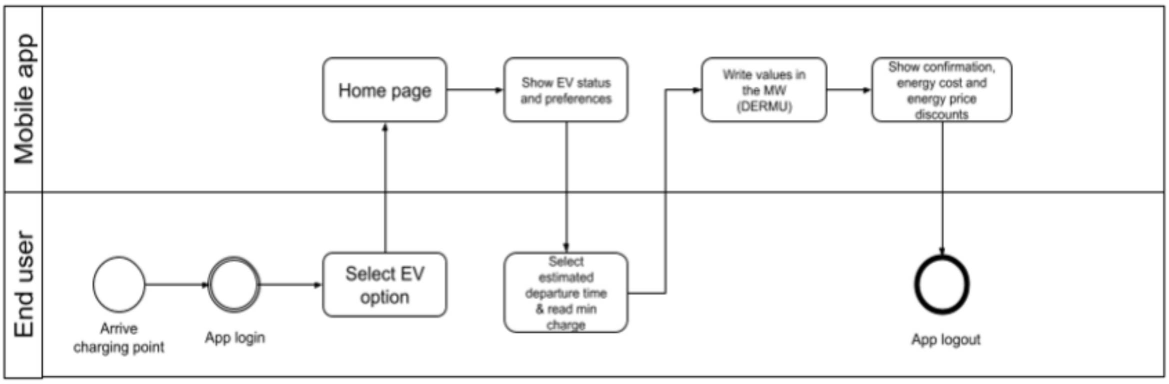

Figure 4 EV Charging User Flow for User Perspective

Via the mobile application, users can determine the energy their vehicles need, set their departure time, and choose between 3 different charging modes, the details of which are given below.

1. Continuous Charging

In this approach, electric vehicles have freely operated within their charging schedules without restrictions or incentives. EVs are regarded as normal loads, like any other appliance. The charging process automatically starts by the time EVs plug-in and finish their charging when the battery has 100 % State of Charge (SOC) or plugging out.

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There is no control, no interruption, or no power regulation in this model. Consequently, it is the most problematic model and not preferable since it has disruptive effects on the distribution network. Although it is offered as an option in the mobile app, it is excluded from the charging modes that are actually encouraged to users because this charging mode does not provide any flexibility of demand and thus results in a peak-generating and generally high carbon-intensity charging process. This type of charging, which is called Uncoordinated Charging or Dump Charging in the literature, is called **"Continuous Charging"** for users in the mobile application. In addition, there is the following explanation for the recognition by users;

"Charging starts immediately after connection and is not interrupted regardless of the electricity network condition. We recommend using it only when you are in a hurry."

2. Smart Charging

Smart Charging is a sophisticated control model based on hieratical coordination between Distribution System Operators (DSOs) and EVSE. In this model, the charging process is operated depending on the price, command, or demand signals coming from the system operator. Thanks to data-driven control architecture, coordinated charging has proven to be very efficient in reducing the loss of energy and, subsequently, the CO2 emissions inherent in the power generation industry, as it prevents high peak loads from occurring. In conclusion, Smart EV charging might be a solution for several targets such as increasing amounts of renewable energy resources, increasing utilization of the existing network infrastructure, and also challenges such as operating cost of EVs, and power network requirements.

Within the scope of the project, a Vehicle-to-Grid usage scenario (explained in detail in D3.6 and D6.1) will be realized with bidirectional charging stations to be located at different project pilots. Two smart charging modes were included in the mobile application, depending on whether the smart charging operation is unidirectional or bidirectional.

2.1. Unidirectional Optimized Charging (V1G)

In the smart V1G charging algorithms, Electric vehicle charging processes are shifted to the most available time periods according to the load trend of the Distribution system. This charging mode is called **"Unidirectional Optimized Charging (V1G)"** for users in the mobile application. In addition, there is the following explanation for the recognition by users.

"Regular charging mode, with an average intensity of current. Average cost and charging time."

2.2. Bidirectional Responsible Charging (V2G)

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Studies on electric vehicle usage behavior show that private vehicles are parked most of the time and they do not have any function in this process. It is possible that EV battery systems are used for not only powering the vehicle; they can also be used for powering the grid or a building. With this feature, it is possible to use EVs in grid operations just like grid-scale energy storage systems. Bidirectional EV Charging has huge potential to solve many problems such as power quality, management of imbalances, demand management.

In the project, the Vehicle-to-Grid usage scenario will be tested at different pilot sites with the use of bidirectional electric charging stations, the details of which are given in D3.6. As a part of the solution, the mobile application is also offered to users as an access interface. In addition, the data to be obtained through the mobile application feeds the V2G charge management algorithm. This charging mode is called **“Bidirectional Responsible Charging (V2G)”** for users in the mobile application. In addition, there is the following explanation for the recognition by users;

“The lowest charging cost and CO2 emissions, but with a longer charging time. During high grid loads, energy can be pulled from your car.”

Detailed explanations of smart charging mobile application modules are shared in the continuation of the section.

Table 20 Charging Session Starter Module Design

Charging Session Starter	
Module Mock-up	**Short Description**
	This is the initial screen for smart charging product. Vehicle plug-in status is presented in this screen. According to the plug-in status; - If EV is not connected user is informed and charging session cannot be started - If EV is plug-in, user may reach charging settings by clicking “Start Charging”
	Benefit
	Users are informed about their plug-in status and guided
	Data Requirements
	EV Plug-in Status should be requested from charging station

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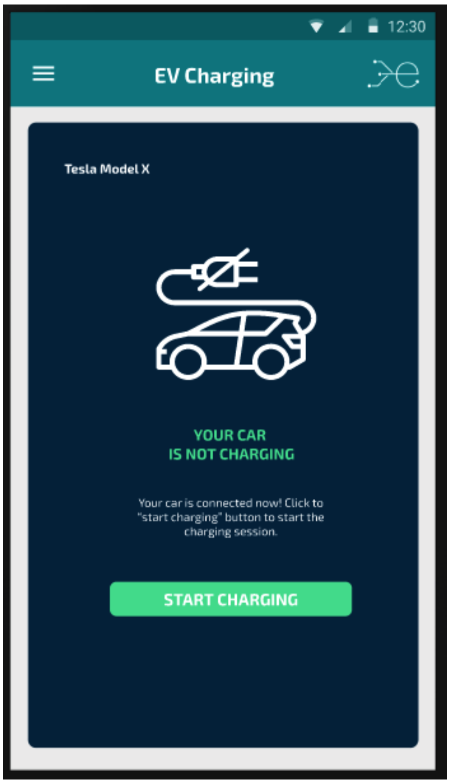
<table>
<tr>
<td rowspan="3">
</td>
<td>Platform should provide plug-in data when mobile app request

During charging session (from this screen to end of the charging process) mobile app requests plug-in status continuously (every few seconds probably)</td>
</tr>
<tr>
<td>Data Calculation & Algorithm Requirement</td>
</tr>
<tr>
<td>Based on raw Plug-in data</td>
</tr>
</table>

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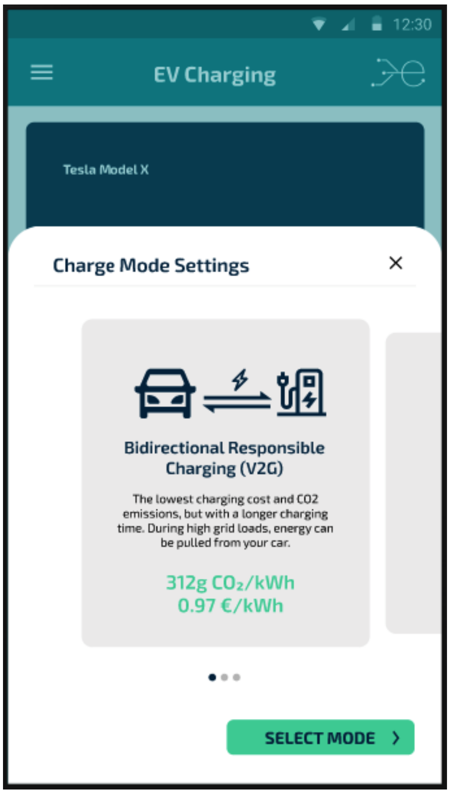
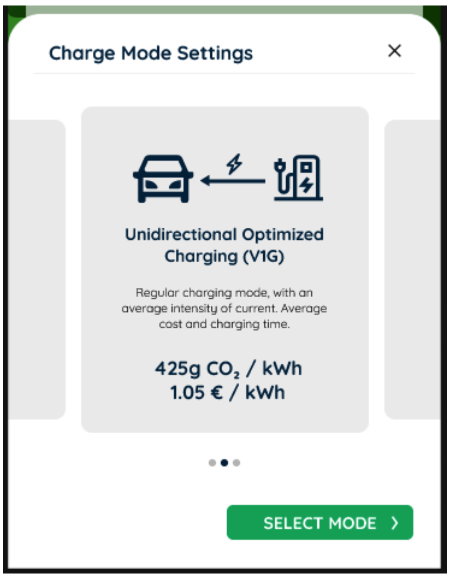
Table 21 Charging Mode Selection Module Design

<table>
<tr><th colspan="2">Charging Mode Selection</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="7">


</td>
<td>On the second screen, the user chooses between 3 different charging methods. These methods;

• Dump Charging not providing any EV Charging Load Scheduling

• V1G with one-way charging and EV Charging Load Schedule

• V2G with Bidirectional charging and EV Charging Load Schedule

It is aimed to give users the average carbon emissions and cost for each method. According to this info, users select a charging option and continue charging session settings.</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>The purpose here is to convince users to prefer smart V2G and V1G charging by presenting estimated cost and carbon consequences for a charging session.</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>Historical charging session data including;
- Charging time (MM/DD/HH included) (historical)
- Charging mode (historical)
- charging session cost (historical)
- Session total carbon emission (historical)
- Received and transferred (for V2G) energy (historical)</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
<tr><td>Average cost and emission per kWh should be calculated for each charging mode. These values can alternatively be given as percentages (such as V2G has %20 less carbon emission). Since charging session settings (energy needed and departure time) are in next step, average cost and emissions can be calculated with historical data</td></tr>
</table>

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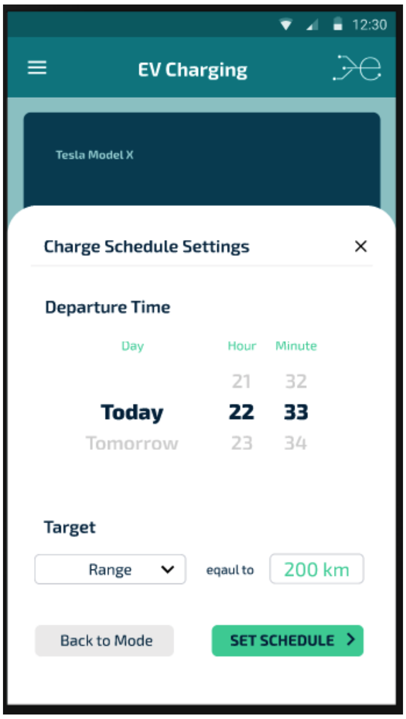
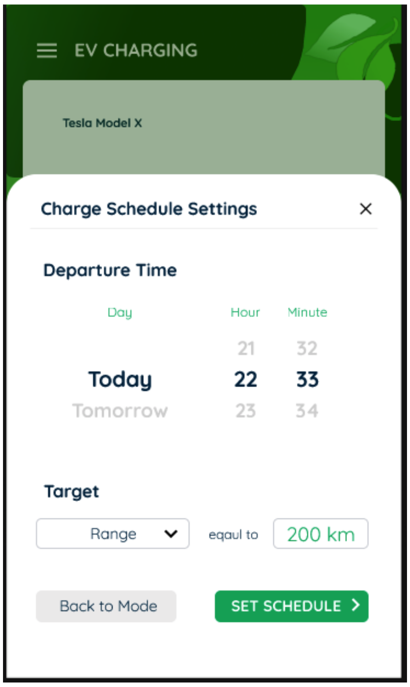
Table 22 Charging Session Preferences Module Design

<table>
<tr><th colspan="2">Charging Session Preferences</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="7">


</td>
<td>According to the selected charging option, in the next step, charging need and departure time data are obtained from the users for the charging process.

- If the user has selected dump charging, the departure time is not requested. It is required for V1G and V2G options. Departure time may be present day or next day.

- Second input is target charging. User may enter his/her charging need as kWh, target range (km, may be converted into kWh with driving cycle or it can be removed if it is not feasible), or battery level as percentage (generally used)

- After adjusting these two parameters, user clicks “Set Schedule” and complete scheduling. If she wants to change charging mode she reselect it wih “back to mode option”

- Both parameters are transmitted into platform and will be used for smart charging scheduling algorithm.</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>These two parameters are essential for smart charging algorithm. Users may schedule their sessions easily with this interface</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>- Vehicle departure time with certain date (desired format)

- Target charging energy amount is sent to the platform

- Average energy needed per 100 km</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
<tr><td>- Departure time and target energy are two raw data and are directly sent to the platform

- According to algorithm developers preference, target energy may be given as SOC percent (usually preferred) or target range. These two inputs should be transformed into energy (kWh)</td></tr>
</table>

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Table 23 Charging Session Summary Module Design

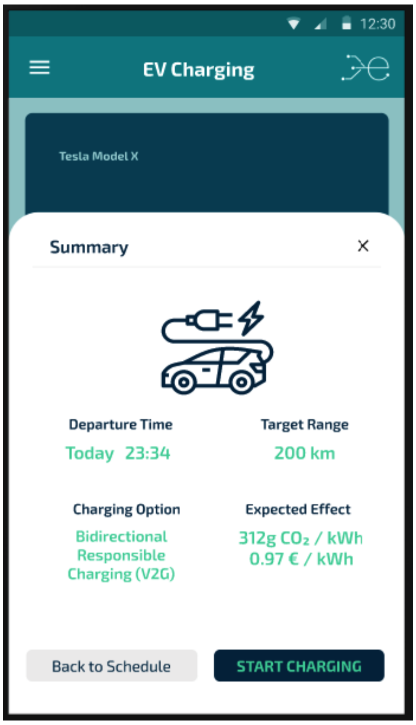
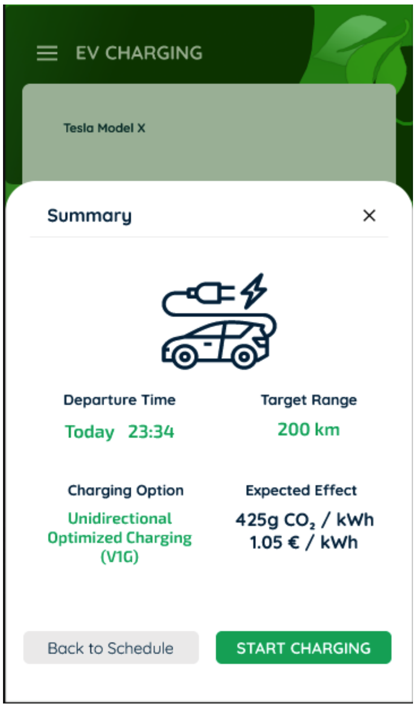
Charging Session Summary	
Module Mock-up	**Short Description**
 	*In the final screen, the user may find the estimated summary of the charging process according to the selected charging parameters. User may start charging session with "Smart Charging" button.*
	Benefit
	This is the last screen before starting charging session and inform users about session summary with estimated parameters.
	Data Requirements
	Selected charging mode (in mobile app) *Selected departure time (in mobile app)* *Selected target energy (according to selected parameter) (in mobile app)* *Expected carbon emission (from algorithm, requested from Platform)* *Expected cost (from algorithm, requested from platform)*
	Data Calculation & Algorithm Requirement
	Estimated cost and carbon emissions should be calculated with scheduled charging session load trend, estimated carbon intensity trend, adjusted dynamic tariff. *For instance; Cost of session = Σ(Charging Load(t)*Tariff(t)). from beginning to end of the charging session* *Energy tariff (€/kWh) and estimated carbon intensity (CO2/kWh) should be provided at least departure time*

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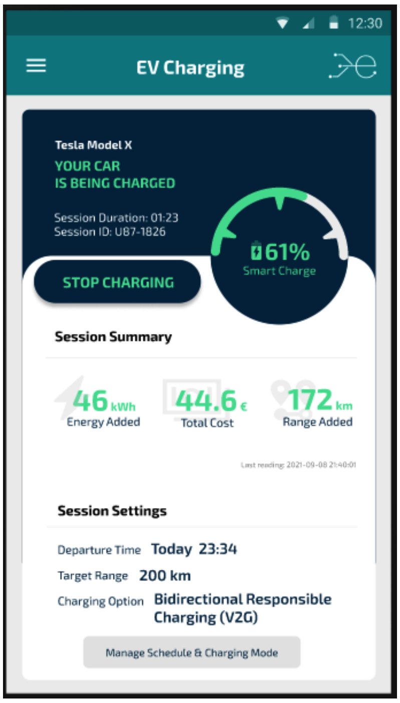
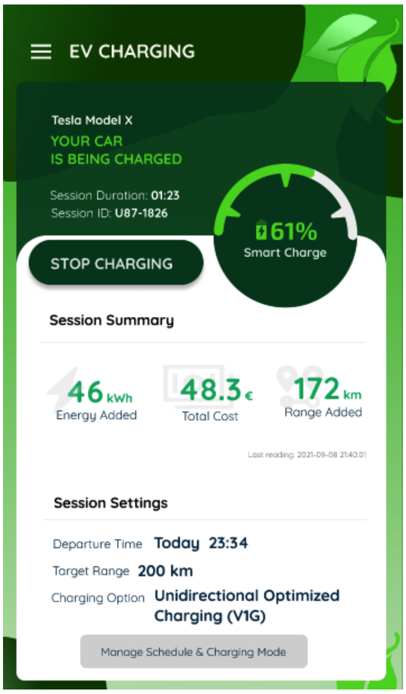
Table 24 Charging Session Tracking Module Design

<table>
<tr><th colspan="2">Charging Session Tracking Module</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="8">


</td>
<td>The screen presenting the charging process will appear after starting charging session. In this panel battery SOC, charging mode, received energy and range and total cost of charging should be presented.

User may track the session or readjust it with “Manage Schedule Charging Mode”. With this button users turn back to the “CHARGE MODE SETTING - SCREEN II”</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>This module presents the actual status of the charging session and gives changes to readjust or stop charging process to the users.</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>-State of Charge of the EV (Actual) (Platform requests this data from station)

- Session duration according to user departure time selection

- Target Charge, Range or SOC according to user selection

- Received Energy during charging (Cumulative, it can be zero within V2G) (from platform)

- Total cost of charging session (Cumulative) (from platform)</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
<tr><td>Total (cumulative) cost of the session (from beginning to actual)(can be negative in V2G)

- Total emission of session (cumulative) (from beginning to actual)

- Total energy received (cumulative) (from beginning to actual)

- Added range (can be calculated with driving cycle of avg passenger car)</td></tr>
</table>

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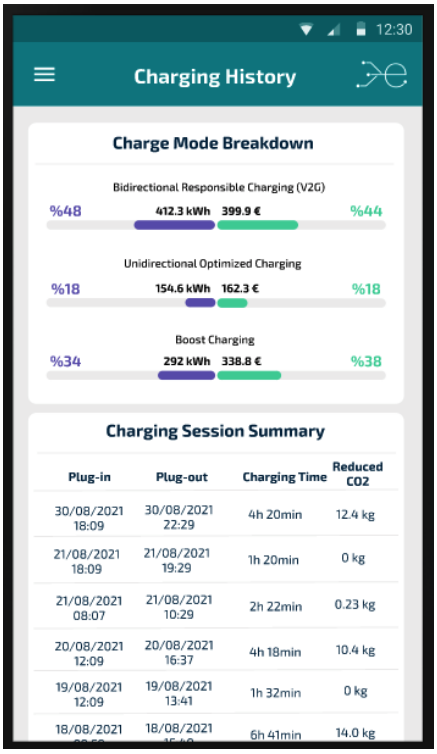
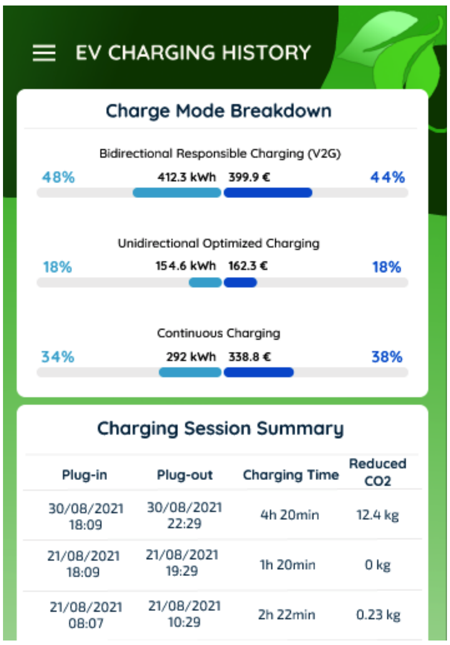
Table 25 Charging History Module Design

<table>
<tr><th colspan="2">Charging History</th></tr>
<tr><th rowspan="8">Module Mock-up





</th><th>Short Description</th></tr>
<tr><td>This module presents charging mode breakdowns from cumulative charging history. Includes distribution of charging modes (boost, V1G, V2G) according to cumulative energy used and cost. Also there is a table in below presents charging history of user by giving them summary info for each session</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>Users may monitor their charging actions and results with this module, track their charging spends and make relations between charging modes and savings.</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>Charging processes should be stored in the database in a special way for each user, and users should be able to follow their own charging history with parameters such as logs, charging time, reduced CO2, cost in desired period (monthly, yearly).

Required Datas:

Plug-in and Plug-out times with certain date (DD/MM/YY HH/MM)

Total charging time

Reduced CO2 Emission (optional)

Reduced Cost (optional)</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
<tr><td></td></tr>
</table>

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	Total Charging time should be calculated with (Plug-out – Plug-in) *Some parameters related to smart charging impact is desired to presented for each charging session. In order to do this:* *Total cost savings or emission should be calculated for each charging session and stored in the platform in suitable structure. It can be cumulative variant maybe like energy consumption indexes* *Saving or emission reduction for each closed session can be calculated as :* *Dump Charging Cost or CO2 (as a baseline) - Realized with Smart Charging)* *Cumulative received energy in respect to charging mode (monthly or yearly sum)* *Cumulative cost of charging in respect to charging mode (monthly or yearly sum)*

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Table 26 Charging Summary Report Module Design

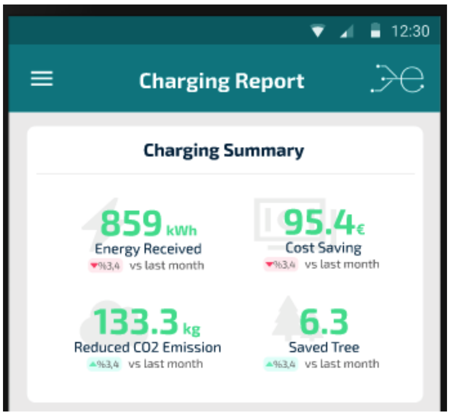
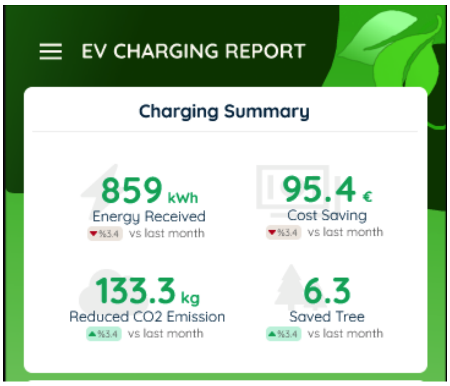
<table>
<tr><th colspan="2">Charging Summary Report</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="7">
</td><td>This module present users result of their overall charging actions in a nutshell. User may reach;
- total charging amount,
- total saving with using smart charging
- Total reduced CO2 emission
- Saved tree according to CO2 reductionin this screen.
Users may reach monthly and total cumulative values of smart charging.</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>This is a module that gives a summary of all the impacts of the smart charging process. Users may understand the impact of the smart charging in economic and sustainability aspects.</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>Charging processes should be stored in the database in a special way for each user, and users should be able to follow their own charging history with parameters such as logs, charging time, reduced CO2, cost in desired period (weekly, monthly, yearly). Required data:
- Total supplied energy (weekly, monthly, yearly)
- Total cost saving with smart charging
- Reduced CO2 (weekly, monthly, yearly)</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
<tr><td>Total yearly and monthly received energy should be able to be requested from the platform
Total cost savings or emission should be calculated for each charging session and stored in the platform in suitable structure. It can be cumulative variant maybe like energy consumption indexes</td></tr>
</table>

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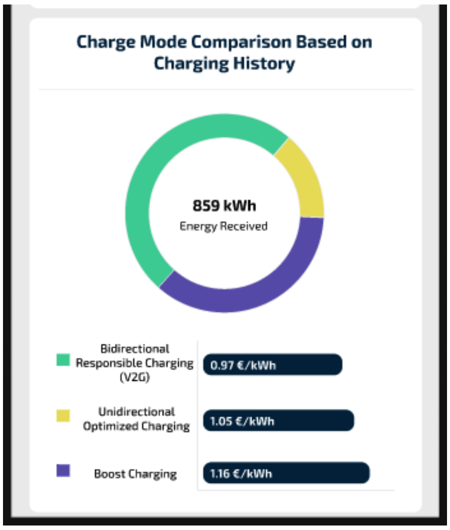
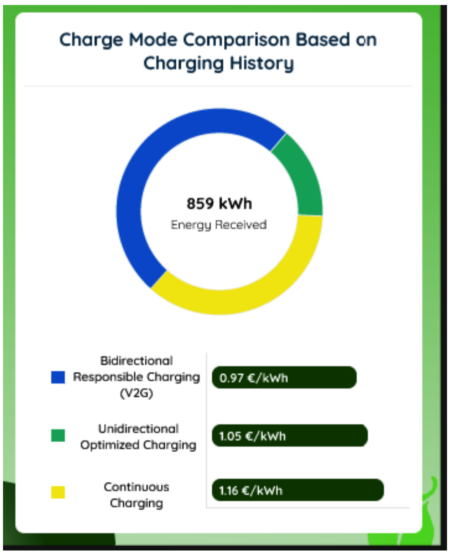
Table 27 Charging History Facts Module Design

<table>
<tr><th colspan="2">Charging History Facts</th></tr>
<tr><th>Module Mock-up</th><th>Short Description</th></tr>
<tr><td rowspan="7">


</td>
<td>This module presents charging mode breakdowns from cumulative charging history.

Includes distribution of charging modes (boost, V1G, V2G) according to cumulative energy used and related emission

Average cost of electricity is listed according to the charging modes

Average CO2 emission is also listed according to the charging modes with same graph</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>This is a useful module for presenting users how cost effective and sustainable is smart charging</td></tr>
<tr><th>Data Requirements</th></tr>
<tr><td>Charging processes should be stored in the database in a special way for each user, and users should be able to follow their own charging history with parameters such as logs, charging time, reduced CO2, cost in desired period (weekly, monthly, yearly).</td></tr>
<tr><th>Data Calculation & Algorithm Requirement</th></tr>
<tr><td>Total yearly and monthly received energy should be able to requested from the platform

Total cost savings or emission should be calculated for each charging session and stored in the platform in suitable structure.

Average cost of energy and emission should be calculated based on charging history of related user. For instance, average cost of V1G should be calculated as

Avg Cost of V1G = [Total Monthly Cost during V1G] / [Total Received Energy during V1G]</td></tr>
</table>

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3 Conclusion

This report includes the description of work for the study and development of systems for turning existing buildings and systems into smart and controllable infrastructures, for deployment of a user-centric and flexibility-focused energy balancing platform. In order to accomplish the objective, requirements are well studied, and design has been conducted considering feasibility analyses with infrastructure investment costs and user preferences. For such specifics, related demo site studies from WP6, user characteristics analyses from WP2, and requirements from WP1 are well considered.

The designed mobile app, connected with innovative IoT systems, algorithms, and models, will be implemented, and tested for a comprehensive and integrated energy-balancing solution. Further studies will be conducted in the following project period under the linked work packages for integration and implementation, therefore the IoT systems management of buildings and the ebalanceplus user mobile app for buildings and EV charging are included for a developed energy-balancing approach with user preferences and engagement.

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