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Smart Island Energy Systems

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Madeira Pilot Case Study Specification and Assessment

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Keywords, Acronym

AC	Alternate Current
ACIF	Madeira’s Trade and Industry Association
AM	Ante Meridiem: Before noon
AMI	Advanced Metering Infrastructure
AMR	Advanced Metering Reading
ANSI	American National Specification Institute
API	Application Programming Interface
BESS	Battery Energy Storage System
BMS	Battery Management System
CB	City Bubbles
CDMA	Code Division Multiple Access
CEME	Operator holding the Electricity Marketing for Electric Mobility
CP	Charging Point
CUR	Last Resort Marketer
DC	Direct Current
DGEG	Energy and Geology General Administrator
DL	Decree-Law
DNP	Distributed Network Protocol
DP	Distribution Point
DRET	Regional Direction of Economy and Transport
DSM	Demand Side Management
DSO	Demand Side Operator
EDGE	Enhance Data GSM Environment
EDP	Portuguese Energy company designated as Energias de Portugal
EEM	Electricity Company of Madeira
EMS	Energy Management System
ERSE	Regulatory Authority for Energy Services
EV	Electric Vehicle
FF	Frequency Fluctuation
FTP	File Transfer Protocol
GAMEP	Office for Electric Mobility in Portugal
GPRS	General Pocket Radio Service
GSM	Global Systems for Mobile Communications
HSPA	High Speed Pocket Access
HTTP	Hypertext Transfer Protocol (world wide web protocol)
Hz	Hertz
I2C	Inter-Integrate Circuit
IDIS	Interoperable Device Interface Specifications
IMT, I.P.	Institute for Mobility and Transport, I. P.
IoT	Internet of Things
IP	Internet Protocol
ITTT	If this, then that
KMS	Key Management Service
LAN	Local Area Network
Li-on	Lithium-ion
LPWAN	Low Power Wide Area Networks
LTE	Long Term Evolution
LV	Low Voltage

M-ITI	Madeira Interactive Technologies Institute
MOBI.E	Portuguese Network composed of charging stations for electric vehicles
MV	Medium Voltage
NiCd	Nickel-Cadmium
NiMh	Nickel–metal hydride
NOS	Portuguese communications and entertainment group
NTP	Network Time Protocol
OFDM	Orthogonal Frequency Division Multiplexing
PLC	Power Line Communication
PM	Post Meridiem: After noon
PPP	Point-to-Point Protocol
PQDIF	Practice for the Transfer of Power Quality Data
PSTN	Public Switched Telephone Network
PV	Photovoltaic
QoS	Quality of service
RESP	Public Service Electric Grid
RF	Radio Frequency
ROI	Return Of Investment
RPMA	Random Phase Multiple Access
RTIEBT	Technical Rules for Low-voltage of Electrical Installations
RTU	Remote Unit Control
RUPAC	Remuneration for Electricity Supplied to RESP
SC	Serial Communication
SIAM	Measuring Inspection Service within EEM
SMTP	Simple Mail Transfer Protocol
SNTP	Simple Network Time Protocol
SPI	Serial Peripheral Interface
TCP	Transport Communication Protocol
TET	Tukxi Eco Tours
UART	Universal Asynchronous Receiver-Transmitter
UMTS	Universal Mobile Telecommunications System
UP	Production Unit
UPAC	Unit of Production for Self-Consumption
UPP	Unit of Small Production
UVE	Users of Electric Vehicles
V2G	Vehicle To Grid
VDP	User Datagram Protocol
VFI	Voltage False Increase
WAN	Wide Area Network
WP4	Work Package 4

Gateway – information aggregation software that allows the communication between metering locations in the Internet.
Middleware – integration software that will allow reading production data and pushing it back to the EMS.
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.

Self-consumption – electricity that is produced from renewable energy sources, not injected to the distribution or transmission grid or instantaneously withdrawn from the grid and consumed by the owner of the power production unit.

1 Introduction

1.1 Scope and Objectives

In this document, we present the specification and assessment of the Madeira pilot study in the scope of the SMILE project.

The objectives of this document are three-fold. First, it provides additional information about the Madeira electric grid, and the current legislation for micro-production and electric vehicles. Second, it gives additional details about the main objectives of Madeira under the SMILE project framework. And third, it motivates and describes the five pilots that will be conducted in Madeira island to achieve the proposed objectives.

1.2 Structure

The document is structured as follows: in chapter 2, we present some national and regional considerations that we believe are important for a better understanding of the full document. In chapter 3, we present the rationale and an overview of the pilots that will be conducted in Madeira island. The different pilots are then explained in more detail in chapters 4, 5, and 6. In chapter 7, we describe the participants recruitment process, whereas in chapter 8 we report the conclusions.

This document also contains four appendixes and two annexes. Appendix A summarizes the different surveys for AMI technology. Appendix B gives an overview of BESS technologies. Appendix C is about communication technologies, whereas Appendix D provides an extended summary of the current legislation for Micro-production and electric vehicles in Portugal. As far the annexes (I and II) are concerned, these contain the questionnaires that will be used during the recruitment process.

1.3 Relationship with other deliverables

This document forms the basis for the Madeira demonstrator under the SMILE project framework and is to be used as the main input for many of the remaining deliverables, in particular D4.2, D4.6, due in months 13 and 15, respectively. In terms of its positioning in what concerns the tasks defined for WP4, it is the direct output of T4.1. Nevertheless, this document is also strongly related to T4.2 (Infrastructure preparation), and T4.6 (case study specification and assessment of EV with smart charging).

Regarding the other work packages and deliverables of SMILE, the pilots specified in this document will, after its assessment, influence the work that will be performed in WP7. Battery storage and EV charging are still at an early stage in Madeira, and although the current legislation already considers this equipment, WP7 (D7.1) might propose some adjustments. Furthermore, we mention throughout this document the change in legislation in 2014, which halted the installation of more UPPs, the work in WP7 will certainly contribute to adjusting the current situation (D7.3 and D7.4).

It is also clear the connection between the specification of each pilot and the work to be developed in WP6. The work presented at D6.1 will consider our pilots and suggested business models in the selected metrics for the evaluation. Then, after each pilot assessment, the viability of potential business models identified in our specification will have to be evaluated and adjusted (D6.4).

All the data generated from our five pilots will be available for our partners of WP8 to use as part of their modelling tasks. The qualitative assessment of the pilots could also be used in the design part of the WP8 scenarios.

2 National and Regional Considerations

In this chapter, we present some national and regional considerations that we believe are necessary for a full understanding of this document. To state more concretely, we first give an overview of the Madeira island electric grid, including details about distribution production from RES and the current situation of EVs in Madeira island. We then present a summary of the current legislation for the micro- and mini-production from solar energy, as well as for EVs and the respective charging stations. Finally, we recall the original objectives of Madeira for the SMILE project.

2.1 Overview of the Madeira Electric Grid

Madeira is a total energy island, and all the energy is generated locally. EEM is the only DSO in Madeira, and is responsible for the activities related to production, transport, distribution and commercialization of electric energy. EEM is also the entity that acquires the electric energy that is produced by private micro- and mini-producers. Figure 2.1 shows an overview of Madeira's electric grid characteristics.

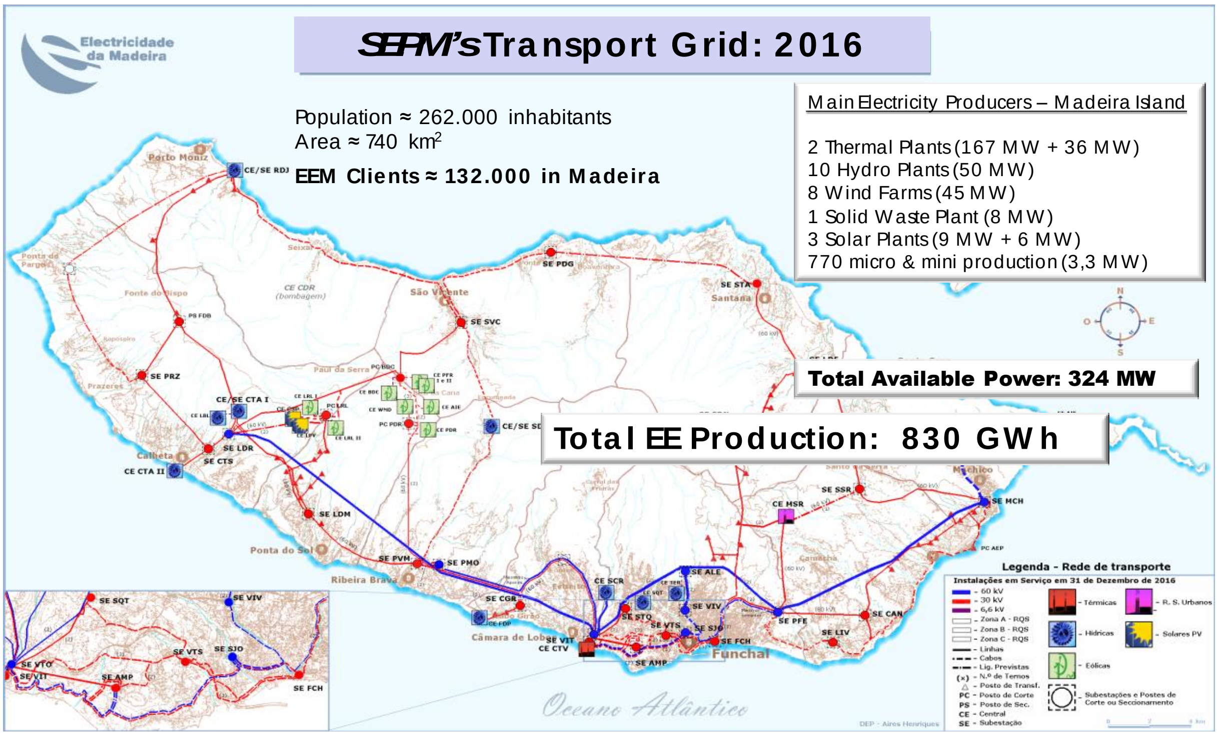

Figure 2.1 – Overview of the Madeira electric grid characteristics

The electric grid in Madeira island is fed by five sources of energy, namely: hydro, wind, photovoltaic, solid waste incineration, and thermal energy from burning fossil fuels like diesel and natural gas.

As of this writing the electric energy production in Madeira island is guaranteed by two thermal plants, 10 hydro plants, eight wind farms, one solid waste plant, three solar farms with 7 MW, 2 MW and 6 MW respectively, and 770 distributed solar micro and mini-producers, with full injection to the grid. The grid is composed of: 20 x 30/6.6 kV substations, 4 x 60/6.6 kV substations 3 x 60/30 kV substations and 2 x 60/30/6.6 kV substations.

The grid total losses amount to 8.6%.

The grid total losses amount to 8.6% of the total emission (2016). From that value, 0.5% are the responsibility of the HV networks (60 kV), 2.5% are losses at the MV level (30 and 6.6 kV), with the remaining 5.6% losses happen low voltage network. It should be noted that LV losses include commercial losses.

Figure 2.2 shows the energy mix in Madeira island from July 2016 to June 2017. As it can be observed, the period with highest renewables in the mix happened between November 2016 and March 2017, mostly driven by the increase in the production of the hydro plants. Finally, in Figure 2.3 we present the overall breakdown on the energy mix by source. This shows that in that period, there was an average of 30% of renewables in the grid, which is still far from the company goal of having an average of 50% renewables in the energy mix by 2020.

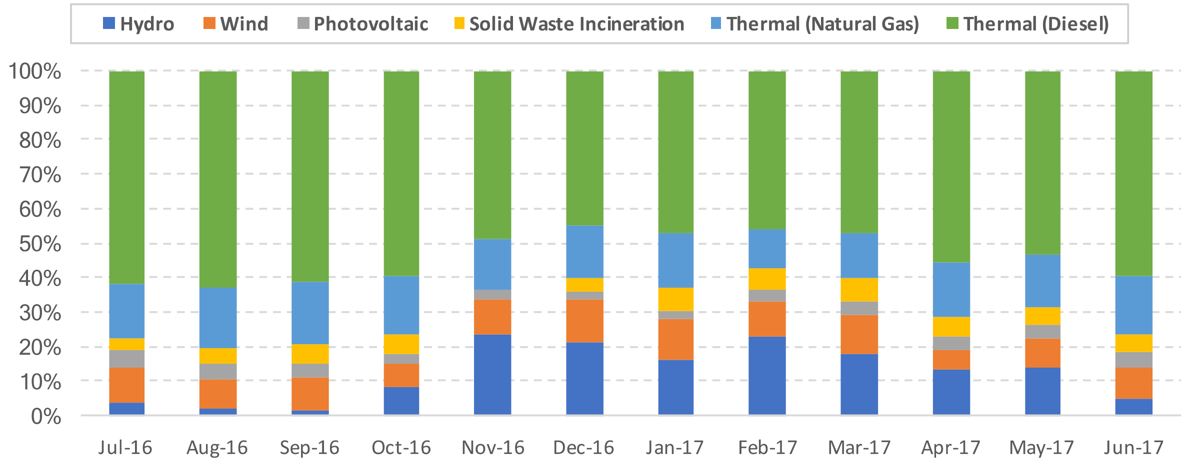

Figure 2.2 – Monthly energy mix in Madeira island between July 2016 and June 2017

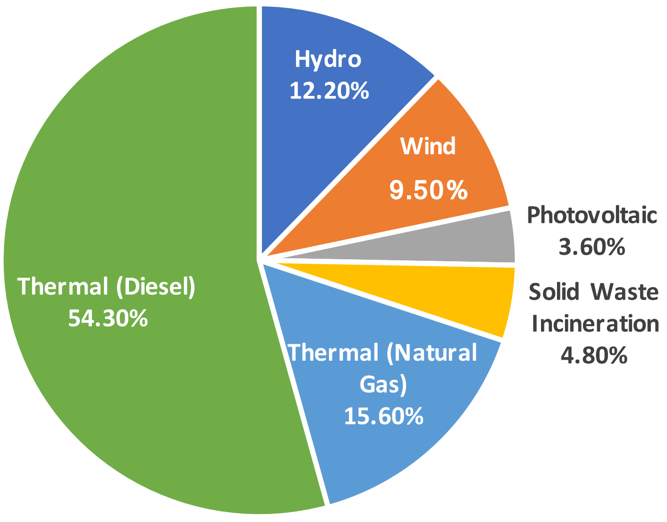

Figure 2.3 – Overall energy mix in Madeira island between July 2016 and June 2017

In 2015, the electric energy consumed in Madeira island was about 798 663 MWh. The non-domestic sector (e.g., tourism and commerce) was responsible for near 46% of that consumption, whereas the domestic sector was responsible for about 30%[1]. The energy consumption by end-sector in 2015 is illustrated in Figure 2.4.

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[1] DREM, https://estatistica.madeira.gov.pt/en/download-now-3/economic/energia-gb/energia-ee-gb/energia-ee-quadros-gb/energia-ee-quadros-geral-gb.html

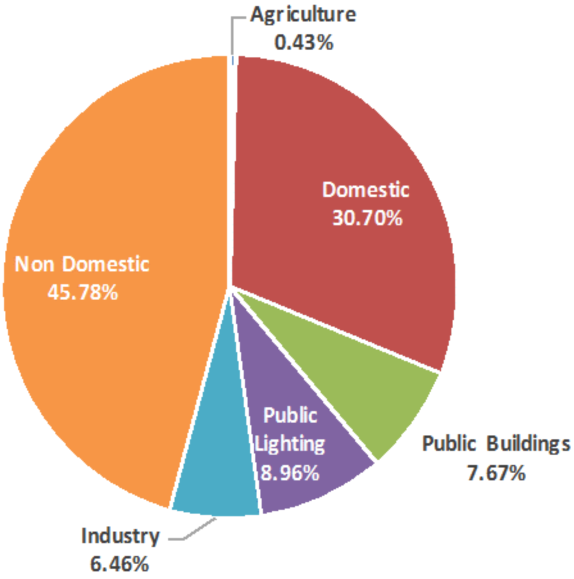

Figure 2.4: Consumption of electric energy in Madeira island by end-sector

The typical load demand for Madeira island is shown in Figure 2.5. As it can be observed, the highest rise in consumption happens in the morning, mostly driven by the beginning of the activity of the commercial sector. The peak consumption usually happens between 7PM and 9PM, which coincides with the periods of highest domestic demand, as shown in Figure 2.6, which displays a typical day consumption for 5 Funchal households. These houses belong to the same apartment building, and have similar topologies (T2 and T3). The number of residents varies between 1 and 4, which can partially explain the variation in the consumption.

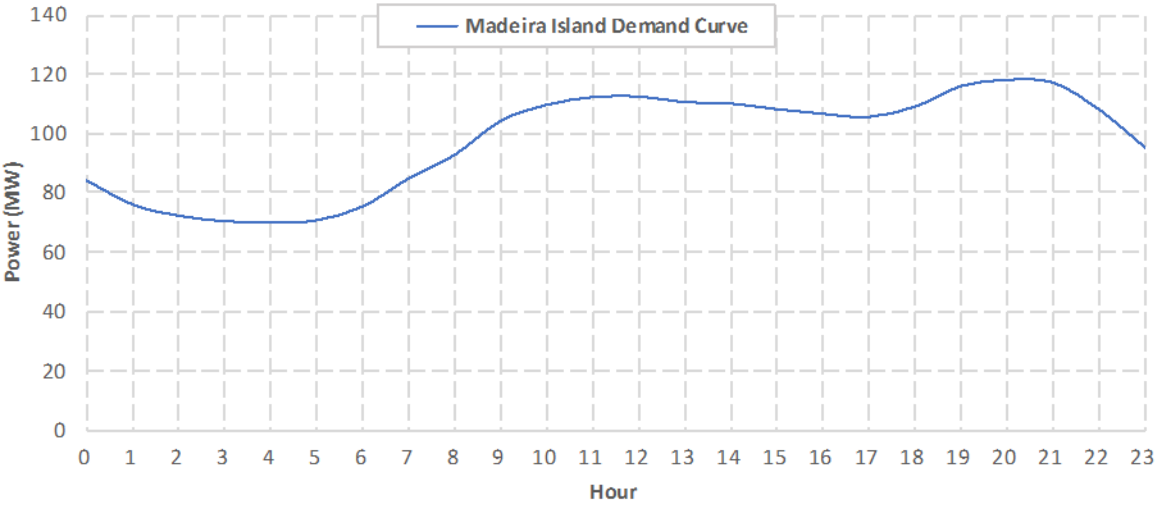

Figure 2.5 – Typical load demand curve in Madeira island

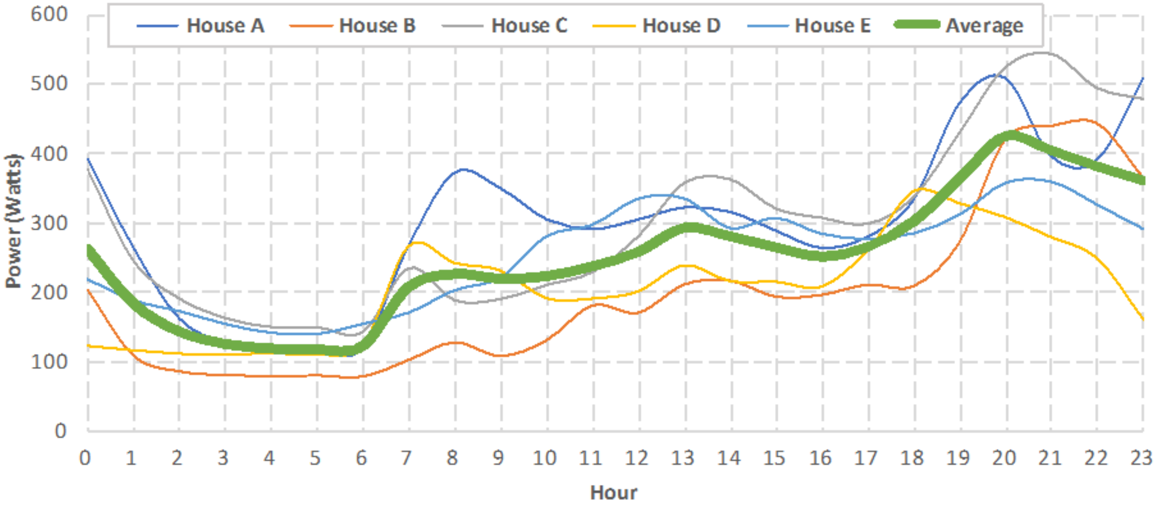

Figure 2.6 – Average active power from 5 households in Madeira Island over 24 hours. Data taken from the SustData public dataset [1].

Currently, there is no AMI deployed in Madeira electric grid. Instead, what is currently deployed is an AMR solution in the micro-production installations for monitoring and billing purposes. This solution uses a combination of *Janz*, *Landis + Gyr* and *Actaris* energy meters and meter data is collected and stored on a 15 minutes interval basis. Likewise, EEM monitors the energy that is generated from non-renewable sources.

EEM already provides a web-service with the mix that is being used to generate energy (updated every 15 minutes).

One important remark is that as of today, with exception of the monthly bill, no feedback is provided to the micro-production site owners.

Regarding telecommunications, EEM owns its own infrastructures, from which we highlight a Wide Area Network based on optical fiber. This network ensures, among others, the connection between the different company facilities. As of this writing, only some distribution points are covered by this WAN.

If required by the SMILE project, EEM will facilitate the access to the network.

Currently, Voltage and Frequency fluctuation are controlled by the thermal power stations, through the available spinning reserve. Hydro power plants also provide some frequency control capability but only in situations where there are plenty of available hydro resources or power plants are close to their rated power. In any case, the hydro plants are slower than the thermal ones, so they are not usually considered for voltage and frequency control.

2.2 Electric Vehicles in Madeira Island

Electric vehicles have just started to gain great traction in Madeira. 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 are ongoing.

There are approximately one hundred EVs in Madeira, most of which are Renault Zoe or Nissan Leaf models. The SMILE partners enquired a local official Renault representative in Madeira; data from 2016 disclosed that out of the 2990 cars that were sold, 32 were EVs. As for 2017, data from January shows that out of 201 cars sold, 11 were EVs.

In Madeira island, EEM has 15 EVs in their fleet of company vehicles, eight Renault ZOE, three Nissan Leaf, one Mitsubishi iMiEV, and three Renault Kangoo Z.E.. Consequently, in order to meet their charging demands, EEM built their own charging infrastructure. The infrastructure is comprised of:

- Three Magnum Cap's "wall boxes" (reference MCWB-32-3P), each one with 2 sockets with a maximum of 22 kW/each (AC 3 phase, 32 A / per phase in each socket).
- 12 sockets with CEE socket-type (AC 1 phase, 16 A), totally dedicate to EV charging.

Apart from these "full-sized" models, there are companies that operate smaller EVs such as the Renault Twizy[2], or the electric Piaggio - APE Calessino[3]. These companies have as well their own charging infrastructure.

The company that operates the 20 Renault Twizzy, owns a three-phase 45A installation. The infrastructure supports the simultaneous charging of two vehicles, and an operator must verify the charge of each vehicle and manually switch between them.

The company that operates the six electric Piaggio - APE Calessino, owns a three-phase 40A installation with 10 F-type plugs. In this case, the drivers plug their vehicles to one socket at the end of the day, or whenever the charge is low. The charging process in not controlled whatsoever.

2.3 Summary of Current Legislation

Under the SMILE framework, the legal aspects for developing smart energy systems will be addressed in WP7 (Legal and regulatory analysis of smart energy supply concepts). Here we provide a brief overview of the legislation that is currently being applied in Madeira island, which we believe is necessary for a better understanding of the remaining of this document. Currently only the installation or renovation in self-consumption facilities is allowed, but without incentives. In the past, there have been incentives for the production of renewables for large facilities and for customer facilities, but these are currently suspended. However, new mechanisms are being planned for the next years. For an extended summary of the legislation, please refer to section Micro-Production of APPENDIX D: Extended Summary of Legislation.

The current legislation for micro-production and self-consumption of energy is defined in Decree-Law nº 153/2014 of October 20th. This Decree-Law defines two types of Units of Production, the UPP (Unit of Small Production), and the UPAC (Unit Production for Self-Consumption). These are briefly described next.

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[2] Renault Twizy, https://drive.google.com/open?id=0BwLg0bl6UTC7TVI0MFZDUGYwZlU

[3] Piaggio - APE Calessino Electric, https://drive.google.com/open?id=0BwLg0bl6UTC7UnpVYTdBOGpQeUk

2.3.1 Unit of Small Production

UPPs are units of production of energy from renewable sources, based on a single production technology. In this situation, all the electric energy produced **must be injected** in the Public Service Electric Grid (RESP). In other words, the micro-producers are obliged to sell all their production.
Before the current Decree-Law nº 153/2014 of October 20th, in Portugal (including Madeira Island) this was the only accepted modality for micro-production, i.e., self-consumption was not allowed.
Since the publication of the Decree-Law 153/2014, EEM **does not accept** new UPPs. This imposition is owing to the isolated nature of the Madeira electric grid that is very sensitive to variations in the energy produced by RES, hence the need to avoid direct injection to the grid. Nevertheless, EEM still maintains the old contracts for the installations that happened prior to this decision.

2.3.2 Unit Production for Self-Consumption

UPACs are units of production of energy from the renewable or non-renewable source, by the production unit **with** or **without** connection to the Public Service Electric Grid (RESP). In the UPAC situation, the produced energy should be injected preferably in the consumption facility (i.e., self-consumption). Eventual surpluses of instantaneous production may be injected into the RESP when applicable.
In **Madeira Island**, due to the grid constraints mentioned above, UPACs can only be **installed without the energy injection to the RESP**. In other words, in Madeira an UPAC cannot inject the reminiscent energy produced on the grid. Furthermore, in **Madeira**, UPACs can only produce energy up to 50% of the contracted power to the local DSO.

One very important thing to notice is that there is nothing in the current legislation that prevents the installation of batteries in UPAC installations, which is of great importance for the goals of the SMILE project.

2.3.3 Electric Vehicles

Regarding the Electric Vehicles, the Decree-law 90/2014 of June 11st is the latest legislation in force, in Portugal. This Decree-law establishes the legal regime of electric mobility, applicable to the organization, access and exercise of activities related to electric mobility, likewise the rules for the creation of a pilot electric mobility grid. It also regulates incentives and creates conditions to encourage the use of electric vehicles. Again, here we only provide the minimum requirements to understand the remainder of this document. For more details please refer to sections Electric Vehicles, Loading Points, Cabinet for Electrical Mobility in Portugal, and MOBI.E of APPENDIX D: Extended Summary of Legislation.

Portugal has a network of charging stations for electric vehicles mostly located in public access spaces called MOBI.E[4]. The main objective of the MOBI.E network is to provide electric vehicles owners access to all public charging stations. Currently MOBI.E network is composed by over 1250 charging points.

The MOBI.E Network allows two types of charging for electric vehicles: **normal** and **fast**. Normal charging allows full battery charging. It can be carried out in charging stations of 3.7 kW and will last

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[4] MOBI.E, https://www.mobie.pt/

approximately 6 to 8 hours; or in 22 kW charging stations that may take at least 1 hour (depending on electric vehicle type). These stations are located in the public access and in private public access places such as parking lots and shopping centres.
Fast charge, on the other hand, only allows the charging of 80% of the battery, which takes about 30 to 40 minutes. These stations are mainly located in service areas and, briefly will be available in the main cities of the country.

Any charging station that is installed in public access space (be it a public or private space) must be connected to MOBI.E. A licensed operator must perform the installation, operation and maintenance. It is also important to mention the *Technical Guide of Electrical Installations for the loading of Electric Vehicles* that was made available by the Energy and Geology General Administrator (DGEG[5]). This guide (only available in the Portuguese language) is currently followed for any EV related installations in Madeira, and supplements the legislation currently in force.

In the case of charging stations in a private access of a private space, the installation, provision, operation and maintenance may be carried out by properly licensed operators or by the owners themselves. In these situations, connecting to the MOBI.E network is optional.
Furthermore, in these cases, the charging of EVs can be performed using only the domestic electrical installation, as long as the technical and safety rules established in the applicable legal and regulatory dispositions are respected.

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[5] DGEG, http://www.dgeg.pt/

3 Madeira Regional Pilot Overview

In this chapter, we provide the rationale and an overview of what will be done in the Madeira demonstrator. To state more concretely, we first present the Madeira objectives under the SMILE framework, and then we briefly motivate and describe each of the five pilots that will be conducted in Madeira island:

- Pilot 1: Getting Started with BESS and DSM
- Pilot 2: Moving forward with BESS and DSM
- Pilot 3: Getting Started with Electric Vehicles and Smart Charging
- Pilot 4: Electric Vehicles Are Our Future
- Pilot 5: Voltage and Frequency Control Pilot

3.1 Madeira Objectives under the SMILE Framework

Within the Framework of the SMILE project, the main goal of the Madeira island pilot is to smarten the distribution grid. Overall, the original objectives can be summarized as follows:

1) Optimize the self-consumption of renewables in the installations that are obliged to self-consumption only contracts, by introducing elements like BESS and specialized battery management software.
2) Provide frequency and voltage control mechanisms by introducing BESS and DSM techniques.
3) Implement the first ever pilot of smart charging of EVs in Madeira island.
4) Evaluate the deployed pilots, to ensure customer / market acceptance and satisfaction, as well as the replicability of the pilot in other places.
5) Identify new business opportunities and financial mechanisms for the solar PV market.

The above-mentioned objectives are strongly interconnected with the other SMILE work-packages:

a) Objectives 1 to 3 will have many inputs from WP5 (Technical models and analysis related to demand response, storage technologies, interaction with the transport sector and smartening the distribution grid).
b) Objectives 4 and 5 will provide inputs and receive outputs from WP6 (Life Cycle Assessment/Costing), socio-economic studies, cost/benefit analysis, market analysis, business cases and financial mechanisms), and WP8 (Impact analyses: energy system impacts, energy strategies and energy market design).

3.2 Proposed Pilots Rationale

As it was mentioned in the previous chapter, since 2014, new solar PV installations are only allowed in self-consumption mode (UPAC with no injection to the grid). While the main reason behind this decision by the local DSO is the need to protect the grid from issues associated with the unstable nature of solar PV production, it is preventing the local DSO from achieving the desired 50% quota of renewables in the mix by 2015.

This trade-off between the introduction of more RES in the mix, and maintaining a stable grid will be partially addressed by in three out of the five pilots that will be conducted in Madeira island. To state more concretely, two pilots will address the optimization of self-consumption, while a third pilot will look at mitigating the voltage and frequency control issues that appear associated with RES integration in isolated grids.

The first two pilots (Getting started with BESS and DSM, and Moving forward with BESS and DMS) are targeted at both domestic and commercial UPACs, and the main goal is to equip these installations with BESS (< 8 kWh) and specialized BMS to maximize the self-consumption of those installations. These two pilots are thoroughly described in chapter 4 (Maximizing the Integration of RES through the Installation of BESS).

As for the mitigation of the issues associated with injection of RES in the grid, these will be studied in the Frequency and Voltage Control Pilot. In this pilot, a sub grid with high RES from solar will be upgraded with a large BESS and specialized voltage and frequency control algorithms. The infrastructure will be used to respond to sudden increases in the demand and/or drop in production, thus preventing unwanted fluctuations in voltage and frequency. At a later stage, this issue will also be addressed using the EV smart charging infrastructure, which will be developed as part of the SMILE project. In Figure 3.1, we show the physical location of these three pilots in Madeira island.

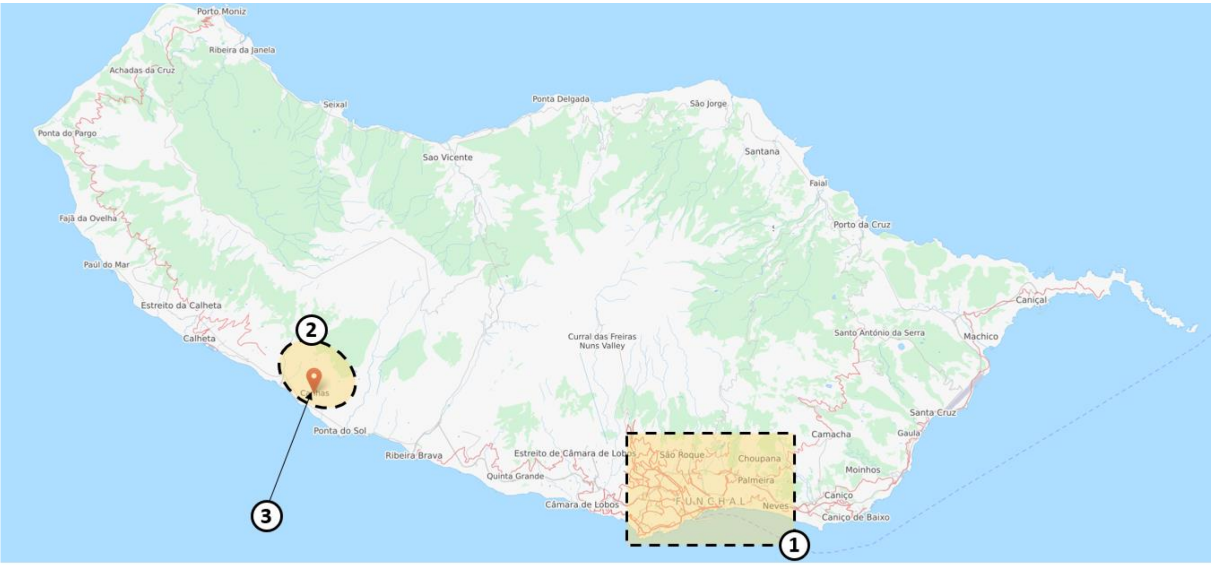

Figure 3.1 – Physical location of the Madeira pilots. 1: Location of the "Getting Started with Electric Vehicles and Smart Charging" and "Electric Vehicles Are Our Future" pilots. 2: Location of the UPP connected to the sub grid affected by the "Getting Started with Voltage and Frequency Control" pilot. 3: Location of the selected DP for the "Getting Started with Voltage and Frequency Control" pilot.

As it was mentioned in the previous chapter, Electric Vehicles are only now gaining some traction in Madeira island. Nevertheless, given the recent advances in these technologies, as well as the recent proposals in some countries for totally removing fuel power vehicles between 2030 and 2050, it is totally expected that in the next few years EVs will become very prominent in Madeira island. Ultimately, while EVs come with the promise of a bright future, this will result in a significant increase in the demand for electricity in the island, which will have to be met by the local grid.

Against this background, we will conduct two pilots in Madeira island that will combine EVs and smart charging technologies. In other words, we are interested in understanding how charging several EVs will affect the grid and how these effects can be controlled based on external factors such as the amount of renewable energy available, total demand, or energy price.

Our two pilots differ in the type of EVs that will be considered. The 'Getting Started with EVs and Smart-Charging' pilot is directed at small EV's such as scooters, bikes, forklifts or golf carts. Whereas, the 'Electric Vehicles Are Our Future' pilot is targeted at full-fledged EV's.

At this stage, the location of the pilots and respective participants are already identified. This is shown in Figure 3.2. A full description of the two pilots in provided in chapter 5 (Electric Vehicles and their Smart Management: A New Opportunity for the Madeira Electric Grid).

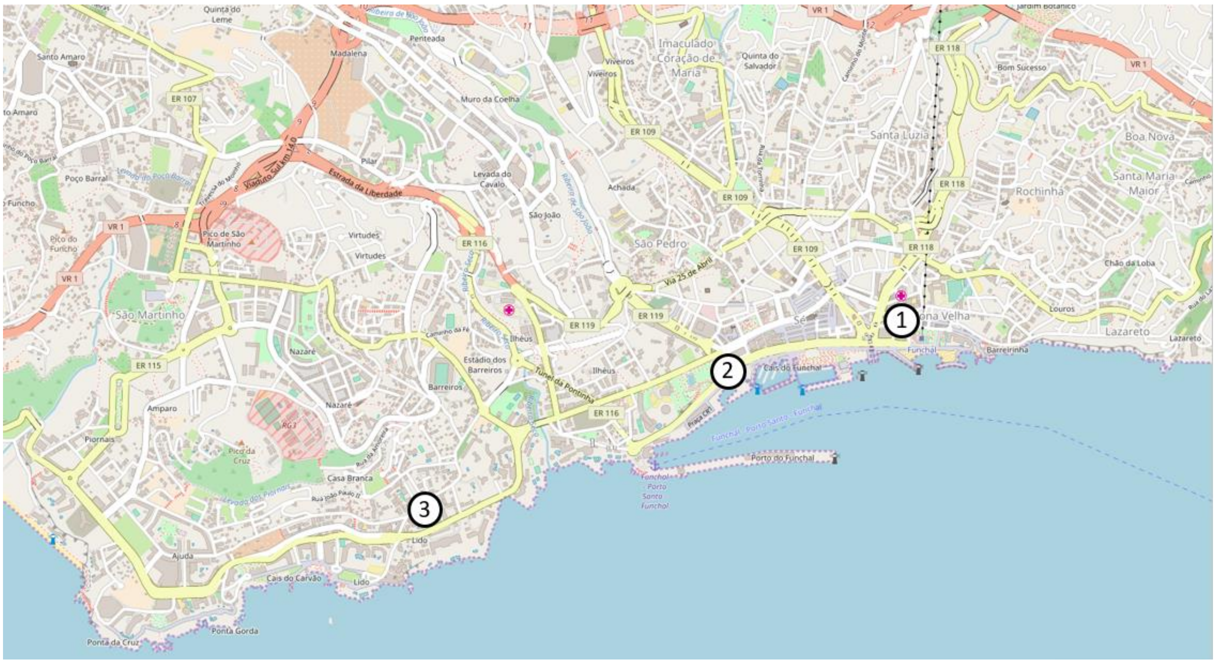

Figure 3.2 – Location of the EV pilots in the city of Funchal. 1: EEM garage. 2: Tukxi Eco Tours. 3: City Bubble guided tours.

4 Maximizing the Integration of RES through the Installation of BESS

In this section, we present two pilot studies aimed at maximizing the integration of RES in the Madeira electric using Battery Energy Storage Systems.

The first pilot is targeted at UPAC owners that are not allowed to sell the excess production to the utility, and thus can benefit from the usage of a BESS to maximize self-consumption. This is the classic scenario of a domestic installation, where the excess RES production is stored in a BESS, and consumed in the periods where the production from RES is lower or non-existent.

The second pilot is targeted at UPAC owners who in their day to day activity consume more than what is produced from RES, and thus can also benefit from BESS by doubling the batteries' utilisation by pre-charging from off-peak periods to cover early morning loads, and then re-charging from the sun to cover evening loads. This is the classic scenario of small restaurants that have peak consumption before lunch and dinner.

Ultimately, these scenarios will result in additional savings for the UPAC owners by optimizing the self-consumption, and also for the utility that will need to produce less energy during peak periods. Next, we describe the two pilots.

4.1 BESS Pilot 1: Getting Started with BESS and DSM

4.1.1 Pilot Specification

It is well known that for the average household, the production of solar energy is higher when the consumption is lower. Consequently, in self-consumption only scenarios, there is normally a considerable waste of renewable energy, as shown in Figure 4.1.

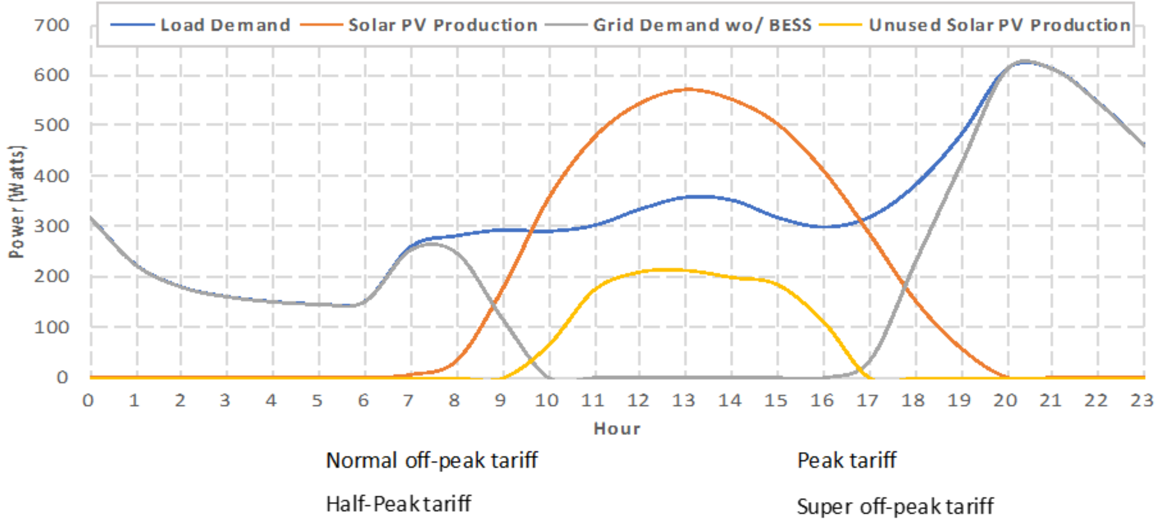

Figure 4.1 – Average active power for 9 households in Madeira Island and the average solar production over 24 hours. Data taken from the SustData public dataset [1]. The shadowed areas represent the different tariffs in Madeira[6]. In this example, we consider the Spring/Summer tariffs.

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[6] Electric Energy Tariffs in Madeira, http://www.eem.pt/media/275396/tarif%C3%A1rio-ram-2017.pdf

This is the scenario in many of the most recent solar PV installations in Madeira, mostly driven by the fact that since 2014 it is no longer possible to inject the excess production in the grid. Therefore, we believe that there is now a very big potential for the introduction of BESS in such installations, as a mean to optimize the self-consumption in Madeira island.

In Figure 4.2 we show a possible solution for maximizing the use of RES by introducing a BESS to store the excess production during the afternoon. The BESS is then discharged between 19:00 and 22:00, when the consumption is higher and the peak-tariff is observed. Another possibility would be to discharge the BESS between 20:00 and 23:00 h in order to reduce the peak-demand. By doing so, it may be possible to propose the new values for peak-contracted power, which immediately represents savings in the monthly bill.

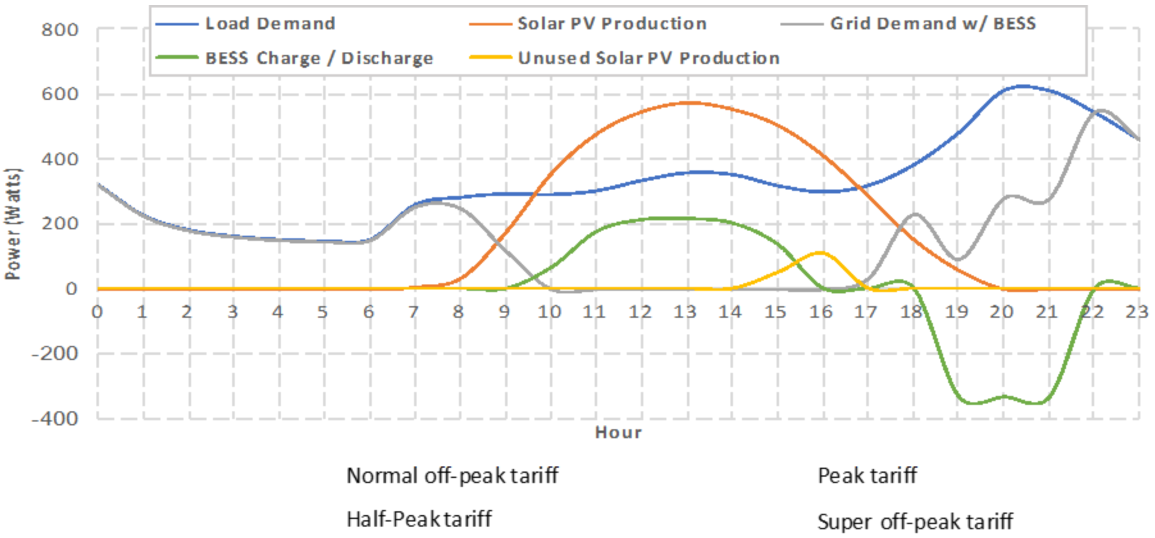

Figure 4.2 – Same data as in Figure 4.1, but here we consider the possibility of storing the excess production in a BESS, and using the stored energy to lower the grid demand during the peak tariff period. The shadowed areas represent the different tariffs in Madeira. In this example, we consider the Spring/Summer tariffs.

4.1.1.1 Sample Recruitment

In this pilot, we wish to implement and evaluate the scenario presented in Figure 4.2, as well as other variations. To this end, the partners involved in this pilot have worked on identifying UPAC installations in Madeira island. In this particular case, we are interested in domestic installations where the situation in Figure 4.1 is more likely to be observed. See chapter 7 (Participants Recruitment Process), section 7.1 for additional details about the participant recruitment and engagement process.

4.1.1.2 Main Tasks

After the initial recruitment, this pilot will evolve in **four** phases:

1) Installation of smart-meters in the selected sites, and collection of baseline production and consumption data during 6 months.
2) Analysis of the baseline data, selection of the more appropriate UPACs, and creation of the initial BESS control algorithms.
3) Dimensioning, acquisition and installation of the BESS.
4) Pilot maintenance and continuous integration / evaluation.

4.1.1.3 Assessment Overview

The initial project stages will be assessed through individualized interviews or close contacts with the participants to gather information about their motivations and specific needs whether these are financial incentives or regional constraints they might have concerning their installations. In addition, we will assess their satisfaction by collecting information about their Return of Investment (ROI), and how they currently manage their micro production site.

In what concerns the technical setup of the installations, we will list and document all characteristics and equipment being used, emphasizing the battery life cycle. Participants will be asked about their satisfaction with the battery performance, bill reduction and/or energy savings, and other costs associated with running and maintaining the installation. Satisfaction will as well be measured through participants perceived sense of support and advice from local entities through initial interviews and questionnaires across the project duration (either political or energy related associations).

4.1.2 Architecture Overview

In Figure 4.3 we present the overall architecture for the pilot installations. In this classic scenario, excess energy is stored in the BESS to be used during the periods when no energy is being produced by the solar PVs. In the diagram, this is depicted by arrows **a** and **b**. On the other hand, the energy that is being consumed "on the fly" is depicted by arrows **a**, **c**, **d1**, **d2** and **e**. Finally, when there is more demand than solar PV production and / or in the BESS, the house will be also powered with energy taken directly from the grid (arrows **f1**, **f2**, and **e**).
All the electric energy streams are monitored in real-time and the values communicated to the EMS at pre-defined intervals such that they can be used in the definition of the most adequate BESS control strategies.

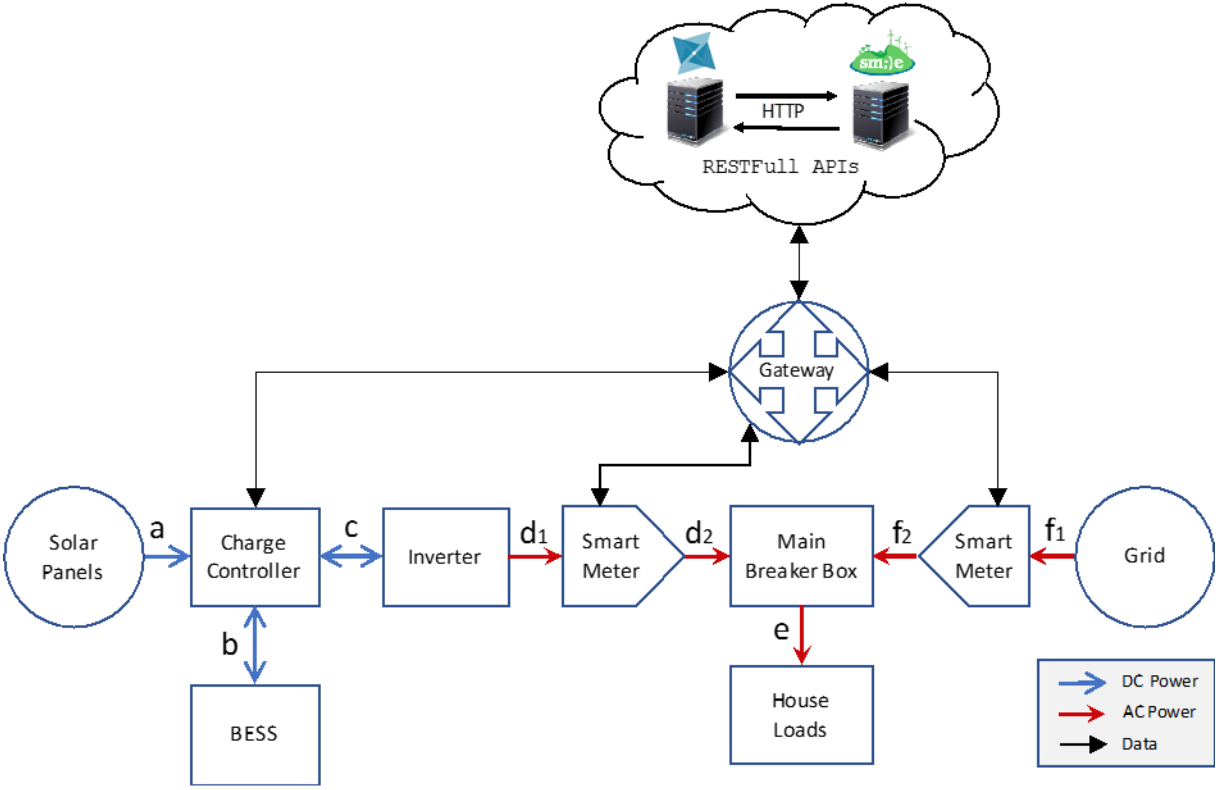

Figure 4.3 – General overview of the DSM pilot for domestic installations

Note that despite the fact that we are presenting the **Charge Controller** and the **Inverter** as separate components, there are solutions that bundle both components. We have opted to show it like this to make the visualization clearer.
Note also that in this scenario we are considering the usage of a gateway to handle the communication with the Internet, this however can be removed provided that all the components are able to communicate directly with the EMS.

4.1.2.1 Hardware and Software Requirements

From a hardware standpoint, this scenario requires the installation of two smart-meters in all the recruited installations, and a charge controller plus the BESS in the selected sites.
In order to select the most appropriate hardware we conducted extensive desk research on the available solutions. See APPENDIX A: AMI Technology Surveys for a survey of smart-meters, and APPENDIX B: Storage Technology Surveys for a survey of BESS.

Based on the identified domestic UPAC's installed equipment, we estimate that an average specification for BESS, should be in the order of 3kWh/1.5 kW.

All the hardware deployed in this study will be fully integrated with an EMS. The EMS will provide data storage, access and visualization facilities. All the integration should be done at a data-level, hence allowing for hardware independence.
Another important piece of software that will have to be deployed is a middleware between the smart-meters and the EMS. This middleware will be responsible for reading the consumption / production data in close-to real-time, and push those readings to the EMS.
Note that this piece of software will either run in the gateway or in the cloud along with the EMS.
Ultimately, there is also software running on third-party servers in the cloud to analyse the production and consumption patterns and come up with the most adequate battery management strategies.
Finally, there is also software running inside the load controller, however this software should be provided by the manufacturers and are therefore out of the scope of this report.

4.1.2.2 Partner Technologies

The following technologies will be provided by the SMILE project partners:

- PRSMA
  - Energy Management System
  - Middleware
  - Gateway software (if needed)
- Lithium Balance
  - Load Controller / Battery Management System Hardware and Software

4.1.3 Participant Requirements

For this study, we are interested in recruiting domestic UPAC's in the Island. We do not have any kind of preference regarding its location. However, to stay true to the pilot premise, recruited individuals will have to, during peak production hours produce significantly more energy than the one that is being consumed. For example, if a UPAC has 250W of PV installed that value is completely absorbed by the baseline consumption, as a result, a BESS is not an appropriate solution there. Other requirements such as ease of monitoring, and accessibility will also be considered during the recruitment. Section 7.1 Self-Consumption, describes the selected sample for this pilot.

4.2 BESS Pilot 2: Moving forward with BESS and DSM

4.2.1 Pilot Specification

For some commercial prosumers, e.g., restaurants, it is expected that all the energy production from solar PV will be consumed since there is normally high peaks of consumption when the solar production is also high. Consequently, in the same settings as the previous study, installing a BESS is of very little use. This effect is shown in Figure 4.4.

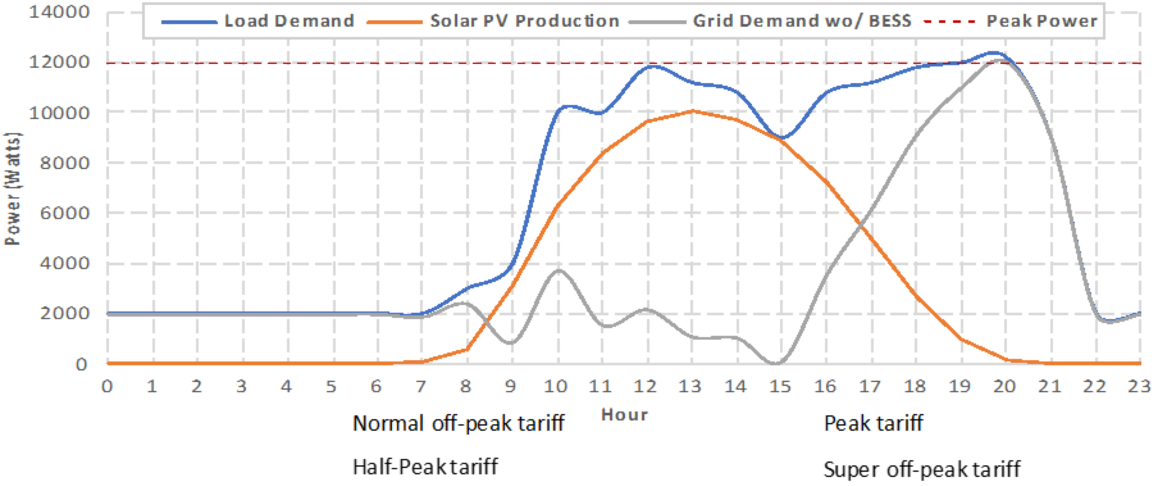

Figure 4.4 – Average active power for 1 commercial kitchen and the average solar production in Madeira Island over 24 hours. The kitchen data was taken from [2], whereas the solar PV production was taken from the SustData public dataset [1]. The shadowed areas represent the different tariffs in Madeira. In this example, we consider the Spring/Summer tariffs.

Nevertheless, we believe that these micro-producers can still benefit from the utilization of a BESS by pre-charging from off-peak electricity to cover early morning and, in particular, evening loads. An example of such a situation is presented in Figure 4.5. In this scenario, the battery is pre-charged during the night when the prices are the lowest and is discharged between 11 and 13, when the tariff is the highest. The battery is then recharged during the afternoon, when the tariff is only half-peak. The battery is then discharged between 19 and 21, when the peak tariff is observed again.

Furthermore, besides allowing the reduction of the consumption in peak tariff periods, if well defined, this strategy can also limit the peak-power consumed, which ultimately can lead to lowering the peak power that is contracted to the utility.

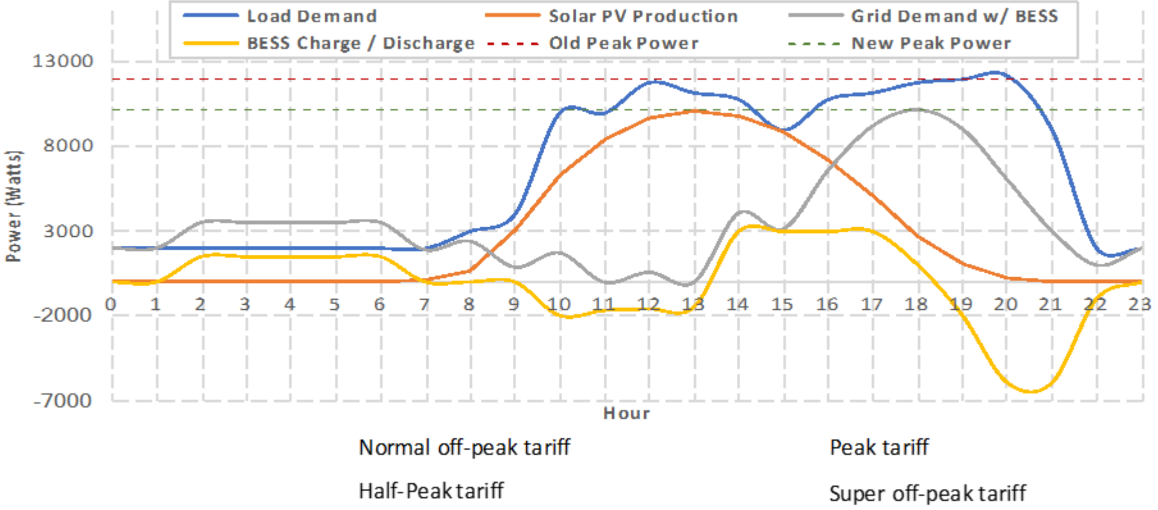

Figure 4.5 – The same data as in Figure 4.4, but here we consider the installation of a BESS and the possibility of pre-charging during off-peak periods. The shadowed areas represent the different tariffs in Madeira. In this example, we consider the Spring/Summer tariffs.

There are already some studies to understand the feasibility of battery pre-charging in households, with the results suggesting that it might not be profitable since it is possible that with pre-charging batteries these will not be able to soak up as much excess solar power than without pre-charging. Furthermore, even in scenarios where one is able to cycle the battery multiple times a day, this will negatively impact the battery life [3], [4]. However, the same studies suggest that businesses that have high morning loads can benefit from this strategy [4].

Here, we want to **understand the consumption patterns of the average restaurant in Madeira**, and explore if the same **results are observed**, considering the fact that the **installations are restricted to self-consumption** and the **installed solar PV cannot exceed 50% of the contracted power**.

4.2.1.1 Sample Recruitment

In this pilot, we wish to implement and evaluate the scenario presented in Figure 4.5. To this end, the partners involved in this pilot have worked on identifying UPAC installations in Madeira island. In this particular case, we are interested in commercial installations, where the situation in more likely to occur. See chapter 7 (Participants Recruitment Process), section 7.1 for additional details about the participant recruitment and engagement process.

4.2.1.2 Main Tasks

After the initial recruitment, this pilot will evolve in **four** phases:

1) Installation of smart-meters in the selected sites, and collection of baseline production and consumption data during 6 months.
2) Analysis of the baseline data, selection of the more appropriate UPACs, and creation of the initial BESS control algorithms.
3) Dimensioning, acquisition and installation of the BESS.
4) Pilot maintenance and continuous integration / evaluation.

4.2.1.3 Assessment Overview

The satisfaction of commercial UPACs owners will be evaluated by collecting information on how they consume their production, and potential strategies than can be used to take full advantage the installation of a BESS. The pilot's goal is to evaluate the impact of installing a BESS, as such these participants will be closely monitored to document the advantages and disadvantages of having such equipment in their business operations. This assessment will not only document successful cases, but also gather information on cases where the BESS may not have the desired effects to make sure the risks and constraints are also properly documented. The satisfaction will include measuring the savings, if observed, before and after the installation of the BESS.

4.2.2 Overall Architecture

In Figure 4.6 we show the overall architecture of the DSM pilot for domestic installations.

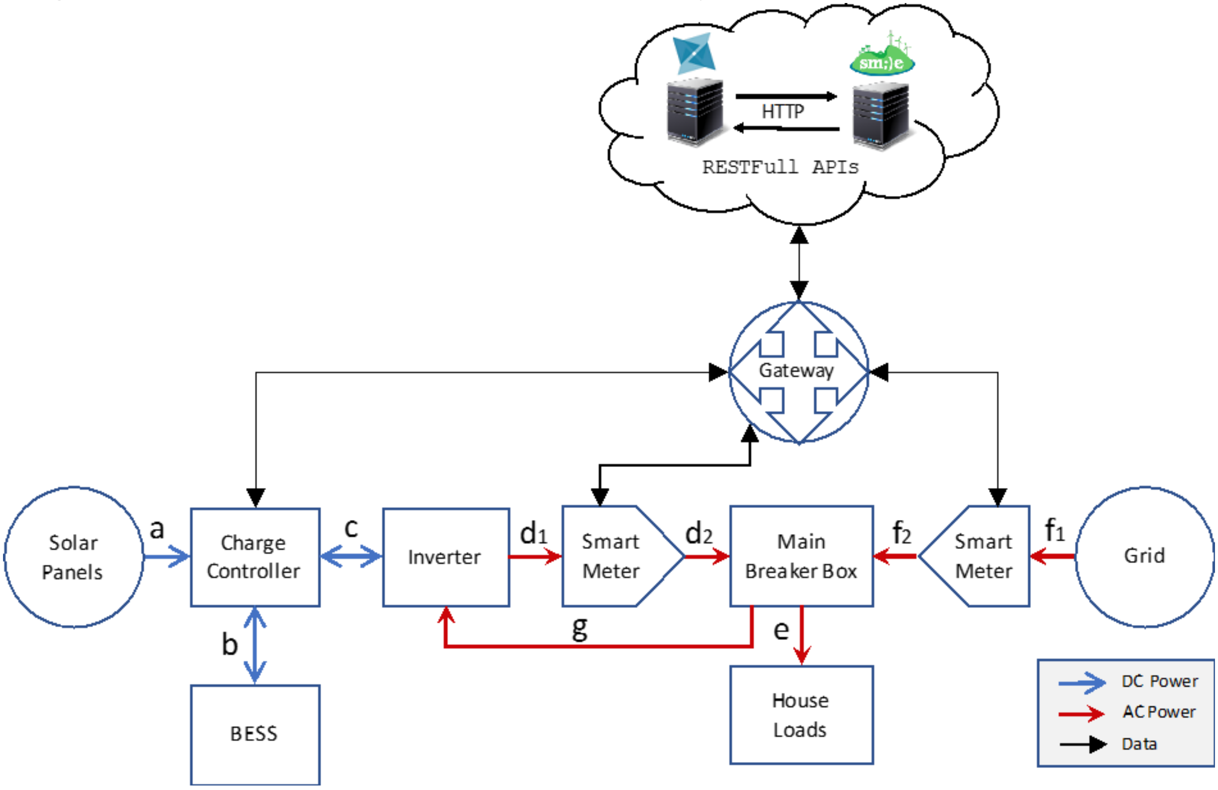

Figure 4.6 – General overview of the DSM pilot for commercial installations

As it can be observed, this architecture is very similar to the one represented in Figure 4.4. The only difference is the possibility of having a flow of electric energy from the grid to the battery (arrows **f$_1$**, **f$_2$**, and **g**). Ultimately, this is what allows for the pre-charging of the battery directly from the grid.

Note that despite the fact that we are presenting the **Charge Controller** and the **Inverter** as separate components, there are solutions that bundle both components. We have opted to show it like this to make the visualization clearer.

Note also that in this scenario we are using a gateway to handle the communication with the Internet, this however can be removed provided that all the components are able to communicate directly with the EMS.

4.2.2.1 Hardware Requirements and Software Requirements

From a hardware and software standpoint, this pilot is equivalent to the *Getting Started with BESS and DSM* pilot.
The main difference will lay with-in the DSM strategies, which will be reflected in the suite of algorithms that will be developed to control the BESS.

Therefore, based on the identified commercial UPAC’s installed equipment, we estimate that an average specification for BESS, should be in the order of 20 kWh/40 kW.

4.2.2.2 Partner Technologies

The following technologies will be provided by the SMILE project partners:

- PRSMA
  - Energy Management System
  - Middleware
  - Gateway software (if needed)
- Lithium Balance
  - Load Controller / Battery Management System Hardware and Software

4.2.3 Participant Requirements

Participants for this study fit in the same group as for the Pilot 1. However, Pilot 2 targets commercial UPACs. For this pilot, we are not as interested in the difference between the installed PV capacity and the consumption during peak production, since we assume most of the energy produced will be consumed. Yet, UPACs with significant installed PV power will allow us to implement battery pre-charging as well as, in particular situations, feed produced energy into the batteries. Section 7.1 Self-Consumption, describes the selected sample for this pilot.

4.3 Potential Replication Sites

In theory, the two BESS pilots can be replicated in all the current and future UPAC installations with or without battery pre-charging.

With respect to the second pilot, if we manage to prove that pre-charging is advantageous, it can easily be replicated to other types of business, like coffee shops and pastry shops, that have similar load curves.

We should also note that, in theory, it is possible to provide the same services in sites with higher load demands, like for example the many hotels in Madeira island. Still, we should stress that the current prices of BESS are likely to make this solution unappealing to the major stakeholders.

4.4 Potential Business Models

In our understanding, the current legislation presents a number of constraints to the creation of innovative business models.

In the present scenario, the most immediate business opportunities are related with the solutions to control the BESS (i.e., software as a service - SaS). This includes, the control algorithms that run on the backstage as well as the feedback services to the end-users.

Another immediate business opportunity is of course related with the value of the collected data for third party entities. For example, geo-tagged micro-production data can be used by the construction sector as inputs to their Building Information Modelling (BIM) systems. Nevertheless, we should stress that this raises several concerns about data protection and ownership, which should be carefully addressed in WP7.

In the future, if legislation allows, it should be also possible to sell excess production to the grid. Ultimately, this can represent a new realm of opportunities to the energy sector with or without direct intervention of the DSO. For example, it should be possible for a prosumer to sell their excess energy directly to a third-party prosumer / consumer (i.e., P2C/P). In such a situation, the existing grid would be used for transmission at the expense of a maintenance feed to be paid to the grid operator / DSO.

5 Electric Vehicles and their Smart Management: A New Opportunity for the Madeira Electric Grid

This chapter describes the two EV pilots that will look at introducing the concept of EV smart charging in Madeira Island.
The first pilot is targeted at small sightseeing businesses that use EVs as their mean of transportation and cannot afford full-fledged charging stations. Instead, they resort to *“ad-hoc”* charging stations without any control mechanisms. The second pilot aims at introducing the benefits of smart charging to full-fledged EVs and private charging-stations with multiple chargers.

Ultimately, we belive that these two scenarios are a simple but yet effective way of introducing and demonstrating the benefits of EVs and smart-charging techniques to the local grid. In the case of the former, the main benefits will the minimizaton of the required capacty to power the EVs. In the latter pilot, respectively, the objective is to provide value added services to infrastructure owners and the utility and improve the business case for EVs.

5.1 EVs Pilot 1: Getting Started with Electric Vehicles and Smart Charging

5.1.1 Pilot Specification

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 have identified **four** scenarios in which smart charging can benefit the two companies that were approached to participate in the Madeira pilot:

1. Automatically control the overall electricity demand when several vehicles are charging in simultaneous by balancing the demand among the EVs according to pre-defined 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.

5.1.1.1 Sample Recruitment

The partners involved in this pilot identified two local companies as possible users of this technology: a rent-a-car (CityBubbles[7]) that operates 20 Renault Twizy[8], and a sightseeing operator (Tukxi Eco Tours[9]) that operates 6 electric Piaggio - APE Calessino[10].

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[7] CityBubbles: http://www.citybubbles.pt/

This study can also be replicated to other domestic/commercial scenarios for instance, electric bikes, golf carts and fork-lifts.

5.1.1.2 Main Tasks

After the identification of the participants for the study we envision the following main tasks:

1) Participants demographic data gathering.
2) EV fleet technical data gathering.
3) Installation and testing of the technical infrastructure.
4) Integration of the components with Routemonkeys' infrastructure.
5) Live testing of the entire the pilot infrastructure.
6) Pilot maintenance and continuous integration / evaluation.

5.1.1.3 Assessment Overview

For this pilot, it will be important to understand how the deployed technologies will change the driver/operator routines. We certainly want to avoid a scenario where the driver is getting ready for a trip and there is no battery in the EV. Similarly, it will also be important to perceive how the implementation of the pilots will impact the company finances, by assessing if the smart charging helped the company decrease the electricity bill.

The technology used in the pilot will also be evaluated, such that this *ad-hoc* solution can be replicated. This evaluation will consider the capacity of the infrastructure to perform smart charging at a low cost, and also evaluate specific components as part of the global task (for example verify if the commercial plugs are a viable solution for smart charging in the long term).

5.1.2 Overall Architecture

In this case study, we assume that the EVs, or the EV charging infrastructure does not provide any remote interface to control the charging (ON / OFF / modulate). Instead, the EVs are plugged directly to a power outlet. Figure 5.1 show the overall architecture of the *Getting Started with EVs* pilot.

The EVs are connected to a power outlet via a smart plug that is able to read and communicate the consumption in real-time, and can be connected and disconnected remotely. Each power outlet communicates the consumption and receives connect / disconnect requests from the central gateway.

The gateway is connected to the Internet, and pushes the consumption and plug-status data to the EMS, that in turn sends the plug-control signals to the gateway. All the logic behind the smart-charging will be on the Route Monkey's servers, hosting the charge point back office system with a smart charging module that will expose their services to the EMS via APIs, using secured HTTP connections.

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[8] Renault Twizy, https://drive.google.com/open?id=0BwLg0bl6UTC7TVI0MFZDUGYwZlU

[9] Tukxi Eco Tours, http://www.tukxi.pt/?lang=en

[10] Piaggio - APE Calessino Electric, https://drive.google.com/open?id=0BwLg0bl6UTC7UnpVYTdBOGpQeUk

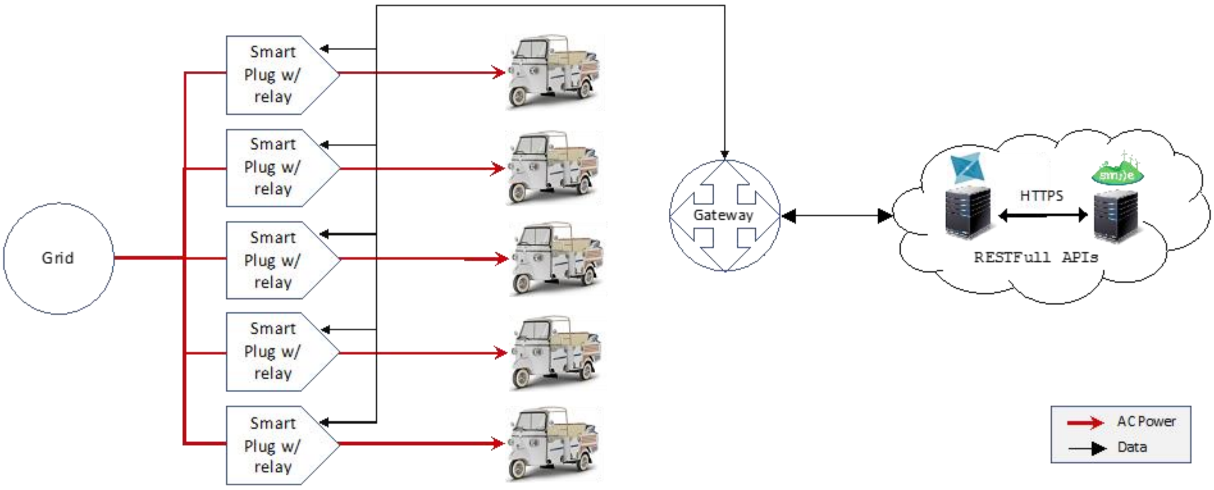

Figure 5.1 – Envisioned smart charging infrastructure for smaller EVs

5.1.3 Hardware and Software Requirements

Considering the architecture above, our main hardware requirement is the plug-level, smart-metering solution. This solution should allow near real-time data readings and the possibility of remotely connecting or disconnecting individual plugs.

From a software standpoint, we are required four main pieces of software: i) middleware to control the plug-level smart-meters and communicate with the Internet, ii) an energy management system to store and provide interfaces to the data that is collected by the metering solutions, and includes end user applications iii) machine-learning algorithms with a smart charging system to control the smart-charging process, and iv) charge point back office system.

The software components can be depicted in the high-level component diagram presented in Figure 5.2:

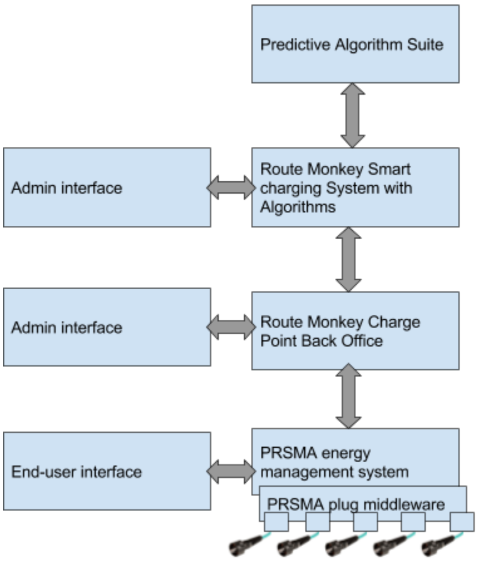

Figure 5.2 – High-level software component diagram of the Getting Started with Electric Vehicles and Smart Charging Pilot

5.1.4 Partner Technologies

In this initial study, we will be relying on the following partner technologies:

- PRSMA
    - Middleware to control the plug-level smart-meters
    - Energy Management System, that already includes end-user applications
- Route Monkey
    - Machine-learning algorithms to control the smart charging process.
    - Smart charging system enabling the settings of the algorithms and potential 3rd party interfaces, or connecting to other systems in the SMILE project
    - Charge point back office system with Admin, or potential end user interface

5.1.5 Participant Requirements

For this pilot, we must select at least one company that owns and operates a fleet of small EVs in the scope of their business model. Furthermore, we are targeting simple charging infrastructures without dedicated charging stations. We are also only considering EVs that consume less than 16A during the charging since that is the maximum current allowed in the identified off-the-shelf device, section 10.2 Plug-level Meters presents a survey of the *smartplugs* to be used in this pilot. Section 7.3 Electric Vehicle Operators presents the sample recruitment process for this pilot.

5.2 EVs Pilot 2: Electric Vehicles Are Our Future

5.2.1 Pilot Specification

The main motivation of this pilot is to provide a smartcharging solution using standard chargers by taking control of the ON/OFF status of the charge. This will allow us to controll the charge 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 of EV's in the grid. In such a sittuation, 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 surpassess the value established in the contract with the DSO. For example, smart charging can take into account 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 belive this scenario is particularly relevant in parking lots and apartment blocks where more than one EV will request charging in simultaneous.

The four points presented above are the main motivation for implementing *the EV's are our future pilot* in Madeira, however after the partners start contacting participants other unforseen oportunities might arise. Ultimately, our main goal is to develop a pilot where the four scenarios can be implemented, although the final scenarios will depend mostly on the participant own goals and motivations.

5.2.1.1 Main Tasks

After the identification of the participants for the study we envision the following main tasks.

1) Participants (drivers) qualitative information such as driving habits.
2) EV fleet technical data gathering.
3) Installation and testing of the technical infrastructure.
4) Integration of the components with Route Monkeys' infrastructure.
5) Live testing of the pilot infrastructure.
6) Pilot maintenance and continuous integration / evaluation.

5.2.1.2 Assessment Overview

This pilot will assess how external factors (e.g., the amount of energy from RES in the mix) affect the charting of EVs, and the participant's reaction to it. Essentially, understanding if the smart charging improved the quality of the grid without affecting the normal operation of the EVs.

We will also evaluate if participants accept the suggested charging profiles and understand the reasoning behind their charging decisions, ultimately it will be important to assess if the everyday users of the EEM charging infrastructure are satisfied with how the charging of their vehicles is being conducted. This assessment will be done with one on one interviews/questionnaires with the drivers and also by inferring each car battery during the pilot. These metrics will be studied in the scope of the main motivations for this pilot, for example, if we consider the goal of making sure that the aggregated consumption never surpasses a certain limit. Then the assessment will study if the smart charging was effective at maintaining the consumption below said limit, and understand drivers' satisfaction and the costs of doing so.

At last, as mentioned in the assessment of the other EV pilot, it will also be important to evaluate the overall the infrastructure used to implement the smart charging (for example the communication with the external servers that will control the charging).

5.2.2 Overall architecture

The overall architecture for this pilot will be similar to the previous *Getting Started with EVs* pilot. However, since this pilot will work with significantly higher electric loads, specialized equipment will need to be added. Finally, the most relevant difference is the possibility of integrating third party services that are not directly related to smart-charging, but that can benefit from it.

Each charging station will be measured using a metering device, which communicates with a central gateway (or hub) to push to the online data server. In addition, there will be hardware to control the charging. Currently, we are considering two alternatives to control the electricity load before reaching the charging station. The most conservative way is to add relays to the grid, which can effectively cut the electricity passing through. The other alternative is to add a smart plug to the actual charging station, which will work similarly to the smart plugs described in the previous pilot. These solutions are now reaching the market of EV charging, thus it is not clear if they will be available in time for the pilot deployment.

PRSMA will provide the web-services layer to access individual charging station consumption information, and to individually actuate on top of them. The smart-charging algorithms will be running on a separate server managed by RouteMonkey. Finally, PRSMA and RouteMonkey will also provide interfaces to the other SMILE technologies, which can be used to facilitate the integration between this and the other pilots. Figure 5.3 shows the block diagram of the envisioned smart charging infrastructure for full-fledged EVs.

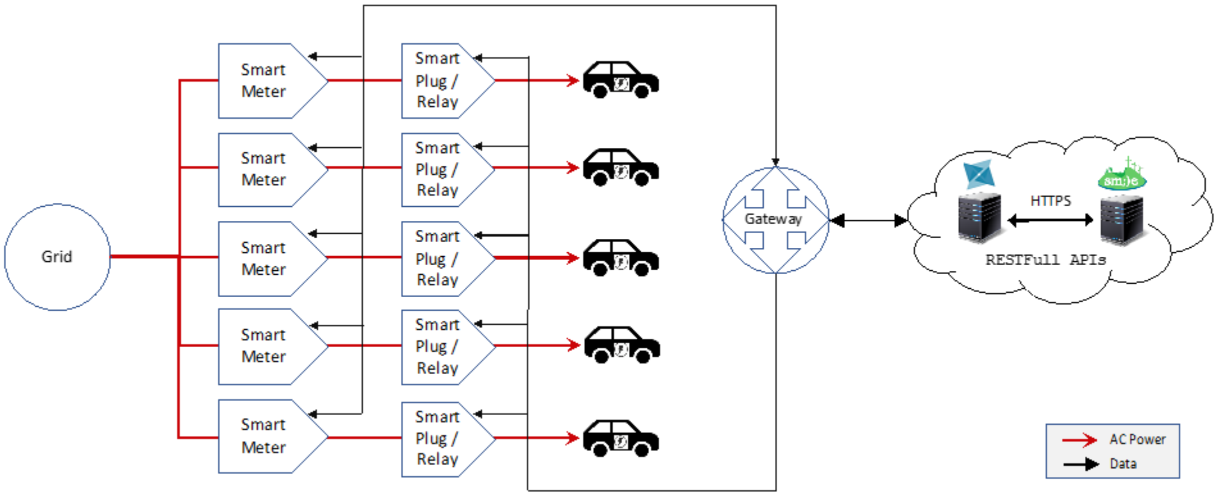

Figure 5.3 – Envisioned smart charging infrastructure for full-fledged EVs

5.2.2.1 Hardware and Software Requirements

Considering the architecture above, our main hardware requirements are the hardware that will monitor the individual charging stations, and a remotely controlled relay / smart plug that will be used to control the electricity before reaching the charging stations.

The software to be used in this pilot will be the same software used in the *Getting started with EV pilot*. This software is implemented to work with different equipment, therefore for this pilot, the requirements will be:

a) Middleware to control the smart-meters, the smart plugs / relays, and communicate with the Internet;
b) An EMS to store and provide interfaces to the data that is collected on the monitored sites;
c) Machine-learning algorithms to control the smart-charging process; includes the Smart charging system and the Charge point back-office, as well as 3rd party interfaces;
d) Applications to give feedback to the different system users.

The high-level component diagram features of the software needed for this pilot is depicted in Figure 5.4:

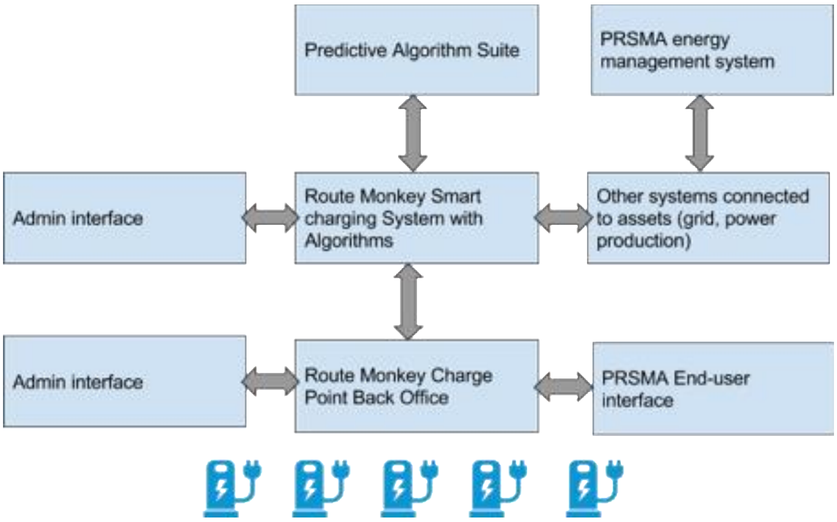

Figure 5.4 – High-level software component diagram of the Getting Started with Electric Vehicles Are Our Future Pilot

5.2.3 Partner Technologies

In this initial study, we will be relying on the following partner technologies:

- PRSMA
    - Middleware to control the energy monitoring and EVs charging
    - EMS, that already includes end-user applications
- Route Monkey
    - Machine-learning algorithms to control the smart charging process
    - Smart charging system enabling the settings of the algorithms and potential 3rd party interfaces, or connecting to other systems in the SMILE project
    - Charge point back office system with Admin, connecting the PRSMA end user interface

5.2.4 Participant Requirements

This case study is targeted at full-fledged EV vehicles and private charging-stations with multiple chargers. Given the lack of private charging infrastructures in the island this study will be performed in the EEM garage that has 18 charging points and 12 EVs. The 12 EVs models are either Renault ZOE or the Nissan Leaf, but this can be replicated to any car brand / model and charging station (e.g., the parking lot of an apartment building). This way, this study could be replicated in other private charging stations, which would be retrofitted to offer smart-charging. Section 7.3 Electric Vehicle Operators present the sample recruitment for the selected participants.

5.3 Potential Replication Sites

As it was already mentioned in the introduction of this chapter, the EVs pilot 1 can be easily replicated in other business that operate smaller EVs. For example, golf courses could benefit from such a solution to optimize their fleet of golf carks. This would be a particularly interesting replication opportunity, since there are currently three internationally recognized golf courses in Madeira (two in Madeira Island and one in Porto Santo).

As for the second EV pilot, in theory, it can be replicated in all kinds of private charging points in the island. A particularly interesting replication opportunity would be retrofitting the already existing parking lots (either in residential or private buildings), without the need for major changes to the existing infrastructures, and above all, without the need to renegotiate the contracted power with the DSO.

5.4 Potential Business Models

Like with the previous pilot, the most immediate business opportunities for EVs smart charging are related to the software to control the smart charging process. This opportunity is even more relevant in the case of the first pilot, given that the smart charging services would be provided with considerably less costs to the stakeholders.

Another immediate business opportunity is related with the value of the collected data for EV fleet operators. For example, historical charging data can be used to assess the life-cycle of the EVs batteries and to provide recommendations on driving behaviours.

Naturally, with the recent advances in EV technology, one can also envision more ambitious business models. For example, in smaller isolated electric grids with high potential for energy generation from

RES, EVs could be used as temporary BESS to support the grid. Using the example of Porto Santo, where daily commutes are small and flexibility is easily predictable, the BESS of the parked EVs could be used as buffers to respond to sudden increases in the demand, and/or decreases in the production for RES.

6 Voltage and Frequency Control through SMILE Solutions

In this chapter, we describe the voltage and frequency control pilot that will be conducted in Madeira island.

Currently the Madeira island electric grid contains in average 30% of renewable energy in the mix. Despite, being already a considerable value, it is still far from the 50% ambitioned by 2020. One of the main blocking forces for the increase of renewables in the grid is the unstable nature of such sources, that when associated with low consumption and high production periods (normally around midday), tend to result in the phenomena of voltage increase (VI) and frequency fluctuations (FF).

With the installation of a BESS in a transformation station, our goal with this pilot is to study the possibility of using RES not only to power the energy mix, but also to stabilize the grid, improving the Quality of Service (QoS) associated with low voltage distribution networks.

The electrical Low-Voltage (LV) networks in the rural areas of Madeira Island are mainly of the aerial type, and have considerable extensions. When associated with low consumption and high production periods (normally around midday), it is very likely to observe the phenomena of Voltage Increase (VI). Additionally, since the Madeira Island's power grid is completely isolated, it is subject to frequency fluctuations (FF) that are much larger than that of the interconnected networks.

With the installation of a BESS in a transformation station, our goal is to improve the Quality of Service (QoS) of the electric power supply, associated with low voltage distribution networks, with many dispersed production facilities, mainly solar photovoltaic (PV).

In such a scenario, a properly dimensioned BESS can work as a buffer for the grid, effectively responding to unexpected demand or storing excess production, thus minimizing the chance of voltage and frequency fluctuations due to the intermittency of renewable production.

6.1 Voltage and Frequency Control Pilot

6.1.1 Pilot Specification

In this pilot, we wish to understand if a properly dimensioned BESS can work as a buffer for the grid, and be used to respond to unexpected demand to the grid, thus minimizing the chance of voltage and frequency fluctuations due to the intermittency of photovoltaic production. Figure 6.1 shows an example of a scenario where this issue might happen. Between 11:15 and 12:00 h the solar production is high; therefore, the grid is relying on this energy. Nevertheless, when there is a sudden decrease on the solar production (between 12:45 and 13:30 h) the grid could use the abovementioned buffer to feed energy into the grid.

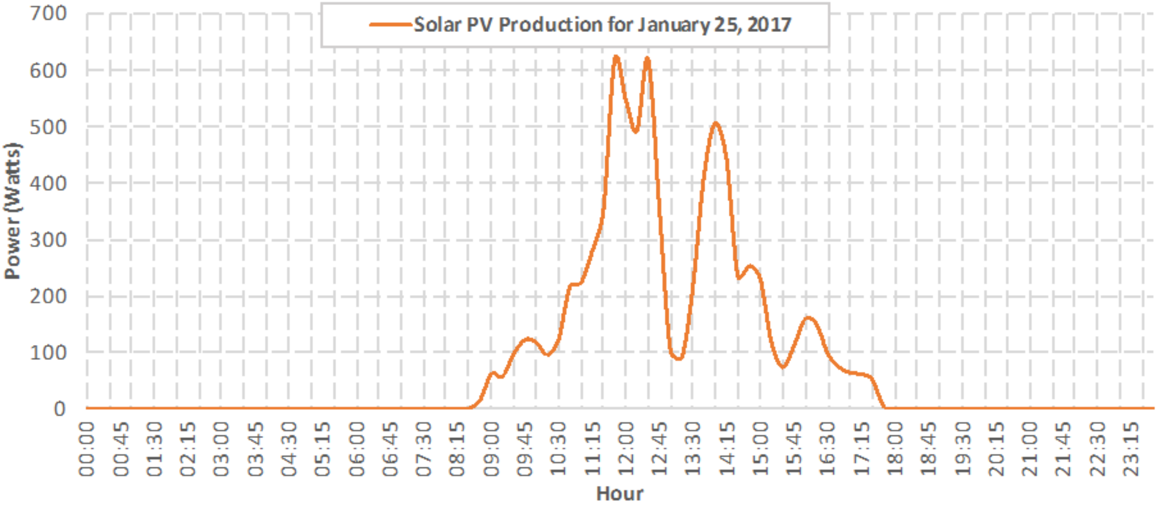

Figure 6.1 – Solar production for two micro-producers connected to the selected DP. Both producers have a 3.45 kVA production contract.

6.1.1.1 Distribution Point Selection

EEM has worked on identifying one DP with the desired characteristics in terms of number of connected micro-producers, accessibility and physical condition of the DP (e.g., having enough space to install all the necessary hardware), and connectivity.
Ultimately, EEM selected a DP with 250 kVA (MV/LW) installed, and with 13 installations or around 50 kW. Please refer to section 7.2 of chapter 7 for additional details about the selected DP.

6.1.1.2 Main Tasks

After the selection of the DP, this study involves **five** phases:

7) Participants demographic and technical data gathering.
8) Installation of smart-meters, grid analyser and data collection for at least 6 months.
9) Data analysis, and dimensioning of the BESS to be installed.
10) Installation of the BESS system and control algorithms.
11) Pilot maintenance and continuous integration / evaluation.

6.1.1.3 Assessment Overview

The main metric to evaluate this pilot is how the voltage and frequency are affected by the penetration of renewables once the demo is in place.
This will be done by continuously monitoring the grid-quality parameters, before and after the installation of the pilot. In this pilot, it will also be important to assess the lifecycle of the battery. Evaluation will be fundamental to understand how the implemented system will impact the global island voltage and frequency control efforts. As such, the research team will be interviewing the actual individuals who are responsible for monitoring the grid for the abovementioned study.

6.1.2 Overall Architecture

In Figure 6.2 we show the overall architecture of the Voltage and Frequency Control Pilot. As it can be observed, all the electric energy that is produced by the solar PV installations is injected in the grid DS (arrows **a**, **b**, and **c**). On the other hand, the household demand is fed directly from the grid

(arrow **d**). In the DS, a BESS system is charged when there is more production that consumption, and discharged when the grid analyser detects Voltage and / or Frequency issues (arrow **f**).
Ideally, the grid control algorithms would live in the cloud, however since the correcting actions normally need to occur close to real-time we might have to have these algorithms running on the gateway itself to avoid potential bottlenecks with communication.

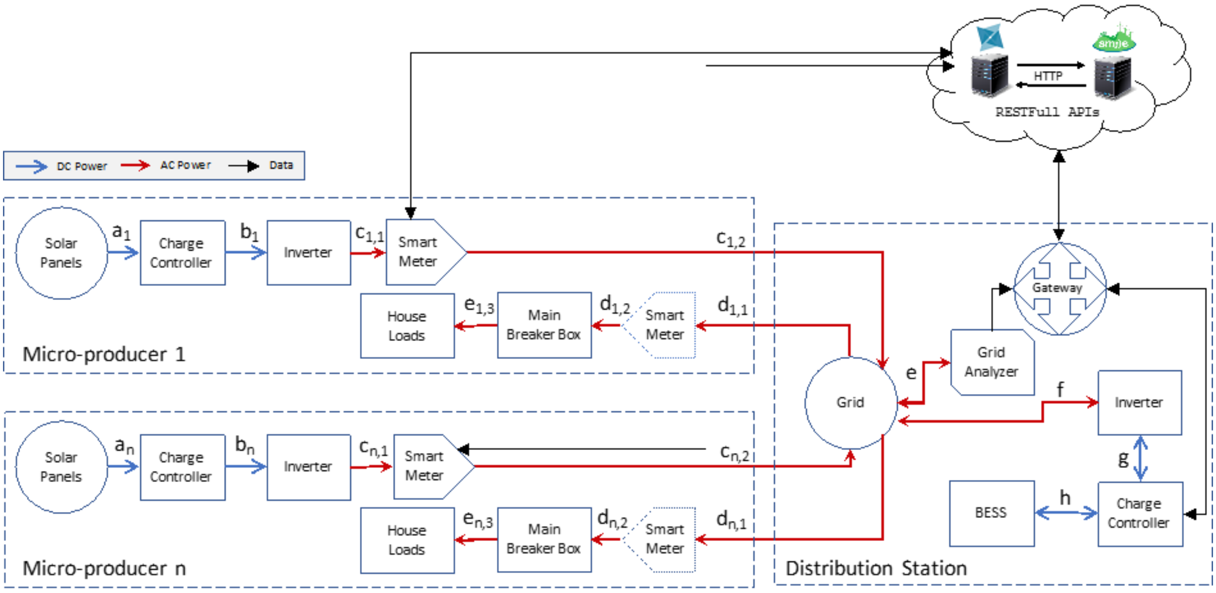

Figure 6.2 – General overview of the Voltage and Frequency control through BESS pilot

6.1.2.1 Hardware and Software Requirements

From a hardware standpoint, this scenario requires the installation of one smart-meter in all the micro-production sites to monitor the production. As for the DS, we will have to install a charge controller plus the BESS, and a grid-quality analyser.

Based on the UPP facilities in the selected sub grid DP, with a total installed capacity 38 kWh, we estimate the minimum indicative specification for BESS, should be in the order of 80kWh/40 kW.

A second smart-meter could be installed in the micro-production sites to monitor the actual consumption, however since this is not necessary for the demo, we have decided not to install a second equipment. This is however subject to change, should we need consumption data as well.

The energy monitors used in this pilot will be the same that will be used in the two previous pilots. In this particular scenario, the individual consumption of the micro-producers does not have to be monitored since we are mainly interested in the difference between the total consumption in the DS (measured at the DS by the grid analyser), and the total micro-production (given by the smart-meters on the micro-production sites).
As for the remaining hardware, we conducted an extensive desk research on the available solutions. See Grid Power Quality Analyser in APPENDIX A: AMI Technology Surveys, and APPENDIX B: Storage Technology Surveys for more details about the necessary hardware.

From a software standpoint, all the monitoring hardware deployed in the micro-production sites will have the same requirements as in the two previous pilots.
Regarding the DS, an important piece of software is the middleware between the grid analyser and the gateway. This software is responsible for reading and analysing the grid quality data in real-time.

This software is also responsible for triggering the correct sequence of actions when some corrections are necessary (e.g., fast discharging to compensate for momentarily shortage of production). This is custom software and should be designed and implemented by the SMILE partners. Furthermore, despite the fact that most of the actions will be executed on the gateway, all the data must be updated to the EMS for further analyses (e.g., execution of prediction algorithms for future grid failures). Finally, there is also software running inside the load controller, however this software should be provided by the manufacturers and are therefore out of the scope of this report.

6.1.2.2 Partner Technologies

The following technologies will be provided by the SMILE project partners:

- PRSMA
    - Energy Management System
    - Middleware between smart-meters and EMS
    - Middleware between Grid Quality Analyser and the gateway
- Lithium Balance
    - Load Controller / Battery Management System Hardware and Software
- SMILE Partners
    - Grid quality control software

6.1.3 Participant Requirements

Apart from selecting one DP, for this study, we are also interested in the micro-producers that are connected in the selected Distribution Point (DP). The selected participants will be selling all their production. The selection of the DP will be made taking into consideration the following aspects:

1. Installed power
2. Number of installations
3. Accessibility

All the micro-producers connected to the DP will be considered as *indirect participants* in the pilot. Section 7.2 Micro-production presents the sample for this pilot.

6.2 Potential Replication Sites

In theory, this pilot can be replicated in all the distribution stations in the Madeira electric grid, assuming that they are ready to receive the necessary technical infrastructure. Nevertheless, even the replication in a small number of DS, can represent a big opportunity to allow more injection of RES in the grid.

We should note that one of the main motivations of the local DSO in the SMILE project is the possibility of increasing the injection of renewables in the grid using the currently available technologies. And while, in the present the costs of BESS make this solution very costly, the SMILE project provides an opportunity to analyse the cost / benefits of such a solution.

6.3 Potential Business Models

The way that this pilot is currently designed is fully transparent to the UPP owners, in a sense that the energy that is produced continues to be injected in the electric grid. Consequently, business models for this pilot should be targeted at the DSOs.

Alternatively, in a scenario where UPACs are allowed to inject directly in the grid, one could consider the possibility of using these installations to achieve the same results (voltage and frequency control) on a distributed fashion. In other words, instead of installing large BESS in the DP, the system would resort to the distributed BESS resources. Furthermore, in a fully integrated electric grid, smart-charging could be used to assist in voltage and frequency control. For example, in the case of a sudden drop in the production from RES, smart-charging could temporarily disconnect EVs based on their flexibility.

Naturally, the DSO would have to compensate all the parties involved in this process. This implies the definition of new business models, which should be explored in the corresponding work packages.

7 Participants Recruitment Process

The recruitment for the Madeira pilots will be focused on three types of individuals: 1) UPAC owners, 2) UPP owners, and 3) EV owners and operators. The participants for each study will be approached using different strategies, as described in the following sections. These might be subject to change depending on the potential participants we successfully get in contact with.

7.1 Self-Consumption

The process was started with EEM providing an anonymous list of the registered UPACS in Madeira island. As of the last update to the list, there are 49 registered UPACs, 36 of which are domestic installations and 12 commercial installations. Figure 7.1 shows the distribution of the UPAC installations in Madeira Archipelago. Not surprisingly, only 1 installation happens to be in the North side of Madeira island (Santana).

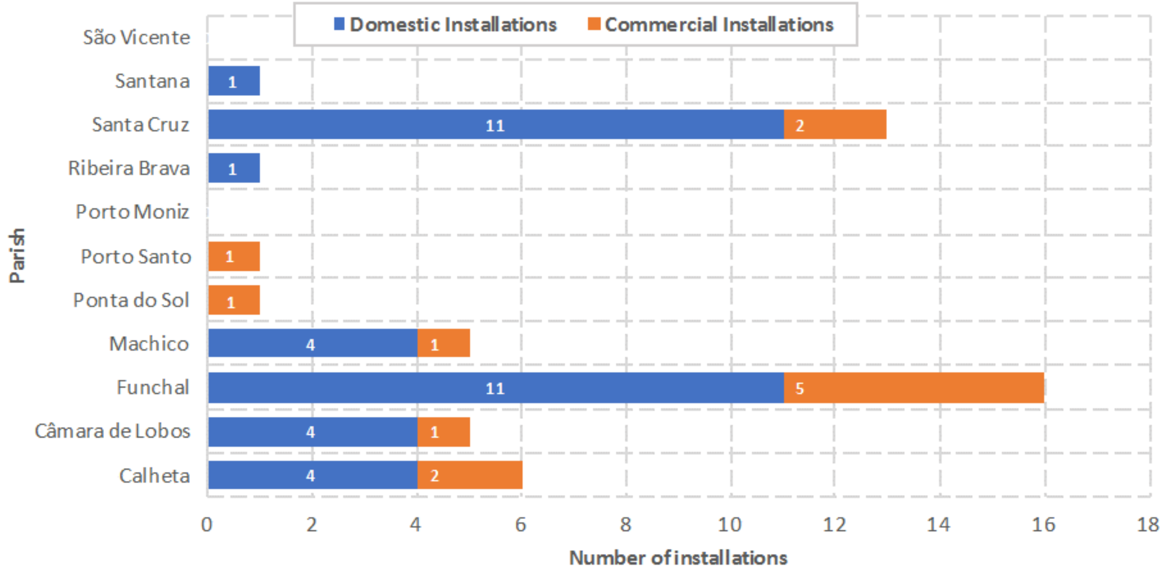

Figure 7.1: UPAC installations across the Madeira archipelago

In Figure 7.2 we present the distribution of the UPAC installations in terms of the installed and contracted power. One immediate observation is the fact that despite having the possibility of installing solar PV power up to 50% of the contracted power, the average installed solar PV power is about 18% of the contracted power in domestic the installations, and 30% in commercial. There are a number of reasons for that, for instance, lack of space or the long pay-back time. This is an example of situation what we will try to uncover during the first round of interviews.

Also noteworthy is the fact that 25% of the commercial installations have over 150 kVA installed. These installations however belong to hotels, and our initial hypothesis is that they consume all the energy that is produced in their installations, which makes these subjects of limited interest to our pilots. Nevertheless, given their relevance for the overall objectives of the SMILE project, we will attempt to engage these stakeholders through individual and collective interventions (e.g., interviews and workshops).

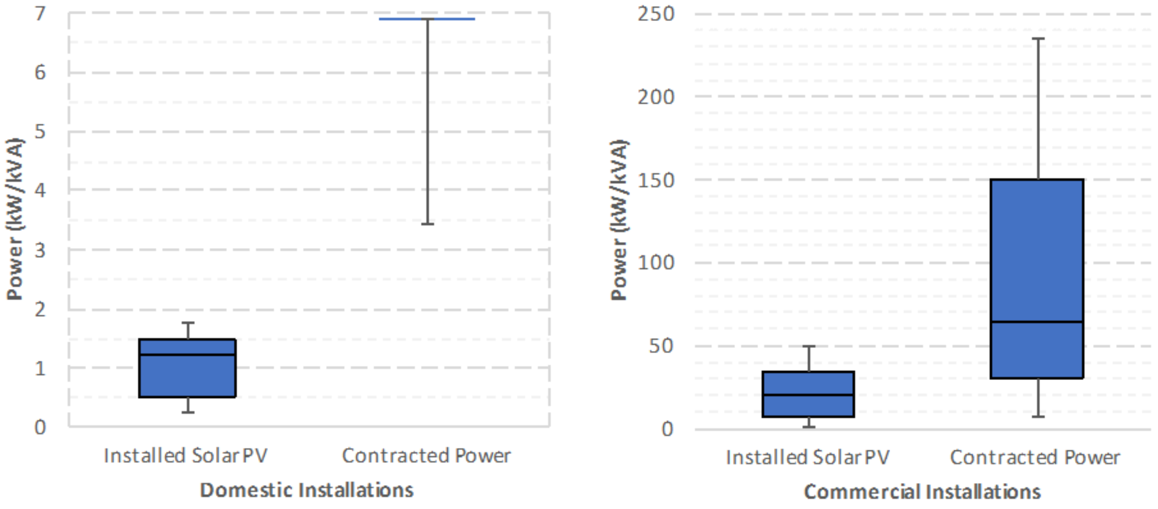

Figure 7.2: Distribution of the installed and contracted power across the 49 registered UPACs

7.1.1 Next Steps

We are now in the process of contacting the UPAC owners. This process is being initiated by the EEM call-center that approaches the UPAC owners, informing them about the SMILE project and the possibility of taking part in it. The SMILE team will contact those that agree to participate for an initial interview, where demographics and technical data will be gathered. In Annex I we describe the different questions that will be made during the recruitment process.

7.2 Micro-production

The process started with EEM providing a list of the UPPs in Madeira archipelago. As of the last update to the list, there are 785 registered UPPS, 701 of which are domestic installations and 85 commercial installations. Figure 7.3 shows the distribution of the UPP installations in Madeira Archipelago. Not surprisingly, the large majority of the UPPs are installed in the southern parishes of the island.

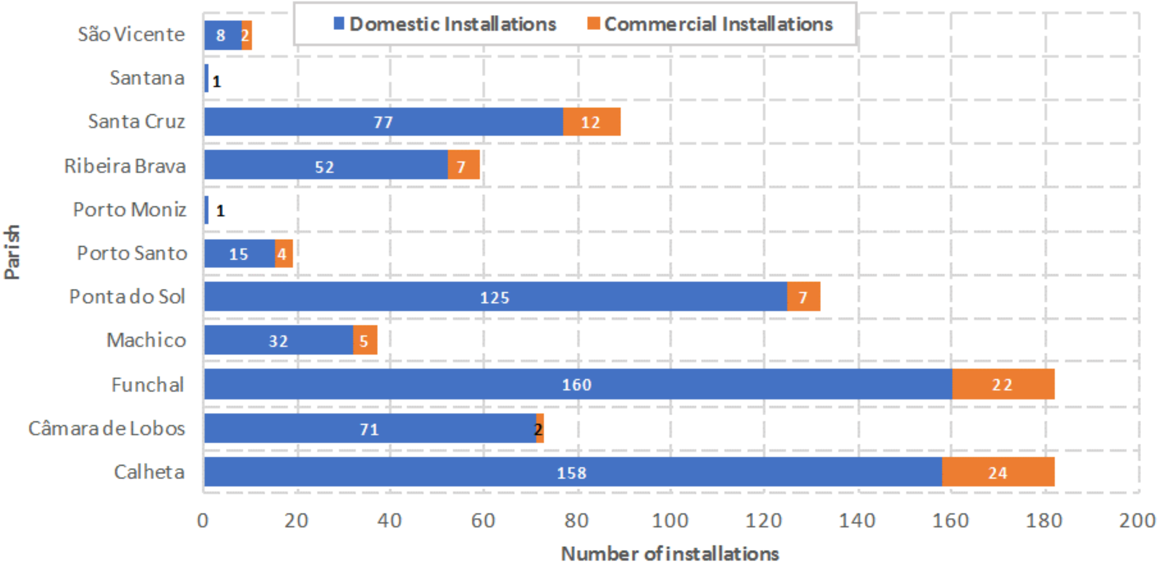

Figure 7.3: UPP installations across the Madeira archipelago

In Table 7.1 we present the summary statistics of the installed solar PV power across the registered 785 UPP. Min is the smallest value observed, Q1 is the 25% quartile, Q2 is the 50% quartile (or the median), Q3 is the 75% quartile, and Max is the largest value. As it can be observed, with the exception of a few very large commercial mini-producers, the installed UPPs range between 1.7 kVA and 3.68 kVA of installed power.

Table 7.1: Summary statistics of the installed power across the 785 registered UPPs

	Domestic	Commercial
Min	1.7 kVA	3.4 kVA
Q 1	3.45 kVA	3.68 kVA
Q 2	3.45 kVA	3.68 kVA
Q 3	3.68 kVA	3.68 kVA
Max	6.9 kVA	250 kVA

In the second step, EEM was responsible for investigating which distribution sub-station had more connected UPPs, while also having the ideal conditions to install a BESS (e.g., enough space and good ventilation). Ultimately, EEM selected a sub-station in Ponta do Sol with 13 installed micro-producers.

Eleven of those producers have a 3.45 kW production contract, whereas the remaining 2 have a 3.68 kW contract. These individuals are also consumers, with contracts of 6.9 kVA (10 consumers), 10.35 kVA (2), and 20.7 kVA (1).

Figure 7.4 shows the average production along the day in six of the 13 micro-production installations, between the 14th of April and the 28th of July. It is interesting to see that despite the short distance between the installations, some installations start to produce energy earlier than others. Also noteworthy is the fact that the micro-production **installation 2** does not seem to reach peak production during the day. This is something to consider during our visits to the production sites.

Apart from these two observations, the production curves are somewhat similar among the installations, which is reflected by an average correlation > 0.9 between the installations.

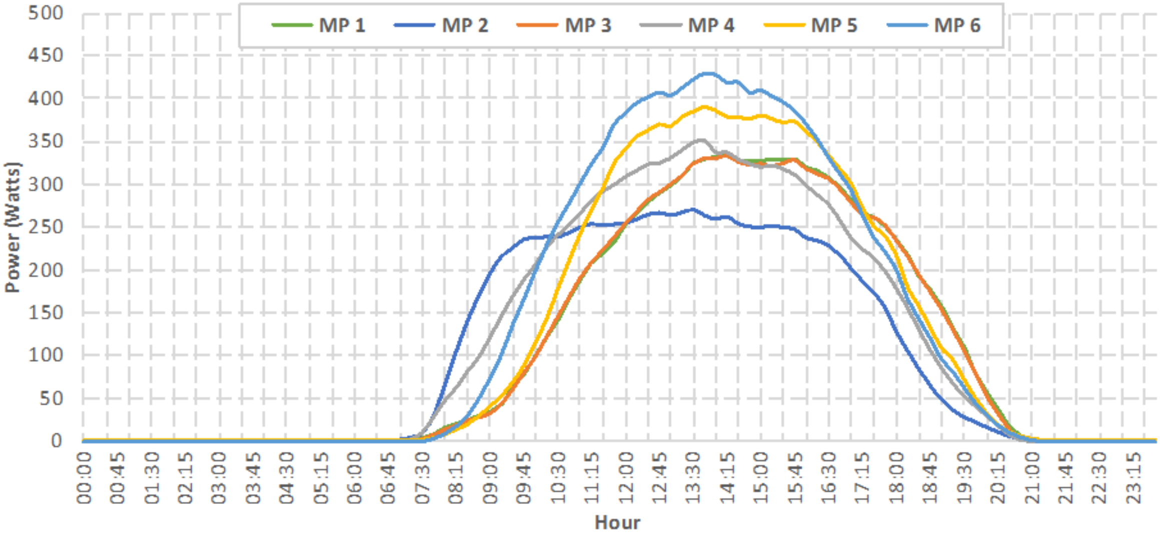

Figure 7.4 - Average production for four clients connected to the selected substations

7.2.1 Next steps

In the coming weeks, we will start contacting the owners of the UPP that are attached to the selected DP. As with the UPAC owners, the EEM call-center will initiate the contacts, and only afterwards will the SMILE members get in touch with the participants.

7.3 Electric Vehicle Operators

In order to survey the potential participants for the EV pilot, ACIF contacted a number of EV fleet owners that are among their associates. Since there are only a few of such cases in the island, all businesses operating in this manner were considered and contacted by the research team for an initial introduction.

For the Getting started with EVs, we have considered the two companies already mentioned in chapter 5.1 (EVs Pilot 1: Getting Started with Electric Vehicles and Smart Charging).
Figure 7.5 shows a picture of one of the installations.

Figure 7.5 – Electric Vehicle charting infrastructure in the Tukxi Eco Tours facilities. The number 1 represents the 16 A sockets user for charging, and the number 2 shows one of the electric vehicles being charged.

Ultimately, we have opted to conduct the pilot in the Tukxi Eco Tours facilities, since their charging infrastructure allows the parallel charging of more vehicles, contrasting the eco-bubbles facility that only allows the simultaneous charging of two EVS.

Regarding the 'Electric Vehicles Are Our Future' pilot, we have opted to use the fleet of EVs that is operated by EEM, as it was mentioned in chapter 5.2 (EVs Pilot 2: Electric Vehicles Are Our Future). Figure 7.6 shows an overview of the EEM garage where the EV charging points are installed.

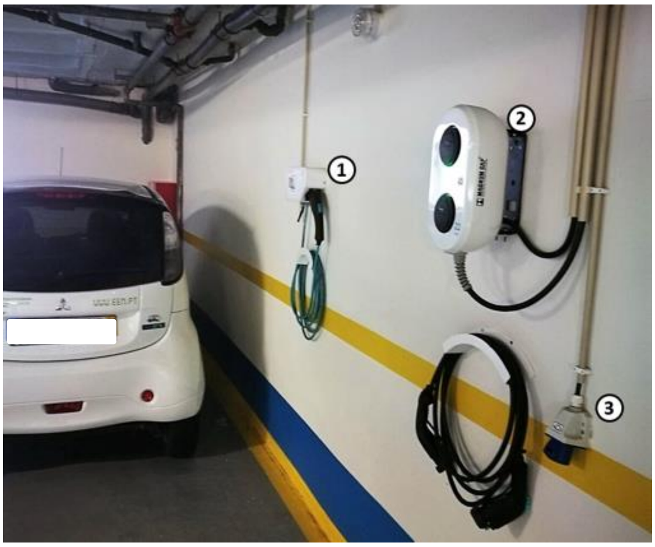

Figure 7.6 – One of the charging stations in the EEM garage. The number 1 shows a charger for the Mitsubishi iMiEv, the number 2 shows a charger for the Renault Zoe / Nissan Leaf, and number 3 a 16 A socket also used for charging.

It is also worth mentioning that we have also surveyed a rent-a-car in Funchal (WeRent) that owns three hybrid vehicles as well as one smart-charging station that is being used as a regular charging point. Nevertheless, at the time of the survey, only one of the hybrid cars had been rented, and for a small period of time. Other than that, only company owners operate the vehicles. Consequently, we had to dismiss this operator from our potential participants.

7.3.1 Next steps

In the next step of these two pilots the research team will enquire the different stakeholders that will be involved in the pilots. To this end, we have already created a questionnaire that can be found in Annex II.

8 Conclusions

In this document, we have presented in detail the pilots that will be performed in the Madeira demonstration site in the scope of the SMILE project. In this section, we first will summarize all the proposed pilots, then reports on its progress, main challenges and the connection of this deliverable to other deliverables and work packages from SMILE.

8.1 Summary

The Madeira demonstrator of the SMILE project will be composed of five pilots. In summary, the pilots will study the implementation of DSM, EV smart-charging and frequency and voltage control in the local grid. In the following sub-sections, we briefly describe each pilot, for the detailed description please refer to chapters 4, 5 and 6.

8.1.1 Pilot 1: Getting Started with BESS and DSM

This pilot is targeted at UPAC owners that cannot sell their excess production to the utility. Since 2014, all the new PV installations in the island are not able to sell energy to the grid. The best way for consumers to maximize their investment is to consume as much energy as possible during peak production. This pilot aims to maximize the self-consumption of local PV owners through the installation of BESS. Our first research identified 36 households and the recruitment process is currently taking place. We estimate an average specification for the BESS in the order of 3kWh/1.5kW to be used in the selected households.

8.1.2 Pilot 2: Moving forward with BESS and DSM

This pilot is very similar to the previous one. However, instead of targeting domestic consumers this pilot is targeting commercial sites (e.g. restaurants). These individuals share the motivation with individuals' who are part of the first pilot. Yet, restaurants consumption usually happens in periods of high solar RE production, therefore maximizing self-consumption is not as challenging. The installation of a BESS will benefit participants in the second pilot by pre-charging the system with cheaper (off-peak tariff) electricity. This can result in lower energy cost for the affected participants in two ways: firstly participants will reduce their overall peak consumption (by consuming energy from the BESS in those periods), secondly the overall peak consumption can also be lowered which can lead participants to lower the contract with the DSO (which effectively lowers a fixed contract cost every month). There are 12 identified businesses that are currently being contacted to participate in the study, we estimate a BESS with an average specification of 20 kWh/40 kW to be used in the pilot sites.

8.1.3 Pilot 3: Getting Started with Electric Vehicles and Smart Charging

The third pilot will be the first ever pilot of Smart Charging in the island. This pilot is targeted at small vehicles (e.g. electric scooters, small cars) and the goal is to achieve Smart-Charging using inexpensive off-the-shelf hardware combined with Prsma and Route Monkey software. We envision the following strengths of using this type of approach, namely by individually controlling each charging point it is easy to control the maximum electricity demand. Individual electricity consumption per vehicle can allow profiling each EV (estimate charging times and batteries status), which ultimately can result in better fleet control and optimization. Finally, this approach can also be used to dynamically control the charging based on external factors such as available RE generation.

Three local businesses were identified for this pilot. One company, which operates a fleet of electric Piaggio scooters was selected as the first site, however the remaining businesses can participate in a later phase.

8.1.4 Pilot 4: Electric Vehicles Are Our Future

The second pilot with EV is similar to the first one (Pilot 3), however for this pilot we are targeting common electric vehicles. Our goal is still to be able to provide smart charging at a fraction of a cost of commercial available integrated solutions. For this pilot exiting charging infrastructures will be retrofitted with off the shelf controllers. Currently we are considering four main factors for controlling the charge in the local pilot: Price of electricity, islands total demand, RE availability and aggregated consumption in the building. However, given the early stage of EV in Madeira, other opportunities might arise during the SMILE project. Pilot 4 will take place in the EEM garage, which possesses their own charging infrastructure for a set of Renault Zoe and Kangoo, Nissan Leaf and Mitsubishi i-MiEV.

8.1.5 Pilot 5: Voltage and Frequency Control Pilot

The fifth pilot aims at implementing voltage and frequency control measures through a large BESS installed in a distribution point. As of now, sudden changes in RE availability in the island result in fluctuation in Voltage and Frequency. Currently, these issues are being addressed by the thermal (mainly) and hydro plants. In this pilot, the BESS infrastructure will be used to meet unexpected demands in the grid. The selected sub grid to be upgraded with a BESS is the subgrid with highest UPP solar production in the island. The rationale is that to use the expected peak in solar production during the day will be used to charge the battery (of course the actual battery operation will not be as linear). At the moment, the sub-grid is already chosen and the connected UPP are identified, for this pilot, both the battery status and individual PV production sites will be monitored. We estimate a BESS specification in the order of 80kWh/40kW for the selected DP.

8.2 Progress

As a summary of the work developed so far, we can look back at the tasks specified in the project proposal and report on their status:

- **T 4.1: Case study specification and assessment:** This task includes all the work presented in this document. It is currently on-going work, some of the sub tasks are already completed (such as the specific goals and target groups of each pilot) while others are still being developed (for example participant recruitment).
- **T 4.2: Infrastructure preparation:** This task started with some tests at PRSMA and EEM, regarding the communication with PRSMA's EMS. PRSMA and M-ITI have started the integration of two possible monitoring solutions with their framework. Furthermore, a critical grid infrastructure for its location and specification was identified as part of this task.
- **T 4.3: Data collection, modelling, analysis, decision:** The project partners already used EEM infrastructure to collect data regarding UPP's, UPAC's and DP's. With this data, decisions were made regarding the specification of each pilot (e.g. its goals or target group)
- **T 4.7: Kick-off of the Madeira pilot for EV with smart charging**: After a visit from Route Monkey to our local demonstrator, the EV pilot kick-off is underway. The participants are selected and most of the technology is also identified. One of the selected locations is also being currently monitored as a baseline for the study.

8.3 Main Challenges

Having the local DSO on the team has helped streamline some of the tasks related to understanding challenges to the local grid as well as potential solutions. EEM has helped the project team reach its customers as potential project participants.
At the beginning of the project, the EV smart charging pilot seemed significantly challenging for all the Madeira partners, since none of the them had experience with this technology. Most of the initial challenges were tackled during the visit of Route Monkey to Madeira in month 3, where significant inputs were provided to draft the two EVs pilots that are presented in this document.

8.4 Next deliverables

The next deliverables, due in month 13 (June 2018), are as follows:

a) D4.2: Infrastructure preparation and kick-off (Public report). Document providing evidence of the installed communication infrastructure, the smart-metering hardware, and the integration with the Energy Management System.
b) D4.3: Data collection, modelling, simulation and decision (Public report). Report describing all the necessary steps before the deployment of the BESS on the selected sites.
c) D4.4: User acceptance report of the initial smart metering deployment (private report). Report describing the outcomes of the assessment of the user acceptance of the initial smart-metering rollout.

9 References

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10 APPENDIX A: AMI Technology Surveys

In this appendix, we provide the details of the surveys that were conducted to understand which AMI technologies are better suited for the proposed pilots. This section is mostly focused in the technical requirements for the local pilots, however after the initial technical specification is finalized, a cost/benefit analysis will guide us to the final selection.

10.1 Smart-Meters

Several metering technologies were analysed to select the best fit for the local pilot. We considered two main types of equipment during our research, smart-meters and energy meter / analysers.
We considered smart-meters, the metering equipment that utility companies use not only to bill customers, but also allows bi-directional access to the device. This equipment's must respect several constrains. As an example, we consider the *EDMI Mk10A* series meter or the *Iskraemeco Mx382* models (see Figure A.10.1 - left). On the other hand, energy meters / analysers are technologies used to metering, but not necessary for billings. These systems are normally used by companies managing large buildings and need detailed information about the electric grid. These systems are often coupled with analytical tools to help users / operators analyse the consumption profiles. Such systems include the *ABB B23* series (see Figure A.10.1 - right) or the *Carlo Gavazzi EM2*4 series meters.
There are a number of features that define each of the solutions, but for the Madeira pilot we are mainly interested in two of them: **Connectivity** and **sampling frequency**. Other features such as safety, security or accuracy were also considered but not studied in detail since our research only sought for equipment's that already meet the requirements in those three areas.

Figure A.10.1: Examples of smart-meters: EDMI Mk10A (left), ABB B23 series (right)

10.1.1 Survey Requirements: Connectivity

The Madeira pilot will be spread across a wide geographical area (see chapter 7, Participants Recruitment Process), for more details about the potential pilot participants), therefore it is imperative to select proper communication technology to allow seamless communication between the deployed hardware with the cloud services.
Ideally, we were looking for equipment that would offer redundancy in the communication, for example one of the surveyed energy meters' functions with both 3G and Ethernet technology. Additionally, we also considered the capacity of the equipment to store high granularity data, in the eventuality that the communications fail. A thorough survey of state of the art communication technologies is presented in Appendix C: Communication Technologies Survey.

10.1.2 Survey Requirements: Sampling frequency

All the pilots in Madeira will require high-frequency data, therefore this feature was also considered in this survey. In the scope of the Madeira pilot, we acknowledge high-frequency consumption data to be data that is aggregated every 5 to 15 minutes. Latency is related to the frequency the consumption data is made available, and similarly we were also searching for equipment with latency between 5 to 15 minutes. We also considered equipment, which operated in the request-reply paradigm (the equipment responds with data every time it receives a request), and this case is up to the aggregator software system to define the sampling and latency speeds.

10.1.3 Surveyed Smart-Meters

We performed an extensive “desk research” of available smart-meter technologies, from manufacturer websites, online forums, academic works and equipment datasheets. This survey was supervised by EEM who already had experience with smart-metering equipment. A summary of the surveyed smart-meters in given in Table 10.1.

Afterwards, we acquired two smart-meters (Landys + Gyr E650, and Carlo Gavazzi VMU-E EM) and performed a more empirical study of the equipment features. The Langis + Gyr E650 is one the most used smart-meters in EEM, whereas the Carlo Gavazzi solution was proposed by the Samso Elektro APS (SEL) during the kick-off meeting in Brussels.

For this study, the two smart-meters were installed at M-ITI, and were tested by the PRSMA and M-ITI teams. Figure A.10.2 shows the two smart-meters as installed in the main breaker box. Next, we present the evaluation results.

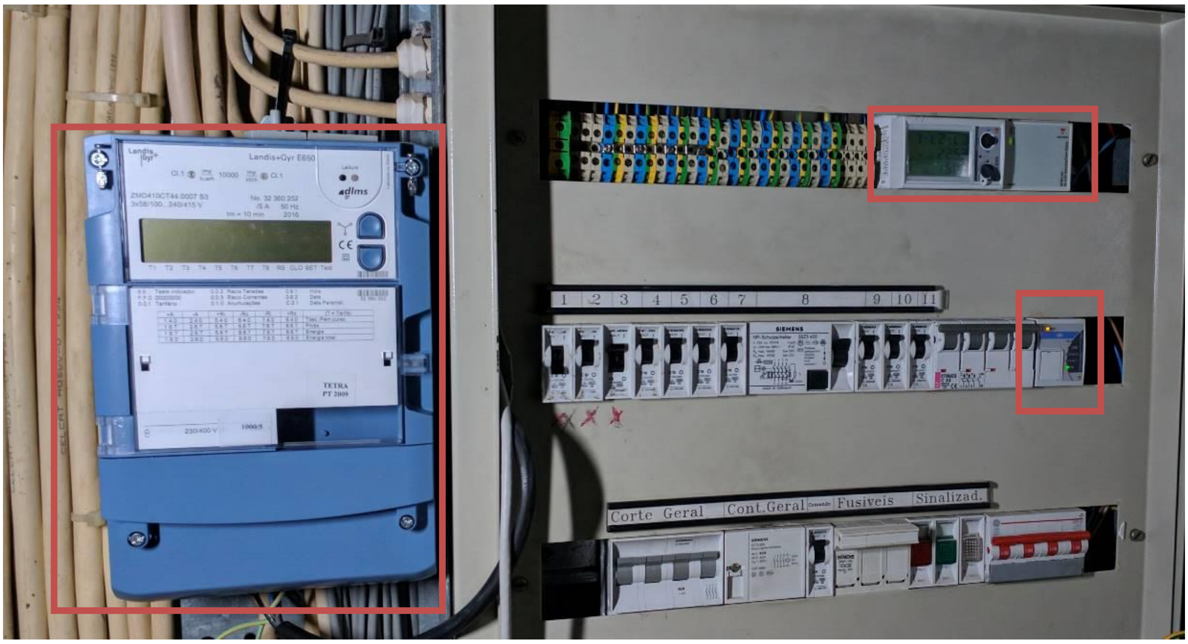

Figure A.10.2: Smart-meters installed in the M-ITI main breaker box. Landis + Gyr 650 (left), Carlo Gavazzi EM 24 (left).

10.1.4 Survey Results: Carlo Gavazzi EM 24

The VMU-E module of the Carlo Gavazzi solution requires a LAN connection. For testing purposes, we created our own LAN using a LALA router; the VMU-E module was then connected to the router via Ethernet.

Using this configuration, all the devices that are in the same LAN can be easily accessed. However, for pushing the data to an online server, or to access the meters from the Internet (e.g., for maintenance purposes) an Internet connection must be available as well. In our test scenario, the router was connected to the Internet via an existing Wi-Fi network. Another possibility, and perhaps more indicated for our real-world deployments, is to use a router with 3G / 4G capabilities, like for example the GL-MiFi[11].
Having said this, we encounter the following strengths and weaknesses in the Carlo Gavazzi equipment:

Strengths:

- The small form factor can make the installation easier;
- The equipment provides consumption information at the required rate;
- The webserver module provides several options to interact with the smart-meter. For example, it is possible to access to the data through an API, and uploading the consumption data to an FTP server, at pre-defined time intervals;
- After some reverse engineering, it was also possible to access the consumption in real-time. This is however dependent on the firmware version, which may not be desirable in the long-run.

Weaknesses:

- The FTP method for extracting data, uses a non-standardized data format, and each upload creates a new file with the respective data. Consequently, it is necessary to parse the name of the files before parsing the actual file contents;
- The current API is very limited. The data that is returned is in the same format of the files uploaded to the FTP server, furthermore the API requires a running session on the server. Since this session must be started through the browser, it becomes troublesome to implement and to scale a full-fledged monitoring solution;
- Another issue that we found is related to the root access in the Webserver module (the module that actually holds all the ftp and API services). SSH root access is reserved for maintenance and not available for customers. Consequently, we are unable to implement bespoke solutions for the weaknesses presented above.

In summary, the Carlo Gavazzi smart-meter provides an adequate solution for collecting the data that will be needed in the SMILE project. During this test, PRSMA already created an initial portion of the middleware needed to communicate with this equipment. Nevertheless, the high final price of this equipment (around 500 Euros per unit), makes this solution somewhat expensive for our purposes.

10.1.5 Survey Results: Landis + Gyr E650

We are currently testing the Landis + Gyr E650 model, and so far, one of the major challenges in setting up the communication with the local gateway.
To state more concretely, we are testing using 3G for communication and the DLSM protocol to interface with the meter using the GuruX open-source API[12].
The main challenge that we are facing right now is the fact that the Landis+Gyr smart-meters require configuration using proprietary software that is only accessible for DSOs and electric utilities. While

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[11] GL-MiFi router, https://www.gl-inet.com/product/gl-mifi/

[12] GuruX, https://www.gurux.fi/OpenSource

EEM owns the software, this means that every time a change is needed, a visit to the EEM labs is necessary.
We have compiled a preliminary list of strengths and limitations for this equipment:

Strengths:

- Widely used by EEM, meaning that we have their expertise on our side to install and solve any technical issues with the meters.
- Uses a standard communication protocol (DLMS) that is shared among most of the smart-meter vendors. This is very important because it will allow us to develop software that is hardware independent.
- It costs less than half of the Carlo Gavazzi Solution.
- Uses a standard communication protocol (DLMS)

Weaknesses:

- Configuration requires specialized software and an optical probe that is not easy accessible. For example, the software is only available for DSOs and electric utilities
- Using 3G communication may become cumbersome, because of the dynamic nature of the IPs. While EEM owns a solution for this (there is a middleware service that translates the dynamic IPs into static IPS), it is already overloaded with their own services. Consequently, we will need a different solution for communication.
- The equipment is considerably big, which may make the installation of two of such devices in the micro-production sites a little bit complicated.

10.2 Plug-level Meters

The pilot Getting started with EVs will require the installation of commercial plug level monitoring devices. Therefore, we have conducted a survey of the solutions currently available in the market.
During this survey, there were main aspects taken into consideration:

1) **Remote access:** It is crucial for the selected solution to be remotely controlled since the logic of the smart charging will run on an external server. The remote access will also allow the plug to push data to external servers.
2) **Open API:** An open API was needed to integrate the smart-plug commands and the other pieces of software (e.g., gateway and EMS).
3) **Enable charging of the EV:** The maximum current allowed trough the smart-plug has to be larger than the maximum current consumed by the electric scooter while charging.

M-ITI and PRSMA have already acquired experienced with smart-plugs, namely the PlugWise system [5]. This system was tested in live deployment, and can be easily adapted to be used in the EVs pilot. Nevertheless, for the sake of completeness, other alternatives were also considered. Table 10.2 provides a summary of the surveyed equipment. The survey was made searching manufacturers and resellers catalogues and online reviews. This review shows that using PlugWise may be the most appropriate, since the other solutions do not seem to offer any relevant advantages in terms of technology capacity or price.

10.3 Grid Power Quality Analyser

The pilot Voltage and Frequency Control through BESS will require the installation of a grid power quality analyser.
A grid power quality analyser shares the basic functions of a smart meter, in terms of measuring the consumption of energy with information such as active, reactive and apparent power, power factor, network frequency, harmonic distortions, voltage and current, allowing, at the same time,

bidirectional communication of the data obtained using cellular networks (i.e., 3G, GSM and GPRS) or Wi-Fi.

One difference between smart-meters and grid power quality analysers is the sample frequency. Typically, smart meters sample data every few seconds or minutes. However, the control of voltage and frequency levels in distribution points need real time information about these quantities, thus the need for such equipment. Table 10.3 summarizes the grid power quality analysers that were surveyed by the research team.

Table 10.1 – Summary of the surveyed smart-meters

Manufacturer	Type	Model	Communication technology	Sampling frequency	Data collection protocol
Kamstrup	Residential	162M	Communication modules GSM/GPRS, M-Bus, TCP/IP and Wi-fi	5, 10, 15, 30 or 60 minutes	KMP via Zibgee
		382M			
		351C			
		OmniPower – single and three phase			DLMS
	Industrial	OmniPower – three phase and CT			
Itron	Three phase	EM420i	Communication modules PLC, GPRS, Mesh RF, Zigbee and M-Bus Wireless	5 seconds	DLMS
		ACESL7000	Communication modules PSTN, GSM/GPRS and Ethernet		
		ACE6000			
	Single phase	SENTINEL	Built-in GPRS and Ethernet	Near real-time	ANSI C12.19 and C12.22
		OpenWay CENTRON	Built-in Zigbee radio Communication modules GPRS and CDMA	5, 15, 30, 60 minutes	
Elster HoneyWell	Three phase	A1180	Modbus, DNP 3.0, DL/T 645 or TCP/IP; PSTN (via external module)	Near real-time	DLMS
		Alpha Smart 3000-3500	Communication modules GSM/GPRS, Wireless M-Bus, Ethernet, PLC/IDIS and PLC/OFDM		
	Single phase	A3 ALPHA	Communication modules E-WIC (Ethernet), W-WIC (CDMA and GSM) and ITM3 internal telephone modem		ANSI C12.19
		A1140	Communication module GPRS	5, 15, 30 and 60 minutes	OpenMetrics web-server

Manufacturer	Type	Model	Communication technology	Sampling frequency	Data collection protocol
ISKRAEMECO	Single and three phase	Mx38y	PLC communication (Mx381) GSM/GPRS communication (Mx382) RS-485 communication (Mx383)	-	DLMS
		AM550-x	PLC 2G/3G, GSM/GPRS/UMTS, LTE, RS-485 and Ethernet	-	
Landis + Gyr	Three phase	E650	Communication modules GSM/GPRS/UMTS and Ethernet	Near real-time	DLMS
		E850			
EDMI	Single phase	Mk7A	2G, 3G, 4G LTE UDP/IP, GPRS, PPP	Under 1 minute	DLMS
	Three phase	Mk10A			EDMI command line
		Mk10D			DLMS
		MK10E			
		Mk10H	GSM/GPRS, 3G and Ethernet		EDMI command line
		Mk11	Built-in Ethernet, GSM/GPRS		DLMS
Carlo Gavazzi		VMU-E EM	Built-in Ethernet and USB port, GPRS, EDGE, UMTS, HSPA and VMU-modules	5 minutes, near real-time API	Web-server and FTP/HTTP push
JANZ		A1700	Communication module GSM/GPRS, PSTN, PLC and Ethernet	Near real-time	DLMS
	Single phase	C380 prime			
General Electrics		kV2c	External GPRS, CDMA, PLC, RF and Ethernet	Near real-time	ANSI C12.19
		I-210+c	External GSM/GPRS, Zigbee radio and Badger Orion	5, 15, 30 and 60 minutes	ANSI C12.21 and C12.22
Emlite		Wi-fi smart meter	Built-in Wi-fi	15 minutes	OpenMetrics Android/iOS app
		EMA1	Built-in GPRS		OpenMetrics web-

Manufacturer	Type	Model	Communication technology	Sampling frequency	Data collection protocol
		EMB1 EMC2	Communication module Wi-fi		server, FTP push and email

Table 10.2 – Summary of the surveyed smart-plug

Manufacturer	Model	Communication technology	API	Specification
PlugWise	Home Stretch Basic	HTTP via HUB to control the plugs Plugs communication is made through Zigbee	Yes	Input: 100V to 240V, 16A Power: Up to 3840W (max)
D link	DSP-W215	http to control the plugs		Input: 100V to 240V, 16A Power: Up to 3840W (max)
Insteon[a]	On/Off Outlet	HTTP via HUB to connect the plugs and some low energy protocol to control the socket		Input: 120V, 15A Power: Up to 1800W (max)
Wink	Outlink	HTTP via HUB to control the plugs Plugs communication is made through Zigbee		Input: 120V to 240V, 15A Power: Up to 3600W (max)
Belkin	Wemo® Insight Smart Plug	HTTP supports the IFTTT (If This, Then That) web based service		Input: 220V, 15A Power: Up to 3300W (max)
OBLO Living	OBLO Smart Plug	HTTP via HUB to control the plugs Plugs communication is made through Zigbee		Input: 220V, 16A Power: Up to 3520W (max)
Samsung	SmartThings Power Outlet			Input: 240V, 13A Power: Up to 3120W (max)
eMotorWerks[b]	JuicePlug	Built-in Wi-fi Data collection via eMotorWerks web-server or Android/iOS app	-	Input: 100V to 270V, 40A Power: Up to 10kW (max) Standard EV J1772 charging plug

[a] Only for 110 V power grids (e.g., USA)
[b] Only for electric vehicles charging points

Table 10.3 – Summary of the surveyed grid power quality analysers

Manufacturer	Model	Communication technology	Communication protocols	Sample frequency
Socomec	DIRIS Q800	Built-in WiFi, Ethernet, RS485 and USB	NTP, HTTP, HTTPS, FTP, MODBUS and PQDIF	51 kHz
General Electric	EPM 9900P	Built-in RS485, USB, ANSI optical port and Ethernet	SMTP, SNTP, FTP and TCP/IP	
	EPM 9900			
	EPM 7000	Built-in RS485 Communication modules Ethernet, Optical port and Pulse output	Modbus TCP/IP, Modbus RTU, NTP and DNP	25 kHz
Fluke	1750-TF	Built-in Ethernet and Wireless	TCP/IP and Bluetooth SPP	10 kHz
BMR Trading	PLA44RGP	Built-in Ethernet and USB	Modbus TCP, TCP/IP, SMTP, HTTP, FTP and NTP	40 kHz
ALSTOM	iSTAT M3x5	Built-in serial (RS232 and RS485), USB and Ethernet	Modbus RTU/TCP, DNP3	31 kHz
Janitza	UMG 96RM	Built-in RS485, USB, M-Bus, PLC and Ethernet	Modbus RTU and TCP/IP	21 kHz
HIOKI	PQ3100	Built-in RS-232, LAN and USB	HTTP and FTP	200 kHz
Siemens	SICAM Q200	Built-in RS-485, Modbus and Ethernet	Modbus RTU, Modbus TCP/IP and integrated web-server	40 kHz

11 APPENDIX B: Storage Technology Surveys

Here we present some additional information about the research that was conducted regarding the BESS requirements of the Madeira demonstration site.
It is important to mention that this survey allowed us to learn about BESS. For the purpose of the SMILE project we are currently working with Lithium Balance for the solution to implement in the local pilots with BESS.

11.1 Types of Batteries

There are a few types of batteries to storage electric energy, such as alkaline, Nickel-Cadmium (NiCd), Nickel–metal hydride (NiMh), Lithium-ion and Lead-acid. However, the batteries most commonly used in PV Storage Systems in households are lithium-ion and lead-acid batteries. Table 11.1 describes some of the differences between Lithium-ion and Lead-acid batteries.

Table 11.1: Lithium-ion vs Lead-acid batteries

Lithium-ion batteries	Lead-acid batteries
More expensive	Cheaper
Lighter	Heavier and larger
Require integrated controller, that manages charge/discharge	Less efficient (about 85% efficient)
More efficient (up to 98% efficient)	Battery compartment/room requires very good ventilation to prevent gas build-up
Can discharge more stored energy	Need good charging and discharging routine to maintain battery health
Longer expected lifetime (5 to 15 years)	Shorter expected lifetime (3 to 15 years)
Increasingly common in domestic grid-connected solar PV storage systems	-

Lead-acid batteries are generally reliable for everyday use; however, these batteries do have their shortcomings. In this type of batteries, it is important to be aware about dangers from chemical burns since the electrolyte of these batteries are made up by sulfuric acid and water. The acid solution can cause chemical burns to the skin therefore, there has to be extreme caution while working around a lead-acid battery. When a lead-acid battery is recharged, some of the electrolytes may evaporate and hydrogen gas will escape from the battery cell vents (conventional lead-acid batteries contain, ate least, one battery vent per cell). Owing to the fact that hydrogen gas is flammable, lead-acid batteries should be stored and recharged away from sources of fire or flame. Another disadvantage of lead-acid batteries is the fact that electrolytes can evaporate. As mentioned above, as the battery is being recharged, the electrolyte may evaporate through cell vents. In case of the electrolyte level in any of the battery cells falls below the minimum required level, the battery may cease to function correctly. If this happens, distilled water must be added to the affected battery cell to bring the electrolyte back to normal levels.
Due to drawbacks mentioned earlier about lead-acid batteries, it was concluded through the Household BESS Survey that Lithium-ion batteries would be used for this project. These batteries are also a better choice for BESS for installation in MV/LV Transformation Stations.

The life span of a Lithium-ion battery does not depend on its state of charge, as long as the voltage per battery cell is kept within (broad) limits. A Lithium-ion BMS (Battery Management System) will do just that, and so battery care will be less needed.

11.2 BESS (Battery Energy Storage System)

A battery energy storage system (BESS) for PV facilities usually contains three different components:
Inverter: it is a bidirectional component, which means that it converts the DC power stored in the battery into AC power to supply the loads or converts the AC power from the grid or PV panels into DC power to charge the battery.
Battery management system (BMS): it is a software function internal to a charge controller that controls the state of charge, the depth of discharge and the temperature of the batteries in order to prevent them from over or under charging, extending their lifetime.
Battery: stores the energy when needed (for instance, when the production of the energy is higher than its consumption) and supplies the energy when there is a demand.

11.3 BESS Survey

Taking into account that for both studies the Lithium-ion Batteries are the best option, Table 11.2 presents a technical comparison between the Household BESS and the Distribution Station BESS.

Table 11.2 – Comparison of the requirements for Household and Distribution Station BESS

Characteristics	Household BESS	Distribution Station BESS
Capacity	Low	High
Voltage	Low	Medium
Cost	Low	High
Maintenance	Marginal	Highly Desirable
Charge / Discharge rate	Low	High
Battery life time	High	Low
Pear power / current	Low	High
Life cycles	Low	High
Efficiency	Low	High
Weight	Low	High

In household BESS, given that the energy stored in the battery is used for supplying low power load such as domestic devices, it presents low voltage and capacity in comparison with its DP counterparts (consequently, the weight and cost of the batteries are also lower).
Regarding the maintenance of the batteries, we assume that the need for it is higher for DP in terms of security and the demand of the task. Due to the complexity of the assignment, it is expected that DP BESS will require greater efficiency.
For bigger dimension storage systems, i.e, a BESS for installation in Medium-Voltage/Low-Voltage Transformation Stations, there are additional requirements for choosing the battery type, owing to the fact that these batteries need to have potential for greater capabilities and work on a higher energy density. Note that for these cases, the batteries have to be more sophisticated in terms of reserving energy for smoothing the load / production, supporting the grid and storage energy

production. As a result, the battery lasts less for the DP BESS. In order to counterbalance this fact, the approach could be investing in longer life cycle batteries.

Finally, considering the purpose of the battery for DP BESS, these should present faster charge/discharge power rate and support higher peak currents.

12 Appendix C: Communication Technologies Survey

In this appendix, we provide additional information about the research that was performed regarding the communications technologies that can be used in the different Madeira pilots.

12.1 Overview of Wireless Communication Technologies

Regarding wireless communication technologies, there are a number of options such as Wi-Fi, 3G, Bluetooth, and ZigBee. These can be classified by their range, speed and power consumption, as shown in Table 12.1:

Table 12.1: Alternative technologies for wireless communications

Short Range (High-Speed)	Short Range (Medium Speed)	Long Range (High-Power)	Long Range (Low-Power)
Ethernet	802.15.4	Cellular	LoRa
Wi-Fi	ZigBee	Satellite	SigFox
-	ZWave	Microwave	Ingenu
-	Bluetooth	-	Waviot
-	Thread	-	NB-IoT

For IoT (Internet of Things) applications, it is important to choose a technology that is capable of sending information with a low data rate, low power and long-range connectivity such as Low Power Wide Area Networks (LPWAN). There are a few solutions for LPWAN (e.g., LoRa, SigFox, Ingenu, Waviot, and NB-IoT), and each of them has different approaches and business models, however, they share the same benefits (in comparison with the other technologies):

1) Low-power;
2) Long range;
3) Low radio chipset costs;
4) Low number of base stations;
5) Wide coverage;
6) Low bandwidth occupation;
7) Low radio subscriptions costs.

Next, we briefly describe the five LPWAN solutions shown in Table 12.1.

12.1.1 LoRa

LoRa uses a modulation technique, based on chirp spread-spectrum, in order to present a good performance against channel noise, multipath fading and Doppler Effect. It operates in unlicensed radio spectrum (no license costs) with lower radio frequencies, which allows for longer ranges. For Europe, it uses the 863-870 MHz and 433 MHz bands.

LoRa handles physical parameters (bandwidth and spreading factor), which influence the data rate. The bandwidth, depending on the frequency, can be 125, 250 or 500 kHz and the spreading factor, chosen by the end-device, can assume values from 6 to 12. Typically, higher spreading factor leaves to higher range but lower bit rates.

In terms of security, LoRa network has three distinct 128-bit security keys, which are generated during different stages of the transmission process.

One of the major advantages of LoRa is that it enables you the opportunity of creating your own private network, as long as you cover the cost of the infrastructure (gateway). With this, there is no need of paying any monthly subscription as Cellular networks.

12.1.2 SigFox

SigFox has an architecture that is very similar with LoRa's. Although, it has its own network across cities, which mean that there are no costs regarding the acquisition of gateways. However, there is the need of paying monthly subscriptions for the service. Also, there is only one network provider and, overall, the end-devices costs are lower in comparison with LoRa.

In order to work with SigFox networks, there needs to be coverage within your city. Currently, Portugal has coverage across the country, although it is not clear if there is coverage for Madeira.

SigFox also uses unlicensed frequency bands. About the service, there are a couple of limitations (that LoRa does not present) such as a maximum of 140 messages per day (which corresponds to 1 message every 10 minutes) and 12 bytes of payload per message. Unlike LoRa, the bit rate is fixed to 100 bits per second (12,5 bytes per second).

12.1.3 Ingenu

Ingenu uses a LPWAN technology called Random Phase Multiple Access (RPMA). It has an approach that is similar to SigFox as it has its own network (hence, there is the need of having coverage in your city). This technology, unlike both presented above, uses the crowded 2,4 GHz frequency band, which may lead to interference problems.

Currently, there is only coverage for the USA. In addition, there is no available information regarding costs of hardware and software (it is mandatory to contact directly to the company).

One particular aspect worth of mentioning is that, even if there is no coverage in your city, you can rent an Access Point.

12.1.4 Waviot

Waviot handles an open source code of NB-Fi protocol. It has an approach that is similar to LoRa and also works on the 868 MHz frequency band. Unlike LoRa, there are not lots of commercial products for both hardware and software components as all of them belong to the Waviot Company and it is important to highlight that the hardware costs are higher.

12.1.5 NB-IoT

Finally, the last LPWAN studied was the NB-IoT technology (developed by u-blox). Its approach is similar to SigFox and Ingenu. Besides the end-device (radio module plus microcontroller), it is also necessary a SIM card in order to connect to its network.

Unlike the others LPWAN mentioned above, NB-IoT is still in its early stages of developments and trials, being one of the reasons why there is not much information regarding hardware solutions or even coverage areas. For instance, the first NB-IoT pilot is currently taking place in Lisbon[13] by the alliance of some companies such as NOS, EDP, Huawei, JANZ CE and u-blox. In order to accomplish this, NOS needed to install two base stations for NB-IoT coverage.

Although the lack of information in hardware solutions, it is true that SODAQ has already developed an Arduino shield for the NB-IoT technology for 74,45 €, using, of course, a radio module from u-blox. In terms of software, one network provider mentioned was *AllThingTalkMaker*.

12.2 Combining LPWAN and Smart-Metering

One possible application for the LPWAN technologies in the SMILE project, could be handling the communication between the smart-meters and the gateways that will be present in almost all the case studies described (BESS for domestic and commercial micro-producers, BESS for Distribution Points and smart charging of EV).

Of all LPWAN studied, it is clear that SigFox and LoRa currently are the best options. Nevertheless, since we are particularly interested in having our own network, we will consider LoRa to provide an example of how this technology could be used to support AMI communications during the project.

In Figure 12.1 we show a diagram representing the installation of smart-meters in a number of micro-production sites. Note that in this example, smart-meters are represented as simple sensors that communicate with the microcontroller via any serial communication protocol (e.g., UART, SPI, or I2C).

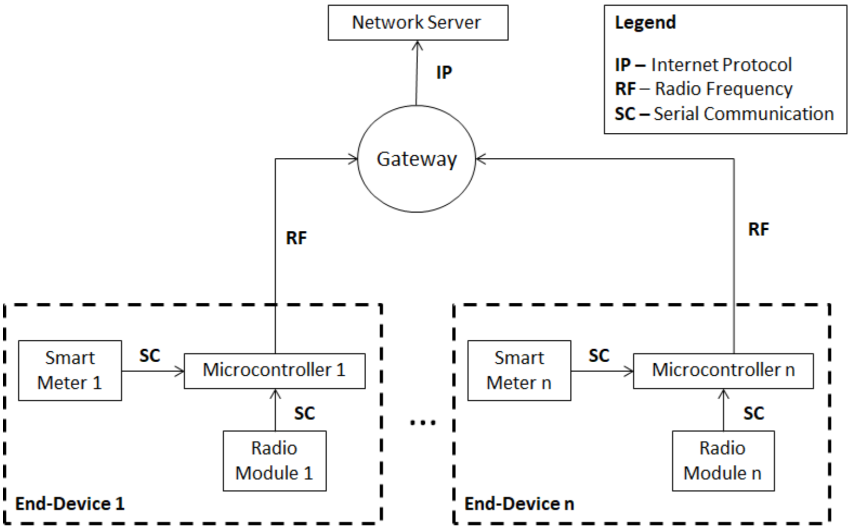

Figure 12.1:

Using this diagram, and considering the cheapest components in the market, we estimated the price of using LoRa to monitor 10 micro-production sites (without considering the cost of the smart-meters). Table 12.2 summarizes the obtained cost estimates:

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[13] NB-IoT Pilot, http://www.jornaldenegocios.pt/transformacao-digital/mobilidade/detalhe/contadores-inteligentes-facilitam-leitura-da-luz

Table 12.2: Cost estimates of using LoRa to enable communication in smart metering

Component	Price (€)
Radio Module	70
Microcontroller	7.53
Gateway	200
Network Server	0
Total per device	**77.53**
Total for 10 installations	**975.3**

It is important to highlight that:

1) It is assumed that one gateway is enough to cover all end-devices;
2) The gateway chosen is the raspberry pi plus the LoRa concentrator version;
3) The microcontroller chosen is the Arduino Uno as it is inexpensive, already has libraries for LoRa and it is easy and fast to program;
4) The radio module, as a consequence of the microcontroller chosen, is the Arduino module;
5) As the simulation entitles to use 1 gateway and 10 end-devices, there are no costs regarding the network server. Even if there is the need of more gateways or more end-devices, it can be used The Things Network for trials.

13 APPENDIX D: Extended Summary of Legislation

In this appendix, we provide extend summaries of the current legislation for Micro-production and Electric Vehicles in Portugal and Madeira.

13.1 Micro-Production

13.1.1 National Legislative Framework

Decentralized electricity production is currently ruled by Decree-Law nº 34/2011, of 8 March, as revised by Decree-Law nº 25/2013 of February 19, which establishes the applicable legal regime to the production of electricity, from renewable resources, through mini-production units, and by Decree-Law nº 363/2007, of November 2, as edited by Law nº 67-A / 2007, of December 31 And Decree-Laws nº 118-A / 2010, of October 25, and 25/2013, of February 19, which establishes the legal regime applicable to the production of electricity by means of micro production units.

These regimes, while assuming that the production activity must be associated with a power plant with actual consumption and an electricity supply contract with a supplier, allow the total delivery of the energy produced in the respective units to the Public Electric Grid Service (RESP), which is remunerated through the general regime or the subsidized regime.

In fact, Decree-Law nº 34/2011, of 8 March, revised by Decree-Law nº 25/2013, of February 19, departed from the paradigm of Decree-Law nº 68 / 2002, of March 25, revoking it, which regulated the activity of production of electricity in low voltage destined predominantly for own consumption, without harming the possibility of excess production remaining to third parties or to the public grid.

New solutions for the production of decentralized energy and technological innovation were therefore required, accommodating the figure of producer-consumer of low-voltage electricity (or the producer in self-consumption) within the scope of the Independent Electric System. There is also the existence of a connection to the public electricity distribution grid, in the threefold perspective of self-consumption, supply to third parties and delivery of excesses to the grid.

The system of production in self-consumption, however, did not have the expected acceptance. On the occasion of the publication of Decree-Law nº 34/2011, of March 8, there were few units with these characteristics that were registered. The immaturity of the technology discouraged large investments of being made that had as only counterpart the cost avoided with the acquisition of the electric energy to the grid. Thus, the focus on this type of technology was based on the attribution of a subsidized remuneration of all the energy produced, which allowed the promoters to recover the amounts invested.

Decentralized production through mini-production and micro production units has demonstrated, however, that technological developments nowadays allow the development of projects with less investment, which, of course, has justified the adequacy of the respective remuneration for the energy coming from these units of production.

In turn, the government recognizes the potential of the production activity in self-consumption, as a way to promote greater knowledge, especially by consumers in low voltage, of their consumption profile, inducing energy efficiency behaviours and contributing to the optimization of resources Endogenous and for the creation of technical benefits for RESP, namely by reducing losses in it.

On the other hand, the implementation of a more balanced energy policy aimed at solving the current problems of companies, families and the country, is assumed as an objective of the Program of the XIX Constitutional Government, seeking to guarantee sources and an energy model of economic rationality with transparent and appropriate incentives for market players, as well as strengthening the diversification of primary energy sources and supporting the development of energy sector companies, with a focus on the renewable energy.

In this context, and enacting the provisions of the National Action Plan for Renewable Energy, approved by resolution of Council of Ministers nº 20/2013 of 10 April, are reshaped and integrated in the Decree-Law, the current regimes of mini production and micro, revoking Decree-Law Nº 34/2011, of March 8, amended by Decree-Laws Nos 25/2013 of 19 February, and 363/2007, of 2 November , Revised by Law nº 67-A / 2007, of December 31, and by Decree-Laws 118-A / 2010, of October 25, and 25/2013, of February 19.

13.1.2 Current Legislation

The small production, while retaining the general features established by the above-mentioned diplomas, thus benefits from a single legal framework.

The decree-law nº 153/2014, October 20th, in relation to what was said previously, also establishes the legal regime applicable to the production of electricity, destined for consumption in the installation of use associated with its respective production unit, with or without connection to RESP, based on renewable or non-renewable production technologies.

Distributed production activities - small-scale production and self-consumption - are governed by common provisions regarding the prior control of the activities and the rights and duties of the promoters, and by specific rules that accommodate the vicissitudes inherent in each mode.

The small production regime allows the producer to sell all of the electricity to RESP with a tariff attributed on the basis of a bidding model, under which competitors offer discounts at the reference tariff, eliminating the general remuneration regime provided in the previous regimes Mini production and micro production. When not included in the remuneration regime applicable to small production, the production unit must be subject to prior control and attribution of remuneration under the legal regime for the production of electricity under special regime.

On the other hand, the electric power produced by self-consumption is predominantly used in the installation associated with the production unit, with the possibility of connecting to the RESP for the sale, at market price, of the non-self-consuming electricity. It should be noted that in this mode of production, the producer benefits when the production unit is sized taking into account the actual consumption needs of the facility.

Finally, it is expected to measure the electric energy produced in self-consumption production units, with or without connection to RESP, which is fundamental for the purpose of monitoring compliance with the assumed objectives regarding the use of primary sources of renewable energy.

In this Decree-Law (nº153/2014, 20 October), two types of Units of production were defined. The differences between both are described in Table 13.1:

Table 13.1: Self-Consumption vs. Small Production – comparison based on decree-law n.º 153/2014

	Unit of Production for Self-Consumption (UPAC)	Unit of Small Production (UPP)
Production activities and sources	Production of energy from the renewable or non-renewable source by the production unit with or without connection to the Public	Production of energy from the renewable source, based on a single production technology, and injection of all electric energy to the Public Utility Electricity Grid

	Unit of Production for Self-Consumption (UPAC)	Unit of Small Production (UPP)
	Service Electric Grid (RESP) with energy injection preferably in the consumption facility. Potential surpluses of instantaneous production may be injected into the RESP when applicable.	(RESP). The Small Production, maintaining the general traces established by the old diplomas of mini- and micro production, becomes a single legal framework.
Power limits	The power of connection will be less than or equal to 100% of the power contracted in the installation of consumption. The installed power must not be more than twice the power of connection.	The connection power will be less than or equal to 100% of the power contracted in the power installation up to a maximum connection power of 250 kW.
Production requirements	Dimensioning of the UPAC in order to approximate the electricity produced with the energy consumed in the installation of consumption. Possible sale of the instant surplus to the Last Resort Marketer (CUR).	Energy consumed in the installation of consumption must be equal to or greater than 50% of the energy produced. Sale of the entire energy to the Last Resort Marketer (CUR).
Producer and location of installation	The consumer (individual, collective or condominium) can install a UPAC for each electrical installation of use and consume the electricity generated in this, as well as export eventual surpluses to the RESP. The Production Unit (UP) is installed in the same place served by the utilization facility. The plurality of UP records on behalf of the same producer is allowed, provided that each installation of use is only associated with a single UP.	The consumer (individual, collective or condominium) or third party duly authorized by the holder of the contract to supply electricity to the installation of use, may install a UPP for each electrical installation of use. The Production Unit (UP) is installed in the same place served by the utilization facility. The plurality of UP records on behalf of the same producer is allowed, provided that each installation of use is only associated with a single UP.
Annual quota	There is no quota.	Annual quota not exceeding 20 MW.
Remuneration and compensation	The UPAC remuneration for electricity supplied to RESP is calculated according to the formula: $\boldsymbol{RUPAC, m = Efornecida, m \times OMIEm \times 0.9}$ where: $RUPAC, m$- Remuneration in the month m in € $Efornecida, m$ - Power supplied in month m in kWh	Rate allocated based on a bidding model in which competitors offer a discount to the reference tariff, established by ordinance and calculated for each of the following categories: Category I: Installation of only one Small Production Unit (UPP). Category II: Associated UPP in the place of consumption with electrical vehicle charging socket, that is, owner or renter of electric vehicle. Category III: UPP associated at the place of consumption with solar thermal collector of minimum useful area of 2 m². The rate to be awarded corresponding to the

	Unit of Production for Self-Consumption (UPAC)	Unit of Small Production (UPP)
	$OMIEm$ - Simple arithmetic average of the closing price of the Iberian Energy Market Operator (OMIE) for Portugal in the month m in € / kWh. The sale agreement to be concluded with CUR has a maximum term of 10 years, renewable for periods of 5 years. UPACs with installed power above 1.5 kW and connected to RESP are subject to the payment of a fixed monthly compensation in the first 10 years after obtaining the operating certificate.	highest value resulting from the largest discount offers at the reference rate. The tariff varies according to the type of primary energy used and is in force for a period of 15 years from the date of beginning of electricity supply.
Score	Compulsory counting of the electricity produced and the electricity injected into the RESP for a UPAC connected to the RESP with an installed power of more than 1,5 kW.	Compulsory counting of the electricity injected into the RESP.

In Table 13.2, the procedures for licensing are indicated, according to Decree-Law nº 153/2014, which producers must take into account:

Table 13.2. UPAC and UPP licensing process – according to decree-law n. º 153/2014

	Exception from prior checking	Mere prior communication	Registration	Certificate of operation	Production license	Operating license
UPP			X	X		
UPAC $Pinst \leq$ 200W	X					
UPAC $Pinst >$ 200 W and $Pinst \leq$ 1,5 kW, Connected to RESP		X				
UPAC $Pinst >$ 1,5 kW and $Pinst$ ≤ 1 MW, Connected to RESP			X	X		

	Exception from prior checking	Mere prior communication	Registration	Certificate of operation	Production license	Operating license
UPAC $Pinst \leq 1$ MW When the producer intends to supply the energy not consumed by RESP			X	X		
UPAC $Pinst > 1$ MW					X	X
UPAC $Pinst >$ 200 W and $Pinst \leq$ 1,5 kW, without connection do RESP		X				
UPAC without connection to RESP that uses renewable energy sources and intends to transact guarantees of origin			X	X		

There are other relevant aspects in the decree-law 153/2014, October 20th that should be taken into account for the SMILE project, such as:

a) The producer must also hold civil liability insurance for the repair of personal injury or material damage to third parties as a result of the exercise of electricity production activities for self-consumption (UPAC) and small electricity production (UPP) provided for in this decree-law, whose minimum safe capital and minimum conditions are defined in a joint ordinance of the members of the Government responsible for the areas of finance and energy;
b) Producers have also to ensure that the installed production equipment is certified;
c) The installer shall guarantee that the equipment to be installed is certified;

d) The following changes to the characteristics of the UP and its registration are subject to registration, upon request:
    a. The change in the production technology used in the UP, provided that the same producer and other characterizing elements are maintained, and the producer is the holder of the contract for the supply of electricity to the associated use facility;
    b. The change of installed capacity, provided that the conditions established in article 5 (Requirements for access to the registry the type of Production Unit) are met and the producer is the holder of the contract for the supply of electricity to the associated use facility, is also subject to endorsement, upon request;

13.2 Electric Vehicles

13.2.1 National Legislative Framework

In the year 2009, it was established a Program for Electric Mobility in Portugal (through the resolution of the Council of Ministers nº 20/2006, of February 20) which had the objective of introduction and subsequent massification of the Electric Vehicle. The resolution of the Council of Ministers nº 81/2009, of September 7, established the objectives of strategic principles and fundamentals of Electric Mobility Program, as well as the approval of the respective model and it stages of development, predicting to the pilot phase, an integrated grid for charging points of electric vehicles, consisting on 1350 charging points installed in municipalities.

Decree-Law nº 39/2010, of 26 April, as edited by Law nº 64-B / 2011, of December 30, and by Decree-Law 170/2012, of August 1, came to regulate the organization, the access and exercise of electric mobility activities and to establish the Electrical Mobility Grid Pilot.

During the pilot stage of the Mobility Program, it was seen that a reduced number of electric vehicles were introduced on the market, with the corresponding use of infrastructure less than planned, compared to the targets initially set by the Government. Nevertheless, the development of the pilot phase has so far allowed for the development and testing of technological solutions, as well as an innovative and reference mobility model based on user and in interoperability of the services. In this context, a critical analysis of this initiative has become essential. In this regard, the extension of the pilot phase of the Electric Mobility Program was determined with a view of revising the program, including the implementation of various studies and the intervention of a wide range of actors.

The review of the Electric Mobility Program included, among other aspects, the redefinition of target groups, new scenarios for the penetration of electric vehicles, the revision of aspects of the framework for the main activities of electric mobility, a reorganization of grid management functions and information systems, support services to market agents and users.

Thus, based on the conclusions of the studies carried out, in the existing electric mobility system and in the experience acquired by the various agents, it is necessary to improve the model of electric mobility adopted, in order to guarantee conditions of sustainability of the activity of electric mobility agents and stimulate the demand. It is also intended to encourage more effective integration with energy and mobility systems within the framework of a vision for smart mobility as well as to ensure the articulation of the strategy for electric mobility in a broader picture of the promotion of diversity and alternative fuels of the transport sector in Portugal, anticipating the main issues raised by the European Commission in the Clean Energy Package for Transport.

In addition, the review led to the definition of rules that facilitate the integration with the grid of electric mobility of points of loading in private spaces, namely domestic and condominiums. At the same time, this review promoted the competition in the activities of commercialization of electricity for electric mobility and operation of points of charge and expansion of the grid of electric mobility for the Autonomous Regions of the Azores and Madeira.

13.2.2 Current Legislation

The Decree-Law nº 90/2014, of June 11, establishes the legal regime of electric mobility, applicable to the organization, access and exercise of activities related to electric mobility, likewise the rules for the creation of a pilot electric mobility grid. This Decree-Law controls the organization, access and exercise of electric mobility activities, establishes an electric mobility grid and regulates incentives for the use of electric vehicles. It creates conditions to encourage the use of electric vehicles, in particular, by:

a) The adoption of rules encouraging the purchase of electric vehicles;
b) The adoption of rules permitting the existence of a national grid of charging points for batteries of electric vehicles;
c) From the adoption of rules that allow the user of electric vehicles to access any charging point integrated in the electric mobility grid, regardless of the operator holding the electricity commercialization register for the electrical mobility that he has contracted;
d) The obligation to provide the necessary infrastructure for the installation of private access charging points in new buildings;
e) The adoption of rules that allow the installation of private access charging points in existing buildings;
f) The adoption of rules allowing electric vehicle users the access to the electricity supply for electric mobility, given by the operator holding the electricity commercialization registry for electric mobility that he has contracted.

The term "electric motor vehicle" means a motorcycle, moped, tricycle or quadricycle with one or more main electric propulsion engines that transmit traction energy to the vehicle, including electric hybrid vehicles, in which the battery is charged by means of connection to the electric mobility grid or to an external source of electricity, and which are intended, for their function, to be carried on the public road without being subject to rails.

The conversion of vehicles with internal combustion engines into electric vehicles, on the following terms and conditions, shall be authorized, with the approval of the Institute for Mobility and Transport, I. P. (IMT, I.P.):

1) The processing shall ensure safety in the movement and electrical charge of the vehicle's batteries;
2) The loading unit must be compatible with the filling point supply systems;
3) The adaptation of the propulsion to the electric mode must ensure the correct functioning of all the other systems with which the vehicle was initially approved.

Electric vehicles must affix, for the purposes of traffic on public or equivalent roads, the identification number, which is the identification element at national level for the purposes of identification and usufruct of positive discrimination mechanisms of electric vehicles, namely for parking purposes.

It is incumbent upon the IMT, I. P., the issue of the couplet mentioned in the previous number.

The exercise of electric mobility activities is carried out in accordance with the principles of universal and equitable access of users to the service of repair of batteries of electric vehicles and other services integrated in the grid of electric mobility, ensuring, in particular:

a) Freedom of choice and contracting of one or more operators holding electricity commercialization registration for electric mobility;

b) Freedom of access, exclusively for the purpose of charging batteries of electric vehicles, to any point of loading of integrated public access in the electric mobility grid, regardless of the operator holding the electricity trading register for the electric mobility with which it has contracted and without obligation to conclude, for this purpose, any legal transaction with the owner or operator of the point of loading;

c) Existence of interoperability conditions between the electric mobility grid and the various brands and systems of charging electric vehicle batteries;

d) Existence of conditions for access to the grid of electric mobility and the charging of batteries of electric vehicles in private access spaces.

The main activities aimed at ensuring electric mobility include:

a) The commercialization of electricity for electric mobility;

b) The operation of charging points of the electric mobility grid;

c) The management of operations of the electric mobility grid.

The sale of electricity for electric mobility corresponds to the wholesale purchase and retail sale of electricity to supply electric vehicle users for the purpose of loading their batteries into the charging points integrated in the electric mobility grid.

The operation of charging points corresponds to the installation, availability, operation and maintenance of charging points of public or private access integrated into the electric mobility grid.

The management of operations of the electric mobility grid coincides with the management of the energy and financial flows associated to the operations of the mobility grid Management of the respective platform.

13.3 Loading Points

For the purpose of this document, loading points are the infrastructures or equipment exclusively dedicated to the charging of batteries of electric vehicles, which may be associated with other services related to electric mobility, excluding conventional electrical outlets.

Public charging points installed in a public domain location with access to a public or equivalent road, or in a private place that allows access by the general public, shall be publicly accessible.

Private access points are charging points installed in private access areas.

Private access charging points shall be used exclusively or shared, depending on whether they are intended to allow the charging of batteries of electric vehicles, respectively, by a single user at the point of loading or by more than one user.

The use of charging points and associated parking spaces may be subject, on an exclusive basis, to the charging of batteries of certain categories of electric vehicles, and motor vehicles, and operators shall comply with the provisions of the law applicable to loading public or private access points.

It is mandatory upon the member of the Government responsible for the energy area to establish, by means of an ordinance, the rules applicable to the installation and operation of loading points, especially in technical and safety matters, which must comply with the technical and functional requirements for smart meters in Ordinance 231/2013 of July 22 and the technical specifications defined in the scope of the European Union.

In order to encourage new mobility models, specific charging schemes and respective parking spaces for loading vehicles associated with these services may be defined through complementary legislation.

The activity of commercialization of electricity for electric mobility can be only exercised by accordingly licensed loading point operators.

In the exercise of its activity, the operator that registers the commercialization of electricity for electric mobility contracts the supply of electric energy with the users of vehicles that requires it and establishes with the load point operators the legal relations necessary to ensure access by the users to the loading points.

The electricity supply contracts referred to in the previous paragraph may not discriminate charging points, preventing or making excessively expensive the use of certain charging points, unreasonably favouring the use of the others.

The commercialization of electricity for electric mobility is subject to registration, whose implementation allows the exercise of the activity throughout the national territory.

The duties of the holder of registration of commercialization of electricity for electric mobility, to be exact, are:

a) Provide the service of commercialization of electric energy for the charging of batteries of electric vehicles to the users that require it;

b) To contract the supply of electricity with one or more electricity traders recognized under Decree-Law nº 172/2006, of August 23, or through organized markets;

c) Pay to the electricity merchants the amount due for the supply of contracted electricity;

d) Pay the remuneration due for the services provided by the other operators of loading points;

e) To pay the management entity of the electric mobility grid the remuneration due for the services rendered;

f) Inform the ERSE (Regulator of Energy Services), through the single electronic service desk, and the managing body of the electric mobility grid, about the energy volumes and prices practiced, at each moment, to its customers, by discriminating the values related to each of the services provided;

g) To allow access by the competent authorities, including ERSE, the Directorate-General for Energy and Geology (DGEG) and the managing body of the mobility grid;

h) To the information provided in the applicable legal and regulatory provisions;

i) To communicate to the managing body of the electric mobility grid the contractors of electricity contracted to obtain the electric power supply, maintaining this information is constantly updated;

j) Demonstrate, every five years, to the DGEG, through electronic communication, through the Company Portal, that the verification of the requirements for the attribution of the respective marketing license is maintained;

k) Respect the legal and regulatory provisions applicable to the exercise of its activity.

The rights of the holder of registration of commercialization of electricity for electric mobility are:

a) The exercise of the licensed activity, in accordance with the Decree-law 90/2014, June 11, and the legal and regulatory provisions applicable to the electricity traders;

b) The marketing of electricity for electric mobility using any point of loading managed by a properly licensed operator;

c) The remuneration for the provision of the electricity commercialization service for electric mobility;

13.3.1 Operating regime for loading points

The procedure of the operation of loading points depends on the granting of a license by the DGEG.

The entities that demonstrate that they meet the technical requirements, provided for in an ordinance of the member of the Government responsible for the area of energy, may carry out the activity of operation of loading points and that they demonstrate, in particular:

a) The existence of an organizational structure appropriate to the duties and duties applicable to loading-point operators;

b) The availability of human resources with the necessary qualifications, knowledge and technical capacity to carry out the duties assigned to it attributed;

c) The technical, technological and safety compatibility between loading points, computer systems and other equipment to be used in the of the operation activity of charging points, and the systems and equipment of the electric mobility grid.

The charging points operators should be autonomous entities for entities engaged in, directly the expected activity in the management operations of electric mobility grid.

13.3.2 Charging point operation license

The operating licenses of charging points of the electric mobility grid are nationwide and are allocated for a period of 10 years, extendable for the same period. The assignment or extension of license for the operation of charging points is instructed by electronic system and depends on the submission of an application through the services electronic single point.

The decision on the application for the attribution or extension of a charging points shall be issued, within 30 days from the date of application, by the DGEG, which shall determine the conditions under which it is assigned.

Once the period provided for in the preceding paragraph has expired without the license or its extension being refused, it is tacitly assigned, and the information relating to the general conditions of the activity is made available through the electronic service counter.

Whenever the member of the Government responsible for the area of energy considers that the commitments of expansion of the grid of electric mobility presented by the set of licensed operators are not sufficient to satisfy the needs of the sector at national level, it can adopt insolvency procedure to assign charging point operator license.

Whenever the member of the Government responsible for the area of energy considers that the charging points of the electric mobility grid installed by the set of licensed operators are not sufficient to meet the needs of the sector at national level, can adopt tender procedure for assignment of operator license of charging points.

13.3.3 Duties of the Charge Point Operators

The duties of the loading point operator include:

a) Allow the access of users of electric vehicles, regardless of the operator who registers electricity commercialization for mobility to the points of loading which they exploit for the exclusive purpose of charging the batteries of those vehicles;

b) To establish the legal relationships necessary to ensure access by users of electric vehicles to loading points by paying a fee due for such access;

c) To permanently make available to the managing body of the electric mobility grid, in a manner segregated by the operator holding the electricity commercialization register for the electric mobility, data on the electricity consumed at the respective points of loading, observing the procedures and establishing the communications necessary for this purpose;

d) To ensure the installation of at least one loading point and the continuity of the operation of the loading points, in conditions of effective security for people and goods and of adequate functioning of the components of measurement, communication and other elements that integrate the above-mentioned infrastructures;

e) Ensure at all times that the equipment, systems and communications of their loading points comply with the technical and safety regulations applicable in accordance with the Decree-Law 90/2014, June 11, and its complementary legislation, as well as those defined by the managing body of the electric mobility grid for the connection and operation of charging points within the electric mobility grid;

f) Integrate the systems and charging points that are explored in the electric mobility grid, by means of payment of compensation to the managing body of the electric mobility grid, and also empower it to promote, at its own expense and upon request, the carrying on of billing operations of the amounts due to entities that carry out activities related to the electric mobility or to receive of the users of electric vehicles;

g) Request the operator of the relevant distribution grid to connect the charging points that are operated by the grid to the electricity distribution grid relevant charges, in accordance with the rules applicable to grid connections;

h) Ensure, in accordance with applicable standards and good industrial practice, the updating, renewal and periodic adaptation of the components and charging point information systems in terms of ensuring constant interoperability between charging points, management systems, brands and charging systems for electric vehicle batteries;

i) Provide access to the competent entities, including the managing body of the mobility grid and electrical inspectors in accordance with the applicable legislation, the loading for the purpose of verifying the conditions technical and safety aspects of the components measurement, communication and other elements integrating the above-mentioned infrastructures;

j) Send to the DGEG, electronically, through the company portal, the certificates of periodic inspection related to the respective loading points;

k) To establish and maintain in force the insurance policies provided for in article 33 of the Decree-Law 90-72014, June 11;

l) Respect the legal and regulatory provisions applicable to the exercise of its activity.

m) Ensure support services for users of electric vehicles that use the charging points, through a specific support line;

n) To contract the electricity supply service with an electricity supplier recognized under the terms of Decree-Law nº 172/2006, of August 23;

o) Pay all amounts due for services associated with electric mobility that are contracted by you or on your behalf;

p) Allow the competent authorities, including ERSE, DGEG and the operator of the electric mobility grid, access to the information provided in the applicable legal and regulatory provisions;

q) To communicate to the managing body of the electric mobility grid the electricity traders contracted to obtain the electric power supply, keeping this information permanently updated;

r) Ensure the confidentiality of information transmitted to them by users of electric vehicles, except to the extent necessary to comply with applicable legal and regulatory provisions.

13.3.4 Information obligations of loading point operators

The loading point operators shall disclose in a clear, complete and appropriate manner, in particular by:

a) Point of loading, procedures and safety measures defined by the DGEG and the managing body of the electric mobility grid to be adopted by the users of electric vehicles to access electric mobility services.

b) Charge point operators shall make available to electric vehicle users appropriate information on prices and conditions access to charging points and, in case the operator is a holder of electricity trading register for electric mobility, must make available to its customers the contracted electricity tariffs and other services, as well as the other conditions of provision services.

c) Invoices to be presented by charging point operators, to operators holding electricity trading register for electric mobility and customers, shall contain disaggregated information, by type of service provided, including all the necessary elements to a clear, complete and adequate understanding of billed amounts.

d) The charging points shall provide, in a clear and visible manner and in advance of their actual use, information on the price of the services available for the charging of batteries of electric vehicles.

e) The operators of loading points must have a complaint book in accordance with Decree-Law nº 156/2005 of 15 September, as amended by Decree-Law nº 371/2007 of 6 November, ERSE receiving and handling the respective complaints.

13.3.5 Charge Point Operator Rights

The operator of loading points shall be entitled, namely:

a) The operation of loading points, in accordance with the applicable legal and regulatory provisions;

b) The remuneration due in consideration of the points of loading usage that they explore;

c) The remuneration for the provision of services complementary to the operation of loading points, which have been provided in accordance with applicable legal and regulatory provisions.

The loading point operator may affix or register commercial or non-commercial advertising messages at the loading points, without prejudice to compliance with other applicable legal and regulatory provisions on advertising.

13.3.6 Periodic inspections

The entities responsible for the approval of the electrical installations of loading points carry out periodic inspections of the loading points operated by each operator.

The inspection provided for in the preceding number shall comprise the examinations and tests required to verify the safety conditions of electrical installations.

The inspection provided for in section of Periodic Inspections shall ensure that the loading points to be inspected are selected at random and that each is inspected at least once every four years.

It is the responsibility of the DGEG, in coordination with the managing body of the electric mobility grid, to manage the inspections referred to in this section of Periodic Inspections.

13.3.7 Assignments of the managing body of the electric mobility grid

The managing body of the electric mobility grid has as its object the management of electric mobility operations, including the management of electric vehicle loading at points of loading operated by duly licensed operators.

The manager of the electric mobility grid shall be responsible for:

a) Monitoring the implementation of the growth phase of electric mobility in accordance with the guidelines defined by the Office for Electric Mobility in Portugal (GAMEP);

b) Establishing and developing the information and communication systems for the integration of the electric mobility grid and adapted to the respective characteristics and management needs, ensuring the operation of the charging points in conjunction with the charging point operators.

c) Managing data relating to energy and financial information of operators holding electricity trading registers for electric mobility, charging point operators, electricity distribution system operators and, where appropriate, other service providers, including the provision of measurement and reading services for the energy consumptions associated with the charging service of electric vehicle batteries at each point of loading;

d) Promoting, upon request and on behalf of each entity that develops main activities related to electric mobility, to carry out operations of billing the amounts due or to be received by each of those entities in virtue of the exercise of said activities;

e) Cooperating in the definition of the technical and safety procedures and standards applicable to the connection and operation of charging points within the electric mobility grid, in particular with respect to their equipment, systems and communications or other services or components or accessories;

f) Monitoring the operation of the electric mobility grid;

g) Ensuring activities to support the operation and management of the electric mobility grid in Portugal and in international projects;

h) Developing and make available to operators of charging points and operators of other mobility and energy services the systems and services appropriate to the management and development of their activity;

i) Cooperating in the development and introduction of charging solutions in private access spaces, which will choose to integrate into the electric mobility grid;

j) Promoting the integration of other charging systems, with the electric mobility grid;

k) Cooperating in scientific and technological research in electric mobility management systems and associated services, including their technological updating and the development of new functionalities, in accordance with the evolution of the international electric mobility markets;

l) Cooperating in the integration of the electric mobility grid with the national electric grid, and management of the electric power grid;

m) Cooperating with the competent entities in the definition of the technical specifications applicable to electrical mobility solutions and their elements or other integral or accessory components;

n) Carrying out tests, technological validation, certification and homologation of electric mobility solutions, namely charging equipment, authentication and communication systems between vehicles and infrastructure, and issue the respective certificates for integration in the electric mobility grid;

o) Monitoring the impact of electric mobility systems, including environmental, economic and energy systems, and all relevant data for this monitoring should be made available to competent authorities, in particular in the transport, energy, spatial planning and environmental sectors;

p) Monitoring the emission reductions of greenhouse gases of the electric mobility grid, producing an annual report on this matter;

q) Cooperating in the dissemination and internationalization of electric mobility solutions;

r) Assuring the management of operations of the grids of electric vehicle battery charging points in the Autonomous Regions of the Azores and Madeira, exercising in these geographical areas the other attributions provided for in this section of Assignments of the managing body of the electric mobility grid, with due adaptations;

s) Communicating to the electricity traders and to the operators of the relevant electricity distribution grids the establishment or closure of the connection of charging points integrated in the electric mobility grid, by means of access to electrical installations used for the supply of third entities, located in spaces Public access or, where applicable, private access;

t) Providing the necessary information for the preparation of municipal plans and programs for electric mobility, as well as other plans and programs for planning and spatial planning, mobility and transport;

u) Exercising any other powers conferred on it by the Decree-Law 90/2014, June 11, and its complementary legislation.

The managing body of the electric mobility grid shall, on an annual basis, report to the ERSE, through the electronic one-stop service, on the execution of the activities carried out by it in the scope of the management of electric mobility operations.

13.3.8 Loading points in public places

The charging points in a public place of public access are installed, made available, operated and maintained by operators of charging points licensed in accordance with section of Charging point operation license and are compulsorily connected to the electric mobility grid through the managing entity of the grid of Mobility.

Without detriment to Article 31 of the Decree-Law 90/2014, June 11, the installation of charging points in a public place of public access in the public domain shall be subject to the ownership of a license for the use of the public domain for the installation and operation of battery charging points of electric vehicles, which shall be granted for a period equivalent to the license of the respective loading point operator and shall cover at least the area necessary for the loading point to be placed and the area necessary for the parking of the vehicles during the respective loading point loading.

The terms of the licenses referred to in the preceding paragraph shall be regulated by joint ordinance of the members of the Government responsible for the areas of energy and spatial planning, with regard, in particular, to the rights and duties of the operators of loading points and conditions of access to the loading point area.

Existing concessionaires, sub-concessionaires or operators of service or fuelling areas with access to public roads or equivalent may request the alteration of the title to include, within their respective concessions or licenses, the installation, availability, operation and maintenance of loading points, as long as they are established as duly licensed operators and without prejudice to one or more of these activities may be borne by an operator duly licensed under the Decree-Law 90/2014, June 11.

For the purpose of the provisions of paragraph 2 of this section, parking spaces for laden vehicles must be properly signalized in accordance with Annex II of the Decree-Law 90/2014, June 11, which forms an integral part thereof, clearly indicating the municipalities and other competent national entities, as applicable, ensure the supervision of their undue occupation.

The provisions of this section shall also apply, in reverse, to loading points installed, made available, operated and maintained in public places for private use.

13.3.9 Loading points in a private public access location

Charging points located in private places intended for public access for users of electric vehicles are installed, made available, operated and maintained by a licensed operator in accordance with Article 15 of the Decree-Law 90/2014, June 11, and are compulsorily connected to the electric mobility grid through the grid managing entity of electric mobility.

13.3.10 Private access load points

The installation, provision, operation and maintenance of private access charging points, for exclusive or shared use, may be carried out by duly licensed operators or by the owners themselves, in any way, from the place of installation of the loading point.

The installation of points of loading provided for in the previous section (Loading points in a private public access location) shall be subject to the provisions of nº 2 of article 31 of the Decree-Law 90/2014, June 11.

In case the installation, availability, operation and maintenance of the charging points is carried out by the owners themselves, they may also choose to request the integration of these charging points into the electric mobility grid, in order to enjoy 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.

13.3.11 Loading points in new urban operations

The urban development operations of horizontally owned buildings or other buildings that have parking places for vehicles, must include an adequate electric infrastructure for the loading of electric vehicles, a concept that does not include points of loading or outlets, which meets the technical requirements and rules to be approved.

For buildings or other buildings subject to the provisions of the preceding section, an adequate power must be ensured for the loading of electric vehicles, and this power may not be less than the value to be defined by ordinance of the members of the Government responsible for the areas of local authorities, energy, infrastructure, transport and housing.

When buildings or other buildings covered by paragraph 1 of this section are intended for housing purposes, the infrastructure for charging electric vehicles may not be fully implemented before they are put into operation, but must be prepared to or a socket in each place of the car park.

The technical standards for electric vehicle charging installations provided for in the previous numbers shall be defined by the ordinance referred to in paragraph 2 of this section.

13.4 Cabinet for Electrical Mobility in Portugal

The Office for Electric Mobility in Portugal (GAMEP) has the nature of a working group that acts as a member of the Government responsible for the area of energy, being responsible for the preparation and implementation of the Program for Electric Mobility.

GAMEP is responsible for:

a) Coordinating the advocacy of the electric mobility grid, by promoting the articulation between the central administration and the municipalities and directing the appropriate guidelines to the various agents related to the electric mobility;

b) Promoting the electric mobility grid, namely through the implementation and definition of a proposal for a national strategy for electric mobility;

c) Organizing initiatives aimed at disseminating the organizational model and the development of the electric mobility grid, including at international level;

d) Promoting the involvement of the national industry in the development of battery charging and electric vehicle construction solutions;

e) Promoting the involvement of the scientific and technological system and its interaction with the national industry with a view to developing innovative solutions for the management of the electric mobility system, battery charging and the construction of electric vehicles;

f) Performing other functions necessary for the achievement of its mission, as well as the powers delegated to it.

GAMEP is composed of a team of three members, corresponding to two members headed by a coordinator, which are designated by order of the Member of the Government responsible for the area of energy.

It is the responsibility of the GAMEP coordinator:

a) To direct the GAMEP;

b) To represent the GAMEP institutionally;

c) To convene the participation of public and private entities in the activities developed by GAMEP;

d) To proceed to the technical, administrative and financial management of GAMEP;

e) To promote the evaluation of the actions developed by GAMEP;

f) To chair and coordinate the work of the advisory council;

g) To submit quarterly reports on the implementation of the GAMEP actions to the member of the Government responsible for energy.

GAMEP is supported by an advisory council, whose operation and composition are defined by order of the member of the Government responsible for the area of energy.

The advisory council consists of a maximum of 10 members, comprising a representative of the DGEG, the ERSE, the Directorate General of Territory, the IMT, IP, the National Association of Portuguese Municipalities, and representatives of various industry players, namely operators of charging points, operators holding electricity trading register for electric mobility, car manufacturers, electric vehicles, parking operators and consumer associations, with unpaid activity.

The logistical and administrative support of GAMEP is ensured through DGEG.

In Madeira Island, the references mentioned above, namely IMT, I.P and DGEG, are represented by DRET (Regional Direction of Economy and Transport).

Regarding to V2G (Vehicle to Grid) systems, there is no Law, in Portugal, for this theme. Due to the fact that, in Madeira Island, there are problems with the grid, such as problems with stability and quality of the grid, it is impossible to put into practice V2G systems.

In the case of mainland Portugal, in particular buildings, owing to security reasons, it is not allowed to install systems to EV in public areas of the building. However, in Madeira Island, it is allowed to install systems for EV users (with the proper knowledge and approval of the condominium owners).

There is a Technical Guide of Electrical Installations for the loading of Electric Vehicles, made by DGEG – Technical Commission of Electro technical standardization – CTE 64, that Madeira Island uses as a guide for EV installations.

This guide provides indications for the design and execution of electrical installations for the supply of EV, applying and interpreting RTIEBT (Technical Rules for Low-voltage of Electrical Installations, regarding electrical installations for the loading of Electric Vehicles.

The rules of the Guide are applied to low-voltage AC circuits intended to power the electrical outlets or charging points of new vehicles or existing installations. The rules do not apply for systems where the charge of the batteries is made through other means other than conduction of electric current, namely the induction charging systems.

This Technical Guide of Electrical Installations for the loading of Electric Vehicles includes a short introduction about the field of application of the same, definitions of terms used, how to feed the installations, information on protection against electric shocks, how equipment is selected and installed, as is the verification and maintenance of facilities, includes standard systems for electric vehicle charging facilities and an annex corresponding to section 722 of the RTIEBT (electric vehicle power supply).

13.5 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.

13.5.1 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).

13.5.2 Existing loading times

Charging times for EV in Mobi-e loading points are:

a) Normal charging station (3.7 kW): about 6-8 hours for 100% capacity;

b) “Semi-fast” charging station (22kW): 1 hour to 80% capacity;

c) Quick charging station: 30 * minutes for 80% capacity;

* The duration of LV charging depends on the characteristics of the on-board charger.

The values of the loading times presented are reference values of the station performance.

13.5.3 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, briefly in the main cities of the country.

13.5.4 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, in order to be able 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.

ANNEX I
SMILE Data Collection Forms – DSM Pilots (English)

SECTION A: Information to be collected or provided by the participants (either through surveys or in person interviews):

Demographic Information:

1. Could you please provide the following information?

Name		Contact	
Address		Education	
Education		Occupation	
Type of Installation	Domestic Commercial Off the grid	Installation number	

2. Could you please indicate which is your yearly income?

Less than 7091 €	
7091 – 20.261 €	
20.261 € - 40.522 €	
40.552 € - 80.640 €	
More than 80.640 €	

3. How many people live in your household?
4. Could you please indicate your average monthly costs with electricity?
5. Do you have an Internet connection in your property? **Yes** **No**
    a. If yes, could you please indicate which is your Internet service provider?

Motivations to purchase micro generation technologies:

1. How long have you been a micro producer?
2. Could you please indicate from the following list, in what way, this list of reasons led you to become an energy micro producer:

	Strongly disagree 1	2	3	4	Strongly agree 5
Save or earn money from lower fuel bills and government incentives					
Increase the value of my home					

Help improve the environment					
Protect against future higher energy costs					
Make the household more self-sufficient/less dependent on utility companies					
Protect the household against power cuts					
Use an innovative/high –tech system					
Improve the feeling or atmosphere within my home					
Show my environmental commitment to others					
Other motivations:					

Adapted from Balcombe, Rigby and Azapagic (2013)[14]

3. Did you receive any kind of financial support (money incentives from government for example) to install such equipment? **Yes** **No**

Installation Characteristics and technical information:

1. In terms of your contract with the local electricity company could you please indicate the following information:

Energy Tariff		Installed Power	
Production (power)		Contracted Power	
Installer		Installer's contact	

2. Did you have to purchase any kind of insurance related to the production system?
3. Is the production equipment installed certified? **Yes** **No**
    a. If so, could you please indicate which entities were involved?
4. Did you have to perform any modification to the system? If so who performed and can you describe what did you have to do?
5. Are you satisfied with this type of equipment? **Yes** **No**
6. Can you indicate advantages in using this type of installation?
7. Did you have any kind of problems? **Yes** **No**
    a. If so, can you describe which type of problems?

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[14] Balcombe, P., Rigby, D., & Azapagic, A. (2013). Motivations and barriers associated with adopting microgeneration energy technologies in the UK. *Renewable and Sustainable Energy Reviews*, *22*, 655-666.

8. Were you satisfied with how the problems were solved? **Yes** **No**
9. Who do you contact to fix any problems with the equipment? Did you fix it yourself or is there any kind of warranty attached to the equipment?
10. Would you like to improve the installation in some way? **Yes** **No**
    a. If so, can you give us an example of how you would do it?
11. Are you satisfied with the service being provided (independent from whom the service supplier is)?

SECTION B: Information to be collected by research team.

The research team will be taking pictures of the equipment setup at each participant's location in order to gather the most information as possible.

1. Characteristics of the PV modules:

Brand	
Rated power of each module	
Voltage of use of the module	
Module efficiency	
Area of each module [m2]	
Age of installation of the system	
Number of modules installed	
Number of modules files	
Installation diagram (set in series / parallel / both)	
Inclination of the modules	
Panel/modules Orientation	
Distance between panel and load	

2. Power meter specifications
3. Other technical data from the system:

Cables (size, diameter, Cable Material, Cable efficiency, Maximum current of use, Maximum operating voltage;	
Inverters (if any) (efficiency, number of inverters, maximum values of use (Power [W], Current [A]);	
Load Regulators (if any)	
Batteries (in case participants might have purchased some type of batteries)	

ANNEX II
SMILE Data Collection Forms – EV Pilots (English)

Demographic Information:

Information to be collected with both fleet operator drivers and full-fledged EV drivers.

1. Could you please provide the following information?

Name		Contact	
Address		Education	
Education		Occupation	
Brand of Electric vehicle		Brand of Charging Station	
Year you purchased the vehicle (if yours)			

2. How long have you been working here?
3. How long have you driving (all types of vehicles)?
4. How long have you been driving an electric vehicle?
5. If the vehicle is your own, did you receive any kind of incentives to purchase it?
6. Could you describe the reasons that led to buy an electric vehicle?

Technical Information (Vehicle characteristics):

1. Could you please describe your normal tasks within the company?
2. How do you get assigned a particular route?
3. Do you usually take the same routes throughout the week? Which ones are these?
4. Is there any route you find more energy demanding in terms of driving/handling the vehicle?
5. Do you see yourself looking at the car remaining battery and making calculations for the next route?
6. Do you track the number of routes you make per day? If not can you estimate?
7. Do you track the distance you have taken at the end of your shift?
8. Do you notice differences in terms of demand for this type of service during the week or weekends?
9. When you need to charge the vehicle what are the procedures? How often do you have to charge the vehicle? Do you notice any problems with the charging? If so do you recall what type of problem? Could you please briefly describe it?
10. In case you charge your vehicle other than at work, where do you charge it?
11. Have you had or noticed any problems with the cars?
12. Is there any other concern with the vehicles you might want to share (battery etc.)?

About the company:

Information to be collected in the pilot with fleet operator owners

1. How many electric vehicles do you currently have within your fleet?
2. What are the business working hours you currently operate?
3. How did you decide to have this kind of business using electric vehicles?
4. Did you receive any kind of incentives to purchase the cars?
5. Have you observed/had any problems with this type of car?
6. How do you usually fix or proceed in these cases?
7. Do drivers get any particular kind of training before they start operating these cars?
8. When planning the routes (touristic routes) did you have any concern about the car's characteristics to perform these?
9. Was there any testing period before?