The Acceptance of energy monitoring technologies: the case of local prosumers

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***Abstract*—With transformations happening in the electricity sector, we need to ensure consumers have access to updated and correct information to accompany such changes. Consumers need to understand technologies available to them but also, learn how to use them to optimize their personal investment in such types of equipment. In this paper, we explore how a group of local prosumers has adopted energy monitoring technologies, their day-to-day strategies, and expectations when handling such systems. We studied 11 prosumers and the technologies they have used for three years, evaluated their satisfaction with the feedback provided and analyzed how a more modern visualization of their energy practices was introduced and adopted into their daily lives. We conducted interviews and questionnaires to evaluate their engagement with these tools. This initial work suggests this particular group of users have already a high level of knowledge about their systems, and as a result have integrated these into their routines. However, more support would be needed from other local actors to help them reach more benefits and as such, more satisfaction as consumers. We conclude by reflecting on barriers that need to be addressed to increase user satisfaction with these systems.**

I. Introduction

The increasing global population has lead to an equal increase in energy use. Due to limited energy resources such as fossil fuels and, climate effects, energy efficiency has become a challenging and pressing problem across the planet [1]. Since a large portion of energy use has been in the residential sector, measures implemented in countries have focused on the energy efficiency of the existing buildings. Policy measures have encouraged investments in innovative solutions such as smart grids, smart homes, self-generation, and storage technologies, which are available but still not widespread [2]. Photovoltaic systems (PV systems) for instance, are technologies that operate in the area of clean energy, not focused on inefficiency but replacing the energy source for renewable energy. It is a solution that helps consumers generate their own energy, and it is easy to integrate within existing buildings. An estimate of 17GW solar PV has been installed in the European Union, and it is predicted to increase up to 32GW by 2030 [2].

Consumers who use such systems are known as prosumers, energy consumers who also produce and generate their own energy. With the increased adoption rate and the technology innovation of these systems, these consumers transition very quickly from passive to active participants in the changing energy market [3]. In other words, decisions that were previously available to electricity suppliers become accessible to these consumers. However, there is some work to be done until that point, since they seem to have limited access to information about ways to optimize their current installations, whether through upgrades or storage solutions that would be most adequate for them [4].

Energy monitoring systems address part of that issue, as these provide users access to the information being collected and consequently, enable them to act on their energy consumption. Energy monitoring technologies or eco-feedback are defined as the use of technologies to monitor energy consumption and production of a specific household [5]. These technologies allow the collection of energy consumption and production by using sensors that send information from the household to a central system. The information is gathered and then presented using various forms such as email, or applications that allow consulting and analyzing the information. In fact, research studies [5], [6], [7], [8] highlight the importance of the mobility aspect.

In this paper, we report on a study of technology acceptance of energy monitoring technologies with residential prosumers using small-scale solar PV to generate electricity. This study describes participants' motivations to become prosumers, the acceptance and usage of the PV system and PrsmaEnergy the application developed within the project, and differences between these two. The ultimate goal is to capture and analyze the empirical data with these users of how they have used a PV system, observe how they adopted it through a more modern application installed to optimize it and identify potential problems that may exist while using it. Finally, provide recommendations that can help service providers and the design of effective user-driven solutions.

II. Related Work

Due to the diversity of existing equipment that can be used to achieve energy generation, there does not seem to be a precise term for residential prosumers. Generally, these are known as energy consumers who produce their own energy but there is not a clear term to classify these users across countries due to differing regulatory frameworks and policies [9]. Even within the EU there are no standard policies followed by the member countries that help create a set of incentives to increase the adoption rates of PV systems. Although, it is expected for the installation of such systems to double by 2030, there are barriers that endanger such adoption [2]. For instance, many consumers decide to install such systems because they see these as an extra source of income, whether through savings in electricity or earnings, they realize that producing their own energy could be very valuable, but when they search for the information, they realize local regulations prevent them from doing so. In spite of some countries have already developed remuneration schemes, few enable prosumers to sell their electricity [2]. Consequently, reducing the uptake of users investing in PV systems.

A. Prosumer Motivations

Recent work suggested a variety of motivations that explain why regular consumers decide to produce energy in their own homes. At an initial phase, the financial factors determine the purchase of PV systems, for instance the upfront cost of installation, borrowing costs, the scale of the financial benefit (in terms of reduced electricity bills and available policy support), and, the expected rate of return, earnings and savings obtained (and payback period) of their investment [2], [10], [11].

In some instances, consumers relied on technical reasons to purchase a PV system, for example, ownership of an electric vehicle, smart meters or the ability to include at a later stage battery storage and demand response technologies. Other motivations included the aesthetics of rooftop solar PV panels, the security of supply, and finally, maintenance costs and efforts over time.

The environmental impact and commitment remain a motivation once the financial factors have been considered, and it is based on the desire to protect future generations, and help reduce the environmental impact of fossil fuel usage [11].

The prevalence of some motivations over others is not similar across European countries, due to the varied policies being followed [9], nevertheless, financial factors and access to capital seem to be the most prevalent. Becoming a prosumer, particularly installing a PV panel, often starts with financial factors, but in a large number of cases it is a decision-based in green and environmental motivations, and it becomes an extension of their lifestyle [12], [13].

B. Shifting energy activities

Demand-side management (DSM) has been one of the strategies within energy efficiency initiatives, used to reduce or optimize the end user's energy consumption in order to reduce the cost and the environmental impact. One of its mechanisms is the Demand response (DR) designed with the objective of adjusting production demand. It does so, through the creation of dynamic tariffs that encourage consumers to conduct their energy consuming activities spread over time or throughout the day, consequently avoiding consumption peaks. From this demand-side perspective, prosumers are given the choice of services they want to use to better match their needs, and which ones they will want to offer [3]. Once users have installed energy generation systems a set of practices or changes emerge within the households. These changes are part of what researchers have designated as "demand shifting" [14], where consumers change their behaviors to match and use most of the energy produced at the time it is being produced [13]. Constanza et al. [15] used an agent-based system to study how users would shift laundry routines based on the electricity tariff, and its results suggested increasing user interaction around automated systems to take more advantage of them. Hansen et al [12] conducted a study with 20 households in Denmark where they observed how participants changed their practices after having smart grid technologies installed. Results indicated participants became prosumers as they changed their knowledge and behaviors to make the most use of the sun while requesting more support and dialogue with the local energy provider. Similarly, Pierce et al [16] and Smale et al [17] conducted interviews with users participating in smart grid trials to find cleaning practices were the ones most suitable for DSM, while other activities (leisure, cooking and eating) were more limited to being conducted in other times than the ones usually taken to perform these.

Nevertheless, having access to information about energy generation is not always possible or easy to achieve. Besides the presence of other factors, such as social influences within the household, there are technical limitations that prevent prosumers from pursuing this demand shifting.

This paper describes a case study of a group of prosumers located in a remote island, using energy monitoring technologies that keep track of their energy generation systems and the technology acceptance observed and measured through the period of 4 to 6 weeks. Barriers are listed and analyzed in terms of recommendations to improve such tools for future service providers.

III. Study Design

This study is integrated in the *SMILE* project that aims to demonstrate nine different smart grid technologies in three islands across Europe in order to foster its market introduction. This study was conducted within one of the pilots (Madeira island) in the project with the main goal to smarten up the distribution grid, through the optimization of self-consumption of renewable energy in the installations by introducing elements like Battery energy Storage system (BESS) and specialized battery management software. These prosumers are not currently allowed to inject the excess energy into the grid due to local regulations, however, for the purpose of battery analysis and testing, these will be allowed to do it.

One of the aspects of the project refers to the evaluation of the energy monitoring technologies being used by participants. We started by recruiting prosumers in the island that owned PV solar systems and collected baseline information about their usage of those systems. Around 4 weeks later, we installed a monitoring system that collected baseline data for 6 months. Afterward, prosumers were given access to an application that provided feedback on their energy consumption and production designated as PrsmaEnergy. This work describes the technology acceptance evaluation of both the PV system (prosumers had already installed) and the project application PrsmaEnergy (which was integrated into the project). The acceptance was measured using: semi-structured interviews and a questionnaire adapted from the Technology Acceptance Model (TAM) [18], [19], [20].

The interviews collected information related to electric energy consumption and production, routines, expenses and awareness about energy-related habits or strategies. All interviews, before receiving PrsmaEnergy and after using it for 4 to 6 weeks, lasted around 20 to 30 minutes. All interviews were recorded and transcribed, and its data were analyzed using grounded theory [21], [22] by grouping quotes into themes, and coding these according to categories, which are further explained in the coming section.

The Technology Acceptance scale was used before providing access to PrsmaEnergy, and around 4 to 6 weeks after users were given the access credentials to use it. The scale included 32 items across 6 dimensions: perceived usefulness (PU) (9 items), perceived ease-of-use (PEU) (7 items), intention to use (2 items), user satisfaction (7 items), ease of learning (4 items), and attribute of usability (3 items) (see table I for more details). The items were slightly adjusted to evaluate the acceptance of energy monitoring technologies. It is believed the higher these aspects are rated the higher is the user's acceptance. The scale was translated to the native language of the user sample and users were asked to rate their degree of (dis) agreement on 7 points Likert scale. The internal consistency of the scale was assessed by calculating the Cronbach alpha value of the overall scale, which was 0.98 for evaluating the current system, and 0.76 for the PrsmaEnergy evaluation.

This study was designed to evaluate the technology acceptance in two moments:

1) Evaluation of the current PV system: Understand how participants were using the PV systems they had already installed in the homes before the project even started. The research team conducted semi-structured interviews to collect information on the following aspects:

1) The reasons and motivations for purchasing such a system and becoming a prosumer;
2) Expenses before and after, as well as current ones;
3) Strategies used to optimize their production;
4) Routines and changes;
5) Use of an application that provides information about their energy production, in case they had one. It included a Think-Aloud while using the PV system. After the interview participants were asked to fill in a questionnaire based on the TAM [18], [19], [20].

2) Evaluation of the PrsmaEnergy satisfaction and usage: Understand how and in which ways PrsmaEnergy changed their behaviors or use of the PV panels. Participants were given access to the digital platform and were interviewed 4 to 6 weeks after having used it. The interviews focused on following up aspects from the interviews conducted in the first moment, namely, changes in expenses, changes to their routines using devices or the system, and strategies they used to handle or interpret the information given. In addition, participants were asked about: frequency of use, most relevant information and tools used to access it, least relevant information and suggestions. After the interviews participants were asked to fill in the acceptance questionnaire based on the TAM.

Fig. 1. A screenshot of the "analytics" page comparing data about production and consumption from two different days. The user can select which day he would to see using the top right search fields.

A. Participants

The study was conducted with 11 households (see Table II) that were recruited through the project using information sessions and ads in social media. During the recruitment phase, we encountered a combination of users that reported they wish to optimize their PV panels as a reason to get involved in the study. All participants had a solar PV system installed in their homes purchased with their own funds with no financial programs or subsidies using local companies as installers or recurring to online sales and installing these themselves. Participants were asked to complete a baseline survey that provided both demographic information and consumption practices. In terms of demographic information, the household size ranges from 2 to 5 people, with an average of 3.54 people per household. Age ranges of participants and family members vary between 2 years old and 84 (average age is 37.3 years old). We measured participants environmental concern by asking them to fill in the New Environmental Scale (NEP) [23], to which all responded in agreement with the new environmental paradigm. All participants were supportive of the impact of human activity in the environment and its fragility, higher scores of this new paradigm are associated with pro-environmental behaviors [23].

B. PrsmaEnergy set up

Each participant household was already equipped with a PV panel to which a smart meter was installed to collect baseline data in terms of 1) energy production, 2) energy consumption, 3) energy being sent to the grid. This data was then stored in the projects Energy Management System (EMS) and displayed through PrsmaEnergy designed with the purpose of tracking the individual installations and providing information about their systems throughout the project. In terms of the feedback, it was decided to represent electricity production and consumption in terms of 1) energy and power,

TABLE I
CONSTRUCT DEFINITION USED IN THE ACCEPTANCE QUESTIONNAIRE.

Construct	Definition
Perceived usefulness	The extent to which a person believes that using a technology will enhance her/his productivity
Perceived ease of use	The extent to which a person believes that using a technology will be free of effort
Intention (to use)	The intention to use the system as often as possible and as long as it is available
User satisfaction	The extend to which the user feels confident in using the system
Ease of learning	The extend to which the user finds it easy to learn and operate
Attribute of usability	The extend to which the user finds the system to be well integrated and easy to interact with

TABLE II
PARTICIPANTS DEMOGRAPHIC INFORMATION

User ID	Household size	Ages	Occupation (main caregiver)	Time as a prosumer (years)
A	4	44,42,14,11	Nature Watcher	18 months
B	4	84,48,47,22	Teacher	1 year
C	4	56,52,23,21	Retired	2 years
D	3	42,41,6	Nurse	2 years
E	2	74, 32	Unemployed	10 months
F	4	62,32,02,44	Business	3 years
G	3	51,45,20	Construction worker	3 years
H	2	64, 64	Electrician	2 months
I	4	55,50,20,15	Teacher	3 years
J	5	42,41,13,10,7	Businessman	4 months
K	4	55,55,28,19	Government worker	3 years

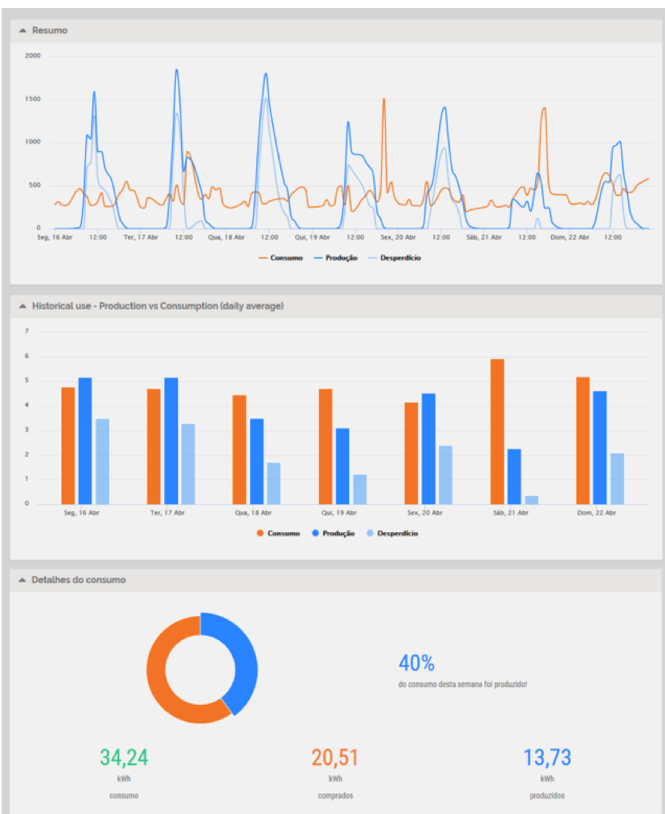

Fig. 2. The three main visualization types provided by PrsmaEnergy, the first one displays consumption, production and excess energy. The second presents this data throughout a week. The bottom visualization provides details about energy produced versus energy used from the grid.

2) cost and 3) environmental impact. The metrics selected - kWh/kW, money, and $CO2$ - are indeed commonly used in combination for the specific purpose of engaging different target groups [5], [24].

The features included close to real-time feedback about consumption and production (updated every minute), historical feedback with three levels of temporal granularity (days, weeks, months), and comparison between dates the users could select to have more information. Real-time feedback (i.e. current consumption and production), together with an overview of recent energy use (last hour and current day/week/month), is displayed in the "dashboard" (which serves as a landing page), while the "analytics" feature provides users with the opportunity of reviewing and comparing data among different periods of time (Figure 1).

We selected three main visualization types (Figure 2): lines chart (to show patterns over time - e.g. the period of the day when production usually exceeds consumption), pie and bar charts (to represent cumulative amounts of data - i.e. daily, weekly, and monthly energy use). Households usually value the opportunity to access feedback and check their energy status via mobile devices. For this reason, we opted for a web-based application designed to be responsive, so that it can be accessed also via mobile devices (smartphone and tablets).

The work presented here aimed to evaluate the acceptance of energy monitoring technologies by a local group of prosumers, focusing on the following questions:

1) What motivations led participants to become prosumers?
2) How do they report themselves in terms of electricity usage and other resources?
3) What was the acceptance for the current PV system they had installed in their homes before we started our research project?

4) Were there differences in terms of previous system and PrsmaEnergy?
5) How did participants use PrsmaEnergy?

The following section summarizes the findings for each of these questions, with a combination of qualitative and quantitative results, gathered through the questionnaire and the interviews conducted with the participants. The qualitative analysis displays more relevant and common themes that emerged from the participants' interviews concerning technology acceptance. The quantitative results refer to the Acceptance scale used to evaluate both systems.

IV. RESULTS

This section presents the key findings of the acceptance study in three areas: a) users energy practices, b) user motivations and c) technology acceptance, of the current system and of PrsmaEnergy. For the first two, the main themes are described in a succinct way, and for PrsmaEnergy, Table III presents the main themes with illustrative quotes.

A. Users energy practices

When asked about their electricity costs before (the costs ranged from 75 to 130 euros) and after the installation of the PV panel (the costs lowered from 45 up to 100 euros) all participants referred to a cost reduction between 20 and 30 percent after installing the PV panels. Participants reported the costs based on expense tracking habits they had before and after installing the PV panel. Four out of the 11 users reported slight increases to their energy bill, which they interpreted as tax increases. Or even due to weather changes, for instance, the fluctuating temperatures during the summer required the use of air conditioning or fans in the homes. One user shared the PV system did not allow so far savings, due to specific appliances in the home that did not allow for it just yet, namely, the water pump used for agriculture. In spite of these increases, all users mentioned the decision to purchase such a system was a great one; otherwise, their expenses would reach higher values.

To understand their routines and the use of electrical appliances, users were asked to list their daily use to which they reported the following:

- A set of devices is always used every day (coffee machine, microwave, and kettle);
- A set of devices is always used during the day when they have the highest energy production (washing machine, stovetop, oven, vacuum cleaner);
- When there is not enough production they postpone the usage of the device for the next day - for instance, doing laundry (washing machine) or cleaning (vacuum cleaner) when it is sunnier;
- In some cases, they anticipate the realization of some activities as early as possible to avoid using energy from the grid at night - for example, they cook dinner earlier than usual (they know the stovetop and oven are highly consuming);
- They charge their phones during the day, which they tried to implement whenever possible.

B. User motivations to become prosumers

All prosumers used their own means to install the solar PV system, meaning they used local installers, searched for local information, contacted the local electricity company or used online sources. They mentioned this process to be cumbersome, as there were no clear paths on how to proceed whether in terms of subsidies they could apply to or even regulation they would need to follow.

In terms of the reasons and motivations for purchasing PV panel system, users reported this decision was aligned to their willingness to keep up with the latest technologies or the opportunity to have an innovative system at their home. In other words, they are the early adopters of such technologies and perceived their purchase as an opportunity to try something new in the area of renewable energy.

Regarding the environmental value users, viewed it as a way to protect the environment but also, part of a greater goal, as they saw it as a part of a lifestyle they want to build around environmental protection and preservation. Not only in the field of energy but also, food production, purchase of organic products or even sustainable home construction. Whenever the environmental concerns were mentioned, users had already integrated into their lives these aspects beyond the area of energy, and these were measures they had started to progressively adopt into their day to day living, even before the self-consumption systems came into the market.

Other users referred to the availability of solar energy on the island, they saw it as a valuable and ready to operate resource that was not being used to its fullest potential. For them, it seemed it could be even more capitalized and an obvious choice to follow by our governments, by our local companies and supported by all kinds of programs. It was not clear to them why this is not supported, as it should be. As well as why are not there more consumers investing in PV systems for their home.

A few users mentioned their motivation to have PV panels was associated with the need to having greater information about the electrical appliances they have at their homes, which consequently helps preventing future problems. Either because they ran into device malfunctioning in the past, or had an energy surcharge that affected their electrical appliances, or a remote way to monitor their equipment when away from home for longer periods of time. This allowed them to keep a record of information they can use as justification in case they have a situation of malfunctioning, and they need to report it to the local electricity company.

The cost reduction was a least motivation mentioned, with time users realized achieving full autonomy from the local grid is still a long distant goal, however, they are pleased for being able to use the energy produced by their self-consumption units during the day.

C. Technology Acceptance

With regards to the acceptance evaluation, users scores were higher for PrsmaEnergy to the exception of one user. To investigate further, we proceeded to test the differences between the two acceptance scores. Due to the data not following a normal distribution for some variables, a Wilcoxon Signed-Ranks Test was run and the output indicated the PrsmaEnergy acceptance scores were statistically significantly higher than the current system acceptance scores $Z = 26.5, p < .034$.

Users scores were higher for all the sub-dimensions for PrsmaEnergy (see Figure 3). The highest scores were on Perceived usefulness, which means users felt the application made them believe it would enhance their productivity, or more specifically help them collect the most relevant information in a fast, easy and simple way about their energy production. The second highest scored was for User satisfaction, meaning prosumers felt confident using the application, felt it was working as expected and they would recommend it to a friend. Intention to use was the lowest for both the PV system and PrsmaEnergy.

In the following two subsections, we explore even further the results regarding the PV system and the project application, through a summarized description of users perceptions of both systems.

1) PV system: Users were asked about strategies used to optimize their production once they installed the system, and these included the use of devices such as washing machines, dishwasher or dryers during the day. For that, they would either program the machines to be used in the highest sun peak hours, or stop using these after a certain time in the day, for example, avoid using these after 4 PM in the winter and 6 PM in the summer. Another strategy was to purchase timers to control device usage, especially at night to regulate their energy usage from the grid. The overall goal was to avoid using energy from the grid, as a result, they specified to use as few devices at night as possible, replaced devices that were demonstrating high consumption for more efficient ones or even replaced some lighting to more efficient lamps.

In terms of improvements, they would like to conduct in their installations these would be the purchase of storage solutions to use the energy they know is not being used and currently wasted, however, the high costs and the lack of financial support programs prevent them from making such investments. As well as the lack of trustworthy information of reliable systems they can use to optimize even more the use they make out of their systems.

Regarding the use of an application with information about their production, only 7 out of the 11 users mentioned to have it available everyday or rather frequently. The other 4 users did not have access to their energy production information. The users who did use it did it to plan their activities in the homes, and their device usage based on that information. In addition, they mentioned the information was useful to:

- detect consumption peaks;
- remotely control their homes when away;
- and to plan their household activities.

In terms of weaknesses, users mentioned:

- the complexity to sometimes customize the visualizations, to the extent they had not figured these applications quite well;
- the lack of being closer to real-time activities. In other words, the system should be placed closer to the spaces where devices are mostly used such as the kitchen or easily available to other family members. In fact, the frequent user of the application in all homes is male, the person who decides to purchase the system, the person who is at most ease with technology and the one most interested in such equipment.

2) PrsmaEnergy: Regarding the application provided by the project (see Table III), users reported using it more frequently in the first three weeks either through their mobile phone or their personal computer. When they wanted to take a quick glance at the data they would use their mobile phone, while if they wanted a more detailed analysis they would use the computer to enlarge the graphs. Once they learned how to interpret the production information based on their household routines and/or weather conditions they used it less frequently.

In terms of reasons to interact with PrsmaEnergy, they would use it to keep track of their energy production information and keep track of their savings. All users mentioned this reason several times. Some users were more specific in terms of which moments led them to use the application, such as:

- to check the influence of a new appliance;
- to confirm production values according to the weather conditions on that specific week or day (especially for sunny days);
- to assess if certain activities could be conducted using self-consumption;
- to identify energy peaks that could be avoided to optimize even more their system;
- and to assess the feasibility of adding other renewable energy systems to his home.

Users mentioned the most relevant information to be the money being saved while using most of their energy production, the carbon dioxide emissions and the production information they used as a hint to start certain electrical appliances in order to avoid using energy from the grid.

In terms of routines, users felt PrsmaEnergy was a good tool to plan laundry and to analyze consumption peaks in order to know where and when they could further optimize their efforts, whether by moving one activity to another time of the day or stop using one appliance in case there were too many being used. One user mentioned the information was helpful to make the family aware, however, they felt they were not taking it to the next level and making these into actual strategies to change their practices at home. Users continued to do the most consuming activities during the times when there was more energy being generated by the PV system.

In terms of suggestions one user who has batteries installed in his home, would like to have had its information added to PrsmaEnergy, similarly to the PV system application that was included with it.

Users found the application user-friendly and accessible in some cases even more than the PV current system. In terms of family members using the application, the majority of users

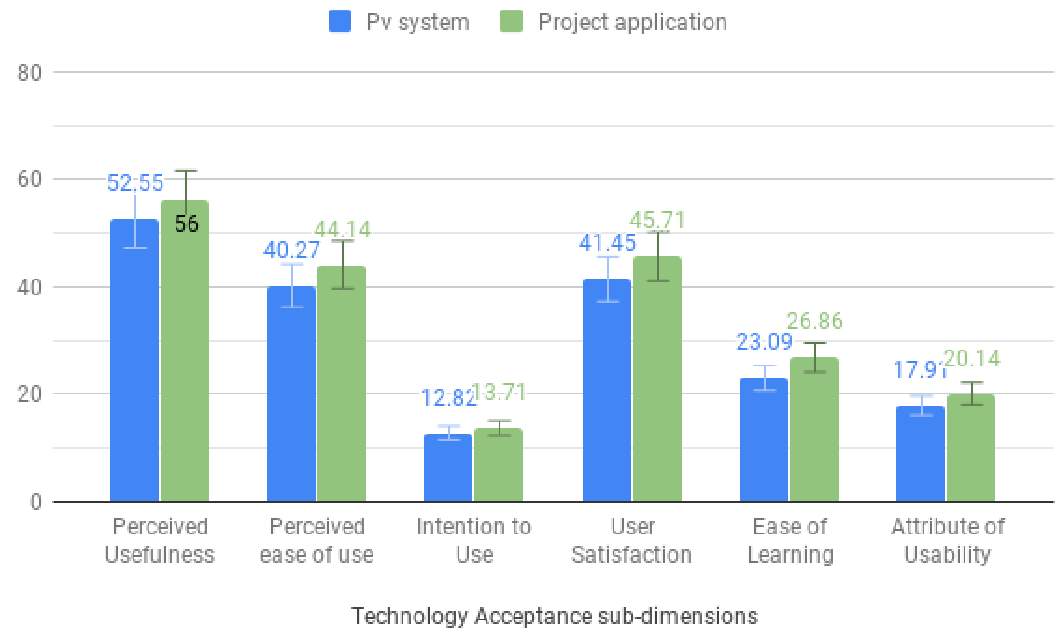

Fig. 3. Technology acceptance for each system in terms of sub-dimensions

TABLE III
PRSMAENERGY THEMES

Themes	**User quotes examples**
Production Information	*Now I really want to buy the (wind) turbine to see through the application how much energy can I produce when there are windy days and perhaps take advantage of night periods to collect it* (User C)
Triggers to use it	*I look at the production and the consumption to make sure everything is working* (User D) *I was not aware of the best time to start the washing machine in the morning and now I avoid starting it too early such as 9 am because there is not much sun yet, it is better to start it after 10 or 11 am, it's the time to start using more appliances* (User E) *I use it mostly when it is sunny, and I'll check several times on those days, when it's rainy weather I don't even bother to look at it because I know it is not producing as much energy* (User F) *The most relevant for me is seeing the bill being reduced, the more savings the better* (User K)
Most relevant information	*I find it very interesting that you have added how much carbon dioxide am I responsible for, I find it very interesting and it was a very great choice from your side to include it in the feedback* (User I)
Ease of use	*Your application is much better, more reliable more complete than the one I used to use that came with the system* (User C) *I think it is very good, it gives the necessary information for regular people who are not experts, if it had much more information I might not know how to interpret it or what it meant. It is simple and user friendly* (User D) *The information I need is here, it is easy to see and very intuitive for me* (User J)

mentioned being just themselves checking the application and using the information in their daily lives. In spite of their efforts to captivate their attention to look at the information, or told they should avoid using an appliance due to low energy production, other family members would not use it.

V. DISCUSSION

Participants in this study being prosumers revealed high scores in terms of environmental concern and had their energy use transformed by the decision of installing a PV system. Similarly to [12], they also changed their consumption activities to take advantage of the hours with most energy production, with the current PV system and even after PrsmaEnergy was installed. In fact, the application enabled them to infer even more information, such as adding or upgrading their current PV system with other energy generation technologies. This follows the recommendations by [2], where consumer acceptance can be increased if governments and local municipalities support the growth of complementary technologies (Electrical Vehicles and storage technologies).

Users continued to use PrsmaEnergy to plan activities and detect consumption peaks. The activities more prone to be shifted were also cleaning and laundry, such as [17], but also, with some prosumers the activity of cooking was considered due to their flexible working schedules. However, in both systems, the most frequent users were the person responsible for purchasing the PV panel, for agreeing to be part of the study, and the one that would already use the information. The fact that other family members were not mentioned, in the majority of the cases, it means PrsmaEnergy could be further improved to engage other users within the homes, since practices tend to be influenced by the social dynamics of families, which has been seen in the area of eco-feedback [25] but also, energy production [13].

In what concerns motivations to become prosumers, our users contrary to what authors have found so far [2], [11], hardly mentioned financial concerns or earnings. At least, this did not emerge until PrsmaEnergy displayed such information, but only for two users out of the 11. The remaining users focused mostly in using the latest technology, helping the environment and that it could be even further used, but local authorities or organizations do not offer proper incentives for more people to join the green energy movement. Although users did not verbalize the financial concerns being a major motivation, we believe that beyond the green values and environment protection, prosumers revealed a need to have greater control over their electricity in their own home. Since they used both PV system and PrsmaEnergy information to keep track of electrical appliance problems, but also problems resulting from the grid supply, and to further learn about their consumption and production practices.

Taking in consideration the fact that prosumers in this study invested their own resources to pursue their motivations of having an energy generation system, it seems that incentives for this group of people and others in similar cases should go beyond economical grounds. One way could be through the creation of subsidies to help users upgrade their installations, but also, include the access to information campaigns, or the creation of community-based activities that allow users to share information and experiences since the installations had specific technical needs that could be overcome through shared knowledge.

In terms of technology acceptance, users felt PrsmaEnergy was easier to interpret, more complete, hence the highest scores for the application. Consequently, users were more satisfied with it as reinforced by their testimonies in the interviews. The high scores can also be explained by the fact that all prosumers decision and investment for the PV system was their personal initiative using their own financial resources, supported by the desire to have an innovative system and have the opportunity to experience it first hand. One user scored the PV system higher than PrsmaEnergy in terms of acceptance, due to the fact that his own application included in the equipment, provided the information about his storage equipment. This user has the most complete PV system in the sample, and our application will only include this type of information at a later stage in the project. As a result, his scores are understandable, since the user expects an application to be even more innovative compared to the one he already interacts with on a daily basis. Nevertheless, this user was impressed by the addition of the emissions information, which he believes is important to bring more people into the environmental protection mindset.

In terms of features used, users referred mostly to the most recent information, and hardly to historical information, which can be explained by the fact that users would use the presence of sun as a trigger to use the application. The fact that this study occurred in the Winter, they felt less motivated to use the application and conduct comparisons between dates, meaning they would only interact with it while there were sunnier days and less interested in exploring different production days. Users enjoyed the application because it expanded on the lifestyle they are trying to pursue, by having information on the emissions they felt it came to strengthen their motivations to use as much renewable energy as possible. Overall, participants revealed high scores in terms of technology acceptance for both the PV system they installed and PrsmaEnergy that came to increase their satisfaction with the user experience and information provided.

VI. Recommendations

Prosumers are a group of people with a considerable level of knowledge and are willing to invest their own resources in order to optimize the equipment they have already installed in their homes. The number of prosumers is likely to increase as the technologies become more accessible. Prosumers have motivations that start by being financial, but just partially as the regulation in each country will support it or not. But this does not stop them from conducting an upgrade to the system or even considering other energy efficiency solutions.

It is becoming more common to find regular consumers interested in green values and environmental protection, and not just because of their local municipality awards it. On the contrary, this study showcased a group of prosumers that are pursuing their goal to become more innovative and become more self-sufficient in spite of having no subsidies or local programs to help them improve the current installations. This project came to help them, what they hope to assess the feasibility of potential storage solutions or even just the installation in itself. What we observed was that prosumers are more than willing to invest in energy generation technologies if it means having greater control of their costs, their information, their consumption patterns and practices, as long as these work and are user-friendly.

How can ICT help these citizens reach a more sustainable future? We believe ICT cannot work alone if local organizations are not involved, and for that matter, ICT can help group and gather the data and information in a more meaningful way in order for municipalities to create tangible measures consumers can easily put into practice. The following measures could be a start to this kind of work:

- create community digital platforms that consumers can access to have clear and neutral information about energy generation systems and regulation;
- disseminate local experiences with these technologies;
- facilitate participatory discussions between governments, companies, and consumers about contextual conditions

that could be implemented to optimize the local resources, and motivate integrated collaborations between all stakeholders for a greener mindset.

VII. Limitations

One limitation of this research is the fact this is a small sample of participants that live in a specific context where they are not allowed to inject the excess produced energy into the grid. This alone makes them prone to become motivated to use most of their energy production through a number of strategies. Having an application that helps them to do so, explains their high scores in terms of acceptance and satisfaction. Having conducted the study in a location where prosumers could make direct earnings from their production, we are left to wonder if the efforts would remain the same. Another limitation regards the fact that a large part of the savings before and after the system, were self/reported, even though participants did keep an accurate track of their expenses, the study would have benefited if expenses analysis prior to our study had been analyzed, either through the utility company records or the participants.

VIII. Future work

This study is integrated into a larger scale project that aims to maximize self-consumption installations into the current grid. The next stage consists on splitting our sample of prosumers into two, one where prosumers will have a battery installed in their homes, and a second one, where prosumers will have more detailed feedback based on their production characteristics. The goal will be to compare the optimization strategies used within the two samples. The technology acceptance will be evaluated again, with the introduction of batteries and its usage in PrsmaEnergy, with an added level of feedback. This will be essential to understanding acceptance and satisfaction for this type of systems, and which factors may affect its user experience or satisfaction, and market entrance.

IX. Conclusions

In this paper, we have presented the technology acceptance of energy monitoring technologies, namely solar PV systems and an application providing detailed feedback on energy consumption and production designated as PrsmaEnergy. The groups of prosumers that participated in this study are a group of people that are deeply motivated to change their practices to optimize even more the technology they have installed, however further support to expand such systems would be needed. The interviews with the participants unraveled their challenges rely mostly on getting other family members to get involved and obtaining governmental support, their expectations are to improve even further their systems with other generation technologies, but also storage. PrsmaEnergy expanded their knowledge and likewise allowed them to identify more strategies to optimize even further their systems.

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