H2020-LCE-2016-2017

EUROPEAN COMMISSION

Innovation and Networks Executive Agency

Grant agreement no. 731249

SMILE

Smart Island Energy Systems

Deliverable D4.6
Detailed plan of action for the EV smart charging demo

Document Details

Due date	31-07-2018
Actual delivery date	31-07-2018
Lead Contractor	PRSMA
Version	Final_rev0
Prepared by	PRSMA
Input from	EEM, M-ITI, ACIF-CCM, Route Monkey
Reviewed by	RINA-C
Dissemination Level	Public

Project Contractual Details

Project Title	Smart Island Energy Systems
Project Acronym	SMILE
Grant Agreement No.	731249
Project Start Date	01-05-2017
Project End Date	30-04-2021
Duration	48 months

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 731249

Table of Contents

Acronyms and abbreviation

AC	Alternating Current
API	Application Program Interface
CCM	Control and Communications Module
CEE	Commission internationale de réglementation en vue de l'approbation de l'équipement électrique
CEME	Electricity Marketing for Electric Mobility Register
DC	Direct Current
DSO	Distribution System Operator
DSR	Demand Side Response
EMS	Energy Management System
EV	Electric Vehicle
GPS	Global Positioning System
HTTP	HyperText Transfer Protocol
QR	Quick Response
URL	Uniform Resource Locator
UVE	User of Electric Vehicle (Utilizador de Veículo Eléctrico)

Shucko plug – Standard for AC power plugs used in several countries in Europe

Smart-plug – Normal socket that can measure the electricity of devices connected to it and/or be remotely turned ON/OFF.

Energy Meter – Equipment installed in an electricity installation that measures the consumption of that installation.

Think Aloud - The think aloud method is conducted by asking the participant or subject to talk aloud his/her thoughts while performing a task or solving a problem. This request is repeated during the problem-solving process but without interrupting or providing suggestions.

Energy Tariff – Price associated with a given electricity consumption unit (normally kWh for domestic clients), also associated with a given time period.

Contactor – Electric equipment which can cut or open a circuit based on a command, normally received through analog input.

Smart charging - charging techniques, which do not follow the normal plug and charge paradigm.

Load curve - is a chronological chart that illustrates the variation in demand/electrical load (in kW or MW) over a specific time.

Web-service - an application that in the context of this project, displays energy production information using the Internet.

Zigbee –Wireless protocol for low power communication, used a lot in home automation.

1 Introduction

In this document, the plan of action for the two smart charging pilots from WP4 is presented. As defined in the grand agreement, Madeira is a follower in this field, meaning that SMILE will effectively be the first smart charging pilot in the island. This way, with the help of Route Monkey (during the visit at the 5th and 6th July 2017), the plan for two pilots was laid out, aimed at two different types of EV's. Given the novelty of this initiative in the island, all the local partners aim at learning something from it: EEM will understand the impact of smart-charging in the grid, ACIF will study business opportunities for its associates, PRSMA will test and develop technology for smart charging and M-ITI will find options for research in this field.

The document is divided into two main sections, which relate to the two EV's and smart charging pilots. Each pilot is summarized, and its technologies, method and evaluation are presented. This means that there will be similarities between the chapters (especially regarding the description of how the Energy Management System fits in the pilot architecture), however it is clearer to present the pilots separately, since the approach, technologies and method clearly differ between them.

Before presenting in detail the plan for the two pilots in the island, in the following subsections a brief overview of the EV presence in Madeira is presented as well as the relation between this document and the other deliverables in SMILE.

1.1 Electric vehicles in Madeira

Before presenting in the detail the goals and interventions planned for the 2 pilots, a general overview of the EV presence and legislation in the island is provided.

There were approximately between 100 and 150 electric vehicles in the island as 2015. Thirty-two EV were purchased in 2016 and eleven orders were placed until January of 2017. Which prove that similarly to what is happening throughout the world, EV's are gaining traction in Madeira. Figure 1 presents the location of the public charging stations in the island.

Nowadays, there are seven public charging stations in Madeira island (performing 3 x Mode 1/2 AC charging sockets, 5 x Charge Mode 3 AC sockets, 3 x Charge Mode 3 AC 43 kVA plugs, 3 x CCS Combo2 50 kW plugs and 5 x ChaDeMo 50 kW plugs), and one in Porto Santo island (2 x Charge Mode 3 AC sockets). From the 19 available EV public sockets/plugs from these public charging stations in Madeira island, 11 are from public fast chargers (mainly brand-new ones from 2nd semester of 2017). Recently, private companies that work in the energy sector started to offer also public charging stations installation as part of their services. As of this writing, one private installation of a charging station was completed in Madeira Island and several more public and private installation are being built/planned.

Figure 1: Public charging station in Madeira

1.1.1 MOBI.E

Portugal has a network composed of charging stations for electric vehicles mostly located in public access spaces called MOBI.E (https://www.mobie.pt/). MOBI.E, SA, is the public company that, by indication of the guardianship, manages the energy and financial flows resulting from the operations of the electric mobility network.

The main objective of the MOBI.E network is to provide electric vehicles owners, when joining the MOBI.E card, access to all public charging stations in a simple and safe way, as indicated in the following steps:

a) Join the MOBI.E card;
b) Wait for the card to be sent by post;
c) Drive to a MOBI.E post;
d) Swipe the card to the station and enter the PIN code;
e) Select loading;
f) Choose the outlet;
g) Connect the plug to the vehicle;
h) Charging process started;
i) Swipe the card in the station;
j) Finish loading;
k) Remove the plug from the vehicle;
l) Loading completed;

The users of Electric Vehicles (UVE) from MOBI.E network, shall have a commercial agreement with an Operator holding the Electricity Marketing for Electric Mobility Register (CEME). Therefore, the price of electricity charged and established by the electricity marketer at the price set in the free market system.

1.1.1 Existing charging modes

There are four charging modes:

a) Charge Mode 1: Refer to normal charging in industrial sockets with a normal vehicle charger (usually motorbikes and similar vehicles);

b) Charging Mode 2: Regarding normal charging in industrial outlets using a control adapter integrated in the cable (usually cars);
c) Charge Mode 3: Regarding normal charging at Mennekes sockets with a normal vehicle charger;
d) Charge Mode 4: For fast charging, using a charger that changes the characteristics of the current supplied to the vehicle (from alternating current to continuous).

1.1.1.1 Types of charging for electric vehicles

The MOBI.E Network allows two types of charging for electric vehicles, normal and fast:

- The Normal Charging can be carried out in charging stations of 3.7kW and will last approximately 6 to 8 hours, allows full battery charging; or at 22kW charging stations and may last for at least 1 hour (depending on electric vehicle type). These stations are located on the public access and in private public access places such as car parks and shopping centres.
- The Fast Charge (43 kVA (AC) or 50 kW (DC)), with a 30 minutes duration, allows charging of 80% of the battery. These stations are mainly located in service areas and, sparsely in the main cities of the country.

1.1.1.2 MOBI.E: Public vs. Private

Any station placed in public access (in public or private space) must be connected to MOBI.E.

The MOBI.E network charging stations can be installed in both public and private spaces.

In the case of charging stations in a private public access space, the charging stations are installed, made available, operated and maintained by a licensed operator, and are compulsorily connected to the electric mobility network through the managing body of the electric mobility network.

In the case of loading stations in a private access of a private space, the installation, provision, operation and maintenance of loading points for exclusive or shared use may be carried out by properly licensed operators or by the owners themselves, in any capacity, of the place Charging point installation.

In case the installation, availability, operation and maintenance of charging points is carried out by the holders themselves, they may also choose to request the integration of these charging points into the electric mobility network, to use the possibility of Supply of electricity for electric mobility or other services associated with electric mobility and ensure the correct energy adjustments with the local installation.

The owners of the place can load the electric vehicles without using points of loading, using only the domestic electrical installation, observing the rules and technical and safety conditions established in the applicable legal and regulatory dispositions.

The General Directorate of Energy and Geology (DGEG) issues the operator license for the installation, availability, operation and maintenance of loading points.

1.2 Relation to other tasks and deliverables

This document lays the ground for the Installation report of the EV smart charging demo, as such it serves as a main input for D4.8, and at some extent to D4.9 (Report on customer acceptance and satisfaction) and D4.10 (Report on market acceptance and replicability).

As for the positioning of this deliverable, with regard to the different tasks of WP4, it is directly related with T4.7 (Kick-off of the Madeira pilot for EV with smart charging), providing input to T4.8 (Evaluation of EV smart charging). It also receives inputs from deliverables D4.1 (Case study specification and assessment)[1], D4.2 (Infrastructure preparation and kick-off) [2] and D4.4 (Use acceptance report of the initial smart metering deployment) [3]. Another relevant input for T4.7 which is directly related to this deliverable is the definition of the data sources that will be used in this pilot (e.g., data weather stations and forecasting models and, from WP5 mainly T5.1 “Definition of most appropriate Demand response services for each pilot”, T5.2 “Data analytics and development of predictive algorithms for DR services” and T5.4 “Development of models and control algorithms for storage integration in form of electrical storage and/or indirectly using interaction with the heating systems”).

Regarding other work packages and deliverables of SMILE project, this deliverable will provide outputs to other tasks more concretely to tasks that related with the definition and planning of the pilots (WP5), as well as in the creation of simulation models (WP8) and, for WP9. This deliverable will also provide inputs to D4.7 (Installation report of the EV with smart charging demo).

2 Pilot 1 - Getting Started with Electric Vehicles and Smart Charging

2.1 Objectives

This pilot is targeted at smaller vehicles with smaller batteries and also smaller instantaneous electricity demand.

Ultimately, the main goal of this pilot is to achieve smart charging using inexpensive infrastructure. The cost of the type of vehicles we are targeting is low when compared with bigger EVs (e.g. Renault Zoe, Nissan Leaf or the BMW i3), thus our goal is to also achieve smart charging at a fraction of the cost of off-the-shelf solutions such that smaller companies can benefit from smart charging technology. We are also envisioning expanding the scope of this pilot further, so far, we only considered small EV vehicles, however, this approach is still valid for normal vehicles charging at normal shucko plugs. It can be considered for example a small business (e.g. restaurant) that wants to offer charging to their customers, but in order, to control the total load a building and avoid having a big energy contract implements a cheap smart charging solution like the one presented in this document.

At the start of the pilot four main objectives were identified as beneficial for business/individuals operating small EV's, which will be studied in this pilot:

1. Automatically control the overall electricity demand when several vehicles are charging in simultaneous by balancing the demand among the EVs according to predefined rules (e.g., avoid of the contracted power, and periods with higher energy costs).
2. EV profiling and per-vehicle measurements to enable the control of charging times and estimate batteries status.
3. EVs fleet control and optimization by using, for example, predictions for mileage and battery cycles.
4. Study the impact of external factors, such as renewable generation and grid objectives on the use and business case of the EV infrastructure.

Furthermore, it is also crucial to understand the social/economic aspects of the smart charging pilot. Since it has the potential to affect the way drivers/users' day to day routines and electricity bill.

2.2 Intervention

This intervention will be focused in a local business that provides small guided tours in the city of Funchal and its surrounding municipalities. The business is called TukxiTours Madeira[1], and it operates in the downtown of Funchal. TukxiTours operate a mix of electric and gasoline powered Ape Calessino scooters. In the scope of this pilot, only the 6 fully electric scooters are considered. The figure bellow presents on of the tukxi scooter charging.

[1] http://www.tukxi.pt/

Figure 2: Piaggio scooter charging at TukxiTours infrastructure

2.2.1 Current charging procedures

Before the smart charging intervention starts, it is important to understand how TukxiTours handles the charging of the scooters. In our preliminary interviews, drivers mentioned that normally the scooters are charged during lunch hour and at the end of the day. On a busy day, it is necessary to charge the EV more than 1 time a day. Tukxi drivers report a range between 30 and 50 Km between charges, however often drivers opt to charge the scooter before the battery is completely depleted so there is enough charge for the rest of the day or for the following day. Figure 3 presents an average day, considering the last 3 months of charging data for two plugs at Tukxi tours. It is also noteworthy to mention that TukxiTours charging happens in a reserved area of a public parking lot, with limited access after at 02:00, after this hour the access to the scooters is limited.

This scenario presents several opportunities for improvement, especially regarding the cost of the charging since as it is most of the charging occur during peak hours, which coincide with the higher energy tariffs (more on smart charging scenarios on section 2.2.3.2). Currently TukxiTours contract is based on a tri-hour tariff, with lower costs at night and dawn (see Figure 4).

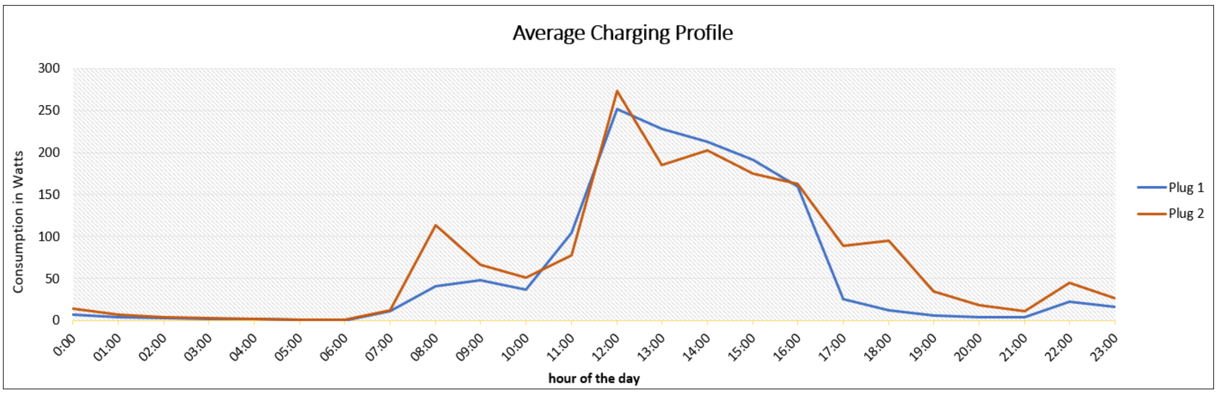

Figure 3: Average charging profile for two plugs from TukxiTours

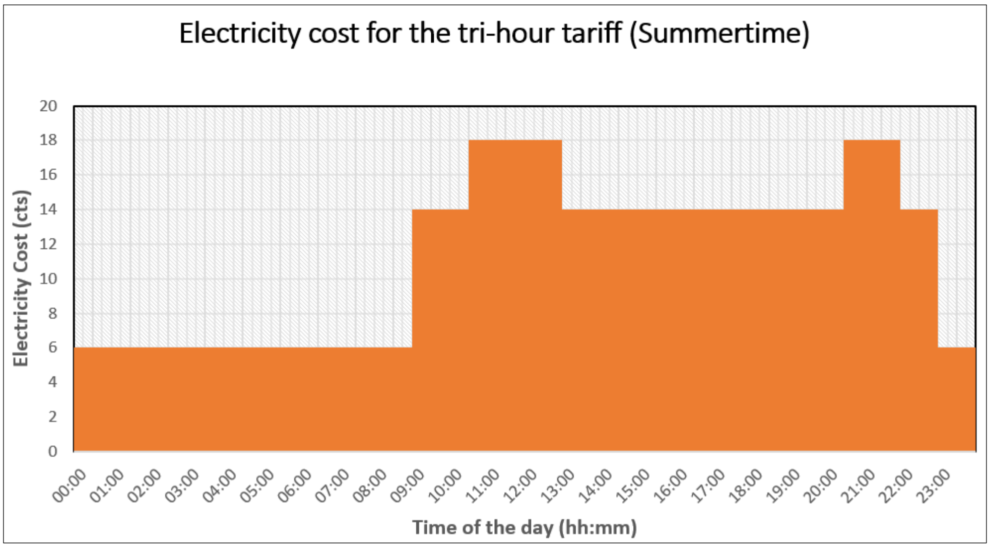

Figure 4: Energy cost for the tri-hour tariff in Madeira (Summer time)

2.2.2 Hardware

The hardware part of the Pilot 1 is composed of three main components, the infrastructure was thoroughly described in D4.2, however in the following paragraphs each components part of the infrastructure needed for this pilot is summarized.

Smart plugs: Each charging point contains a smart plug which can sense the electricity consumption of the devices connected and it can also be remotely turned ON/OFF. The smartplug is placed inside a box which transforms the connection from CE16 to schuko. Each plug is also uniquely identified by a number and QR code. Figure 2 shows one of the tukxi charging, in this picture at the top it possible to see the “box” where the smartplug are located.

Energy meter: A 3-phase Carlo Gavazzi Energy meter is used to measure the total consumption from the charging infrastructure. This aggregated information is more accurate than simply summing the consumption of each plug, since it provides more decimal values and voltage, frequency information (among others).

Gateway: The gateway is a microcomputer (Raspberri Pi[2]), with custom hardware/software developed in the project. It communicates with each plug through a Zigbee mesh, this communication is composed of consumption points and ON/OFF commands. It also reads aggregated consumption from the Energy meter described in the paragraph above. The gateway is also responsible to push individual and aggregated consumption information to the EMS, on the other had it also forwards ON/OFF commands from the EMS to individuals plugs.

EVs: It is also important to describe the EV’s. The Ape Calessino [4] scooters have a 6.88kW/h battery and are limited to charging at 16A (normal schuko plug limit). In practice, and based on the data we

[2] https://www.raspberrypi.org/products/

collected so far, the most power extracted by a scooter was approximately 2700 W. During this pilot each plug is also uniquely identified by a id and QR code.Software

On the software side, the Getting Started with Electric Vehicles and Smart Charging relies on three main modules, the software running on the gateway, a smartphone application used to collect information about the driving behaviour and charging habits, and finally the EMS which is shared between all the pilots in Madeira.

The **EMS**, as described in D4.2 is a heterogeneous server, which holds data regarding all the pilots. For this particular pilot, it is possible to visualize, which cars are available, trip sizes, batteries estimation, charging consumption among other information. All this data is also made available by the EMS to (authorized) client applications and project partners. Furthermore, the EMS also directs specific ON/OFF commands to the charging points.

The **gateway** described in section above also holds a set of software components. Generally, the software is composed by a set of daemons, which are responsible for pushing the data to the EMS, and managing a consistent backup so no data is lost is a case of connection failure. The software in the gateway is also responsible for redirecting specific ON/OFF commands to the correct plug.

The last software component it is a **smartphone application** to be used by the EV's drivers [2] This application will ensure that there is always a connection between an EV and a charging point, this will be done by reading the QR codes both in the cars and in the station every time a driver wants to start and stop charging, see Figure 5. Figure 7 presents how all the components fit into the infrastructure that implement the smart-charging for Pilot 1 *Getting started with EV's and smart charging*

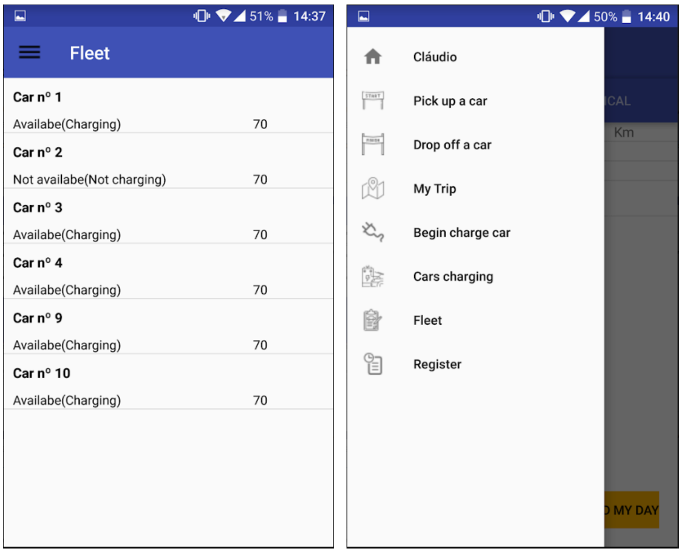

Figure 5: Different screens of the interface to be used by the Tukxi drivers

2.2.3 Smart charging implementation

In this section, the infrastructure, and know-how from the partners which will allow the implementation of the smart charging techniques proposed in this pilot are summarized.

2.2.3.1 Route monkey - infrastructure

Route Monkey's optimisation engine analyses as much data as possible relating to charge points in order to be able predict when demand will be high and when it will be low. This helps to inform when ideally a vehicle (tukxi) should charge, or when in future it could provide energy to the grid.

2.2.3.2 Route monkey - algorithms

Route Monkey could provide the following as the algorithms employs machine learning from data acquired over time around typical charging patterns:

1. An estimation/forecast of how long each user might stay plugged in
2. Develop a picture of where and when charging is occurring
3. Analyse the demand on the local network as a result of charging to:
    i. Identify peaks in demand for EV charging
    ii. Analyse whether these EV charging demand peaks coincide with wider demand on the local network
    iii. Identify potential DSR opportunities as a result of a) and b)
4. Speculate on the potential future scalability of EV charging in Madeira, given the above analysis.

The current data that is being collected will be used to create a baseline charging/building profile which could be used to evaluate the intervention of Pilot 1. This data is already being used by Route Monkey in the development of energy production forecast algorithms see Figure 6. Regarding the specific smart charging algorithms Route Monkey technologies is summarized below:

Route Monkey's Electric Vehicle optimised charging algorithm can:

- Schedule recharging based on duty cycles
- Understands the charging characteristics of the vehicle batteries
- Optimises recharging based on local area supply constraints
- Maximises value to client according to energy tariff
- Can provide demand response service to Grid

The data sources Route Monkey uses for algorithm learning are typically:

- Access to local weather station APIs at sites of interest to SMILE
- The energy generation mix for Madeira (wind, solar…)
- Any other relevant data about the energy system
- Access to an API or other clear information about Madeira energy prices and/or relevant tariffs.

For algorithm learning, it is important to obtain as much baseline data as possible before the various hardware and software interventions are introduced the island, to demonstrate the situation before and after.

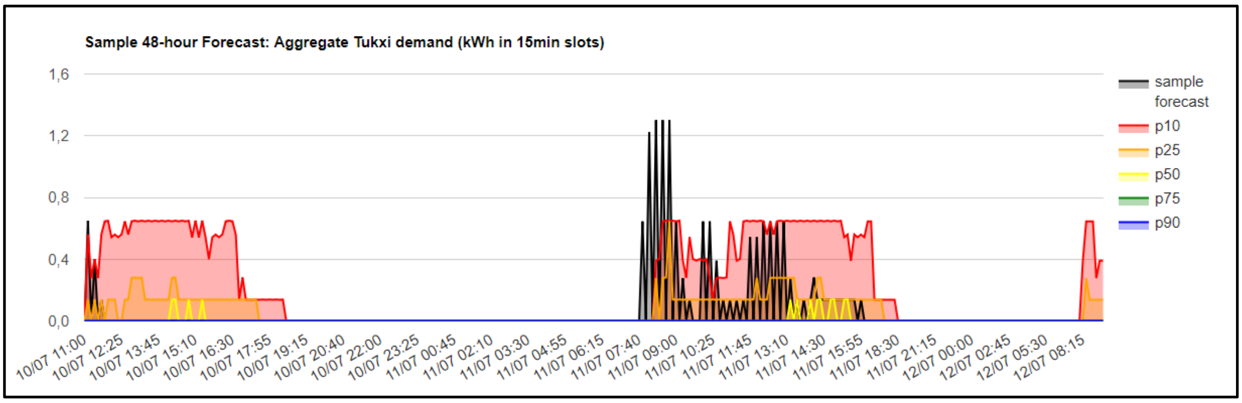

Figure 6: Output of one of the forecast algorithms developed by route Monkey for this pilot. In this case, the demand for specific charging spots is estimated.

2.2.3.3 Charging process

It is also important to mention how the drivers' application fits in the smart charging implementation since it is a critical component for this process. Before the start and at the end of each driving cycle the application asks the user to estimate the battery state of the tukxi. The EV has a small display with 10 bars that indicate the battery state. The user must input the number of bars in the application. The mobile application also uses GPS to provide an estimation of the number of kilometres the EV has travelled between each charging cycle. Additionally, the GPS coordinates of each are recorded, which can be used to assess the most travelled routes by the tuxis.

An essential part of the process the identification of what car is connected to each socket. This is done using QR codes at the plug and at the socket. The driver application asks the driver to scan 2 QR codes, one at the plug and one at the car every time a car is picked up or dropped at a charging point. The process, cumbersome as it might be, assures that relation between car and charging point (plug) is never violated.

2.2.3.4 Implementation

In practice, all the functionalities mentioned in the two previous sections come together through the EMS, which exposes authenticated routes accessed by all the components part of the smart charging, as it is summarized by the scheme below. We are still discussing with our partners the actual method to forward the results from Route Monkey algorithms to the actual plugs, but currently we are considering the following process:

1. Route Monkey provides an API which PRSMA EMS calls at a fixed time interval
2. The returned result are recommendations for control actions over the next 60 minutes, always overriding the previous call
3. There will be different recommendations for different goals (e.g. minimizing cost, overall power, renewable penetration)
4. The translation from recommendations into actual controls for the charging will be done in PRSMA EMS

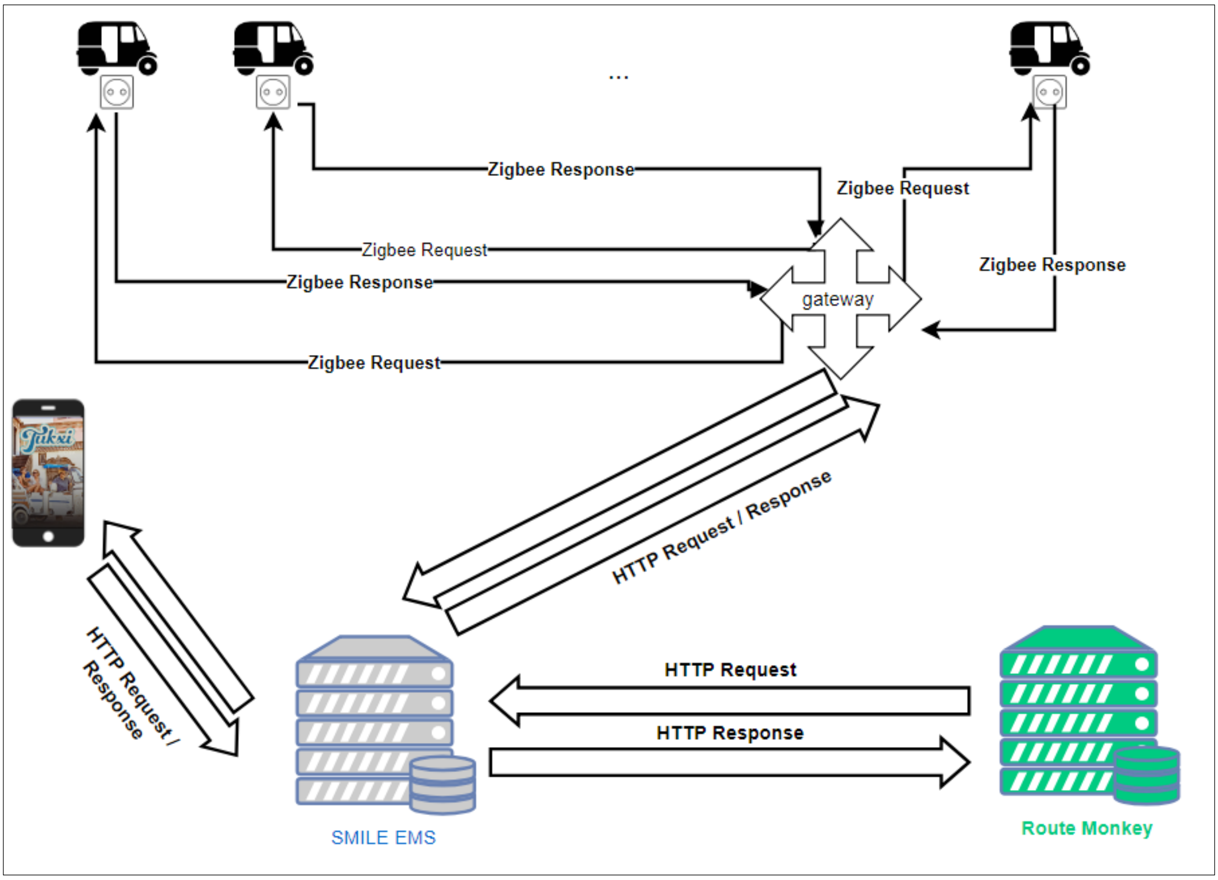

Figure 7: Overall architecture of the hardware and software components for the Getting started with EV's and smart charging pilot

2.3 Metrics and Evaluation

In this section, we present how the evaluation of the intervention for the *EV's are our future* pilot is planned. We present the metrics being collected and the method used to evaluate the effectiveness of the smart charging implementation for the Tukxi fleet. Firstly, we present the metrics and evaluation method for the smart charging algorithms, and then the method to evaluate the drivers and users of our solution is presented.

2.3.1 Metrics

The deployed infrastructures (**hardware + EMS + driver app**), collects the following data, which we considered relevant for evaluating the smart charging algorithms:

- Consumption in W per charging point
- Total Kilometers traveled between charges (per car)
- GPS coordinates for each trip between charges (30 seconds interval)
- State of battery [3]at a car pick up

[3] Inserted by the user through the mobile phone application

- State of battery before start charging
- State of battery after stopped charging
- All the plug transitions between ON/OFF

Regarding the aggregated consumption for all the plugs, the following data are collected:

- Voltage measured in volts
- Current measured in Amps
- Real power measured in Watts
- Reactive Power measured in Var
- Apparent Power in VA
- Power factor (value from 0 to 1)
- Frequency measured in Hz

All the data presented above is associated with the timestamp of its collection.

2.3.2 Smart charging evaluation

To evaluate the concrete effectiveness of the smart charging we will focus in 5 main aspects mentioned in section 2.2.3.2 . For each one of these, a method that can be used during the project to assess its performance is proposed.

Schedule recharging based on duty cycles

- Assess with drivers if the intervention impacted the availability of the cars at each moment
- Measure kilometres travelled between charges before and after the intervention
- Compare the remaining range before each charging cycle before and after study

Understand the charging characteristics of the vehicle batteries

- Compare the calculated charging characteristics with the values inputted by the users

Optimises recharging based on local area supply constraints

- Gather the constraints of the charging infrastructure before the intervention
    - Compare amount of EV's which can be plugged in at each moment before and after
- Assess with the drivers the impact in their day to day work routines
    - Currently, caused by the infrastructure limits, a driver/employee must manually connect/disconnect cars to make sure the infrastructure integrity is not compromised

Maximises value to client according to energy tariff

- Calculate current costs of charging the fleet
- Assess with the fleet owner the economic impact in the company
    - The company spends some effort manually plugging the car late at night at non-peak hours

2.3.2.1 Driver/User experience

This pilot requires input from users to work as planned. Therefore, it will also be relevant to gather users/drivers' impressions. Furthermore, the actual drivers of the EV's are also important stakeholders in the pilot, because ultimately the ability for them to do their job can be affected by the pilot.

An initial stage already started and allowed the Madeira demo pilot team to collect information about charging frequency and procedures, technical information about the vehicles, information needs, and type of phones used. This information was obtained directly with the drivers using semi-structured interviews. This information informed the application design that drivers will use to register their travelling using the electric vehicles.

After the application is launched, we will be measuring the driver's satisfaction and experience using interviews and think-alouds. This evaluation will focus on the four following aspects: user's performance (can users perform their tasks using the application), the time a task requires, the error rate, and the user's subjective satisfaction. The tasks being evaluated will be specific to the smart charging, whether drivers understand and can use the application to help them charge their vehicles, and how relevant it is for them in their daily work activities.

2.3.2.2 Business operations

It will also be important to assess how the smart charging influenced the business operation. To assure the replicability of this pilot it must meet the business expectations before the pilot. A simple metric to consider here can be the electricity bill, which is a relevant expense for Tukxi.

3 Pilot 2 - Electric Vehicles Are Our Future

3.1 Objectives

The second EV and smart charging pilot will focus on providing a smart charging solution using standard chargers by taking control of the ON/OFF status of the charge. The overarching goal of this pilot is to retrofit existing installation with hardware/software which would allow controlled charging. We are also focused in scenarios where more than one EV charge at the same time, (for example a common parking lot at an apartment building), since these are especially challenging since more than one vehicle could "compete" for rights to charge, or the charging must consider the physical limitation of an outdated electricity installation. In summary, we are interested in implementing a smart charging approach based on:

1. **Pricing**: Controlling the state of the charge based on the price of the electricity. The charger will be turned OFF during peak prices and ON during off-peak prices.
2. **Electricity demand on the island:** This scenario is particularly relevant for the DSO when we consider a future situation with a much higher number of EV's in the grid. In such a situation, charging the EVs can be considered a way of implementing demand side management strategies to avoid issues with the grid stability.
3. **Renewable availability:** The charging can also be controlled based on the energy mix. This can be done considering the availability of renewables in the grid, thus being more advantageous to the DSO. Alternatively, it can be implemented considering local renewable availability for micro-producers, which can reduce the impacts (financial and environmental) of charging the EV directly from the grid.
4. **Aggregated energy consumption in the building:** It might also be important for electricity consumers to ensure their consumption never surpass the value established in the contract with the DSO. For example, smart charging can consider the current and future demand and decide if it is possible or not to charge the car at a given moment. In such a scenario, the providers of the charging facilities will be able to contract less power from the DSO. We believe this scenario is particularly relevant in parking lots and apartment blocks where more than one EV will request charging in simultaneous.

3.2 Intervention

This intervention will be focused on the garage of EEM, which is one of the partners. This is an appropriate location for this pilot since it contains a relevant number of EV's (which can allow us to relate the results to other building such as apartments), there is easy access to the chargers and drivers (to assess the social aspects of the smart charging). Furthermore, it is also noteworthy to mention that EEM garage electricity installation/contract is over dimensioned, therefore we will not be limited by that factor during the project.

3.2.1 Electric vehicles and charging infrastructure

EEM garage contains the following EV on a "permanent daily basis"

- **5 Renault ZOE (GEN3)** with a 65 kW (maximum net power) 100% electric engine + 22 kWh battery capacity;

- **3 Nissan Leaf** with a 80 kW (maximum net power) 100% electric engine + 30 kWh battery capacity;
- **1 Mitsubishi iMiEV** with 49 kW (maximum net power) 100% electric engine + 16 kWh battery capacity.

There are also 3 Renault ZOE (GEN3) and one 1 Renault Kangoo with 100% electric engine + 22kWh battery capacity,that can visit/charge at EEM garage for different periods of time.

The charging at EEM garage is covered by **6 x 22kW (three-phase, 32A/phase, 230/400 V)** EV charging points and **several CEE (16A, single-phase, 230V)** sockets (IEC/EN 60309) all connected to a single electric board (1 electric meter).

3.2.2 Charging procedures

The charging at EEM is not as straightforward as the one at Tukxis, since apart from the Renault Kangoo, which is part of EEM maintenance services, all the cars belong to their employees which in average have less need to charge the car every day, additionally some of the drivers might charge their cars at other locations. The garage is managed by an EEM employee which normally parks the cars next to the charging station and is also responsible from switching the charging once a car is charged, working as the *de facto* smart charging at EEM.

As mentioned above the charging does not follow any pattern, but after averaging the charging at two stations in the past 3 months, most of the charging happens at the start of the day, probably once the employees arrive at EEM and in the middle of the day, see Figure 8. Looking at the data in detail in the past 3 months there was a maximum of 61kW of instantaneous power demand in a situation were 3 charging stations were pulling more than 20kW each, there were, of course other situations with 3 and 2 cars charging at the same time consuming a high amount of energy, these preliminary analyses present an opportunity for the scenarios which take into account the maximum infrastructure or contract limit from a building, since it is not common to have an installation that can handle 60kW of instantaneous power (see section 3.2.3).

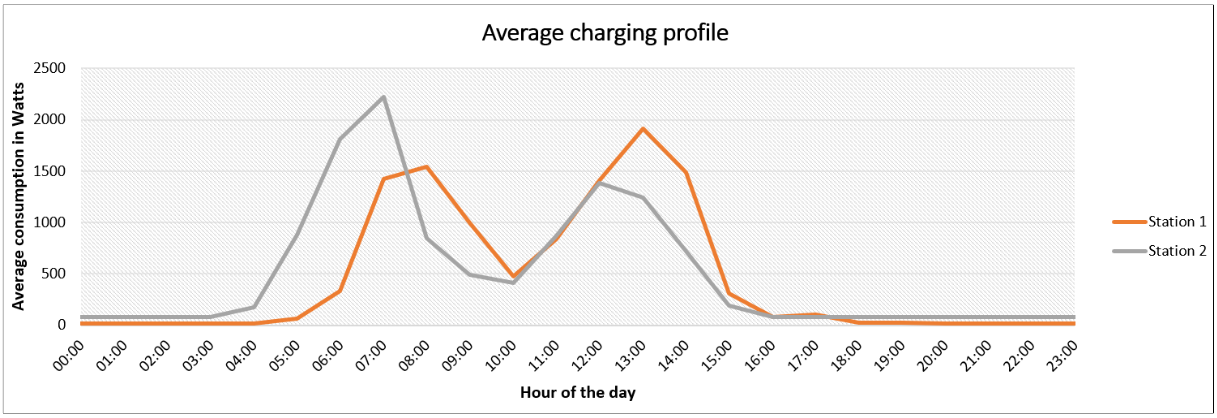

Figure 8: Average charging profile for two charging station from EEM garage

3.2.3 Smart charging Implementation

The Madeira partners along with Route Monkey, envision the following concrete scenarios for implementing the smart charging in the *EV's are our future pilot*. Please note that in the first two scenarios, the benefits to the EV fleet owner are immediate (e.g., less contracted power, and automatic fleet control). Nevertheless, in the last two cases the direct benefits are for the grid operator. Consequently, during the pilot we will study mechanisms to provide added value to the EVs fleet owners as well.

3.2.3.1 Take into consideration the contracted power

Control the EVs charging taking into consideration the total power being used and the contracted power. Ultimately, we will be attempting enable the reduction of the contracted power by smartening the way the charging is conducted.

- To make this possible, we must take into consideration the load profile of each EV when charging to decide which cars should have the highest priority.
- We must guarantee that, depending of the fleet size, n EVs are always in the verge of being fully charged.

3.2.3.2 Take into consideration the trips made by the EV and the driver profile

We can also try to use trip information and driver profiles to change how the smart charging is done. This includes, for example, estimating the battery status and possibly predicting when the driver will need to leave the garage.

Like in the scenario above, we must guarantee that, depending of the fleet size, n EVs are always in the verge of being fully charged. This should be adjusted in time, as the algorithm *gets smarter*.

The data that is relevant to this is as follows:

- Regular up to date monitoring data from each plug socket
- Associated background data and constraints (contract, typical charging profile, number of vehicles)

Route Monkey will process the data as follows:

- Very simple estimate of state of charge of each vehicle plugged in
- Calculate and maintain on/off schedules that collectively work within the constraints and reduce overall kWh
- Update those schedules with each new event (plug out/plugin)
- Send those schedules and updates as necessary back to PRSMA.

Alternatively, if Route Monkey can obtain information about individual EV trips and drivers, they can provide a better prediction, better estimation of SoC when they plug in, better estimation of demand over the next few hours, and hence better potential for optimising: whether that means reducing consumption, maximising green, or some other objective to be defined.

To be able to create a driver profile Route Monkey would need additional equipment in the EVs, for instance, telematics data to map each journey, such that we can create extract a driver profile. Please note that the trips are highly dependent on external conditions, e.g., weather, time of the year. Thus, creating such a driver profile from this may become a very interesting machine-learning problem.

Route Monkey will also need to find a way to associate drivers to EVs, and since this is not done automatically (i.e., it is not possible to know which EVs is connected to each plug), we must find ways to do that. A possibility would be to introduce an intermediary step in the charging workflow. In this step, the driver would need to use a central application to start the charging. A very simple example follows:

1. The driver arrives at the garage and plugs the EV to plug number 1.
2. The driver needs to access the app and switch ON the corresponding plug.
3. Once the driver enters the garage, and the local WI-FI connection is detected, the data from the cell phone can be uploaded to the server.
4. From this point onwards, it is possible to analyse the previous trips data, and estimate the battery state and when the driver will most likely leave the garage again.
   4.1. Note that by using the phone data may be possible to identify the driver and estimate to which plug it was connected. Nevertheless, this can become problematic if two or more drivers arrive at the same time, or if a driver arrives and does not connect the EV to the charging system.

Ultimately, combining data from the mobile phone and the charging applications, would allow us to fully track the EVs fleet.

3.2.3.3 Take into consideration the renewables in the grid

Control the EV charging based on the degree of renewables generated for the grid (actual and forecasted data). For example, charging all the EVs during the night period when there is plenty of energy generated from wind, will represent an increase of renewables in the energy mix.

In such a scenario, if the EV fleet operation already benefits from a dual-tariff contact, they will benefit immediately from lower energy prices.

3.2.3.4 Take into consideration grid frequency control

Using frequency and voltage fluctuations on-site, Route Monkey could also try to use smart-charging to enhance the quality of the grid.

3.3 Hardware

Currently the deployed hardware used in the Pilot 2 only allow us to monitor the individual consumption at each charger part of the selected infrastructure. In this section, we describe the current state of the infrastructure and the next steps needed before implement the smart charging. Even though the control mechanism to be used in this pilot is still being developed, the monitoring equipment is already installed. This data can already be used to study the charging profiles and build the algorithms.

3.3.1 Monitoring

The monitoring infrastructure was described in deliverable 4.2, [2] however in the section we summarize the main components used to monitor the charging site (EEM garage) part of EV Pilot 2 - *EV's are our future*. The monitoring of the EEM garage is currently being accomplished by a set of **commercial Open Energy Monitor** equipment (EmonTx), currently 4 charging stations are being monitored at a frequency of 1 points per minute. Moreover, we are also collecting 6 points per minute data for offline analysis.

3.3.2 Communication

Similarly, to the installation for the first EV pilot, the EEM garage is also using a gateway in order to "connect" all the equipment with the EMS. In this case, the gateway is part of the commercial **Open Energy Monitor EmonTx**. It provides the consumption from each plug in a URL which is queried by the EMS. EEM created a network in their garage to be used by the equipment in the pilot.

3.3.3 Control

The control of each vehicle charge will be accomplished by placing a contactor between the charger and the car. This allow us to control the ON/OFF state of each charger. Additional hardware is necessary to assure the contactor can be remotely controlled (a gateway), and to safely place the contactor between the car and charger (J1772 plugs). Furthermore, it was decided to also place a three-phase energy monitor (Carlo Gavazzi EM340) to gather more accurate electricity consumption values while the cars are charging. In the remaining of this document these components will be named as control and communication module (CCM), the CCM was described in detail in deliverable 4.2 [2].

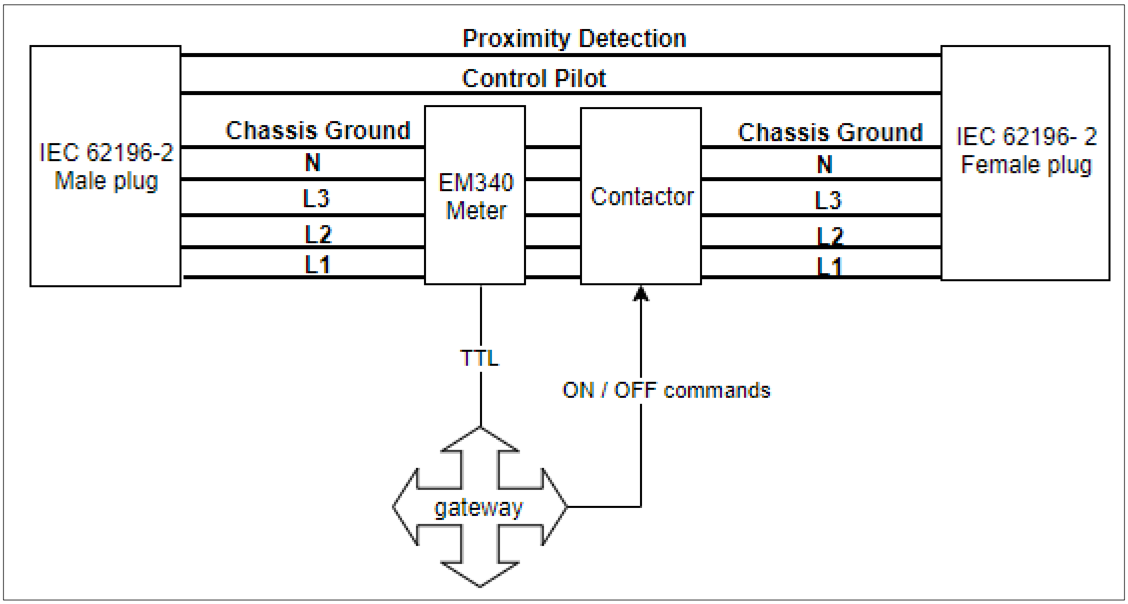

Figure 9: Components part of the Communication and Control module

3.4 Software

The *EV's are our Future pilot*, like the all the pilots part of WP4 relies heavily in the **EMS** provided by PRSMA. Therefore, this is the main software component in this pilot. It aggregates the consumption and forwards ON/OFF commands from/to each CCM. It also provides individual and aggregated consumption to clients (web visualizations for example) and partners (Route Monkey). The EMS also provides an administration page, where it is possible to visualize consumption and vehicle status among other metrics. For this particular pilot the EMS will provide authenticated routes for Route Monkey to access the data and publish charging schedules for the EEM vehicles.

The **CCM** also encompasses software components which push data to the EMS and control the hardware responsible to act on the received commands (see Figure 9). The scheme below summarizes the communication between the CCM, responsible for physically controlling the charging, the PRSMA EMS, which holds the historical data and provides access to individual plugs, and Route Monkey's infrastructure, which runs the smart charging algorithms and provide specific charging commands. To redirect the actual ON/OFF commands from Route Monkey to the CCM, we are considering to following the same method used for the first pilot (see section 2.2.3 implementation).

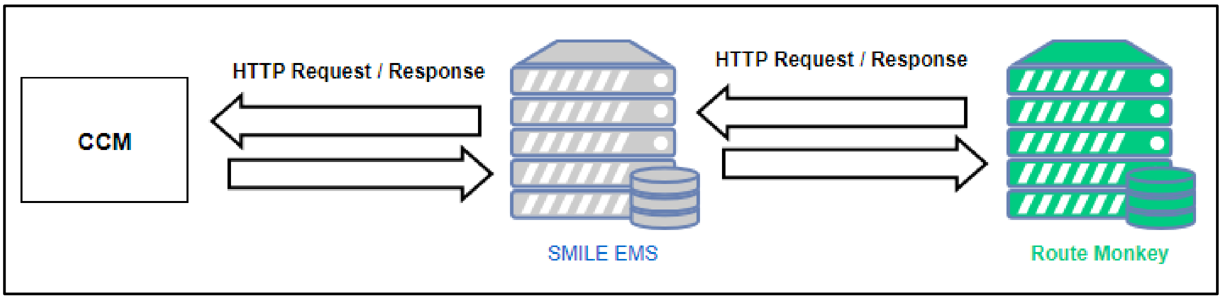

Figure 10: Communication between the EMS, Route Monkey and the CCM.

Recently it was proposed (see section 3.2.3.2) that it would also be valuable for the *EV's are our future* pilot to use a mobile application for the drivers. This application would be similar to the application to be used in the Tukxi drivers in pilot 1 *Getting Started with EV's and Smart charging*.

At this stage, we are still studying this possibility. From the technical standpoint there are no significant challenges, however there are human/social challenges that might need to be considered before the EEM drivers adopt this application. In any case, this application would fit parallel to the gateway, like the scheme presented for the first pilot EV's are our future, see Figure 7.

3.5 Metrics and Evaluation

In the following section, we present how the intervention presented above should be evaluated. We took into account two main topics, the smart charging and the more human aspect of assessing how the intervention influenced drivers' expectations and routines.

3.5.1 Metrics

Before the intervention takes place a period of baseline consumption data is being collected, this data will be used for A/B testing after the implementation. It is also noteworthy to mention that the sub-grid which feeds into the charging infrastructure was monitored for electricity quality for six months before the individual plugs started to be monitored. Therefore, this data can also be used during the evaluation of the intervention. Figure 12 presents the consumption profile from one of the plug as monitored by the EMS, and Figure 11 presents the energy quality metrics monitored before the per-plug monitoring started (more on the monitoring infrastructure is presented at D4.2 [2]).

Currently, the infrastructure based on the Open Energy Monitor collects per charger consumption in **Watts** with a **timestamp** associated, every minute. After the adapter described at section 3.4 is deployed, we are aiming at collecting:

- Voltage measured in volts
- Current measured in Amps
- Real power measured in Watts
- Reactive Power measured in Var
- Apparent Power in VA
- Power factor (value from 0 to 1)
- Frequency measured in Hz

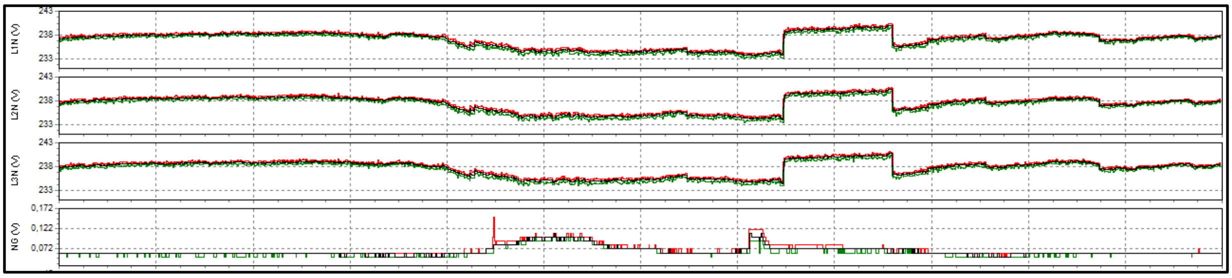

Figure 11: Different metric gathered by the energy quality analyser that was monitoring EEM charging sub grid before the start of the smart-charging pilot

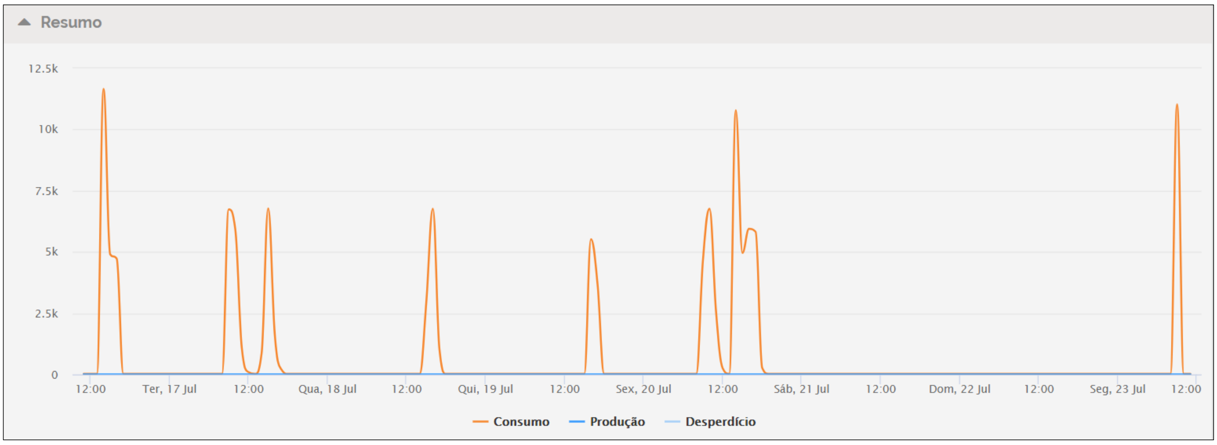

Figure 12: Consumption from one of the charging stations as presenteted by the EMS

3.5.2 Smart charging

Regarding the specific methods used to evaluate how well the smart charging performed, in the sections below we present how the evaluation could be carried out considering the 4 scenarios presented in section 3.2.3.

Scenario 1 - Take into consideration the contracted power

- Comparison between the aggregated consumption by all the charging points and the contract limit from EEM garage.
- Simulate for other scenarios with the more realistic contracted energy limits
  - Condominium
  - Office buildings

Scenario 2 - Take into consideration the trips made by the EV and the driver profile

- Individual assessment with each driver, to understand if the intervention impacted their driving routines.
- Comparison of the overall kWh of the infrastructure before and after the intervention.
- Comparison of the overall cost of the charging before and after the intervention.

Scenario 3 - Take into consideration the renewables in the grid

- Comparison between the forecasted renewable mix in the grid with the actual generated electricity over a time period.
- Compare the overall renewables used during the EV charging, before and after the intervention

Scenario 4 - Take into consideration grid frequency control

- Identify frequency fluctuations in the baseline data that is currently being collected
- Measure and compare the frequency fluctuations during the intervention

3.5.3 Drivers

We believe it will be important to assess how implementation of the smart charging affected the drivers of the vehicles. To do that the drivers will be interviewed to compare their previous charging routines before the pilot started and around 4 weeks after it has been deployed. Two moments of interviews will be planned, before and after the pilot deployment. In addition, the drivers will be given a similar application as in Pilot 1 where their charging routines will be tracked, and users will insert their information. Semi-structured Interviews, Think-aloud techniques and observations will be the methods used to collect this data from the drivers.

4 Conclusions

In this document, the plan to evaluate the 2 pilots with Electric Vehicles and smart-charging is presented. We detailed the intervention, what will be measured and how its success will be evaluated.

The document was developed with the help of the project partner responsible for the implementation of the smart charging algorithm (Route Monkey). Due to the nature of the smart charging algorithms, which are influenced by diverse features such as electricity consumption, weather, or even social features like drivers' willingness or satisfaction it was not feasible or wise to detail the actual algorithms. Therefore, we detailed a set of scenarios in which the smart charging will act, and a set of metrics to evaluate its effectiveness.

In the following section, we present the status of both interventions part of the pilots, and which are the future steps necessary to execute the first two smart charging pilots in the island.

4.1 Current status and Future Steps

This section presents the current status of the two pilots described in this document

Pilot 1 Getting Started with EV's and Smart-Charging

The intervention for first pilot with EV's and smart charging in Madeira is almost ready to start. Most of the infrastructure is ready the three pending tasks are:

- The **installation of the energy meter** to sense all the charging aggregated from TukxiTours. We are waiting for an authorization from the site manager/owner before installing the equipment
- The **deployment of the smartphone application** is halted, since there were a few late requirements which are now being implemented.
- The **communication with Route Monkey** services (as detailed in section 2.2.3.4) still needs to be refined and tested, although the its outline is as mentioned before.

Pilot 2- EV's are our Future

Regarding the second pilot, the integration with the EMS is defined and the communication protocols and hardware are specified. The integration with the Open Energy Monitor EmonTx is complete, and the outline for CCM is also defined. The communication between the CCM and the EMS is also complete as it is similar to the UPAC installation [2]. The integration with Route Monkey algorithms will be like the approach presented at 2.2.3.4. The remaining task needed before the start of the intervention are :

- **Development of the CCM**, as we are currently waiting for equipment. In some cases, the suppliers have been sourced and in other cases are searching for the most appropriate supplier.
- **The test of the CCM** will be done once it is built.
- **Development of the algorithms** for the EEM garage will be done together with Route Monkey once more accurate per plug data is available (through the CCM)

It is also important to consider the timeline defined in the grant agreement and state the status of the planned tasks. The EV and smart charging pilots encompass the following tasks. Task 4.7 has started and Task 4.8 is yet to start

- **Task 4.7:** Kick-off of the Madeira pilot for EV with smart charging from M6-M48"
    - Sub-task 4.7.1: Installation of communication infrastructure
    - Sub-task 4.7.2: Hardware installation and systems integration

Both these tasks have started, the communication infrastructure is complete, both pilot sites are communicating with the EMS without issues. Most of the integration effort is also complete, the only major task that is yet to be finalized is the implementation of Route Monkey commands in the SMILE EMS (although a method was defined in section 2.2.3.4).

- **Task 4.8:** Evaluation of EV smart charging from M36-M48.

This task will formally start at month 36, in which we will assess the effectiveness of the smart charging decisions in each pilot (section 2.2.3.4 and 3.5.2). This task will take into account the baseline data being currently acquired as well as the charging profiles after the intervention. The impact of the smart charging in the drivers and business owners will also be considered.

4.2 Timeline

In this section we define a timeline with the proposed tasks until the end of the project. Figure 13 presents the tasks of the EV and smart charging pilots in a Gantt chart together with the other tasks part of SMILE.

M15-M18:

- Sub-task 4.7.1: Installation of communication infrastructure
    - Sub-task 4.7.2.1: Development of and test of the CCM
- Sub-task 4.7.2: Hardware installation and systems integration
    - Sub-task 4.7.2.2: Testing and integration of the Tukxi Smartphone application
        - Sub-task 4.7.2.2.1: User data collection and feedback using think-aloud

M18-M24:

- Sub-task 4.7.2.3: Installation and testing of the CCM
- Sub-task 4.7.2.4: Hardware and software integration test for EV pilot 1
- Sub-task 4.7.2.5: Hardware and software integration test for EV pilot 2

M24-M30:

- Sub-Task 4.7.2.6: Acquisition of baseline data with the CCM
- Sub-task 4.8.1: Kick-off of the Intervention for EV Pilot 1
- Sub-task 4.8.1.1: Customer feedback and satisfaction information collection

M30-M36:

- Sub-task 4.8.2: Kick-off of the Intervention for EV Pilot 2

- Sub-task 4.8.2.1: Customer feedback and satisfaction information collection

M36-M42:

- Sub-task 4.8.3: Evaluation of EV smart charging pilots
- Sub-task 4.8.3.1: Customer feedback and satisfaction follow up

M36-M48:

- Sub-task 4.8.4: Report of the results from both pilot studies.

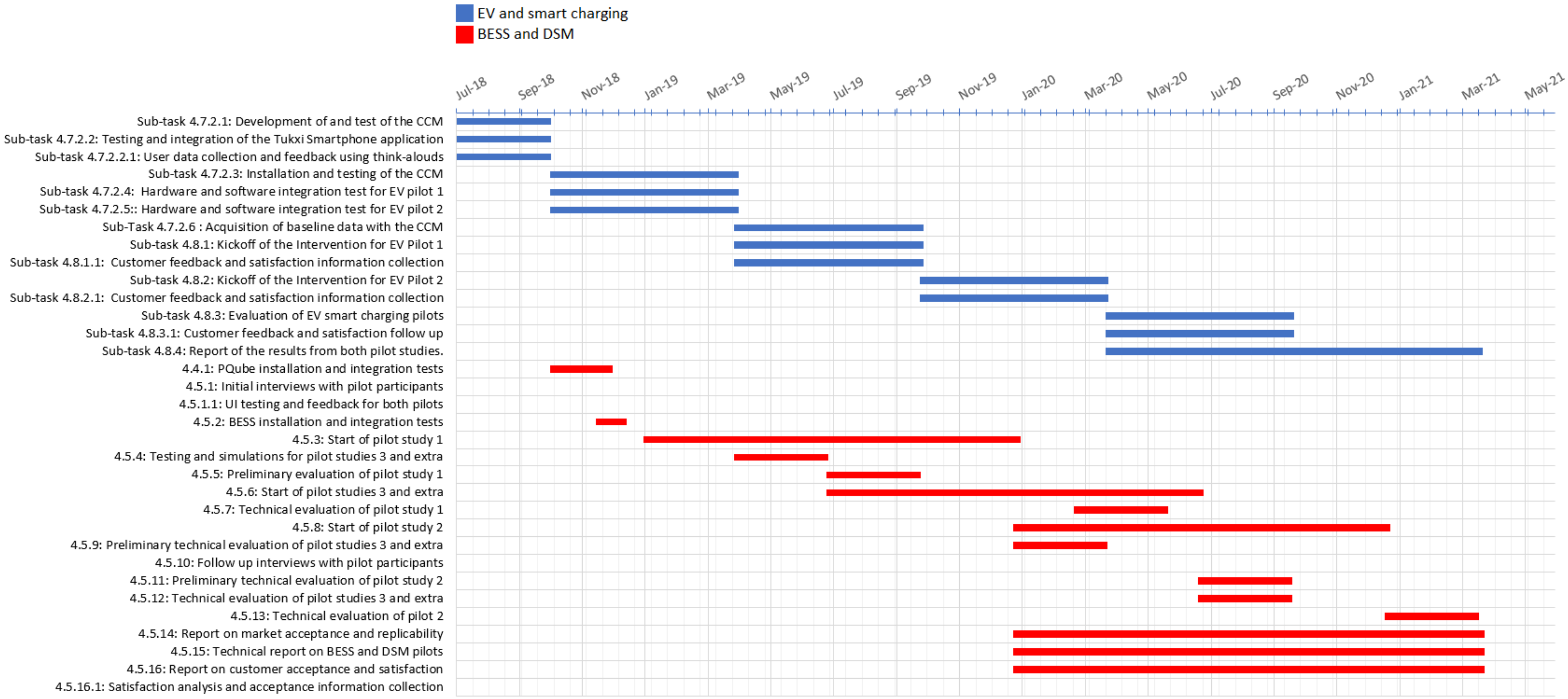

Figure 13: Proposed timeline for the remaining tasks for the DSM, BESS and smart charging pilots

5 References

[1] ACIF-CCIM, M-ITI, PRSMA, EEM, e Rute Monkey, «Madeira Pilot Case Study Specification and Assessment», European Union, 4.1.
[2] PRSMA, M-ITI, EEM, Route Monkey, e ACIF-CCIM, «Infrastructure Preparation and Kick-off», European Union, 4.2.
[3] M-ITI, EEM, Route Monkey, ACIF-CCIM, e PRSMA, «User acceptance report of the initial smart metering deploymen», European Union, 4.4.
[4] R. Motorbox, «Novità:: Piaggio Ape Calessino Electric», *MotorBox*. [Em linha]. Disponível em: https://www.motorbox.com/moto/magazine-moto/moto-novita/piaggio-ape-calessino-electric. [Acedido: 12-Jul-2018].