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Peer-To-Peer Energy Trading: Representing the Dynamics of Energy Consumption, Production and Exchange

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Abstract

Nowadays we are witnessing a complete energy transition towards more sustainable sources. However, this process requires substantial adjustments of the current energy systems. One technology, that represents a potential support in this process is blockchain. One of its promising implementations could be peer-to-peer (P2P) energy trading, that has been addressed by many companies and projects globally. Nonetheless, there has been insufficient research performed on the aspect of adoption of such systems with relation to the potential users.

This work builds on a study performed with PowerShare (PSv1) platform that was developed in order to answer the question of adoption drivers and understanding of P2P energy trading systems. In this paper further aspects were addressed such as trust between peers in a large community, giving up control over energy data to the DSO (Distribution System Operator) and encouraging behavioral change through non-monetary incentives.

A P2P energy trading platform (PSv2) comprising of an application and a website was designed and low-fi prototypes were presented to five study participants. Based on feedback received we answered the relevant research questions, created design guidelines for similar platforms and drafted a potential business model together with suggestions for future research.

Keywords

behavior change; collective efficacy; P2P energy trading; Sustainable HCI

Resumo

Na atualidade, continua a observar-se uma transição energética para fontes mais sustentáveis. No entanto, esse processo requer ajustes substanciais dos atuais sistemas de energia. Uma solução com potencial para suportar este processo é a “blockchain”. Uma de suas implementações consiste no comércio de energia ponto a ponto (P2P), a qual foi abordado por muitas empresas e projetos em todo o mundo. No entanto, não existem resultados suficientes sobre o impacto da adoção de tais sistemas em relação aos já utilizados.

Este trabalho baseia-se num estudo realizado com a plataforma “PowerShare” (PSv1), desenvolvida para responder a questões relativas aos fatores potenciadores e à compreensão dos sistemas de comércio de energia P2P. Nesta dissertação, foram abordados outros aspetos, como a confiança entre os diversos intervenientes de uma grande comunidade, com partilha dos dados de energia pelos operadores da rede de distribuição (DSOs) e incentivando a mudança de comportamento por meio de incentivos não monetários.

Uma plataforma de negociação de energia P2P (PSv2) composta por uma aplicação e um sítio virtual foi projetada e protótipos de baixa-fidelidade foram apresentados a cinco participantes do estudo. Com base nas reações e comentários recebidos, foi possível responder às questões em investigação, criando diretrizes para o projeto de plataformas semelhantes e delineando um modelo de negócios, conjuntamente com sugestões para trabalhos de investigação futuros.

Palavras Chave

Mudança de comportamento; eficácia coletiva; comércio de energia ponto a ponto; Interação Homem-Máquina sustentável

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List of Abbreviations

AI – Artificial Intelligence

BM – Brooklyn Microgrid

DER – Distributed Energy Resources

DG – Distributed Generation

DLT – Distributed Ledger Technology

DSO – Distribution System Operator

EV – Electric Vehicle

HCI – Human-Computer Interaction

IoT – Internet-of-Things

P2P – Peer-to-peer

PBFT – Practical Byzantine Fault Tolerance

PoAc – Proof-of-Activity

PoET – Proof-of-Elapsed-Time

PoS – Proof-of-Stake

PoW – Proof-of-Work

PSv1 – PowerShare version 1

PV – Photovoltaic

SMILE – Smart Island Energy Systems

TSO – Transmission System Operator

VPP – Virtual Power Plants

1 Introduction

In the recent years the matter of more efficient energy use and increased amount of renewables in the global energy mix is becoming of higher and higher importance, forced by international laws and agreements addressing global challenges such as providing universal access to affordable, reliable and sustainable energy services [1]. Numerous companies and projects emerged from this need. One of the latter is the SMILE project, established under Horizon 2020 research programme [2] aimed at introducing new smart grid technologies in three different European islands. Presented paper intends to test a possible business model for one of the solutions tested in the island of Madeira (Portugal) in the scope of SMILE and therefore support its implementation in other promising locations.

Motivation

There are already a lot of strategies fostering the adoption of sustainable energy sources and Distributed Generation - i.e. small power generation units connected to the distribution network [3]. For instance, solar photovoltaic is a renewable power source with the highest growth rate in recent years due to decreasing costs, attractive incentives and feed-in tariffs in some places [4]. Distributed Generation is also a promising technology thanks to its scalability and adaptiveness to the demand, which is particularly valuable for remote locations such as islands.

On the other hand, there are certain barriers to the increase of DG that need to be addressed, such as e.g.: the intermittency of renewable energy sources that has to be tackled in order to provide stable power supply at all times, as it puts big strains on grids and increases fees for industrial grid users with high power demand [5]. On the consumers' side, the power demand curve is hardly ever smooth, usually presenting morning and evening peaks in consumption, adding up to grid stability issues. More efficient energy use can be handled either from the grid perspective (smart grids) or from the customers' side by improving the way energy is consumed i.e. demand side management. An ideal solution would be to lower dependence on a grid operator and local DSO (Distribution System Operator). Having own photovoltaic installation certainly lowers the amount of power purchased from an energy provider but it is still not popular and inexpensive enough for a lot of people to afford. There is also a question of what happens to the energy if it is not self-consumed by the owner of a system, when they are absent throughout the day or simply do not need the energy at the moment – it is obviously wasted unless stored in a battery or injected back into the grid. Moreover, in the current energy scenario, consumers are excluded from decision-making on where they buy their energy from. Most of the techniques implemented already are designed in a top-down manner, making it difficult for regular customers to improve anything without having a generation asset.

State of the art

Blockchain technology could take the load leveling one step further. It "allows storing transaction data in a decentralized fashion, meaning that the information is recorded and managed on a Peer-to-Peer (P2P) basis" [6]. Transactions between two parties happen automatically without an intermediator while verifying and saving all the processes in a chain, ensuring anonymous and reliable transfers.

This technology has the potential to change current energy supply systems “since it enables individual consumers and prosumers - i.e. people that produce, consume and store their own energy - to enter the energy market and buy/sell energy directly to each other without the need of an intermediary” [6]. With blockchain technology inclusive microgrids can emerge on community-level, enabling maximum renewable energy use by creating virtual pools, thus providing cheaper energy and helping DSO manage the grid better [6].

Proposed solution

Presented work is based on previous project performed in scope of SMILE at Madeira Interactive Technologies Institute – a P2P energy trading platform called PowerShare. It builds on results obtained from the first deployment of PowerShare [7], which was meant to assess users’ acceptance of energy trading in Madeira at a neighborhood scale, whether this could be a potential business model and gather feedback on blockchain adoption. It could be a particularly valuable innovation for the island of Madeira considering that since 2014 the prosumers there are not allowed to inject surplus energy into the grid due to power fluctuations and need to maintain a stable grid [8]. Starting from opportunities and drawbacks that emerged from PSv1, this thesis aims to take a step further in understanding the human aspects affecting the adoption of P2P energy trading systems.

Specifically, the main goal of this thesis consists in testing whether collective efficacy – a shared group’s belief that collective efforts bring collective benefits [9] - could be a potential driver to foster engagement of large communities in P2P energy trading. There is an abundance of literature on blockchain-based platforms however the findings focus on the technology itself and do not address the barriers towards their adoption, especially when scaling up the system. This work tries to explore further aspects like trust and technology complexity, which are often presented in the HCI (Human-Computer Interaction) literature as barriers towards the adoption of blockchain technology, and tests several strategies for fostering engagement in P2P energy trading.

Under this work a gamified mobile application together with a website were designed and tested with residents in Madeira. The Low-Fi prototypes were evaluated using both quantitative (survey) and qualitative (focus group discussion) approach. Results obtained helped to draw meaningful conclusions regarding the characteristics that engaging, large-scale peer-to-peer energy trading systems should have and facilitated drafting a business model for such platforms.

This paper is structured as follows: Chapter 2 presents a summary of related work on blockchain technology, peer-to-peer energy trading and eco-feedback technology, together with relevant business cases. This includes a description of the previous version of PowerShare and lessons learned from its deployment. The main research gaps are pointed out and the focus of this work is explained. Chapter 3 provides details of the proposed solution together with examples of the low-fidelity prototypes of both the application and the website. Chapter 4 describes the methodology used for testing the system, the results of which are elaborated on in Chapter 5 together with a draft of a potential business model for P2P energy trading platforms. Design guidelines emerged from the study and future recommendations are discussed in Chapter 6.

2 Related work

This thesis' scope clusters technology, psychology, design and other areas. Due to the topic complexity, there is not a single academic work focusing on this particular matter thus an extensive and multidisciplinary literature review was done in order to get a bigger picture and to better articulate the subject. For this reason, the present chapter collects contributions belonging to a variety of research areas and is structured as follows. Before presenting a selection of relevant existing business cases of P2P energy trading platforms, this chapter provides an overview of blockchain technology and its application in the energy sector. A review of previous work on eco-feedback technologies and sustainable HCI is also reported, followed by an overview of recent work addressing the human aspects affecting the adoption of blockchain technology. The chapter ends with the description of PowerShare version 1 (PSv1) and results from its initial assessment, which served as a basis for the development of the present work.

2.1 Blockchain technology

"Blockchain" has probably been the buzzword of the past few years, yet at the same time few people understand what it actually means and how this technology works. This subchapter provides a brief explanation of this term together with examples of its application in the energy sector and some relevant business cases.

Blockchain is a Distributed Ledger Technology (DLT) and should be considered as a digital ledger, a distributed database that allows for secure, immutable and anonymous transactions. In a blockchain network transaction data are shared, time-stamped and cryptographically secured from tampering, forming blocks that are then linked together into a chronological chain (thus the name), which consequently grows together with the number of transactions performed [10] (Figure 2.1).

The first and the most mature application of blockchain technology is Bitcoin [11], a decentralized, digital currency, created to disrupt the financial sector by establishing an alternative payment mechanism that allows for faster and cheaper transactions. In the traditional scenario, a central authority - e.g. a bank - is the only responsible for validating the transactions between parties and has to manage, process and securely store transaction data. The entity here serves as an intermediary, meaning that the system is centralized, and requires the payment of a transaction fee. Blockchain works in a different way, as there is no central authority, transactions are executed and validated directly by the participants in the network, which are also responsible for storing transactions data. The great advantage of such technology is that transaction fees are strongly reduced since third-party intermediaries are no longer required. Besides, the content of the ledger is public, since every user has a copy of transactions' list, and can be verified by network's members. This ensures transparency. Moreover, there is no need for a trusted authority to guarantee security, as every network member contributes to validation of the transactions by comparing their version of the ledger with others. Its decentralized nature makes it difficult to interfere with blockchain without a considerable number of users tampering with it at the same time. As mentioned before, it is also protected by cryptography, namely hash functions that are complex mathematical algorithms that allow only authorized users to decipher the transactions. Moreover, transactions can be executed automatically via smart contracts - self-enforcing pieces of software embedded in the ledger, defining the rules behind each transaction - which introduce changes in the ledger based on previously defined terms of agreement and, consequently, speed up the process.

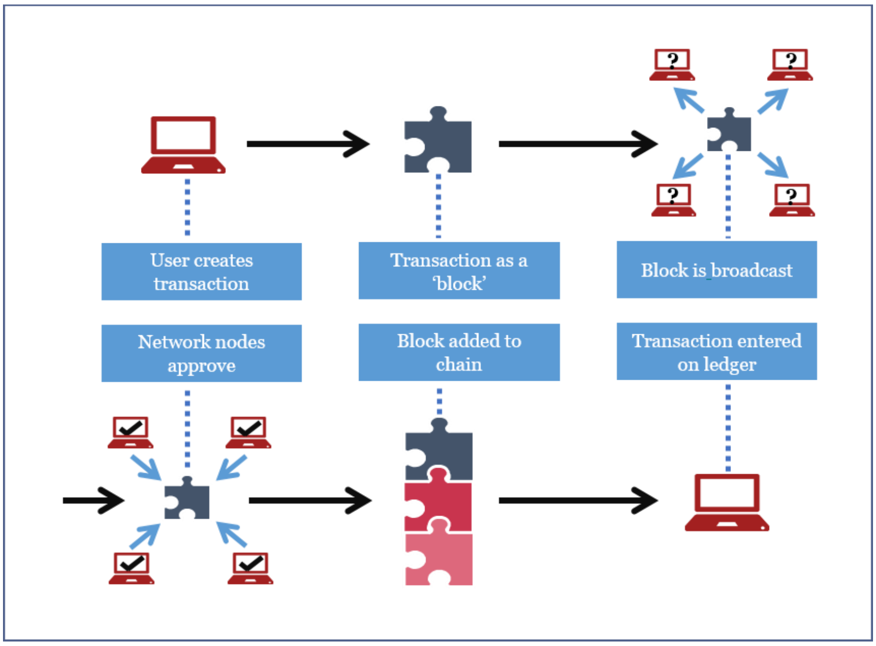

Figure 2.1 Simplified diagram of how blockchain works [12]

There are numerous consensus algorithms used to validate transactions. The Ethereum network - the most widely used in the energy sector - is based on a Proof-of-Work (PoW) algorithm, which requires the network members (called 'miners') to compete against each other to validate transactions by solving a cryptographic puzzle. As a reward for their effort (and computational power), they receive a transaction fee ([6], [10]). A strong disadvantage of this mechanism is a large amount of energy needed to process and validate the transaction, which grows together with the dimension of the network.

To solve this problem, other consensus algorithms have been developed. Among them, Proof-of-Stake (PoS) is probably the most famous one. In this mechanism each user's maximum mining power is relative to their individual coin ownership - the personal stake. Assuming that someone owns 5% of all the coins available, they could only mine up to 5% of all the blocks. Unlike PoW, this mechanism avoids potential attacks on the network, as it would be inconvenient for the miner to negatively impact the system where they hold a large share.

There are more consensus strategies developed, e.g. Proof-of-Activity (PoAc), Practical Byzantine Fault Tolerance (PBFT), Proof-of-Elapsed-Time (PoET) and others. The subject of different consensus algorithms is not relevant for this work and more detailed description can be found in [10].

2.2 Blockchain in energy

Interest in blockchain is spreading across several industries, including the energy sector, which is one of the areas that could be the most revolutionized by the potential of such technology. Fossil fuel fired power plants are frowned upon due to decreasing amount of non-renewable materials and harmful emissions generated. However, transition towards renewable energy sources is not immediate and faces numerous obstacles, from lack of proper regulations to high investment costs and intermittency of generation. For this reason, Distributed Energy Resources (DER) - e.g. small-scale renewables (turbines, photovoltaic panels) or combined heat and power systems - and independent microgrids could be the answer to better integration of renewables. A microgrid is a small network that can operate autonomously from the main grid, powered by local energy sources such as power plants, energy storage systems, renewable energy installations etc. An example of an independent microgrid are islands with no connection to the mainland. The biggest advantages of such systems are lower transmission costs thanks to exploiting local generation, self-sufficiency for remote locations and possibility of integrating renewables into the mix [13]. However, introducing new sources requires new solutions to manage them in order to ensure the stability and safety of supply. Blockchain technology appears to be promising for addressing some issues that current energy systems face. Its main applications in the energy sector are briefly described below.

Billing

As a database technology, blockchain has the potential of improving the current billing system. In the end, every person consumes energy in a different way, yet payment options are not well-adapted to customers. Individual energy profiles are still hardly known as on the energy bill there is usually a cumulative amount to be paid for consumed electricity. Knowing use patterns together with implementing micropayments or pay-as-you-go systems could bring significant benefits to both energy companies and customers. Automated billing adds value to current, rather old-fashioned systems [14].

Data management

As integrating renewables into the energy mix is challenging due to their intermittence, new technologies are required for such transition. More responsive grids that deliver electricity in a “smarter” way (thus the name - smart grids) are a part of this solution. They consist of the existing networks equipped with devices that communicate and manage supply and demand in real-time. For instance, smart appliances installed in a household could automatically turn off when the local consumption is high. In a similar manner, integrating energy storage technologies or electric vehicles (EVs) could help to shave peaks in production and conserve the surplus electricity. Part of the implementation of smart grids is providing customers with information and control over their energy use. This is typically done through smart meters installed in households and institutions. These devices collect and analyze energy data, enabling information transfer to and from a central system e.g. the energy provider. This is performed through various communication technologies depending on infrastructure available [15]. With blockchain such data transfer would be more reliable and secure, moreover, it would ensure transparency and the records would be harder to tamper with on both sides. What is more, it holds all sorts of information, in the case of energy - its origin and ownership, which was so far impossible to keep track of. It is worth mentioning that for energy utility having access to time-stamped data is highly valuable and provides them with the opportunity to improve their operations and offer better services. This strengthens competition between suppliers, offering customers a wider choice [10].

Carbon credit trading

Trading mechanism of carbon emissions was introduced by United Nations to reduce current heavy environmental impact of industries. Entities polluting more than their carbon credit allows for are fined unless they purchase more emission rights from companies that have a surplus of them. This carbon trading market currently involves a lot of players and assets verification processes take a long time. This requires multiple file transfers and makes certifications easy to tamper with. Blockchain technology introduced in carbon emissions trading could support the reliability of this mechanism and reduce the complexity of data transmission [16]. All information is be time-stamped and securely stored and the trading itself can be performed automatically via smart contracts [10].

Peer-to-peer energy trading

The rapid increase of distributed energy generation is an important issue nowadays and requires to rethink the traditional energy infrastructure. The challenges faced are not only technical e.g. matching power outputs and ensuring stable network operation. Regulatory changes regarding market liberalization are called for too. In a decentralized system new players (small producers) enter the electricity market and compete against big providers. Such competition influences the price of electricity as distributed generation units typically run on one fuel type and one unit of energy produced is more expensive than the one of a bulk provider. There are also shortcomings in policies such as who pays for upgrades of the grid that is used by numerous players.

Peer-to-peer energy trading supports decentralized grids implementation as it only involves two members of the network. It might be one of the most promising blockchain applications in energy sector explored so far [17]. The most popular platform used in P2P trading is Ethereum since it implemented the smart contract infrastructure. As mentioned above, in a blockchain application third party intermediaries are no longer required. Members of the network can buy and sell energy between them freely and in a reliable way. It allows every energy consumer to enter this marketplace enabling them to have better control over their consumption and providing them with better choice of the source of their energy. They can choose where they buy energy from and possibly get a better price, which is not the case in centralized energy systems. Prosumers with their own generation asset can now become a supplier and make maximum use of the energy they produce, selling the surplus or storing it for future use or for the DSO's disposal. The latter is particularly beneficial as such virtual pool of multiple charged batteries can secure grid operation and smoothen consumption peaks throughout the day, by providing stored renewable energy in critical moments, simultaneously guaranteeing uninterrupted supply. In this scenario system operators are not excluded (as in the case of e.g. banks in financial systems based on blockchain) as the energy still needs to be physically transferred by the traditional grid. That makes infrastructure owners (DSOs/TSOs) partners in a potential business model instead of a competition.

Including energy consumers in the market, where they usually do not have a "voice" and are limited in their supplier choice has numerous benefits. Local generation empowers community not only in regard to the energy itself but also economically and socially, as such a system cannot function without members' engagement. Naturally, it provides more diversified and secure electricity supply, but also results in price variations that depend on all market players. Additionally, prosumers being allowed to sell their energy, do not have to go through an official entity to do so, making it more profitable for them and for the buyers. This could encourage further investments in own generation assets of other community members, increasing the share of renewable energy in the mix. For the rest, there is still a choice of buying green energy at good price as blockchain is supposed to ensure traceability of where the energy comes from.

Grid flexibility

The intermittent nature of renewable energy sources requires the grid to be more adaptable. The load on the network can be significantly lowered if the surplus electricity is stored or directed where it is most needed. Blockchain technology introduces better coordination of energy sources and smarter energy management, by e.g. connecting consumer with a local producent. Another advantage stemming from flexible grids is dynamic pricing based on real transmission costs and defined by all market players [14]. Blockchain can facilitate these processes by handling large number of transactions between numerous participants and achieving a fair consensus.

Opportunities emerging from implementing blockchain in the field of energy are being explored by numerous start-ups that offer services revolutionizing the way energy is currently used and exchanged.

2.3 Existing projects

This subchapter introduces some of the start-ups testing some of the possible applications of blockchain technology in the energy field described above. However, the ones presented here are just a small sample of what already exists in the market. These case studies have been chosen because they are particularly relevant for this work and well represent the main applications of such technology, ranging from transparent billing services to demand response and grid flexibility services.

Brooklyn Microgrid (BM) [18] by LO3 is a project worth mentioning in this work, as it is in full commercial operation and is based on decentralized generation in communities where participants can trade energy between each other using the already existing grid. It was the first microgrid operating on a neighborhood level and based on blockchain. “BM connects local prosumers who own solar panels with consumers who want to purchase local green energy” [6]. At the core of BM there is an online platform, called *Exergy*, which serves as a marketplace for both parties and allows them to set their trading criteria by means of a mobile application (Fig. 2.2). Users can also exchange so called “energy tokens” that represent the amount of energy produced and are available within the community. In general terms, a token symbolizes a unit of value and incentivizes users to join and participate in some network or community - the *Exergy* marketplace in the case of BM. Within the network tokens represent ownership and serve as a currency to facilitate transactions and reward distribution. Tokens can be compared to vouchers for goods or other means of representing a certain commodity but recognized only by the entity issuing it (e.g. casino money). Digital tokens are cryptographic assets that run on an existing blockchain, such as Ethereum.

LO3 provides smart meters for their clients that gather energy data. Nevertheless, as the company strongly encourages network growth, devices issued by third parties can be made compatible with the BM system.

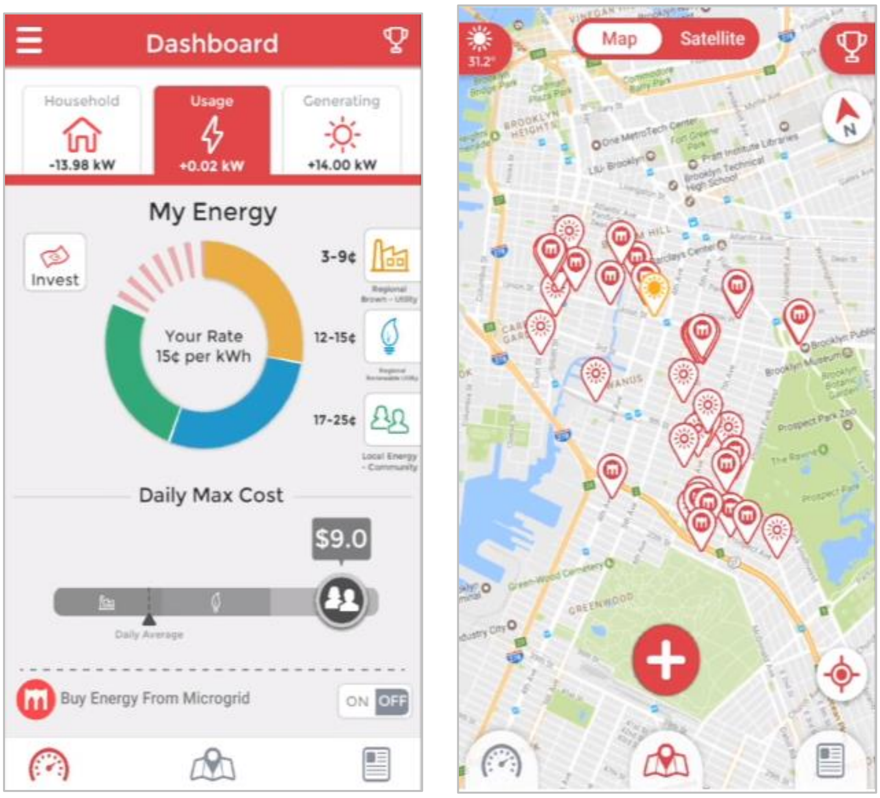

Figure 2.2 Brooklyn Microgrid Application - setting transaction criteria and map of prosumers [18]

In the distributed ledger provided by LO3 transaction consensus is automatic. Brooklyn Microgrid deployed blockchain for a wide range of energy market purposes, for instance:

- energy marketplace in an app,
- entire information system with proprietary ledger,
- hardware working as an “asset control switch” [19],
- EV charging enabled by tokens.

Brooklyn Microgrid leverages on sense of community, encouraging clients to vote for and invest in new solar assets locations in the neighborhood. Depending on users’ individual motivations to engage, they can choose between different features the platform offers. For instance, when buying electricity, the price they are willing to pay determines the kind of energy purchased. Preferred energy sources can be enabled/disabled and the mobile application then establishes the optimal price. If the user wants to go green, they are free to opt only for renewables. Another possibility is to shut off appliances at certain times to generate “negawatts” - units of absence of energy. In peak-production periods in the area revenue can be made by reducing consumption. The application includes a ranking, where the individual score and achievements are displayed and shared with the community. Data gathered from users’ smart meters and available in *Exergy* is shared with energy utilities, providing them with valuable information regarding consumption patterns of their clients [6].

Another example of blockchain application in the energy sector is **Grid+,** a US-based start-up implementing Ethereum domain. It works as an energy retailer and allows small and medium-scale consumers to access the wholesale electricity market. Grid+ solution comprises of software enabling cryptocurrency payments and hardware (the Smart Agent – Figure 2.3) that trades energy on behalf of the user. It leverages on retail and transmission costs together with more affordable local generation. Grid+ promises automated billing processes and as a consequence - lowering utility bills. The only cost involved in their model is for executing smart contracts responsible for recording payments on Ethereum network. Automation is at the heart of Grid+ value proposition, everything is managed by the "Smart Agent", which runs a simple AI (Artificial Intelligence) software predicting energy use and developed by the company itself.

Figure 2.3 Smart Agent Grid+ prototype [20]

The device is Internet-enabled and works as long as it has tokens purchased by the user i.e. reads the smart meter and pays for electricity bills. Energy trading decisions are made by Smart Agent without user's involvement. The only thing the customer needs to do is to ensure token availability by buying it. Further cost reduction promised by Grid+ comes from real-time payments performed in short time intervals, therefore the customers always pay for the amount of energy they use. Smart Agent connected to household appliances through IoT (Internet of Things) could manage user's energy demand by turning devices on or off depending on the market prices predictions and load curve. It is purely based on "install-and-forget" concept [20].

The Australian start-up **Power Ledger** offers a wide range of blockchain-based services for energy trading, environmental commodities trading and renewable asset ownership, namely:

- VPP 2.0 - a concept of Virtual Power Plants (VPPs), where battery owners can sell their stored electricity to the energy company to support peak shaving. The system automatically decides on purpose the battery should serve in the given moment, namely: frequency control, capacity control or as an ancillary service. With numerous batteries connected grid companies can use this distributed capacity as support for the grid in high-demand times.
- xGrid - platform for P2P energy trading. It supports local energy investments by enabling access to prosumers in the neighborhood. Excess energy is sold across the traditional grid and blockchain stores all transaction data.

- μGrid - a similar platform as xGrid operating on a smaller scale - in one building, for instance. It allows tenants of one apartment building to benefit from a common asset (e.g. solar PV panels installed on a rooftop), lowering their dependence on the grid. Each resident receives a share of the energy produced that they can use for self-consumption or sell to their neighbors.
- C6 - a tool for tracking renewable energy and carbon credits. It supports reporting procedures and automates them for plant operators and infrastructure owners by measuring energy generation.
- C6+ - a supplementary platform to C6 tool that serves as a marketplace for credit trading. Its main advantage is digitalization and simplicity, allowing less experienced players to join and trade immediately. Small-scale generation asset owners can sell credits easier and offer better price to their buyers than brokers [21].

A similar start-up connecting consumers and prosumers is **Drift**, which is taking up the role of an electricity supplier and providing their customers with choice regarding the type of energy they want to use and how much they are willing to pay for it. The start-up is currently undergoing a change regarding their business model, therefore the description presented below is based on information available at the moment of writing this document. The previous offer of Drift involved two plans: the Custom Impact Plan allowed customers to set a fixed price to offset their consumption with "renewable energy credits" whereas the Drift 100 Plan enabled them to purchase 100% of renewable energy at all times. There is no hardware involved but all transactions are encrypted in a ledger. Drift connects generators such as power plants and enterprises creating a network of local suppliers and in that way tracks where energy in the grid comes from. The costs for both providers and clients are lowered thanks to the direct connection between them without other intermediaries. Customers pay for ensuring that some electricity they use comes from renewable sources, supporting new investments in green energy where it is needed, however, Drift offers as well significant savings on electricity bill (up to 20%, as claimed on the website). It is based on blockchain combined with machine learning algorithms and AI that support forecasting the price of energy. They aim to provide their customers with transparent billing and comprehensive information on power mix and curb electricity prices, making green energy accessible for everyone [10], [22].

Another start-up focused on creating decentralized energy trading communities using blockchain is **Hive Power** [23]. These communities, called Hives, are independent energy trading communities regulated through smart contracts and composed of "Workers" and a "Queen". The workers are nothing but smart meters representing prosumers (households, institutions, storage systems). The Worker forecasts production and consumption of the prosumer and bids for the price of energy. Such simulations create most cost-efficient scenarios for the users that can interact in the system via the User App. The Queen, on the other hand, gathers and aggregates all this data and communicates it to the Hive. It handles the payments, also between the Workers themselves. Each Hive is set up by an Administrator (e.g. a DSO), which manages the community through the Admin App. A Hive "is able to interact with the external grid as a single entity, selling and buying energy and services".

Hive Power deployed two smart contracts on Ethereum: Beekeeper and Hive. The former allows for hive management and uses additional contracts for other functionalities, such as adding new meters (i.e. worker), whereas the Hive is responsible for a single hive. What distinguishes Hive Power system is high degree of modularity - from the smallest components (Workers) that create clusters up to the entire system. It is highly coordinated, so as when a new member joins the network, he is automatically placed in a Hive. The algorithms are designed to smoothen hive management and simplify processes.

"Hive Power provides an energy marketplace that encourages everyone to participate and benefit from it". They developed smart contracts responsible for trade and token management, deployed on Ethereum, an open-source ledger technology. At the moment of this writing Hive Power is working on a new offering as it had been announced that the project did not reach a minimal amount of funding to proceed with development due to Ethereum losing 30% of its value.

It is evident that blockchain technology can bring numerous benefits to the traditional energy sector and there is no doubt that changes are really needed, given the recent global push for more sustainable services. In this scenario, one of the most promising applications of blockchain technology in the energy sector seems to be peer-to-peer energy trading, which is being tested all over the world by several companies and start-ups like those presented above. Successful deployments of some solutions prove that this can be a milestone in the transition towards decentralized and inclusive energy markets. However, behind every prosperous start-up there is one that failed, due to different reasons. These reasons still need more exploration to ensure a better blockchain take-up in today's world. Naturally, obstacles faced are highly dependent on local regulations, culture, financial aspects and technology shortcomings. However, despite much work addressing the technical and regulatory aspects related to DLT for P2P energy trading, our understanding of the human aspects affecting the adoption of these systems and technologies is still minimal. This work tries to make the most out of available literature and similar projects in order to shed light on these barriers and define a set of guidelines for designing P2P energy trading systems.

2.4 HCI for motivating pro-environmental behavior

P2P energy trading has the potential to radically change the traditional energy infrastructure, challenging the way energy is perceived and used.

Understanding people's perception of energy for promoting pro-environmental behaviors is a fundamental topic of interest for Human-Computer Interaction (HCI) research, where a lot of work has been done, particularly in regards to eco-feedback technologies (EF) - "i.e. the technology providing feedback on behaviors with a goal of reducing environmental impact" [7].

According to Froehlich et al. [24] "Eco-feedback technology is based on the working hypothesis that most people lack awareness and understanding about how their everyday behaviors such as driving to work or showering affect the environment".

Introducing such an innovative concept as peer-to-peer energy trading requires understanding how people use and perceive energy. Research on eco-feedback brings relevant insights into this work and can support implementation of such systems by making them attractive for different types of customers. As our goal is to encourage more sustainable behaviors, appropriate methods need to be used to inspire people to make an effort and change their habits.

EF leverages on the motivations that drive people to modify their actions. There are several theoretical models of pro-environmental behavior presented in the literature, among them, the Rational Choice Model and the Norm Activation Model - which are the most commonly used [24] - were considered for designing the final solution proposed here. The Rational Choice Model is considered as “rational-economic” as it is based on an assumption that people get involved in actions that are economically rewarding. It is hard to deny that the strongest motivation for lowering energy consumption is saving money on the bill [25]. Besides economic benefits other aspects, such as comfort or convenience (e.g. time saving), can act as incentives according to such model. Some of the existing P2P energy trading platform center their offering on such model (e.g. Grid+).

On the other hand, the Norm Activation Model speculates that personal drivers such as social recognition or acting according to one’s beliefs can be a motivation to change behavior. An example related to sustainability is making choices that will positively affect future generations such as opting for green energy - a pro-social, altruistic behavior. Choosing an adequate model strongly depends on the target audience of the end product, what assumptions we prefer to take in the design phase and other solution-specific aspects. This then decides about what will be the core of the reasoning – how and what kind of data will be presented in order to encourage positive changes.

Research on EF also provides some important insights on how to display energy related data and suggests a set of motivational techniques that can be used to foster behavioral change. According with Froehlich et. al [24], some relevant aspects to consider while designing an EF system are:

- Information – as described above, eco-feedback is based on the assumption that people are not aware of their consumption patterns, therefore providing them with energy data that is presented in a clear and attractive way, at the right time, is the appropriate trigger. There are numerous papers where authors tried to articulate specific design guidelines for encouraging energy conservation and more sustainable lifestyle. As complex as this task is, it is known that a good eco-feedback system provides “multiple options (e.g., for time periods and comparisons), [is] updated frequently (daily or more), [is] interactive, and/or capable of providing detailed, appliance-specific breakdown of energy usage” [26]. Users in general like having a choice of what kind of data they see (monetary or CO_2 savings, kWh etc.), explore the consequences of their actions in real-time [25], and act on them, for instance by shifting the load when seeing a peak in consumption [27].
- Goal setting – This strategy sets a certain threshold to be achieved by the user, that is constantly reminded of the gap between desirable state and current moment. Goal setting for energy conservation has been evaluated by Becker [28]. The results proved that an objective that presents a significant challenge, together with energy feedback can help conserve more energy compared with “average” groups. Having a defined target keeps people persistent and creative at finding new ways to achieve it [24].

- Rewards/Penalties – Studies show that "...people are motivated to avoid punishment and to seek rewards" [29]. Together with incentives/disincentives (coming before a certain behavior) these strategies are proven effective for motivating pro-environmental actions. It is relevant that the reward should follow a target behavior "as closely as possible" [24]. They do not need to be monetary, like e.g. in computer games - points. Users can just as well receive a non-monetary gratification for completing a task that reinforces the feeling of doing something good, as shown in [29], [30].
- Comparison – Both self and social (between different players) comparison are proved to be effective strategies in encouraging behavioral change. People want to evaluate themselves and keep track of their progress. This motivates them to further improve and gain more knowledge on a particular topic [29]. Social comparison helps the users place themselves in a bigger context, e.g. a neighborhood, and understand their habits with respect to a given environment. However, this is a tricky strategy as it is impossible to predict how one will behave with respect to the average, e.g. research studies found that even though "above-average" users have space to improve and conserve, a "boomerang effect" might occur for the ones below average, thus they would consume more [29].

Eco-feedback systems are often implemented in a gamified form and provided through mobile and/or web applications. Studies on gamification design show that intrinsic rewards are valued more than extrinsic, especially when user is mastering a certain skill step by step, all by himself [14]. Based on Xu [14], gamification can be defined as "the use of game design elements in non-game contexts". Gamification is often implemented in fields like language learning, fitness, self-improvement or task management, and has been applied to energy conservation as well.

According to McGonial (as cited in [31]) games create positive emotions and kind of stress ("eustress") that makes us productive and supports achieving goals in an entertaining way. Use of psychology in designing persuasive technologies can strongly benefit from gamification strategies. As valuable as intrinsic rewards are for users, extrinsic ones such as points, badges and rankings are the reason game-like platforms are very popular nowadays.

Designing a user-centered solution requires adapting it to different kinds of audience. It is evident, that some people enjoy playing with different features and competing or checking their score regularly, while others have no interest in such activities or simply do not have time for them. Despite strong focus on effectiveness of competition among users for motivating behavior change, the aspect of collaboration cannot be neglected. Pursuing a common goal with other members of a community is often mentioned as encouraging [32]. Slavin et. al [33] reports that "because it is difficult for any individual to increase his or her own rewards acting alone, there is a strong motivation to socially reinforce others for behaviors that help the group attain its goal." This study shows that a common objective can strengthen conversation between members of the community and motivate them to support each other. On the other hand, there is research proving the opposite effect of group feedback and goal setting for energy conservation [34]. However, the intervention implemented in this study [34] was based on one group contingency type, in a very particular environment - an office, where certain tasks need to be performed regardless of the energy use. On the other hand, in two works of Kotsopoulos et. al ([35], [36]) based on research in an office environment, it has been shown that for some employees it might be promising to be a role-model for others and set positive examples. Participants in that study also believed that "in the end only collective actions will have a really deep impact" and that competing between users has a small potential in this setting [35].

HCI research on blockchain technology

Understanding the barriers behind the blockchain technology adoption is a considerable challenge this work faces. In order to design a solution that would successfully introduce blockchain to a wider audience, it is necessary to understand what obstacles need to be overcome. Some main insights from research on blockchain from the HCI perspective are presented below.

An important aspect which needs to be mentioned in the presented work is trust in relation to blockchain technology. DLTs are considered "trustless", as there is no central trusted authority and procedures are transparent, anonymous and encrypted. However, this technology introduces new kinds of interactions and it raises a challenge of how to communicate this reliability to the end user. Most research done on this topic focuses mainly on Bitcoin and cryptocurrencies and there is little information available about trust in P2P energy trading.

Based on a study conducted by Sas et. al. [37] three types of trust can be distinguished in relation to interactive systems: technological, social and institutional. Technological trust is linked to e.g. need of implementing a technology to improve task performance or perception of its usability and user's skills and motivations to use it. Level of trust between parties in the network is defined as social trust. Institutional trust refers to regulations and organizational structure of the technology.

Sas et. al [38] explored the topic further by conducting a study among Bitcoin users in Malaysia and gathering their feedback on various aspects of trust in relation to cryptocurrencies. It identifies certain challenges this technology faces but also adoption drivers that could support its implementation. Outcomes most relevant for this work are presented below:

- **Decentralization of technology** - results showed that people generally appreciate avoiding an intermediary, whose honesty they cannot fully rely on in the case of financial institutions, such as banks. Another argument in favor of Bitcoin was much quicker (instant, in fact) money transfer compared to ordinary banking systems where authorization processes can take days.
- **Lack of regulation** - blockchain system is not regulated by any entity, allowing members of the network for unlimited transfers, which is considered an advantage. Users enjoy being free to handle their finances without any restrictions.
- **Transparency** - public knowledge on all transactions performed in the network is valued by the members. Every process can be tracked in the blockchain.
- **Dishonest parties** - trading with anonymous peers represents a significant risk of being cheated on in transaction. Research shows that such situations take place in blockchain networks.

Distributed Ledger Technologies are a relatively recent invention compared to regular payments systems. Their complexity might seem discouraging for people with limited knowledge on cryptocurrencies. This is also where some of the distrust mentioned above stems from - lack of understanding on how the technology works leads to mutual suspicion between buyers and sellers. Moreover, reputation surrounding blockchain technology and bitcoin, often linked with black market activities, negatively affects its adoption [38]. It may seem that sophisticated, tamper-proof algorithm should not raise particular concerns regarding security. Lack of central authority involved lowers the possibility of a human error occurring. Trading takes place between anonymous parties and there is no possibility to verify someone's honesty. However, apart from trusting the technology itself, members need to trust each other within the community.

Design implications of the elements mentioned above include providing a list of all transactions performed. The user should have access to their wallet at all times with a clear overview on its status. Moreover, all information regarding the technology should be clear and easy to understand to avoid confusion and discouragement. The feature that confirms the user's identity and honesty is connecting the account with their smart meter's ID - this data is stored by the energy provider and should prevent potential fraud.

2.5 PowerShare v1

It is essential to point out that this work builds on results from previous version of PowerShare (PSv1), which was created in the scope of a bigger undertaking – the H2020 SMILE (The Smart Islands Energy System) project [2]. SMILE comprises of three large scale pilot projects located in three European islands, namely Madeira (Portugal), Samsø (Denmark) and the Orkneys islands (Scotland), and aims at testing different smart grid technologies based on the characteristics of the three demonstrators. Among them, Madeira is a very challenging use case because its electrical grid is completely isolated from the mainland. Increasing the share of renewable energy in the energy mix is one of the goals of the local DSO, nevertheless, the unstable nature of renewable sources (especially solar) is putting strain on the local grid, causing frequency and voltage fluctuations. For this reason, since 2014, prosumers - i.e. someone that both consumes and produces energy - are not allowed to inject excess production into the grid. Since Madeira receives yearly a lot of sunlight, one of the solutions tested in the scope of SMILE includes upgrading selected domestic photovoltaic installations with Battery Energy Storage Systems (BESS) in order to maximize self-consumption from solar PV. PowerShare draws on a scenario where several small installations are equipped with a BESS. In such a scenario, P2P energy trading becomes feasible and has the potential of providing the DSO with a virtual pool that can be used to maintain the grid stable.

For locations like Madeira P2P energy trading could be truly valuable for all parties involved. On one hand, prosumers could stop wasting excess energy and inject it back to the grid - what is currently not possible due to safety reasons. This would help them monetize their generation assets and result in increased share of renewable energy in the mix. Such distributed energy infrastructure has the potential of further improving the quality of supply and limit energy losses, since the electricity is generated and used locally, instead of being transmitted across great distances through the grid. This brings further benefits for the DSO, as the maintenance costs decrease. Involving prosumers in the energy market could support the grid stability as well, resulting in a smoother load curve and improved operations.

PSv1 has a more technological focus and attempts to address some shortcomings that can be found in related projects implementing blockchain technology for P2P energy trading, namely cost of fee, scalability and energy consumption.

Despite the fact that the main goal of PowerShare v1 was addressing the technical issues related to the use of DLT for P2P energy trading, it also provided some insights on the human aspects affecting the adoption of such technology and P2P energy trading in general.

The deployment of PSv1 took place in September 2018, involving 9 families of prosumers living in the same neighborhood in Funchal (Madeira). At the core of PSv1 there was a mobile application which, using real production and consumption data collected through smart meters installed in each household, simulated energy trading between members of the community. Through the app, users were given control over their energy (they could manually set buying and selling criteria) and received feedback on their energy usage patterns. The detailed description of the system architecture can be found in [8].

The PSv1 application (Figure 2.4) comprises the following 6 main sections:

- **Home** - The main screen where current consumption and production data is provided. Studies show that users appreciate real-time feedback, as it helps them adjust their behavior immediately and shows immediate consequences of their actions. It also provides a brief summary of transactions performed on that day, battery status and displays current share of renewable energy on the user's overall weekly consumption.
- **Transactions** - A feature where users can adjust their trading criteria or opt for automatic ones (and immediately start trading). Such choice was provided in order to test the principle of "install and forget" and observe whether the users would interact with the settings. In the case of choosing the manual mode, they need to set manually the price per kWh of energy (fixed by them or tied to user's power consumption rate) bought and sold. Here a full list of transactions performed is displayed.
- **Historical data** - In order to help users understand their energy behaviors historical consumption and production data is provided in this feature. Breakdown of production and consumption data is highly detailed and interactive. According to literature on eco-feedback technologies historical feedback for self-comparison is very effective in triggering positive behavioral changes.
- **Wallet** - This feature serves as an overview of the current IOTA balance and managing payments.
- **Ranking** - Another type of comparison proved efficient in HCI studies is social comparison. The "Ranking" feature was designed with this motivational technique in focus. It displays a list of users according to the share of renewable energy in their overall consumption. Every week ten

users with the highest score are presented, allowing the user to place himself in the context of the community and compare his score with one of the other members.

- **Settings** - This component was designed for accessing and managing the user's account.

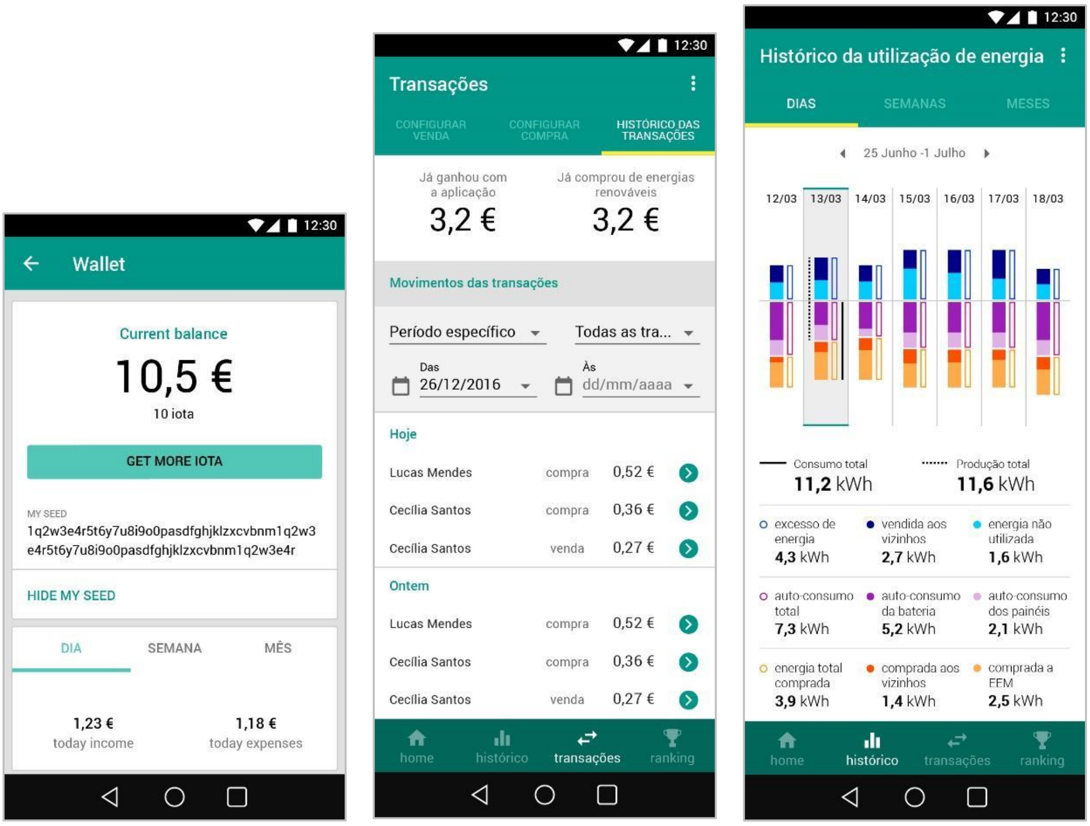

Figure 2.4 PowerShare app v1 (wallet, transactions, historical data) (2018) [8]

Results after the one-month deployment provided the research team with some interesting findings in terms of users' engagement. Specifically, as reported in [6] PSv1 deployment has helped to shed light on aspects related to 1) motivations for engaging in energy trading; 2) barriers towards the adoption of the system; and 3) provided several interesting design insights.

Motivations for engagement

Results from the study suggested that the economic rationale (Rational Choice Model) is not as motivating as expected. Indeed, since the amount of energy traded between participants in the study was quite limited, P2P energy trading was not considered as a business opportunity. However, participants found the sense of being part of a community much more motivating. Another motivation for engaging with the system can be explained by the norm-activation model. People experienced intrinsic reward - dealing with a solution based on a "new and advanced technology" made them feel like experts - and personal satisfaction - they felt they were doing something good for the environment. Even more valuable was the transparency of the system, i.e. the opportunity to access to real-time consumption and production data, and the consequent fair and transparent billing system [7].

Barriers towards the adoption of DLT for P2P energy trading

This study addressed several of the barriers towards the adoption of DLT mentioned in the HCI literature, especially issues related to trust, privacy and technology embedded complexity. The lack of a trusted central authority did not seem to be a major issue for participants of the study, as they emphasized, they knew each other well enough, living in the same neighborhood. Contemporarily, having access to all transactions data increased trust in the technology and, interestingly, did not express any serious privacy concerns. Indeed, despite two participants did acknowledge that the information provided on the weekly ranking could expose people to some risks, they clearly stated that it was not a concern for them. As mentioned in literature, there is a general lack of literacy on DLTs and people are quite suspicious about them, especially when it comes to cryptocurrencies. Participants in the study reported several concerns about the use of cryptocurrencies as a mean of exchange for energy, in particular the lack of market regulation, their volatility (people doubted whether a virtual coin could well represent the value of energy) and the risk of losing money when exchanging fiat currencies (government issued, regular currencies in use by institutions) for cryptocurrencies.

Design insights

Results from the study showed that social-comparison is an effective strategy to keep users engaged. The weekly ranking was the most popular feature among participants in the study, suggesting that competition was a strong driver for being active in the community. One participant also said that he would be willing to change his consumption patterns in order to increase the percentage of consumption from renewable and thus improve his performance. Another finding worth mentioning is the lack of interest from some family members. It was indeed found that it was almost always the householder, the one that manages the family's expenses, the only person engaging with the system. At the same time, energy feedback provided through the app fostered participants curiosity, resulting in increased understanding of their energy usage patterns willingness to modify their behaviors. In this regard, it was found that all participants initially selected the automatic mode and, only after going through a learning period, some of them finally started to manually modify the trading criteria. Despite most of the participants kept using the automatic mode for all the duration of the study, when asked, they reported to feel reassured by having the opportunity to manually modify the trading settings. In terms of data presentation, it has also been pointed out that having data presented in a more visual form was extremely valuable and did help them to better understand their habits. Together with the app, participants were provided with a weekly report sent via email, showing a summary of their production, consumption and exchange performance. Participants did appreciate such addition, which was reported to be a quick and alternative way to access energy feedback. Some of them, also suggested to “expand” the system by providing access to energy data via a website.

2.6 Main Findings from the Related Work

This work builds on some shortcomings noticed during desk research phase regarding people’s perception and adoption of blockchain technology, behavioral change and community-based strategies for energy management and conservation, as well as results from the previous empirical study performed on PowerShare. The present work does not address the technical aspects of the platform (its architecture and performance). Instead, it leverages on the human aspect involved in P2P energy trading, trying to provide a better overview on how users interact with such system and draft a more user-centered approach towards its design.

Literature and results from the deployment of PSv1 shed light on some aspects of HCI for P2P energy trading. Few strategies that could be implemented to design more engaging P2P energy trading platforms, as well as issues that still need to be investigated, were identified and are listed below.

Automation and technology complexity - It is evident that DLTs represent a new kind of technology, whose complexity can be intimidating for people less familiar with digital solutions. The question is whether full understanding the technology behind the system is necessary to use it. There are numerous actions we undertake on a regular basis, often without a thorough comprehension of how these processes work such as banking transactions, use of medications, driving a car, but we still trust in them. Therefore, there is a possibility that blockchain technology could be one of them - a common solution everyone uses without fully understanding it. The challenge is to present it as a trustworthy and simple system, without oversimplifying or complicating it. Drawing from the reviewed blockchain-based projects, it emerged that high degree of automation is a popular practice to reduce the perceived complexity of the system. It was indeed concluded that the majority of existing projects rely on the “install and forget” principle, that is to say, they do not require a lot of attention from the user nor encourage them to interact with the system. Existing schemes leverage mainly on convenience of trusting the technology. Customers do not need to change their behaviors or control transactions once the trading criteria are set. Nonetheless, the deployment of PSv1 showed that participants were curious about different transaction parameters and wanted to explore them themselves, suggesting that full automation might be less favorable in users’ perception. The results of the last year’s work on PowerShare support the idea of emphasizing human influence in more efficient energy use, namely people appreciated being able to modify the trading settings whenever they wanted or set their own criteria (price, trading times). Despite general lack of literacy on energy and often lack of interest in exploring this topic, participants wanted to feel that they have control over their system if needed. For this reason, an option of setting criteria manually should be available, even though it should be kept as simple as possible and limited to a few parameters in order to increase perceived ease of use.

Data presentation and learning support - Studies show that users prefer having detailed energy feedback presented in a visual form with simplified wording to increase ease of understanding. At the same time, participants wanted to learn more about their energy habits and explore their options freely, therefore providing more information could keep them engaged. Moreover, findings show that people are willing to learn and explore the available options so the amount of data should not be too limited in order to support them in their research and encourage to study such topics.

Social pressure - In PSv1 the ranking of best performing members was the most popular feature. Study participants admitted that they enjoyed comparing their score to others and they were willing to do more to get better results. Therefore, competition could be another aspect that keeps users active and push them to engage in energy trading.

Norm Activation Model vs Rational Choice Model - P2P energy trading is often presented to potential users as a business opportunity - as it is usually associated with monetary transactions, people might expect significant savings. This is usually not the case for P2P energy trading and not the main goal of it either. First tests of PSv1 proved that participants expected it to be more profitable. Leveraging the Rational Choice Model when designing such a system will most likely not turn out effective for fostering users' engagement. Moreover, findings show that some participants were willing to get involved only to help their community. This proves that Norm Activation Model could be more applicable for P2P energy trading. Results from previous studies suggest that stressing the importance of belonging to a community and contributing to its benefit might be more advisable for designing an engaging platform than leveraging on monetary incentives.

The above-mentioned aspects were sufficient to provide an overview on what has been done so far in the area of HCI for P2P energy trading. However, there are still some research gaps that need to be addressed. The ones relevant for this work are described below.

Scalability problem - In the previous study of PSv1, sense of community appeared to be the main driver for engaging in P2P energy trading. Participants in the study claimed they would be willing to trade for free with their neighbors because they know and trust each other. But what happens when scaling up the system? Despite existing solutions and technology adaptiveness, it is unknown whether this mutual trust would prevail with growing number of members in the network. For instance, when involving a larger community, e.g. at the city-level, trust in peers might decrease - since people will not know who is the user they are trading with - which consequently could negatively impact the sense of being part of a community. A workaround would be "de-anonymizing" community members but, in that case, privacy concerns may arise. Therefore, identifying a strategy to foster a sense of community among unknown members is very needed.

DSO involvement - Drawing from the available research, it can be concluded that lack of central authority is usually well-accepted by users of blockchain applications. However, when designing a P2P energy trading platform, the DSO cannot be completely ignored. This, not only because the system requires the use of the existing grid infrastructure, but especially because having the DSO as a further actor involved in the management of the distributed energy infrastructure would be quite beneficial to ensure the quality of the supply. As VPPs and grid flexibility are common use cases of blockchain in P2P energy trading, it is necessary to address user's perception on the amount of control they are willing to give up for the energy provider. If the DSO manages a pool of household batteries, it is not only limiting the residents' usage over their storage but also holds a great tool for power load management. How can people ensure that it is being used according to its purpose and for the benefit of everyone? This can be a promising solution for maintaining grid stability, especially in isolated locations, like Madeira, but more attention needs to be dedicated to understand whether residents would be willing to trust the DSO and let it dispose of their storage units.

Inclusive technology - Another issue that is often brought up in relevant literature is the non-inclusive nature of technologies aimed at encouraging energy conservation. There is a general lack of sources on this matter for P2P energy trading platforms, however results from the test of PSv1 leads to the same conclusion. Namely, it is usually the householder taking care of the energy bills and involving with any solutions that foster more sustainable actions. How to involve all family members in energy trading and push them to adopt more sustainable behaviors is still an open question.

2.7 Hypotheses and Research Questions

Based on the above-mentioned findings and with the goal of addressing the existing research gaps, some hypotheses to be tested in PSv2 were proposed:

H1: **Leveraging collective efficacy increases sense of community among anonymous members in large communities and motivates to engage in P2P energy trading** - The tests of PSv1 took place in one neighborhood in Madeira, thus involving people that know each other, but the future goal would be to create a model that could be successful in different locations and wider areas. Scaling up the system can be challenging not only from a technological point of view, but also from social or operational standpoint. In larger communities trust between members decreases as they don't know each other. We assume that if people feel like they belong to a community and thus, they depend on each other, they would be more likely to engage in P2P energy trading. Our hypothesis is based on the occurrence of "collective efficacy" - defined as e.g. "perceived probability that collective effort will result in collective accomplishments" (Shamir as cited in [9]). PSv2 aims to test whether working for a common goal can make people more engaged despite the lack of other personal bonds. Results of an action might not only aggregate when performed by 20 people instead of one person, it can also work as a motivation to stay involved or join a certain group in their efforts.

Trust in members of a community could serve as a strong foundation for designing a peer-to-peer energy trading platform, especially since a central authority is lacking in this case. Fostering pro-environmental behaviors might be more challenging for more populated areas but, on the other hand, the collective effort of a high number of people has a stronger impact. This hypothesis explores whether a proposed model of leveraging on belonging to a community for P2P energy trading could function on different scales.

H2: Norm Activation Model can be used to engage people in P2P energy trading and undertaking selfless actions for the greater good - Deviation from the Rational Choice Model has not been sufficiently explored in P2P energy trading platforms, despite the fact that savings in this scenario are insignificant. It is not economically attractive to get involved; therefore, other motivations must be fostered. Norm Activation Model could be a potential strategy for promoting engagement and sense of belonging to a community, thus supporting it and acting for the common good. The hypothesis here is that people will act in a less self-centered manner if confronted with the opportunity to do something valuable for their neighborhood, e.g. help ensuring grid stability by giving up control over their batteries to the system operator.

H3: **Gamification of P2P energy trading platforms can make them more inclusive and attractive for different audiences -** Based on previous findings, we hypothesize that gamification is an effective strategy for fostering engagement in P2P energy trading. Different challenges might involve not only the youngest family members but all household residents. Moreover, being part of a community challenge may make the users feel obliged to participate and show their contribution.

This work aims to test some of these remarks and further explore questionable matters. A platform was designed according to previous work done in these areas, addressing the main hypotheses stated regarding such systems. The main driver behind this work was the lack of understanding of the human aspects affecting the adoption of DLTs for P2P energy trading. The main goal is to address this issue and develop a set of design guidelines that could support implementation of future P2P energy trading platforms.

In order to test our main hypotheses and explore further those aspects that are still poorly understood (e.g. trust, privacy, technology embedded complexity), we elaborated the following research questions:

RQ1. Is collective efficacy a driver to foster a sense of community between unknown peers?

RQ2. Would a reward system based solely on encouraging environmental protection and collective effort be motivating enough to engage in P2P energy trading?

RQ3. Is gamification a promising design strategy for fostering engagement in peer-to-peer energy trading?

RQ4. Do members of a community trust each other despite not knowing who is contributing to a challenge and who's not?

RQ5. Are people concerned about sharing their energy data with other members of the network or the energy provider? Would they be willing to trade anonymously?

RQ6. Is the full understanding of the technology necessary for its adoption? Are there any concerns regarding blockchain and cryptocurrencies?

These questions aim to further elaborate on hypotheses and help address the main aspects of the PSv2 study.

3 Proposed solution

This chapter describes in detail how we approached the gaps in the area of HCI for P2P energy trading, building on successful strategies and steering away from less favorable ones, in order to create a set of guidelines for designing such systems. Conclusions drawn from testing of the prototype presented below should serve as a basis for future work of designers facing a similar challenge.

The system was designed based on literature and relevant projects. The platform offers two different channels: the application and the website, which are described in detail respectively in 3.1 and 3.2.

In order to assess Hypothesis 1, a set of features was proposed to gather feedback on. One of the main ones is “Challenges” that are divided into two types: community and individual. Only the latter are optional for a user to join. The community challenges are tasks that are performed by all members of the network. The goal of this strategy is to evoke the feeling of belonging to a community and introduce social pressure. The users should feel that their contribution matters and be motivated to cooperate with their peers to reach a common goal. This feature should demonstrate that results from joint efforts greatly exceed the ones from individual actions. Furthermore, it aims to explore other motivations than financial ones for engaging in P2P energy trading (Hypothesis 2). Helping others and selfless behaviors are in line with Norm Activation Model, that is based on the assumption that “moral or personal norms are direct determinants of prosocial behavior” [24]. The community challenges have different goals depending on the time of day and actions to be undertaken, but all aim at better energy management and load balancing. We distinguished three kinds of community challenges: “Evening savings” challenge relates to peak shaving i.e. avoiding sudden consumption increase during peak hours (usually in the evening). “Lowering consumption” implies energy conservation throughout the whole day to keep consumption below a certain level and “Local and green”, which is a challenge aimed at motivating users to consume local generated renewable energy – and reaching a 50% daily share of it. Such challenges were designed to address different motivations people might have for engaging in more sustainable actions, e.g. caring about being “green” and using renewable energy. Additionally, they could apply to different lifestyles and age groups - research shows that children involved in household energy conservation remind their parents to turn off the lights etc. The application is designed in a gamified way (testing Hypothesis 3) to make it entertaining and possibly inclusive for all family members. UI and game dynamics have been designed based on the analysis of existing fitness applications.

However, for the most competitive users, the system offers three main individual challenges among which one is to choose: (1) give up control over their battery to the DSO. This challenge was meant to test whether people would be willing to support the operations of the energy company by not having access to their battery (more altruistic behavior); (2), allow the DSO to have access to the user’s energy data - having such challenge is supposed to explore whether sharing detailed energy data with the DSO would raise any privacy concerns. (3) Additionally, “Challenge another user” offers users with the opportunity to engage in a one-to-one challenge.

The users receive points for their efforts. After reaching a certain limit (new level) a piece of information about energy and sustainability is provided as a reward. It is necessary to emphasize that all points users gather add up in the cumulative score of the whole community. An individual person cannot collect points just for himself - this is another choice aimed at stressing the value of the joined effort. For the same reason, the reward system is based on the dependent group contingency model, indeed the rewards (“tips”) for reaching a new level in the game are provided to everyone within the community. According to literature, dependent group contingency is applied when “the same response contingencies are simultaneously in effect for all group members, but are applied only to the performance of one or more selected group members” [39]. Providing rewards in the form of “information” serves to move the focus from financial benefits and, contemporarily, is meant to support learning and provide the users with knowledge they did not have before.

One of the main goals of this study was to gather feedback on the above-mentioned hypotheses and shed light on further research questions that emerged during desk research. The platform was separated into two channels - the application and the website - in order to make an easy distinction between fostering engagement through collective actions and supporting learning. The gamified application should keep the user engaged and entertained while the website serves as a promotional medium and provides detailed energy data. Such division was decided upon in order to avoid information overload and draw a clear line between “action” and “analysis” or “playing” and “learning”. This solution diverges slightly from the previous version of PowerShare, where users received energy feedback through multiple channels - the mobile application and a weekly report sent via email. In this study, it was decided to provide two different channels serving different purposes.

3.1 Application

In order to provide a comprehensive description of the application and the design process, it is presented below in the form of user journey from the moment of registration.

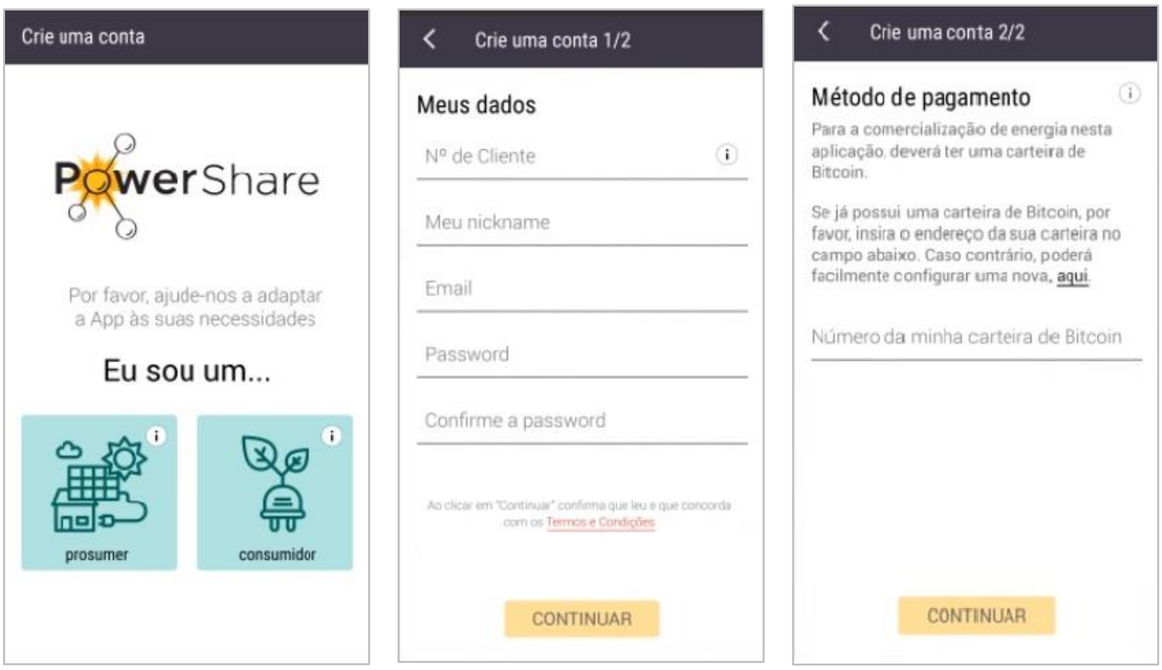

Figure 3.1 Registrations screens

When registering a new account (it is necessary to have one) the user needs to choose whether he/she is a consumer or prosumer (Figure 3.1). In the case of the latter, some characteristics of their generation asset need to be provided, e.g. battery capacity. The last registration step is adding a Bitcoin wallet number or setting up a new one. Bitcoin was chosen purely for design purposes as it is the most well-known cryptocurrency and people would immediately understand that the platform uses them for payments.

Home screen

After successful account creation, a home screen opens (Figure 3.2). From here, the user can access other features of the app (bottom bar), his/her profile and see notifications (top bar). When the user opens the application for the first time a short tutorial guides him through the options and describes them briefly.

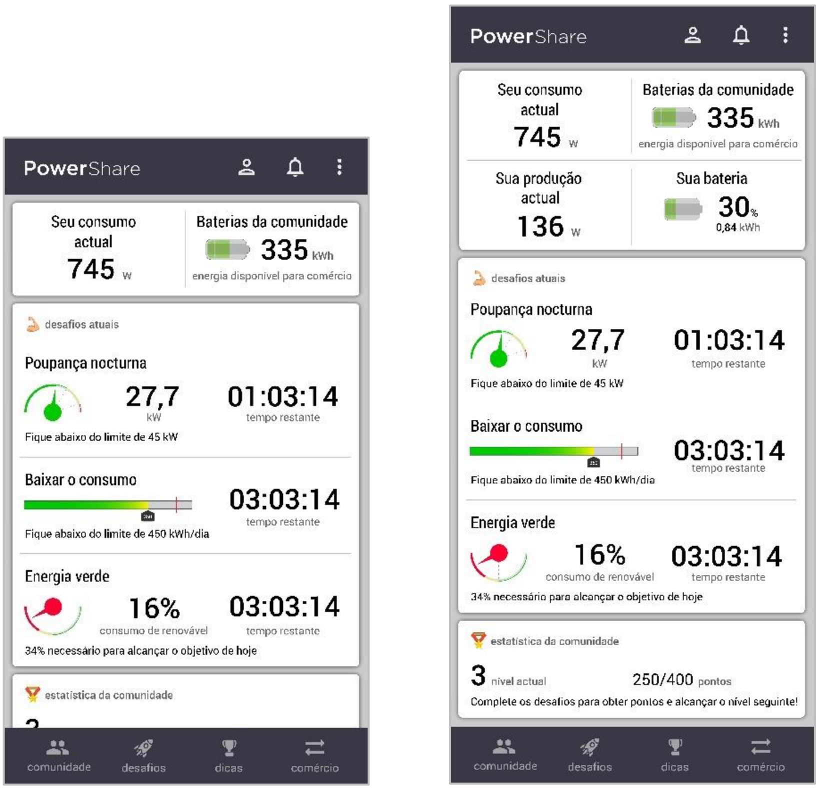

Figure 3.2 Home screen for a consumer and prosumer

The home screen comprises of different cards, which, by default, are:

- **Real-time data** – Current consumption and the state of "energy pool" (batteries of all prosumers in the community) are displayed. In case the user is a prosumer, status of his battery and current production are also presented. Studies on Eco-feedback show that users appreciated having the opportunity to access real-time data at any moment so as to be able to act upon it and see immediate results of their actions [25] – such as turning off appliances in stand-by mode.
- **Ongoing challenges** – this card presents the status of ongoing community challenges (as well as one-to-one challenges if the user is engaging in any). When a new user registers, he/she automatically joins the community and thus the current challenges, which they can contribute to. The "ongoing challenges" feature provides an overview of the collective progress of all members. By tapping this tab, the user can access detailed information regarding challenges, further described below. If the user starts a new challenge (an individual one) it appears in this section.

- **Community statistics** – In this application, community is one entity that gets points for completing tasks. This card displays the current status of the entire community in a simple way and, when selected, it opens a dedicated screen to access detailed information (described below).

The goal of displaying precisely these cards in the home screen was to present the user with the most actionable and up-to-date information that they could act upon. The cards can be moved, added or removed from the home screen; the arrangement presented in Figure 3.2. is the default one.

Community

This feature provides an overview of joint efforts of all users (Figure 3.3). It comprises of four different categories: community score (level and points obtained), energy breakdown (detailed energy feedback with historical data), CO_2 savings and energy exchange (statistics on transactions).

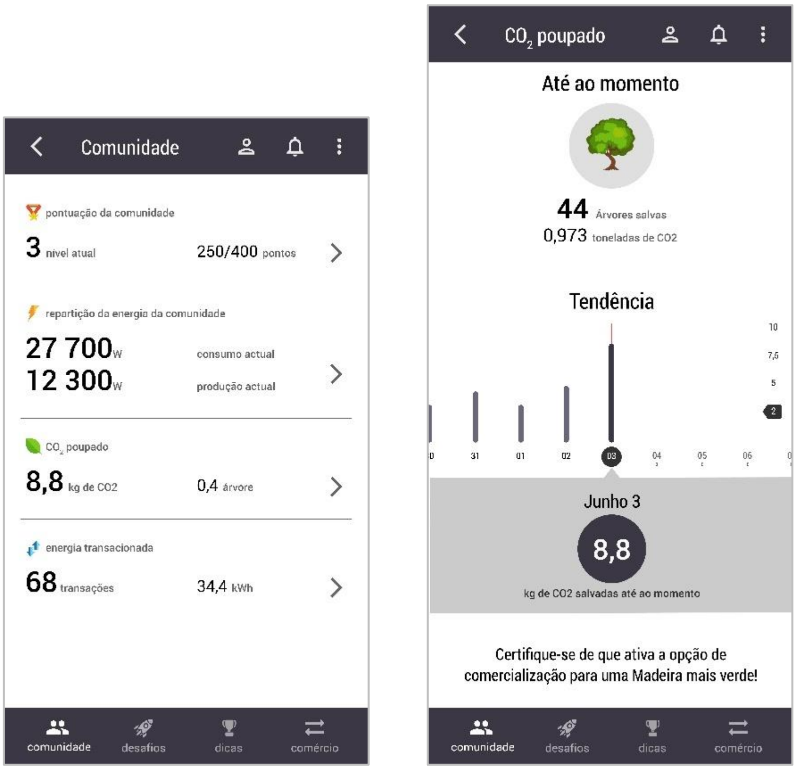

Figure 3.3 Community feature (the main screen and CO2 savings respectively)

Similarly to the home screen, every category of community statistics displays real-time data of the entire neighborhood and historical data to keep track of the progress. Some information provided is based on the Norm Activation Model, such as CO_2 saved thanks to trading renewable energy instead of buying electricity from the DSO. It is presented in the form of trees "saved" i.e. trees that do not need to absorb the CO_2 that would have been emitted when using conventional energy sources. All information presented focus on energy usage patterns and their consequent impact on the environment (CO_2). This choice is meant to move the focus from economic aspects (savings) and personal benefit to the importance of adopting pro-environmental behaviors for the common good.

User's individual statistics are not available in the application, as it is designed in a way to promote collective efforts instead of individual ones. The consumer needs to feel that his contribution matters and is noticeable. By limiting their consumption or participating in energy trading they can recognize differences in overall statistics.

Challenges

This part aims at keeping the participants active and interested in energy trading by gamifying the process and providing them with tasks. Exemplary screens are presented in Figure 3.4.

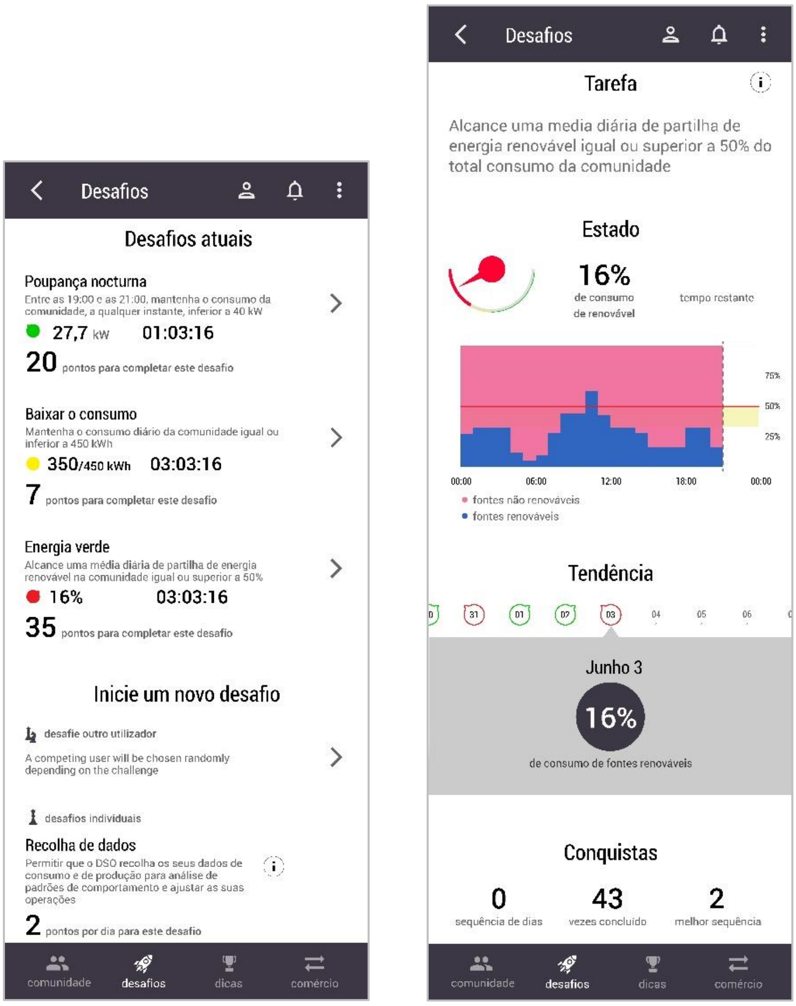

Figure 3.4 Challenges screens

The main screen of the "challenges" feature (left picture) presents a more detailed overview of ongoing tasks and is accessible through the bottom navigation bar. An example provided in Figure 3.4 (right picture) is "Green energy" ("Energia verde"). Here the user can find out more about the specific challenge, see its current status and history. A timer shows time remaining and the hourly graph presents the exact progress throughout the day. Historical data is available together with past achievements that are provided as an additional impulse to break a record. It is essential to remember that even though it is an individual person using this application, the statistics and challenges displayed are for the entire community.

Even though the user of PowerShare is automatically contributing to the collective goals from the moment of registration, he/she also has the possibility to commit in a more personal way. In the main screen of the "challenges" users are given the opportunity to "open a new challenge" either by challenging another user or giving up some control over their energy data or, in the case of a prosumer, battery (Figure 3.5). The challenge of sharing energy data with the DSO means allowing the company to analyze user's consumption (and production) patterns. The "battery challenge" would allow the DSO to take control over the battery storage system of the user and charge or discharge it when needed to support grid stability. This would allow certain flexibility of the grid and smooth sudden consumption peaks. The aim of this option is to test whether participants would be willing to give up control over their battery for the greater good – balancing the grid, ensuring its stability and providing renewable energy for the entire community, not just themselves.

Figure 3.5 Competing with another user

When the user decides to challenge another member of the community, a list of challenges to choose from opens. In "challenging another user" the challenges available are the same as the community ones and the points are still for the benefit of the entire community. However, this feature was introduced to foster the engagement of more competitive users. A competing user is chosen randomly depending on the household and the number of people living there (therefore consumption) and other factors that might influence fairness of the challenge. The person chosen by the system needs to accept the challenge (they receive a notification) for it to begin. Statistics of individual challenges are tracked in the same manner as for the entire community and displayed in the home.

The individual challenges are not compulsory, they serve as a "bonus' for people that enjoy competition or want to contribute even more, but the community challenges open automatically (there is no option to press a button and start a challenge) and everyone is involved – whether with positive or negative contribution. This puts additional peer pressure on participants, as nobody can withdraw unless they uninstall the application.

In order to respect users' privacy only nicknames (chosen by them during registration) are shared within the community. The winner of a one-to-one challenge receives a piece of interesting information ("curiosidade" - curiosity) as a reward, while, as mentioned above, points gathered are added to the score of the entire community.

Tips

Completing a challenge is rewarded with points that add up until a new level is achieved – just like in a computer game. As shown in Figure 3.3. (Community) all users collect points and everyone gets rewarded regardless of their participation.

The reward for reaching a new level is information on how to improve one's energy behaviors. This is a separate feature in the application called "Energy tips". Here users can learn more about how to conserve energy in different aspects of their life (Figure 3.6). A new tip unlocks every time the community manages to upgrade their level. When this happens, everyone receives a notification that informs about a new energy tip.

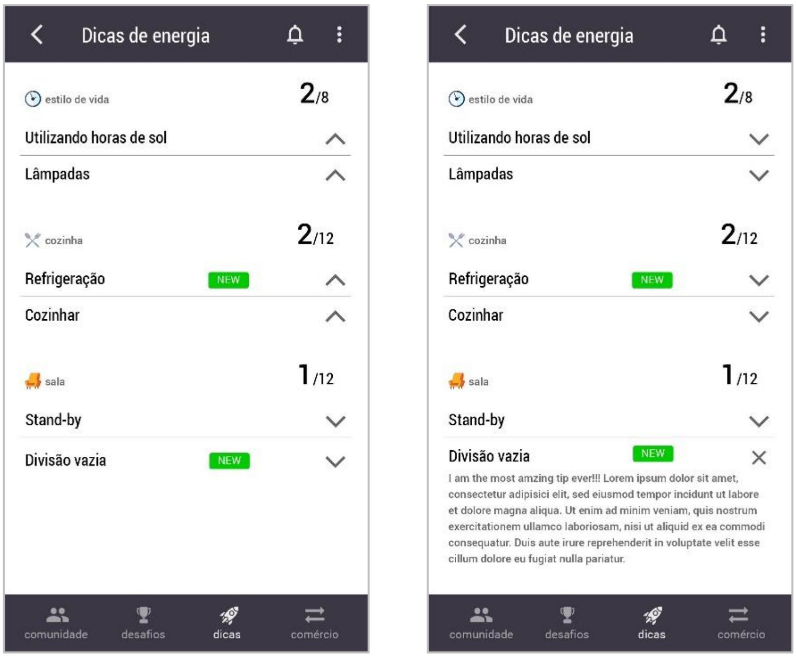

Figure 3.6 Notifications and energy tips

This feature was designed to support learning and curiosity regarding energy savings. Such functionality is often mentioned in studies regarding eco-feedback ([30], [34], [40]) as a desirable and enjoyable one for the users. It is divided into house areas and "lifestyle", for the advice that is not necessarily applicable to households.

Trade

Giving users less choice in this area simplifies the process of getting familiar with the application. Someone who is not an expert in the energy field and, like most residential customers, is not aware of their consumption will find it easier to figure out optimal pricing and other trading criteria. Both prosumer and consumer can only enable or disable energy trading that takes place automatically. Prosumers that own a battery also have the opportunity to set the amount (in kWh) of the battery capacity they want to save for self-consumption only, as shown in Figure 3.7. Tariff information is provided together with the user’s transaction history. A complete summary of all transactions performed by the user can be accessed on the website and downloaded as a PDF file.

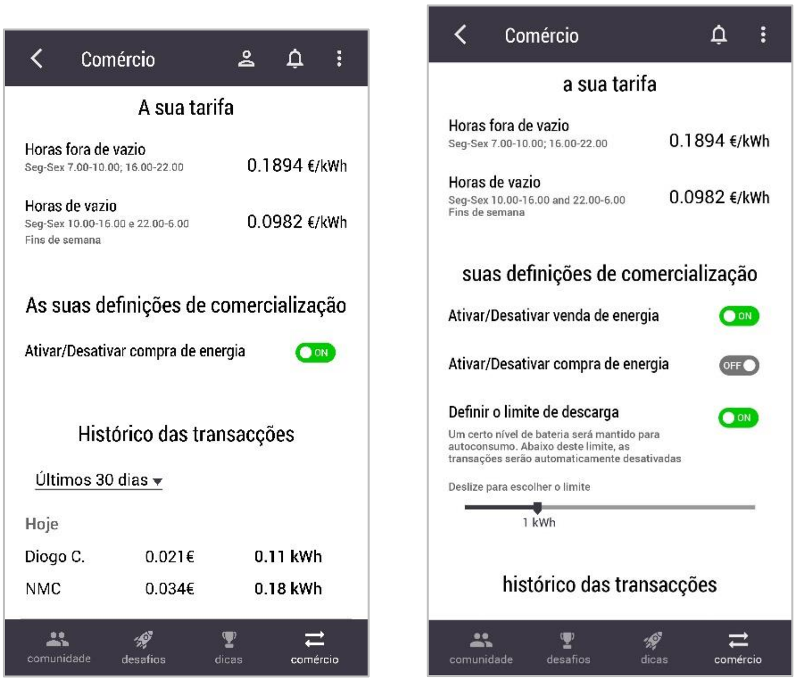

Figure 3.7 Trade screen for a consumer and prosumer respectively

This feature was designed to increase users’ control over their energy data and provide them with a sufficient overview on their transactions. It aims to raise transparency and reassure the users that they have the opportunity to adjust the trading settings and disable it whenever they want. Results from the assessment of PSv1 suggested that even if this feature is not used, people value having this “freedom” and control over their system. The manual system configuration has only a few options in order to keep the application simple and avoid potential discouragement due to high complexity.

3.2 Website

The web platform was created as a complementary part for the application. It provides detailed information on energy use of both user and community but also serves for promotional purposes. It should advertise PowerShare project, invite to join the community of Madeiran prosumers and consumers and promote Madeira as an eco-friendly island. Examples of the homepage are provided in the Figures 3.8 and 3.9.

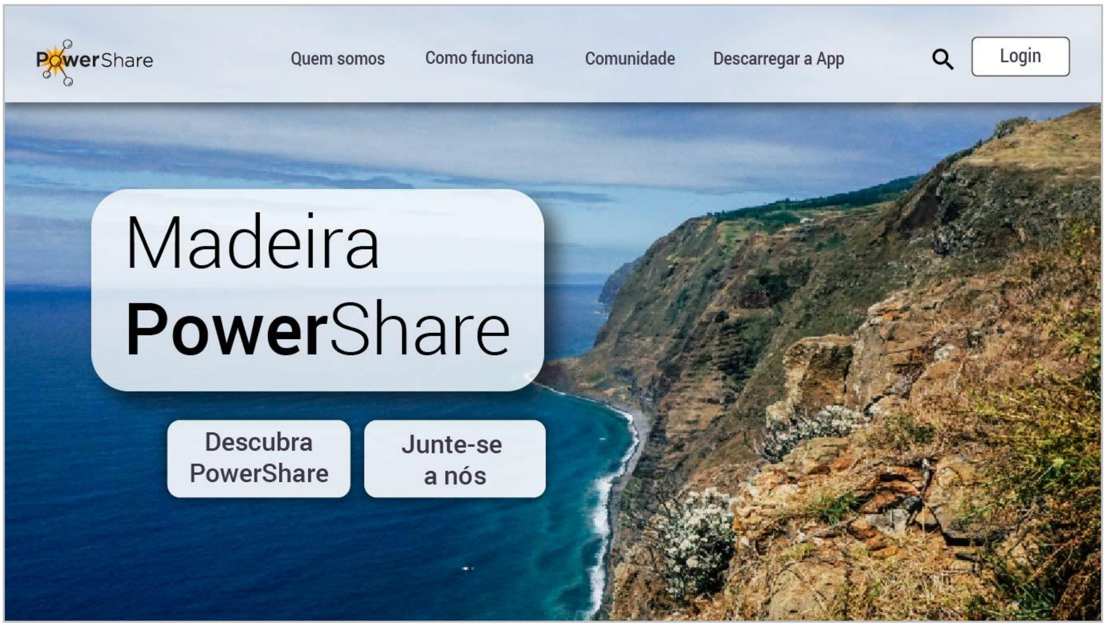

Figure 3.8 Homepage (top)

Figure 3.9 Homepage (bottom)

Once the user is signed in, he/she has access both to his/her personal energy data, that is not provided in the application, and community data with higher degree of detail. All information is presented in a visual form since findings show that such presentation modality is effective for supporting understanding.

The ways different data is displayed have been chosen based on literature on eco-feedback and relevant guidelines.

The layout is designed in the form of a dashboard - such arrangement is common for providing multiple data in a clear way. To ease the navigation process there is a side menu where the user can move between individual and community statistics. Visualizations include production and consumption data (also real-time) with different degrees of temporal granularity (days, weeks and months) together with accurate energy breakdown, CO_2 savings, number of transactions and battery state of charge over time. Apart from overview, the website provides a comparison option between different periods of time. This feature was designed based on the theory that self-comparison is an effective tool for behavioral change [32].

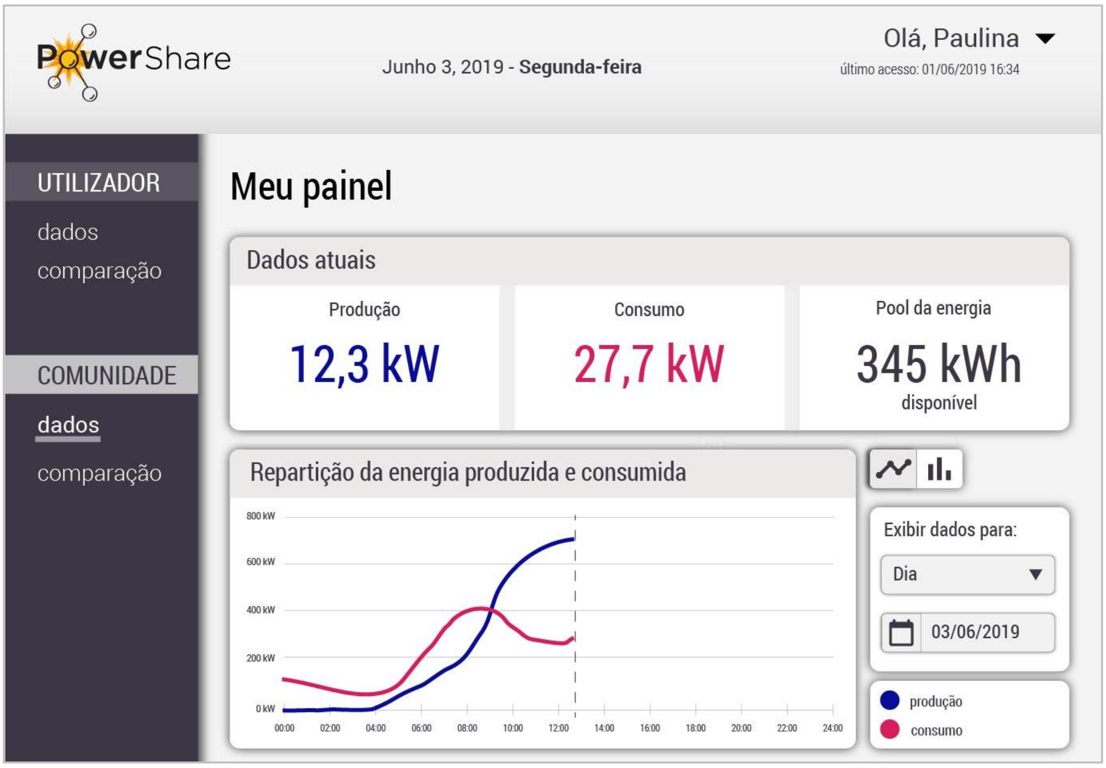

Figure 3.10 User dashboard

Users can change the way data is displayed: in the form of a bar or a line graph (Figure 3.10). They have access to their historical data and can either explore their patterns themselves or use the “comparison” tab in the left menu. It allows the user to compare data (energy use, CO_2, renewable energy share, state of battery, transactions) from one time period e.g. a week with another one.

Corresponding options (historical and current data, comparison) are available for the whole community as well. References to score and challenges are not included in the website as its purpose is purely informational.

4 Methodology

In order to test the hypotheses mentioned above, mockups of both the app and the website were used to conduct a user study aimed at collecting feedback from potential users - consumers and prosumers living in Madeira. Before defining the final layout, a low-fidelity prototype of the app was pilot-tested with a group of researchers from Madeira Interactive Technologies Institute in order to identify bottlenecks in both layout and navigation flow. The feedback was implemented when designing the final mockups.

Study design

The study consisted of a demonstration organized at the Madeira Interactive Technology Institute and was structured into four main blocks.

We first introduced PowerShare and its purpose to participants, including a short explanation on blockchain technology. The introduction was followed by a video demo showing all main features of the platform.

A short, 6-question survey was conducted in order to collect some quantitative data regarding, for example, environmental attitude of the participants and their understanding and acceptance of the system (Appendix A). It covered the main research aspects of this study such as trust in unknown peers, feeling of belonging to a community or gamified features.

The study ended with a focus group discussion where participants were asked to express their ideas and concerns regarding the platform. Such structure (survey and discussion) was based on similar case studies from relevant literature [41]. Three members of the research team were present at the study - one was conducting the discussion and two others took notes and recordings. Before the study a list of questions and probes for the focus group discussion was elaborated in order to address all necessary aspects of PSv2. The conversation was facilitated to gather all the needed answers; however, participants could freely talk about all aspects of PowerShare. We asked everyone to shortly say what they liked or did not like in the platform, whether something was missing and what they would do to improve the system. Further questions related to challenges and the reward system proposed, sense of belonging to a community and trust in peers, motivations to engage and perception of blockchain technology. Since the platform consists of two channels (application and website), we also asked if they perceived the role of each channel and appreciated having such distinction.

The whole study was performed fully in Portuguese. In the beginning participants received and signed an informed consent. The focus group discussion was recorded with their permission. As a reward for their participation, at the end of the study, a free prize draw was performed.

Participants

The study participants were invited by the research team. Five people confirmed their attendance and took part in the test (2 women and 3 men). Some of them participated in PowerShare v1 deployment in 2018. They represented different age groups, interests and levels of technology expertise. We recruited

3 prosumers and 2 consumers. Participants' ages ranged from 29 to 49 years and some of them had children (2,3 children on average).

Evaluation of results

Audio recordings of the focus group discussion were transcribed and used for a thematic analysis with general inductive approach. Participants feedback was analyzed using affinity diagrams, clustering valuable information and identifying main aspects that arose in the conversation.

5 Results

Quantitative and qualitative data gathered during the users’ test provided us with valuable insights that were further used for elaborating design guidelines and drafting a business model for P2P energy trading platforms.

The main research questions (Chapter 2.5) were addressed in the survey as well as during the focus group discussion.

5.1 Results of the survey

The survey (Appendix A) comprised of six 5-point likert-scale items (1 - strongly disagree to 5 - strongly agree) addressing the main research questions. Results are reported below.

Table 5.1. Results from the survey

Question	Mean result
Q1: I consider myself to be environmentally aware.	3.8
Q2: I understand how the system works and I would be able to explain the application to someone else.	3.8
Q3: Having a common goal and act as a community would motivate me to engage in P2P energy trading.	3.8
Q4: I believe points and challenges are a good addition to regular energy statistics and would improve my engagement with the app.	3.6
Q5: I would feel comfortable sharing my energy data with the DSO (energy consumption and/or production and exchange).	4.4
Q6: I would feel comfortable trading with anonymous peers.	4.6

The first question relates to the pro-environmental attitude of the study participants. The goal of it was to assess whether study participants are concerned about the environment and most of the answers confirmed it. The perceived usability of the system (Question 2) was roughly estimated as “good” or “neutral”. It was an estimation due to the fact, that the participants were only presented with a demo of the platform and did not have a chance to interact with it. Question 3 is based on the hypothesis of collective efficacy for encouraging energy trading. Based on the answers, selfless actions and cooperation between peers seem to be a strong motivation for engaging in energy trading (mean score was almost 4 on a 5-point scale). Question 4 relates to gamification of the system, about which the opinions were rather positive. The firmest results appeared from questions 5 and 6 that addressed trust in the DSO and in unknown peers. Results of these two items show that our participants are prone to trust both the DSO and their peers, even without knowing their identity. All the aspects mentioned in the survey were further addressed during the discussion and some inconsistencies appeared between the results provided above and participants' comments. These contradictions are further elaborated in the document.

5.2 Results of focus group discussions

Focus group discussions allowed participants to express their doubts and opinions on the proposed solution. All insights were gathered and grouped into main themes addressing both the research hypotheses and research questions mentioned before.

Hypothesis 1: Collective efficacy

Based on previous work done on PowerShare, a hypothesis has been made that working together, pursuing a common goal, fosters a sense of community, especially between peers that don't know each other. The first Research Question was elaborated in order to understand this aspect. Indeed, collective effort was confirmed to be potentially effective by most participants of this study: "*I've found interesting (...) the awareness of being a community that, as a joined effort, would reduce consumption and help the environment*" (Participant 2), "*What I liked the most was being able to collaborate with the community*" (Participant 3). On the other hand, one participant, when asked about the positive and negative aspects of the application, said: "*I don't consider myself as a part of the community*" (Participant 1). This might mean that the entire concept of cooperation between peers may not be interesting for some people or other motivations need to be triggered in such case. However, this participant suggested that if she were to get involved in the community, she would be motivated by more tangible outcomes of the collective effort, such as planting trees. This suggests that she cares about the community wellbeing and wants to contribute to it, simply in a different (and more tangible) way. This finding shows that engaging in collective effort might depend on the benefit it can bring, which is strongly related to pro-environmental behavior models described in Chapter 2. It also brings new insights into the aspect of implementing Norm Activation Model in such platforms (Hypothesis 2).

In order to stress the concept of collective effort, the dependent group contingency model was used in the reward system. This means that the entire community receives a "prize" after completing a task, regardless of individual contribution of each member. This approach was adopted to strengthen the idea of collaborative work of the whole community, acting as one entity, where everyone contributes within their capabilities. RQ1 aimed to gather feedback on this strategy and help us understand whether it has potential in P2P energy trading platforms for large communities.

The designed prototype assumes equal rewards for all members of the community. Once a new level is obtained, every person gets an "energy tip", nobody is excluded or punished even if they do not actively contribute. Study participants agreed in the beginning that penalization for underperforming is not a good strategy. Nonetheless, they said later that rewards should not be equal for everyone and should depend on the performance of each member: "*If you don't manage to complete the challenge you don't* *get the reward. (...) It is a kind of a positive penalization*" (Participant 4), "*I save more and I get more points*" (Participant 3). This contradiction has been further described in "Design inconsistencies".

Participants in the study generally claimed that they would like to know their contribution to the overall score and compare it with others. This does not necessarily mean that competition would be preferred over collaboration, but possibly the approach of "equal reward system" is not considered fair. Maybe the reason is that knowing whether one's score is lower than the average would further motivate users: "*Just to know if it is me that needs to lower consumption in order to improve the community performance*" (Participant 3). This could stem from genuine commitment to collective efforts and adjusting the reward system would perhaps result in higher user engagement in pro-environmental actions.

Hypothesis 2: Norm Activation Model vs Economic Rational

Research Question 1 focuses on the strategy in which the rewards for contribution are provided - in the case of PSv2, equal for everyone. We hypothesize that proper reward system that encourages people to commit for the greater good can foster the feeling of belonging to a community. Research Question 2 addresses the actual quality of these rewards, in order to understand what motivates people to devote their time and attention for P2P energy trading.

We tried to explore the ways of implementing Norm Activation Model in the design of PSv2. The way challenges were structured did not imply any economic benefits. On the contrary, only kilowatt hours and CO_2 saved was displayed in "Challenges" to support the core idea behind the platform, namely collaboration for the benefit of the community and the environment. In PSv2 the rewards are in the form of information ("energy tips") instead of monetary incentives.

The answers gathered to the RQ2 suggest that there is still space for improvement: "*What disappointed me a bit were the tips, since tips should be something always available, since the beginning*" (Participant 3), "*What doesn't really make much sense to me is that what I can earn from a challenge is information. To me, information is something I should be able to access always, because it is something that should help me change my habits and become more "sustainable*" (Participant 1), "*A tip is something you can find on Google…*" (Participant 5). These comments imply that information is an insufficient trigger to get involved and it should be available at all times to help people do better. On the other hand, the approach of fostering learning via tips was appreciated by some: "*I think the tips are interesting. From my experience, I learn from the information I receive. (...) To me the main reward is knowing that I'm contributing to improve the environment and that, contemporarily, I'm saving energy and/or buying clean energy which could, or could not be cheaper… still, even if not, I'm contributing to improve the quality of the environment*" (Participant 2). This comment suggests that some users might have an altruistic approach towards environmental protection - even if there are no savings involved, they still want to contribute. Effectiveness of Norm Activation Model is also confirmed by the feedback quoted in the previous paragraph, about planting trees for the community as a reward. More tangible rewards do not necessarily need to mean financial benefits but should have a more practical effect on the community.

Nonetheless, some participants admitted they would like to gain some savings from energy trading in PSv2: "*For what concerns myself, the main reason to use the app would be economic*" (Participant 4), “*In my case, it would be to generate savings and to get rewards as well… If they are interesting. I don’t know why, but if I think of rewards, discounts at the supermarket is what comes to my mind*” (Participant 3). Participants proposed building cooperation with companies, such as small supermarkets or local businesses (in order to support them) for providing discounts as rewards for contributing to challenges in PowerShare. This proves that complete abandonment of the Rational Choice Model in fostering behavioral change in P2P energy trading might not be effective. This does not contradict the results from the previous PS study (that P2P energy trading is not considered as a business opportunity), but only shows that people are still interested in financial benefits, even indirect ones, in the form of e.g. supermarket discounts. This confirms that “people will adopt environmentally responsible behaviors that are economically advantageous” [24].

In the previous version of PS participants could set the price of energy bought (and sold in case of prosumers) and after testing the application they claimed the savings were less than expected. Results showed that they did not interact much with this feature due to insufficient understanding of their energy consumption and found it rather overwhelming in terms of complexity. This affected some design decisions of PSv2 - it was meant to be more automated. In this work, the platform does not offer a possibility to set your own price but it is equal to the one set by the energy provider.

However, this year participants expressed the need to have a chance to adjust the price of energy themselves - even though last year, most of them chose automatic settings proposed in the app. Results obtained proved that users would like to have a possibility to set the price of energy. Those two insights from both versions of PS (not setting the criteria manually but still expressing the need of having this possibility) show that people want to feel like they have control over their energy and be able to modify the trading settings whenever they wish to do so.

This work tried to explore other motivations to engage than monetary incentives, but the results show that only information is not sufficient. Despite P2P energy trading not being a business opportunity, people are still considering their involvement from economic perspective. Perhaps full deviation from Rational Choice Model is not an effective strategy and the system would perform better if some sort of financial benefit was included.

Hypothesis 3: Gamification

Research Question 3 aimed to gather answers whether a gamified P2P energy trading platform can foster engagement and make the system more inclusive.

Both the individual and community challenges were in general considered interesting, however, one participant stated that “perhaps group challenges should be optional. “*People should do what they want, engage in individual challenges if they want, for self-growth*” (Participant 3). Only one person did not like the game approach at all, saying: “*I’m not interested in the challenges. I don’t have time (...). It is hard because we are all busy and new app means more stress*” (Participant 1). This confirms that generally gamified systems are approved of. However, they should not be mandatory and users should choose what they want to get involved in: “*Perhaps this should be optional, meaning that people don’t necessarily need to join the community challenges*“ (Participant 3). In order to better adapt the solution to different lifestyles and agendas, more varied challenges could be designed. One participant suggested more flexible time slots for challenges: "*We need to have time slots for participating in a challenge as well as enough time to "act/react" in order to complete it (...). For example, it is easier if the challenge goes from 19h to 21h, while it would be tricky during the day, especially for those who work or have an activity*" (Participant 2). A gamified solution would require more varied tasks that can be adapted to different lifestyles and needs. This matter becomes more complex with another obstacle - usage patterns. Simply not everyone is willing to use their mobile device more often to check their status and get more points, even for good reasons. Participants also suggested that different challenges can be applied for less active users to motivate them to engage and contribute more: "*Something to push them to do things differently*" (Participant 3). Implementing this feedback into the design of potential gamified P2P energy trading platforms could mean introducing more challenges that are not mandatory and people could join them depending on their availability.

The feedback gathered on platform gamification delivered some valuable insights regarding making the platform inclusive for all family members. According to study participants, it could be a trigger to start a conversation between children and parents: "*I guess it would be possible, in some cases, to involve all family members in using the app and perhaps having a discussion about it, for instance while dining*" (Participant 2). The same person said that: "*young people, which are interested in video games and so on, would spend more time checking the challenges status*". This might suggest that involving teenagers and children could have a positive effect on the whole family fostering their engagement in the collective challenges.

Trust and privacy

Research Questions 4 and 5 were prepared to check how participants feel about trading with anonymous peers and their data being shared with other entities (in this case the DSO). Additionally, trust applies to challenges too, as users cannot know who is actually contributing and who is hindering the community from getting a better score.

In the survey the answers showed that participants do not feel the need to know who the other users are (average = 4.6) and that they are not concerned about sharing their energy data (production, consumption) with the DSO (average = 4.4). However, this raised questions later in the focus group discussion.

According to feedback on the challenges, transparency regarding individual performance is needed. People stated that they would like to know who is underperforming and what is their result with respect to the average: "*I'd like to compare my performance with the others in order to understand if we are not doing well because of me or is it the others that are over-consuming*" (Participant 3). On the one hand we have no interest in knowing who they are trading with, on the other - demand for transparency, showing publicly (in the community) who is not performing well: "*If everything is private and you don't know how others are doing, then it is not a real community*" (Participant 5). This paradoxically shows the lack of trust in peers. Feedback gathered in the focus group discussion confirmed as well that competition is a motivating aspect: "*People are competitive by nature*" - Participant 3. Participants expressed the need of having the possibility to compare their scores with other people, which is not possible in the designed application. However, there were no concerns expressed regarding users' anonymity - even though only people's nicknames are displayed, nobody mentioned this as a potential problem.

Regarding trust issues with sharing personal energy data, energy provider (in this case EEM) was mentioned too, as a possible partner for this project, a promising channel to reach more potential users and a trustworthy entity overseeing the project. This could mean that people trust the company and would use the app knowing that an official institution is involved. Perhaps DSO's involvement is not considered an obstacle for users, as the survey results confirm. This could further help implementing flexibility as a service (VPPs) in P2P energy trading platforms. If people trust the DSO, they are more willing to give up control over their system for e.g. supporting grid operations. In this study participants did not express any concerns regarding energy company's participation

Technology

Blockchain technology adoption faces a lot of obstacles and another hypothesis that had to be tested was whether this can be a limiting factor for PowerShare.

According to the results obtained, no participants expressed the need to fully understand how blockchain works (none of them did, in fact) in order to use the app. As long as no additional hardware is needed and everything works well, they expressed no concern regarding trust in this technology. They were also open to use cryptocurrencies after a short explanation of how they work and assuring that there are no extra costs - on the contrary, removing intermediaries lowers the costs: "*As long as I know my balance and how much I have to pay, I'm fine*" (Participant 2). It was proposed to make the message clear about what needs to be done on the user's side to implement the system and what are the benefits from it: "*Basically, at the end what matters is money. That's the info we need*" (Participant 5).

Participants agreed that this is a complex topic and needs to be explained carefully - sufficiently but without information overload. A suggestion followed, that information should be available on demand, mostly for people wanting to explore this subject further. Moreover, participants proposed to dedicate a section of the website to provide a quick and simple explanation on blockchain technology, cryptocurrencies and what their use implies. They all found the explanation during the study quite confusing and admitted that not all the information delivered was necessary, but also some was missing - e.g. what advantage do cryptocurrencies have over fiat currencies.

Design inconsistencies

Not all of the results obtained were fully confirming or denying certain hypotheses. Some opinions were contradictory. The most critical insights emerged are:

- **fairness of dependent group contingency** - All participants agreed that working together towards a common goal is a good idea and they found it motivating, confirming our hypothesis about collective efficacy for fostering engagement. In the PSv2 scenario, all members of the community receive a reward, even though not everyone might be contributing positively to the end result. However, underperforming is not penalized.

This approach was based on dependent group contingency strategy and participants seemed not to agree with it fully. They all stated that there should be no penalization, yet some suggested adjusting rewards to individual contribution, e.g. best performing members should get a discount and others just an energy tip. This was considered a “positive penalization”, which is a contradiction to what had been said before about not penalizing anybody. One participant proposed having a different challenge that would target members that do not perform so well. This is again inconsistent with the idea of a community where everyone is equal and receives the same treatment.

A solution to this needs to be a compromise between encouraging everyone to contribute within the best of their abilities and adjusting the rewards to individual efforts. This seems to be a contradiction, since social pressure was not taken into account when designing a prototype to test collective efficacy for fostering engagement.

- **privacy and trust vs. transparency** - another interesting discrepancy emerged from the results regarding trust in peers and transparency in the community. Since getting involved in the challenges and trading energy requires some level of trust in the other members, it was necessary to test whether users would feel comfortable and safe using such system.

  Again, the answer was not explicit. All participants claimed that they do not need to know their peers in order to trade with them and take on challenges. Nonetheless, they did not like the fact that they do not know who is underperforming. They stated that a real community should be transparent. Interestingly, when asked about knowing the peers they trade participants also said that they don’t find it necessary - this is a contradiction to a transparent community.

  This represents a challenge regarding creating a community that one can trust in without competition or privacy issues. User’s confidentiality should be protected, but on the other hand it is hard for people to trust the system if they do not know individual performance. A solution to this should be a trade-off between a transparent platform where all peers trust each other or displaying only as much information as needed for everyone to understand the overall situation in the community.

Additional findings

Throughout the study participants freely expressed their opinions, concerns and suggestions. During the thematic analysis, further categories not belonging to the topics addressing the main research questions emerged. Some of them represent valuable insights for designing similar systems and are thus reported below as additional findings.

- **perceived target audience** - participants of the study said that the system seems to be targeted at people interested in technology and very familiar with it. This applied both to the fact that it is a mobile application (“*There are people that like to actively interact with mobile apps [but not* *me*]" - Participant 1) and that it relates to energy and consumption ("*Who installs the app is someone that has knowledge on energy*" - Participant 5). This showed that people less acquainted with either apps or energy topics might be less likely to use the system.

Engagement strategies (gamification, challenges and rewards) implemented suggest mainly early adopters as primary users of PowerShare, according to study results. Participants agreed that it is usually young people that have time and motivation to play with apps, receive points etc. They also have more time to commit for such activities. One participant also asked whether the app was mainly for consumers, as a big part of it focuses on lowering or adjusting energy consumption and much less on the actual production, as it is a passive process.

- **obstacles for adoption** - the goal of this study was to try to overcome the biggest barriers in adopting such systems. The main ones identified in previous studies concern privacy and trust in peers and the complexity behind blockchain technology itself.
  Another very important aspect that all ideas aimed at engaging people to become more sustainable need to face is that comfort of users comes as a priority. One participant mentioned that he tries to use his appliances in a more responsible way, in order to take advantage of his own electricity production, but it is not always possible or convenient. This confirms that people would like to become more sustainable but they do not want to compromise their comfort and often budgets (e.g. choosing a flight over a train ride because it is usually cheaper and faster). Such barrier to adopt more sustainable behaviors has already been identified in eco-feedback literature ([30], [34]) and confirmed in our study.
- **opportunities** - despite significant obstacles for PowerShare implementation, participants pointed out some interesting opportunities to look into.

  Some opinions stated that the most important factor for creating a strong, united community is awareness: "*I think awareness should be a basic requirement, the main rational*" (Participant 5). Raising awareness, providing valuable information and stressing the importance of joint effort for sustainable actions could foster participation.
- **perceived usability** - the aspects of usability and information presentation were not tested due to the lack of a working prototype. From the survey and focus group discussions we gathered feedback on how participants perceive the system based on the low-fi prototypes presented during the test. One person stated that current versions of PowerShare (both the app and the website) display too much data at once and detailed information should be available only on request. We asked participants whether they understood the concept of challenges and rewards (quantitative result = 3.8), and the result might imply that it is understandable (to some extent or to some people more than others).

  According to participants the public section of the website should provide more information so as also someone who is not yet a member of the community, but is interested in energy consumption and sustainability, can access it. It could also be connected to social networks in order to engage more people and support advertising the system.

5.3 Design guidelines

This subchapter gathers all the answers to the main research questions and provides a set of design guidelines for P2P energy trading platforms based on the feedback from the assessment of PSv2.

Transparency in collective efforts

Leveraging on collective efficacy was found to be an effective strategy for creating a goal-oriented community, which confirms our first hypothesis. Although, people would like to know who is underperforming and whether it is them contributing positively or negatively compared to the average. This was described as a real, transparent community where everyone can trust each other and verify individual contribution. Therefore, such a platform should provide sufficient information for the users to give them an idea on how they are performing with respect to the others. Perhaps a personal notification when someone is underperforming could suffice in terms of encouraging collective efforts. However, findings show that users are interested in social comparison as well - a ranking of the 10 best performing users (displaying only their nicknames) could be an interesting feature to provide an overview on how well the community is doing and which members are contributing the most. Apart from comparison, that should be included when designing a P2P energy trading platform, people want to know their own contribution to the overall score. This should be taken into account when presenting community statistics as it can encourage users to do better and provide them with the intrinsic reward (feeling like an expert, making a positive impact in the neighborhood) [42].

Flexible and non-obligatory tasks

Regarding gamification (RQ3), it is in general approved of and enjoyed in the form of challenges and rewards. It can foster engagement, especially when there are younger family members involved in carrying out tasks, that can motivate their parents and start a conversation. However, in terms of design, there should be more tasks available and they should be more flexible in terms of duration and attention required from the user’s side (e.g. different “experience” levels). The in-app games should take into account various lifestyles and perhaps offer the opportunity to customize time slots. According to our study results, joining a challenge should be voluntary so as not to put unnecessary pressure on the user or negatively affect the collective results.

Rewards depending on personal contribution

Participants of this study agreed to not penalizing anyone. On the other they proposed different rewards based on personal performance, meaning not everyone should be rewarded equally. These two statements can be considered contradictory. This also suggests that the chosen type of group contingency was perhaps not the most effective in the case of a gamified peer-to-peer energy trading platform. Adopting a different kind of group contingency, e.g. independent, where everyone is rewarded according to their contribution, seems to be a better option.

More tangible rewards

During this study it turned out that users might want to adjust their price and generate savings, even though they are relatively low. Participants said that they would use the app for economic reasons, additionally, they suggested discounts as potential rewards, confirming that money is of importance for them. This shows that economic incentive cannot be neglected in energy trading platforms. Additionally, information as a reward was considered insufficient for fostering engagement and more tangible ones were suggested such as supermarket discounts or collaborative actions in the neighborhood. Perhaps implying some sort of financial benefit when designing a reward system in such platform could encourage more people to get involved. Based on this we drew a conclusion that information should not be considered a reward, but should be always available for the user. Moreover, it is a valuable insight regarding the business model – creating partnerships with local enterprises could provide interesting incentives for people to participate.

Impression of being in control

Our results proved that even though people do not really use the manual price settings in P2P energy trading (PSv1) they still want to have the option to set the price of energy and be in control. This shows that providing this opportunity to users cannot be neglected when designing such a platform - they might not take advantage of it, but they want to have this opportunity. On the other hand, they do not want to check the application all the time so it should be highly automated. A design decision in this situation should be a trade-off between a convenient system that does not require a lot of attention from the user and a solution that allows to manage one's energy transactions independently.

Relevant information on demand

Blockchain technology behind PowerShare was confirmed to be a sophisticated topic but did not raise participants' apprehension. It was compared by them to other systems (banking, PayPal, Facebook) in terms of system complexity and adoption time, which could mean that potential barriers can be overcome as it happened before. As long as the explanation of the technology is clear and encouraging (easy to install, brings benefits) the perception seems to be positive. Therefore, when providing an explanation on the system, it is necessary to address the direct perks for users e.g. the amount of savings in one year or CO_2 saved. Moreover, in the case of two channels, the website should be open for everyone and provide sufficient information about the project, how it works, what advantages it delivers for the community. The application should be user-friendly, so as not to discourage people that are less familiar with mobile solutions and display the most relevant data the user can act upon.

5.4 Business model

During the PSv2 study some suggestions regarding possible partnerships and system management emerged, that provided a good basis for drafting a potential business model of a P2P energy trading platform. Feedback received together with ideas for improvements helped to create a draft of such a system based on blockchain technology and focused on empowering local communities.

The full canvas is attached as Appendix B, and this subchapter briefly describes the elements of the business model. It is a draft of a framework for a gamified, large-scale community P2P energy trading platform. It addresses some obstacles that emerged during the study and mentions valuable suggestions that could be applied in such platforms.

- **Value Proposition -** two main values were identified that could be provided by Power Share. The first one is creating a sustainable community that (i) saves energy, (ii) increases the share of renewable energy sources in the energy mix, (iii) provides flexibility as a service. This is done through delivering an energy trading platform that serves also as a source of information, potential marketplace for carbon credits and donations, and offers a space for sustainable local initiatives. It is also a game that keeps the users engaged and motivated through various tasks and rewards. Another value is empowering local communities and improving their well-being by not only fostering awareness about lowering consumption and renewable energy but also by establishing cooperation with local businesses and small producers.
- **Customer Segments** - both energy consumers and prosumers can be customers of PowerShare.
- **Channels -** the main channels are the app and the website, the core parts of our platform. Participants of the study suggested involving DSO as an intermediary entity that helps to reach customers, in this case via traditional mail, the way all clients are reached now. The feedback regarding the website proposed connecting it with social networks to support its growth and advertising. Finally, once the system is successfully up and running, a word of mouth could serve as a channel too.
- **Customer Relationship -** the values that design of PowerShare was based on are strongly related to building a community, where everyone is treated fairly and can contribute to its growth in their own way. It is essential that there is mutual trust - in the system and between peers. Moreover, different people have different motivations for engaging in activities, so the platform should take that into account and offer both to generate savings and to help the environment, depending on what a particular person seeks to achieve.
- **Key Activities** - in order to provide the values mentioned above, certain activities must be offered in PowerShare and similar platforms. The main one is peer-to-peer energy trading, namely the core of the system. Given that prosumers have batteries together with their PV assets, another activity would be granting flexibility as a service - sufficient number of batteries could help the DSO balance the inconsistencies between production and demand and protect the grid in critical moments by charging or discharging the batteries depending on the need. Additionally, using energy data collected through the smart meters installed in the households of the community members, energy feedback can be provided to customers, together with valuable insights that could help them adjust their consumption patterns. Data analytics is a necessary activity for PowerShare operation.
- **Key Resources** - for developing a P2P platform we identified three main resources. One is infrastructure (the physical electrical grid), as the energy traded needs to be transported between peers. For developing the software behind the system competent staff is required (human resources). Finally, smart meters are a necessary component to collect the data.
- **Key Partners** - for having the permission to utilize the necessary physical infrastructure mentioned above, a decisive key partner would be a DSO/TSO/retailer (depending on the location and regulations of the place the system is to be established in). Such entity could also

contribute to the dissemination of the project and foster trust among potential users. For the hardware needed (smart meters) a technology provider is necessary. In order to offer more tangible rewards for engaging in in-app challenges, as suggested by participants of the study, partnerships with supermarkets and (preferably) local producers could be established.

- **Revenue Streams** - as of now the most promising revenue stream identified is data sold to the DSO. It is indeed a valuable information as consumption patterns can greatly influence the operation of an energy company, helping them reduce risks and costs.
- **Cost Structure** - regarding the costs, the main expenses would involve the staff (HR) and IT infrastructure needed for running the platform.

6 Conclusions

There is no doubt that a transition towards more sustainable energy sources needs to happen in the nearest future. Facing climate crisis and global concerns related to decreasing amount of natural resources, governments are forced to implement new strategies to prevent the complete catastrophe. The traditional energy system as we know now strongly contributes to this deteriorating worldwide situation and substantial modifications need to take place. Technological growth is currently on the most rapid rise in human's history, with new solutions being developed so frequently, it is challenging to keep up. Things that were unimaginable before are possible nowadays, for instance generating energy yourself and being self-sufficient. The increase of Distributed Energy Resources, and especially distributed generation, represents a great opportunity to reach a sustainable energy transition but contemporarily requires to re-think the current energy infrastructure.

Such solutions are necessary to steer the world's current development into the right direction. A lot of companies and start-ups are exploring innovative business models for modern technologies. One of them, which is getting increasing attention into the energy sector, is blockchain technology. Blockchain offers a broad range of innovative solutions for supporting transition towards decentralized energy systems, one of them being peer-to-peer energy trading, further described in this work.

A lot has been done to address the technological and regulatory aspects related to blockchain-based P2P energy trading but our understanding of the human aspects affecting the adoption of such systems is still minimal. To address and try to overcome them, PowerShare project has been set up under a bigger international consortium focused on developing sustainable solutions for islands (SMILE).

Based on literature review and analysis of existing blockchain-based P2P energy trading platforms the main research gaps were identified. In order to address them in this work, we stated hypotheses and research questions to be answered by PSv2 study. The main aspects were focused on collective efficacy for fostering engagement in large-scale communities, where people don't know each other. We wanted to explore whether this represents a trust issue and whether collaborative work towards a common goal is considered encouraging in anonymous community. Considering that P2P energy trading does not bring significant financial benefits, the behavior model tested in this study was based on the Norm Activation Model i.e. behavior change for the benefit of others (e.g. future generations). Another hypothesis was related to making the system inclusive for all family members and making it more engaging by providing gamified challenges. Research questions addressed all these hypotheses and provided other insights regarding technology embedded complexity, privacy issues, information presentation etc.

The focus of PowerShare project lies in creating design guidelines for building a strong large-scale community based on trust between its members and in the blockchain technology. The goal of this work was to test some aspects of designing a successful peer-to-peer energy trading platform and answer questions that until now remained unaddressed.

In line with previous work, a new version of the application was created together with a website. The purpose of such division was to stress the difference between actions (gamified app) and information (data-oriented website) and provide different channels for different audiences. The test was conducted with five participants. They were presented with a demo of the platform and description of the fundamental features of both the app and the website. Quantitative results were obtained from a survey with likert-scale questions addressing the main hypotheses. A focus group discussion was conducted in order to collect relevant feedback for qualitative results.

Answers provided by participants helped to compose a preliminary set of proper design practices for peer-to-peer energy trading platforms focused on community engagement. Aspects such as collaborative work proved to be interesting, however, participants stated that they would like to know their own contribution and make the scores transparent. As results show, perhaps it would have been better to provide a ranking of the competing members or comparison with the average. Moreover, rewards (in the form of energy tips) delivered to everyone were described as “insufficient”, as information is readily available on the Internet and the benefits should be more tangible. Fairness of the chosen group contingency was questioned too, as some members might be contributing more than others. It was suggested that best performing people should receive “better” rewards, such as supermarket discounts. This feedback touches on the aspect of trust as well - or lack of such. The need to know how each member of the community is contributing shows that there is no confidence placed in peers, among themselves, that they contribute to the community’s well-being.

Based on all the data gathered and answers from participants, a simple business model of an improved version of PowerShare was created. It could be adjusted and applied to similar platforms based on blockchain created for energy trading in communities.

Limitations

Despite addressing the main research gaps regarding the adoption of P2P energy trading platforms, this work presents some limitations that need to be mentioned. Firstly, we didn’t test a working prototype of the system, so participants didn’t have the chance to actually interact with it. The feedback gathered was based on perceptions people had on certain features and aspects of the platform.

Moreover, we only recruited five study participants due to summer holidays at the moment of testing the platform. We aimed to invite people with different demographics, energy literacy and lifestyles but it is highly likely that this number was insufficient. Despite gathering a lot of feedback from this sample, we are aware that more issues and relevant comments could emerge when testing PSv2 with a bigger group.

Future work

This work tried to address the main hypotheses stemming from relevant literature and similar blockchain-based projects. However, due to the limited time and resources available, there is still space for improvement and further exploration of this topic.

Based on study results a hypothesis emerged that rewards for active participation in community challenges should be based on individual contribution. Participants agreed that this would be a motivating aspect, to know that more interesting incentives are provided for more effort. Perhaps redesigning the platform according to this suggestion could result in better feedback in the next test.

Another promising refinement of the system could relate to challenges i.e. making them non-mandatory and more flexible. For instance, higher number of tasks could be provided with shorter time limits, in order to adapt them for people that do not have a lot of time to interact with the application.

As mentioned in the previous subchapter, a working prototype was lacking for the test. In order to fully address the hypotheses and research questions regarding PSv2, it should be tested by prosumers and consumers for a longer time (e.g. a month). This way they could thoroughly understand the core ideas behind the platform and provide a comprehensive evaluation of all features. Currently the feedback gathered is based on perceived usability of the system and a vague feeling of how collective challenges work. Having a possibility to actively participate and trade energy (even in a simulation) could profoundly change the impressions participants have on the system. Developing a working prototype for the future tests of Power Share might deliver significantly better and more reliable results. Additionally, the next test of the platform should be conducted with a larger sample in order to diversify the potential feedback and adapt the system to a broader range of people.

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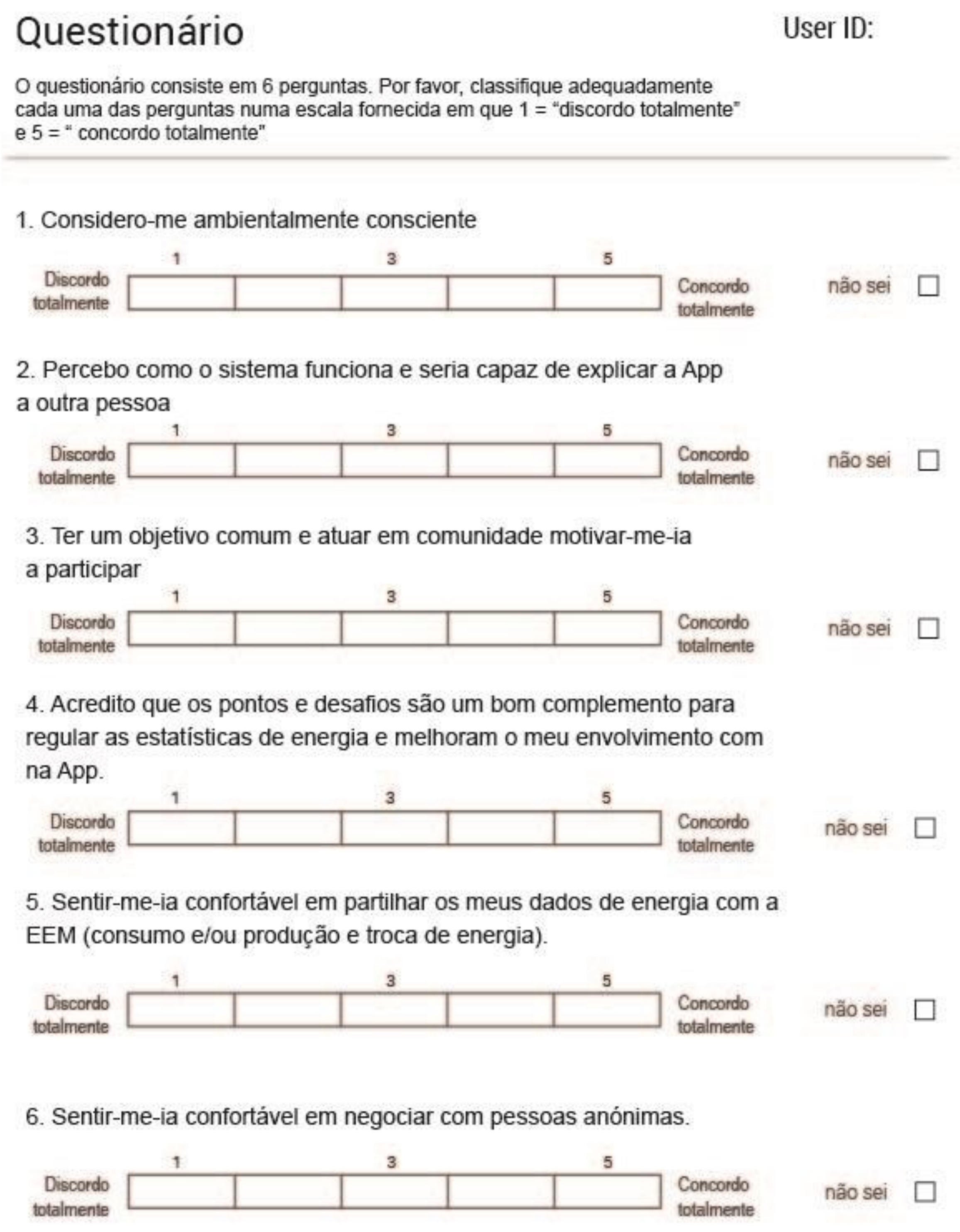
A. Appendix

Survey performed during the user study (in Portuguese).



Questionário

User ID:

O questionário consiste em 6 perguntas. Por favor, classifique adequadamente cada uma das perguntas numa escala fornecida em que 1 = "discordo totalmente" e 5 = " concordo totalmente"

1. Considero-me ambientalmente consciente

Discordo totalmente | 1 | | 3 | | 5 | Concordo totalmente | não sei ☐

2. Percebo como o sistema funciona e seria capaz de explicar a App a outra pessoa

Discordo totalmente | 1 | | 3 | | 5 | Concordo totalmente | não sei ☐

3. Ter um objetivo comum e atuar em comunidade motivar-me-ia a participar

Discordo totalmente | 1 | | 3 | | 5 | Concordo totalmente | não sei ☐

4. Acredito que os pontos e desafios são um bom complemento para regular as estatísticas de energia e melhoram o meu envolvimento com na App.

Discordo totalmente | 1 | | 3 | | 5 | Concordo totalmente | não sei ☐

5. Sentir-me-ia confortável em partilhar os meus dados de energia com a EEM (consumo e/ou produção e troca de energia).

Discordo totalmente | 1 | | 3 | | 5 | Concordo totalmente | não sei ☐

6. Sentir-me-ia confortável em negociar com pessoas anónimas.

Discordo totalmente | 1 | | 3 | | 5 | Concordo totalmente | não sei ☐

Figure A.1 Survey

B. Appendix

A draft of Business Model Canvas for PowerShare v2.

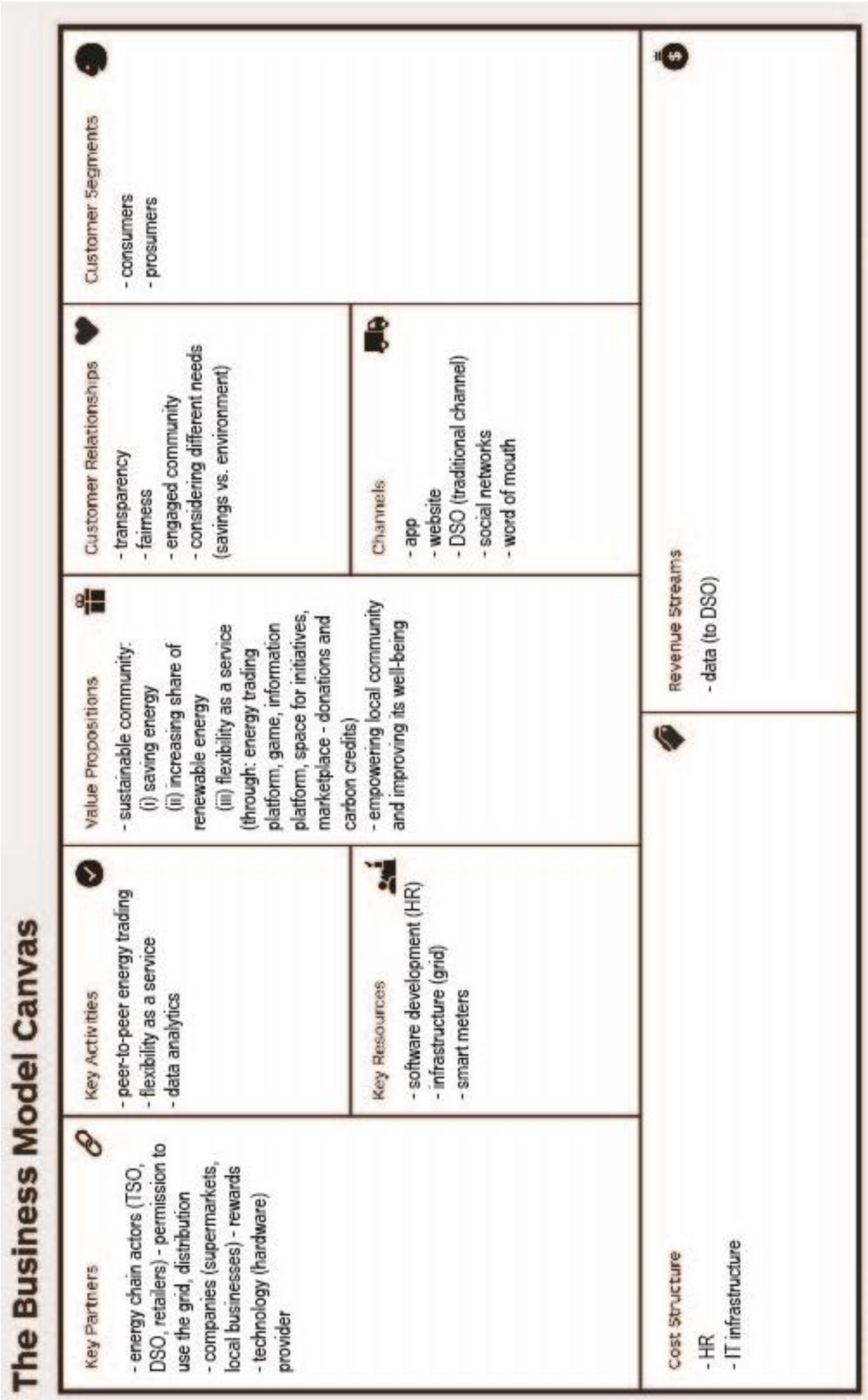


Figure B.2 Business Model Canvas