Understanding the challenges behind Electric Vehicle usage by drivers - a case study in the Madeira Autonomous Region

Luísa Barros
ITI, LARSyS, M-ITI and University of Madeira
Funchal, Portugal
luisa.barros@m-iti.org

Mary Barreto
ITI, LARSyS, ARDITI and prsma.com
Funchal, Portugal
mary.barreto@prsma.com

Lucas Pereira
ITI, LARSyS, Técnico Lisboa and prsma.com
Funchal, Portugal
lucas.pereira@prsma.com

ABSTRACT

Electric Vehicles (EV) adoption targets have been set by governments from countries throughout Europe, related to the European goals, for the decarbonization of the road transport sector. The change for electric vehicle technology can be challenging to EV users for several reasons such as battery autonomy, time to charge the vehicle, and the different driving conditions. The work in this paper aims to study how users from Madeira and Porto Santo islands deal with the challenges of EV usage. Furthermore, this paper also studies the role of the orography in the Regenerative Braking System technology integrated into electric vehicles. To assess such information, an online questionnaire was prepared and sent out to the electric vehicle community of both islands. The main results of this study show drivers' preference to charge the vehicles at their household and that users are satisfied with the vehicle's technology. Also, users' battery range anxiety did not seem to have a significant impact. Moreover, from the drivers' point of view, there is still the need to study the role of orography, while using the regenerative braking system.

CCS CONCEPTS

• **General and reference** → *Evaluation*; • **Human-centered computing** → *User studies.*

KEYWORDS

Electric Vehicles, Driver, Charging Infrastructure, Regenerative Braking System, Orography, Islands

ACM Reference Format:

Luísa Barros, Mary Barreto, and Lucas Pereira. 2020. Understanding the challenges behind Electric Vehicle usage by drivers - a case study in the Madeira Autonomous Region. In *7th International Conference on ICT for Sustainability (ICT4S2020), June 21–26, 2020, Bristol, United Kingdom.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3401335.3401667

1 INTRODUCTION

It is undeniable that climate change has been recognised as the most serious and threatening global environmental problem. There is scientific agreement that humanity is contributing to climate change through the emission of greenhouse gases[1]. The decarbonisation, defined as the reduction of the greenhouse gas emissions to the atmosphere, is strongly dependent on the implementation of governmental incentives and policies in different sectors[2][3][20].

Electric Vehicles (EVs) are considered to be one of the greatest options for the decarbonisation of the road transportation sector by increasing the introduction of Renewable Energy Sources (RES) into the sector [5]. RES are known for being vulnerable in terms of the uncertainty of weather conditions, inherently intermittent and non-dispatchable [1]. Hence, it is predictable to schedule charging EV batteries when RES are available.

Electric Vehicles are slowly gaining traction in Madeira Autonomous Region (RAM), which includes Madeira and Porto Santo Portuguese islands (254 368[4] total inhabitants). According to Madeira Regional Executive of Economy and Transports (DRET) representative, 268 EVs were registered until the end of 2018[5]. Madeira and Porto Santo Islands have specific conditions regarding electrical grid and EV usability, meaning that, since being an isolated electrical grid (with no connection to the mainland), internal power resources and consumption management of power quality is harder to control [25]. Moreover, the accentuated orography of Madeira island and the exemption from payment to charge EVs at public charging stations, at both islands, there are specific issues that might contribute to different results stated by related work regarding EV drivers.

The aim of this study is to gain knowledge about the demographic characteristics of current EV owners in RAM as well as to gather information related to this sample population. The information collected refers to the main charging infrastructure used among drivers and, the EV owners' perceptions concerning the Regenerative Braking System (RBS). Additionally, it is also investigated if the orography of the roads influences drivers' attitudes towards battery range satisfaction, thus providing additional feedback regarding this specific EV technology.

This paper is organized as follows: background and related work are presented in Section 2. The research objectives and research questions of the present study are given in Section 3. In Section 4, the study methods used are presented. The results of demographics, research questions, and other collected data are presented in section

[1]https://ec.europa.eu/clima/change/causes_en
[2]https://ec.europa.eu/clima/policies/strategies/2020_en
[3]https://ec.europa.eu/clima/policies/transport/vehicles/cars_en
[4]https://estatistica.madeira.gov.pt/download-now-3/social-gb/popcondsoc-gb/demografia-gb/demografia-emfoco-gb/finish/310-demografia-em-foco/10057-em-foco-2017.html
[5]https://www.madeira.gov.pt/dret/

ICT4S2020, June 21–26, 2020, Bristol, United Kingdom

ACM ISBN 978-1-4503-7595-5/20/06…$15.00
https://doi.org/10.1145/3401335.3401667

5. Section 6 discusses the results obtained. Section 7 presents the limitations and future work of this study and, in Section 8 Conclusions of the research are given. As supplementary material, the Annex section is presented at the end of the manuscript.

2 BACKGROUND AND RELATED WORK

Nowadays, the availability of EV Charging Stations (CS) has been increasing due to the growing demand for EVs. Nevertheless, occasionally, it is not enough for EV charging requests as some CS have their own limitations (only normal or fast charging type, for instance) or even difficulties in having CS available [7]. A major concern for EV technology potential buyers' is the charging time of EV batteries, compared to Conventional Vehicles (CV) with internal combustion, such as diesel or gasoline. Normal EV charging time can be done between 2-6 hours, while EV fast-charging among 0,4-1hour or 0,2-0,5hour [14]. There are different approaches when it comes to modelling the charge/discharge EV batteries load management. EV batteries can be influenced by several factors such as climate and battery conditions (e.g. battery State Of Health, temperature) [35], seasonality [6], integration of RES [13][21], household charging incentives in order to reduce the cost of EV charging's [9][31][22], availability of public CS [26] [14], and others. Usually, this battery management, not only tends to decrease the time available for EVs to charge but also may increase the time of EVs charging. Furthermore, the mentioned approaches may not likely be implemented in particular cases, as there might be circumstances where EV user's liking may overlap the overall options to model the EV battery load [26].

The research about charging EV from the users' perspective can be divided into two main thematic extents [27]: A) charging behaviour in terms of dealing with the EV range (total range per charge) and battery technology from a psychological point of view; B) users' demand on charging infrastructure along with the decision processes for the selection of charging stations.

2.1 Users' charging behaviour in terms of dealing with the EV range and battery technology from a psychological point of view

Authors from [27] studied users' behaviour from two different samples, EV and CV users, underlining that the fear of running out power/fuel between samples is similar. Besides referring to differences between both technologies, authors did not focus on EV sample behaviour about time to charge EVs and, on the concern from fewer resources in terms of the number of CS for EVs. CS are the main anxieties about EV technology that cannot be compared with the advanced technology of CVs. At [10][34][11] it is stated that EV drivers have to face different type of driving conditions compared to CVs. EVs have an RBS, which converts kinetic energy into electric energy during deceleration manoeuvres. With RBS, during the deceleration manoeuvres of the vehicle, when the driver does not use both pedals (acceleration and braking pedal), the battery recharges. A sample was tested by [34] in order to investigate drivers' aggressiveness on a track test. Results evidenced that the most efficient driver recovered 93% from the RBS, while the most aggressive driver only achieved 15% of regenerative energy capture efficiency. Another study from [11] considered a specific and closed track with two between-subject groups of drivers. One group had previous knowledge in when to use RBS mode where the second group did not receive information about the upcoming RBS mode. In general, both subjects kept control and were able to drive with RBS. The drawback of [11] study was the extremely simple and oval-shaped track, absent of any traffic lights, other cars and did not contain any difference in the orography (different altitudes) during the test course. Additionally, besides the existing difference in the RBS between EVs, in [10] authors discussed that some participants expressed the wish to modify or switch off the RBS as those participants took longer to adapt, which corroborates the findings of [11] highlighting the need to provide more information about functionalities and potentiality of RBS. At EVs, the only way of not using the RBS is by using the Neutral mode. In this mode, the electric motor is not engaged with the wheels, which is not considered a good practice while driving. Using other possible driving modes apart from Neutral mode, the RBS is required during vehicle commutes. In [10] the vehicle used in the field was a CV that was converted to an EV. An RBS was implemented in the accelerator pedal of the CV. It was not mentioned in this study if Neutral mode was an option or not for users from this test experience. Additionally, despite the fact that the experience of driving an EV is different from a CV, the conversion introduced in this study may have led users not to appreciate the driving experience. All changes that differ a CV from an EV may have not been implemented and contributed to some users of this sample to express the wish to modify or switch the RBS back off. Several studies [11][8][23][15] pointed out that practical experience with EVs can change user's perception and experience of limited range. Authors from [16] and [17] claimed that the expertise plays a key role in exploiting the potential vehicle range, arguing that as the experience with EVs increases, the range anxiety decreases, increasing the users' range satisfaction. Likewise, authors from [34] stated that RBS serves as an energy-saving system and increases the range of the EV. As there is a disagreement between scientists concerning users dealing with the EV range and battery technology when driving with RBS, it is imperative to continue analysing these issues and the RBS technology among users. Furthermore, to the best of the author's knowledge, no formal study was conducted in the field to study the user's point of view about the effect of the orography, while using the RBS in the EV battery technology.

2.2 Users' demand on charging infrastructure along with the decision processes for the selection of Charging Stations

A way to model charge/discharge EV batteries was used by authors from [36] by having Battery Swapping Stations (BSS). BSS are useful when there is no availability by public CS and/or it is not possible to charge EVs in a domestic environment. However, from the point of view of charging behaviour, in terms of dealing with range and users' psychological perspective about battery technology, the BSS solution, does not make such a difference. With the BSS solution, EV users do not need to worry about the charging time of the battery as it is managed by the BSS. EV users have to notice whether they need to swap the battery in order to BSS fully-recharge a battery from the stock, which BSS might not have available. Additionally, the cost of using BSS is much higher than other charging points (household or public CS), as these have further operational costs. Operational costs are, for instance, costs related to the stock of batteries and, costs from using slow-chargers to recharge the swapped batteries in order to minimize the charging damages to the batteries. This implies a decision from the user to select the place to charge the EV.

During respective studies [26][19][33][32], authors found that EV users prefer to carry out the majority of their EV charging at home. EV users' favouritism for charging at households is justified with diverse reasons. Essentially, the seldom availability of public CS [33], the alignment the EV consumption with electricity production from the household [32], the costs associated with using public CS preferring low cost EV charging [19], and ultimately, their own comfort and convenience [26]. Despite the well-founded evidence, there is still an issue, which needs to be investigated with the specific case of Madeira and Porto Santo Islands. As there is no financial requirement to charge EVs at public CS (at least, until the end of this study), it needs to be understood if the payment exemption would refute other investigations. Likewise, there is the requirement to analyse if the accentuated orography of Madeira Island does make a difference in users' driving conditions compared to the population of Porto Santo Island (where there is a more flat type of road). Additionally, we want to find out if RBS serves as an energy-saving system and if it increases users' perception of EV battery range.

3 RESEARCH OBJECTIVES

This study will address two research foci, based on the aforementioned related work and the existing knowledge gaps:

- *Research Question 1 (RQ1)*: Does the economic factor influence the location where users charge their EVs or is the commodity of charging in the household still predominant in RAM as found by the Literature Review?
  Hypothesis 1 (H1): The Literature Review reveals that EV users prefer to charge their EVs at their households. However, with the specific case of RAM, users do not pay to charge their vehicles at Public CS. Thus, in this part of the case study, users may prefer to charge their vehicles at a Public CS.
- *Research Question 2 (RQ2)*: Does the orography of Madeira Island influence users charging behaviour in terms of dealing with EV range and battery technology?
  Hypothesis 2 (H2): There is no consensual agreement among EV users about the potentiality of EV technology, more concretely the usage of the RBS. Hence, it will be studied users' opinion about RBS and, if the orography influences users' behaviour about battery autonomy.

The contribution of the current study is from great importance as, it was never studied whether orography may influence user's perception about EV battery technology, mainly the usage of RBS within the accentuated difference in terms of road altitudes. Furthermore, there is the need to underline if EV users still prefer to charge their vehicles at the household as mentioned by [24], as it states that EV user's select to charge at their household due to the costs associated with using public CS preferring low-cost EV charging. In the case of RAM, the low-cost infrastructures to charge the EVs are the Public CS (free of charge).

4 METHODS

The following section describes the methods used to investigate EV users' point of view of charging EVs in Madeira and Porto Santo islands. Specifically, the user's main infrastructure to charge their vehicles, user's perception and feedback about potentialities of the RBS and, the role of the orography within the RBS.

4.1 Sample

An online questionnaire was developed and sent to potential participants. The link of the questionnaire was disclosed on different social media platforms (i.e. *Facebook* group page of EVs enthusiasts from Madeira Island, *WhatsApp* conversation group of EV users from Madeira). The sample was selected using a Snowball Sampling Method[12]. Moreover, participation was anonymous and no compensation was given to participants. The data collection was carried out from November 24th of 2019 until December 12th of 2019 (20 days).

4.2 Experimental procedure

The online questionnaire was provided in Portuguese, with open- and closed-ended questions. The procedure of the online questionnaire was divided into 10 sections (S). For additional details about each section of the experimental procedure, please refer to Appendix 1 at the end of this manuscript.

- *S0 – Consent form* – General information about the study and presentation of a consent form;
- *S1. Demographic data* - A general section with demographic questions;
- *S2. User's preference infrastructure to charge the EV* – Here it was requested to indicate the location that participants utmost charge their EVs;
- *S3. Feedback about the RBS and influence of orography* – This section is to study users' feedback about the RBS and the effect of orography;
- *S4. Users' opinion about EV technology* – Participants indicated battery range satisfaction and their feedback about EV technology;
- *S5. Reasons to charge at a particular infrastructure* – This section was to collect possible reasons why participants choose a particular infrastructure to charge their vehicle.
- *S6. Opinion about public charging stations* – This section was created to test users feelings' about public CS;
- *S7. Information about users' vehicle* – Here it was asked technical information about users' EVs;
- *S8. Driving an EV* - Participants gave their opinion about driving an EV.
- *S9. Consent for the researcher to use participants' data for further research without additional consent* – it was requested for participants to give consent to use their data for further research without additional consent.

The online questionnaire contained some questions with open-ended answers (e.g. type of incentive when they purchased the EV) although the majority of the questions consisted of multiple-choice and Likert-scale.

4.3 Analysis

In terms of data quality checking, answers with inconsistent responses regarding the target sample were excluded from the analysis. Responses with incomplete data on user characteristics and incomplete answers to thematic questions were included in the analysis to evaluate the most users as possible. Non-parametric tests were used due to the sample not following a normal distribution. The level of significance was set to a=0,05 and a two-tailed test was used. Since the data of the questionnaire are ordinal and three groups (Household, Work and Public) are being compared, the Kruskal-Wallis test was used to answer Research Question nº1 (main infrastructure users' charge the EVs). Additionally, to study the reasons why users prefer to charge on a specific infrastructure, it was examined whether there is an association between two categorical variables. In this case, the profile type of user (*Location* variable – where users mainly charge their EV) and each dependent variable. The dependent variables, in this case, are a group of 4 Linear-scale questions (variable names: *Faster*, *Cheapest*, *Comfortable* and *Public SOS*). A Pairwise comparison between each profile group of users was also made when a significant effect was found in the Kruskal-Wallis test. Spearmans' correlations were used to measure effect sizes for variables comparison.

To analyse the data for RQ2 (the effect of orography), it was necessary to take into account that, two sample groups were going to be analysed in this study: Madeira and Porto Santo island groups. The Mann-Whitney test was used to analyse the data to answer Research Question nº2.

5 RESULTS

5.1 Demographics

A total of N=42 data records were obtained from online interviews. However, one had to be excluded from the data records for the statistical analysis owing to the fact that, it was filled in by a Plug-In Hybrid Electric Vehicle user (Vehicle that has a combination of internal combustion and electric battery technology). It was decided to remove this participant, as one of the main goals of this study was to investigate users' satisfaction regarding the battery technology, battery autonomy and range anxiety from using a Vehicle 100% dependent on a battery. As of this, a total of N=41 data records were included in the analysis. It is important to notice that the N=41 total of responses of the online questionnaire, on a total of 268 EVs registered in RAM (Madeira and Porto Santo) corresponds to approximately a variation ratio of 15% of EV RAM population.

There was a significant difference in size from the two samples. Only 9,8% (n=4) of the users are from Porto Santo island, and 90,2% (n=37) of users are from Madeira island. Regarding this issue, in this demographics section, the samples of Madeira and Porto Santo were studied as one. 21,95% (n=9) of the participants were female and 78,05% male (n=32). The average age was 42,58 (SD=6,85), which is slightly below the average age of the Portuguese population of 44,8 years [29]. The youngest participant was 33 and the oldest 60 years old. The sample was rather educated, where 75,6% had a university degree, 19,5% had the mandatory school diploma and 4,9% of the sample did not finish the mandatory national education. The percentage of the Portuguese population with a university degree is 18,7%[28]. 9,8% (n=4) of the participants indicated household annual net income below 7000€ interval, 14,6% (n=6) indicated an annual net income between 7001€ and 20000€, 53,6% (n=22) mentioned that their annual net income was higher than 20001€ and, 22% (n=9) preferred not to provide this information. With this, the annual income of participants is slightly higher than the average household net income in Portugal of 11063€[30].

5.2 RQ1 - Main infrastructure users charge their EVs

5.2.1 User's preference infrastructure to charge the EV (S2).

Locations where users charge their vehicle. From the total N=41 data records from the analysis of the entire sample of the study (RAM users), 36,59% (n=15) of users stated that they charge their vehicles both at their Household and at Public CS, 24,39% (n=10) of users mentioned charging their vehicles only at their household, 9,76% (n=4) charge at public CS or at their household, 9,76% (n=4) only charge at public CS, 9,76%(n=4) charge in all existent infrastructures (household, work, and public CS), 4,88% (n=2) charge their EV at work and 4,88% (n=2) charge at work and at public CS. See Figure 1 for these results.

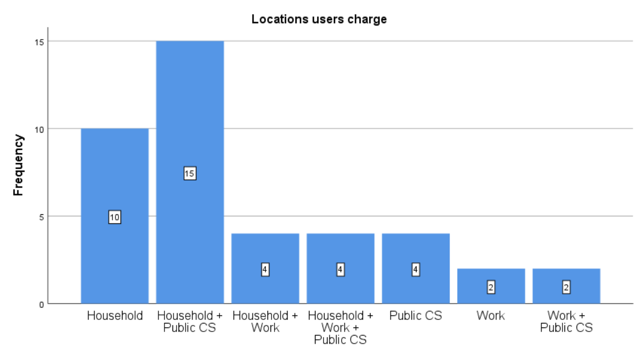

Figure 1: Location where users charge their vehicle

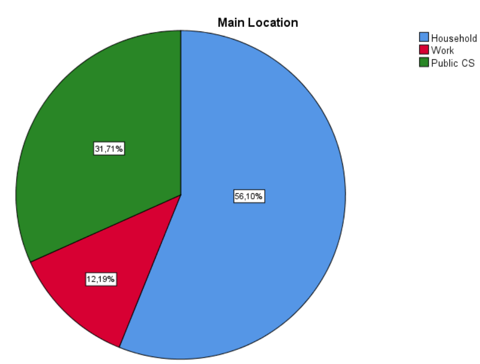

Figure 2: Main location users charge their vehicle

Main location to charge EVs. Regarding the main location where user's charge their EV, responses revealed that 56,10% (n=23) mainly charge at their household, 31,71%(n=13) charge at public CS and 12,19% (n=5) charge at work, see Figure 2.

5.2.2 Reasons for charging at a particular infrastructure (S5). Table 1 presents Median values and respective Interquartile Range (IQR) values (in brackets) for the sample. It can be observed from Table 1 that *Faster*, *Cheapest* and *Public SOS* variables had a pairwise with *Household* group and *Public CS* group from *Location* variable.

Table 1: Median (IQR) values for variables of Research Question 1. *pairwise comparison

	EV charger infrastructure Locations		
Variable name	*Household*	*Work*	*Public CS*
Faster	2 (1)*	2 (2)	4 (2)*
Cheapest	4 (2)*	4 (0)	4 (1)*
Comfortable	1 (0)	2 (1)	1 (1)
Public SOS	2 (2)*	4 (1)	5 (1)*

*Independent variable is related to dependent variable.

Results from the correlation test between dependent variables (*Faster*, *Cheapest*, *Comfortable and Public SOS* variables) and the independent variable (groups of users separated by EV charging infrastructure location (*Household*, *Work* or *Public CS*)), are presented in Table 2. From Table 2 it can be observed that significant correlations between *Faster* and *Cheapest* variables and, *Faster* and *Public SOS* variables were obtained. The locations users chose to charge the EV are the ones that offer slower and expensive way of charging. The faster charging options are also the ones that are located at public CS.

Table 2: Spearman's correlation (coefficient) results between dependent variables

	Faster	Cheapest	Comfortable	Public SOS
Faster	1	0,638**	-0,12	0,341*
Cheapest	0,638**	1	0,015	0,237
Comfortable	-0,12	0,015	1	0,116
Public SOS	0,341*	0,237	0,116	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

From Table 1 it can also be inferred that users that mentioned to charge at their household and public charging stations have pairwise correlation with the costs associated with charging the EV.

From Table 2 it can be observed that significant correlations were obtained between *Faster* and *Public SOS* variables, which means that users only use the public CS in SOS cases. I.e., when they need fast charging.

5.3 RQ2 - The effect of orography

5.3.1 Users' opinion about EV technology (S4). Figure 3 shows the entire population sample from RAM. 48,78% (n=20) are satisfied with battery autonomy, 34,15% (n=14) are unsatisfied, while 17,07% (n=7) do not have an opinion about their EV battery autonomy. There is no significant difference (U = 50,5; p = 0,80) between the Madeira island group compared to the Porto Santo Island group, to what concerns the users' opinion about EV battery autonomy. The effect size of this study was small, r= 0,17, p = 0,80.

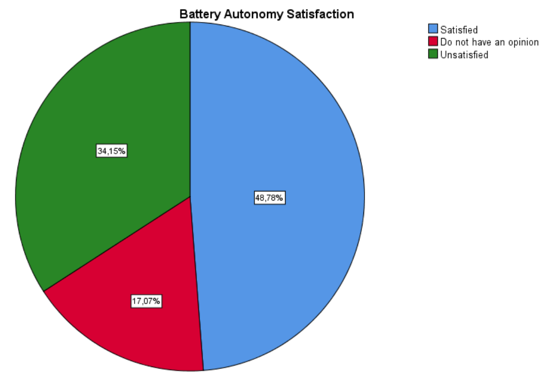

Figure 3: Battery autonomy satisfaction

5.3.2 Feedback about the RBS and influence of orography (S3).

Orography. Concerning the question about whether the orography undermines the way that users' drive the EV, for a n1=37 (Madeira inhabitants) and n2=4 (Porto Santo sample) the test showed that there was no significant difference (U=77; p=0,80) between the Madeira island group compared to Porto Santo Island group. The effect size of this study was not significant, r= 0,022, p=0,80. Besides this part of the study has to be studied in separate groups, Figure 4 shows the answers from the entire population sample from RAM, where 1- orography positively affects their driving, 5- orography negatively affects their driving.

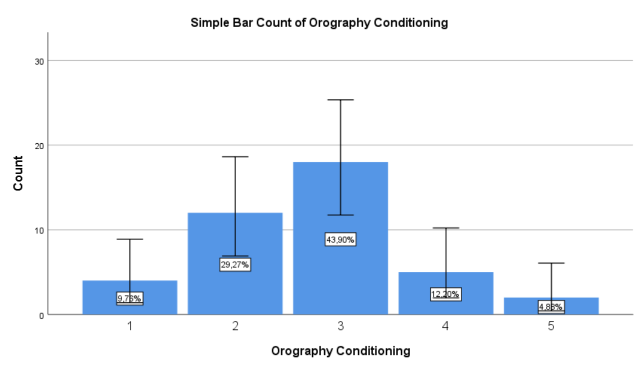

Figure 4: Orography conditioning users' perspective

Madeira VS Porto Santo RBS. Regarding the question where users think that EV has better regeneration profitability (at Madeira, at Porto Santo island or do not know), 80,49% (n=33) of users answered that in Madeira EV batteries regenerates greater in the (accentuated) orography of Madeira, whereas 19,51% (n=8) mentioned that it is in Porto Santo Island (flat island) that the RBS has greater performance. Observing this question from the perspective of each group of users (Madeira group and Porto Santo group), within Madeira group, 83,78% (n=31) of users mentioned that battery regeneration is more significant in Madeira, while 16,22% (n=6) stated that it is in Porto Santo island where there is more significant battery regeneration.

Percentage of battery regeneration. Within Madeira group, 43,24% (n=16) point out that their EV regenerates between 1%-10% on a daily base commute, 27,03% (n=10) mentioned a range regeneration between 11%-20% and, 29,75% (n=11) mentioned that the EV battery regenerates more than 21%. 75% (n=3) of Porto Santo group mentioned that, on average, the daily battery regeneration is between 11%-20% and, 25% (n=1) regenerates between 1%-10%.

Strategies to maximize battery lifetime. 60,98% (n=25) of users mentioned they use strategies to maximize battery autonomy while 39,02% (n=16) do not use any strategy. For the ones that use strategies of maximization of the battery, from an open-ended question, users mentioned: use of regenerative braking before stopping at traffic lights; avoiding high start-up accelerations; choosing less-traffic paths to avoid permanent braking; avoiding unnecessary use of HVAC; never let the battery go below 20%-30%; ECO mode usage and, speed control.

ECO mode is never used by 12,19% (n=5) of the users, 24,39% (n=10) always uses ECO mode and 63,42% (n=26) uses ECO mode in specific cases such as when there is a low percentage of battery, when they need to do long journeys or when they do not know the exact course that they will do with the EV.

Anxiety related to battery range. Users' anxiety on the subject of a low battery autonomy was expressed while answering one question. 26,83% (n=11) expressed they never had been anxious in a case of a low battery of the vehicle, 29,27% (n=12) felt anxious just once, 41,46% (n=17) stroke anxiety few times while 2,44% (n=1) mentioned feeling anxious oftentimes.

5.4 Users' current experience with their EV

5.4.1 Opinion about public charging stations (S6). Out of N=40 of a total sample of users (one user did not answer the question), 40% (n=16) of users do not agree or disagree about the availability of public CS, 32,5% (n=13) agrees that public CS are available and, 27,5% (n=11) disagrees that public CS are available. Users evaluate the location of public CS with 10% (n=4) of the sample expressing public CS are very well located, 45% (n=18) are placed in a good location, 35% (n=14) mentioned that are neither well located nor in a bad location and, 10% (n=4) says that are not well located. The quantity of public CS are mentioned by 30% (n=12) of users that there are very few of public CS, 27,50% (n=11) only a few public CS, 27,50% (n=11) neither few or many public CS and, 15% (n=6) express that there are many public CS.

5.4.2 Information about users' vehicle (S7).

EV Brand. Regarding the brand of the vehicles, two brand models of EV appeared with more frequency. 35,59% (n=15) of sample users have a Nissan Leaf model, 34,15% (n=14) a Renault ZOE, 9,76% (n=4) BMW i3, 4,9% (n=2) a Volkswagen e-golf and, 2,4% (n=1) was the percentage of models Citroen C zero, Hyundai KAUAI, Jaguar iPace, Kia Soul EV, Renault Kangoo Z.E., and Smart for Four Electric.

Users experience using EV technology. Most of the respondents were also new to the technology, where 41,46% (n=17) of the EV users had their EV for a period less than a year (year of purchase = 2019), 26,83% has used them since 2018, 19,51% (n=8) purchased the EV in 2017, 7,32% (n=3) in 2016, 2,44% (n=1) since 2013 and, 2,44% (n=1) has the vehicle since 2012.

First hand purchase. Additionally, 63,41% (n=26) of users bought the EV brand new, while 36,59% (n=15) mentioned second hand purchase. 48,78% (n=20) claimed they received an incentive to purchase the vehicle, while 51,22% (n=21) did not have access to purchase incentives.

Type of incentive. Users mentioned support from the Portugal governmental fund, support from RAM governmental fund or the EV brand incentive.

Private car parking. Private car parking is an issue for 19,51% (n=8) of users who mentioned not having access to car parking at their household, and thus not having the possibility to charge the vehicle at their household, while 80,49% (n=33) had car parking at their household.

Changes to their household electrical installation. About one-third of the sample 73,17% (n=30) did not have to make changes to their household installation to be able to charge the vehicle there, whereas 26,83% (n=11) said they had to make changes to charge the EV. Responses from the open-answer of what type of change(s) users had to make to charge the EV were: Increase the peak power contract (In Portugal, domestic consumers are subject to a maximum Peak Power Contract (PPC), which is selected by the consumer, based on their estimated peak power consumption [18]); build an electrical installation from their apartment upper floor electrical panel to the garage; placement of an electric plug near the parking space; place a box on the street for the outer wall of the house; outward electric extension and; electric meter placement for the EV.

Type of charger. Moreover, regarding the type of charger, 4,88% (n=2) of users did not know the type of charger they have, 58,54% (n=24) used only an electrical outlet (slowest and less power household charger) to charge the EV, 17,0% (n=7) had only a Wallbox (faster and more power household charger) to charge the EV and 2,44% (n=1) had a Flexi charger (medium household power charger), the remaining sample 17,07% (n=7) has more than one type of charger.

5.4.3 Driving an EV (S8). What concerns the EV driving experience before acquiring the vehicle, 7,32% (n=3) of users claimed they had never driven an EV before the purchase, 46,64% (n=19) only drove it once and, 46,34% (n=5) drove more than once. Regarding the comparison between driving an EV and a CV, 85,36% (n=35) claimed that it is better to drive an EV, 12,20% (n=5) did not express the difference between EV and CV, 2,44% (n=1) mentioned that is worse to drive an EV. Furthermore, 78,05% (n=32) had another vehicle, while 21,95% (n=9) state that the EV is the only family vehicle.

6 DISCUSSION

6.1 RQ1 - Main infrastructure users charge the EVs

Literature Review revealed that EV users prefer to charge their vehicles at their household [26][19][33][32]. However, with the specific case of Madeira Autonomous Region (Madeira and Porto Santo Islands), users do not pay to charge their vehicles at public charging stations. Results showed that more than half of the sample (56,10%) of users preferred to charge their vehicles at their household, 31,7% mainly charged at public charging stations and, 12,2% mentioned their workplace. This means that the results were not what was expected and, in fact, these were similar to [26][19][33][32]. From the sample target of this study that does not pay to charge the EV at public CS, one cannot claim that the reason to choose to charge the EV at household is that users prefer low-cost EV charging, as mentioned by [19]. In the case of [19], users prefer to charge at the households as it is the low-cost option.

From Table 1, *Faster* variable with *Location* variable results seem to suggest, users that prefer to charge their EVs at public CS, mentioned they preferred to charge their EV where it is faster to charge. The faster chargers are the ones from the public CS and the slowest are the ones at the households. From Table 1 it can also be inferred that users that mentioned to charge at their household and public charging stations have pairwise correlation with the costs associated with charging the EV. The household group does not mind to pay to charge the EV, while users that mainly charge at public CS prefer not to pay to charge the EV. Still in Table 1, *Public SOS* has also the same pattern of previous variables. The household group agrees that public CS are only meant to be used as SOS resource while, public CS group charge when they want.

Significant correlations between (*Faster*, *Cheapest*, *Comfortable* and *Public SOS*) variables that were thought to be reasons for users to charge on a specific charging infrastructure location were obtained (see Table 2).

Positive correlations were observed between the *Faster* and *Cheapest* and, *Faster* and *Public SOS* variables. Thus, it can be inferred that users take into account two factors when deciding where to charge: 1) the time to charge the vehicle related to the economic factor (observing the results from *Faster* and *Cheapest* variables); 2) the time to charge related to the type of infrastructure (observing the results of the *Faster* and *Public SOS* variables.

6.2 RQ2 - The effect of orography

The results obtained from tests to *Battery autonomy Satisfaction* and *Orography Conditioning* variables between Madeira and Porto Santo Islands were not significant to analyse the data obtained. A possible explanation is the fact that a balanced scale with five items was used, thus preventing a lack of balance in the response. Perhaps, a four-item scale would be a better choice since it would force users to respond positively or negatively. Nevertheless, further information from other data acquired from the online questionnaire can be discussed:

Percentage of battery regeneration. From the results, nearly 40% of users estimate that their battery regenerates between 1%-10% on a daily average commute, while 60% of users mentioned more than 11% of battery regeneration. Thus, it can be inferred that users are aware of battery regeneration mechanisms and how it affects the battery range they have available while driving. This suggests that these users learned about this technology and know how to handle it. This is a positive point for the adoption of EV technology since it demonstrates users can easily learn and use it overtime very quickly, considering the majority of the drivers just purchased their EV a year ago.

Strategies to maximize battery lifetime. In addition, more than 60% of users are careful to use strategies to maximize the lifetime of the EV battery and, a considerable number of strategies were defined by users. Strategies that use the RBS were mentioned by users (e.g. usage of regenerative braking before stopping at traffic lights, ECO mode). ECO mode is extremely used by users (only 12% of users never use this mode). This can be a result of the potentiality of EV technology, namely the RBS in the way that users can use different behaviours to maximize the battery lifetime. With this, it can be inferred that EV technology can be versatile in the way that a considerable amount of strategies can be used in order to maximize battery duration.

Anxiety related to battery range. Approximately 55% of users never felt anxious or just felt once regarding EV battery range. This is even considered a positive result for this type of technology as, users need some time to get acquainted with new technology and, this result means that for more than 50% of users, they only have small issues in embracing EV technology. Furthermore, 70% of the sample supported that it is much better to drive an EV compared to driving a CV, highlighting the EV technology preference.

6.3 Users' current experience with their EV

Users' experience using EV technology. 41,46% of the sample bought their Vehicles in 2019, which mean that a significant number of participants from the expected sample of at least 286 EV owners did not answer the questionnaire/participate in the study. Additionally, this shows that a considerable part of the sample are users who started to use EV technology very recently.

Incentives during EV purchase. Almost half of the users (48,78%) benefited from an incentive during the EV purchase. However, due to the percentage of users that purchase the vehicle in second hand (36,59%), it might contribute to lower the percentage of users that received an incentive. It is stated by [33] that incentives have been divided into monetary parameters and non-monetary parameters. In this study, users only mentioned monetary parameters to describe the incentive, which it is believed that other incentives were not mentioned.

Changes to the household electrical installation. In Portugal, electrical domestic consumers are subject to a maximum Peak Power Contract (PPC), which is selected by the consumer, based on their estimated peak power consumption [18]. If the household demand exceeds the PPC value the supply is shutdown locally. While the householders can always bring the power-up in the breaker box, that is a situation that is not desirable and should be avoided. In this study, some users mentioned the need to change (increase) the maximum PPC to be able to charge at their household. This is inline with our previous work where it was found that without increasing the PPC or adopting smart-charging strategies the PPC limits were easily reached [3]. It should be also noted that increase the PPC also represents an increase in the fixed component of the electricity bill since there is a EUR/day fee indexed to the PPC. Also, some users mentioned changes to their household electrical installation, which is another additional cost to charge the EV at their household. Due to the accentuated orography of Madeira island, it is common for certain houses to not having a car road access to their households. Results from this study revealed that 19% of users do not have car parking at their household to park their EV. This might suggest, there might be extra concerns while acquiring an EV.

Users' age and Annual income. In this particular case, it can be said that age and annual income are related in the sense that older users are the ones that tend to have more financial stability and, annual income can prove the willingness to purchase a vehicle as well as demonstrate financial stability. However, younger users have more openness and willingness to try new technologies compared to people with advanced age. It was expected to have younger drivers using EV technology nonetheless, the comparison was to infer if it is the best time/opportunity for the population to the change to EV technology (if both results were similar). The Annual income from the sample comparison with the average national annual income was to study if the age of the sample had higher annual income compared to the average National population. Results revealed that the sample age was near the average age Portuguese population (slightly younger, 2 years difference), and the sample population has higher annual income compared to the national average. This seems to suggest that our sample is more open to change their mobility options from standard CV to EV technologies. Not only are they a young portion of the population, but also they can afford to acquire such technologies. Local entities could consider the promotion of incentives to EV technology purchase, as there is a portion of this population that is ready to adopt it if given the right resources and support.

7 LIMITATIONS AND FUTURE WORK

It was difficult to approach the samples, as the entities that have direct access to EV users from Madeira and Porto Santo Islands have specific RGPD data agreements, making it harder to reach the users as fast as possible. Moreover, it was more difficult to get in touch with users from Porto Santo Island, as the Electric Mobility in Porto Santo has just started to be developed recently. It was asked both samples to define (between Madeira and Porto Santo island users), which orography typology (Madeira or Porto Santo) the RBS is more relevant/useful) and, there might be a limitation regarding this answer, as there is the possibility that users are not familiar with the information (orography) of the other island. By using an online questionnaire we may not have been able to reach certain participants (eg. elder people) because they may not have internet access or use it in a limited way. The conclusions of this study may not apply to the general behaviour of what is stated in the literature, as the sample of this study has specific conditions that may influence and produce opposite results (external validity). This might be since only around 15% (N=41) of 268 expected users answered the questionnaire. Thus, it might not represent the entire EV user's behaviour to other situations and to other people even with the same characteristics.

EV owners are going to start to pay at public CS sometime in 2020, hence this questionnaire can be replicated for example, in a year, to analyze the responses from users about public charging stations and if the tendency of charging at their household will increase. Moreover, it would be interesting to test RBS technology with users, in a field track with differences in the orography, in order to further analyse the effect of the difference of altitudes towards a track, and study the impact of the orography in the RBS.

The results from study can form the base for further research in Information and Communications Technology (ICT) for Sustainability. For example:

- *Facilitate the charging of EVs at the household*: One of the key results of literature is that EV owners often prefer to charge their vehicles at home. Nevertheless, like in the case of the Madeira Autonomous Region where installations are subject to a maximum PPC, many countries also apply mechanism to stabilize or reduce the peak demand (for example peak demand tariffs [4]). Consequently, there is a need to devise smart-charging strategies for EVs that involve not only the development of hardware, but also of advanced software algorithms that can properly manage the demand of the household and the EVs to be charged.

- *Promote a fair and sustainable distribution of public charging infrastructures*: One of the concerns expressed by our respondents is the fact that they do not have an EV charger in the household, whereas others don't even have access to a parking space where they can charge their EVs while at home. We consider that government and industry representatives can have a crucial role by carefully deploying more public chargers, such that more people can own an EV and still be able to charge in the comfort of their homes [24]. Furthermore, by deploying these chargers in locations where they have high demand, will lead to the not less critical reduction of e-waste in the long term.

- *Promote the adoption of EVs beyond financial incentives*: Our results also highlight the positive impact of financial incentives on the acquisition of EV. Nevertheless, in line with what happened to the adoption of solar PV technology, financial incentives can not be perpetuated in time. Therefore, the potential of ICT should be leveraged towards highlighting all the benefits of wide-scale adoption of EVs, such that in the long-run the EV adoption is not halted by the drain of financial incentives.

- *Promote sustainable driving in EVs*: Despite the limitations of this study concerning the use of the RBS in flat vs. hilly road systems, we firmly believe that if appropriately used, this technology can lead to significant reductions in the electric energy consumption of EVs. Hence, there is a big opportunity for the ICT4S community to leverage existing research in Eco-driving [2] towards promoting sustainable driving behaviors for EV owners.

8 CONCLUSIONS

Despite these uncertainties concerning the seamless integration of EVs in isolated grids such as RAM islands, their adoption is experiencing steady growth. Madeira and Porto Santo islands have many features that make the RAM suitable for penetration of EVs, such as, governmental incentive programs during EV purchase, the share of renewable energy sources and citizens' environmental awareness. The electrical grids constraints from isolated electrical grids are an issue for the integration of large-scale penetration of EVs and needs to be further studied. A survey to all private EV owners from RAM was used as a way of gathering information from EV early-adopters, in order to use current trends to analyse the potential impact in isolated grids. The aim of the questionnaire was to gather information about current EV owners demographics in RAM, the main location where drivers prefer to charge the EVs, users' opinion about orography while driving the EV and orography linked to RBS, and users satisfaction level about EV technology among other information.

The results characterized RAM EV drivers as mainly charging their vehicles at their household. There are still uncertainties about how the orography contribution to the RBS, and consequently to the EV technology. Besides, RAM EV owners are satisfied with their vehicles. From the testimonials of the study, Governmental incentives are considered an encouraging way to buy an EV in RAM. EV technology is also considered an inspiring technology regarding the obtained results. Not only users mentioned their preference about driving an EV compared with driving a CV, but also users' battery range anxiety mentioned in the Related Work did not seem to have a significant impact on RAM population.

In some cases, users need to first consider household car parking existence and household electrical grid infrastructure. This can be an advice provided from RAM EV owners experience to be used with other samples initial stage of implementation, in order to know what to expect in terms of these early adopters.

Nevertheless, there is still the need to continue studying the role of the orography in the driving experience of EV drivers and, the contribution of this variable in the driving track condition in the RBS and, consequently in EV technology.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to all the Madeira and Porto Santo islands EV owners that took time and interest to respond to the questionnaire. Additionally, the authors would like to thank Professor Mónica Cameirão for her support and guidance throughout the study.

This project has received funding from the European Union's Horizon 2020 research and innovation program under the grant agreement no. 731249 and from LARSyS (Projet - UIDB/50009/2020).

REFERENCES

[1] Kyungsung An, Kyung-Bin Song, and Kyeon Hur. 2017. Incorporating charging/discharging strategy of electric vehicles into security-constrained optimal power flow to support high renewable penetration. *Energies* 10, 5 (2017), 729.

[2] Jack N. Barkenbus. 2010. Eco-driving: An overlooked climate change initiative. *Energy Policy* 38, 2 (Feb. 2010), 762–769. https://doi.org/10.1016/j.enpol.2009.10.021

[3] Luisa Barros, Lucas Pereira, and Parakram Pyakurel. 2018. On the Challenges of Charging Electric Vehicles in Domestic Environments. In *Proceedings of the Ninth International Conference on Future Energy Systems*. ACM, Karlsruhe, Germany, 420–422.

[4] Cajsa Bartusch, Fredrik Wallin, Monica Odlare, Iana Vassileva, and Lars Wester. 2011. Introducing a demand-based electricity distribution tariff in the residential sector: Demand response and customer perception. *Energy Policy* 39, 9 (Sept. 2011), 5008–5025. https://doi.org/10.1016/j.enpol.2011.06.013

[5] Sara Bellocchi, Marco Gambini, Michele Manno, Tommaso Stilo, and Michela Vellini. 2018. Positive interactions between electric vehicles and renewable energy sources in CO2-reduced energy scenarios: The Italian case. *Energy* 161 (2018), 172–182.

[6] Bernt A Bremdal and Stine Sofie Grasto. 2014. Seasonal impacts of EV charging on rural grids. In *2014 IEEE International Electric Vehicle Conference (IEVC)*. IEEE, Florence, Italy, 1–8.

[7] Waldemar Brost, Teresa Funke, Ralf Philipsen, Teresa Brell, and Martina Ziefle. 2018. Integrated model approach STELLA method of site identification for charging infrastructure. *IFAC-PapersOnLine* 51, 9 (2018), 206–211.

[8] Louise Bunce, Margaret Harris, and Mark Burgess. 2014. Charge up then charge out? Drivers' perceptions and experiences of electric vehicles in the UK. *Transportation Research Part A: Policy and Practice* 59 (2014), 278–287.

[9] Kalpesh Chaudhari and Abhisek Ukil. 2016. TOU pricing based energy management of public EV charging stations using energy storage system. In *2016 IEEE International Conference on Industrial Technology (ICIT)*. IEEE, Taipei City · Taiwan, China, 460–465.

[10] Peter Cocron, Franziska Bühler, Thomas Franke, Isabel Neumann, Benno Dielmann, and Josef F Krems. 2013. Energy recapture through deceleration–regenerative braking in electric vehicles from a user perspective. *Ergonomics* 56, 8 (2013), 1203–1215.

[11] Peter Cocron, Isabel Neumann, Maria Kreusslein, Daniel Wanner, Maxim Bierbach, and Josef F Krems. 2018. Regenerative braking failures in battery electric vehicles and their impact on the driver. *Applied ergonomics* 71 (2018), 29–37.

[12] James S Coleman. 1958. Relational analysis: the study of social organizations with survey methods. *Human organization* 17, 4 (1958), 28–36.

[13] David Dallinger, Schubert Gerda, and Martin Wietschel. 2013. Integration of intermittent renewable power supply using grid-connected vehicles–A 2030 case study for California and Germany. *Applied Energy* 104 (2013), 666–682.

[14] Maria Carmen Falvo, Danilo Sbordone, I Safak Bayram, and Michael Devetsikiotis. 2014. EV charging stations and modes: International standards. In *2014 International Symposium on Power Electronics, Electrical Drives, Automation and Motion*. IEEE, Ischia, Italy., 1134–1139.

[15] Thomas Franke, Madlen Günther, Maria Trantow, and Josef F Krems. 2017. Does this range suit me? Range satisfaction of battery electric vehicle users. *Applied ergonomics* 65 (2017), 191–199.

[16] Thomas Franke and Josef F Krems. 2013. What drives range preferences in electric vehicle users? *Transport Policy* 30 (2013), 56–62.

[17] Thomas Franke, Nadine Rauh, and Josef F Krems. 2016. Individual differences in BEV drivers' range stress during first encounter of a critical range situation. *Applied ergonomics* 57 (2016), 28–35.

[18] M. U. Hashmi, L. Pereira, and A. Bušić. 2019. Energy storage in Madeira, Portugal: co-optimizing for arbitrage, self-sufficiency, peak shaving and energy backup. In *2019 IEEE Milan PowerTech*. IEEE, Milan, Italy, 1–6. 00000.

[19] Fakhra Jabeen, Doina Olaru, Brett Smith, Thomas Braunl, and Stuart Speidel. 2013. Electric vehicle battery charging behaviour: findings from a driver survey. In *Proceedings of the Australasian Transport Research Forum*. National Library of Australia, Darwin, Northern Territory, Australia, 15.

[20] Cosima Jägemann, Michaela Fürsch, Simeon Hagspiel, and Stephan Nagl. 2013. Decarbonizing Europe's power sector by 2050—Analyzing the economic implications of alternative decarbonization pathways. *Energy Economics* 40 (2013), 622–636.

[21] Chenrui Jin, Xiang Sheng, and Prasanta Ghosh. 2014. Optimized electric vehicle charging with intermittent renewable energy sources. *IEEE Journal of Selected Topics in Signal Processing* 8, 6 (2014), 1063–1072.

[22] Sinan Küfeoğlu and Michael G Pollitt. 2019. The impact of PVs and EVs on domestic electricity network charges: A case study from Great Britain. *Energy policy* 127 (2019), 412–424.

[23] Elodie Labeye, Myriam Hugot, Corinne Brusque, and Michael A Regan. 2016. The electric vehicle: A new driving experience involving specific skills and rules. *Transportation research part F: traffic psychology and behaviour* 37 (2016), 27–40.

[24] Albert Y.S. Lam, Yiu-Wing Leung, and Xiaowen Chu. 2013. Electric vehicle charging station placement. In *2013 IEEE International Conference on Smart Grid Communications (SmartGridComm)*. IEEE, Vancouver, BC, Canada, 510–515. https://doi.org/10.1109/SmartGridComm.2013.6688009

[25] ACIF-CCIM Route Monkey prsma M-ITI, EEM. 2017. *D4.1 Madeira Pilot Case Study Specification and Assessment.* Technical Report 4.1. H2020 SMILE, EUROPEAN COMMISSION. 93 pages. http://www.h2020smile.eu/wp-content/uploads/2018/06/Deliverable-D4.1.pdf

[26] Patrick Morrissey, Peter Weldon, and Margaret O'Mahony. 2016. Future standard and fast charging infrastructure planning: An analysis of electric vehicle charging behaviour. *Energy Policy* 89 (2016), 257–270.

[27] Ralf Philipsen, Teresa Brell, Waldemar Brost, Teresa Eickels, and Martina Ziefle. 2018. Running on empty–users' charging behavior of electric vehicles versus traditional refueling. *Transportation Research Part F: Traffic Psychology and Behaviour* 59 (2018), 475–492.
[28] Pordata. 2020. PORDATA - População residente com 15 e mais anos por nível de escolaridade completo mais elevado (%). https://www.pordata.pt/Portugal/Popula%C3%A7%C3%A3o+residente+com+15+e+mais+anos+por+n%C3%ADvel+de+escolaridade+completo+mais+elevado+(percentagem)-884
[29] Pordata. 2020. PORDATA - População residente: idade mediana. https://www.pordata.pt/Europa/Popula%C3%A7%C3%A3o+residente+idade+mediana-2265
[30] Statistics Portugal. 2020. Statistics Portugal - Statistics on income and living conditions. https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&contecto=pi&indOcorrCod=0009373&selTab=tab0
[31] Y. Sun, H. Yue, J. Zhang, and C. Booth. 2019. Minimization of Residential Energy Cost Considering Energy Storage System and EV With Driving Usage Probabilities. *IEEE Transactions on Sustainable Energy* 10, 4 (2019), 1752–1763.
[32] Michael Kvist Svangren, Rikke Hagensby Jensen, Mikael B Skov, and Jesper Kjeldskov. 2018. Driving on sunshine: aligning electric vehicle charging and household electricity production.. In *NordiCHI*. ACM, Oslo, Norway, 439–451.
[33] Iana Vassileva and Javier Campillo. 2017. Adoption barriers for electric vehicles: Experiences from early adopters in Sweden. *Energy* 120 (2017), 632–641.
[34] Chris Walsh, Steve Carroll, Andy Eastlake, and Phil Blythe. 2010. Electric vehicle driving style and duty variation performance study. *University of Sheffield* (2010), 11.
[35] Nicolas Watrin, Benjamin Blunier, and Abdellatif Miraoui. 2012. Review of adaptive systems for lithium batteries state-of-charge and state-of-health estimation. In *2012 IEEE Transportation Electrification Conference and Expo (ITEC)*. IEEE, Dearborn, MI, USA, 1–6.
[36] Hao Wu, Grantham Kwok Hung Pang, King Lun Choy, and Hoi Yan Lam. 2017. An optimization model for electric vehicle battery charging at a battery swapping station. *IEEE Transactions on Vehicular Technology* 67, 2 (2017), 881–895.

A APPENDIX 1

This supplementary section presents, in more detail, the description of each 10 sections of the procedure of the online questionnaire of this study.

- *S0 – Consent form* – This section included the general requirements of a consent form (i.e. introduction to the study, where it was explained the sample target; potential risk for the individual; the extent of confidentiality protection for the individual; the conditions of participation including the right to refuse or withdraw without penalty; whether research material could be anonymized; time required to answer the questionnaire; and the contact information for questions regarding the study);
- *S1. Demographic data* - This group of questions comprised information regarding the drivers' personal characteristics: age, gender, place of living; educational level and annual income;
- *S2. User's preference infrastructure to charge the EV* – Infrastructures that EV drivers used the most to charge their EVs and it was also requested to indicate the location that participants utmost charge their EVs;
- *S3. Feedback about the RBS and influence of orography* - The purpose of the third section was to study users' feedback about the Regenerative Braking System and if orography may reflect in users' sensitivity an additional perception of the potentialities of RBS and consequently battery energy savings. Here it was asked if orography undermines the way that users' drive; where users think that EV has a better regeneration profitability (in Madeira or Porto Santo); during the users' daily commute, on average, how much battery does EV regenerate; what RBS was for the user;
- *S4. Users' opinion about EV technology* - The fourth section obtained participants battery range satisfaction and users feedback about EV technology. In this section it was asked if users were satisfied with battery autonomy of the vehicle; if users used some strategy to maximize battery autonomy; if they use ECO mode; if they had ever been anxious in a case of low battery autonomy of the vehicle;
- *S5. Reasons to charge on a particular infrastructure* - Fifth section was to collect possible reasons why participants chose a particular infrastructure to charge the vehicle. In this section, it was asked if they agreed or disagreed to charge their EVs in a fastest way, in a cheapest way, where it is more comfortable for them to charge and, if public CS should be used only in SOS occasions. The fastest meant that they charge a public CS and slowest way at their household, the cheapest way to charge is at public CS, which is free of charge and, the most expensive way at their household, The more comfortable place to charge is considered at their household and the less comfortable one at a public CS. Strongly agreeing that public CS must be used only in SOS cases means that users mainly charge at their household or at work;
- *S6. Opinion about public charging stations* – This section was created to test users' sensitivity about public charging stations availability, location and quantity;
- *S7. Information about users' vehicle* – Technical information about the EV and the battery charger (such as brand, model, capacity of the battery, type of charger they use, etc.) and, the year that participants purchased the vehicle, so as to know about technical data and, if the participant was more or less experienced with EV technology;
- *S8. Driving an EV* - Participants gave their opinion about driving an EV and compared it with an internal combustion vehicle.
- *S9. Consent to use participants' data for further research without additional consent* - After finishing the questionnaire, participants were requested to provide consent and provide their name/email in order for the researcher to use the data for further research without additional consent.