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D3.6 Final ChArGED gamified system

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Table of Contents

Table of Contents

Abbreviations *6*

Executive Summary *7*

1 Introduction *8*

2 Summary of the feedback received from D4.3 ..... *10*

3 Overview of the ChArGED concepts, use cases and game challenges *32*

ChArGED approach **32**

The game concept **33**

Types of challenges **34**

4 Final system architecture and system components *37*

Integrated system architecture **37**

4.1.1 Data/Core Backend System 38
4.1.2 Gateway 41
4.1.3 Analytics Backend 43
4.1.4 Gamification Group 45
4.1.5 User authentication 47
4.1.6 Component for microgeneration Energy Forecasting 56

5 Integrated (End-to-end) description of Challenges *59*

5.1 Switch off your pc before leaving for home **59**

5.2 Switch off pc if leaving your desk for more than 30min **62**

5.3 User is directed to use the stairs **63**

5.4 Close the windows if the A/C is on (Team) **64**

5.5 Switch off the A/C and lights after hours (Team Challenge) **67**

5.6 MNHA Specific Challenges **68**

5.7 Solar Challenges - DAEM **73**

6 Conclusions *78*

7 References *79*

8 Annex Deployment plan *80*

List of Tables

TABLE 1: D3.4 DEPENDENCIES AND HANDOVERS 8

List of Figures

FIGURE 1 CHARGED APPROACH 32
FIGURE 2 CHARGED UI INCLUDING THE TREE "PERSONA" 33
FIGURE 3 CHARGED UI INCLUDING THE LIST OF CHALLENGES 36
FIGURE 4 CHARGED SYSTEM ARCHITECTURE 37
FIGURE 5 ORGANISATION OF SITEWHERE SYSTEM COMPONENTS IN CHARGED 39
FIGURE 6 CAPABILITIES PROVIDED BY CHARGED BACK-END 40
FIGURE 7 ASSET MANAGEMENT IN THE CHARGED BACK-END 41
FIGURE 8 ILLUSTRATION OF THE SENSOR GATEWAY AND INTERCONNECTED DEVICES AND MODULES 42
FIGURE 9 TYPICAL IOT ARCHITECTURE WITH MBS AND MPRM 42
FIGURE 10 WATTICS CLOUD BACKEND SYSTEM ARCHITECTURE 43
FIGURE 11 INTERMEDIATE STEPS FOR ENERGY MONITORING AND PERFORMING ANALYTICS 44
FIGURE 12 ARCHITECTURE OF THE ANALYTICS ENGINE IN CHARGE OF VALIDATING USER CONTROL ACTIONS AND ESTIMATING ENERGY SAVING GENERATED 45
FIGURE 13 GAME BACKEND INTERNAL ARCHITECTURE 45
FIGURE 14 SCREENSHOTS OF THE MOBILE APP 46
FIGURE 15 LOGIN SCREEN 47
FIGURE 16 HOME SCREEN (SMALL TREE) 48
FIGURE 17 HOME SCREEN (FULLY GROWN TREE) 48
FIGURE 18 ACCEPTING A NEW CHALLENGE 49
FIGURE 19 CHALLENGES OVERVIEW 49
FIGURE 20 INDIVIDUALS LEADERBOARD, BODGES AND TEAMS LEADERBOARD 50
FIGURE 21 OVERVIEW OF ACHIEVEMENTS 50
FIGURE 22: ENERGY SAVINGS VISUALISATION TO THE USER 51
FIGURE 23: GAME FEEDBACK 52
FIGURE 24: GAME LOG/HISTORY 53
FIGURE 25: OVERVIEW OF SITEWHERE ALERTS 53
FIGURE 26 NFC SWIPED MESSAGE 54

FIGURE 27 BLE MESSAGES SENT BY THE USER'S SMARTPHONE INSIDE SITEWHERE 55
FIGURE 28 TIPS APPEARING IN THE GAME 55
FIGURE 29 SOLAR PV PREDICTION ARCHITECTURE 56
FIGURE 30: PHOTOVOLTAIC GEOGRAPHICAL INFORMATION SYSTEM 57
FIGURE 31 WEATHER FORECAST INPUTS TO THE MODULE 58
FIGURE 32 SOLAR PV PREDICTION RESULTS 58
FIGURE 33 USER SELECTS A CHALLENGE 59
FIGURE 34 USER SWIPES NFC TAG 60
FIGURE 35 USER MODEL INSIDE SITEWHERE 60
FIGURE 36: NFC SWIPE EVENT IN SITEWHERE 61
FIGURE 37: PC ELECTRIC CONSUMPTION 62
FIGURE 38: MESSAGES EXCHANGED BY THE SYSTEM COMPONENTS 62
FIGURE 39: USER LEAVING AND RETURNING TO HIS DESK HAS BEEN IDENTIFIED 63
FIGURE 40 USER ACCEPTS THE CHALLENGE 64
FIGURE 41 SENSOR DEVICE IN SITEWHERE 65
FIGURE 42: SENSOR AND GAME BACKEND ALERTS 65
FIGURE 43: ENERGY ANALYTICS ALERTS 66
FIGURE 44: A/C ELECTRICITY CONSUMPTION MEASUREMENTS 66
FIGURE 45: A/C ELECTRICITY CONSUMPTION MEASUREMENTS 67
FIGURE 46: BADGES AND PROGRESS OVERVIEW 68
FIGURE 47: END-TO-END PROCESS OF THE VISITORS' CHALLENGE 69
FIGURE 48: VISITORS CHALLENGE APP 70
FIGURE 49: VISITORS CHALLENGE APP TREE GROWING 70
FIGURE 50: END-TO-END PROCESS OF THE GUARDS' CHALLENGE 72
FIGURE 51: REAL TIME DATA GATHERING FOR WEATHER FORECAST 73
FIGURE 52: ACTUAL ENERGY PRODUCTION FROM SOLAR PANEL 74
FIGURE 53: SOLAR ICON STATES 75
FIGURE 54: SOLAR PANEL INFORMATION 76
FIGURE 55 USERS RECEIVING REWARDS AT INDIVIDUAL AND TEAM LEVEL 77

Abbreviations

API	Application Programming Interface
BLE	Bluetooth Low Energy
IoT	Internet of Things
JSON	JavaScript Object Notation
kWh	Kilowatt hours
MVP	Minimum Viable Product
mPRM	mPower Remote Manager
MQTT	MQ Telemetry Transport
NFC	Near Field Communication
SSL	Secure Sockets Layer
SQS	Simple Queue Service
TCP	Transport Communication Protocol
TLS	Transport Layer Security
REST	Representational state transfer
UI	User Interface

Executive Summary

This deliverable presents the final integrated system of ChArGED that has been developed following the feedback collected during the real life evaluation at the three pilot sites.

Technical testing/validation mechanisms take place prior to providing the solutions to end-users for validation, to make sure that, as subsystem development is progressing, there are no unforeseen integration issues and technical problems.

The deliverable complements the work done in Deliverables 3.5: "Integrated Charged System for real life evaluation" that described the first version of the complete prototype that has undergone 1st and 2nd validation at all pilot sites. The feedback that has been collected has been reported in D4.3: "Intermediary end users feedback" and has been submitted in M29. The deployment instructions, which have been also delivered with the previous version of this document, have been updated as well and are attached to this document.

The application is downloadable from Google Play and also at the project website. A video also demonstrates the function of the game which is published on Youtube. The following links provide access to the app and the project video demonstrators:
https://play.google.com/store/apps/details?id=eu.charged_project.charged

App Video
https://www.youtube.com/watch?v=iHbthu0PBxY

App Video – MNHA Visitors Version
https://www.youtube.com/watch?v=hH02Bzyqa6E

1 Introduction

Purpose and scope

The goal of D3.6 is to provide a complete description of the final version of the Integrated Charged System and Mobile App based on the feedback from pilots and peer review that has taken place till the submission of this deliverable. It is to be noted that some further updates will take place, as further feedback will be collected during the large scale validation which started a bit late in the project. This will take place within the context of WP4, as this is considered support for the users' validation.

Intended Audience

The purpose of this deliverable is to document and demonstrate the final ChArGED integrated system.

The intended audience includes the project partners, especially the pilot users and the general interested public. Members of the development team can use this report as guideline for future work.

This report also provides clarity on the ChArGED integrated system that will be deployed at public buildings through various installation stages and also shows the working modules that can be used for hands-on system demonstration and evaluation by the intended public buildings.

Relation to other activities

The integration between the backend system, the gateways and the Mobile App will be still on-going process, following agile methodology approaches and enriching the challenges with new ones which will be implemented during the validation year.

Technical testing/validation mechanisms took place prior to providing the deliverables to end-users for validation, to make sure that there are no unforeseen integration issues and technical problems.

Table 1: D3.4 dependencies and handovers

D3.7	Incentive mechanisms final report	It provides the design principles to be integrated within the game mechanics component and affects the chosen game challenges.
D3.2	Architecture and system components specification	It describes the initial system architecture and design of system components and interfaces that will also be followed for the 1st integrated system.
D3.5	Integrated Charged System for real time validation	This document complements the real system that has been deployed initially at the pilot sites and presents the functionality of the entire system. A document complements this with the deployment guideline.
D4.2	Trials specifications	It provides the specifications of the system components that will be tested at various stage of the piloting exercise, affecting the choices for the 1st integrated system..

Document Overview

The deliverable is the demonstration of the final integrated version of ChArGED system which adopted the first feedback that has been collected by the pilot users and peer reviewers, and goes for real life validation with the end users. This document provides an accompanying description for this demonstrator and give an update on the evolution of the system components and the integration process for 5 complete game challenges. It is organised as follows:

Chapter 2 presents the review feedback we received by pilots and advisory board and gives our perspective of how we have dealt with this feedback in the final version of the system.

Chapter 3 presents an overview of the ChArGED approach, the game concepts, the related use cases and challenges that are implemented in the final version of the system.

Chapter 4 describes the updates on the system architecture and software implementation details for the Data/Core Backend components.

Chapter 5 provides the updates of the challenges and indicative screenshots of an end-end challenge implementation involving all integrated modules.

Finally, Chapter 6 concludes the document.

2 Summary of the feedback received from D4.3

Following the D4.3 the following feedback has been collected from pilot end users that included suggestions for the final version of the Charged system. This table shows an overall status of the implemented feedback in the final version. Note that some of the feedback has been already addressed in the previous version and this is not included here.

Feedback during validation	
Usability Issues	**D3.6**
D5: It may become boring to activate the same daily challenges each day. Some could be activated on a weekly basis. However we have to ensure that players login every day – daily logins should be rewarded. **D14:** A user belonging in a given division but located in another divisions' office should be able to participate in the shared devices upon which they act (e.g. his/her division printer but the other offices' air-conditioner). **D20:** In things that a user does as part of their routine (every day), maybe the relative challenges could be automatically accepted for N days (i.e. for the whole month).	D14 Done, D5/D20 The implementation of actually selecting a challenge is a way of engagement and continuously reminding of the tasks to do about EE.
I2: Some new features have been added to the app (energy savings, visual depiction of them, reasons of failure, messages history). **M1, M2:** The users want to be able to see the actual impact of the app on energy savings/consumption.	**I2,M1,M2:** Done
D1: Energy impact for each single actions? **D2:** I would like to see the energy saved through the game-the progress of the game.	**D1,D2:** Done
M3: Users want to include challenges for guards and lights.	**M3:** Done
D3: Wrong placement of NFCs, or are too small to use e.g. in the staircase scenario (elevator challenge). **I5,I6:** The energy impact both for a single user and for a team has been implemented and it is presented in the app.	**I5,I6:** Done **D3** Challenge has been tested and no issues have been reported
M6: Users want to compete against the other Charged sites and teams.	**M6:** Done
D6: What happens when someone doesn't have access to some of the challenges?	**D6:** Challenges visible to a user's smartphone can be changed dynamically

	depending on which challenges they have available.
D8: One of the users commented that the system should detect their actions instead of having to do NFC swipes all the time.	**D8:** Challenges redesigned, In the redevelopment of the challenges, a combination of system detection via BLEs and NFC swipes is established.
D11: The game should include visual feedback on actions (swipes) in the case that the conducted action is not enough to grow the tree (e.g. an on-screen effect).	**D11:** Added to the app (energy savings, visual depiction of them, reasons of failure, messages history)in D3.6.
D10: The BLE beacons have been configured properly.	**D10:** Changes in BLEs installation, fixed overlaps.
D17: The pilot site managers should have a mapping of allocated measuring devices (e.g. smartplug) relevant to the user utilizing it so as to be enabled to account for changes in user location [different desk] or changes in equipment [a monitor or PC is replaced / introduced]	**D17:** Shared documents have been created that keep track of the (anonymized) user details
D18: The pilot site managers should be given a step-by-step manual of how to introduce the end users in the ChArGED project, including guidelines (technical and soft) on the NFC sticker placement, respecting the NFC technical limitations as well as the users' preferences for preferred placement for optimal use.	**D18:** to be updated in the manual of D3.6 and below in the relevant demonstration part of this deliverable.
D19: Some important tasks cannot be shifted in time (with the forecast mechanism).	**D19:** This is known, so the project proposed some alternative tasks to consume the available energy from sun.

Direct feedback from users	
Usability Issue	D3.6
Challenges goal not clear, User confusion.	The app has been extended with more clear descriptions of the challenges and the steps that the users need to do in order to complete the challenge.
Badges (which are awarded when someone wins a	A new screen in the mobile app was added that contains all the badges in groups so the users can have a complete overview of the badges won/currently available.

challenge) should be more visible/better categorized.	
Users requested more feedback about the reasons a challenge they played has failed.	Messages have been added to the mobile app generated by the server to give users the reason the challenge have failed (For example pc not closed, played the same challenge too soon etc.)

Direct feedback from users	
Game Design Issues	D3.6
Users do not like their progress to be visible to all the people participating in the game.	The leaderboards which contain the users' progress relative to the other players were modified to only allow the members of the same team to see the progress of a user. The other participants can only see the team's progress but not the individual members separately.
Users have requested more tree images/tree changes when they complete a challenge.	In addition to the tree's different stages of growth birds were added that appear on the tree whenever a user completed a challenge. This provides an additional visual reward for the players.
Show in addition to the total score, the energy savings that the users have achieved by playing the game.	A new screen added showing the energy that the users have saved by playing the game.
Some challenges were found too confusing by the users and hard to follow.	Problematic challenges have been redesigned and more detailed information have been added in each challenge's description.
Direct feedback from users	
Performance Issues	D3.6
During the testing of the game in different devices some older devices may have a laggy behavior due to low processing power.	General modifications and improvements were added in order to handle situations where users use an older device. These modifications include partial user interface redesign and helpful popup messages that warn the user about potential performance reduction while playing the game. On low end or very old devices specific messages have been added to inform the user that they may experience some performance loss and also some functionality can automatically be disabled.
Slow internet connection which results in latencies that cause	Improvements added to the system in order to be able to adapt to the network's speed to provide faster results

energy measurements to take too long to arrive at the server or game results to arrive to the mobile app.	when possible as well as ensure there will be no data lost in case of no internet connection.

Feedback from Advisory Board		
Reviewer:	Paul Tighe, CEng MCIBSE, MIEI, Dublin	
Report Identifier:	D2.1	
Comments and recommendations		**CHARGED actions taken**
RE: 2.2.3	*"**employees do not own the machines and do not pay the bills of the buildings, having therefore little incentive in optimising electricity spending**"* I strongly agree with this opinion and it is borne out in my experiences with the Optimising Power @ Work programme. In attempting to address this we often advise participants that they are in fact the bill payer because they are tax payers and are employed in the Public Service and funded by taxes. We also offer assistance and advice to participants about saving energy in the home. This element is very popular at energy awareness open day events etc.	*Positive comment* *No action taken*
RE: 2.2.3	***"The potential of energy efficiency through proper users' behaviour in workplaces could be as important as the potential of technology. An approach integrating the two would have the largest impact. ChArGED can play a key role in this integration".*** ***"There is a lack of interaction between building energy management systems and end building users"*** I strongly agree with the above extracts from this section. It is my experience that engagement is increased by informing employees regularly about recorded consumption data and in particular timely feedback about any positive outcomes measured from their energy saving efforts. The ability to "individualise" consumption through a gamified App has good potential for increased engagement.	*Positive comment* *No action taken*

RE:2.3.1.1.1 Power meters	I concur that the use of split core devices or Rogowski coils are the most unintrusive method of retrofitting energy logging systems and I specify these devices exclusively for retrofit projects. In terms of safety I prefer to use the mV option for CTs which effectively mitigates open circuit risk and reduces ongoing maintenance requirements. In terms of accuracy in recording small variances in load Rowgowski coils may be a good installation option for ChArGED however carful positioning is required in order to centre the conductor within the coil. In smaller downstream distribution boards adequate space to meet this requirement may be an issue on sub circuits. The use of Modbus to record different sub circuit parameters in order to obtain unique consumption signatures for given loads has a distinct advantage over taking pulse outputs (kWh only).	*Positive comment* *No action taken*
RE 2.3.3.3	***"Many reasons explain the lack of adoption……Yet, the primary reason is that today, one needs to be an expert with plenty of time to decipher complex energy data, and it is agreed that no one can continuously check dashboards, smart phone apps, monitors and displays to detect and fix irregularities as they occur"*** I strongly concur with the above extract. It has been my experience that building managers aspirations are to have as much data as possible recorded but in reality they do not ultimately have the time to analyze it and the more that is recorded the more complex and time consuming the analytics become. I believe that in this area the ChArGED gamified App has the potential to be an excellent asset to complete complex consumption analytics behind the scenes and to present disaggregated data to the end users in meaningful and insightful forms.	*Positive comment* *No action taken*
RE 2.5 Serious Game for Energy Efficency	I note that a serious game for energy conservation for students in a Hawaiian University used a reward system for participation in educational content and workshops. Participation in the game was an extracurricular activity and the training was designed to be "time persistent" in order to have a long term impact. This appears to support my previous comments in D3.2 regarding educational content for ChArGED.	*Positive comment* *No action taken*

RE 2.9 Educational mini games and mobile Apps	Section 2.9 of the document lists a range of free and paid Apps for use domestically in pursuit of energy savings and education. I recommend that these links are included in the education repository of ChArGED. This is a good way to heighten awareness and offer advice to employees about saving energy in the home. This can lead to personal monitory reward for personal effort. In this way ChArGED may leverage the "Bill Payer" motivation of employees and perhaps effect behavioral change in the home which in all likelihood will transfer to the workplace.	The links have been included in the project website, but not in the app.
RE Results DAEM Pilot site -3.4.2.2 Energy conservation behavior at workplace	***"Overall, we may conclude that more than 2/3 of DAEM participants exhibit positive environmental awareness and environmental worldviews. Out of the remaining 1/3, half are neutral towards the subject, whilst the other half, a relatively small minority to the total, are negative towards environmental awareness."*** From this information one can deduce that 33% of the respondents may benefit from environmental educational content and of these half are neutral and so may respond positively in terms of enhanced awareness (behavioral change).	*Positive comment* *No action taken*
	Locus of Control ***Questionnaire item: "I would change my energy-consumption behaviour at work, if others do so." The employees are divided between 47.5% that seem to agree, whilst 15% remain neutral and 37.5% that disagree in various degrees.*** ***We observe a general consensus that saving energy is a collective effort, whilst there is no strong general trend as to whether changing energy-consumption at work is something that depends on the peers' relative behavior (the employees are equally divided on this subject).*** This finding could be relevant whilst assessing the potential positive effects of peer pressure in the gamified App. From the other pilot results this trend appears to be consistent.	*This finding was interpreted as a differential effect of peer pressure among employees. Therefore, some employees are expected to be greatly influenced by peers, while others like to pursue their own goals. To this end, we added into the game several features to exploit the different behavioral factors, namely team and individual (within a team) competition for peer pressure and badges/awards for personal accomplishment. Thus, the employees are expected to have a personalized experience with our game app.*

RE 3.4.5.1 Demographic Info **Inclusivity**	***"……..Therefore, the ChArGED app should be designed to mostly fit the preferences of users aged 25-55. Depending on the gender of the employees, perhaps the app could provide content, or interface, adaptable to the gender of the participants"*** I think that this finding is very good and the gamified App will be designed to engage a wide age group 22 – 55 and should therefore be fairly inclusive. In terms of inclusivity I think due consideration should also be given to other user groups to ensure inclusivity and to ensure that the App is not unconsciously bias or discriminatory towards any group. For example it may not be appropriate to challenge an employee who is confined to a wheelchair to take the stairs or not to use the lift. There is also a fairness factor to consider here. It may be necessary to apply kWhr allowances or some other methods to ensure fairness. In terms of Health and safety and Corporate liability it may not be appropriate to challenge a pregnant or visually impaired person to take the stairs. These are examples to demonstrate my point. I would recommend that a structured audit of this area be conducted to mitigate potential issues.	*Positive comment* *No action taken* *This is a good point. The various challenges may not be applicable to the various users/groups. We address this fairness issue as follows: a) In principle, we offer a different set of challenges per pilot site. b) We assign different points per challenge per pilot site, based on the energy impact and the easiness of each challenge per pilot site.* *Currently, based on our interviews/surveys, we did not find any user/group exclusions for the challenges of each pilot site. However, challenge exclusions will be monitored during the run of the pilot experiments and if any is found for a user/group, then this challenge will be omitted for this group and its corresponding points will be split to the remaining challenges proportionally to their current points.*
Page 139 – Self reported behaviors	This graphic includes results indicating that a very high percentage of respondents 95%+ switch off their computers and turn their lights off before they leave the office at the end of their working day. Whilst this is self-reported behavior it is very consistent across all pilot sites. These findings surprised me. My observation in terms of ChArGED is that if these findings are valid, it leaves very little scope for	This finding is not in line with the observations of the continuous measurements. In fact there, the analytics have recognized cases where the PC was on during the night. The energy-saving

	measurable energy savings for an individual's use of personal computer equipment and lighting. PC monitors generally get a standby signal when the PC shuts down. The scope for saving energy therefore may be limited to encouraging employees to turn the power button of the monitors off to save the standby power. This is a much smaller saving potential and indeed may place the measuring equipment under more pressure in terms of accurate detection. In terms of Air conditioning savings these may realised only if individual controls are available.	potential of an individual action could be small, but, it is repetitive, and hence, its cumulative energy-saving impact remains to be measured during the validation. Moreover, the game is fair both for already "green", i.e., energy efficient, and for non-energy efficient employees: they originate from the same positions and get points for each accomplished challenges, as opposed to their delta energy savings.

Report Identifier:	D3.2 -	Regarding the A/C, individual controls for the fancoils are available at DAEM.
Comments and recommendations		**CHARGED actions taken**
Introduction: **RE: Field Devices**	I think that low cost of field devices and their deployment and also reliable operation in terms of accuracy and longevity will be important factors in proving the viability of this proposal. (Particularly for multi-site deployment)	*Positive comment* *No action taken*
2.1 **RE: U.3, U.4 &U21**	I think providing a web based repository with educational material on how energy is wasted and conserved is an excellent idea. This feature could be included at low cost and has the potential to significantly enhance the user experience. I note however that item U21 –Energy educational Quizzes is classed as a low priority. I consider this to be a good method of ensuring educational material is consumed and indeed understood correctly. I would also suggest that the educational repository could be utilised to good effect by providing incentives within the gamified App for viewing tis material as Team and individual challenges. For example: 1. Include quizzes to ensure educational material is absorbed and understood correctly 2. Extend the repository to include wider environmental issues such as global warming, International Carbon reduction accords, severe weather events etc. 3. Link educational materials to the gamified App by setting team and individual challenges to watch content or complete quizzes etc.(Points or badges awarded on successful completion) I strongly believe that enhanced awareness in this area leads to environmental mindfulness which can translate in to action (in this case participation and meaningful engagement with charged) to reduce energy waste.	At the moment, we have introduced educational material on the energy impact of good and bad energy-consumption behaviors in the form of tips that are given to the users. These tips are linked to the various actions of the users at the game. Also, we provide the users with graphs of their achieved energy savings on a daily/weekly/monthly basis and on an individual/team level. The induction of additional educative material will be considered in the course of the pilot studies.
RE:U13	I Agree that it is very important for the ChArGED App not to take up too much employee time. Therefore, it could be a requirement for the challenges suggested above to be completed outside of scheduled working hours or for their design to be of short duration.	*Positive comment* *No action taken*

RE:U11	I consider it essential that the ChArGED App be accessible in both Android and IOS. Failure to do so may preclude participation by a large number of employees.	This is an issue that requires new development, will be considered later
RE: U.9, S.7	Data protection concerns – Careful consideration should be given to what measures are taken to protect personal data and how these measures are communicated to participants. Employees may not have confidence in the 3 stage / tier arrangement for accessing data within an organization. For example the anonymizing of personal data and the inclusion of an independent ethics expert should be clearly communicated to employees. This issue is even more prevalent now in light of recent reports of serious data breaches in social media platforms.	*Positive comment* *No action taken*
RE 2.2.2 Maintainability	Maintainability appears to deal well with the software issues however I think that the ongoing maintainability of field devices is an important consideration. These devices are decentralized and due to their installation environments may be vulnerable to damage. (E.g. window sensors)	NFC and BLEs are quite resilient. The window sensors are easy to detect. No action taken.
4.4.4.1 – Use of smart plugs	I think the use of smart plugs during initial set up will be significant. In my experience there may be many end user loads connected to the same sub-circuit. The initial set up to ”individualise” loads may be quite labour intensive in order to achieve the granularity required.	*Positive comment* *No action taken*
4.1.4.3 – RE Measurement and Verification	The ability of measuring devices (meters and in particular CTs) to accurately detect and record very small consumption values is an important consideration when disaggregating at this level. For example an individual switching off their lighting in a modular single office may account for as little as 50W to 100W. Therefore the measuring equipment must be able to “see” very small variances in consumption.	*Positive comment that the system already implements.* *No action taken*
4.5.1 – RE Team Play	I consider Team mode functionality to be very important and should be available from the onset of trialing the gamified App.	*Positive comment, already available* *No action taken*
Significant potential Barriers	Data protection concerns	There is the support for legal/ethical issues by the experts hired.

Report Identifier:	D3.5	
Comments and recommendations		**CHARGED actions taken**
General Comment	Generally I am of the view that energy awareness campaigns need bolstering in order to increase engagement levels of participants and to offer a user friendly link between measurement technology and end users. Current methods of reviewing data and making it meaningful to end users can be time consuming. The ChArGED programme has good potential to do just that through well designed gamification concepts. I think gamification concepts which foster time persistent engagement are crucial to the success of the programme. Developing emotional bonds with the App, educational content targeted at harnessing the end users environmental conscience and reliable and sustained operation of field devices are all important factors in this regard. In order to be viable I think it is essential that there is a large "pick up" rate from end users is achieved.	*Positive comment* *The pickup rate to be seen still during the project this cannot be evaluated as users are particiipating through the decision of their management.*
Assigning end load equipment to individual users	I understand that loads will be disaggregated to single items of equipment where possible and then assigned to individuals however I wonder would it be necessary to assign all equipment to all users to allow for situations such as: a. Interdepartmental or (team) use of equipment in circumstances where malfunction of equipment or work pressure to quickly produce printed matter requires employee to use equipment they normally would not use. Or indeed to mitigate interdepartmental cheating. b. Employee transfers from one department to another although in a "team" situation the employee would need to be reassigned to a different team anyway.	The loads are associated to one or multiple employees dynamically (i.e., not statically) based on the usage of the various equipment and the challenges undertaken by the employees. The loads and the points assigned to an individual employee are transferable along with the employee to different teams.

System costs associated with deployment and administration v user pick up and energy savings	The programme I am involved in uses energy measurement, energy advisor targeting and feedback to engage participants. However our metering systems tend to be less granular than that proposed by ChArGED. At best we can report the values of consumption at departmental level. As a consequence the consumption data we report on is not personalized and therefore less insightful for individuals. Obtaining and in particular maintaining end user engagement can be challenging. The ChArGED proposal has serious potential to bridge this gap however I believe careful consideration of the costs associated with initial field device roll out and the ongoing ChArGED system administration (onsite) is required in order to ensure viability. These elements to be balanced against the estimated sustained "pick up" rate of the gamified App by end users and the actual potential for energy savings in this area. I flag this because one very surprising survey result (for me) from the pilot sites was the consistency at which end users across all sites self-reported excellent conservation habits in terms of shutting down PCs and lighting. (95%+). If this is the norm then the potential for energy savings in this area may be less than estimated. On a more positive note however (in terms of viability) it has not been our experience to record such high levels of personal conservation where night audit reports on many of our participating sites frequently note that PCs and lighting has been left on.	The issue of pickup rate and costs of the investment required to adopt this system is an interesting point to be tacked at the latest version of business analysis report.
Query on the take the stairs challenge	I am unclear of how this challenge will work in practice in terms of measurable energy savings. Is it an overall calculation of reduced lift journeys over a period of time? Should the game points be penalty based (if one takes the lift). For example if four people take the stairs challenge but one person chooses to take the lift. This person will use almost as much energy using the lift for his/her single person occupancy than if all four travelled in the lift.	The measurements at the person level do not allow us to take this approach. Charged rewards individual actions that contribute to energy savings.
Wireless devices in sensitive installation environments	It is important to ensure that the devices used have the necessary compliances and "in house" sign offs for use in sensitive medical equipment environments (for example)	This is a valid point in general, however, not applicable to our pilot sites.

Ongoing site administration of the system	I wonder how this area will be handled (internally on site or externally). I understand that the intention may be for the energy manager or team lead on site to take on the ongoing administration of the system. In a large building / organization the systems ongoing administration may require significant inputs for the following: a. Assigning / reassigning equipment as it moves in the building b. Catering for staff movements – leavers, new entrants, movers. c. Password administration d. Ongoing maintenance of a large number of field devices many of which may be installed in vulnerable areas. (windows, stairwells, printers etc.) e. Device validation and recalibration checks These tasks have the potential to generate "push back" from employees particularly in austerity affected work sectors and if not catered for adequately could become a barrier to the ongoing operation of ChArGED. In our case I am aware of the significant resource requirement required for energy meter data mapping, password control, meter system validation, alarm responses etc.	The major effort that is required is at the setup phase, which can be undertaken by the suppliers of the system. The follow up phases do not require significant effort. However, the idea to also outsources this support has been also considered.
Suggestions for educational game play	Team awarded points for arranging an energy awareness event – points awarded for a task based challenge or based upon attendee feedback Individuals or Team awarded badges or points for watching prescribed educational video content Team awarded points for accepting a poster challenge – Where the team puts up "free issue" posters on targeted topics in key poster locations throughout the building. Points allocated for each poster site Individuals or Team awarded points for a "Bright Idea" regarding energy saving in the workplace – Points awarded based on a gamified voting system or social media comment. Team rewarded for carrying out a Work place Temperature mapping survey. With this activity members are allocated a specific location (occupied) to visit periodically and to record temperature observations based on a basic thermometer card and opinion. The surveyor records either "Too hot" "Just Right" or "Too cold" on each visit and the findings will inform a process for further action to alter heating or cooling.	These are good ideas that should be supported by the building managers and not by the game itself.

BLE Integration **RE: Figure 23 BLE Messages**	The use of individual movement tracking hardware to record presence data needs to be presented carefully to employees to avoid negative impacts. Examples: Potential I.R. Issues and end user tampering / interventions on field devices used for detection.	The whole concept of the game is designed in collaboration with personnel of the organisations, who also explain these issues. These are also addressed by the consent forms.
Mobile phone belt holders or neck strap holders	The consistent operation of the system requires end users to carry their mobile phones with them at all times whilst moving around the workplace. Users may often leave their phone on the desk during short trips to the printers or tea station for example. Some behavioural change may be required here and in order to assist perhaps consider the "free issue" of mobile phone holders that fit onto a neck strap or trouser belt etc. Or free issue an IoT tag as a back up for times when an employee does not have their phone with them or programme access control cards with tag on / off capability as another alternative.	This problem will be tackled when the game is commercial. It is a valid point, that has been also noticed during the trials.

RE High Level Description	In addition to the goals of the integrated system now supports the following complete demonstrationscenario • User's smartphone / ChArGED Mobile app scans an NFC tag while user interacts with the corresponding appliance (or enters the proximity area of a BLE beacon), thus the user action is identified by the system in the specific area. • The user action events are transmitted via the Mobile App to the Game Backend, processed, and then forwarded to the Analytics Backend. • The Analytics Backend analyses the energy measurements of the electrical circuit/smartplug that corresponds to the appliance that the user manipulated (e.g. PC, lights, etc.) and calculates the energy drop related to the reported user action (e.g. energy of last minute for thisappliance). • The Energy Analytics backend then calculates the energy savings that are the result of the users' actions. • These calculations are then sent to the Game Backend that notifies accordingly the user via the Mobile App regarding the achievement of the related challenge. • The Game Backend also produces other various statistics such as number of challenges completed per day/week/month, assigns user/team titles and monitors user and team scores separately. • The user can access these resources through the app to monitor the current game state. I understand how this process works for steady state loads such as P.C.s and lighting however how will standby states of printers be handled?	The game is organized on a per-challenge basis, e.g., "turn-off lights when leaving office". When a challenge is undertaken by a user, the associated energy savings by its accomplishment are calculated. Our emphasis is put on measuring the energy savings from changed behaviours and not on real-time energy measurement per device.

RE: Page 45 **Figure 31 User model inside SiteWhere**	 **Comments** • The gamified App associates peters phone with Peters P.C. • Peter is accredited with the award associated with switching his P.C. off. • If Peter fails to switch his P.C. off but then his office is visited by the security guard on his lock up rounds….. 1. Can the security Guard tag on and obtain a reward for shutting Peters P.C. Down? 2. Consider setting up a separate game challenge specifically for security, cleaning and lock up staff where they can audit lighting and PC status as they pass through the building and obtain rewards for switching lighting and equipment off. 3. Is this another argument for associating all employees with all equipment?	These are good ideas to be considered for the future. A new challege for the security personnel can be added to guide them through the appliances that are still on. There is not always a security guard available at the pilot sites. At MNHA, indeed, we involve the security guards in the game and ask them to opportunistically turn off the lights.

RE: 4.4.2.2 **User leaves / returns to desk**	**Comment:** If two or more users leave their desk and return at the same time and some users have turned their P.C.s off and some have not…….Can the system accurately differentiate between the users that did and the users that did not switch off their PCs and can the system accurately allocate the resultant energy saving to the correct users? This scenario may be quite feasible in a Public Service environment where tea breaks and lunch breaks are taken at the same time every day.	Mostly positive comment. The system monitors circuits in a building which results in measuring the consumption groups of devices (for example an office). So in this sense the only information that can be derived from the energy measurements on the circuit is if a device has been turned off or not but not which specific device is it (and thus if it belongs to a specific user). So in this scenario it is not possible to conclude who turned off the device (assuming both behaved similarly simultaneously). This is a tradeoff that is investigated in the project i.e. the savings that can be achieved using much cheaper measuring equipment (against i.e. smart plugs) come with the drawbacks for each specific device) which offers a clear energy footprint for a higher upfront investment. In conflicting scenarios the goal is to not demotivate users that behaved correctly so we assign points to everyone involved.

RE: Page 57 **Step 1**	***Extract*** • ***The game admin creates devices based on the device asset specifications. The devices are the electrical equipment that we want to include into the game.*** • ***The game admin assigns each device to a person. If the device is used by many users at the same time, the game admin assigns each device to a location/room.*** Should all devices be assigned to all users? How is Anomalous consumption data allocated? (e.g. A non-team member uses equipment that is not assigned to him/her or someone fails to tag on)	The main entities that a device can be assigned to are: a single person (for work pc, monitor etc), a team (for devices such as office lights in a room, A/C and devices that can be used by everyone such as kitchen appliances, shared printers etc.) It is assumed that the people in the office use their assigned devices (offices A/C, their pcs etc). In general each device gets power from an electrical circuit which is what we actually measure. These circuits can either give power to plugs (for example all the PCs in a room), to lights (for example kitchen lights), or to A/Cs (for example the A/Cs in the administration office). Then we assign NFCs to different circuits/devices which in turn the users can scan with the mobile app. Thus for example light switches have an NFC placed next to them that is associated in the backend with the circuit that these lights belong to (that we measure) and also with the specific device type (so we can know that this NFC refers to lights). Then a user can swipe an NFC and inform the system that they are performing an action in the specific device and circuit (for example "I switch off the lights in the IT offices"). In this sense no devices are associated with specific users but the users can dynamically associate themselves temporarily with a specific device and perform an action (for example switch of A/Cs, lights, use a printer etc). A special case is the user's personal PC which is, in addition to the above, also associated with a specific username so only the user the PC belongs to can gain points from switching it off.

Report Identifier:	D3.7	
Comments and recommendations		**CHARGED actions taken**
Mobile Apps	Consider adding links to domestic targeted mobile energy saving Apps in the education repository of ChArGED	The links have been added to the project website.
2.3 Engagement Mechanisms	***"maintain and grow customer and wider public trust in its activities by putting non-negotiable safeguards in place on issues such as cybersecurity and use of data".*** **Comment:** Very important commitment to build and maintain end user trust.	Not really relevant to the focus of this project.
	".....set of successful engagement principles to serve as a resource for all industry stakeholders: 1) Educate customers before deployment, In this regard I consider the information given to end users in advance of roll out and the actual launch of the initiative itself requires careful consideration.	The process of deployment and validation has started by the appropriate workshops and explanations for the game.
Risk Assessment	No comments	

Reviewer:	Paul Tighe, CEng MCIBSE, MIEI, Dublin
Report Identifier:	General Comment

	Comments and recommendations	**CHARGED actions taken**
	The ChArGED initiative certainly has great merit and could bridge the gap between main distribution system metering and individual / departmental consumption. This fine grained disaggregated approach has the potential to directly link consumption data to the individual in meaningful ways and if successful may greatly influence behavioral change at this level. The campaign I am involved in in Ireland has a focus on energy measurement and expert advice to effect behavioral change and we are constantly looking for innovative ways to engage with public sector staff in pursuit of this objective. As you state in your documents these groups are not the bill payers and so we focus on the following ways to try and effect behavioral change 1. *"Simply because it is the right thing to do"*. We try to harness individual's environmental conscious by informing them of the disproportionate amounts of Carbon we produce as a Nation in comparative terms to a third world country. We inform staff about global warming trends and severe weather events and encourage our energy teams to get these issues discussed in informal settings. I think there is scope within ChArGED to leverage environmental awareness to effect behavioural change. 2. We offer help and advice to participants with regard to saving energy in the home. In this environment the individual is the bill payer and there is good take up on this advice. This can lead to monitory rewards for the energy saving effort in the home and can assist with changing habits in the work place. We impress upon participants that our programme seeks to change behavior regarding energy consumption in the work place for a culture where energy is habitually wasted to one where energy is habitually saved.	The aspect of environmental benefit is well supported within ChArGED. The concept of caring for the environment is represented in the concept of the tree growing. Regarding the educational aspects CHARGED adopted the tips which provide energy saving ideas. These combined with the game concepts, may provide some positive contribution to the implementation of this vision.
Final Note	*Thank you for the opportunity to review this interesting and very well researched and targeted proposal. I wish the ChArGED development team every success with this project. I hope my comments are of some use to the ChArGED group and are taken in the positive and constructive spirit in which they are intended. I am happy to assist further if required.*	

Reviewer:	Dr. Aris Theotokis
Report Identifier:	Overall comments

Comments and recommendations		**CHARGED actions taken**
Overall	ChArGED addresses the energy consumption in public buildings and proposes a framework that aims to facilitate achieving greater energy efficiency and reductions of wasted energy in public buildings. The framework leverages IoT enabled, low-cost devices (NFC or iBeacons) to improve energy disaggregation mechanisms that provide energy use and (consequently) wastages at the device, area and end user level. The suggested design and architecture look good and the overall objective is viable. System architecture has to efficiently tackle data acquisition from legacy and new data sources, as well as integration of heterogeneous software components. Initial research provides useful insights about the potential of this project	*Positive comment*
Gamification elements and design	In the later stage of the project some experimentation would be needed to test how different designs and game mechanics could be optimally exploited in order to improve user response. Ideas may include, competition, difficulty type, leaderboards and other game elements. Importantly, these elements should be investigated in combination with user characteristics and psychographic data (see next comment)	This requires additional effort that we may consider in the following months

User requirements and characteristics	The project takes into account very nicely user requirements by examining motivation and ability of users and integrating these into "personas". This is a very good idea for user segmentation that could be extended using other psychographic characteristics of the users. For example, type of thinking (analytical vs. holistic) (*Epstein, Seymour, et al. "Individual differences in intuitive–experiential and analytical–rational thinking styles." Journal of personality and social psychology 71.2 (1996): 390*) or cognitive styles (McElroy, James C., et al. "Dispositional factors in internet use: personality versus cognitive style." MIS quarterly (2007): 809-820) are individual user characteristics that could be measured so as to build more elaborate personas and better predict user response to the system. Ideally a framework can be provided that will combine system/gamification characteristics with user personas. This framework, coming as an outcome of the project- will have significant theoretical and practical implications.	We have defined and employed a pre-game user questionnaire, in order to register individual behavioral aspects and related them with each individual's game performance. Another post-game questionnaire will be employed at the end of the pilot experiments, in order to locate altered behavioral aspects and associate different "personas" with exerted game performance.

3 Overview of the ChArGED concepts, use cases and game challenges

ChArGED approach

ChArGED (CleAnweb Gamified Energy Disaggregation) develops a gamified framework that aims to change occupants' energy-consumption behaviors and reduce energy wastage in public buildings. By leveraging low-cost IoT devices (NFC/BLE), ChArGED improves energy disaggregation mechanisms and identify energy wastages at the device, area and end user level. At the same time, it engages and motivates users with serious game approach accessible through a mobile app. The gamified approach in ChArGED advances the state of the art, since it will be employed in public buildings, where multiple appliances are shared among multiple users. Energy disaggregation in this context is particularly challenging due to the vast area that needs to be monitored and the difficulty of associating particular actions to specific users. In addition, other related applications, e.g., Kill-Ur-Watts, Energy Tracker, Watts Plus, etc., mainly focus on increasing energy-consumption awareness, assuming that the users are already interested in their energy consumption and motivated to reduce it. In a public building, employees are primarily busy with their job activities and moreover they do not pay the energy bill. Therefore, their engagement to such a game app cannot be taken for granted and thus a carefully-designed gamified approach has to be followed. There have been some prior efforts to employ serious games for demand side management [1], [2] in public/office buildings. "Energy Chickens" [1] evaluated the effectiveness of a virtual pet game in reducing plug-loads in a mid-size commercial office. Changes in device-specific energy consumption were reflected in the relative "health" of chickens in a virtual farm. ChArGED app has far more ambitious goals than [1] in the sense that it aims to change a vast range energy-wasting behaviors at work. Also, most efforts in [2] focus on boosting user awareness towards energy efficiency, as opposed to incentive building in ChArGED. The ChArGED app employs both direct incentives and peer pressure to achieve the desired behavior change towards energy-consumption reduction.

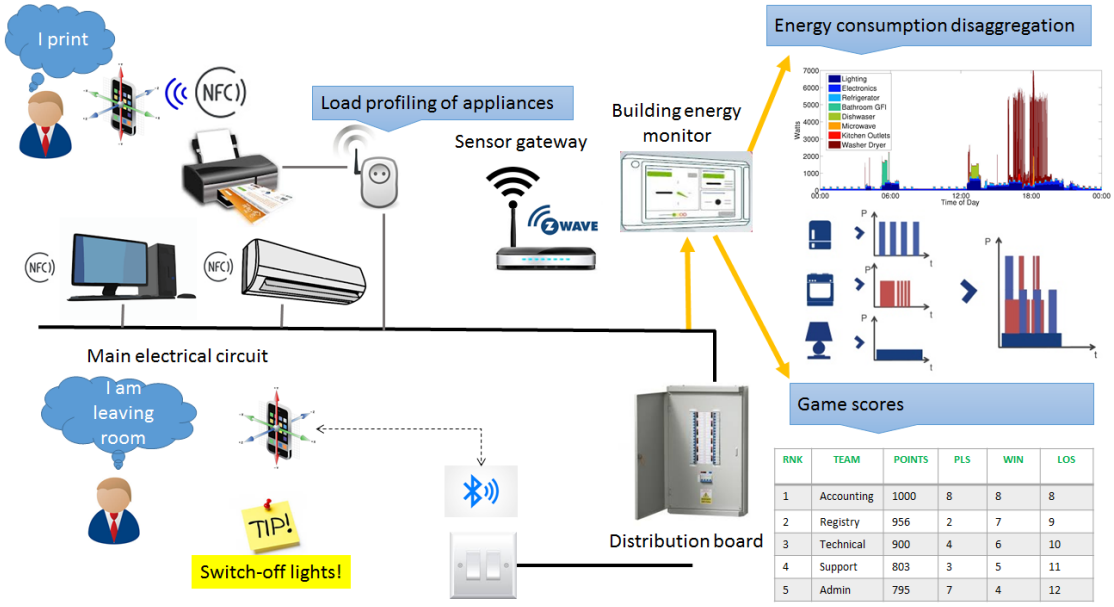


Figure 1 ChArGED approach

The game concept

The Charged Mobile app revolves around a main theme (persona) of a Tree. It shows both the persona as well as the informative parts (current score, team information, current challenge etc.) in a separate but thematically merged user interface the Mobile App includes an onboarding process, revolves around teams and is based on specific challenges that can be either pursued individually by each user or in teams. The users' actions performed and validated by the ChArGED system will be rewarded. Rewards can be towards individuals and/or teams; they can also be inside (e.g. badges) or outside (e.g. real awards) the gamespace. The Mobile App also includes leaderboards showing the progression of individual members of the same team or the aggregate progression among different teams. [13]

The core ChArGED concept revolves around a virtual living and evolving main "Persona", in the form of a Tree, that represents the effects of the energy consumption behaviour of the cumulative users in terms of each (and groups) individual effect on all the energy consuming devices in their vicinity of operation".

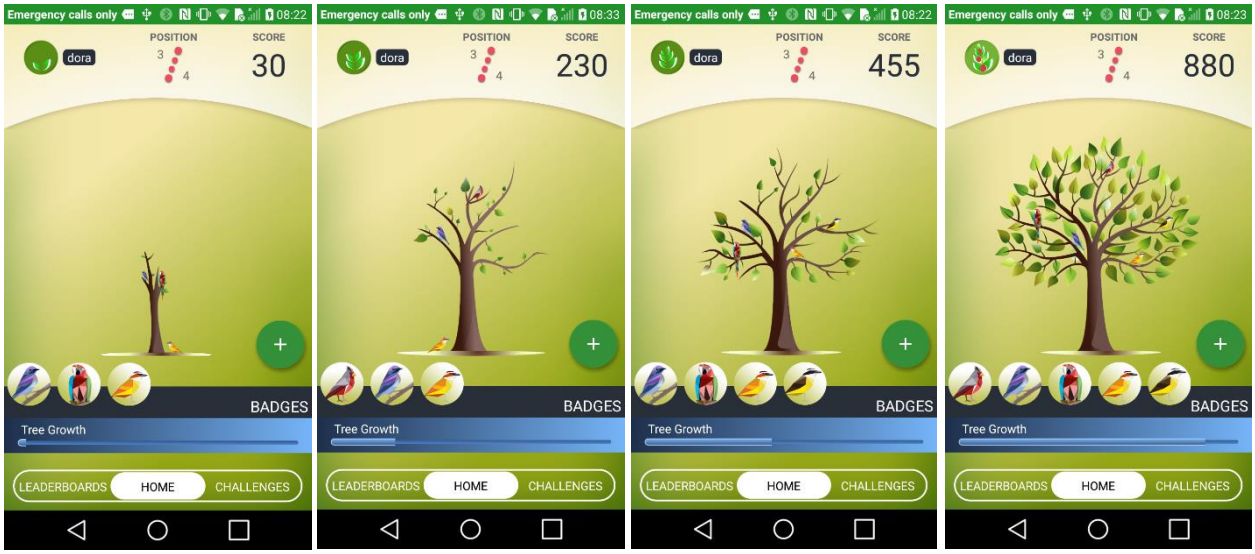


Figure 2 ChArGED UI including the Tree "Persona"

In order to achieve that feedback on energy consumption, the gamification outcomes of users' actions are directly shown to the end user and in parallel the virtual evolving persona accommodates in a graphical form the current state of the game/position or player/state of consumption etc. to create an emotional connection with the end user.

The ChArGED gamified app utilizes a two way on-boarding mechanism to ensure a smooth introduction of the end pilot users to the Mobile app. Initially users will be invited (by the person designated as Pilot Game Admin, at pilots' premises) to download the Mobile app and on first open, users are invited to "Create an Account" or "Login" to their account. Following registration, the game onboarding process begins.

Teams within the ChArGED game are formed with the following criteria:

- **Geographical:** Employees working in the same shared office space belong to the same team. In cases where a number of individual offices/rooms exist next to each-other, the employees may belong to a team competing vs other workplaces/buildings.

- **Role-oriented:** Employees of the same department / with similar, or the same, work description may be grouped in a team.
- **Device-oriented:** In cases where energy-consuming devices (such as printers / air-conditioners, lights, windows) are shared by employees, these users may be teamed together.

Employees will be assigned to teams by the administrator in the beginning of the game and as needed afterwards.

The comparison between teams will be made by their position in the team leaderboard, as well as relative notifications within gameplay. Such messages could read: "Congratulations to the TECHNICAL team for completing the morning challenge first today". "Congratulations to the TECHNICAL team for reaching the 10.000 points threshold" [3].

Types of challenges

Two types of challenges were designed in order to be included in the Mobile App:

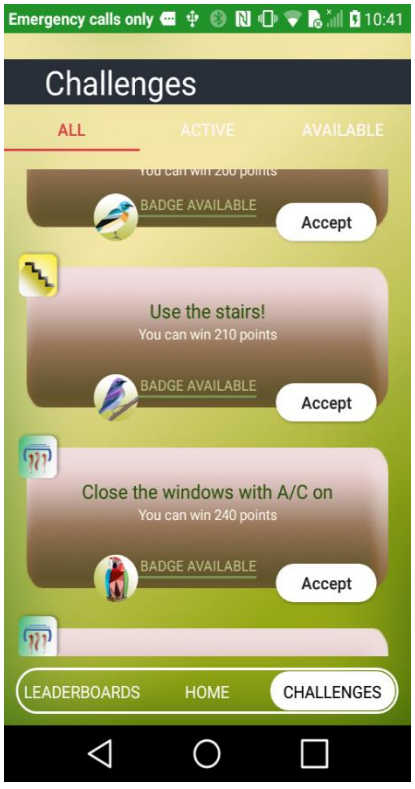
- **Personal challenges**: They are taken-up by individual participants and their outcome is mirrored on the participant's progress in the game, as well as incentives.
- **Team challenges**: They are taken-up by individual participants, but their outcome is mirrored both on the personal and team progress in the game, as well as incentives.

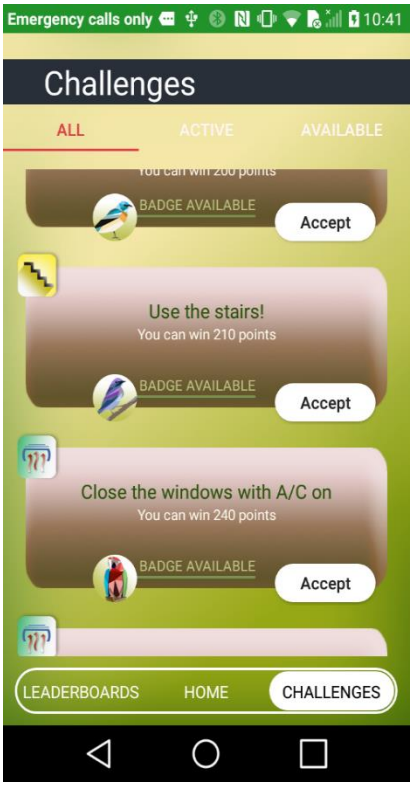
There is set of main challenges that runs over the course of the game and around which the game revolves. Several challenges can run in parallel. Each challenge is graded, according to the level of adherence. The entire list of challenges that have been implemented in the final version of the app are listed below:

"Stairs" challenge: The employees opt for using the stairs, instead of the elevator, to reach and leave their office. (this behaviour is corroborated by swiping on NFC tags existing in the middle of the stairs to ensure that no cheating occurs).
"Windows" challenge: The users are prompted to close the windows when the air conditioners are on.
"Away" challenge: Whenever employees are away from their office, they are prompted to switch off any unnecessary devices that are forgotten on
"Lights and A/C off" challenge: The lights are switched off in the workspace by each team, by the last team member leaving their office. As team members switch off the lights, they swipe the corresponding NFC tags.
"Equipment off" challenge: Before leaving their desk, the employees turn off any equipment that isn't needed after hours (PCs, printers, etc), at the same time swiping their tags.
"Museum Visitors" challenge: This challenge will aim at involving the visitors at the MNHA museum. Since they will not play the same game as the employees, the objective will be to provide them an NFC sticker as they enter the museum (at the reception) and challenge them to use the stairs instead of the elevator. Every time the visitors use the stairs they will swipe their NFC sticker over a fixed device (a customized mobile handset fixed on a booth or on the wall in the middle of the stairs and will be scored accordingly. As they leave the museum they will be able to see their score and possibly get a small gift (e.g. a museum poster) or other kind of reward in the form of a reduction, etc. The visitor will see the tree at the screen of the Museum and each time one visitor

is using the stairs and confirming this by the NFC swipe, the tree will grow more and more. The NFC will be reset at the exit of the visitor to be reused for the next one.
"Museum Guards" challenge: This challenge involves the control of lighting in the exhibition areas of the National Museum of History and Art (MNHA). Lighting in these areas is controlled by the light control room at the museum. The guards will play the game by notifying the control room on the occupancy of a certain exhibition room, so that the lights are switched off/on at that room. These notifications are sent by the guards via the ChArGED mobile app. The control room has to respond to these notifications by taking the appropriate actions.
"Solar" challenges**:** This applies to the DAEM site that has a solar microgeneration system. The objective will be to motivate the employees to shift their energy consuming activities to the periods of high expected solar energy production (that will be provided with the solar power microgeneration forecast component. The challenges here involve using common appliances found in the workplace (such as printers, microwaves etc), A/Cs as well as charging phones when electricity is produced by the panel. The weather forecasting is correlated with the live electricity production of the solar panel to identify the minute that the users should be informed when it is the actual time to reschedule common tasks that need energy. In order for the users to win points during these challenges they need to scan the NFCs on the devices before they use them while the solar panel is producing excess energy. The energy analytics are consulted to confirm the users' actions based on the actual energy measurements and the system assigns points accordingly.

In each case the ChArGED platform validates the user's actions (kWh decrease on energy measurements) and platform calculate the kWh savings to determine whether the user has completed the challenge and to provide a respective score to the user.





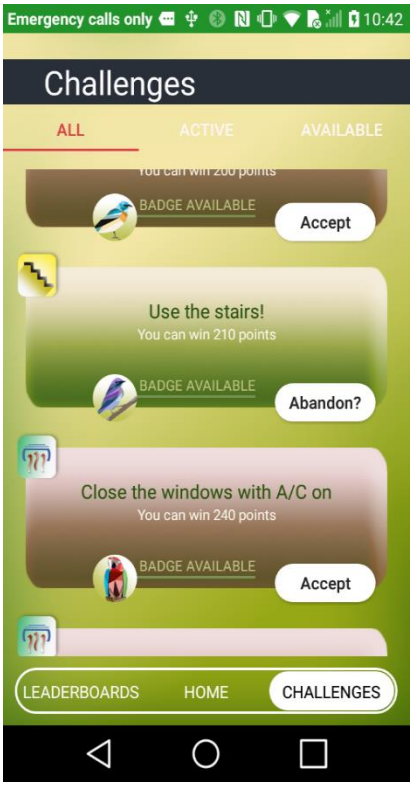


Figure 3 ChArGED UI including the list of challenges

Based on the aforementioned complete list of challenges, the ones that have been selected to be included in the 1st integrated system are:

1. **Personal challenges**
   - **a.** Challenge users to switch PC off when going home. The steps towards the realisation of this challenge are:
     i. the platform engages a user to switch his/her equipment off when going home
     ii. the users swipe NFC sticker with mobile phone to say they're leaving
     iii. the platform validates actions (kWh decrease on energy measurements)
     iv. the platform calculates kWh savings and provides score to user
   - **b.** Challenge users to switch PC off when going away for more than 30 minutes. Steps:
     i. the platform engages a user to switch his/her PC off when going away for long periods
     ii. the platform monitors with BLE when user leaves and returns to the room
     iii. the platform checks if PC has been left on during that period
     iv. the platform provides score to user (bonus points if PC was off or if user returned within 30mn, malus points if PC was on and user left for more than 30mn)
   - **c.** C3. Challenge users to use the stairs instead of the elevators. Steps:
     i. the platform engages a user to use the stairs for a given period (e.g. one week)
     ii. the users swipe mobile phone to say they're taking the stairs
     iii. the users swipe mobile phone to say they're up the stairs (we can also consider the possibility to use only one NFC sticker in the middle of the stairs)
     iv. the platform validates actions (nobody in the elevator using BLE beacons and NFC stickers swiped)
     v. the platform calculates savings and provides score to user
2. **Team challenges**
   - **a.** Challenge team to close (do not open) all windows if A/C is on. Steps:
     i. the platform engages a team to close all windows (keep windows closed) when the A/C is on.
     ii. the platform monitors if windows are open using switch sensors
     iii. the platform assigns points to team if windows are closed and A/C energy measurements show A/C is on
     iv. the platform requests team to close windows if A/C is found to be on
     v. the platform validates action (kWh on A/C energy measurements to check A/C on and sensors on window to check if open), but if no action taken after timeout period the team loses points (or gets no points)
   - **b.** C5. Challenge team to switch lighting and A/C off in room after hours. Steps:
     i. the platform engages a team to switch off lighting and A/C when there is no one left in the office
     ii. the last user swipes mobile phone to say the room is now empty
     iii. the platform validates actions (kWh decrease on lighting and A/C energy measurements and nobody in the room using BLE beacons)
     iv. the platform calculates savings and provides score to team

4 Final system architecture and system components

Integrated system architecture

The system architecture (depicted on Figure 4) has been developed, consisting of four main groups of functional blocks:

- The Data/Core Back-end group is responsible for providing an environment in which data, assets and users are stored and managed. The Back-end components provide the software infrastructure on which the ChArGED application is developed. That group of components is application agnostic, however it is tuned towards the needs of ChArGED project.
- The Gateway group is responsible for integration of energy use and environmental data to the Back-end system, to determine variations over the energy context within the building.
- The Analytics Back-end component is responsible for delivering insights that will enable the ChArGED application to deliver custom and targeted feedback and incentives to the end-users.
- The Gamification group is responsible for processing field data and insights created from such data and make decisions as to the evolution of the game for each user, i.e. what the next step is towards more energy savings. That group also delivers the mobile app the end-users interact with which acts as an interface between the user and the charged system updating the user with the current game state and also provides information to the system about the users' behaviour towards the energy saving goals set.

The architecture also includes an external system that is utilized to provide a solar power microgeneration forecast based on weather predictions for the specific location. It serves to maximize the building energy savings, increase end user awareness as well as to enable the use of the mobile app to maximize the solar-based electricity consumption during production, avoiding the need for energy storage.

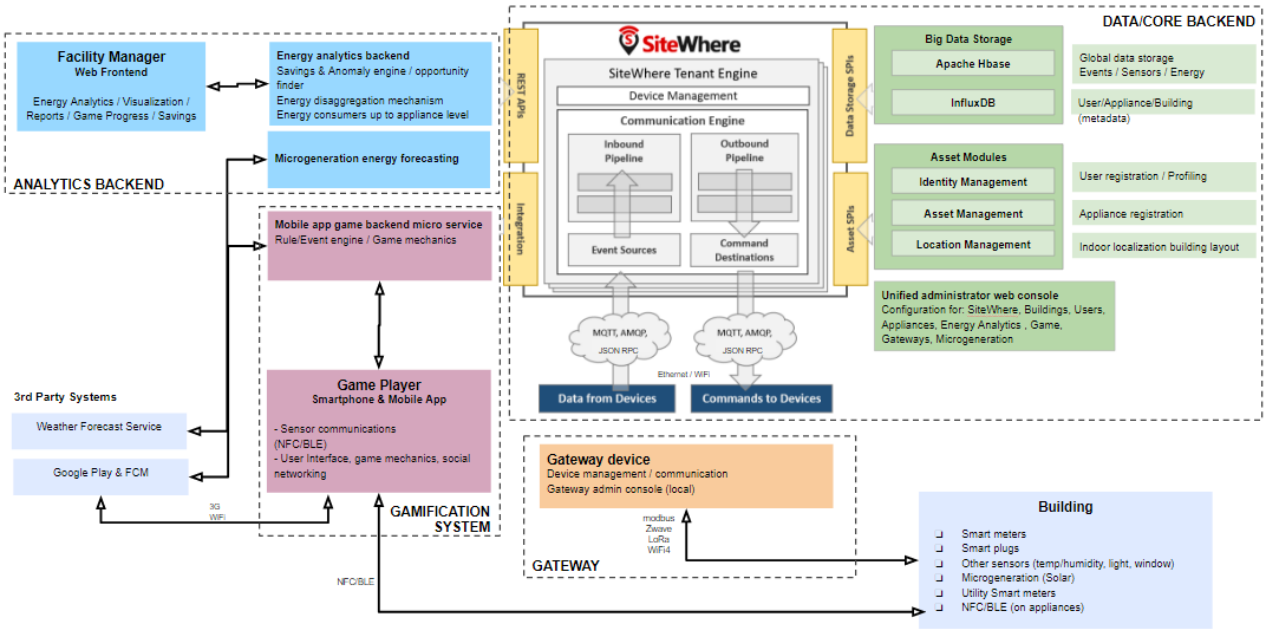


Figure 4 ChArGED system architecture

4.1.1 Data/Core Backend System

The Data/Core Back-end system components and infrastructure were implemented in SiteWhere [4]. This was chosen as the Data/Core Back-end system, as it provides an open-source platform with a number of rules and mechanisms for data exchange and operations. SiteWhere's main functionality is to supply a server-based JAVA SPRING middleware between the sensing infrastructure and the different system components and acts as a controller for the processing of device data. It connects with NoSQL & Timeseries databases in order to provide persistence of the sensor data and scales effectively with a large number of devices so that the whole sensor data history is maintained and can be accessed at any point. It also provides the entities management mechanism in order to structure the devices and categorize them according to their type, location and ownership and offers full control on a device's lifecycle (providing the functionalities of creating, deleting, updating, grouping, sending data). Moreover, it provides a web based administrative console application that allows all of the system data to be viewed and manipulated in a structured way which makes their overview and administration easier and more accessible. The available functionalities are the following:

- Each new asset or entity (i.e. a sensing device, an appliance, a specific location area, a person) is assigned a unique ID and can be autonomously monitored via external software. Specifically, a model for standard types of generated event data is provided for each device (which includes measurements, alerts issued and location updated by the device). The logged events are stored in massively scalable time series datastores (InfluxDB).
- Devices (appliances such as printers, air conditioners, a PCs etc) can be assigned to / associated with other entities. A device can be associated with a person, a location or another sensor device of our infrastructure thus giving us the ability to establish ownership room/location metadata and establish relationships with device.
- Devices can be grouped together according to a common role they fulfil, thus, enhancing efficiency by simplifying the way the devices can be retrieved by other backend processing services.
- Every top-level entity is modelled as a tenant and can have a completely different configuration and structure without affecting other tenants. This can be used for modelling infrastructures that are unrelated to each other such as different locations, different buildings, pilot users etc on the same server.

SiteWhere provides an extensive list of third party frameworks and software tools that can be interconnected in order to extend its capabilities. The options include different databases, identity management frameworks, event streamers, event processors, enterprise service buses and others. Moreover, being an open source software solution, new interfaces with other software tools and services can be created as needed. External communication with SiteWhere was achieved via a built in extensive REST APIs. A communication interface utilizing the MQTT protocol was also implemented to be used by devices and other embedded systems to send or get notified about new events and sensor data (e.g. NFC/BLE alerts and energy measurements).

The integration and connection of major system components as implemented is illustrated on Figure 5. The WSO2 Identity Server handles the identity management and user authentication, the Game Backend implements the logic to update the game progress of the users (i.e. score, completed challenges etc) by processing the users' actions, the Energy Analytics Backend performs estimations on user savings and is responsible for the energy monitoring of the building, and the mobile app acts as a frontend for the whole system and is the main point of interaction with the users.

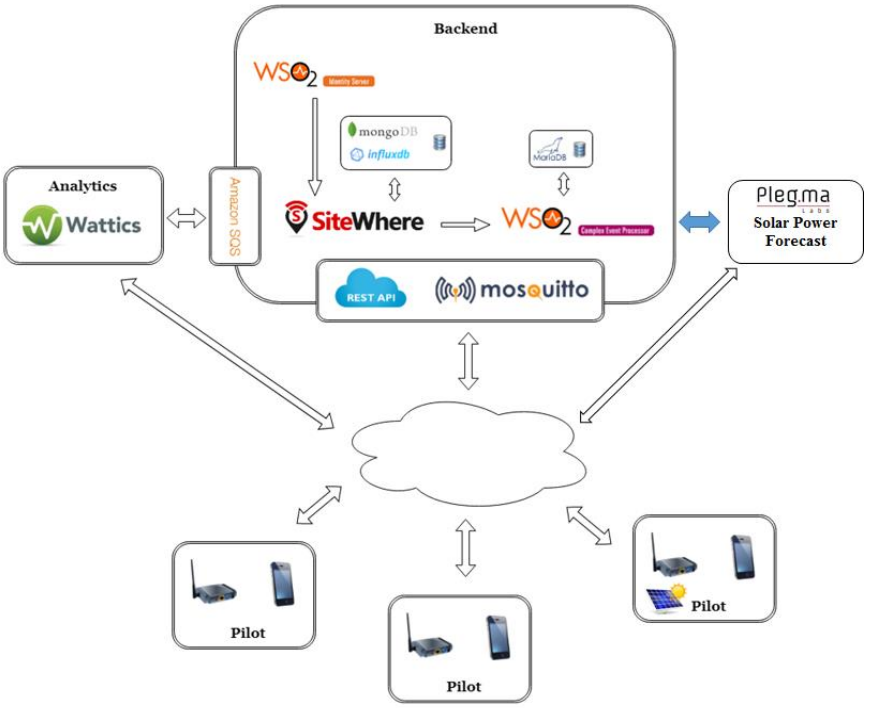


Figure 5 Organisation of SiteWhere System Components in ChArGED

WSO2 Identity Server is used for the creation, management, deletion and accessing of the user accounts. Its main functionalities include the following:

- *A sign in solution for the mobile app*

Users will need to sign in to the server through the app that will run in their smartphones. This allows their participation in the game challenges and offer personalized data to them (progress in a challenge, team information for group challenges, leaderboards etc). Persistent login functionality is provide to the users, i.e. so that users log in and then for a certain period of time they are remembered by the system so they don't have to frequently enter their credentials. WSO2 Identity Server adopts many state of the art open standards, used today by the industry, that provide user authorization/authentication (oauth2/openid connect, SAML2).

- *A user account provisioning tool*

WSO2 also handles the storage of the user credentials and user info on the server in a secure way. These data are imported by SiteWhere on the background to be used for creating the user entities.

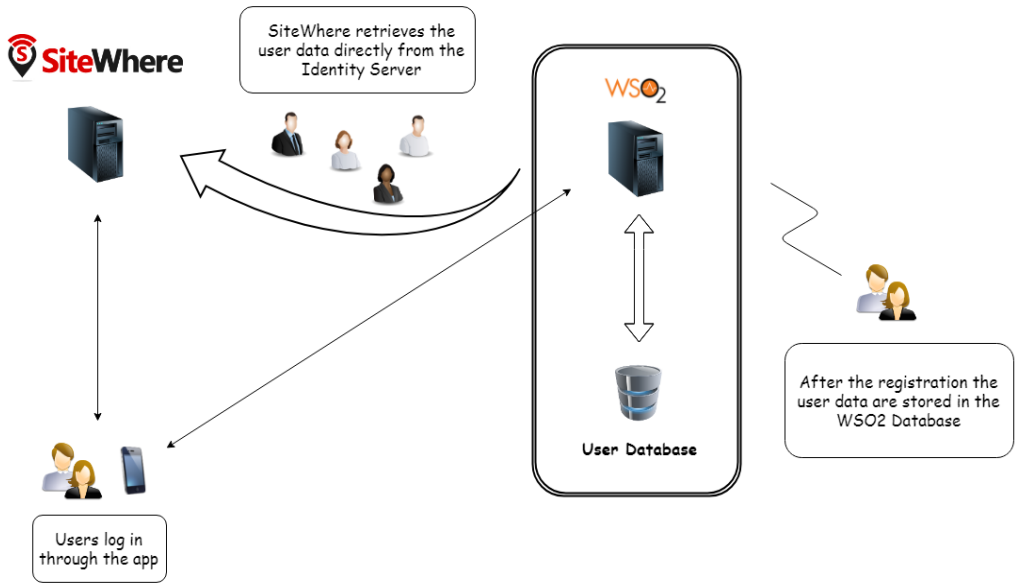


Figure 6 Capabilities provided by ChArGED Back-end

Devices and locations of the infrastructure are modelled as assets inside SiteWhere. In the case of the devices the asset provides a general description of the device (for example Printer). This asset was used to create a specification. Specifications also provide a general description of a device but are more specific that an asset (for example Printer Model). This specification then was used to create all the devices that exist in the infrastructure. For example, as described above, Asset -> Printer is used to produce a Specification -> Printer Model and then this specification can be used in order to create all the printers of the specific model in the building.

The devices can be inserted manually in the system by the site administrator through the graphical interface or created remotely through the SiteWhere API. This enables easily addition of a new device without access to SiteWhere's user interface as well as enable the possibility for devices to self-register when they are first integrated in the system. Locations can also be modelled as assets. The administrator can then associate the assets with devices to denote the room each device is in.

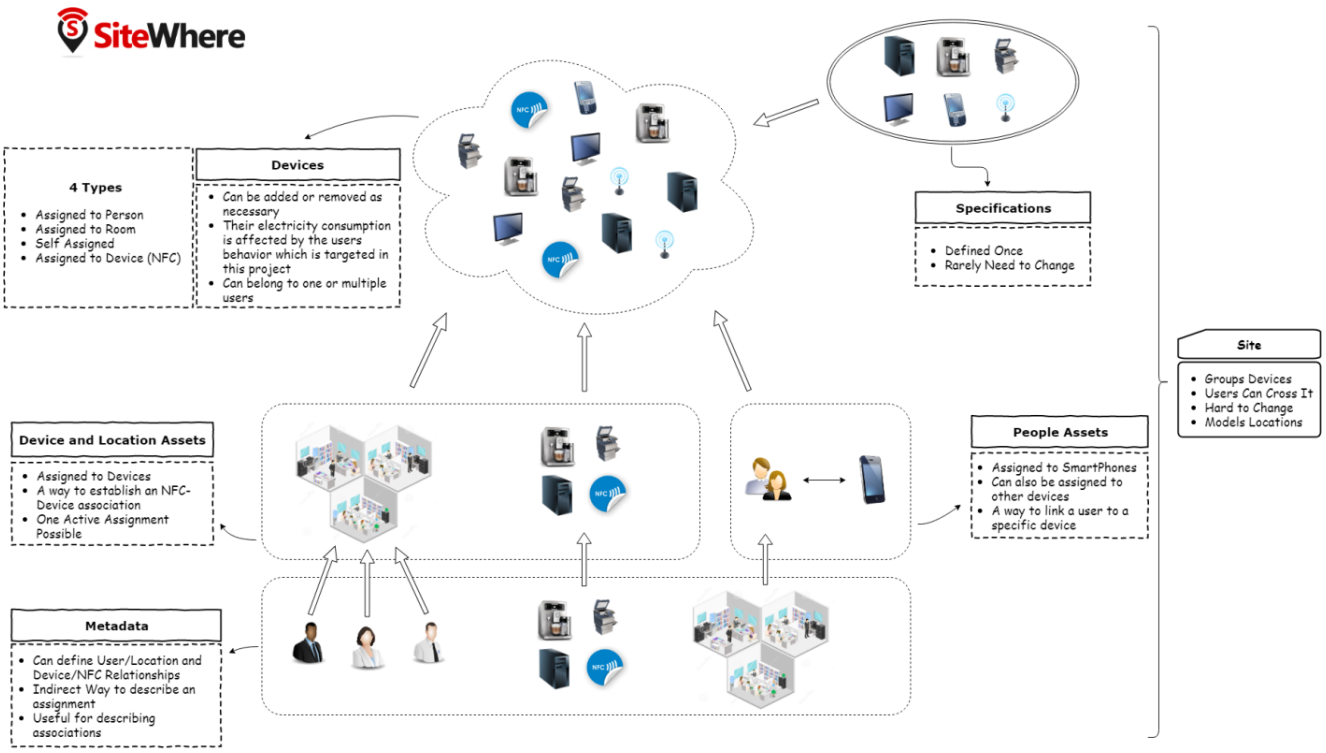


Figure 7 Asset management in the ChArGED Back-end

4.1.2 Gateway

To achieve the data acquisition process the Sensor Gateway has two connection interfaces within the global architecture, one with the building sensors (e.g. Smart plugs and Smart Meters) and another with the SiteWhere Data/Core backend. Various hardware and software requirements have to be fulfilled to support the needs of the platform. The Sensor Gateway software/middleware by Bosch Software Innovations is used as the basis of the Sensor Gateway. For the remote software management and provisioning of the product, the ProSyst Remote Manager (PRM) [5] is also used.

The Raspberry Pi (version 3 Model B) was chosen as the hardware basis for the Sensor Gateway. The Raspberry Pi is installed with a standard Raspbian OS, including the Oracle Java SE Runtime Environment (Java8), the Communications Device Class Abstract Control Model (CDC_ACM) USB to serial driver and, as mentioned before, the ProSyst mBS SH Runtime for ChArGED.

The data collection process required development of sensor drivers to retrieve data from third party sensors using industry leading communication protocols. For the connection of Z-Wave (Plus) devices, various controller options have been investigated, and two units have been selected: (1) “Razberry” GPIO Module for Raspberry Pi, (2) USB Z-Wave Controller.

Various Z-Wave devices were connected to the Sensor Gateway such as: (1) Fibaro Smart Plugs, (2) Fibaro 4in1 Sensor (Temperature, Humidity, Luminosity, Motion/Presence), (3) Fibaro Contact sensors.

These devices are managed by the mBS SH Runtime and included into the product portfolio, which allowed data to be immediately collected from the devices. The AcuRev 2000 multichannel Modbus

meter by Accuenergy and the Solar Inverter by Kaco was also connected to the Sensor Gateway via the Modbus protocol, to collect detailed energy measurements at the three pilot sites and the solar energy measurements at the DAEM pilot side. All connected devices communicate their data to the Sensor Gateway, which pre-processes and forwards it to the SiteWhere backend via MQTT.

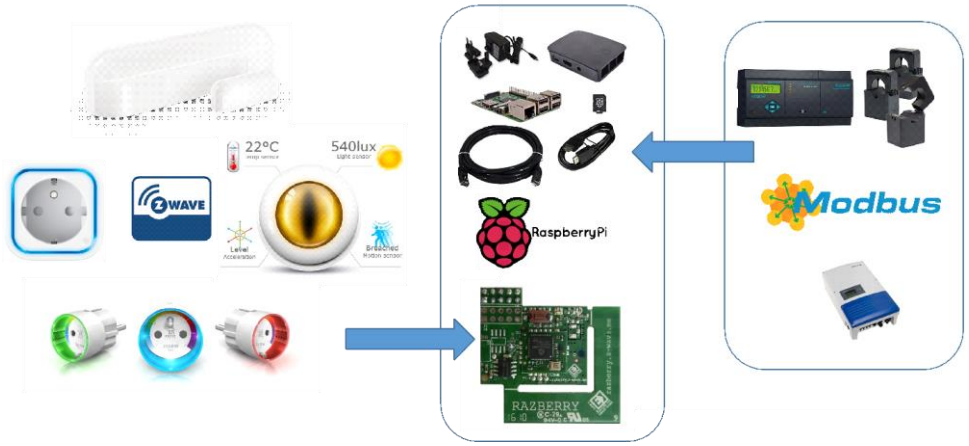


Figure 8 Illustration of the Sensor Gateway and interconnected devices and modules

For the management of the mBS Runtime the ProSyst Remote Manager (mPRM) backend is used. mPRM is a software and device management system developed by Bosch Software Innovations. mPRM enables lifecycle management of software bundles running in the mBS Runtime. Existing bundles can be updated, new bundles installed and depreciated bundles uninstalled. All of these actions are done during runtime, this means that all not affected bundles are actively running, while the specific bundles are processed. Therefore, a 24/7 runtime of the sensor gateway is achieved.

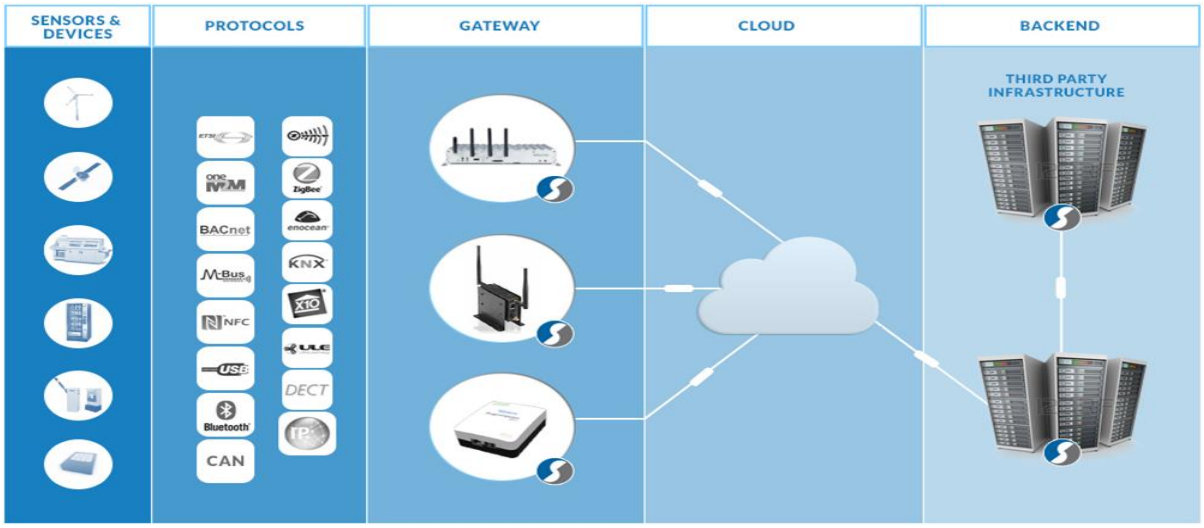


Figure 9 Typical IoT Architecture with mBS and mPRM

4.1.3 Analytics Backend

The Wattics Analytics backend is interfaced with the Sitewhere backend via RESTful web services, which allow energy measurements, NFC swipe alerts and BLE location events to be received as input, and measurements of load demand reduction and energy savings as well as energy saving opportunities to be returned. Authenticated data streams are processed in real-time through parallel analytics engines to produce valuable insights for the application.

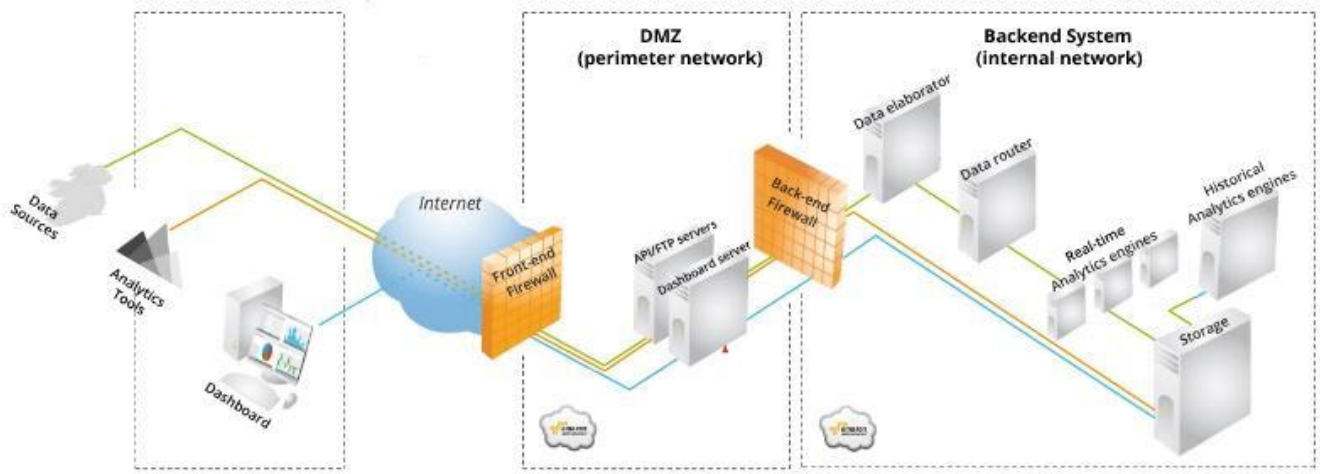


Figure 10 Wattics Cloud Backend System Architecture

The Wattics backend infrastructure is brought to the project as background IP, and has been adapted to the needs of the project with the following additions:

- API endpoints to process NFC and BLE data packets.
- Analytics engine to validate control actions have been taken by users (e.g. device switched off when going home or when away for more than N minutes), and to estimate the energy savings achieved by such actions. In addition, the new Analytics engine is able to diagnose inefficient operation of electrical devices based on concurrent power activity (e.g. A/C left on when window is open), and to estimate the energy wasted due to such actions.
- Notification mechanism to export insights generated to Sitewhere. In addition to these extensions to the Wattics backend, a micro service was developed to reside in between SiteWhere and the Wattics Analytics backend to enable seamless integration of both backend systems via Amazon SQS.

The analytics component in charge of validating the control actions and estimating the savings generated. The following set of figures shows the intermediate steps for monitoring a building, gathering events and performing the necessary analytics actions to identify energy savings.

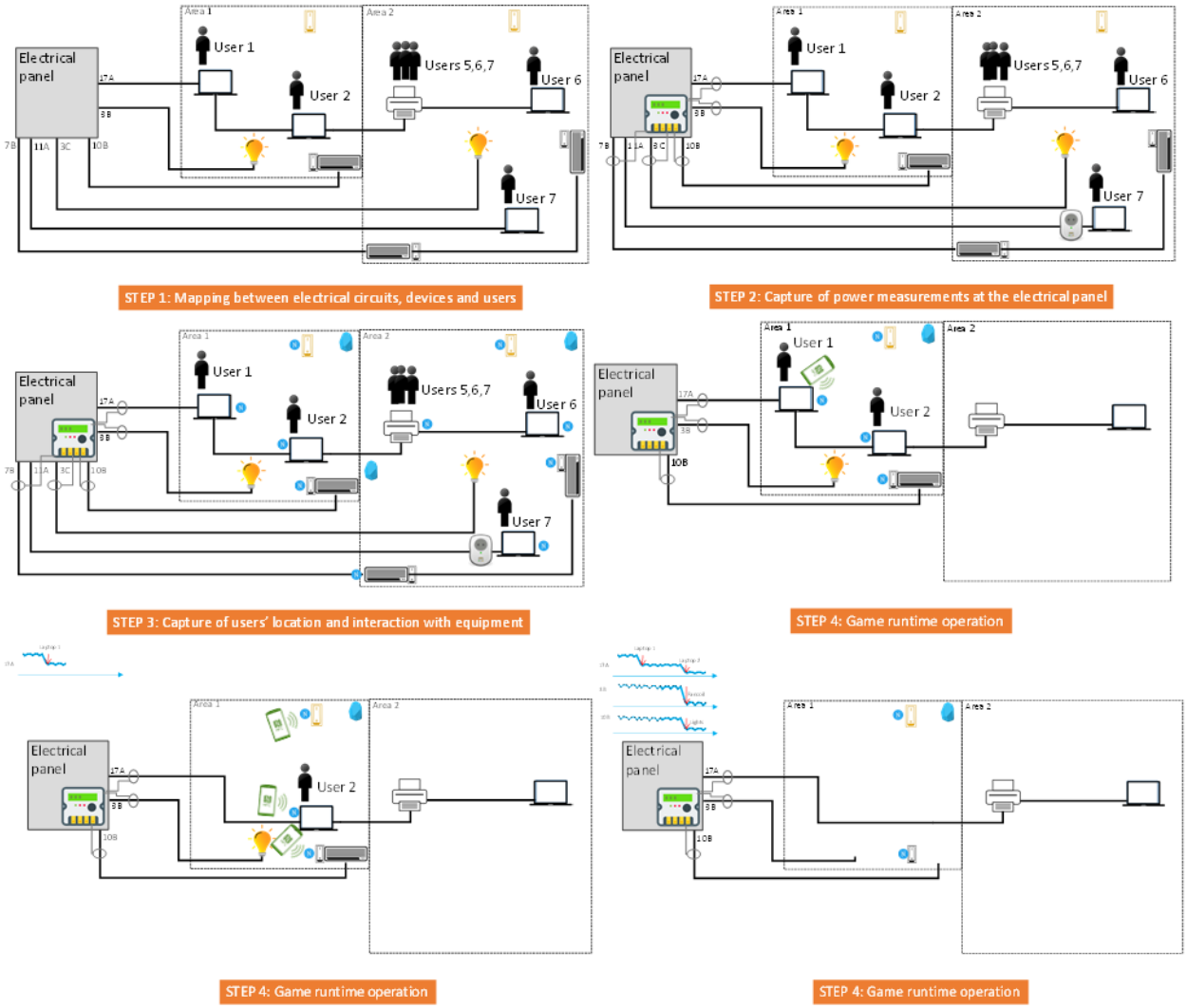


Figure 11 Intermediate steps for energy monitoring and performing analytics

The Pre/Post Event Analysis is where the algorithms for control validation and energy savings estimation happen. The disaggregation and energy allocation engine works as follows: (1) The core/backend platform informs the analytics engine that an appliance has been operated by the user after it received an NFC swipe alert from the user's mobile app, (2) the analytics software runs the NFC swipe alert against the power measurements of the circuit feeding the appliance operated by the user to detect significant power variations, (3) the analytics software analyses the power variations and informs the core/backend platform of the drop in energy use measured in relation to the user's operation of the appliance, as well as a quantification of the savings achieved by doing so and (4) the game backend calculates the points to be given to the user and the savings are stored within the platform database.

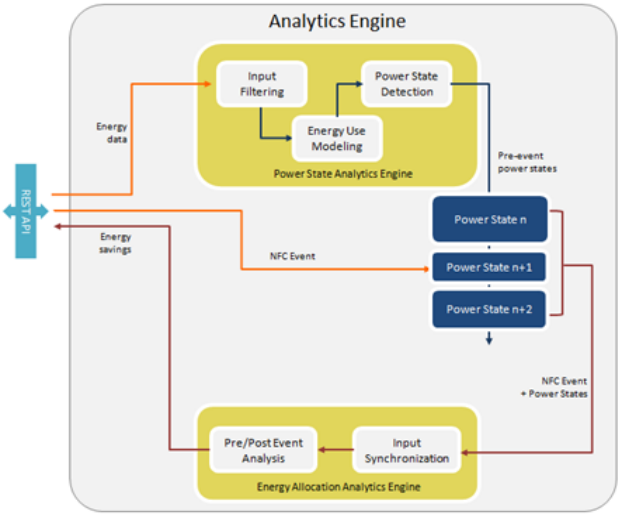


Figure 12 Architecture of the analytics engine in charge of validating user control actions and estimating energy saving generated

4.1.4 Gamification Group

The Game Backend implements the game rules logic that is going to be used in order to decide the progress of a user or a team in the game, update the scores and leaderboards, and keep track of the currently accepted/available challenges. It has been implemented in Java and interfaces with SiteWhere via MQTT and REST. All the communication between the software components happens through SiteWhere.

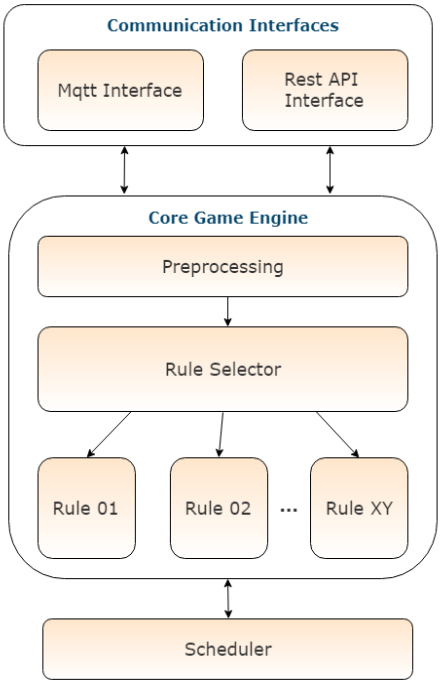


Figure 13 Game Backend Internal Architecture

Whenever an event is sent to SiteWhere from a device (i.e. a measurement or an alert), the event is stored and forwarded to a predefined MQTT topic which is listened by the other software components. The Game Backend listens to events sent to SiteWhere that describe the users' behavior and its results (such as NFC swipes, user location updates and energy updates), processes the data and determines the user progress with respect to the challenges that have been accepted or schedules delayed or recurrent processing. The processing performed by the game backend is not necessarily tied with the specific time an alert has arrived. Separate logic can also be triggered or executed at a different time to check/update the game progress and provide updates to the other system components. Internally the Game Backend consists of three different subcomponents. The first one is responsible for interfacing with the rest of the system through MQTT and REST. This interface is used to receive/request and update data according to the results of the rules. The second sub component is the core engine that implements the game logic. It consists of a pre-processing component which handles the incoming messages and accordingly selects the relevant rule out of a list of rules. These are the main part of the game logic and game challenges or actions that should be performed. One such rule determines that at the end of the week the challenges which have not been completed should be identified released if they have been assigned to any user. The third subcomponent is the scheduler. Its main use is to schedule delayed rules that should be scheduled for the future or executed at specific time intervals (i.e. every day, every week etc). New rules can be added as needed to incorporate new challenges. A separate submodule allows to easily add rules thus, ensuring the scalability and continuous enrichment of the game challenges. It organises rules in a specific structure by inheriting from an abstract class Rule, which defines a common interface as well as implements common functionality.

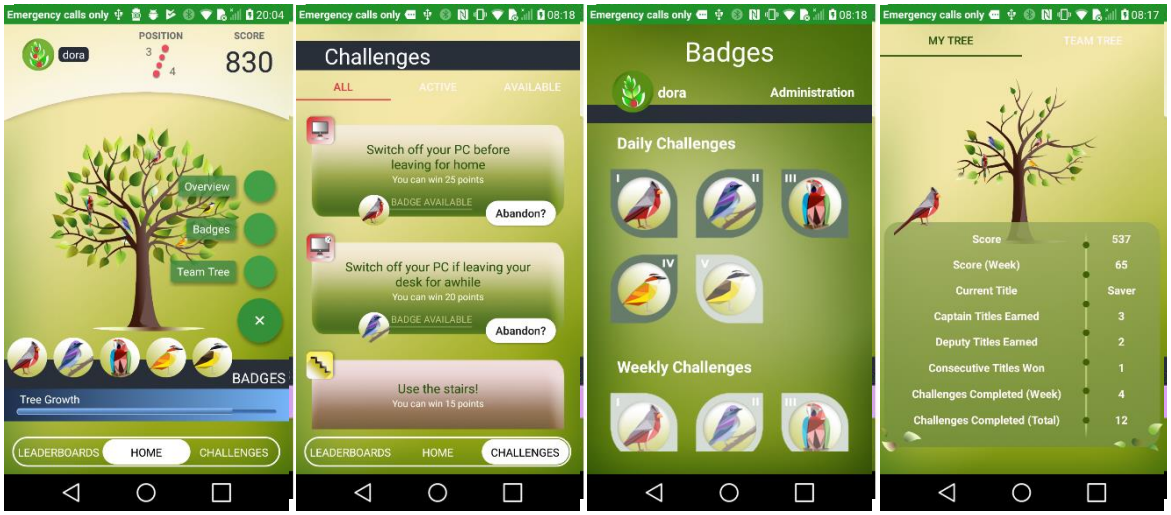


Figure 14 Screenshots of the Mobile App

The ChArGED Mobile App is the end-user front-end and visualizes data and game challenges in a user friendly, appealing, modern and motivating interface to ensure continuous engagement. The app is designed for Android smartphones supporting API Layer 21 (Lollipop) and above, equipped with NFC and BLE capabilities. The gamified app visualizes information about energy behaviour both at user level and team level. Users are informed about their progress while their actions directly contributing to the energy impact can be traced. Achieving energy savings and accomplishing challenges results in accumulating scores. A visual emotional inceptive in the form of a living tree grows and prospers according to the user score, thus rendering the game also visually attractive and engaging. When a challenge is completed, the scores and the game progress for each user and their team are updated in real time between the backend and the mobile app. The game backend has been installed on the

project server and connected with the other software components through MQTT and REST. The design goal of the backend is to implement the game mechanics, manage user/team scores and leaderboards and send notifications whenever there is a new update.

Besides the design and engagement concept, the following subsections present the functionalities that are provided to the user in order to use the first prototype:

4.1.5 User authentication

Users authenticate at the backend using their username and a password. The implementation will follow the functionalities described in "Identity Management" and also support automatic re-login using a provided token mechanism.

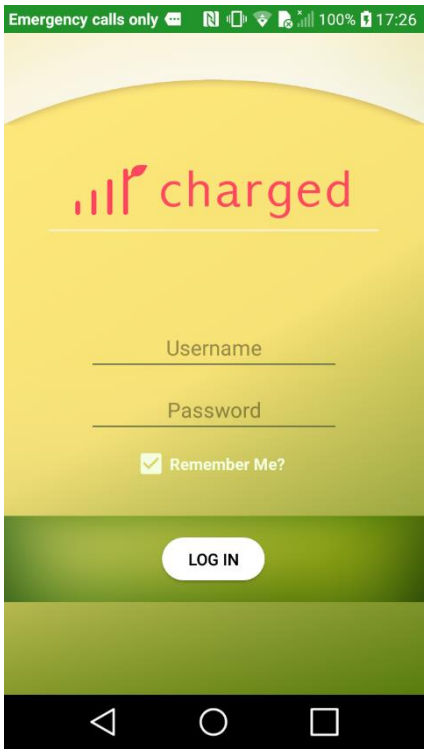


Figure 15 Login screen

Home Screen

The home screen is the first screen after a successful login. It displays a general overview of the current progress. It contains the personal and team trees as well as the player's score and badges.

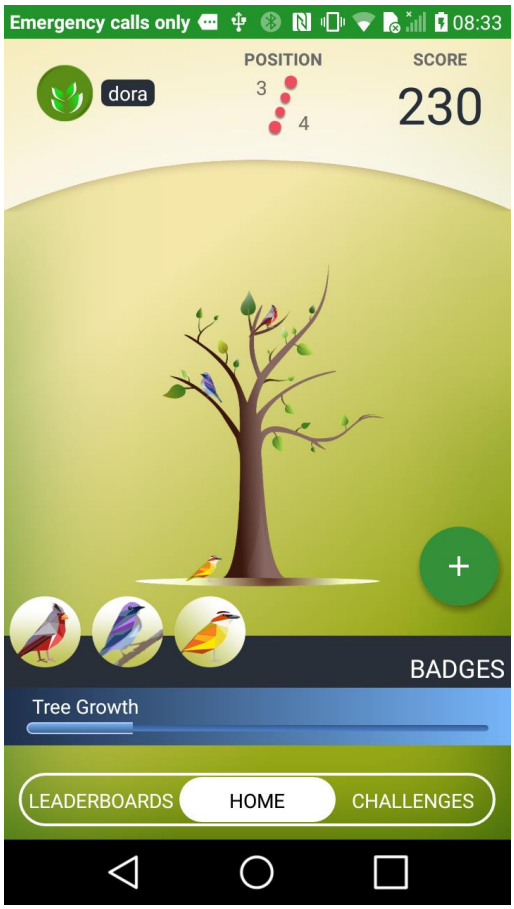


Figure 16 Home screen (Small Tree)

Figure 17 Home screen (Fully grown tree)

As the user completes different challenges he is awarded points and challenge badges. If the score is high enough (according to predefined threshold) the tree will also bloom and grow bigger. The longer the game is played the player gains experience and is assigned a corresponding user avatar (top left). Special borders of CAPTAIN and DEPUTY are also available for the two first players in each team.

Challenge Selection

The challenges screen contains all currently available and active challenges. A user can start playing by selecting one or more challenges. A challenge can also be abandoned at any time.

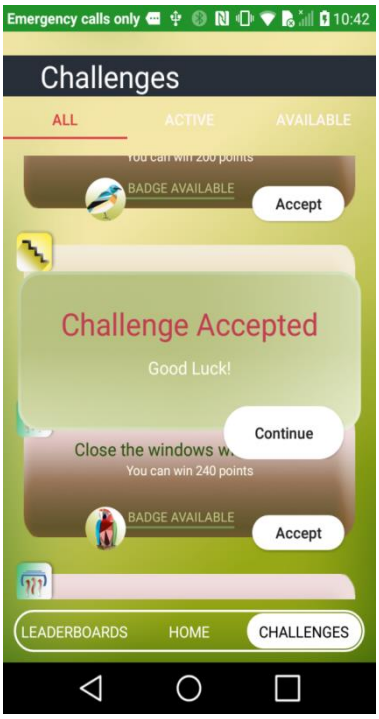


Figure 18 Accepting a new challenge

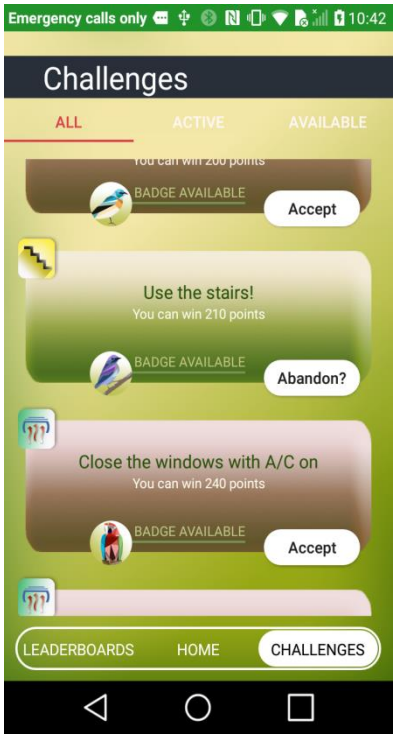


Figure 19 Challenges Overview

Leaderboards and Badges

The leaderboards screen enables the users to track their progress with respect to the other players of the same team as well as the progress of the different teams. The app communicates with the server to get and display the most recent game data.

This screen contains all the obtained and available badges that one has been awarded when completing a challenge.

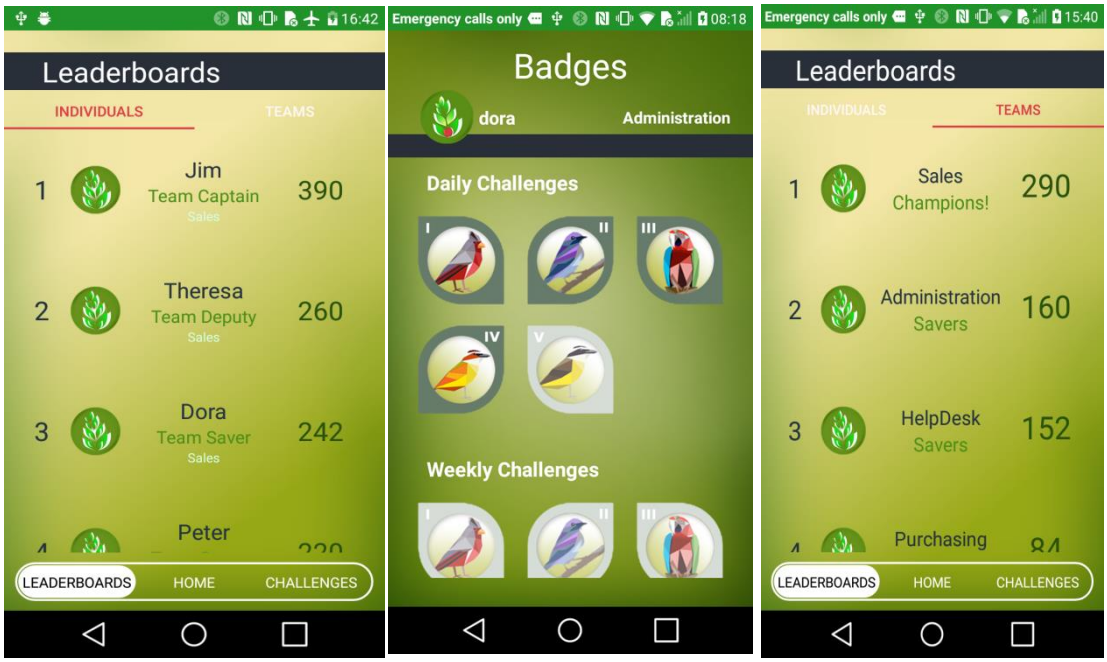


Figure 20 Individuals Leaderboard, Bodges and teams leaderboard

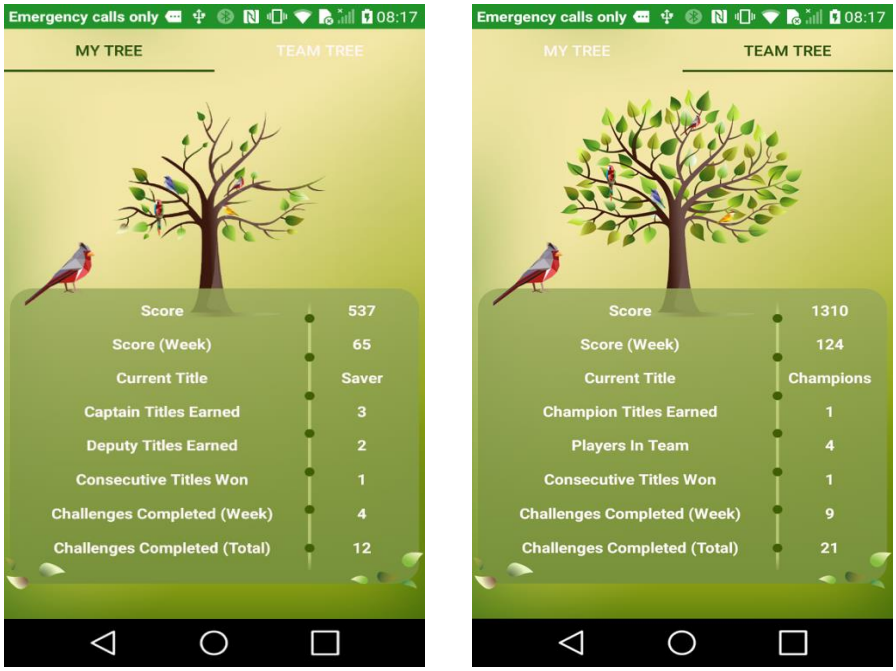


Figure 21 Overview of achievements

Energy Savings

The basic concept of the App is to support users in their behaviour change and actios towards saving energy by playing some specific challenges. The initial concept of the game was to demonstrate energy saving achieved by alternative visualisation methods (points and tree growth) and not by visualising the energy savings, as the users at the initial stage did not really show interest in this. However, during the first stages of validation, the users clearly requested to be informed on their contribution to the overall target of energy saving. Thus, this has been added later. The backend and analytics modules are supporting the calculation of the energy impacts of users in order to allocate the points. However, this was now a requirement for the visualisation at the user level and team level and per challenge.

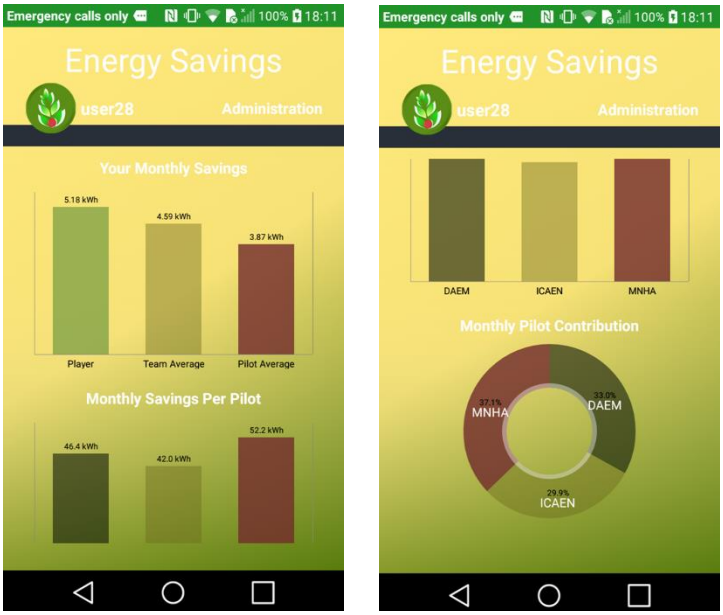


Figure 22: Energy Savings Visualisation to the user

The above energy saving screen has been added, the estimations have been calculated and statistics are displayed, for example how much energy each player saved, what was the mean value per player saved in their team and the pilot they participated in as well as the total energy saved for each pilot.

Game Feedback

The usability and the user experience were improved by feedback, which is generated by the Game Backend and informs about the current game state, for example the current status of a challenge (i.e. started, completed, failed). This was a request by the users during the first two validation cycles (D4.3). This has been achieved with the implementation of an event log which stores user actions such as accepting/completing or failing a challenge. When a challenge is failed the reason for this is also stored and transmitted to the user to be able in this way to improve its behaviour in the future. Similarly, when a challenge is completed a

new message is sent to the user/team participated in the challenge to inform them about the challenge completion as well as their rewards.

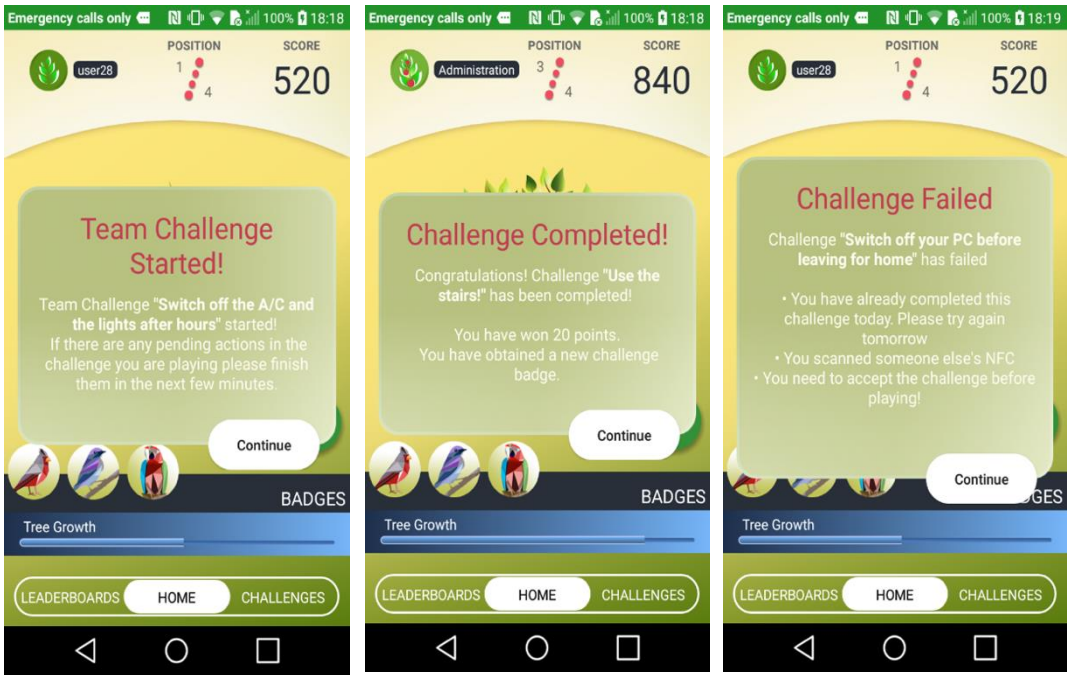


Figure 23: Game feedback

This log is also accessible by the user to be able to track the progress.

Overview of achievements

Detailed info about the user's progress can be viewed at any time. Separate tabs for the user's and team's progress are available. This screen provides various statistics such as user/team scores, titles won and completed challenges.

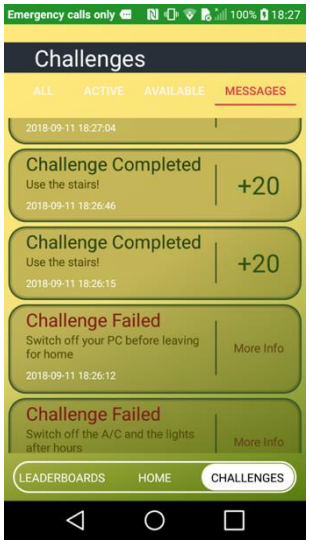


Figure 24: Game Log/History

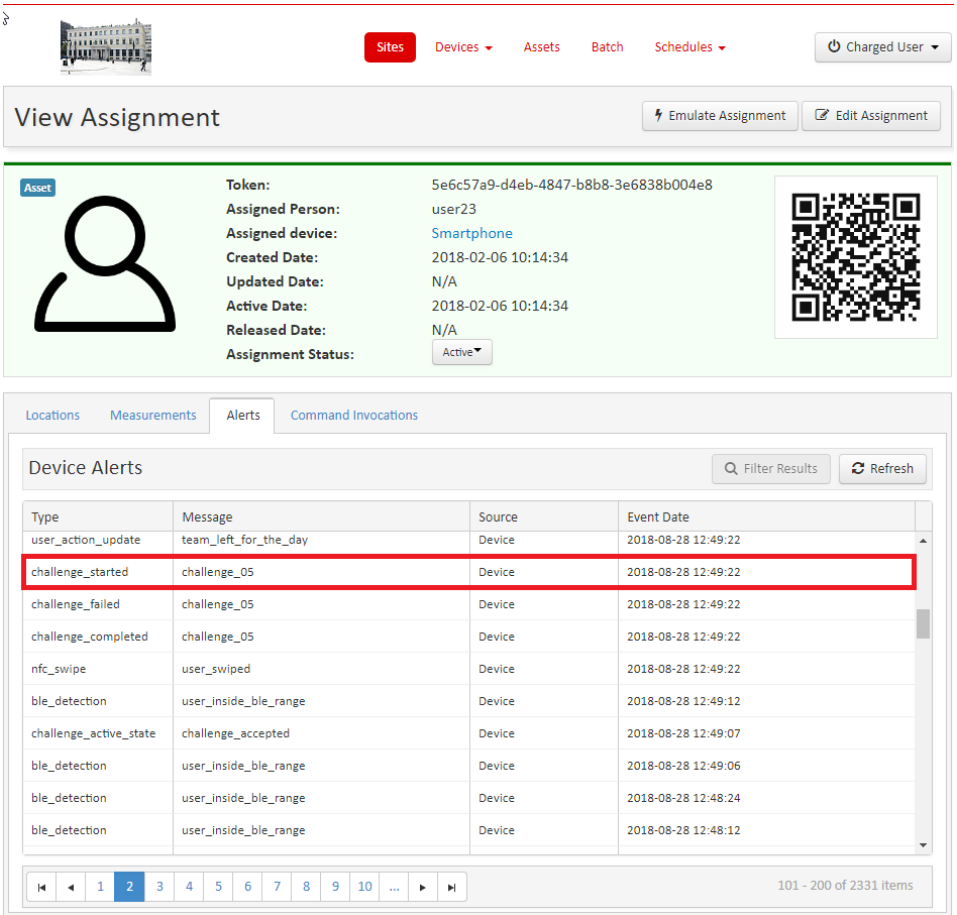


Figure 25: Overview of Sitewhere alerts

NFC integration

Smartphones NFC functionality is exploited to inform the system about specific user actions that correspond to challenges, for example switching off appliances such as desk equipment or monitoring a shared device usage such as a printer. NFCs associated with devices are used by each player by swiping their phones on the especially for this purpose installed NFC stickers on the CHARGED involved devices. By doing this, the energy saving that is identified by disaggregation /analytics engine is assigned to a specific player.

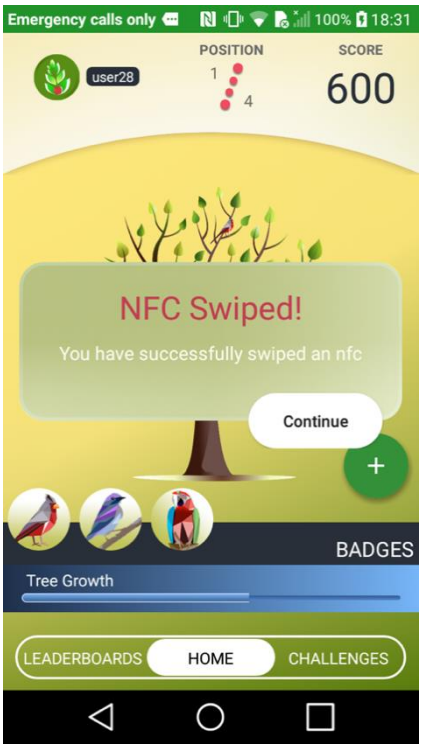


Figure 26 NFC Swiped Message

BLE integration

BLE is used to track the presence of users within a specific part of a building and can be used to distribute energy consumption from appliances which are shared between different users (ceiling lights, air conditions etc). The smartphone detects the closest BLE and informs SITEWHERE about its ID. This information is processed by the Game Backend. All the BLEs are modelled in the system and each incoming ID is matched to a specific location inside the building. Like the NFC this is a separate mechanism used to assign energy disaggregation to a user or a team.

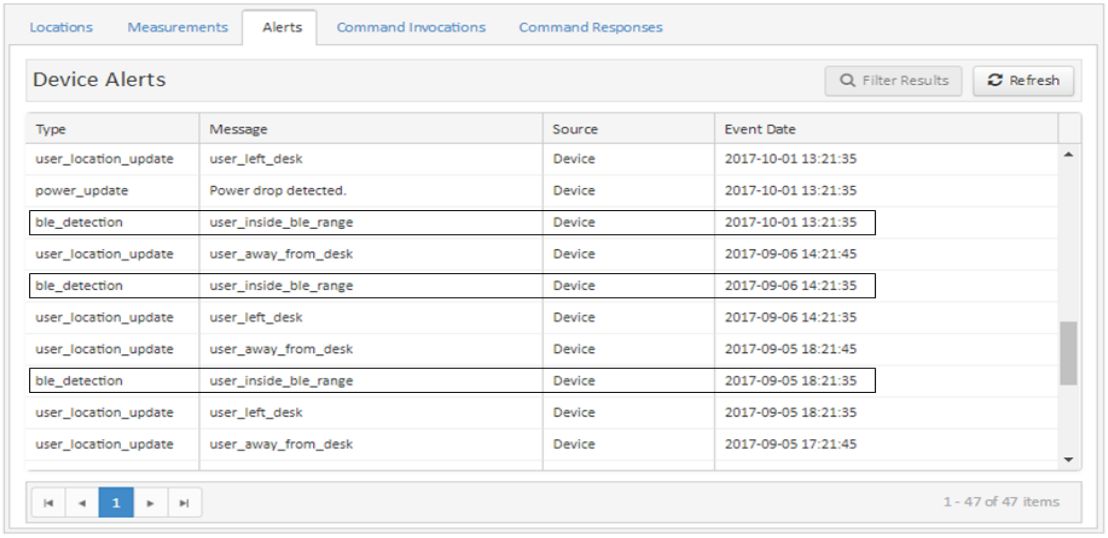


Figure 27 BLE messages sent by the user's smartphone inside SiteWhere

Tips

Another feature that was added in the final version of the game was the "tips" to support on how to play more efficient the game, also contributing to changing the user behavior in the long term.

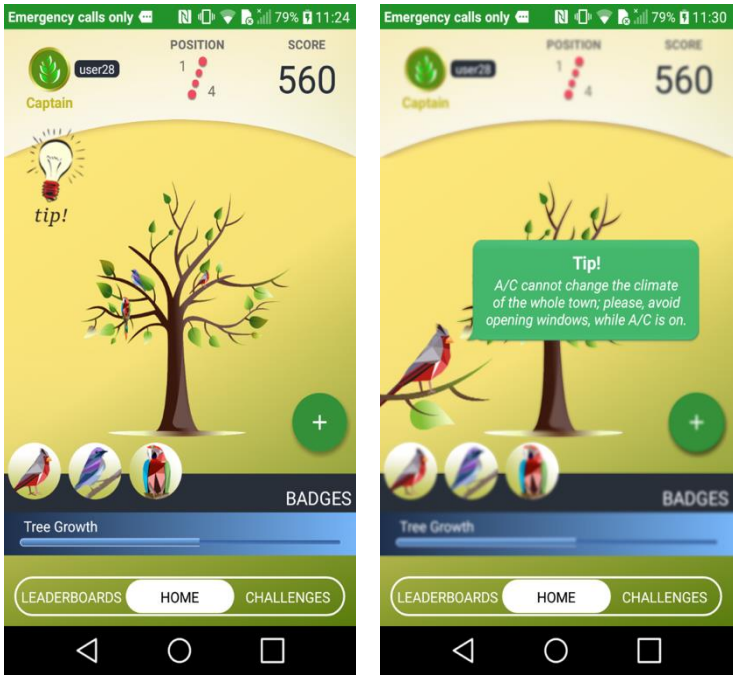


Figure 28 Tips appearing in the game

Other Updates in Game following the validation feedback

The backend system has been designed and developed in a modular way to allow for optimizing its performance, or providing new functionality and even more responsive behavior towards the users.

Particularly, some usage statistics have been integrated to support and evaluate the involvement of the user in the game, its interest to it (by recurring daily logins), the grouping of the game usage data for every pilot to derive conclusions about the local teams activities, etc.

Schedulers have been implemented and secondary helper rules have been assigned to them. These start periodically (at the end of each day, week, or month). The schedulers perform the following functionality:

Firstly, they finish the challenges that need to be evaluated at the end of the day, for example a challenge that has started in the afternoon by a player can monitor the energy consumption till midnight and then decide if the challenge was successful.

Secondly, they keep track and update the game state. For example, the weekly scheduler decides every week the Captain and Deputy of each team based on their performance. Lastly, they perform maintenance tasks i.e. they reinitialize the game data (they reset the daily score, daily challenges completed, etc. and finally the back the game data.

4.1.6 Component for microgeneration Energy Forecasting

The opportunity for a solar micro-generation in ChArGED, is to maximize the advantage of free/clean energy, without storing it, by shifting loads during peak generation time at most beneficial times. The most beneficial use of this component is to plan activities that consume energy when solar power production is maximised or reduce the activities when price of electricity is higher than normal - in future dynamic pricing scenario. Load shifting can be achieved again by altering user behaving via gamification, however, an accurate solar power generation forecast is required to optimize the results and thus a dedicated component was introduced in to the system architecture.

This component utilizes a solar inverter (Kaco) with rich data communication capabilities (over Modbus TCP protocol) in order to monitor the generated electricity and assist the energy production forecasting mechanism which is based on daily weather forecasts. This forecasting is used for directing the game challenges towards optimizing energy use. The solar inverter is connected to the Sensor Gateway with the middleware / IoT integration software mBS SH. Through the device abstraction of the mBS SH the data are sent via MQTT to the ChArGED core platform and from there they are made accessible to all other system components. The Component for Microgeneration Energy Forecasting gets periodically (every day for five days ahead) updated on the specific location weather forecast and provides the hourly forecast of the expected energy. The solar forecast software is connected to 3rd party weather forecast provider APIs for obtaining the weather forecast data (yr.no, wunderground.com, weatherxm.com etc).

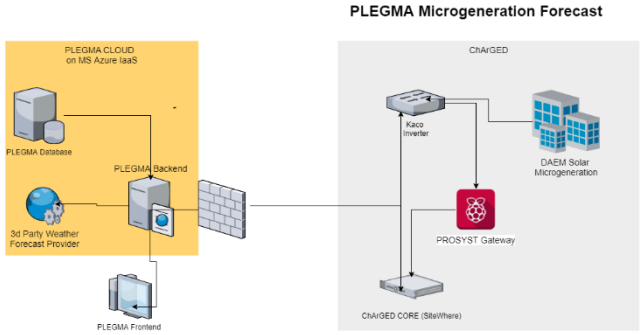


Figure 29 Solar PV Prediction Architecture

During the initial staged of development, various approaches where explored:

a) Forward calculator
   Enriched by weather forecast PV & inverter specs X theoretical solar radiation based on lat/lon & cloud coverage and historical area performance. Apply cloud coverage forecast and temp cell efficiency correction
b) Butler FP7 solar forecast server

http://open-platforms.eu/library/renewables-energies-forecasting-smartserver/

c) Machine Learning

Finding correlations between all weather conditions and actual production on the pilot site.

The first approach (a) was initially considered adequate for the requirements of the project, by all technical partners. The solution was built by utilizing / validating results with data from EUs Photovoltaic Geographical Information System.

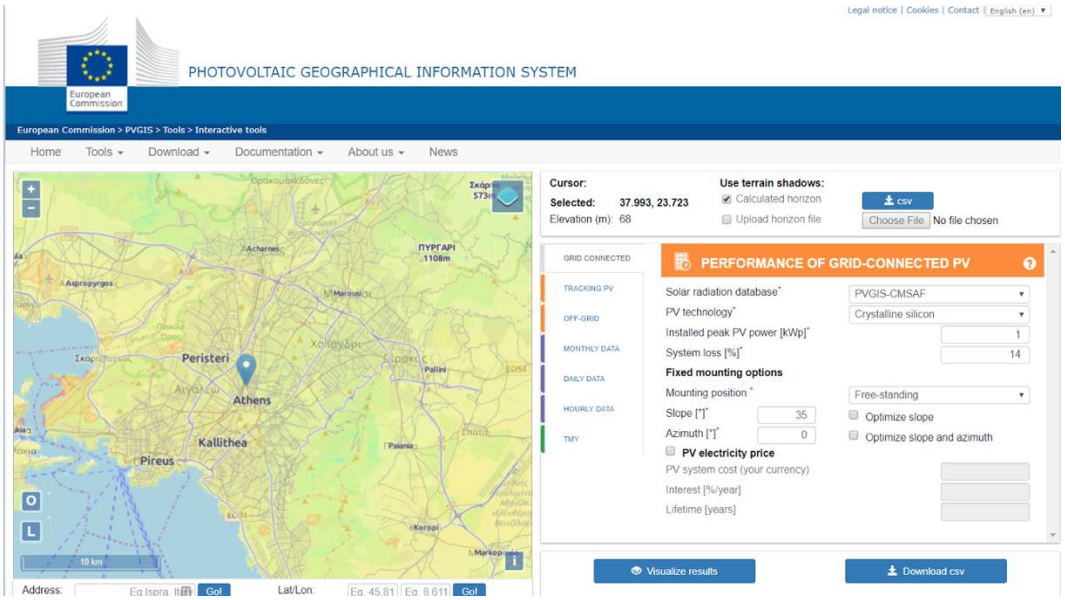


Figure 30: Photovoltaic Geographical Information System

A theoretical yearly forecast was produced for the specific PV system deployed in DAEM and was later corrected utilizing real data from the Kaco inverter and weather data / forecast from YR.NO.

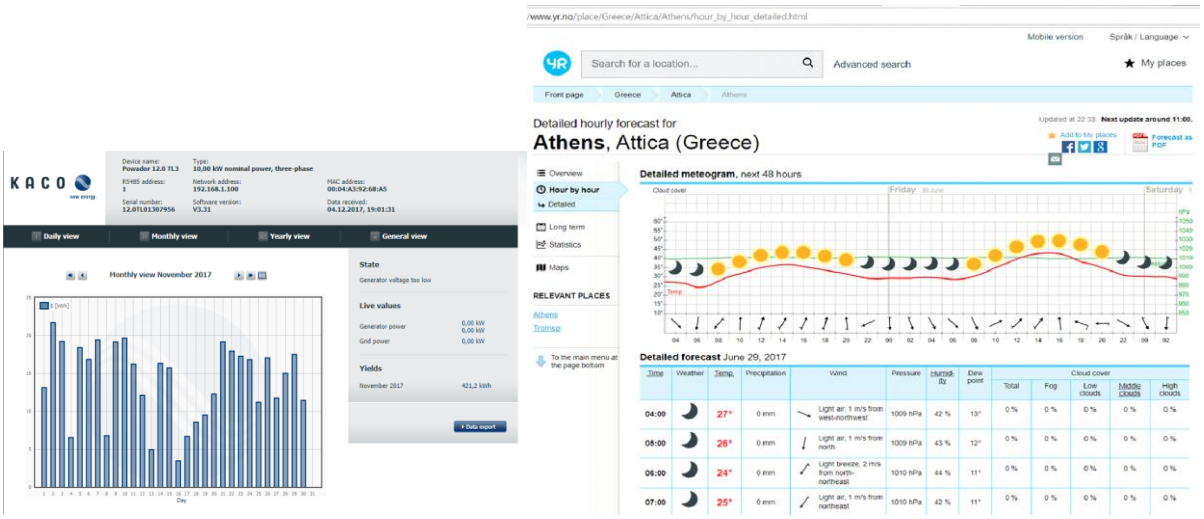


Figure 31 Weather Forecast inputs to the module

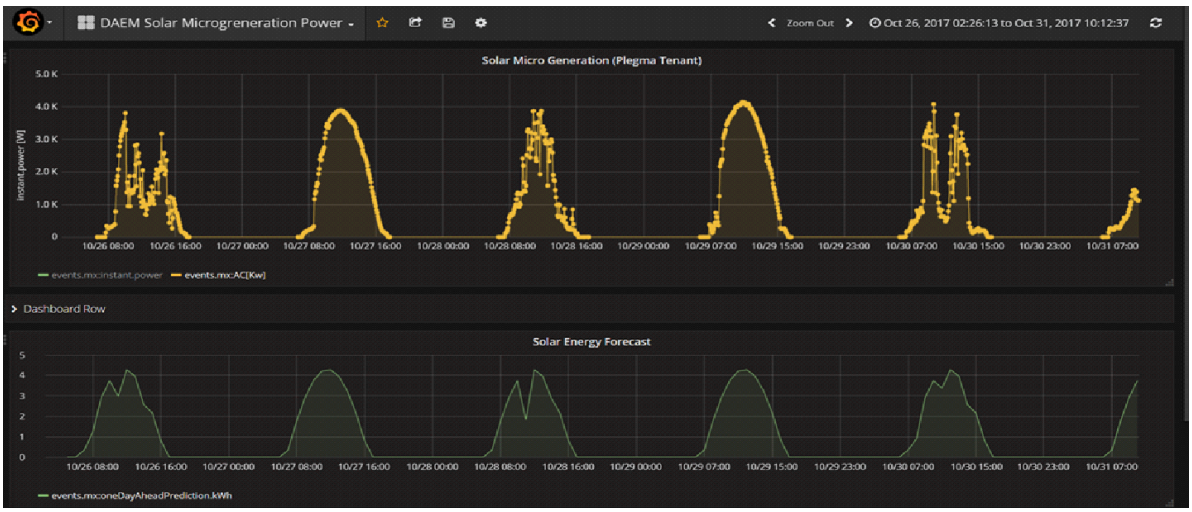


Figure 32 Solar PV Prediction Results

The results of the forecast are submitted on a daily basis to SiteWhere and include the weather data and energy forecast data for the next 48 hours, in hourly intervals, so that any component from SiteWhere can utilize it. Actual energy produced vs forecasted the day before, is plotted in the above figure, using the Grafana quick dashboard capabilities.

5 Integrated (End-to-end) description of Challenges

This version of the game includes other challenges that target specific user groups as already described in the D3.5. The backend keeps track of the users that belong in that group (for example the museum guards) and gives them a specific challenge to play not available to the other players. Examples of these are the museum visitors challenge and the museum guards challenge (including also the control room employees.). These have been added below.

5.1 Switch off your pc before leaving for home

The user is asked to switch off their pc when they leave for home. The system then waits half an hour and checks if the player has left by using the BLEs. If the event of player leaving has been confirmed by the BLEs then the system checks whether the pc has been shut down by evaluating the electricity consumption. If the pc is off then the challenge in completed. The process is as follows:

The user selects the appropriate challenge from the mobile app

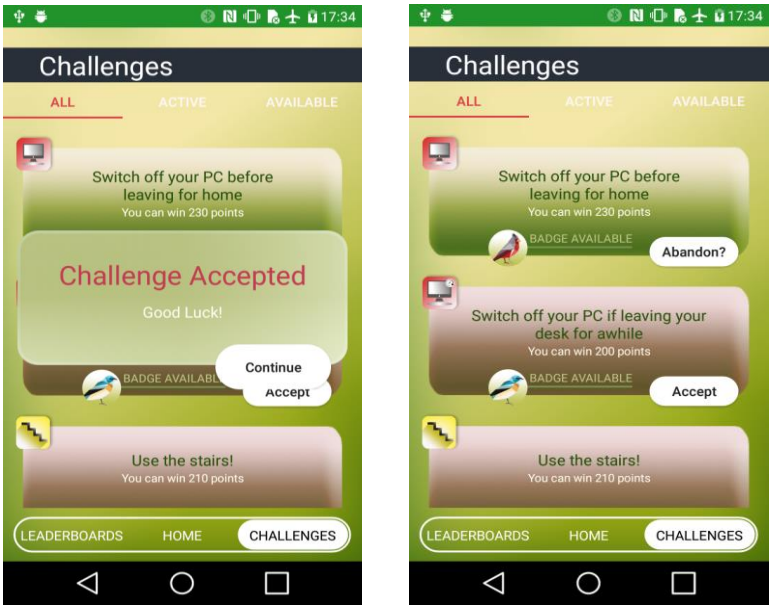


Figure 33 User Selects a Challenge

User Swipes the NFC

The user swipes the NFC attached to the desk. This even is recognised by the game, which informs SiteWhere with the other relevant information (i.e. date and time the event happened, username, and identifier for the smartphone that produced the alert etc.). The PC on the desk is paired in the system with the corresponding NFC which lets us match the action being performed to the appropriate device.

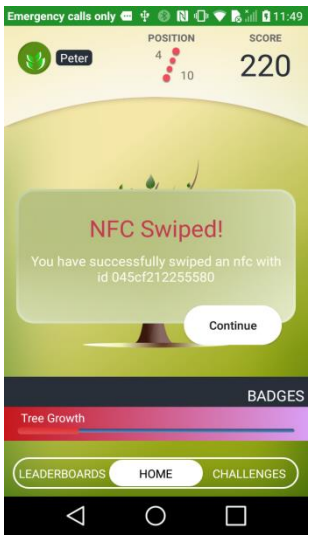


Figure 34 User Swipes NFC tag

Alert Received by the System

Inside SiteWhere a relationship has been declared which allocates players to smartphones. Thus, when an event is received by a specific NFC, the Game Backend queries the relationships identifies the players who did the NFC swapping. The following screenshot presents the pairs of players and phones (example).

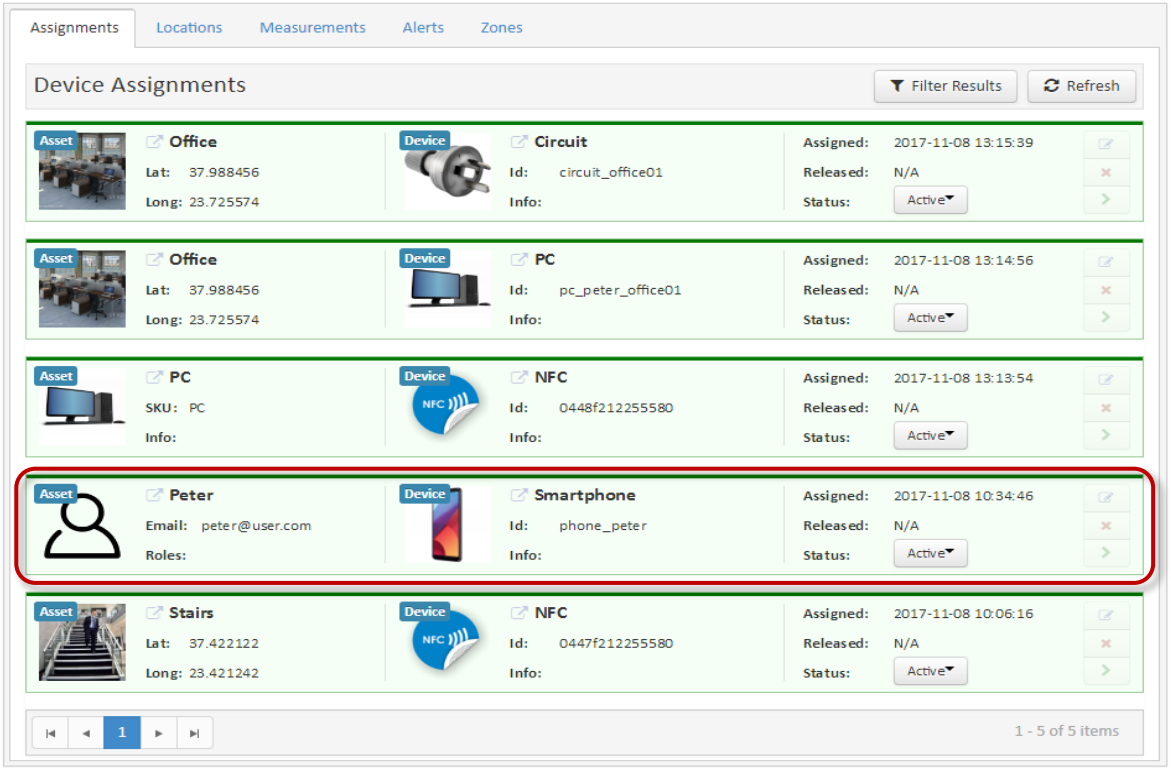


Figure 35 User Model Inside SiteWhere

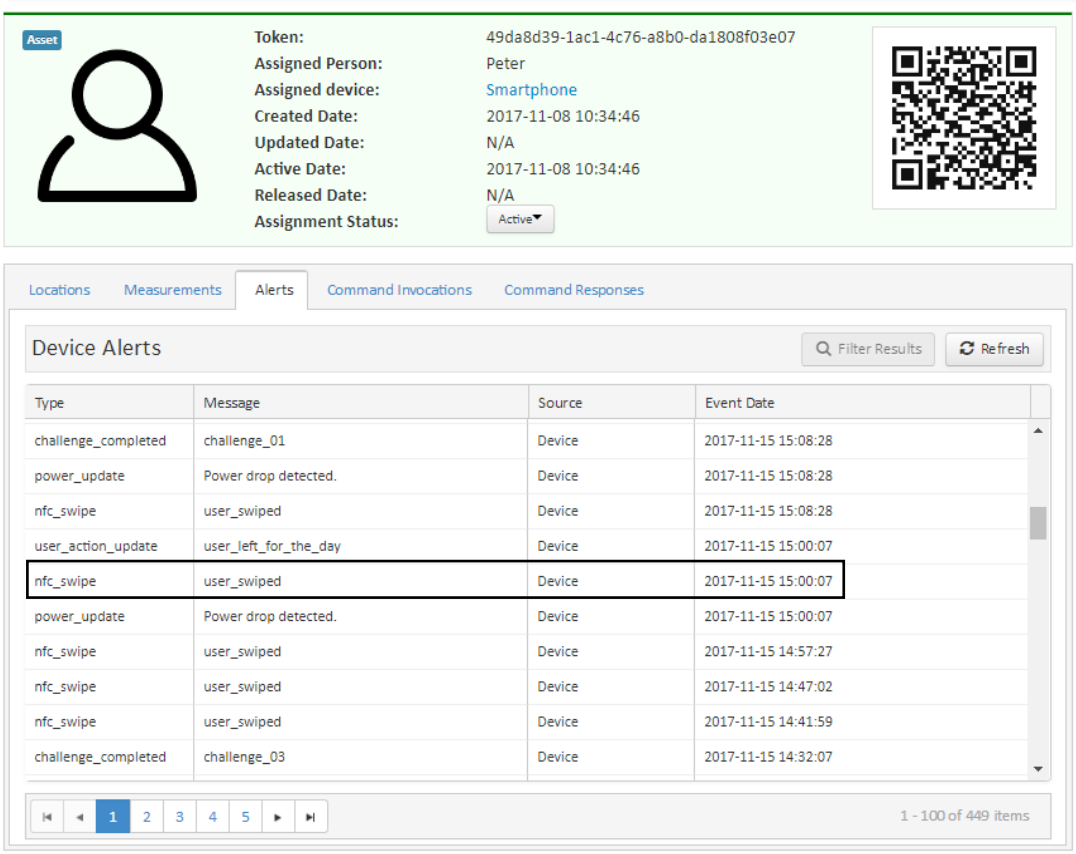


Figure 36: NFC Swipe Event In SiteWhere

Alert Processing

Each alert received by the Game Backend is processed and matched to the specific challenge (using data from the system and the time of the alert). When the challenge is identified the game backend communicates with the energy analytics to confirm that the event i.e of shutting down the PC has been identified. For this the measurements for the specific PC are retrieved by the energy analytics which then confirms the power drop in the electricity consumption. If the energy analytics confirm the power drop matching to the event of PC shut down (Fig. 33), the challenge is considered completed. The entire communication is stored in SiteWhere (see Fig. 34).

Figure 37: PC Electric Consumption

Error! Reference source not found.

Figure 38: Messages Exchanged by the System Components

Challenge Completion

When the event "PC has been shut down" has been recognised the system checks whether the user has left the building and then the game backend sends a "challenge completed" message to the app and assigns points to the user and a challenge badge. It also stores the results on the database and updates the game data in the system. If the user achieves enough points the tree will also grow to the next stage.

5.2 Switch off pc if leaving your desk for more than 30min

When a user leaves the desk (detected by means of BLE), a new message is sent by the app to the backend. The time is then measured and if half an hour passed and the user has not returned to their desk, then the power consumption of the user's desk is processed at the time the user left. Then, by detecting the drop in the electricity consumption, we deduce if the user closed their pc and if yes we the challenge is completed. When testing the challenge a large number of inaccuracies were caused by overlapping signals from BLEs in neighbouring offices. This made it hard to accurately detect if a user was in their office. Therefore the BLEs were not any more installed inside each room. Now less BLEs were used (3-4) to cover the entire shopfloor. This was decided after measuring the signal strength which was now improved. These BLEs covered more area (a few offices were covered by each BLE) in an attempt to reduce overlapping. In the end, similar issues were encountered and the challenge was deactivated because the challenge outcome could not be deduced with enough accuracy.

User leaves/returns to desk

One way that has been adopted to reduce the scanning for the user, was the use of BLEs. When a user leaves or returns to his desk the event is detected by the mobile app with the help of the installed BLEs. The alert is then sent to SiteWhere.

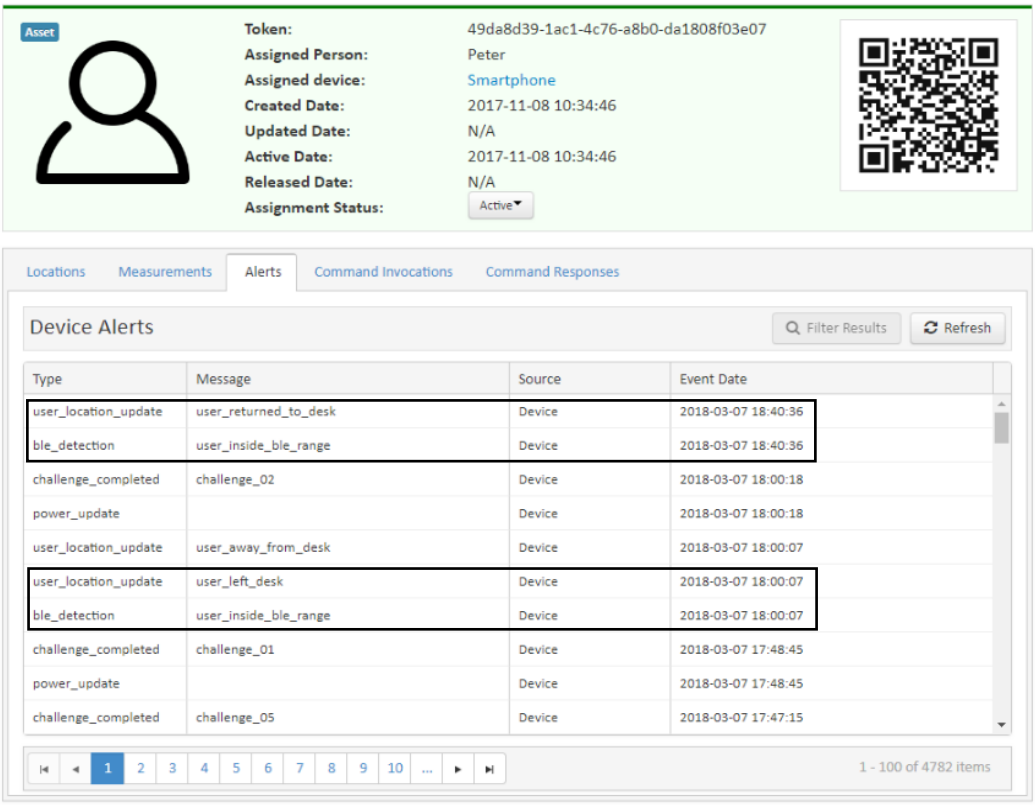


Figure 39: User leaving and returning to his desk has been identified

Alert processed by the system

The game backend waits 30 minutes and then informs the system that the user is away. The energy analytics processes then the measurements from the users pc and returns a power alert with the drop in the electricity consumption the game backend then evaluates the result and decides if the use has closed the pc and if yes the challenge is completed.

5.3 User is directed while using the stairs

An NFC sticker is placed in the middle of each flight of stairs. When users climb the stairs instead of an elevator they scan the NFC to inform that they did so. This challenge can be played multiple times per day but a time period restricting the repeated scanning is imposed (for example 5min).

Alert processed by the system

When the user scans the NFC a specific alert is sent to the system and matched to a specific user. Here there are no electric power measurements to evaluate so the event indicates that the user used the stairs and thus completed the challenge.

5.4 Close the windows if the A/C is on (Team)

In this challenge the players are asked to close the windows if they turn on the A/C. An inductive proximity sensor is placed on the windows of the room. When someone closes or opens the window an alert is sent to the system. The backend validates if the A/C was off while the window was open. If yes, the challenge is completed and all the users working in the same room are awarded points and the challenge badge.

User selects the appropriate challenge from the mobile app

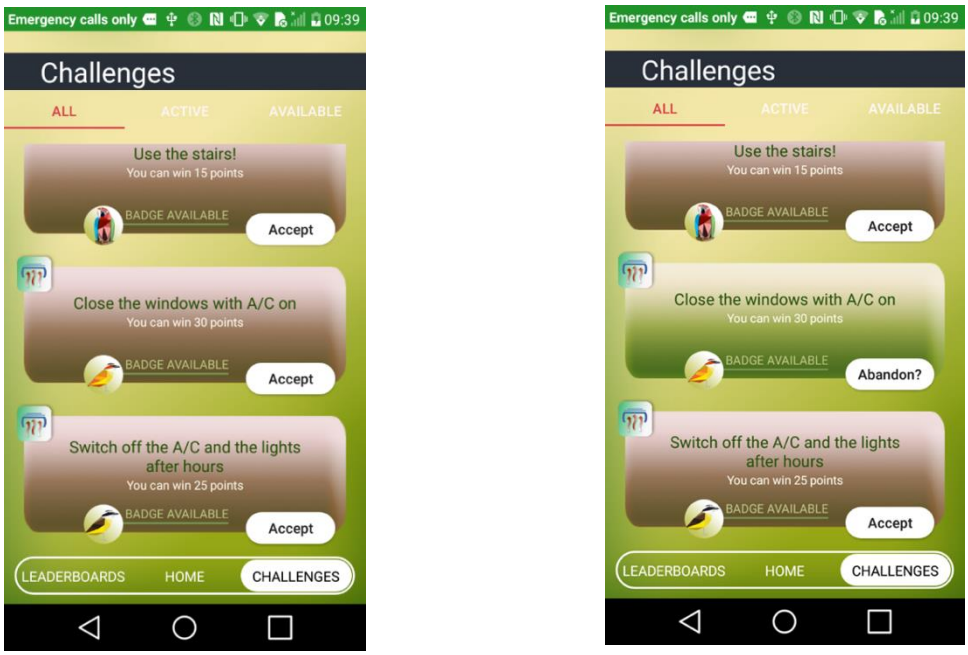


Figure 40 User Accepts the Challenge

User opens or closes the window

When a user opens or closes a window the change is detected by the magnetic window sensor. The sensor communicates with the gateway which sends an alert to SiteWhere.

Alert Received by the System

Inside SiteWhere all the window sensors are assigned to specific rooms and the teams that work in these rooms. Every new alert from the real sensor is sent to a modelled sensor device as seen in the figures below:

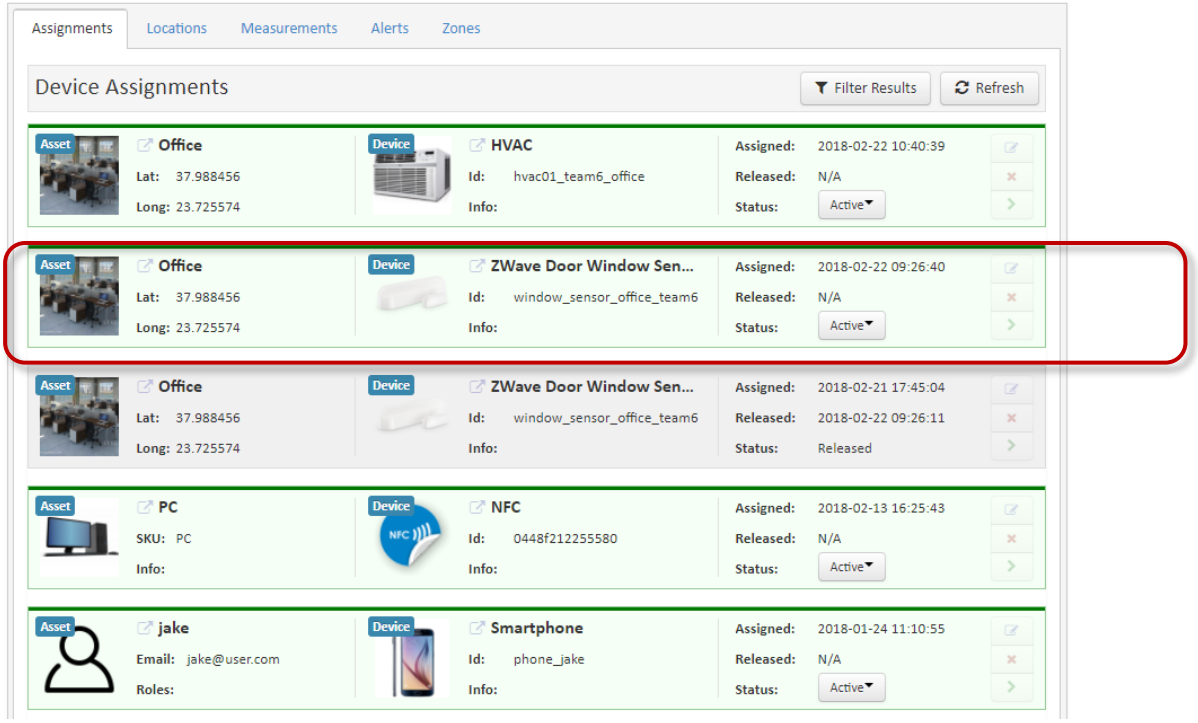
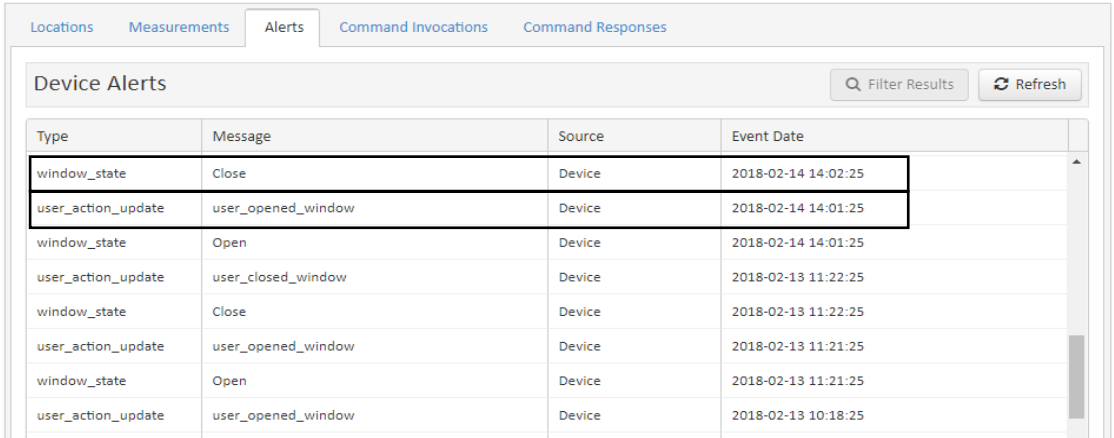


Figure 41 Sensor Device in SiteWhere

The Game backend processed these alerts and produces a user action update message read by the energy analytics.



Type	Message	Source	Event Date
window_state	Close	Device	2018-02-14 14:02:25
user_action_update	user_opened_window	Device	2018-02-14 14:01:25
window_state	Open	Device	2018-02-14 14:01:25
user_action_update	user_closed_window	Device	2018-02-13 11:22:25
window_state	Close	Device	2018-02-13 11:22:25
user_action_update	user_opened_window	Device	2018-02-13 11:21:25
window_state	Open	Device	2018-02-13 11:21:25
user_action_update	user_opened_window	Device	2018-02-13 10:18:25

Figure 42: Sensor and Game Backend Alerts

Challenge Completion

By the end of the day the energy analytics calculates the amount of energy that was used by the A/C units in the room while the window was open as well as the energy savings (if any) achieved during the same period. This information is sent back to the Game Backend which decides if the energy

consumption detected was low enough to indicate that the A/C was closed. In these cases all the users in the room are awarded points and get a challenge completed message in their smartphones.

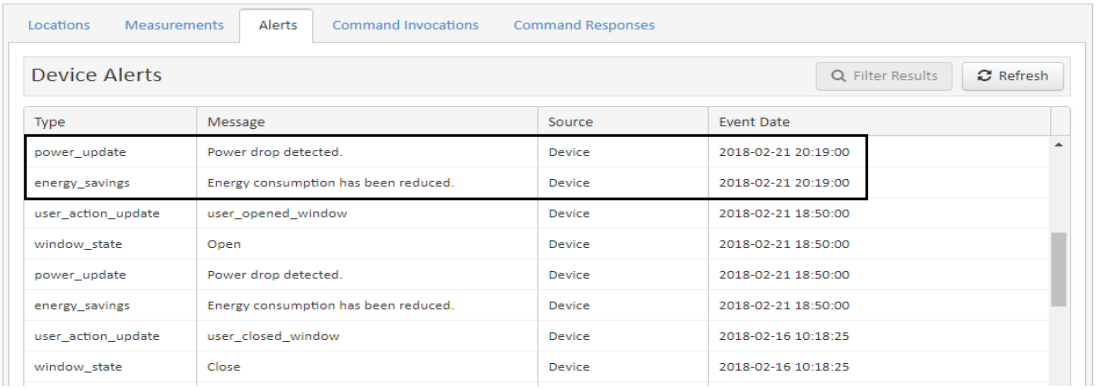


Figure 43: Energy Analytics Alerts

Figure 44: A/C electricity consumption measurements

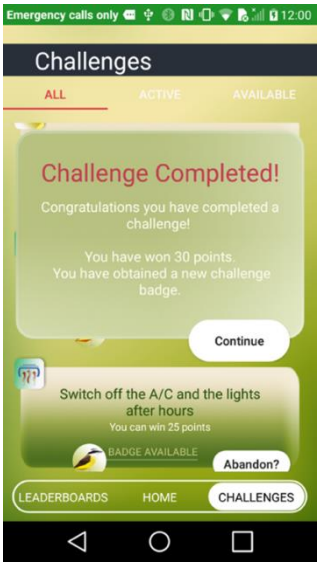


Figure 45: A/C electricity consumption measurements

5.5 Switch off the A/C and lights after hours (Team Challenge)

In this challenge the person leaving the room at the end of the day is asked to turn off the A/C units and lights. This is a team challenge so when successfully completed all the users belonging to the same team are awarded points.

Alert processed by the system

An NFC is placed at the exit of each room close to the light switches. When the last user leaves they can scan the NFCs and turn off the A/C and lights. A new event signifying that the user scanned the NFC on the room is sent to the Game Backend. This event is then identified as corresponding to the users having left for the day. The Energy Analytics then calculates from the measurements if the devices have been turned off and the game backend also checks if the users left, by using the BLEs. If yes the challenge is completed and each player of the team is awarded points. To detect if the lights and A/Cs have been closed the check of the consumption of the circuits from the time users left till then takes time at midnight. For the energy consumption the evaluation is happening at midnight where the whole consumption of the circuit is measured from the time the last user left.

The ChArGED system keeps statistics of the current game state. The users have the possibility to access different screens on the app to get an overview of their own , as well as their team's current progress.

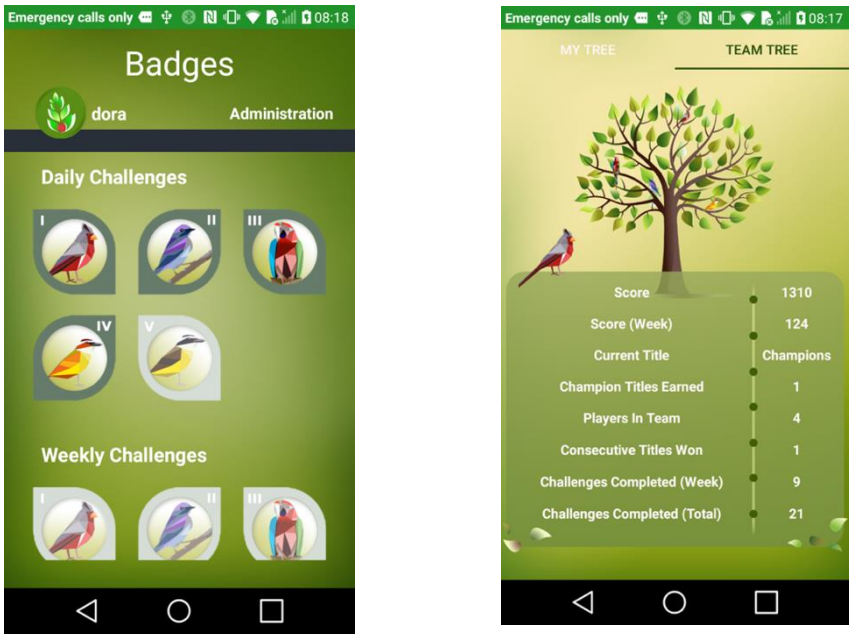


Figure 46: Badges and progress overview

5.6 MNHA Specific Challenges

MNHA pilot for the visitors and for the guards (and control room personnel) have been designed and developed in the final version.

a. Visitors Challenge

In this challenge, a visitor together with the purchase of the ticket is invited to contribute to the energy saving initiative of the MNHA. The specific designed card with the NFC tag at the entrance of the museum is offered to them. Then, the visitors are motivated to use the stairs and avoid the elevators. Each time they climb a floor, they scan the frames that have been placed at the stairs. These include a smartphone with the mobile app for the visitors and a label to indicate where to scan their NFC card. Each time they scan, the visitors' tree grows, indicating the progress of the game. When the visitors return to the exit with the card, the points are checked and a reward is offered by the MNHA.

The end-to-end process for the integration of the visitors' challenge is depicted in the figure below:

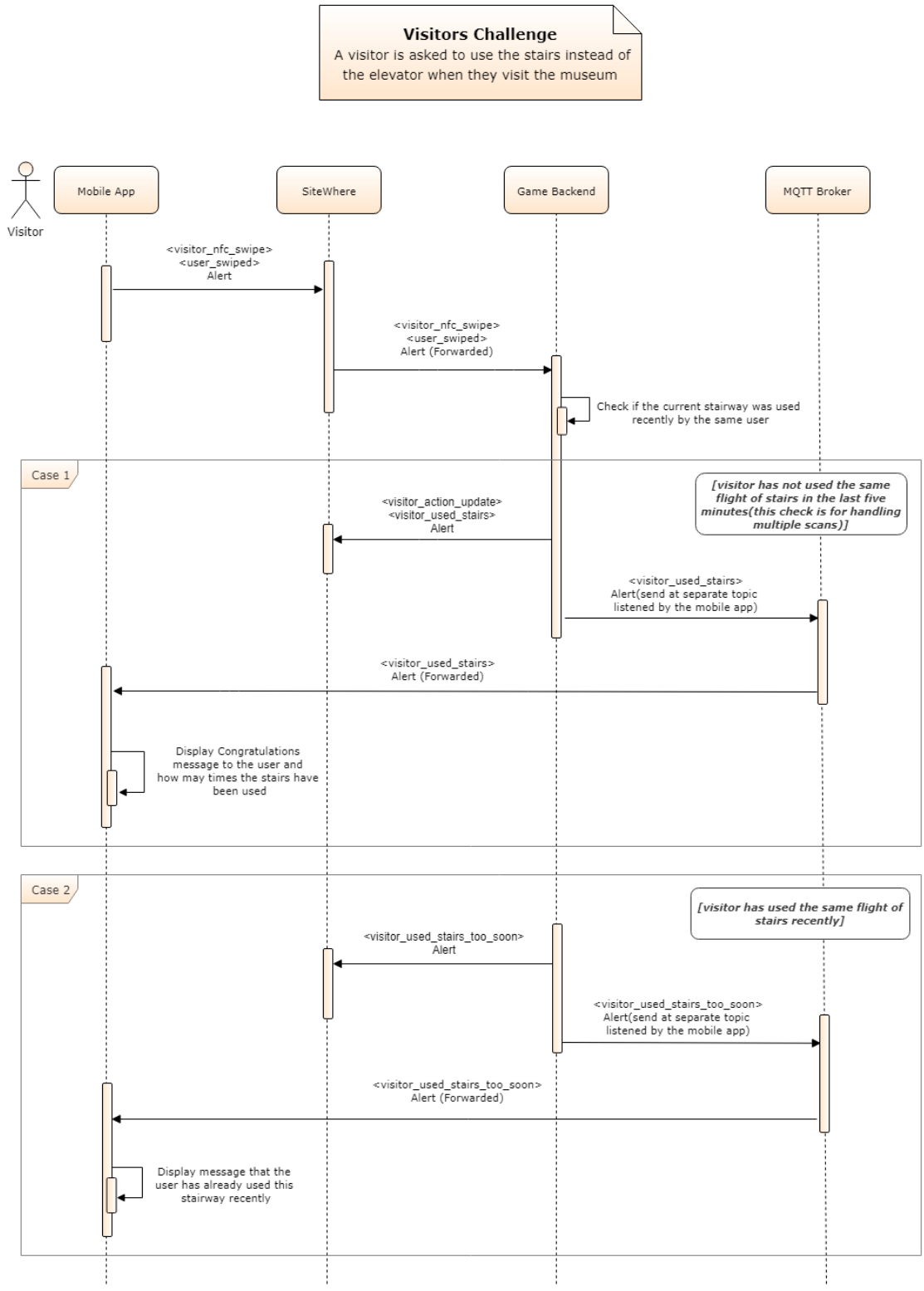


Figure 47: End-to-end process of the visitors' challenge

Each time they scan they are informed about the time they have used the stairs and their tree grows. To prevent multiple scans each visitor is allowed to scan on a frame on a specific stairway once every 5 minutes.

Figure 48: Visitors Challenge App

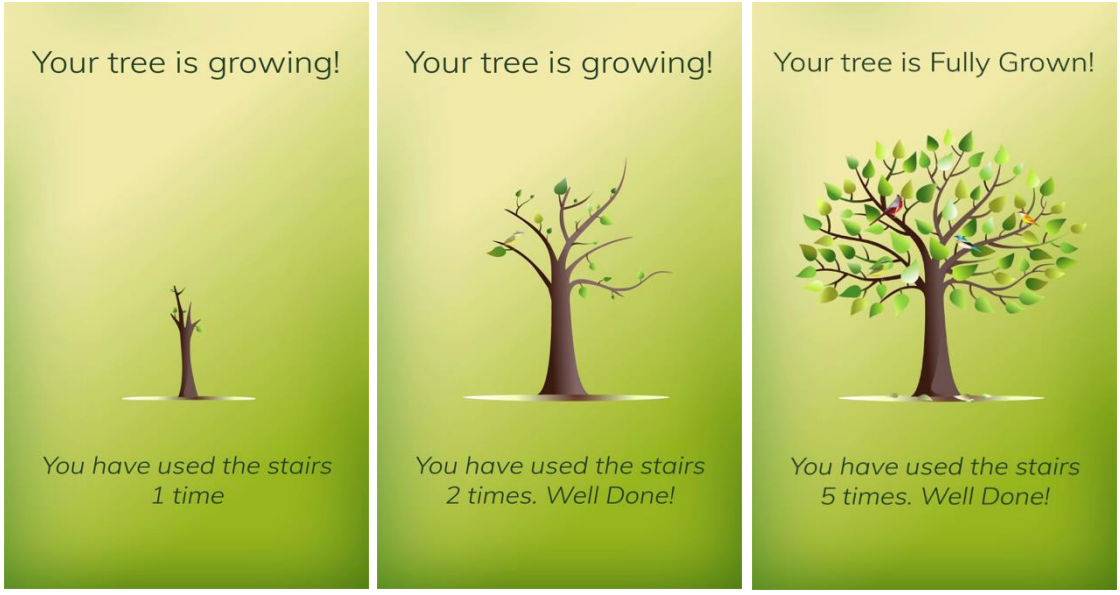
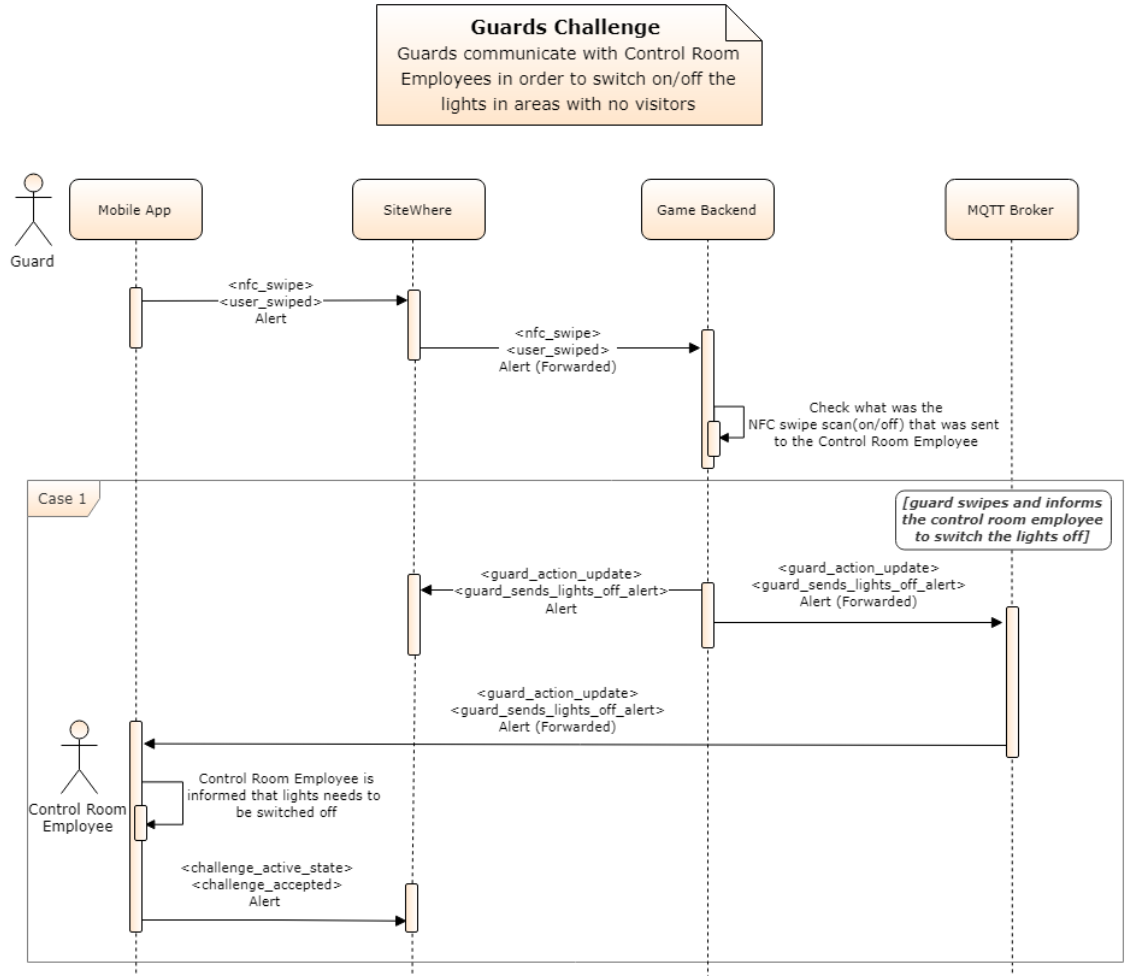


Figure 49: Visitors Challenge App Tree Growing

b. Guards' Challenge

This challenge is played based on the good cooperation and communication between the guards and the control room employees. This challenge aims to address a big energy saving opportunity as the lights of all the exhibition areas are turned on during the visiting hours. The guards are offered the task to inform the control room to turn off /on the lights in areas where there are no visitors /visitors are coming. This message is transferred by scanning the NFC off/on tags in each area. Then, the control

room employee receives the message from the guard and switches off the lights. In the other case, when there are visitors who are intended to enter to a specific room, the guard scans an “lights on” NFC tag which informs the control room to switch on the lights. At the end of the day the actions of all the players that participated in the challenge are evaluated and points are assigned according to the number of “switch the lights off” events that have been sent, as well as the actual time the lights have been switched off.



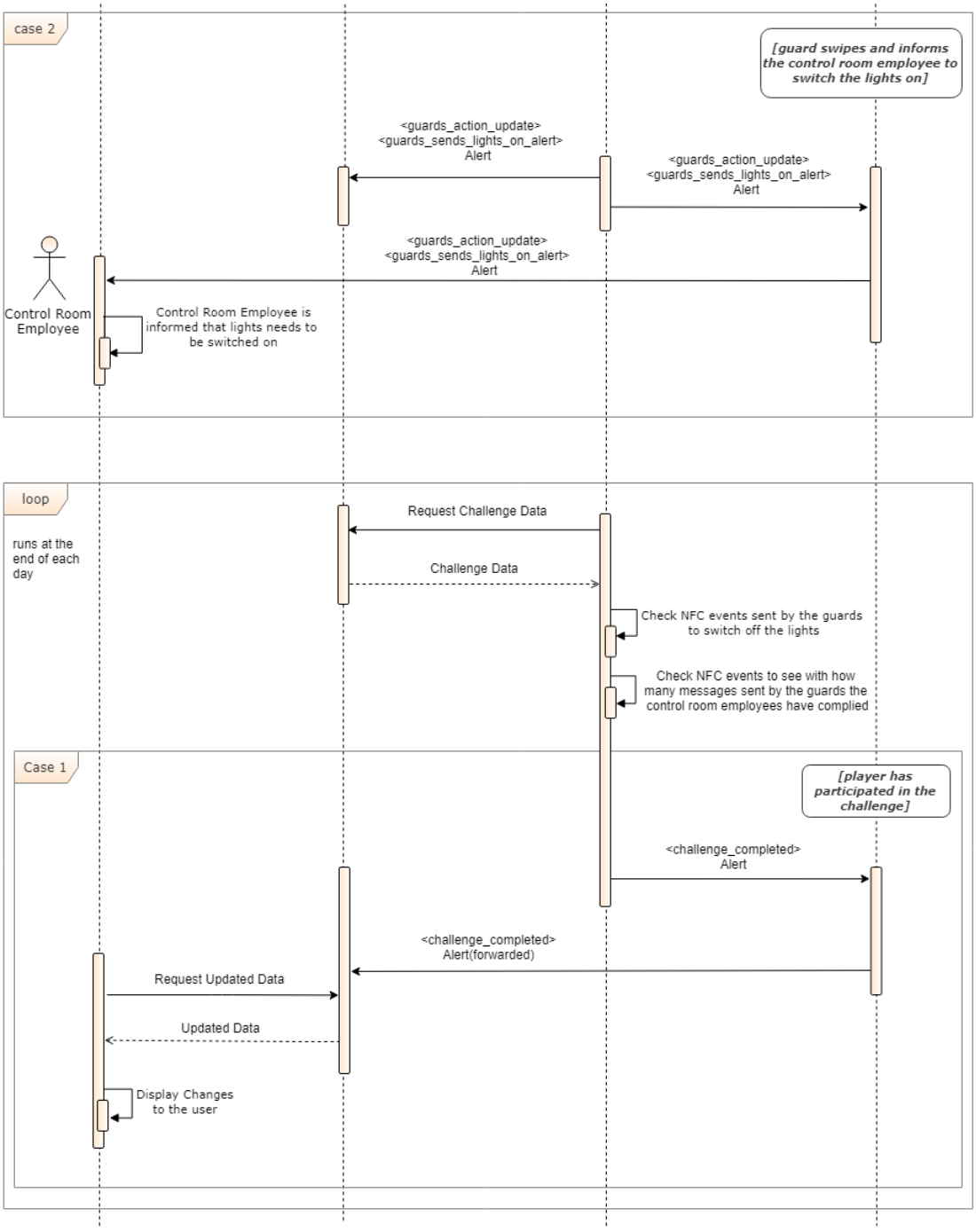


Figure 50: End-to-end process of the guards' challenge

5.7 Solar Challenges - DAEM

In DAEM a solar panel has been installed which gives the possibility to implement unique challenges utilizing the produced energy. These challenges aim to incentivize users to reschedule the things they do during the day that use electricity to a time when there is free energy available from the panel.

Weather Forecast

The weather forecast is continuously retrieved each day by a separate module and fed to the backend. The backend then analyses the data to find the time windows during the day that the energy production from the solar panel is expected to be high (not very cloudy sky/high temperature). This information is communicated to the users so they can reschedule their activities, if possible, (i.e. printing, charging their cell phones, using the A/Cs) during these time slots.

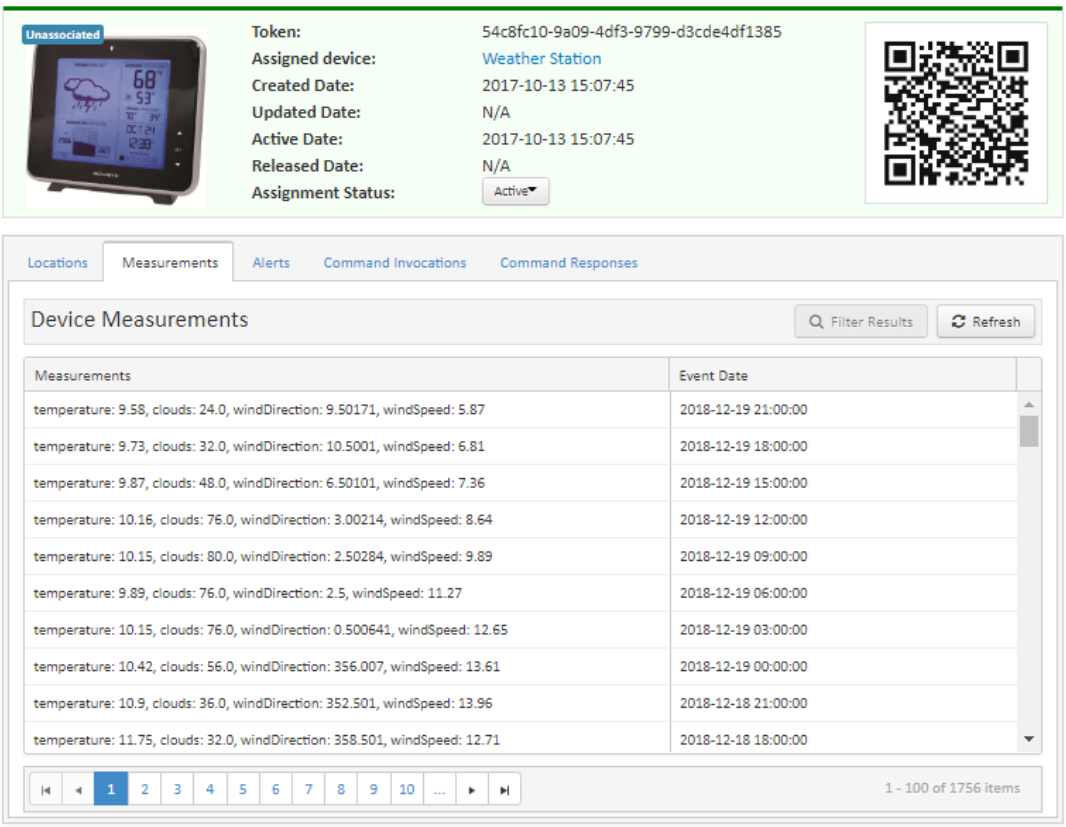


Figure 51: Real time data gathering for weather forecast

Current Solar Production

The current production of the solar panel (kW produced) is also continuously monitored. The users are informed when energy is produced so they can start using their appliances. When the energy production drops, a similar notification is sent to inform them that from now on the electricity consumed will be from the grid.

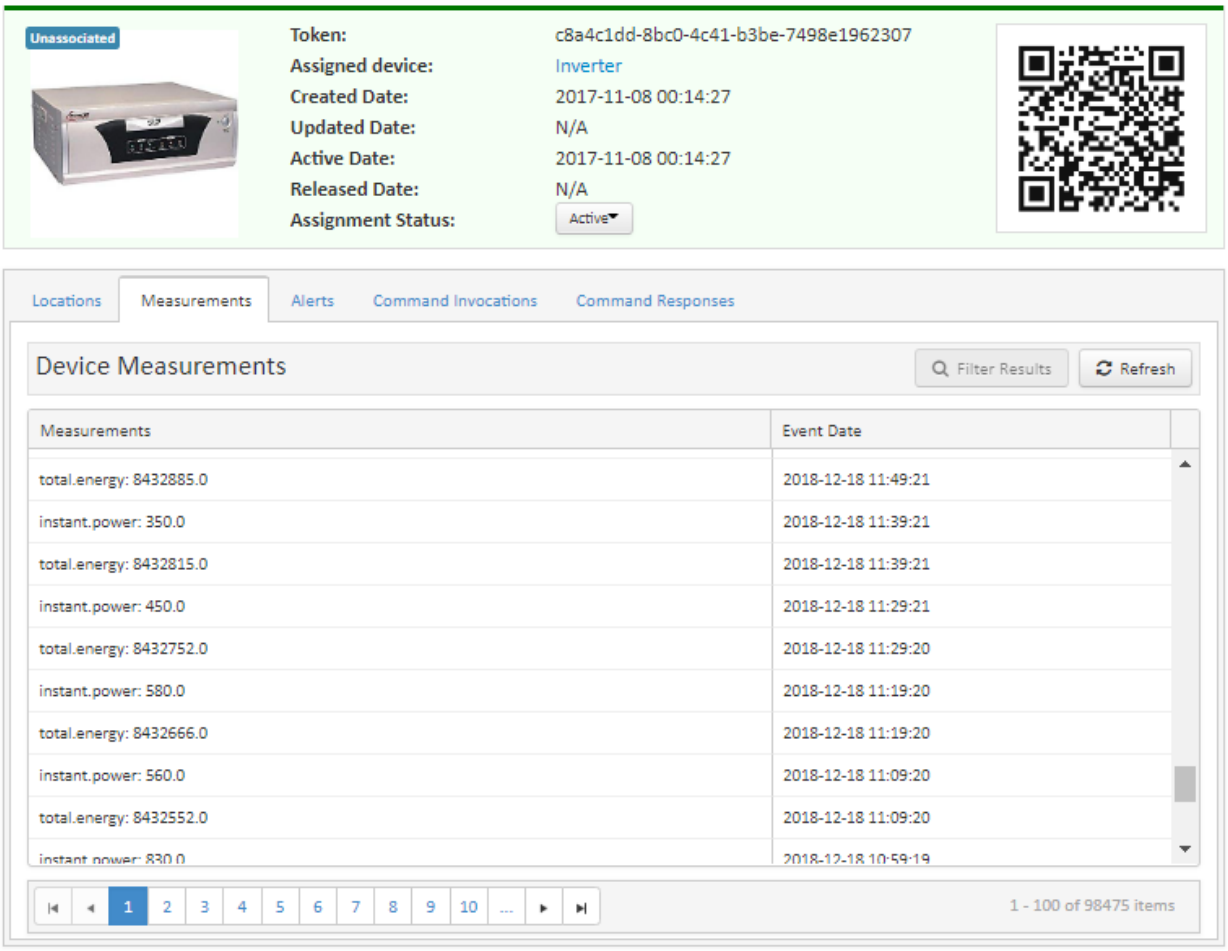


Figure 52: Actual energy production from solar panel

App Screens

The players receive the above information through the app. A separate icon has been added to the Home screen that when tapped displays more information for the solar panel. When the icon is grey it means that all the electricity currently produced by the solar panel is currently consumed by the already active devices in the building. If the icon is displayed in color then this means that there is excess power that could be used to power devices for free.

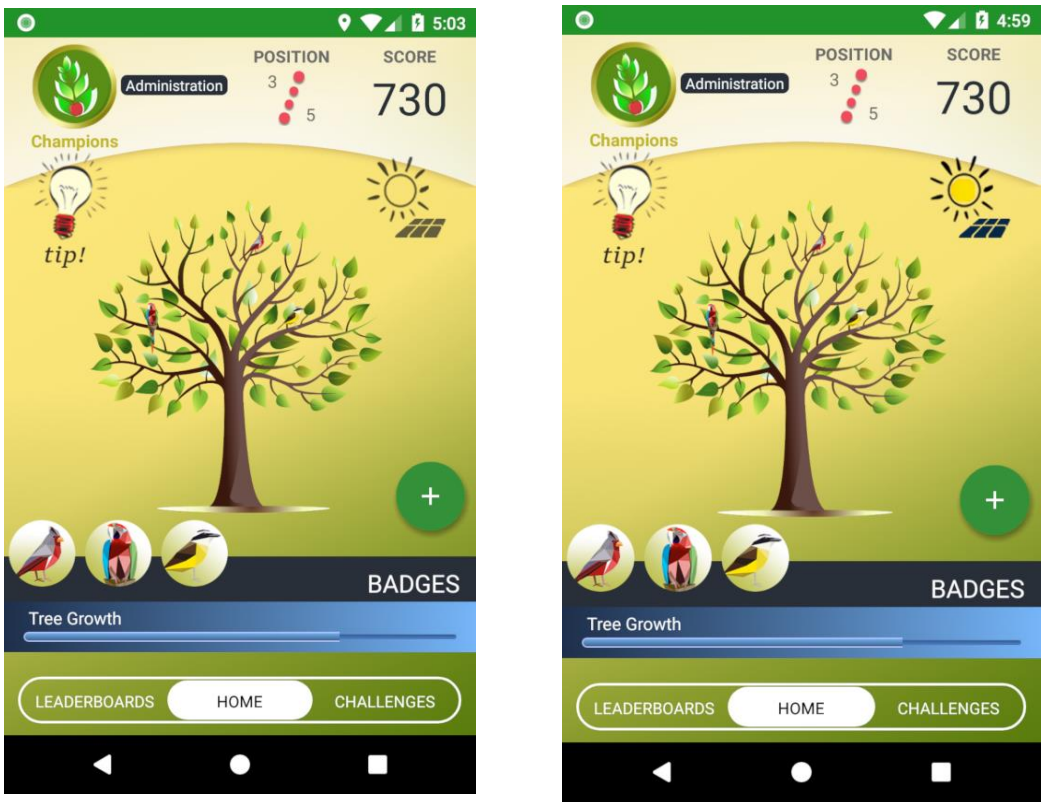


Figure 53: Solar Icon States

When the players tap the icon they receive more information regarding the current electricity production from the solar panel and a message describing the current state. On the top of the popup the predictions of when we expect to have high production (sunny weather) are displayed, which have been made using the weather forecast. These predictions are per hour for the current and next day and can be used by the players to reschedule their tasks. Then using the live feed in the same popup they can be sure when the solar has available power (in the case the prediction has some deviation).

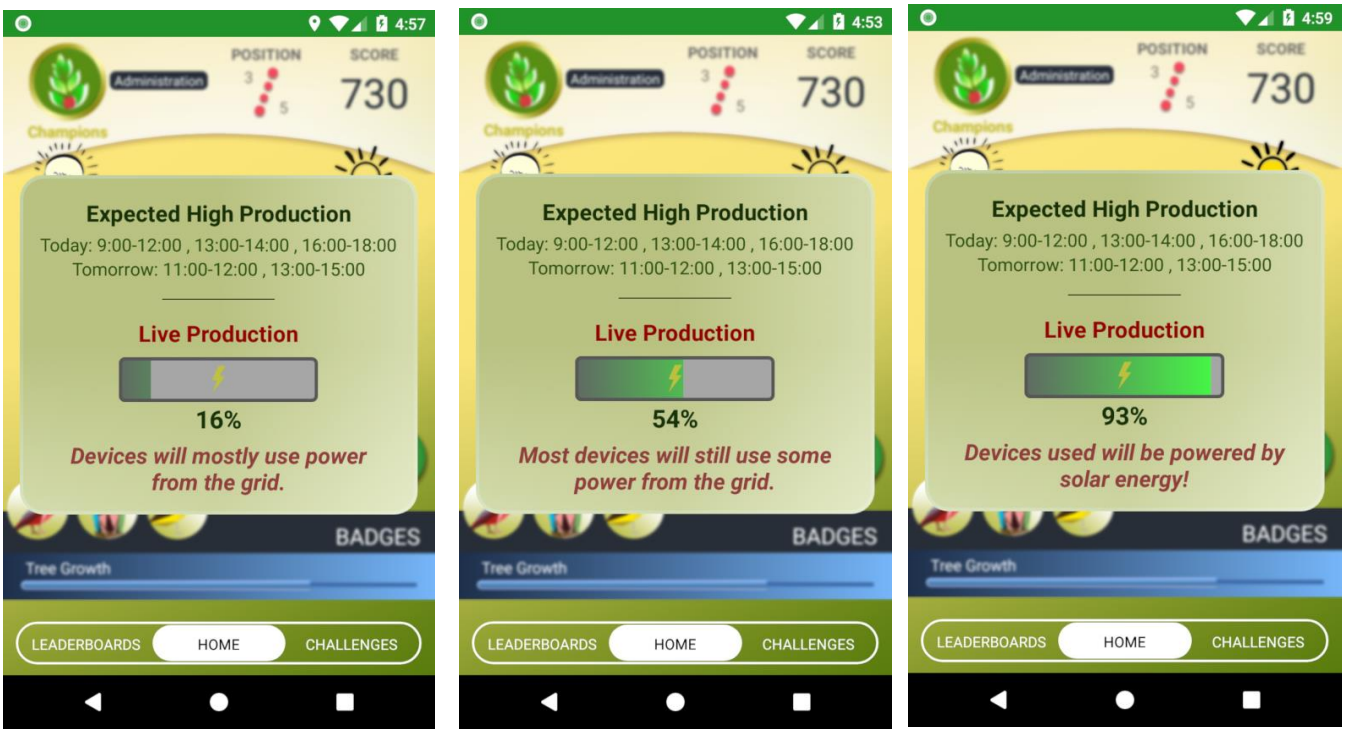


Figure 54: Solar Panel Information

Challenge Completion

The challenges presented in previous sections aim to reduce energy waste by incentivizing specific energy-conservation behaviours. The solar challenges involve rescheduling of irreducible loads related to everyday tasks, e.g., a long printing job, the use of the microwave (or other kitchen appliances), using the A/Cs or charging their phones when solar energy production is high. Using the weather forecast, the players can get a rough estimation of the time of day where it is most likely that energy from the solar panel is higher. When weather forecast is inaccurate (as it happens sometimes), the real solar-panel production is used to inform the user if energy is currently available, so they can start using devices. The players can start challenges by activating them from the app and scanning NFCs on each device that they are going to use (for example an NFC on a printer or an A/C). The game and energy analytics analyze all these events as well as the consumption of the circuits. If a user plays a challenge when there is in fact solar energy available and energy consumption for the device scanned is detected the user is considered to have saved energy and the challenge in completed. The user is then awarded points for them and their teams as well as challenge badges.

5.1.8 Rewards

Points are calculated after any successful challenge completion the user receives points and the daily challenge badge. The challenge badges appear at the badges section and the birds appear on the tree. The points are added to the users and the users' team scores. The home screen can display two different versions of the tree one that belongs to the user and one that belongs to the team.

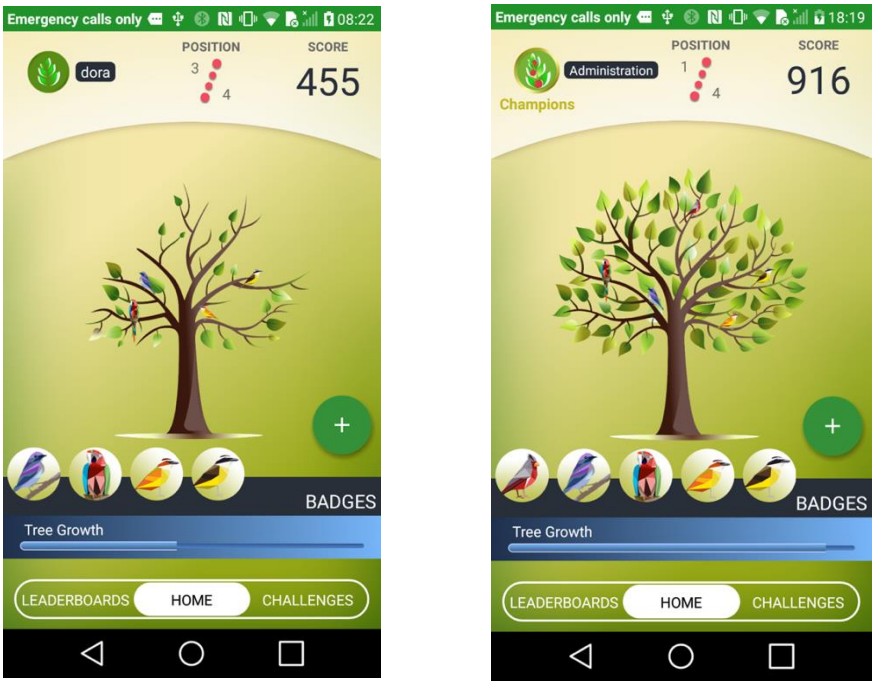


Figure 55 Users receiving rewards at individual and team level

6 Conclusions

The deliverable presented the description of the final Charged integrated system, along with an overview of the ChArGED approach, the game concepts, the related use cases and challenges that are addressed with the integrated system. The entire spectrum of the challenges that have been implemented have been presented. The new features that have been added following the users' feedback have also been presented. This is the version that is now being validated in full scale by all employees, visitors, guards and control room personnel.

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8 Annex Deployment plan

H2020 – EE – 11 – 2015

Research Innovation Action

CleAnweb Gamified Energy Disaggregation

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Deployment Instructions

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Contributors:	European Dynamics Bosch Software Innovations Wattics AUEB Plegma		
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Executive Summary

ChArGED solution is based on a complex architecture and combination of technologies, protocols and sub-systems. This document provides a summarized, simplified overview of the steps required to deploy the ChArGED solution and each specific component.

Table of Contents

1 Introduction 6
2 Hardware components / sensors 7
2.1 Architecture overview 7
2.2 SiteWhere Server 8
2.2.1 Asset Modules 10
2.2.2 Object Model 10
2.2.3 Sites - Buildings 10
2.2.4 Zones - Rooms 11
2.2.5 Device - Appliance Specifications 11
2.2.6 Devices - Appliances 11
2.2.7 Device - Appliance Groups 11
2.2.8 Device Assignments 11
2.2.9 Device - Appliance Events 11
2.3 Solar Microgeneration Inverter 12
2.4 Multi-channel smart meters 12
2.5 Gateway and zwave controller 14
2.6 zwave smart plugs 15
2.7 zwave window contact sensors 15
2.8 zwave 4in1 sensors 15
2.9 NFC tags 16
2.10 BLE beacons 16
2.11 Smartphone 16
3 Installation Guide 17
3.1 Overview of deployment steps – high-level 17
3.2 Gateway preparation 18
3.2.1 Required Hardware 18
3.2.2 Required Software 18
3.3. Installation 18
3.4 Pairing of Zwave devices 19
3.5 BLE placement 20
3.6 NFC placement 21
3.6.1 Password protect the NFC tags 22

3.7 ChArGED Deployment App 22
3.7.1 Overview 22
3.7.2 Description 22
3.8 Multi-channel meter installation 26
STEP 1: Prepare the meter installation report 27
STEP 2: Provide voltage references to the meter 28
STEP 3: Supply power to the meter 28
STEP 4: Prepare the meter for Rogowski coil or CT connections 30
STEP 5: Deploy the CTs 31
STEP 5: Switch the breaker on to power up the meter 33
STEP 6: Configure the meter 33
STEP 7: Provide network access to your meter 34
3.9 SiteWhere entities 35
4 Maintenance and support guide 37
4.1 Zwave Battery monitoring 37
4.2 Zwave battery types to replace 37
4.3 Troubleshooting 37
4.3.1 Multi-channel meter 37

1 Introduction

ChArGED aims to develop a framework that will leverage IoT enabled, low-cost devices (NFC or BLE Beacons) to improve energy disaggregation mechanisms that provide energy use and -consequently- waste at the device, area and at end user levels. This energy waste will be targeted by a gamified application that will feed personalized real time recommendations to each individual end user and will thus implement a novel social innovation process based on human incentive factors and will help users to understand the environmental implications of their actions and adopt a greener, more active and responsible behaviour.

This document provides the deployment guidelines for the CHARGED system and each specific component.

2 Hardware components / sensors

2.1 Architecture overview

This figure presents an overview of the architecture to support the understanding of the system topology outlined below. Each of the components are analysed separately.

The system architecture consists of four main groups of functional blocks:

- The Data/Core Back-end group is responsible for providing an environment in which data, assets and users are stored and managed. The Back-end components provide the software infrastructure on which the ChArGED application is developed. That group of components is application agnostic, however it is tuned towards the needs of ChArGED project.
- The Gateway group is responsible for integration of energy use and environmental data to the Back-end system, to determine variations over the energy context within the building.
- The Analytics Back-end component is responsible for delivering insights that will enable the ChArGED application to deliver custom and targeted feedback and incentives to the end-users.
- The Gamification group is responsible for processing field data and insights created from such data and make decisions as to the evolution of the game for each user, i.e. what the next step is towards more energy savings. That group also delivers the mobile app the end-users interact with which acts as an interface between the user and the charged system updating the user with the current game state and also provides information to the system about the users' behaviour towards the energy saving goals set.

The architecture also includes an external system that is utilized to provide a solar power microgeneration forecast based on weather predictions for the specific location. It serves to maximize the building energy savings, increase end user awareness as well as to enable the use of the mobile app to maximize the solar-based electricity consumption during production, avoiding the need for energy storage

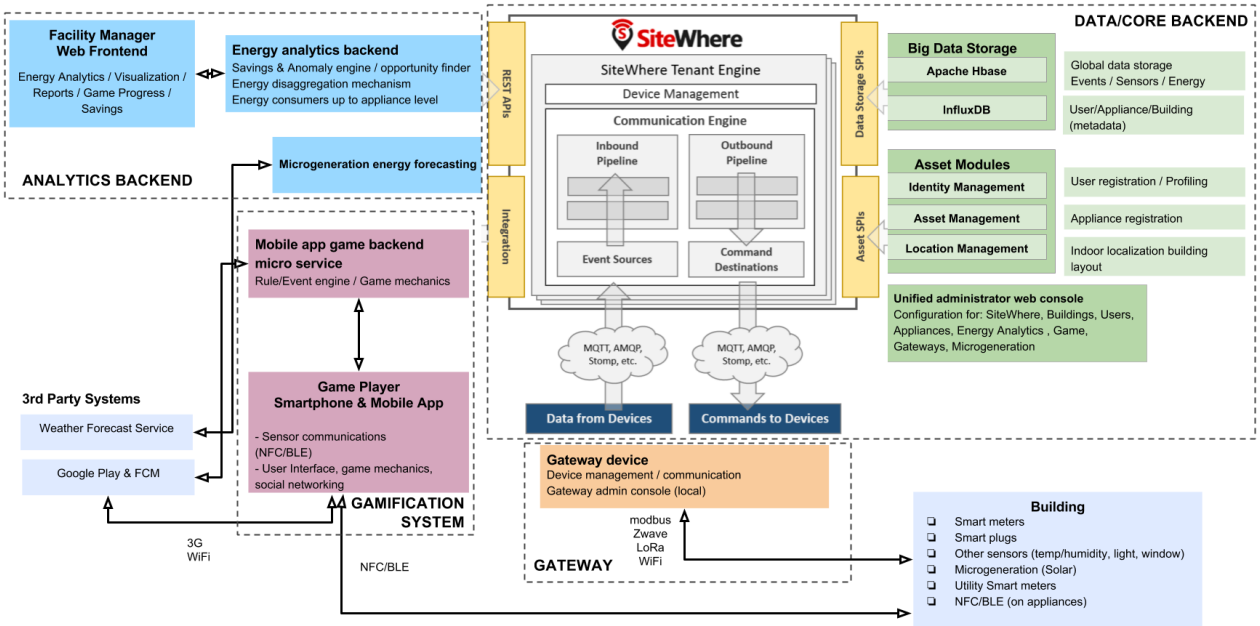


Figure 1 ChArGED architectural overview

2.2 SiteWhere Server

The Data/Core Back-end system components and infrastructure were implemented in SiteWhere[1]. The available functionalities are the following:

- Each new asset or entity (i.e. a sensing device, an appliance, a specific location area, a person) is assigned a unique id and can be autonomously monitored via external software. Specifically, a model for standard types of generated event data is provided for each device (which includes measurements, alerts issued and location updated by the device). The logged events are stored in massively scalable time series datastores (InfluxDB).
- Devices (appliances such as printers, air conditioners, a PCs etc) can be assigned to / associated with other entities. A can be associated with a person, a location or another sensor device of our infrastructure thus giving us the ability to establish ownership room/location metadata and establish relationships with device.
- Devices can be grouped together according to a common role they fulfil, something that enhances efficiency by simplifying the way the devices can be retrieved by other backend processing services.
- Every top-level entity is modelled as a tenant and can have a completely different configuration and structure without affecting other tenants. This can be used for modelling infrastructures that are unrelated to each other such as different locations, different buildings, pilot users etc on the same server.

Registration of new or existing devices (building appliances and sensors)

SiteWhere devices can be created manually with API calls, or they can be self-registered. In later case, the device provides a unique hardware ID and a specification token to the system which in turns creates a new device record that can start accepting events. SiteWhere assumes that each device will have a unique ID in the system so it can be independently addressed. The specification token passed at startup indicates the type of hardware the device uses and references a device specification that already exists in the system. Devices send a registration event when they boot or connect to the network and SiteWhere either creates a new device record or finds an existing one.

Registration of electrical circuits (monitored by submeters and smart plugs)

Power measurements retrieved by the ChArGED gateway from the deployed submeters and smart plugs need to be uploaded to SiteWhere and be associated to devices. The type of device depends on the entity being monitored, for example, if a multi-channel submeter monitors 18 single-phase circuits, 18 'Circuit' devices must be registered in SiteWhere to hold the measurements. If a smart plug is used to monitor a specific computer, power measurements will be associated to a 'PC' device.

[1] Sitewhere: The Open Platform for the Internet of Things, https://www.sitewhere.org/

Figure 1: List of Sitewhere Device entities that can be created to hold measurements by the metering and IoT infrastructure

Physical electrical circuits feed wall plugs, lighting fixtures and air conditioning equipment within locations of a building, as such 'Circuit' devices registered in SiteWhere must reflect that setup. 'Circuit' devices are therefore assigned to 'Location' assets, see example below.

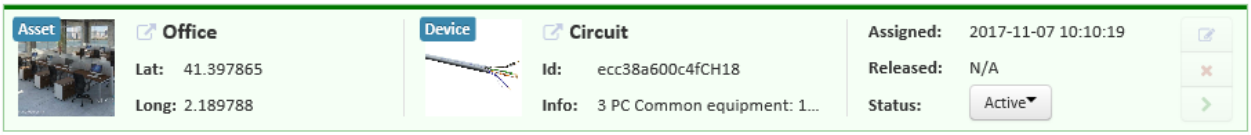


Figure 2: Illustration of the assignment of SiteWhere Circuit devices to building Locations

The ID used when registering the 'Circuit' device should be globally unique. This is the ID that the gateway will use when pushing data to SiteWhere.

The naming convention chosen when using the 18-channel meter from Accuenergy is to set the ID as <metermacaddress>CHx, with <metermacaddress> to be replaced by the mac address of the meter in lowercase without space, and x the channel number. For example, the screenshot above shows that the ID is ecc38a600c4fCH18.

For Zwave smart plugs, the ID is the device specification token automatically assigned by SiteWhere when device is registered.

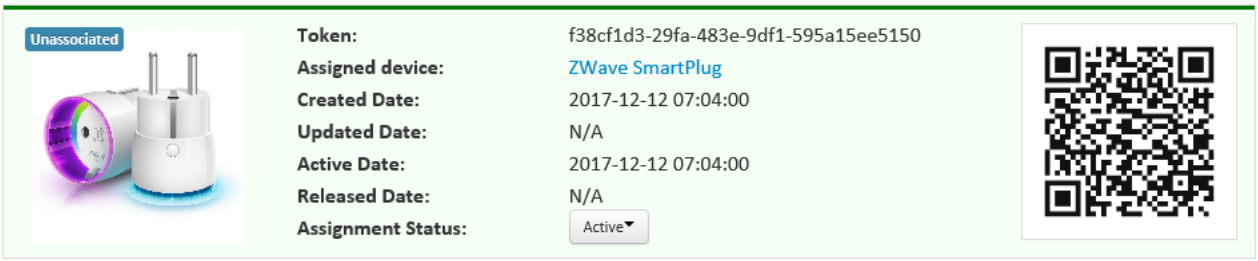


Figure 3: Illustration of Zwave smart plug device registration within SiteWhere

2.2.1 Asset Modules

Assets represent objects in the physical world – people, places, and things. Device specification assets are used to describe the hardware information/configuration for a type of device. Rather than hard-coding a schema for assets in the system, SPIs will be defined for general asset types, allowing asset modules to be plugged in to provide asset definitions. This allows existing identity management systems to be used in providing a list of available person assets. It also allows product catalog systems to be used in defining available hardware assets. The concept of asset categories which reside in the datastore will also be provided.

2.2.2 Object Model

A comprehensive object model captures the relationships between all of the various concepts in tracking device data. The diagram below shows some of the core objects in the model and their relationships:

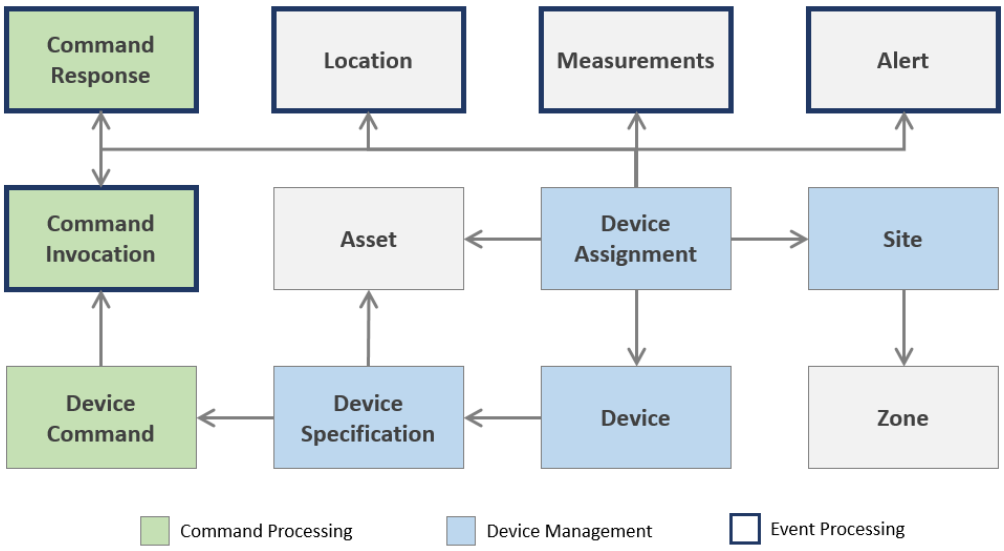


Figure 4: ChArGED entities overview

2.2.3 Sites - Buildings

Sites are used to organize devices that are cross-related so that their events can be looked at from a grouped perspective. The primary use case for sites is in location-aware devices. A site provides a

containing entity to which a map can be assigned so that location data can be viewed in the context of that map.

2.2.4 Zones - Rooms

Another important feature for location-aware applications is the concept of zones that carry special meanings. For instance, in a building, there are areas where certain devices can be used (e.g. photocopy machines) so when a person enters this zone the energy consumed by those devices can be associated with this person.

2.2.5 Device - Appliance Specifications

Specifications are used to capture characteristics of a given hardware configuration. A device specification contains a reference to a hardware asset which provides the basic information about the hardware including name, description, image URL, etc.

2.2.6 Devices - Appliances

Devices are a representation of connected physical hardware that conforms to an assigned device specification. Each device will be addressable by a unique hardware ID that identifies it uniquely in the system. A new device can register itself in the system by providing a hardware id and device specification token.

2.2.7 Device - Appliance Groups

Device groups allow multiple related devices or subgroups to be organized into logical units. The groups can then be used for performing operations collectively rather than performing them on a per-device basis. Each group can have zero or more roles assigned to it, allowing arbitrary groupings based on application needs. Devices may belong to multiple groups and may be assigned zero or more roles within the group

2.2.8 Device Assignments

Events are not logged directly against devices, since a given device may serve in a number of contexts. For instance, a visitor badge may be assigned to a new person every day interacting with appliances and their energy. Rather than intermingle event data from all the people a badge has been assigned to, the concept of a device assignment allows events to be associated with the asset they relate to. A device assignment is an association between a device, a site, and (optionally) a related asset. Some assignments do not specify an asset and are referred to as unassociated.

2.2.9 Device - Appliance Events

Device events are the data generated by connected devices interacting with system with types of events such as **Measurements.** Measurement events send measured values from a device to the core system. Measurements are name/value pairs that capture information gathered by the device. For instance, a smart plug sensing device will send measurements for total energy and instant power.

2.3 Solar Microgeneration Inverter

Figure 5: ChArGED solar inverter - Kaco blueplanet 5.0 TL3

ChArGED system takes advantage of a solar energy generation net metering solution in one of the pilot sites, maximizing the building energy savings, increasing end user awareness and also maximizing the solar-based green electricity consumption during production, avoiding the need of energy storage.

The solar solution is based on the solar inverter (Kaco blueplanet 5.0 TL3) which provides rich energy metadata information via both modbus TCP communication and web based / dsv export capability, enabling the detailed monitoring of the generated electricity assisting production forecasting mechanisms.

Solar inverter is connected via the gateway and its gateway middleware IoT integration software mBS SH. Through the device abstraction of the mBS SH the data are prepared for the ChArGED backend and sent via MQTT to the ChArGED core platform and distributed to all other system components.

2.4 Multi-channel smart meters

Public buildings are supplied with three-phase power to be able to deliver power to both single-phase end-loads e.g. lighting and wall-plug appliances, and three-phase end-loads e.g. air conditioning.

Three-phase meters are generally used in non-residential settings to measure electrical energy consumption of an entire distribution board using three current transformers (CTs), each clamped to a different phase of the supply line.

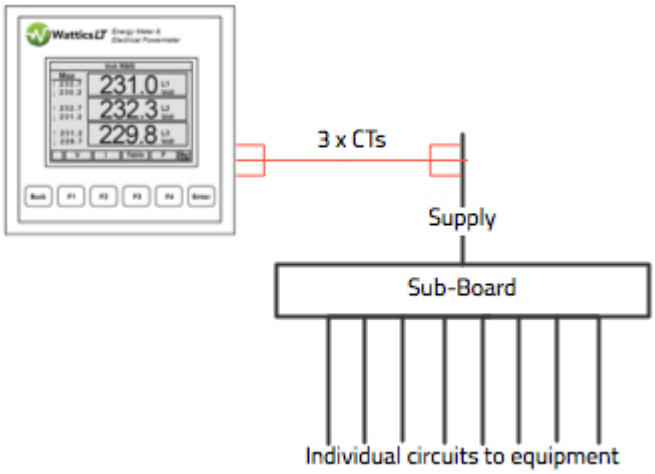


Figure 6: Illustration of a three-phase meter monitoring the electrical supply of a distribution board with three current transformers clamped to the three phases of the supply line

Because small loads are widespread in public buildings, e.g. lighting units and plugs for computers and office equipment, electrical panels are generally made of many single-phase circuit breakers, feeding lighting fixtures and plugs individually.

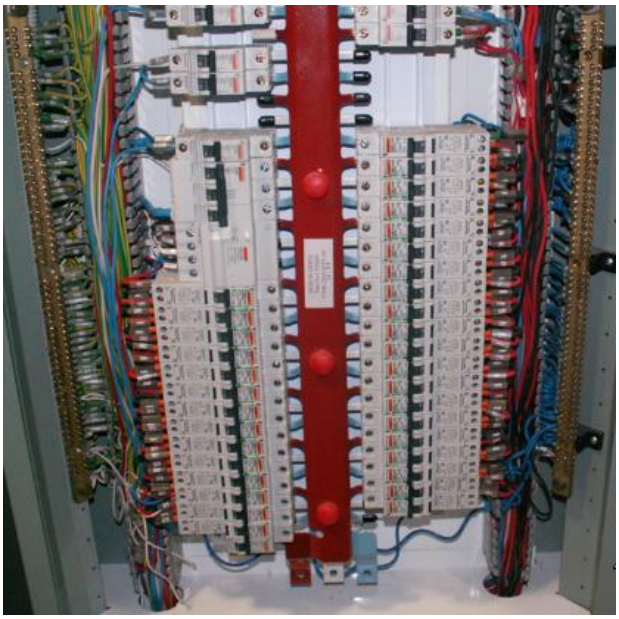


Figure 7: Example of office building electrical panel, showing many single-phase circuits feeding equipment on the floor plan

In that setup, all circuits must be monitored individually with dedicated CTs in order to measure energy use and demand variation for equipment fed by such circuits. Multi-channel meters offer a cost-effective solution for monitoring multiple circuits, by allowing many CTs to be connected to a single meter.

Figure 8: Photo of the Accuenergy AcuREV2000 18-channel meter used for monitoring single-phase circuits in public building environments

Accuenergy offers with their AcuREV 2000 series an 18-circuit power metering system that monitors kilowatt-hour (kWh), power, energy, demand, peak demand and time-of-use (TOU) in high-density applications. It is best used for tenant submetering, commercial facilities and branch circuit monitoring where multiple circuits require monitoring.

2.5 Gateway and zwave controller

2.6 zwave smart plugs

Zwave smart plugs are installed into any power outlet and that outlet is instantly smarter that captures the energy that is used through this outlet. This information is sent through the zwave network to Sitewhere in the CHARGED system.

Figure 9: Zwave plugs

2.7 zwave window contact sensors

Door window sensors serve a simple purpose: they capture events related to a door or a window opening or closing. When connected to Z-Wave network this information can is captured in Sitewhere.

Figure 10: Zwave window sensors

2.8 zwave 4in1 sensors

This is a 4in1 sensor which monitors motion, temperature, humidity, and light level and transmits those to the Sitewhere.

Figure 11: zwave 4in1 sensors

2.9 NFC tags

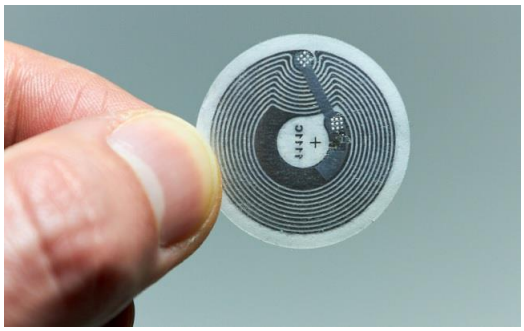


Figure 12: NFC sensor tag

NFC sensors **NTAG213** at 38mm diameter provide the lowest-cost while keeping a very fast reading speed and long range. ChArGED mobile app is designed to capture the NFC events and trigger the verification of a user action, through the energy disaggregation mechanism, i.e. if a user swaps the phone over a turned-on computer, means that he turns it off, and this is confirmed by the analysis of the energy consumption measurement in the energy disaggregation engine.

2.10 BLE beacons

Figure 13: BLE Beacons

Estimote Proximity Beacons are used for indoor localization. Battery life time is 2 years by default. The estimote mobile app can be used to "lock" the write ability of the BLEs.

2.11 Smartphone

Figure 14: Samsung K8 Smartphone-CHARGED recommended

Recommended and tested smartphone for Charged application is the Samsung Galaxy K8 2017 are used due to their low cost, Android 7, and BLE/NFC capability.

3 Installation Guide

3.1 Overview of deployment steps – high-level

The following presents an overview of the steps that are needed to install and deploy the CHARGED components, which are further detailed in the following chapters:

1. Setup RPi gateway as the ChArGED gateway and configure according to Bosch's 10 page instructions (is included from chapter 3.2 following)
    a. Linux admin or developer skills required
2. Open Bosch mBS web console (e.g http://192.168.1.25:81/system/console/hdm)
    a. go to zwave controller (node1) change mode to "adding"
        i. Repeat as needed
3. Power up new every zwave device, one by one
    a. Triple click to pair (or follow manufacturer's instructions)
    b. Add a paper sticker with node id given to device by controller (visible in /system/console/hdm)
    c. Repeat with all plugs, 4in1, window contacts
4. Place new plug/4in1/contact in appropriate location, keep note on a document* for later update in SiteWhere
5. Program each NFC sticker using ChArGED app in admin mode (or NFC TOOLs app)
    a. Make a node of the UUID of each NFC on a document*
6. Place every sticker on appropriate location and keep notes on a document* for updating SiteWhere later
7. Identify BLEs and record their Mac Addresses on a document, as they will be registered later to SiteWhere. The identification of the BLEs can be done by using ChArGED app in admin mode (or Estimote app) identify each BLE.
    a. Take all BLEs away a few meters from the smartphone, keep one close and read it's Mac Address(Estimote app requires BLE owner to be logged in)
    b. ALTERNATIVE approach: scan the internal NFC of the beacon and via the estimote cloud find out the BLE Mac Address
8. Place every BLE on appropriate location and make a node on document* for later update in SiteWhere
    a. Select locations that maximize variation of distance between users / and differentiate
9. Install multi-channel meters at electrical panels to monitor circuits feeding plug-load, lighting and air conditioning equipment of the floor plan
    a. Registered electrician will need to be contracted to conduct the installation wrk
    b. Labeling work will be required before installation to identify which circuits to monitor for the needs of the ChArGED application

*keeping notes of Mac Addresses on document makes deployment slower, cumbersome and prone to errors. These actions should be fully automated and be part of the game process even if the end-users will not perform the deployment.

3.2 Gateway preparation

3.2.1 Required Hardware

1. Raspberry Pi 3 Model B / SD card / PSU / Enclosure.
2. USB ZWave controller attached to the one of Raspberry Pi USB ports (serial controller http://www.vesternet.com/z-wave-me-razberry-2-pi-gpio-daughter-card-gen5 is supported also).
3. ZWave Smart Plug with Power Metering http://www.vesternet.com/z-wave-fibaro-wall-plug-schuko-gen5 http://www.vesternet.com/z-wave-aeon-labs-smart-switch-6-gen5, optional.
4. ZWave Window contact sensor http://www.vesternet.com/z-wave-fibaro-universal-door-window-sensor, optional.
5. ZWave Motion 4-In-1 sensor http://www.vesternet.com/z-wave-fibaro-motion-sensor-gen5, optional.
6. Modbus Power meter AcuRev 2000, optional.
7. Modbus Solar Inverter Powador 12.0, optional

3.2.2 Required Software

1. Bosch mBS runtime installation file
2. Oracle ejre on Raspberry
3. cdc_acm module on RaspBerry. Check if available with 'lsmod | grep cdc_acm'. If the ZWave USB stick is attached 'ls /dev' should show one /dev/ttyACMx (e.g dev/ttyACM0) device.
4. SSH Client program like Putty https://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html
5. SFTP client like WinSCP for Windows https://winscp.net/eng/download.php]

3.3. Installation

1. The installation archive is called com.prosyst.clients.funded.charged.image.runtime-x.x.x.tar.gz, where x.x.x is the installation version.
2. The archive has to be copied into the Raspberry PI to a temporary folder, for example '/home/pi/mbs-install'. For file transfer from Windows machine it could be used WinSCP.
3. Login in Raspberry PI with your client application (Putty) and extract the archive from the respective directory with the command:

```
tar xvzf com.prosyst.clients.funded.charged.image.runtime-1.0.2.tar.gz
```

4. After extracting, you have to make the script 'install.sh' executable and to start it:

```
chmod +x install.sh
sudo ./install.sh

output:
Executing pre-install script...
Executing pre-install script... done!
MAC Address: b827eb45fe87
Serial Number: 00000000fc45fe87
```

```
Configuring stack with:
Provisioning SPID: b827eb45fe87
PRM Manager URL: ssltcp://35.157.248.28:2443

insserv: warning: script 'mbssh.setenv.sh' missing LSB tags and overrides
Executing pre-install script...

Note: When using serial USB devices ensure that usb-to-serial modules are available for this kernel

The stack will start automatically after reboot
Manual start via:
 /etc/init.d/mBSSH.sh start

Installation complete.

Executing post-install script...
Executing post-install script... done!
```

5. Warning may be printed like:

   ```
   insserv: warning: script 'mbssh.setenv.sh' missing LSB tags and overrides
   ```

   The installation will produce following folders:

   ```
   /mbs - program location
   /mbs-data - data location for storage and logs
   ```

   It is using 'update-rc.d' command with 'defaults' parameter for auto starting runtime after reboot of the system.

   Manual start or stop is possible via several ways:

   ```
   'sudo /etc/init.d/mBSSH.sh start' or 'sudo /etc/init.d/mBSSH.sh stop'
   or/and
   'sudo /mbs/mbsa/bin/mbsa_start.sh' and 'sudo /mbs/mbsa/bin/mbsa_stop.sh'
   ```

6. Configure the system as shown in section 4.
   Modify the SiteWhere siteToken as descibed in section 4.1. (If not modified the devices will be attached to ProSyst site.) Define Modbus devices as shown in section 4.2)
7. Reboot the system via:

   ```
   sudo reboot
   ```

8. The runtime will be started automatically after reboot.

3.4 Pairing of Zwave devices

1. Read the ZWave device vendor instructions first.
2. Set the ZWave Controller in Adding mode:
   a. open http://<RPi-ip>:<port>/system/console/hdm (port should be 80, 8080 or 81)
   b. click on icon 'i' (right) of the ZWave Controller
   c. find Device Class ZWaveNetworkController table
   d. set **mode** to Adding
   e. click 'set property value' button (right arrow)
3. Set the end device in pairing mode via the vendor instructions. (It is popular to be quick triple click of a button)
4. After a few seconds the ZWaveNetworkController **mode** property should change to Normal and at http://<RPi-ip>:<port>/system/console/hdm should appear new end device with Online Status.

If the end device was paired to another network before it must be removed from this network first. This is ZWave protocol specifics. If this is the case set ZWaveNetworkController **mode** to Removing and follow the vendor instructions.

Figure 15: Photo of ChArGED 4-in-1 sensor deployed in ICAEN office floor plan

3.5 BLE placement

BLEs are used to capture the location of users. This is particularly necessary for offices with many rooms and areas for example DAEM where one BLE is placed per room. In the case of big spaces with a lot of desks one BLE will be placed for small groups of desks (for example every 4 desks). The local administrator will need to log in at the account of the BLE provider at google play (where there is ESTIMOTE app https://play.google.com/store/apps/details?id=com.estimote.apps.main&hl=en) (the email and password used when buying the BLEs is required) and configure each BLE. In the configuration screen disable all options except for the IBeacon protocol which is the one used in CHARGED. Set the the Advertising Interval = 300ms. Also set in the same tab:

a. if the BLE covers a whole office, Transmit Power (Tx) = Weak (-20 dBm) (coverage radius~3.5m)
b. if the BLE covers a small area of around four desks close to each other in the same room, Transmit Power (Tx) = Weak (-40 dBm) (coverage radius~0.25m).

The MAC address of the BLE is then retrieved through the ChArGED app and mapped to all the users it corresponds to in a separate document which should be then sent to ED to integrate in the SiteWhere. In case of a common area (for example kitchen) or elevator the same process can be followed with Transmit Power (Tx) = Weak (-20 dBm) is the BLE is placed in a room or Transmit Power (Tx) = Weak (-40 dBm) for an elevator.

The BLEs which were originally foreseen to be installed one in each room showed a lot of interference in their signal and therefore no clear conclusion about the user position could be derived. This lead to some new configurations: The new BLE installation plan includes the use of less Beacons, which are set up at the corners of each pilot with Transmit Power(Tx) = Weak (-12dBm) (new coverage radius ~15m). By this logic, a BLE is now able to capture the location not only of the players of a single team, but for a group of teams.

3.6 NFC placement

Each NFC should be placed according to the map on the building as follows: An NFC is placed at each desk, one for each room (towards the exit of the room) and one in the middle of each flight of stairs, one for each shared device. Each NFC is empty in the beginning. Using the ChArGED Deployment app (see below in the app section) each NFC is registered to SiteWhere with specific metadata that will be needed to identify it during the actual game. The NFC will also be automatically locked by the app so it cannot be further modified.

It is recommended to first design and number the NFCs on the map so that all of them are well representing the devices in the building. The guidelines detailed below present the process to be followed for the NFC configuration in the SiteWhere and CHARGED system.

Figure 16: Photos of NFC stickers deployed at ICAEN officefloor plan near lighting control switches

Figure 17: Photos of NFC stickers installed near computing and kitchen equipment at ICAEN office to allow users to inform the system when equipment is switch off for energy saving purposes

3.6.1 Password protect the NFC tags

Upon (or before) placing the NFC stickers use the ChArGED Deployment app (See below) to pre-configure the URI Package so that only ChArGED app will handle the tags and password protect NFC stickers to ensure no tampering is possible.

3.6.2 NFC tags installation in MNHA pilot

The installation of NFC tags at the MNHA followed a different approach for the Guard Challenge. The idea was to set a pair of NFC tags, outside of watched space of the museum. These pairs are labeled with on and off indications respectively. The purpose is that the guards, swipe the relevant NFC to communicate their "on" or "off" request towards the Control Room Employee.

For the Visitors Challenge the NFCs are firstly prepared according to the above deployment instructions, then NFC tags are managed by pilot's staff. NFCs are added to MNHA-Charged cards, which are given to the visitors together with an invitation to participate in the MNHA energy saving initiative. These frames include a smartphone device, with an app committed to this challenge and are set at the stairs of every floor in the museum.

3.7 ChArGED Deployment App

3.7.1 Overview

The app can be downloaded at

https://drive.google.com/file/d/1Q1fv2TMuXSQz4YAHeZjnC9ZR9Pao93B-/view)

The app supports the deployment in order to easier gather the NFC and BLE IDs. It is capable of reading/writing NFCs, listening to BLEs and storing the data in the smartphone in two separate csv files. The files can then be emailed through the app.

The data are stored in the following format

1,<NFC_id1>,NFC

2,<NFC_id2>,NFC

3,<NFC_id3>,NFC

the same for bles.

We also need to have a map of the building where we will note the NFC/ble number 1,2,3,4 etc. Then we can then find the corresponding id from the mapping.

3.7.2 Description

1. The app has two tabs one for the NFC and one for the BLE IDs to support the configuration of NFC and BLEs respectively. In the NFC tab one can scan NFCs that have already been written by the app. On the BLE tab the app will identify and display the closest BLE to the smartphone.

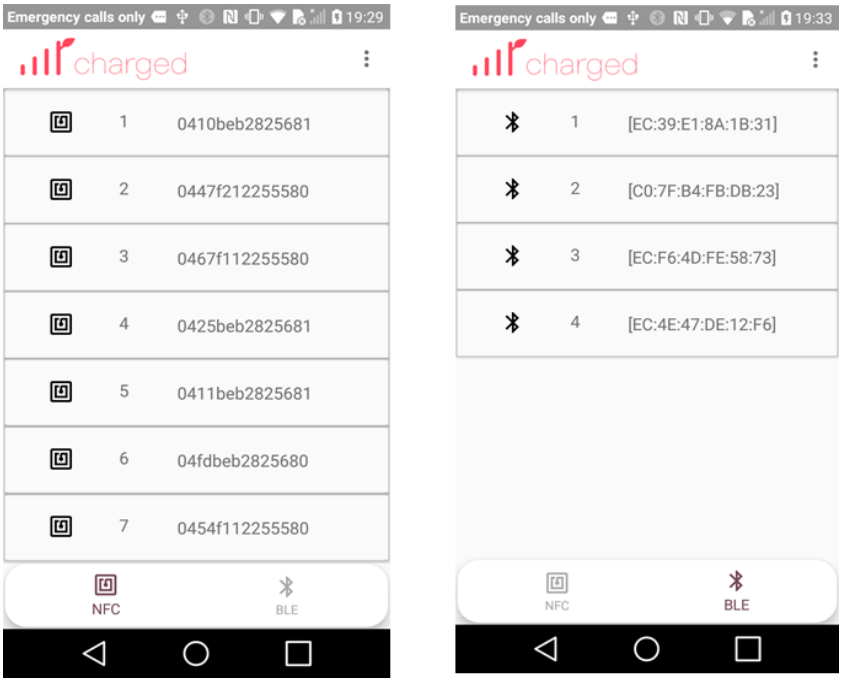


Figure 18: Screenshots of the ChArGED Deployment App showing how NFC stickers and BLE beacons deployed on the floor lan can be registered and assigned a unique ID for mapping to floor plan location and use for the game application

2. All the data are written in the Document/Charged folder in the ble-mappings.csv and NFC-mappings.csv files. The files are visible for most devices through the File Manager but in some they may marked as private and hidden. In either case you will be able to send them via email through the app.

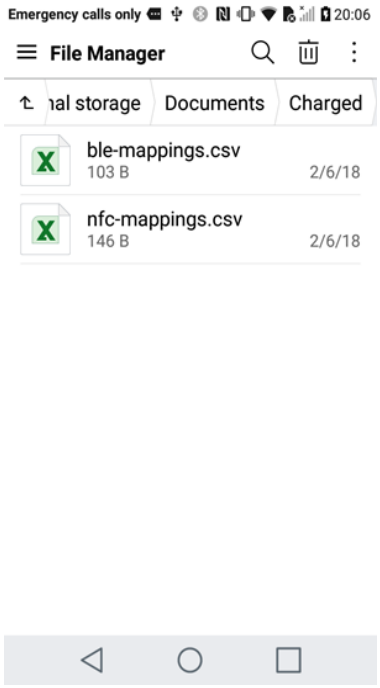


Figure 19: Screenshot showing the CSV files created by the ChArGED Deployment app to export the registered NFC stickers and BLE beacons for configuration of SiteWhere

3. From the menu select Write/Lock NFC. The app will ask you to scan, the NFC and write on it the CHARGED metadata (the given name/number you have selected from the map). The NFC will also be locked by the app so it cannot be modified later.

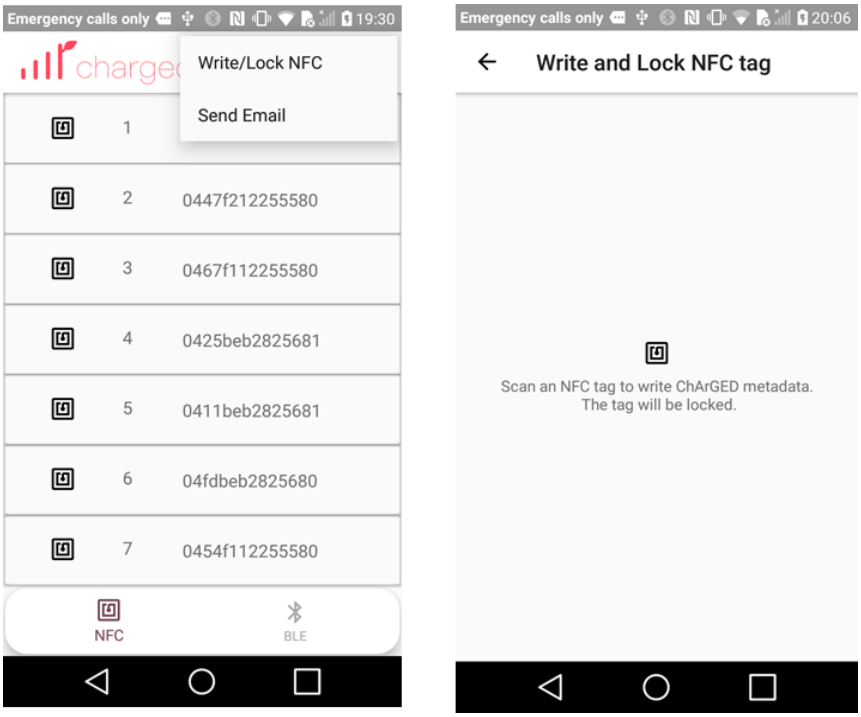


Figure 20: Registration of NFC stickers starts by writing the ChArGED metadata using the Write/Lock NFC feature

4. Each NFC and BLE ID can only be stored once. If an ID has already been stored, a message with its details is provided.

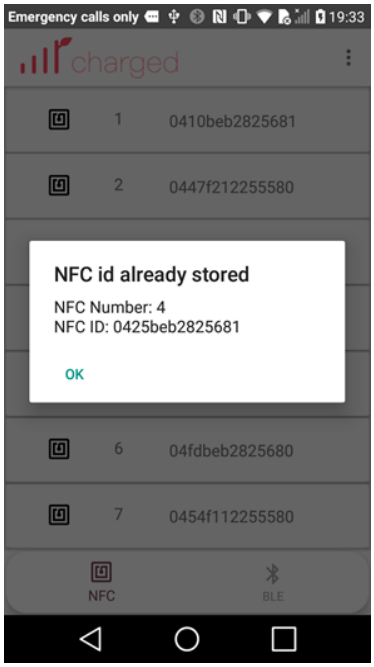


Figure 21: Screenshot showing that duplicate NFC sticker registration is prevented

5. When the deployment is finished select Send Email from the menu to send the files via email. For the beginning they can be sent to the default email preconfigured.

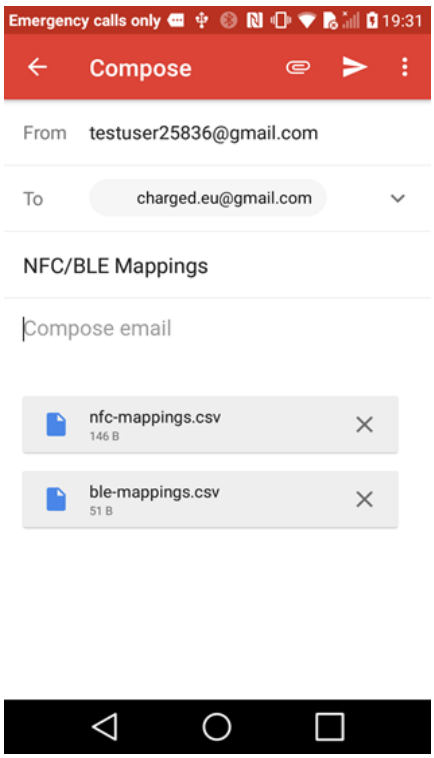


Figure 22: Screenshot showing how lookup tables for NFC stickers and BLE beacons can be exported by email

3.8 Multi-channel meter installation

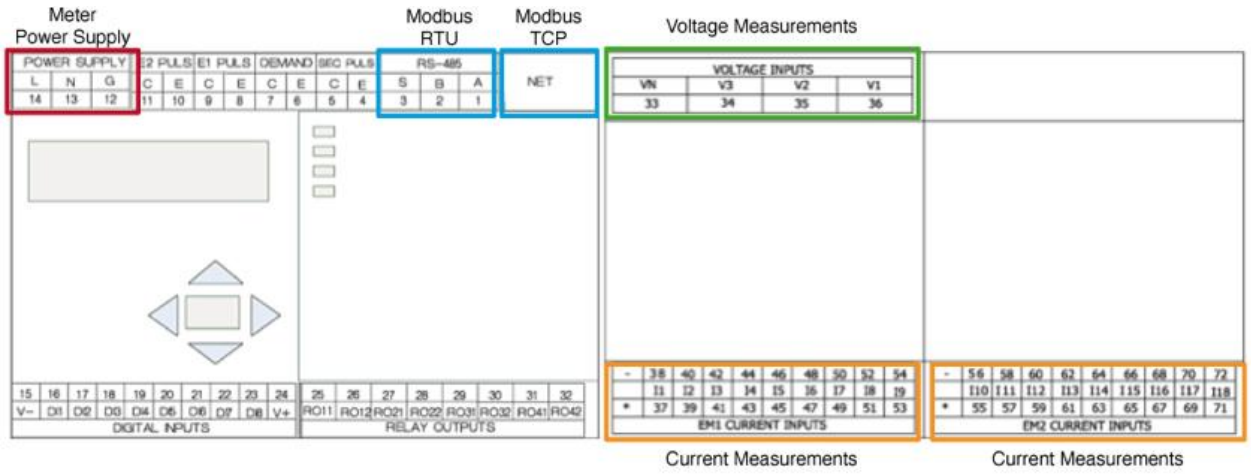


Figure 23: Schematics of the Accuenergy AcuREV 2020 18-channel meters showing the terminals used for voltage and current measurements, as well as power supply lines and Ethernet port for Modbus TCP communication with the ChArGED gateway.

Installation of the meters must take place according to the steps below, using suitable equipment and tools. Be careful to consider the following advises in this process:

- Devices must be installed without voltage applied and by qualified personnel.

- General safety regulations and nationally applicable accident prevention guidelines must be observed.
- Electrical installation must be carried out according to the relevant safety guidelines

STEP 1: Prepare the meter installation report

The meter has 18 terminal inputs (I1 to I18) to connect 18 CTs that will monitor 18 monophase circuits. Before the actual electrical wiring starts it is good practice to plan and document which CT will be used for which circuit, and how they will be connected back to the meter.

- The first step is to choose CTs with the most suitable primary rating for the circuit being monitored (e.g. a CT with a 300A primary rating for a circuit fed through a 250A circuit breaker).
- You can then label all the CT heads to facilitate deployment and not get mixed with all the CTs around (e.g. a CT head labeled S3 will be clamped to circuit called S3).
- The labeling of the CT leads is also useful to avoid getting the leads mixed when pulling them through the distribution board, and to quickly identify where to connect the CT leads back at the meter terminals (e.g. a CT lead labeled S3-15 will be clamped to the meter input terminal I15).

Important: it is necessary that the following is respected:

- All circuits fed from L1 (phase A) must be connected to inputs I1, I2, I3, I10, I11 and I12
- All circuits fed from L2 (phase B) must be connected to inputs I4, I5, I6, I13, I14 and I15
- All circuits fed from L3 (phase C) must be connected to inputs I7, I8, I9, I16, I17 and I18

For example, a single-phase lighting circuit fed from L2 can be clamped with a CT wired back to meter terminal input I4, I5, I6, I13, I14 or I15. Similarly, a three-phase circuit fed from L1, L2, L3 can be clamped with three CTs wired back to meter terminal inputs I1, I4 and I7 for example.

The table below shows how 18 monophase circuits can be wired based on their supply phase.

		CT inputs																	
		I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16	I17	I18
Supply phase	L1	1	2	3							10	11	12						
	L2				4	5	6							13	14	15			
	L3							7	8	9							16	17	18

Figure 24: Mapping table showing how monophase circuits can be wired to the 18 terminal inputs of the Accuenergy AcuREV 2020 meter based on their supply phase.

Now that the wiring setup is pre-configure, fill in a meter installation report.

Wattics	Wattics Limited	31-33 The Triangle, Ranelagh, Dublin 6, Ireland Tel. +353 1 532 7875 e-mail: support@wattics.com				
Customer Name	WATTICS LTD					
Site Name	HEAD OFFICE					
Site Address	RANELAGH, DUBLIN, IRELAND					
Electricity Supplier Name	AIRTRICITY					
Installation Date	01/03/2016					
Area Name	**Circuit monitored**	**Meter input (I1..I18)**	**Phase monitored**	**CT size (A)**	**Parent circuit**	**Meter serial number**
1st Floor	C5	I1, I4, I7	1,2,3	250		ecc21f21045
1st Floor	C1	I2, I5, I8	1,2,3	250	C5	ecc21f21045
1st Floor	C2	I3, I6, I9	1,2,3	250	C5	ecc21f21045
1st Floor	C3	I10, I13, I16	1,2,3	250	C5	ecc21f21045
1st Floor	C4	I11, I14, I17	1,2,3	250	C5	ecc21f21045

A WattREV-6 Meter Installation Report template is available for download **HERE**.

STEP 2: Provide voltage references to the meter

Wire the meter voltage reference inputs to a Type C 6AMP 3P breaker to provide voltage reference for power calculation. Make sure the breaker is in the OFF position.

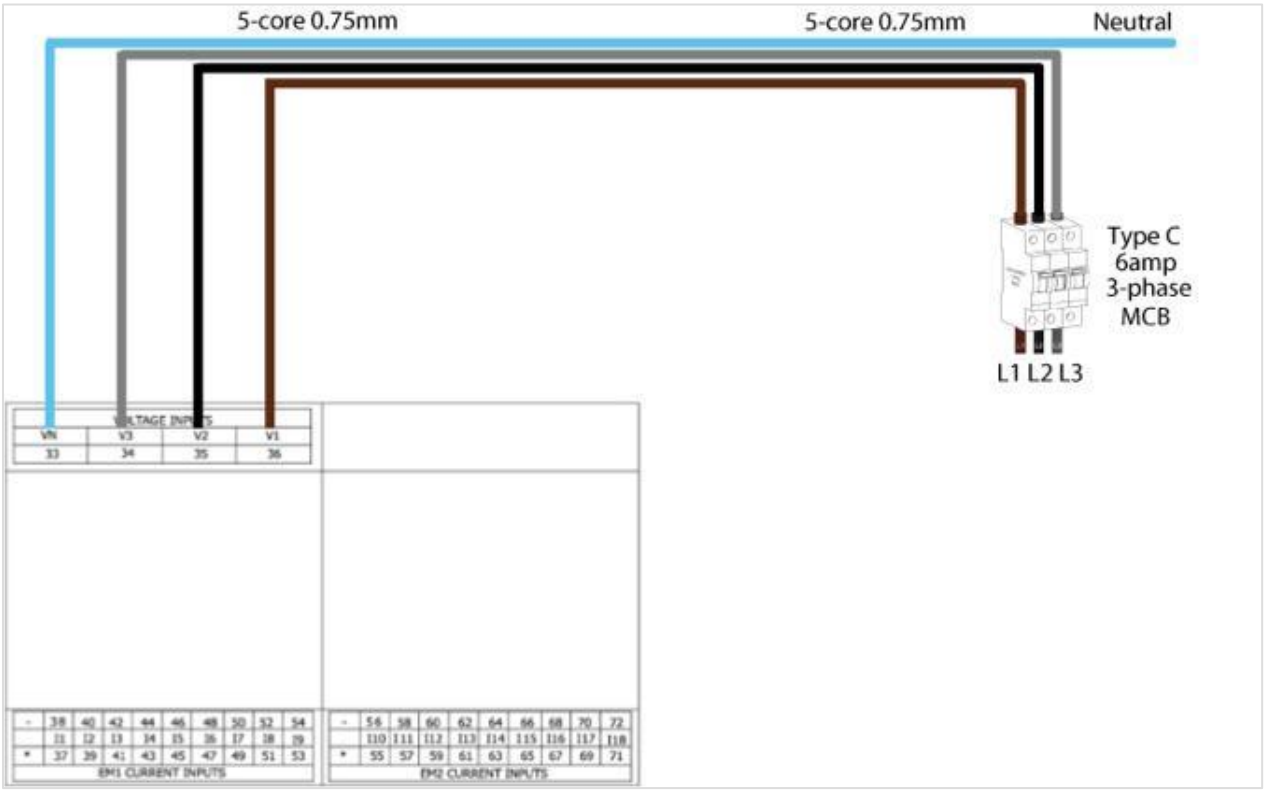
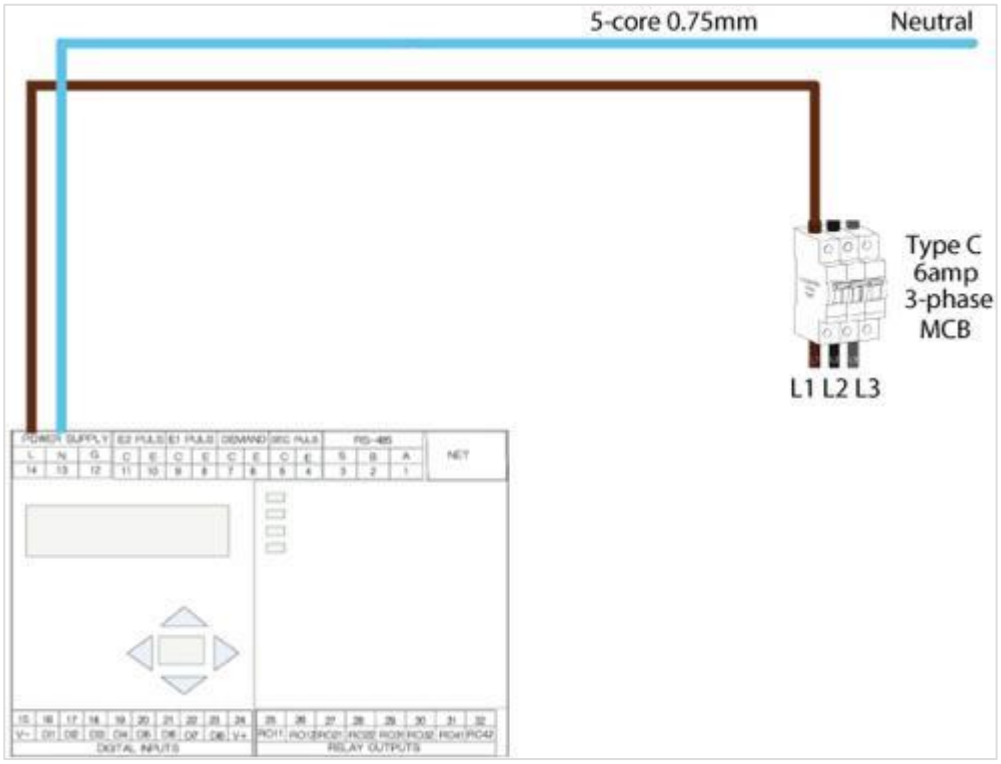


Figure 25: Illustration showing the way voltage reference should be provided to the Accuenergy AcuREV 2020 meter via a 3P Type C breaker

Note: the breaker must be fed from the same transformer as the circuits being monitored to ensure that the correct voltage references are applied for power calculations.

STEP 3: Supply power to the meter

Wire the meter L and N voltage supply inputs to the breaker L1 and N output terminals or short the V1 and VN reference voltage lines to the L and N voltage supply lines as shown in the figure below.



or

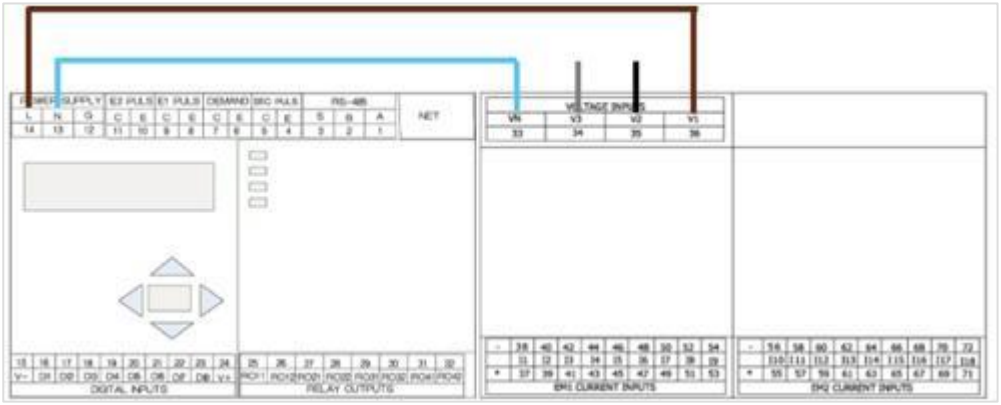


Figure 26: Illustration showing how the power supply line of the Accuenergy AcuREV 2020 meter can be wired, either from a circuit breaker or by creating a loop from the voltage reference lines

Figure 27: Photo showing the wiring of the voltage reference and power supply lines of the AccuenergyAcuREV 2020 meter deployed at the ICAEN pilot site

STEP 4: Prepare the meter for Rogowski coil or CT connections

Carefully attach the meter to din rail pre-mounted within the meter compartment or enclosure. This process can also be done once all the Rogowski Coils and CTs are wired in the case wiring is made easier with the meter outside the meter compartment.

Figure 28: Electrician adding an enclosure to locate the meter outside of the electrical panel compartment

Now remove the two current measurements terminal blocks from the meter (see below cover and terminal). The left terminal block has 9 inputs (I1 to I9, left to right), and the right terminal block has 9 inputs (I10 to I18, left to right).

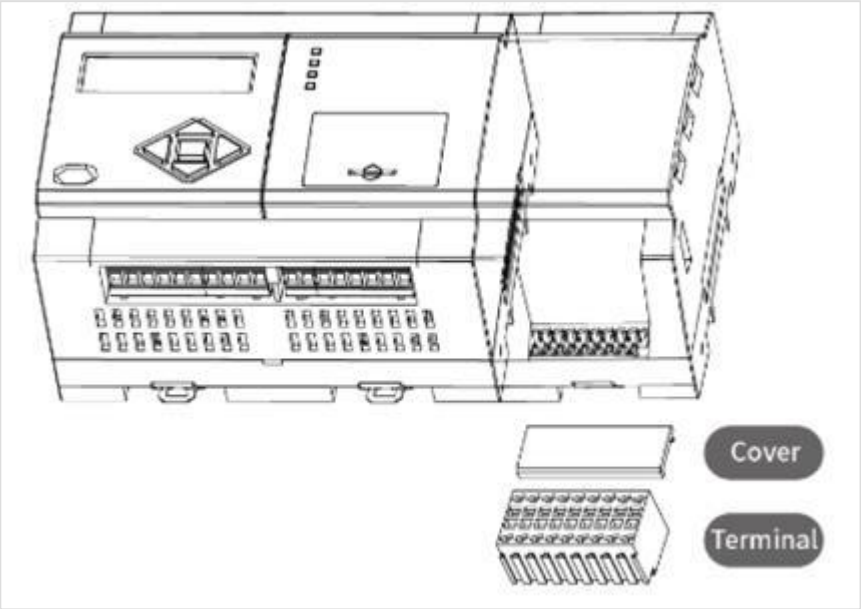
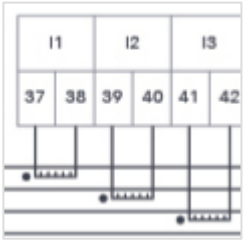


Figure 29: Diagram showing how the current terminal block can be removed for easy wiring of the CT end cables to the AcCuenergy AcuREV 2020 meter.

STEP 5: Deploy the CTs

The next step is to clamp the CTs to the electrical circuits and wire them back to the meter current measurements terminal blocks. This procedure must be conducted as follows with extreme precautions:

- Power the circuit down temporarily (working with live circuits may be possible if all safety precautions are taken and under agreement from the customer)
- Position the CT next to the circuit to be clamped, but do not clamp them until the CT lead has been wired to the meter to avoid major safety risks (this is valid for CTs with 1A or 5A output, however 333 mV CTs do not require shorting blocks or prior connection to the meter because they have a burden resistor built into the CT that limits the output voltage to a safe 333mV under all conditions.)
- Pull the CT lead back to the meter via pre-mounted cable glands, trunken and other covers.
- Wire the two CT lead wires to the correct meter terminal input. Take the positive (white or red) lead wire and insert it into the lower circular opening of the current measurement terminal (e.g. I1 37, I2 39, etc.). A tiny screwdriver should be inserted into the upper square opening and pressed down to allow the lead wire to be inserted properly.



White/Red wire = + (positive)

Black/Brown wire = – (negative)

- Repeat for all CTs you plan on deploying and place the terminal block back into the meter module when the wiring is complete.
- Clamp the CT heads to the circuit paying attention to the labels to ensure that you clamp the correct circuit and to the direction in which you clamp the circuits.

  The red/white leads will be your positive wire and the black will be the negative wire. Also, on the CTs there is an arrow which dictates the polarity. The arrow should be facing the load. If you have the arrow towards the load and the red/white lead and black lead in the correct positive and negative terminals of the meter's CT input channels then the kWh will accumulate correctly.

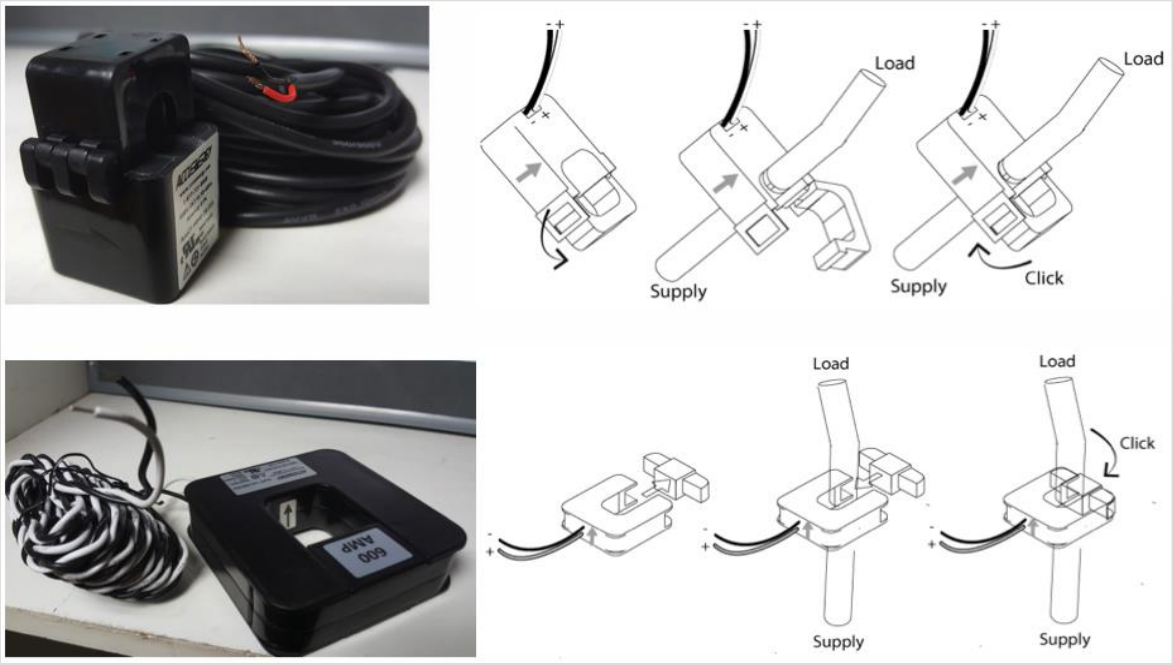


Figure 30: Illustration showing how different types of current transformers should be clamped to an electrical circuit

- Power the circuits back up after all Rogowski Coils or CTs have been deployed
- At this stage, the meter is wired to the circuit breaker and all CTs are clamped and wired back to the meter.

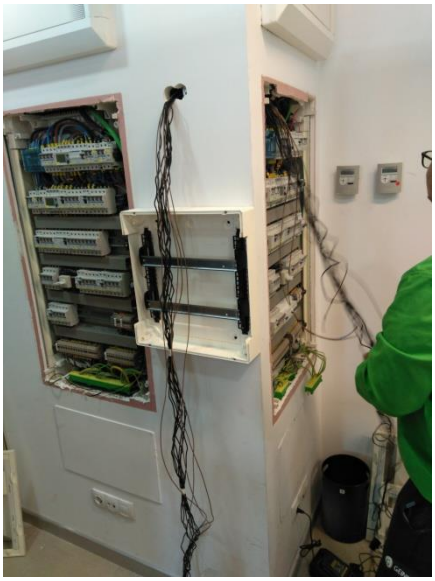


Figure 31: Photo showing the current transformers end cables being pulled from the electrical panel to the meter enclosure where they will be wired to the meter current terminal block

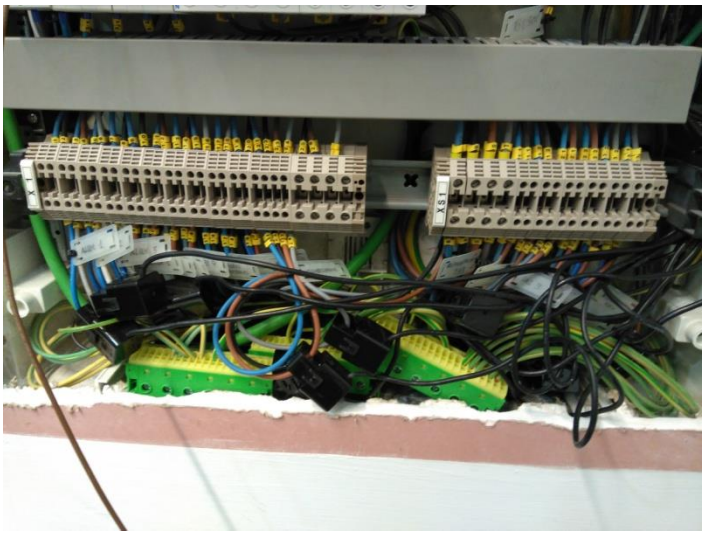


Figure 32: Photo showing the current transformers heads clamped to the electrical circuits

STEP 5: Switch the breaker on to power up the meter

Switch on the breaker to supply power to the new meter. The meter will power up and will after a few seconds emit a red LED light (L1).

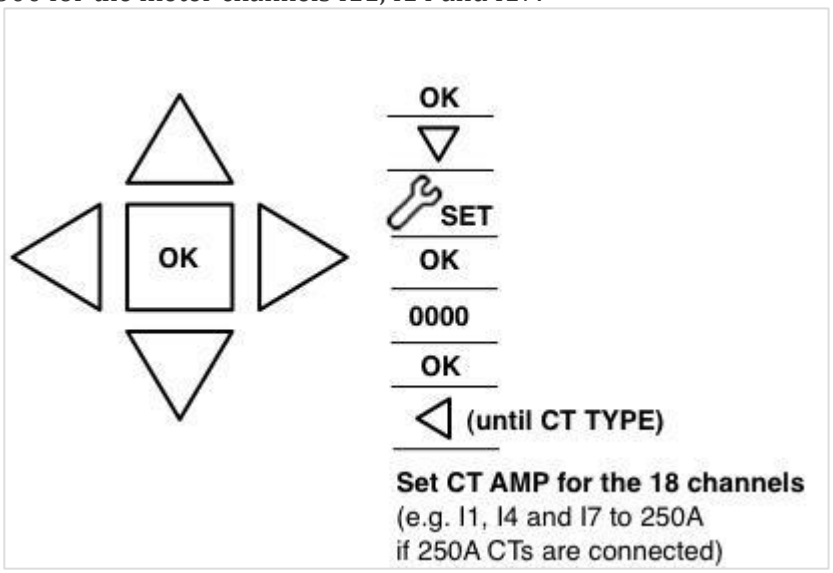
STEP 6: Configure the meter

The meter has a total of 18 current measurements terminal inputs called channels (I1 to I18), that are connected to up 18 CTs used to monitor 18 single-phase circuits or a mix of single-phase and three-phase circuits. You must now configure your meter terminal inputs to the correct primary

rating size of the CTs wired to them (e.g. if a 300A CT is wired to the channel I1 then I1 must be configured to 300A). This procedure is executed via the meter display:

- Press the meter display's left and right arrows together to go back to top menu

- Select the Settings menu, enter the password 0000, then press the cursor left until you reach the CT TYPE submenu. There you need to set the correct AMPERE size for each terminal input, one by one. For example, if you used a WattRCT16-2500 Rogowski Coil to monitor the three phases of your circuit 5, you need to set a value of 2500 for the meter channels I11, I14 and I17.



- Press the OK button to register each AMPERE value, and move on to the next channel until you are done. At the end verify that all channels are configured properly in case you didn't save correctly, this is extremely important as you will otherwise get incorrect readings.

STEP 7: Provide network access to your meter

- Connect an Internet cat5 cable to the meter's Ethernet port.
- Press the meter display's left and right arrows together to go back to top menu
- Select the NET menu, enter the password 0000 and press OK. Then press OK to enter the DHCP Setting configuration.
- You must either enable DHCP (so the meter gets discovered and is assigned an IP address automatically), or change its IP address to be within the correct IP range. To

enable DHCP, set the DHCP Setting tab to AUTO and press OK to save it. If you want to assign a static IP address, follow the steps below:

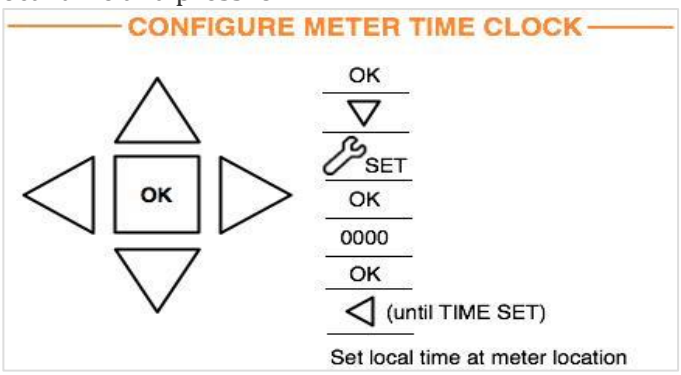
- Press the right cursor until you reach the DHCP Setting tab, press OK and set to MANU. Press OK to save.
- Press the right cursor until you reach the IP ADDRESS tab and register the IP address to be used.
- Press the right cursor until you reach the SUBNET MASK tab and register the IP address to be used.
- Press the right cursor until you reach the GATEWAY IP ADDRESS tab and register the IP address to be used.

- The meter network interface must be rebooted to enable the new network settings. Turn the meter off via its MCB circuit breaker for 5 seconds and turn it back on.
- Press the meter display's left and right arrows together to go back to top menu
- Select the NET menu, enter the password 0000 and press OK. Press the right cursor until you reach the IP ADDRESS configuration.
- Write down the IP address of your meter, you may need it to access the meter's webserver configuration page.

STEP 8: Configure the meter time clock

Set the meter time clock to your local time via the meter display menu:

- Press the meter display's left and right arrows together to go back to top menu
- Select SETTINGS at the main screen and press 'OK'.
- Enter the meter password (default is 0000) and press 'OK'.
- Press the left cursor until you reach the TIME SET tab.
- Set the local time and press 'OK'



3.9 SiteWhere entities

After the deployment we need to model all the entities of our system. An entity is created inside sitewhere in the following way.

We navigate to the devices tab and there click create new device. We give the device id a unique identifier and a specification (which denotes the type of the device for example pc, NFC, ble, hvac etc.).

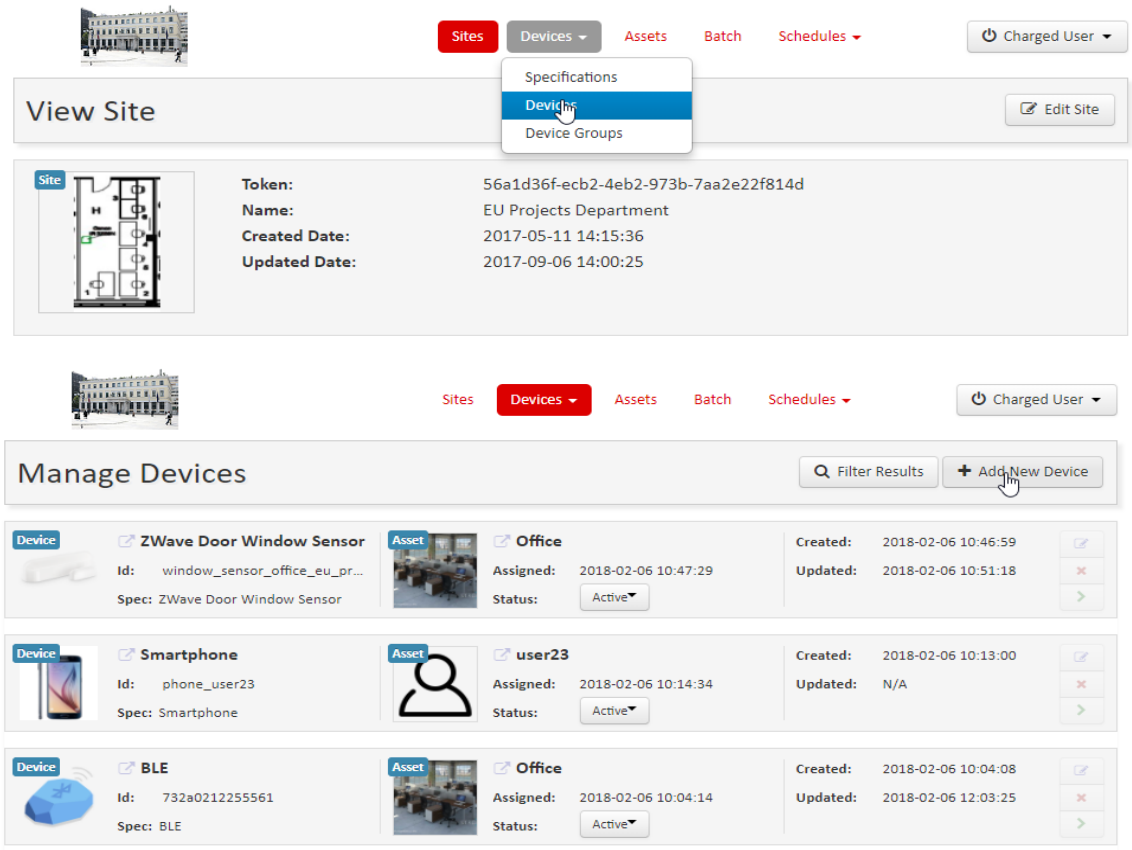


Figure 33: Manage devices screen in SiteWhere

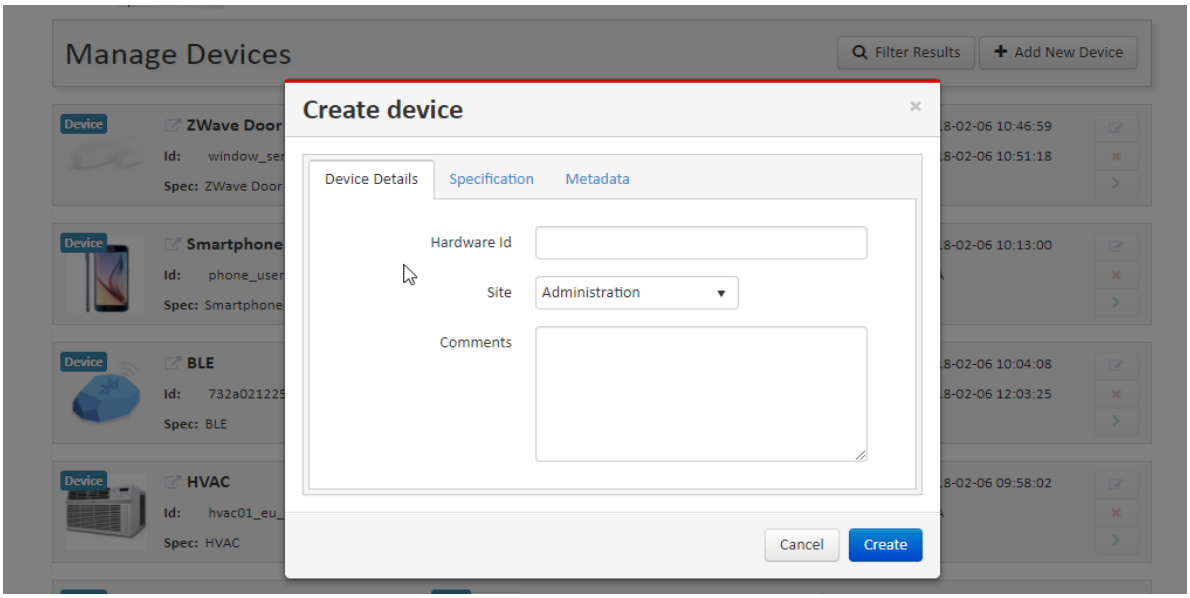


Figure 34: Create Devices screen in SiteWhere

When the device is created we also associate it with another asset. For example, a NFC can be associated with a pc if it is on a desk, with a room if it is placed close to a light switch, with a common place like stairs etc.

Figure 35: Configured devices in SiteWhere

4 Maintenance and support guide

4.1 Zwave Battery monitoring

Battery lifetime should last the pilot time. If battery powered device isn't sending any updates anymore, battery should be changed. No battery watchdog was implemented during the project.

4.2 Zwave battery types to replace

Battery Types of Window Contacts and 4in1 Sensors can be checked in the vendors manual.

4.3 Troubleshooting

4.3.1 Multi-channel meter

KW values shown are wrong

It is very likely that the CTs have not been wired correctly at the meter. Check that the CTs of the circuit with incorrect kWh values are connected meter inputs with the correct phase lines, i.e. CTs connected to first three current inputs of the meter (I37/I38, I39/I40 and I41/42) should monitor the L1 phase of three different three-phase circuits, etc). When using 333mV CTs, white wires will go into 37 and black to 38, white to 39 and black to 40 etc. When using Rogowski Coils RCTs, white wires will go into 37 and brown to 38, white to 39 and brown to 40 etc.

kW values are negative

The voltage and current may not be aligned. Make sure your voltage references V1. V2 and V3 come from L1, L2 and L3, and that CTs wired to L1, L2 and L3 current inputs are clamped to L1, L2 and L3 circuits.

The CTs may be mounted in the reverse direction or the CT leads are wired to the meter in the opposite direction. Make sure the P1/S1/H side of the CT faces the utility/source and that the black and white leads of the CTs are connected in the way specified by the CT manufacturer.

Power Factor values are very low

This indicates an incorrect wiring, either of the voltage lines or the CTs. Check wiring of the meter's V1, V2, V3 and VN from circuit breaker, and wiring of the circuit breaker from main supply, to ensure no cables were switched or fed from incorrect voltage line which would lead to incorrect voltage references. Check that the CTs of the circuit with incorrect kWh values are connected meter inputs with the correct phase lines, i.e. CTs connected to first three current inputs of the meter (I37/I38, I39/I40 and I41/42) should monitor the L1 phase of three different three-phase circuits, etc).

Both kW and kWh values are wrong

Check that the electrical system is the same as the one specified in the project specifications. It may be that the system is in reality different (e.g. Delta instead of Wye), meaning that the meter must be reconfigured for the correct system.

Voltage values are wrong

Check wiring of the meter's V1, V2, V3 and VN from circuit breaker, and wiring of the circuit breaker from main supply, to ensure no cables were switched or fed from incorrect voltage line which would lead to incorrect voltage references.

AMP values are wrong

Verify that the size of the CTs used is equal to the CT rating mentioned in the project spec and pre-configured in the meter (see CT TYPE setting).

If not the same, CT ratio must be modified via the meter's web interface using laptop, see AcuREV user manual.

AMP values are zero

Confirm that the CTs are closed properly around the circuit cables

Confirm that the wiring of CTs at the meter is good and not loose. Pull on CT cables and check that no wire comes out.

kWh are zero

Confirm that the CTs are wired in the right direction (arrow facing the load) as per installation manual.

Data holes

Identify if the meter could be powered off by staff or during ongoing works