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The role of Intelligent Systems in the development of Peer-to-Peer systems for energetic distribution management

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To my Professors, for all the help;

To my family, for all the support;

And to my friends, for all the patience:

Thank you.

Resumo

Sistemas Inteligentes são um dos maiores benefícios dos dias de hoje, enquanto a sustentabilidade ambiental é um dos maiores desafios. Este estudo pretende integrar as mais recentes inovações em tecnologias inteligentes com o desenvolvimento de redes de energia inteligentes (*Smart Grids)* e sistemas Peer-to-Peer (P2P) para distribuição energética. Especificamente, investiga as relações complexas entre estes conceitos, enquanto analisa como desenvolvimentos em cada área influenciam e são influenciados pelas outras. Para isso, este estudo responde a três questões de pesquisa. A primeira relaciona-se com a implementação de Sistemas Inteligentes, a segunda com o desenvolvimento de Redes Inteligentes, e a terceira está relacionada com a possibilidade de construir Sistemas P2P. Para obter conclusões relevantes, foi feita uma extensa revisão de literatura relativa a todos os temas, assim como uma análise estatística de três questionários online. Os resultados obtidos mostram que existem influências e conexões significativas entre o desenvolvimento de tecnologias inteligentes e a implementação de *Smart Grids* e Sistemas P2P, suportando assim múltiplas hipóteses formuladas para este estudo. Com esta base, são retiradas conclusões que confirmam o elevado valor de cada tópico em separado, e o ainda maior valor dos tópicos quando integrados.

Palavras-Chave: Sistemas Inteligentes, Smart Grids, Sistemas P2P, Energia, Sustentabilidade, Inovação

Classificação JEL:

M10 Business Administration: General

O31 Innovation and Invention: Processes and Incentives

Q42 Alternative Energy Sources

Abstract

Intelligent Systems are one of today's greatest strengths, while environmental sustainability is one of today's biggest challenges. This study aims to integrate the most recent innovations in intelligent technologies with the development of smart energy grids and Peer-to-Peer (P2P) systems for energetic distribution. Specifically, it investigates the complex relations between these concepts, while analysing how developments in each field both influence and are influenced by each other. To do so, this study answers three research questions. The first one regards the implementation of Intelligent Systems, the second concerns the development of Smart Grids, while the third is concerned with the possibility of building P2P Systems. To provide relevant conclusions, an extensive literature review regarding all subjects was carried, along with a statistical analysis of three online surveys. The obtained results show that there are significant influences and connections between the development of intelligent technologies and the implementation of smart grids and P2P Systems, thus supporting several hypotheses formulated for this study. On this basis, conclusions are drawn concerning the high value of each topic in separate, and the even higher value of the topics when integrated.

Keywords: Intelligent Systems, Smart Grids, P2P Systems, Energy, Sustainability, Innovation

JEL Classification:

M10 Business Administration: General

O31 Innovation and Invention: Processes and Incentives

Q42 Alternative Energy Sources

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List of Abbreviations

AI – Artificial Intelligence

AMI – Advanced Metering Infrastructure

ANNs – Artificial Neural Networks

BMG – Brooklyn Microgrid

CBA – Cost-Benefit Assessments

DERs – Distributed Energy Resources

DSO – Distribution System Operators

DL – Deep Learning

DRI – Demand Response Implementation

DRPM – Demand Response Program Marketing

EDP – Energias de Portugal

EU – European Union

FPP – Federated Power Plant

GPS – General Problem Solver

ICT – Information and Communications Technologies

IoT – Internet of Things

IRENA – International Renewable Energy Agency

M2M – Machine to Machine

MGs – Microgrids

ML – Machine Learning

P2P – Peer-to-Peer

PVs – Photovoltaic Systems

PwC – PricewatherhouseCoopers

RAA – Rational Agent Approach

SCs – Smart Cities

SEDA – Sustainable Energy Development Authority

SGs – Smart Grids

VPP – Virtual Power Plan

Chapter I – Introduction

1.1. Framework and Research Problem

Innovation is key for nearly every business area. As such, this dissertation intends to provide possible solutions for old problems with new and exciting technologies: Intelligent Systems dependent on Artificial Intelligence, Blockchain, or the Internet of Things; Smart Grids capable of optimizing energy distribution using complex technology; or Peer-to-Peer systems for energy distribution, capable of increasing the use of renewable energies while also reducing prices for consumers.

These and other examples of innovation and progress are mentioned in this study since there is an urgent need to find solutions for problems related to the global energy network, still overly dependent on non-renewable energy sources and highly polluting processes. In 2019, Portugal's share of renewable energies in the total consumption of energy was of around 26.7%, while 42.1% was from oil products. Although this share is relatively small, it shows an important increase in renewable energy consumption, from 13% in 1999 (DGEC, 2021). For this reason, this is the right time to try and implement new projects that may further increase consumption from renewables.

As such, the connection to intelligent systems, which are bound to optimize and improve a variety of areas of business, is extremely significant. Data from 2020 regarding the use of AI in European enterprises that employ 10 or more people show that Portugal has an above average percentage of AI usage, at 9% (EU at 7%) (Eurostat, 2021a). Usage of the IoT, on the other hand, is below the EU average in Portugal (Eurostat, 2021b), meaning that there is still room for improvement in the rollout of intelligent systems in the country.

Hopefully, the present study will provide a meaningful insight into the possible development of intelligent systems, and their advantages for the energetic distribution sector. This research links the possible benefits of advanced systems for data management and optimization with the development and improvement of energy distribution grids, while also showing the advantages of the expansion of intelligent technology to renewable energy projects such as P2P energy trading. This is an area where technology is constantly finding more ways to improve and be improved, and this dissertation shows some of the ways in which this can happen.

1.2. Objectives and Research Questions

This dissertation intends to address two specific theoretical objectives, using three research questions. But for the general scope of this study, the intention lies in positively contributing to these areas of research, namely the area of the development of intelligent systems and the area of renewable energy projects. All being well, this project will prove to be a constructive addition to the existing literature concerning the abovementioned topics.

Regarding the specific objectives and respective research questions, which will be further explained ahead, they are:

1. To understand the possible role of intelligent systems in the development of Peer-to-Peer systems for energetic distribution management:
   - Which factors influence the willingness to implement and develop Intelligent Systems that rely on Artificial Intelligence, Blockchain, and the IoT?
   - Do Smart Technologies and Intelligent Grids bring value to modernized energy grids, which may include P2P Systems and lead to Smart Cities?
2. To analyse the Portuguese energy sector to understand if consumers and companies are ready and/or willing to implement Peer-to-Peer systems:
   - Is there value in the implementation of Peer-to-Peer projects for energy distribution, and if so, do companies and consumers recognize this value?

1.3. Dissertation Structure

This dissertation is composed by the following structure: Chapter I, the introduction, presents the framework for this study and the research problem from which it derived. Chapter II, the literature review, presents each topic addressed in the research. Ranging from Intelligent Systems, AI or Blockchain to Smart Energy grids and P2P projects, this extensive review of available literature intends to explain how each technology/project operates, and how the interconnection between every topic is possible.

Following the literature review, Chapter III, the theoretical approach, presents the objectives, research questions, and hypotheses ensued by the previous chapter. Immediately after, Chapter IV, the methodology, addresses the research model, the conceptual models for each survey, the extended hypotheses and the relation between each survey question and its indicator. Also under the methodology, a description of the sample for each survey is presented.

Chapter V, result presentation and discussion, addresses the findings from the statistical analysis of the online surveys, along with the validation of the previously formed hypotheses. Here, a confirmation of the research questions is done, and an integrated result discussion is also performed in order understand how the topics presented before may connect and influence each other. Finally, Chapter VI presents the conclusions for this study, along with a mention of the limitations and suggestions for future investigations.

Chapter II – Literature Review

2.1. Intelligent Systems

According to the Stanford University's Artificial Intelligence Index Report of 2021 (Zhang et al, 2021), the world is observing an increase in interest in AI. The number of journal publications has increased by 34.5% from 2019 to 2020, and while most publications come from academic institutions, interest has also increased in governments (15.6% in China and 17.2% in the EU) and in the corporate world (19.2% of total publications in the US). For the general public, interest in AI, measured by the attendance of AI related conferences where the multiple benefits of intelligent technologies are shown has almost doubled in 2020, although this difference may be partially explained by the Covid19 pandemic, which forced these conferences to be held online.

Siau and Wang (2018) refer that several factors are important to understand trust in IS. To form initial trust, it's important to show transparency and to have a good performance. To maintain confidence, aspects such as reliability, security, and interpretability are essential. Also important is the perception of the purpose of these systems, since some people may show distrust due to the fear of losing their jobs, or regarding the science-fictional aspect of AI – the eventual overcoming of human intelligence and subsequent destruction of society.

Another important factor regarding user trust in Intelligent Systems is the perception of the inner workings of AI. A study by Holliday et al (2016) demonstrates that users tend to show more confidence in these systems if explanations are given about how results are obtained. We will now define IS, and explain the various components necessary for their existence.

There are several definitions regarding Intelligent Systems. Authors Stuart Russell and Peter Norvig (2010) describe them as agents which perceive their environment through sensors, and act upon it through effectors. More recently, Molina (2020) describes these systems as tools operating in a complex world with limited resources, and which possess cognitive abilities like perception, reasoning, action control, or language use. According to the same author, these systems exhibit an intelligent behaviour, supported by abilities such as rationality, adaptation through learning, and introspection in order to explain the use of their knowledge.

An equally important characteristic of Intelligent Systems is their autonomy. These systems are able to make decisions on their own, choosing the best available course of action by learning from their previously obtained knowledge. Leikas et al (2019) describe autonomous systems as going beyond automation, adding self-governing behaviour, and requiring intelligent decision-making abilities. But for systems to be autonomous, they cannot simply be programmed by their creators. They need the technology that enables this sort of rational thinking and learning that was for centuries only available to humans: they need Artificial Intelligence.

2.1.1 Artificial Intelligence

Artificial Intelligence as a discipline has its origin in 1956, when the term was coined at the Dartmouth Summer Research Project on Artificial Intelligence (DSRPAI), hosted by John McCarthy and Marvin Minsky. Until today, definitions of the term have varied greatly. Russell and Norvig (2010) describe AI as systems divided into four categories: systems that think or act like humans, and systems that think or act rationally. Another definition is provided by McCarthy himself in 1956, saying that as every aspect of intelligence can be accurately described, so too can it be simulated by a machine.

Although AI has been studied and developed for more than half a century, its real applications and benefits were always under discussion. It wasn't until 1997 that something remarkable changed the idea about the discipline all over the world. That was the year in which Deep Blue, IBM's chess playing intelligent system, defeated the then world chess champion Garry Kasparov. According to McCorduck (2004), there was a realization that computers that fused "minds" and sensors were able to perform tasks previously thought to be unique to humans, and that intelligence was finally in the reach of machines.

As previously mentioned, Russell and Norvig described four types of categories for AI. The first one, Thinking Humanly, is based on cognitive science. The authors considered that if we understand the functioning of the human mind (through introspection or psychological experiments), we can accurately express it as a computer program. The work of Newel and Simon (1961) is used to express this reasoning, as these authors created the GPS (General Problem Solver), a computer program designed to solve any general problem that could be put into symbolic terms. However, Newel and Simon where more focused on using the GPS as a theory of human problem-solving, rather than a simple computer program.

The second category of AI for Russell and Norvig is Acting Humanly. This is based on the work of British mathematician Alan Turing (1950), who designed the Turing Test. This test sought to capacitate machines to achieve intelligent behaviour, described by Turing and according to Russell and Norvig as "the ability to achieve human-level performance in all cognitive tasks, sufficient to fool an interrogator" (2010). The same authors refer that in order to obtain this level of performance, the machine would need four main capabilities. They are *Natural Language Processing*, to successfully communicate in any human language; *Knowledge Representation*, for storing information; *Automated Reasoning*, to draw conclusions and answer questions from the information stored; and *Machine Learning*, to adapt to new circumstances and to extrapolate new patterns.

The third category from Russell and Norvig is Thinking Rationally. This is based on the Laws of Thought Approach, which derive from logical thinking (with its origins in Aristoteles' syllogisms and rational thinking). This approach proposes that machines would take any problem described in logical notation, i.e. mathematical symbols, and find an appropriate solution given enough time. This, however, poses two problems: first, it is not easy to describe every problem as logical notation, because complex problems may not have an answer that is 100% certain. Second, some problems may be so complex that machines wouldn't have the skills or the time to solve them accurately if they weren't provided with some sort of guidance as to which steps it should take first.

Finally, the Rational Agent Approach (RAA) brings us to the fourth category described by Russell and Norvig: Acting Rationally. This is the most important and relevant category, considering that an agent that acts rationally englobes the characteristics of the three previous categories. According to the authors, acting rationally implies acting concordantly with your beliefs in order to achieve your goals. An agent, therefore, must act given into account what it perceives – and AI is then viewed as the study and construction of rational agents.

As mentioned, the Rational Agent Approach englobes the other categories. This is because, for instance, the cognitive skills implied by the Turing Test are there not only to fool the interrogator, but also to allow rational and logical actions and reactions to his or her questions. All the cognitive knowledge that a machine may have, could be used not only to pass a test and solve complex problems, but also for it to learn how to adapt and improve itself in face of ever-changing environments and situations.

Regarding the Laws of Thought Approach, in which logical and correct inferences are necessary to reach the "right" conclusions, the RAA goes further because it sees that making correct inferences is not the entirety of rationality (Russell and Norvig, 2010). There are some situations in which there is no one correct solution, and yet something must be done. A machine must be able to make a decision based not only on rationality, but also based on its prior knowledge and future predictions regarding its actions.

We now have a somehow sufficient knowledge on the foundations of AI and its many possible definitions. It is time, then, to go deeper into the possible uses of this technology and understand how it may be used by machines to learn and improve their own capabilities. We will therefore mention Machine Learning, the technology that can be used to, according to Singh et al (2020), identify patterns and make predictions based on data generated by any system. These possibilities will be extremely useful ahead, when we mention the integration between the Energy sector, Peer-to-Peer (P2P) Systems, AI, Machine Learning, Big Data, and the Internet of Things. But let's not get ahead of ourselves – for now, our focus is Machine Learning.

2.1.2 Machine Learning

Machine Learning (ML) is essentially a subfield of Artificial Intelligence, consisting of the ability that computers, aided by algorithms, have of learning how to make accurate predictions based on previously gathered data. According to Segaran (2007), algorithms infer information from a set of data, learning about that data's properties. The author explains that machines are able to do this by recognizing patterns that exist in most non-random sets of data, and by generalizing these patterns into predictions about other data it may see in the future. Algorithms do this by generating models which determine the important aspects of each type of data, allowing them to become more and more complete and accurate.

The most important models for this paper are those that allow for *Predictive Data Analytics*. Prediction in data analysis isn't the same as prediction in common language. As Kelleher et al (2015) explain, in contrast to everyday usage of the word, which means to predict what will happen in the future, prediction in data analytics means assigning a value to any unknown variable. These predictions provided by models are based on patterns from historical data and may be used in anything from price forecasting to medical diagnosis or risk assessment.

As ML will be mainly used for accurate forecasts and predictions of supply and demand in our proposed P2P energy trading systems, the most important scenarios of this technology will be concerned with what is known as labelled data. Mohri et al (2012) give a good explanation into how different types of data available, the method and order by which the data is received, and how the test data is used can influence the evaluation of the learning algorithm. The authors differentiate how labelled and unlabelled data are used by two scenarios of ML – supervised and unsupervised learning, respectively.

Mohri et al (2012) explain how in supervised learning the *learner* receives a set of labelled data (such as information from costumer usage or historical data on resource consumption) as training data and makes predictions based on this data to accurately forecast how the information will behave in the future. In unsupervised learning, the algorithm receives unlabelled data (data in which there is no specific value, but that still has some information such as location or dimension), and learns how to, for instance, cluster the information based on similarities it may find. We will be focused mostly on supervised learning, although some unsupervised learning may also be useful for costumer segmentation.

The methods we will mostly focus on are known as *Inductive Learning*. According to Zhang (2020), induction is used to extract patterns from sets of data, and the author mentions several key characteristics for the expected performance of ML algorithms. Among others, they are scalability (ability to handle increased amounts of data), training and response time (time it takes to train an algorithm and for the algorithm to make predictions, respectively), training data (how much data it needs to be trained), complexity (amount of mathematical operations the algorithm needs), and accuracy.

Now that we understand the general characteristics of ML and its algorithms, we must dwell deeper into the world of how machines "think". But before that, a note from Proserpio et al (2020). These authors mention how ML is essentially a series of computations mapping inputs into outputs, and that, therefore, machines have no soul. This soul, according to the authors, is what can turn the results obtained by a machine into "art", to provide valid and useful insights and action. But for the time being, machines are still machines, although they are increasingly functioning as human brains – as such, we will now briefly mention the technology of Artificial Neural Networks.

2.1.3 Artificial Neural Networks & Deep Learning

According to Zhang (2020), Artificial Neural Networks (ANNs) are inspired by the brain. These networks are composed of artificial neurons, which are interconnected and capable of computations regarding their inputs. The same author explains how the input data in the first layer of the network activates that layer's neurons, and the output of those neurons activates the next layer, and so on until a final output is obtained. The layers between the first (input) and the last (output) layers are referred to as hidden layers.

Schmidhuber (2015) refers the capacity that these networks have of influencing the environment, given that the input data is essentially measured through sensors, and that some neurons may influence the environment by triggering actions. In a more technical fashion, based on the work by Nielsen (2015), we understand that an algorithm gives a weight (a value representing the importance of each input to its output) to every input, and computes a value known as threshold (or bias). The sum of the weighted inputs must be either smaller or greater than the threshold, and the output depends on this comparison. It then learns, based on previous analysis of training data, what are the best values of weights and biases for this particular type of data, and which values offer the most accurate outputs.

This is also the way in which Deep Learning (DL) functions. Essentially, DL is a form of ANNs with complex multilayers (Abiodun et al, 2018). These authors explain that the difference between ANNs and DL is that the latter has more complex ways of connecting layers, more neurons, and more computing power.

This concludes the section of this paper on the properties of Intelligent Systems. We will now mention how these systems may work while integrated on the Internet of Things, and also how they can be improved by technologies such as Blockchain. The objective of these sections is to hopefully provide knowledge about how Intelligent Systems may contribute to the development of P2P Systems, and how it may help in these systems' implementation.

2.1.4 Internet of Things

The phrase "Internet of Things" (IoT) was probably coined in 1999 by Kevin Ashton (2009) as the title of his presentation at Procter & Gamble, according to himself. Since then, many definitions have been given to the term IoT. We will make use of the words from Sethi and Sarangi (2017), who refer, quite simply, that the IoT is a new kind of world, in which the majority of devices and appliances used by humans are connected to a network. The same authors state that these objects may be used collaboratively, in order to achieve complex tasks requiring a high degree of intelligence.

But before we define the concept of IoT, a word about user trust is important. User trust in the IoT is mostly concerned with privacy and security (Rose et al, 2015; Abera et al 2016; Lin and Dong 2018). According to Rose et al (2015), users of the IoT need to be assured that their data is secure as it travels through interconnected devices, much in the same way in which we trust that browsing the Internet is safe and that our data is private and anonymous. Abera et al (2016) show the need to verify that remote IoT devices are properly functioning and behaving as expected, and Lin and Dong (2018) mention several ways for trust to be ensured in the IoT, such as feedback from other users, reputation of the service providers, or the context of the transactions.

Moving on, it would be unfair to talk about the IoT without mentioning an essential concept for its existence. Machine-to-Machine (M2M) is described by Holler et al (2014) as a solution that enables communication via wired or wireless networks between devices that share the same types and specific applications. The authors also state that these solutions make it possible for users to capture data about events from their devices, and gives the examples of temperature or inventory levels. Other possible applications are mentioned by Fadlullah et al (2011), who claim that with efficient M2M communication, an electric grid may have enough smart capabilities to allow the players in the power management system to maintain near-real-time awareness of each other's requirements and capabilities.

To distinguish IoT from M2M, Holler et al (2014) state that the IoT encompasses M2M, but it also refers to the connection of intercommunicable systems and sensors to the Internet, as well as using general Internet technologies. The IoT is, therefore and according to Lin et al (2017), an extension of the Internet, which means that in the IoT multiple networks should coexist and offer an interoperability among networks which is essential for information delivery and for the support of the many applications the IoT may provide. To understand these applications and features, it is important to explain the most commonly suggested architectures for the IoT. Before that, a small description of Big Data is necessary, since this concept deeply influences the architectures to be discussed.

2.1.5 Big Data

Big Data is a concept which is increasingly growing in importance and relevance, mostly because of the already mentioned advances in the IoT and its smart devices, but also due to the ever-increasing creation of data provided by social networks and online sales. Oussous et al (2017) explain that the term Big Data refers to large growing data sets, in which data appears in heterogeneous formats, like structured, unstructured, or semi-structured data.

Gandomi and Haider (2015) refer that Big Data could be explained by mentioning three V's – *Volume*, *Variety*, and *Velocity*. Volume refers to the magnitude of data. As the name Big Data implies, there are massive amounts of information being transferred between devices, and a structure to analyse and storage this information is necessary. Variety alludes to the heterogeneity in data sets, as mentioned above. Using Big Data analytics, the several formats in which data is presented can be analysed more efficiently than with normal statistical and small data analytical tools. Finally, Velocity is about the rate at which data is generated, and the speed necessary to analyse it and act upon it. With Big Data analytics, real-time intelligence may be created from large volumes of data.

The same authors (Gandomi and Haider, 2015) also mention three more Vs to explain Big Data, although the ones mentioned in the previous paragraph are more widely used. The three extra Vs are *Veracity* (referring to the unreliability of some sources of data), *Variability* (referring the variation in data flow rates), and *Value* (referring that the received data usually has a low value comparing to its volume). Big Data analytics can be extremely useful in addressing these characteristics. Let us now proceed into the possible architectures for the

Internet of Things, and how they may address the processing of these large amounts of data in the most effective way.

2.1.6 IoT Architecture

An interesting proposed architecture is given by Ning and Wang (2011). The authors suggest a "Man-like Nervous" model, which consists of three parts: the brain, for management and as a centralized data centre; the spinal cord, as distributed control nodes; and a network of nerves, which are the IoT networks and sensors. This proposal is interesting for its simplicity and resemblance to the human body, but it is, however, quite insufficient.

Better proposals are mentioned by Sethi and Sarangi (2017), consisting of architectures with either three or five layers. The three-layer architecture is comprised of the *perception*, *network*, and *application* layers, and data flows in this order. The first (perception) is physical, with sensors that gather information about the environment by sensing physical parameters or identifying smart objects around them. The second (network) is responsible for the connections with other smart objects in the network, and it transmits and processes sensor data. Finally, the third layer (application) is where specific application services are delivered to the user, with the example of smart homes or smart cities.

For the five-layer architecture, the same authors (Sethi and Sarangi, 2017) explain that three layers are added, and network is removed. Keeping the same order for the data flow, a *transport* layer is added after perception, and it is where the sensor data is transferred to the next layer, *processing*. Here, data is stored, analysed, and processed by technologies such as cloud computing or big data processing modules. Finally, the *business* layer is added after application, and it is where the whole IoT system is managed, including business/profit models and users' privacy.

There are, however, some limitations to these architectures. In the systems described above, data is processed and analysed mostly through cloud computing technology. But the main constraint of this systems is their limitation in terms of the capacity for processing large volumes of data. According to Varghese and Buyya (2018), the increased availability of devices equipped with sensors, such as smartphones, tablets or wearables, is generating such volumes of data that the cloud computing infrastructure needs to evolve and requires new computing models in order to satisfy large-scale applications.

Due to this limitation, an architecture for the IoT based on fog (or edge) computing is proposed. Although fog and edge computing are slightly different concepts, their main characteristics are quite similar. Li et al (2018) define edge computing as the offloading of computing tasks from the centralized cloud to edge nodes near the IoT devices, which allows for the pre-processing of data in the edge, drastically reducing the amount of data that is transferred from these devices to the cloud. Sethi and Sarangi (2017) refer that fog computing may be seen as a sort of cloud where data is pre-processed, but close to the ground and near the IoT devices. This is achieved through a strong communicability between devices on the edge of the network, and by giving smart data pre-processing capabilities to physical devices.

We will use these two concepts interchangeably, since the goal of both is to pre-process data before it is transferred to the cloud. As Lin et al (2017) mention, given the increase in generated data, fog/edge computing may provide computing and storage services to the devices (or nodes) at the edge of the network, thus removing pressure from the centre of the cloud. Another advantage is mentioned by Li et al (2018), who show us how technologies like Deep Learning may optimize network performance in the edge computing environment, as well as protect user privacy when data is uploaded.

Li et al (2018) claim that since DL can find features and patterns in large amounts of data, it is appropriate for edge computing because it reduces the load sent to the cloud by learning common features in data sets provided by the edge devices. For privacy purposes, DL may preserve the privacy in intermediate data transferring because it is harder to understand the original information when given the patterns and features extracted by Neural Networks, according to the same authors. Another way to ensure privacy and security when transferring data is the developing technology of Blockchain. The next chapter addresses this model and gives an insight into how it may be applied and improve networks among the IoT.

2.1.7 Blockchain

Blockchain is a technology first presented to the world by Satoshi Nakamoto (2008), a pseudonym whose real identity is still unknown. According to Yli-Huumo et al (2016), this technology is a database with a distributed architecture, where records of every transaction are available for all participants in the chain. This public ledger maintains all data records, and thus the information about every completed transaction in Blockchain is shared and available in all nodes (or blocks). The same authors add that this technology is a decentralized solution since it does not require a central authority to verify each transaction.

The main characteristics and advantages of Blockchain are well described by Zheng et al (2018). They are *decentralization*, meaning that, as opposed to a centralized system where each transaction must be verified by a trusted third-party, in the Blockchain transactions are conducted between peers without authentication from central agencies; *persistency*, since transactions need to be confirmed and recorded in blocks throughout the entire network, meaning that any falsification is easily recognized; *anonymity,* since user addresses are generated and there is no record of them by any central authority, ensuring a great amount of privacy; and *auditability*, since all transactions are recorded and accessible by any user who wishes to verify them.

We can easily understand that these characteristics may be useful if applied in the IoT. Reyna et al (2018) explain the reasons why Blockchain may improve IoT networks. These improvements (among others) are related to *decentralization* and *scalability*, as there is no central authority and, therefore, no centralized points of failure and no opportunity for few to control the information of many; *identity,* since in the Blockchain every single device is identified and its data is unique and immutable; *autonomy*, since devices may communicate amongst themselves with no need for servers; and *reliability* and *security*, as information and communications are verifiable at any given moment, and are fully secured if treated as transactions in the Blockchain.

But Blockchain is not a magical entity that provides every solution, and there are still several challenges to the implementation of the technology. Lin and Liao (2017) mention some, such as the possibility of a 51% (Majority) Attack, which happens when one user (or a group of users) has sufficient computing power to control more than half the blocks on a certain chain, creating security issues. This is, however, highly unlikely due to the number of users in the chain. Other challenges are concerned with time and scale, as Blockchain takes time to verify each transaction and with increased amounts of data this may represent a problem; with regulations, which are still quite unclear on Blockchain; or with costs of implementation. Solutions for these and other challenges are necessary, but out of the scope of this paper.

Finally, user trust in Blockchain is essential for its development. Understanding user trust in Blockchain is quite difficult, as it is a very recent technology and not many studies were made regarding the subject. However, the work of Fleischmann and Ivens (2019) shows that Blockchain may facilitate the creation of trust-free systems, in which the technology itself guarantees the safety of the transactions. The same authors conducted an inductive and qualitative research, whose results demonstrate that user trust benefits Blockchain technology because the benefits of an elevated trust in the technology span across several dimensions (economic, social, personal, etc.), since users and consumers who trust Blockchain (and by extension the other peers involved in the transactions) are more willing to use it.

The study conducted by Fleischmann and Ivens (2019) shows that people who are familiar with the technology (e.g., chief officers in Blockchain related companies or Bitcoin users) show a high degree of trust in the system, whereas people with less familiarity show more reluctance and disbelief regarding its benefits (such as cost savings, increase in efficiency and speed, and safety and anonymity). This shows that information is key regarding the implementation of Blockchain, and that willingness to use is directly related to knowledge – which, in term, increases trust in the technology.

We conclude this section by mentioning the work of Singh et al (2020), in which an integration between Blockchain, IoT, and AI is proposed. The authors propose an architecture for this integration based on four layers. The first one is *Device Intelligence*, which consists of several IoT devices and sensors collecting data with the aid of AI and ML techniques. This data is then transferred to the second layer using a Blockchain network for increased privacy and security. In the second layer, *Edge Intelligence*, AI is used to efficiently process the data. The third layer is *Fog Intelligence*, and the fourth layer is *Cloud Intelligence*, in which similar approaches are used to provide secure, reliable, efficient, and fast IoT solutions.

The conclusion above opens path to the next chapter of this dissertation. We will understand how the technologies and innovations previously mentioned allow for the construction and development of Microgrids and Smart Grids for energy trading, as well as for the Smart Cities of the future. After that, we mention how these concepts are necessary for the development of Peer-to-Peer systems, and how these systems may be implemented.

2.2 Smart Technologies' Applications

In this section, we will mention how devices such as Smart Meters may be applied in the creation of grids for an optimal energy distribution chain. We will focus on Microgrids (MGs), Smart Grids (SGs), and Smart Cities, showing how the technologies previously mentioned in this paper may help in the development of these concepts. We start with a small description of Smart Meters, followed by MGs and SGs, and finally with an introduction into the concept of Smart Cities. To avoid the repetition of descriptions, we must bear in mind that Intelligent Systems and all their previously mentioned capabilities may be applied in the concepts mentioned in this section.

2.2.1 Smart Meters

According to Zhou et al (2016), smart meters are advanced energy meters, equipped with the capacity to measure a consumer's energy consumption and provide information about that consumer to power utilities using a two-way (or bi-directional) communication scheme. The authors refer that the main functions of smart meters are measuring energy usage, communicating the usage, accepting instruction information, enabling responses to specific energetic requirements, and collecting data for forecasting purposes.

These characteristics allow for multiple applications. Wang et al (2018) mention three main applications for smart metering, which are *Load Analysis*, *Load Forecasting*, and *Load Management*. The first one is mostly concerned with bad data detection, energy theft detection, and load profiling (the classification of consumers according to electricity consumption behaviours). The second (Forecasting) is quite self-explanatory, and smart meters allow for it in two ways: first, energy providers are able to better understand and forecast loads for individual houses or buildings; second, the large amount of data received allows for accurate forecasting in aggregate levels, such as Microgrids or even cities. Finally, Load Management refers to consumer characterization, Demand Response Program Marketing (DRPM), and Demand Response Implementation (DRI).

These last concepts, DRPM and DRI are explained by Shakeri et al (2017), who state that demand response is the modification in normal consumption patterns of demand, either by increasing or decreasing the demanded loads when there is an excess or a shortage of power, respectively. These changes are made by individual consumers in response to the condition of suppliers, which implies a challenge: according to Shakeri et al, most consumers either don't or can't calculate their own power consumption, and therefore smart metering technologies are necessary to provide optimal responses when changes are needed, or even when they are simply useful for consumer cost savings.

A survey conducted by Viegas et al (2016) provides meaningful conclusions regarding the efficiency of smart metering devices. The authors refer that smart metering paves the way for the development of SGs, since its two-way communication capabilities empowers consumers by allowing them to actively participate in the energy market. Other advantages of smart metering mentioned by Viegas et al refer mainly to the clustering possibilities given by the large amount of smart metering data. Clustering consumers enables the creation of targeted tariffs regarding energy consumption expectations, enables a greater personalization of services and offers, and provides energy saving and sustainability services that consumers may want to be engaged in.

Finally, recent data shows that the implementation of Smart Technologies (Smart Meters, AMIs, etc) in the EU is well under way. According to Prettico et al (2020), the majority (66%) of interviewed Distribution System Operators (DSOs) are already using some type of AMI, mostly to obtain consumption data from their customers, prevent frauds, and to allow for time-based pricing of consumption. A report for the EU (Alaton and Tounquet, 2019) shows that most countries in Europe (including Portugal) have reached positive conclusions in Cost-Benefit Assessments (CBAs) regarding the implementation of smart meters, showing monetary benefits (in €/meter) ranging from 43€ in Latvia to 969€ in Cyprus, the average being 282€/meter.

Alaton and Tounquet (2019) also show that an 80% target on the roll-out of smart seters in the EU should be reached by 2025. In 2018, 34% of all electricity metering points in the EU were equipped with a smart meter (around 99 million SMs), and Portugal is set to go from 25% (1.5 million SMs) in 2018 to 80% in 2022-23. Moving on , let us now see how smart metering may be applied into practice, in particular in the creation of Micro and Smart Grids for energy distribution.

2.2.2 Microgrids & Smart Grids

The concept of Microgrids is not particularly new. A good definition of this technology is given by Chowdhury et al in 2009, who state that Microgrids are small-scale supply networks of energy for small communities, consisting of an active distribution network of different energy sources, mostly coming from Distributed Energy Resources (DERs). DERs are defined as small to medium scale resources connected to distribution grids and near the end user, according to a report to the European Commission (SWECO, 2015). Also, DERs are usually small renewable energy sources, such as Photovoltaic systems (PVs) or windmills, and according to Hatziargyriou et al (2007), MGs are entities that coordinate these DERs in decentralized ways, reducing the control burden of normal distribution grids.

More recently, authors like Yoldas et al (2017) focus on Microgrids integrated with smart metering technology, proposing an Advanced Metering Infrastructure (AMI) which provides bidirectional communication for Smart Grids. According to the same authors, this infrastructure consists of an integration between smart meters, communication systems, measurement hardware and software, and data analysis techniques. With this sort of infrastructure, SGs may provide numerous benefits comparing with normal distribution networks, such as an increased reliability, a lower investment cost, reduced power losses, reduced emissions, and improved power quality.

To understand why smart technologies may improve the distribution of energy in MGs, and thus open path to the creation of SGs, the work of Sethi and Sarangi (2017) provides a valuable insight. Regarding Smart Meters, the authors explain how these devices collect and analyse consumption patterns of power during regular or peak load times. The information obtained by the meters is sent to a server and also made available to the consumer, which allows for both parties to better understand when and how to use the provided energy. This allows for cost reductions, since both user and provider of energy are able to optimize the usage of power – the consumer uses it when prices are lower, the provider knows in advance what the consumption will be.

However, this alone does not make a grid *smart*. Again, Sethi and Sarangi (2017) state that the concept of SGs adds intelligence at each step, from generation to transmission and distribution. If there is an optimized analysis of data at each step, and if intelligent capabilities such as AI and Deep Learning are able to improve the process, SGs become extremely efficient in the management of the energy distribution chain. As an example, Li et al (2018) claim that DL may accurately predict electricity consumption through the data collected by smart meters, and thus efficiently improve the electricity supply in the SG.

Another advantage of SGs is the possibility to include renewable energy sources in an efficient and sustainable manner. When DERs are included in MGs or SGs, the management of energy provided by these sources becomes increasingly important. But DERs represent both an opportunity and a challenge – while renewable sources are essential for environmental sustainability, they are also dependent on uncontrollable conditions, and therefore are somehow unreliable sources of power. Another important challenge regards the increased system complexity brought by DERs (SWECO, 2015)**.**

Sethi and Sarangi (2017) mention how SGs may solve this question, since smart grids allow for the balancing of energy loads, based on usage and availability. In SGs the supply of energy may automatically switch from conventional to alternative sources of energy, depending on the availability of power provided by DERs and by the regular source. The same authors mention the integration of intelligent technologies to make this process more efficient, by stating that the above-mentioned balancing of loads can be done by smart gateways at the edge of the network, through the analysis of real time data provided by smart meters.

Mohanty et al (2016) mention how these technologies permit the development of smart energy systems. The authors explain this concept as an intelligent integration of decentralized sustainable energy sources, optimized power consumption, and efficient distribution. The integration between these three concepts is made possible by using a smart infrastructure based on state-of-the-art Information and Communications Technologies (ICT), since they may be used to effectively purchase and distribute green energy, to control operations, and to collect and share information regarding energy distribution.

ICT are therefore extremely important in the development of SGs. Mohanty et al (2016) explain that SGs effectively integrate actions and behaviours of all parties within the grid, such as consumers, generators, and prosumers (individuals who are both consumers and generators of energy). This integration in SGs is what allows for efficient, economical, and sustainable energy systems, which are safeguarded against losses, safety and security issues, low supply quality, and low fault tolerance. Mohanty et al also mention the important integration of different sources of energy, paving way for a more sustainable and environmentally friendly production and distribution of energy in SGs.

These concepts of integration and optimized distribution may lead to the construction of Smart Cities, in which most processes are interconnected and make great use of the technologies already described in this paper. We will now briefly mention how Smart Cities may profit from the introduction of intelligent systems, and how SGs may improve energy distribution in the cities of the future.

2.2.3 Smart Cities

The development of more sustainable cities represents an important challenge for the future of our society. According to a study conducted by the UN, urban areas are projected to hold around 68% of the world's population by 2050, in contrast to around 55% in 2018 (UN, 2019). Therefore, and as stated by Mohanty et al (2016), the creation of Smart Cities (SCs) appears to be a natural strategy to challenge the problems presented by rapid urbanization and urban population growth. Once implemented, these cities, despite their associated costs, may reduce energy and water consumption, carbon emissions, city waste, transportation requirements, and several other aspects consistent with city life.

These advantages of SCs in comparison with "normal" cities arise mostly from digitization of processes. Allam and Dhunny (2019) mention that this digitization happens through the installation of sensors, computational cores, and communication systems, and when these concepts are tied to AI and ML technologies it becomes possible to understand how cities evolve, adapt, and respond to several conditions. Ismagilova et al (2019) indicate that the increasingly connected devices within SCs result in significant levels of growth in data, as we already mentioned before. As such, this data needs to be communicated, processed, and stored, and intelligent systems show an advanced capability to manage this necessity.

In a Smart City, the amount of generated data is colossal. Silva et al (2018) propose an architecture that is reminiscent of the IoT architectures already mentioned in this paper. The authors propose a *sensing* layer in which data is collected and analysed; a *transmission* layer in which data is communicated through connecting data sources; a *data management* layer in which data is manipulated, organized, analysed, and stored, and which also performs decision-making tasks; and finally an *application* layer, which mediates urban citizens and the available data, influencing the user’s perspective, satisfaction, and actions towards the SC.

It is easy to understand how the IoT helps in the development and creation of SCs. Arasteh et al (2016) propose that all available devices should be connected to the Internet to increase accessibility. Going further, Allam and Dhunny (2019) claim that AI could capture hidden structures of urban cells, to provide a deeper understanding of common features. We already mentioned in this paper the integration of AI and the IoT, and these concepts seem quite helpful in the development of SCs.

Finally, SCs are also important for sustainability purposes, and they may allow for a greater efficiency in energy trading and distribution. Ahvenniemi et al (2017) show that although studies on Smart Cities are more concerned with social and economic aspects, environmental sustainability is also an important focus in the development of SCs. Therefore, the inclusion of intelligent energy trading systems is substantially important for sustainable cities, and these two concepts are in fact inseparable from one another.

The concepts mentioned above help us understand how smart energy systems, SGs, strong ICT, the IoT, and many other factors are essential in the development of SCs. However, SCs are large projects with a multitude of factors necessary for its progress, combining several different aspects of living that go way beyond the energetic sector, and therefore beyond the scope of this paper. While SCs are helpful to explain the integration of these technologies, we should now slightly lower the scale and mention other projects for energy trading. The next chapter of this paper is related to Peer-to-Peer Energy Trading Systems, and will hopefully be useful in the development of strong, efficient, and sustainable systems for energy distribution management.

2.3 Peer-to-Peer Energy Trading

2.3.1 Definition

Multiple definitions can be found to describe Peer-to-Peer (P2P) energy trading. In a paper conducted by the International Renewable Energy Agency (IRENA), P2P is described as a business model based on an interconnected platform, functioning as an online marketplace in which consumers and producers of electricity can trade energy without the need for an intermediary. According to Tushar et al (2018), in a P2P network the members can share part of their own resources (energy from DERs owned by prosumers) with each other, communicating their information and facilitating trade among the system.

Park and Young (2017) compare P2P energy trading with the overall functioning of the Internet. The authors claim that as happens on the Internet, in P2P each peer operates both as a client and a server who exchange information, and where most hierarchies are overturned. In P2P energy trading, each node of the distributed energy system has a responsibility in producing and consuming energy, since prosumers may make their excess energy production available to others in a nearly automatic and effortless manner.

Yet another definition is found in Zhang et al (2018), who state that P2P energy trading refers to a group of local energy prosumers, who buy and sell energy directly between each other in a decentralized way, meaning that there is no central control authority confirming each transaction. Zhang et al also state that P2P trading is enabled by strong ICT-based online services, which provide the possibility of efficient analysis of transaction and forecasting data grounded on customer usage, as well as the possibility to complement these services with AI and ML techniques and to integrate them in the IoT.

We should now understand how P2P trading systems function. The next chapter explains the way in which transactions are made through these systems, as well as which technologies may enhance energy trading in P2P networks.

2.3.2 P2P - How it Works

There are two main components in a P2P energy network: the virtual and the physical layers. Tushar et al (2018) state that the virtual energy-trading platform is what provides the technical infrastructure for the local electricity market. According to the authors, this platform must be based on a secure information system, e.g., a blockchain-based architecture in which information is transferred through the network. Another important feature of this virtual layer is that each peer must have equal access to the information, so that data referring the generation, demand, or consumption of a peer may be transferred from a smart meter to the virtual layer and create buy and sell orders in a fully transparent and fair manner.

After the order is given and accepted through the chain, the exchange of energy takes place in the physical layer. Tushar et al (2018) refer that this component may be the traditional distribution grid, provided that a bidirectional flow of energy is possible, or it may be a separate and independent grid such as a Microgrid functioning in conjunction with the traditional distribution grid. Zhang et al (2018) mention that the MG allows for a flexibility between traditional sources and energy coming from DERs, which means that in P2P energy trading there is a possibility for an enhanced use of renewable sources.

Morstyn et al (2018) mention that if DERs are owned by multiple prosumers, a single entity-run management system is not necessary, since these prosumers need an incentive to coordinate the operation of their DERs among themselves and not with a central control system. According to the authors, this means that a market mechanism able to incorporate prosumers' individual preferences and resource characteristics is necessary and can be found in a P2P trading system. In these networks, a mutually beneficial energy transaction scheme between prosumers is facilitated, consisting of the trading of excess energy between prosumers exceeding their energetic needs and prosumers with a demand higher than their production.

What this means is that through the coordination of DERs in a P2P network, it becomes easier to manage prosumers' production and demand, and it is also possible to facilitate renewable energy trading accounting for the time and location of energy generation, storage, and consumption (Morstyn et al, 2018). The same authors propose a Virtual Power Plant (VPP), consisting of a coalition of DERs coordinated to have controllability, visibility, and impact at the transmission level of a power network. However, VPPs would require a centralized control system, unless they allow for a P2P trading system – the authors then propose a Federated Power Plant (FPP), which would allow for prosumers to engage in P2P trading and also control the terms of their own transactions.

Many more proposals for P2P systems exist. Tushar et al (2020) mention three types of markets: a *fully decentralized market;* a *community-based market;* and a *composite market.* The differences between these proposals are simple – the first one requires no centralized control unit for peers to trade between themselves, the second requires a community member to oversee energy transactions between peers and outside markets (such as neighbouring P2P systems or MGs), and the third one is a conjunction of the previous two, in which peers trade freely between themselves but also with other markets through a community manager.

Proposals related to the management of communication systems in P2P are also relevant. We will focus on those related to Blockchain, as it is an exciting new technology which shows a great potential for these types of systems, but it is worth mentioning that several other approaches exist. To mention a few, Tushar et al (2020) indicate *Game Theory* (where peers act as competing players whose actions depend on each other), *Auction Theory* (a bidding system for peers to choose trading prices), or *Constrained Optimization* (a mathematical model to determine the best available trading options).

Blockchain is, however, the most interesting for this paper. As already mentioned above, Blockchain has the potential to integrate intelligent systems and to be greatly improved by AI technologies, which could in turn improve the efficiency of energy trading in P2P systems. A study conducted by PricewatherhouseCoopers (PwC) in 2016 mentions the possible uses of Blockchain in the energy sector. The main focus of this study is the opportunity to enhance transactions via Smart Contracts, which allow for a fully decentralized process of data communication and energy trading.

Smart Contracts are essentially machine-readable descriptions of what each party wishes, and are rather flexible regarding the objects, subjects, actions, and conditions expressed in each contract (Drescher, 2017). According to the study by PwC, in a decentralised energy transaction system such as P2P the transactions may be fully automatic when based on Smart Contracts, provided that these contracts include sell-orders when excess energy exists and buy-orders when demand is higher than production. These transactions are then securely recorded on a blockchain, and energy is delivered through the physical network.

Finally, Tushar et al (2020) explain that Smart Contracts are triggered when a transaction is addressed to it, and it is automatically and independently executed on every node (or block) in the network, thus ensuring a secure and transparent energy trading process. When AI is included in this process, the execution of Smart Contracts may become even more efficient since the data provided by smart technologies is extremely accurate. This paves way for an efficient, secure, and transparent energy trading system, based on P2P transactions enabled by Blockchain and Intelligent Systems. We will now review some existing projects in order to understand the possible applications of this innovative paradigm in energy trading management.

2.3.3 Review of Existing Projects

In IRENA (2020), several requirements for the implementation of P2P systems are mentioned. The first one is about *technical requirements* – for hardware, a physical and a virtual layer are required; for software, a platform for P2P electricity trading, strong ICT, robust data analytics tools, and blockchain technologies are necessary; and a communication protocol is also important. Regarding *policy requirements*, a better use of existing grid infrastructure and power systems' decentralisation encouragements are necessary, along with the encouragement of pilot programs and capital access for platform developers.

Concerning *regulatory requirements*, legal frameworks for data collection, cybersecurity, and privacy of users are needed, along with an assurance of compliance with consumer rights. For the distribution network, regulations are necessary to assure that flexibility is possible and that the P2P network is well integrated in the distribution grid. Finally, stakeholder responsibilities for both prosumers and market operators must be defined, to ensure that everyone engages in the P2P trading and that the platform is secure and trusted (IRENA, 2020).

We must now mention several projects that try to fulfil at least some of these requirements. Starting with the most advanced one, the Brooklyn Microgrid (BMG) has been in operation since 2016 and is owned by LO3Energy. The BMG operates a data platform named Exergy to enable P2P electricity trading between the existing grid infrastructure, and this platform is runed through Blockchain technology to ensure privacy and security (BMG, 2019). Prosumers and consumers use a mobile app to trade their PVs' energy freely, ensuring an easy and user-friendly trading system.

Another project involving P2P electricity trading was developed by SOLshare in Bangladesh. SOLshare developed an IoT-driven trading platform (SOLbazaar), in which users who own PVs may sell their excess energy to people who rely on the traditional grid, bringing renewable and affordable electricity to people in sometimes remote areas of the country (SOLshare, 2019). Energias de Portugal (EDP) has invested in this project through the company's investment vessel EDP Ventures in 2018 (EDP, 2018a).

Yet another P2P electricity trading project was tested in Malaysia by the country's Sustainable Energy Development Authority (SEDA). The 8-month pilot run started in November 2019 and ended June 2020, and provided a better understanding of the P2P concept and its possible benefits, as well as its risks and technical requirements. The decision to continue this project is still under discussion by the Malaysian government, but strong interests from industry are recognized (SEDA, 2020).

German industrial giant Sonnen (owned by Royal Dutch Shell) developed a virtual pool where users may sell excess energy stored in their PVs-attached batteries (SonnenBatterie), offering rewards to users who provide their energy to others (Sonnengroup, 2021). In Portugal, EDP has several innovative projects that may enable the future smart energy distribution. For example, the project Smart4RES aims to efficiently predict renewable source's production through data science, and in a partnership with Riddle&Code, EDP Brasil developed a Blockchain enabled electricity distribution scheme in Brazil (EDP, 2018b and 2018c).

In Portugal, the most relevant project to have been implemented was the project *NetEffiCity – CommunityS*, implemented in two villages in the north and centre of the country. This project, launched in a partnership between VPS-Virtual Power Solutions, Energia Simples, and GECAD-ISEP promised to create a solar powered P2P project, which would reduce electrical bills, increase energetic efficiency, and increase consumers' autonomy (Community-s, n.d.). The results of this project, conducted between 2016 and 2018, were quite positive, showing a decrease of around 27% in energy costs for the consumers involved (ISEP, 2019). However, there isn't sufficient knowledge of these projects from the Portuguese population, something that will hopefully change in the near future.

To conclude, we mention two studies regarding the benefits of P2P systems in Portugal. Klein et al (2019) showed that P2P systems may reduce energy prices by subtracting taxes regarding the distribution of energy from traditional sources. Neves et al (2020) show that benefits occur since prosumers sell electricity among themselves at a higher price than what the traditional market would pay for their excess energy, as well as through a reduction in energy prices for consumers who purchase energy from the local P2P network.

Chapter III – Theoretical Approach

3.1 Objectives and Research Questions

Following the Literature Review in this dissertation, several questions arise that are worth investigating. As such, and based on the great amount of information available, we propose to answer three Research Questions in order to achieve two main objectives. For the first objective, we begin by trying to understand the factors that influence the implementation of Intelligent Systems, while also asking if Smart Technologies may bring value to modernized energy grids. Regarding the second objective, we ask if there is value in the implementation of P2P systems while also trying to understand if the Portuguese market is willing to implement them.

Concerning the first objective – *Understanding the possible role of intelligent systems in the development of Peer-to-Peer systems for energetic distribution management*, we see that Intelligent Systems play an enormously important role in the development of stronger and more modern energy grids. The main focus of this dissertation regarding this type of systems shall be how energy distribution may be integrated in the IoT, showing that energy grids that use the IoT may obtain an exceedingly good level of efficiency, based on supply and demand forecasting, costumer classification and segmentation, and communication between user and supplier (Sethi and Sarangi, 2017).

Also, as mentioned in the Literature Review section, we try to understand how technologies such as Artificial Intelligence and Blockchain may help in the development of Intelligent Systems for the energy sector. This opens the path for the first Research Question:

RQ1 – Which factors influence the willingness to implement and develop Intelligent Systems that rely on Artificial Intelligence, Blockchain, and the IoT?

Still under the first objective, we mention the role of Smart Technologies and how they may influence the modernization of energy grids. We focus mainly on Smart Meters, Smart Grids and Smart Cities, and try to show how the interconnection of devices such as Smart Meters allows for the almost instantaneous communication of data and subsequent development and improvement of energy grids and their management. This leads us to the second RQ in this dissertation:

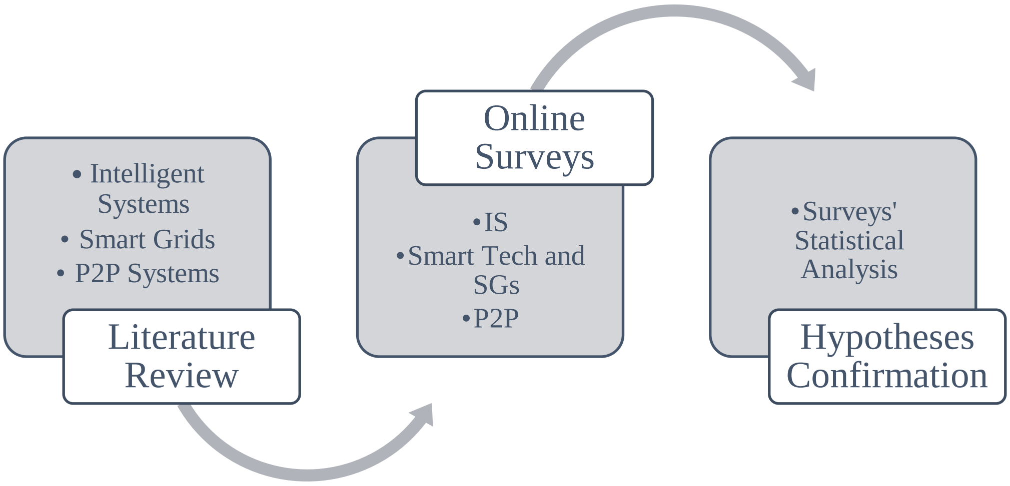
RQ2 – Do Smart Technologies and Intelligent Grids bring value to modernized energy grids, which may include P2P Systems and lead to Smart Cities?

Moving on to our second objective – *Analysing the Portuguese energy sector to understand if consumers and companies are ready and/or willing to implement Peer-to-Peer systems*, we will try to evaluate the value of P2P projects for energy distribution, along with the possible interest of consumers and companies in these projects, both in Portugal and in the rest of the world. Our Literature Review includes benefits of P2P systems, interest from national consumers and interest from international companies, along with a review of existing projects. Therefore, our third RQ is:

RQ3 – Is there value in the implementation of Peer-to-Peer projects for energy distribution, and if so, do companies and consumers recognize this value?

In the following table 3.1, the objectives and RQs are presented, along with the hypotheses derived by them and the bibliography used to compare results. The hypotheses will be mentioned in another section when we show the different conceptual models used for each RQ. Finally, and considering that the Literature Review is insufficient to answer these questions, another methodology (Figure 3.1) is used, which will be presented in the following section of the dissertation.

Figure 3.1 - Research Model Design



Author´s Elaboration

Table 3.1 – Theoretical Approach

Objectives	Research Questions	Hypotheses	References
I. **Understanding the possible role of intelligent systems in the development of Peer-to-Peer systems for energetic distribution management**	**1.** Which factors influence the willingness to implement and develop Intelligent Systems that rely on Artificial Intelligence, Blockchain, and the IoT?	*Influence of Perception of Intelligent Systems*	Zhang et al (2021)
		Influence of Benefits from Intelligent Systems	Gandomi and Haider (2015); Kelleher et al (2015); Li et al (2018); Reyna et al (2018); Russell & Norvig (2010); Sethi and Sarangi (2017); Singh et al (2020)
		Influence of Trust in Intelligent Systems	Siau and Wang (2018); Holliday et al (2016); Rose et al (2015); Abera et al (2016); Lin and Dong (2018); Fleischmann and Ivens (2019)
	2. Do Smart Technologies and Intelligent Grids bring value to modernized energy grids, which may include P2P Systems and lead to Smart Cities?	*Influence from the Willingness to Use Intelligent Technologies*	Tounquet and Alaton (2019); Prettico (2020)
		Influence from the Benefits of Intelligent Technologies	Zhou et al (2016); Wang et al (2018); Shakeri et al (2017); Viegas et al (2016)
		Influence from the Advantages of Intelligent Grids	Sethi and Sarangi (2017); Mohanty et al (2016); Mohanty et al (2016)
II. **Analysing the Portuguese energy sector to understand if consumers and companies are ready and/or willing to implement Peer-to-Peer systems**	**3.** Is there value in the implementation of Peer-to-Peer projects for energy distribution, and if so, do companies and consumers recognize this value?	*Influence of Interest from International Companies in P2P Projects*	SOLshare (2019); Sonnengroup (2021)
		Influence of the Benefits of P2P Systems	Morstyn et al (2018); Klein et al (2019); Neves et al (2020); Tushar et al (2018); Zhang et al (2018)
		Influence from National Consumers in P2P Systems	Community-s (n.d.); ISEP (2019); BMG (2019)

Author´s Elaboration

Chapter IV – Methodology

4.1 Research Model

Following the Literature Revision in this dissertation, several hypotheses appeared for each Research Question. In order to answer them, a quantitative methodology was used, which consisted of three separate online surveys, one for each RQ. To analyse the answers obtained in the surveys, a *Structural Equations Model* (SEM) was used, which is a technique that allows us to establish relationships between dependent and independent variables, by resorting to multiple regression analyses of different factors (Ullman and Bentler, 2012).

This approach allows us to measure the relationships free of measurement error, since it estimates it and removes it. Also, and according to Tarka (2018), by using diagrams in which the researcher's proposed relationships between variables are easily understood, this technique proves to be extremely useful for this type of study. One more advantage of the SEM analysis is that it allows for statistically relevant comparisons between theories and models, which will prove useful once we try to analyse our three research questions in an integrated result discussion.

Tarka (2018) also mentions the importance of SEM in analyses that require a certain background knowledge of topics, as it aids in the model's estimation procedures. SEM models let us conduct a complex and multidimensional analysis of empirical data in which theoretical constructs are considered, as well as aspects of the examined reality or sometimes even abstract concepts. Ulman and Bentler (2013) mention how SEM is a confirmatory analysis, rather than an exploratory technique. This is important since the goal of the surveys used in this dissertation is to verify the veracity of affirmations derived from the Literature Review, and this is one of the main reasons why a SEM analysis is used.

Finally, the software SmartPLS 3 was chosen to analyse the data from the surveys. SmartPLS 3 uses a *Partial Least Squares* (PLS) path modelling approach to the data analysis, which is variance-based structural equation modelling technique, most useful when conditions such as small sample sizes are present (Henseler et al, 2015). The Conceptual Models for each Research Question, along with the hypotheses presented for each question, can be found in the next section of the dissertation.

4.2 Conceptual Models

4.2.1 Conceptual Model – 1st RQ

Hypotheses for the 1st Research Question – **Which factors influence the willingness to implement and develop Intelligent Systems that rely on Artificial Intelligence, Blockchain, and the IoT?**

H1a – The perception on IS positively influences the possibility of developing IS

H1b- The perception on IS positively influences trust on these systems

H1c- The perception on IS mediates between the benefits of IS the possibility of developing IS

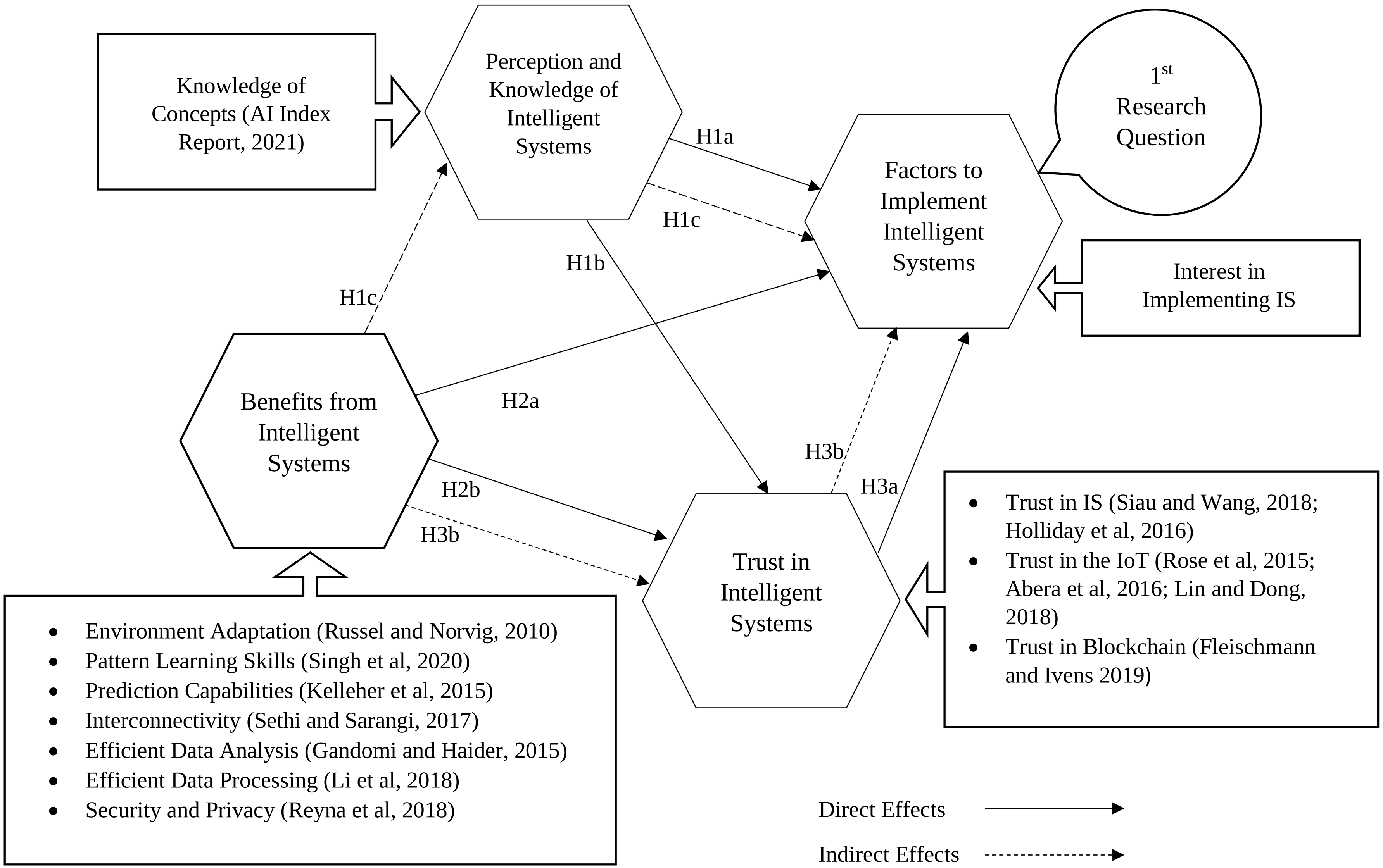
H2a- The benefits of IS positively influence the possibility of developing IS

H2b- The benefits of IS positively influence trust in IS

H3a- Trust in IS positively influences the possibility of developing IS

H3b – Trust in IS mediates between the benefits of IS the possibility of developing IS

Figure 4.1 - RQ1 Conceptual Model



Author's Elaboration

Table 4.1 - RQ1 Variables, Indicators, and Questions

1. Which factors influence the willingness to implement and develop Intelligent Systems that rely on Artificial Intelligence, Blockchain, and the IoT?		
Independent Variable	**Indicator**	**Questionnaire Questions**
Perception and knowledge of Intelligent Systems and their concepts	Knowledge of Concepts (Zhang et al, 2021)	I am aware of what IS are
		I am aware of the concepts and applications of AI and ML
		I am aware of the concept and applications of the IoT
		I am aware of the concept and applications of Blockchain
Benefits generated by Intelligent Systems and their concepts	Environment Adaptation (Russell and Norvig, 2010)	An Intelligent System can adapt to any situation and provide the best available solution
	Pattern Learning Skills (Singh et al, 2020)	An Intelligent System learns from the data provided to it and finds ideal solutions to solve complex transactions
	Prediction Capabilities (Kelleher et al, 2015)	An Intelligent System learns from the data provided to it and is able to predict future patterns of supply and demand
	Interconnectivity (Sethi and Sarangi 2017)	On the Internet of Things, devices connected among themselves may complete highly complex tasks
	Efficient Data Analysis (Gandomi and Haider, 2015)	An Intelligent System can analyse massive amounts of information, and draw results that provide the best applications for each user
	Efficient Data Processing (Li et al, 2018)	An Intelligent System, through a Smart Meter, can pre-process data (such as patterns of usage or predictions of future energy needs), and send simplified information to the suppliers
	Security and Privacy (Reyna et al, 2018)	An Intelligent System that registers transactions through Blockchain allows for more security, anonymity and resilience (since there is no central point for data processing)
Trust in Intelligent Systems and their concepts	Trust in IS (Siau and Wang, 2018; Holliday et al, 2016)	An IS that shows transparency and good performance is reliable
		An autonomous IS that is safe and easily interpretable is reliable
		An IS with a clear purpose is reliable
		An IS that explains the results it obtains is more trustworthy
	Trust in the IoT (Rose et al, 2015; Abera et al, 2016; Lin and Dong, 2018)	I would only trust the IoT if I knew my data is secure and private
		I would trust the IoT more if there was feedback about the systems and if the service providers had a positive reputation
	Trust on Blockchain (Fleischmann and Ivens 2019)	I would trust other users of a Blockchain to verify my data
		Blockchain technology guarantees the safety of transactions more than a central authority would
Factors to Implement IS	Interest in Implementing IS	Having the opportunity, I would like to implement an IS

Author´s Elaboration

4.2.2 Conceptual Model – 2nd RQ

Hypotheses for the 2nd Research Question – **Do Smart Technologies and Intelligent Grids bring value to modernized energy grids, which may include P2P Systems and lead to Smart Cities?**

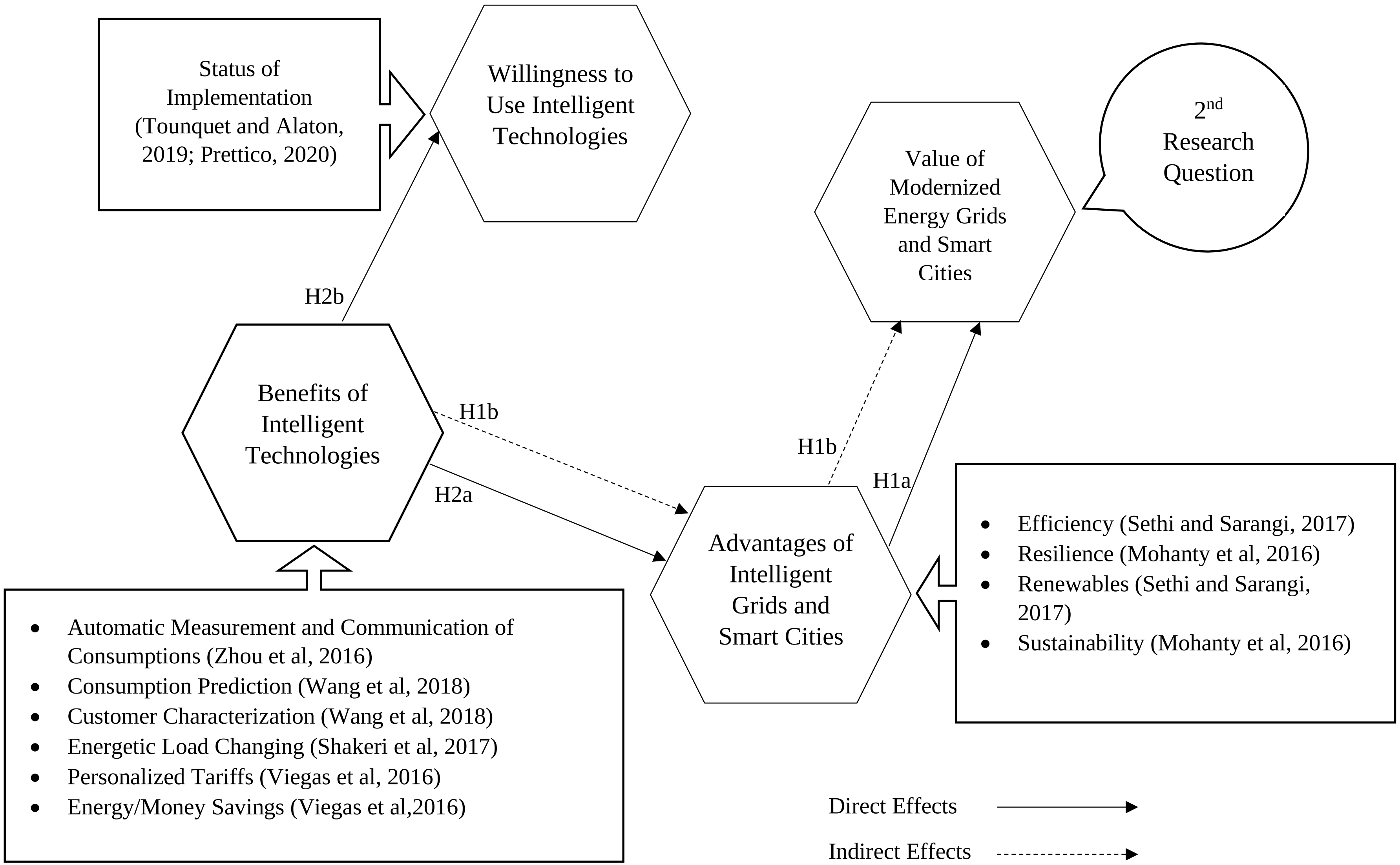
H1a – The advantages of intelligent grids positively influence the construction of modernized energy distribution grids

H1b - The advantages of intelligent grids mediate between the benefits of intelligent technologies and the construction of modernized energy distribution grids

H2a - The benefits of intelligent technologies positively influence the advantages of intelligent grids

H2b – The benefits of intelligent technologies positively influence the willingness to use intelligent technologies

Figure 4.2 - RQ2 Conceptual Model



Author's Elaboration

Table 4.2 - RQ2 Variables, Indicators, and Questions

2. Do Smart Technologies and Intelligent Grids bring value to modernized energy grids, which may include P2P Systems and lead to Smart Cities?		
Independent Variable	**Indicator**	**Questionnaire Questions**
Willingness to Use Intelligent Technologies	Implementation Status of Intelligent Technologies in the Energy Market (Tounquet and Alaton,2019; Prettico, 2020)	It would be useful to have a Smart Meter so that my energy supplier could obtain data about my consumption
		It would be useful to have a Smart Meter so that my energy supplier could prevent fraud and reading mistakes
		It would be useful to have a Smart Meter so that my energy supplier could offer prices based on my real-time consumption
		If there is a monetary benefit for an energy supplier, having a Smart Meter should be a priority
		In the near future, most energy consumption meters should be "intelligent"
Benefits of Intelligent Technologies	Consumption Prediction (Wang et al, 2018)	A Smart Meter is useful since it allows for a supplier to predict its customers' future consumptions
	Customer Characterization (Wang et al, 2018)	A Smart Meter is useful since it allows for a supplier to segment its customers in an efficient way
	Energetic Load Changing (Shakeri et al, 2017)	A Smart Meter is useful since it allows for the changing of energy loads of each client according to their consumption (for example having a lower load during the night)
	Personalized Tariffs (Viegas et al, 2016)	A Smart Meter is useful since it allows for a supplier to offer more attractive and personalized tariffs to each customer
	Energy/Money Savings (Viegas et al, 2016)	A Smart Meter is useful since it allows for a customer to save energy and money
Advantages of Intelligent Grids and Smart Cities	Efficiency (Sethi and Sarangi, 2017)	Smart Grids are important because, having "intelligence" in every step of the distribution of energy, the process becomes more efficient
	Resilience (Mohanty et al, 2016)	Smart Grids are safer against, for example, security risks or energy shortages
	Renewables (Sethi and Sarangi, 2017)	Smart Grids allow for the maximum usage of renewable sources, since they can automatically change the source of energy being used in the grid according to the conditions available
	Sustainability (Mohanty et al, 2016)	Smart Cities are important to counter the effects of the rapid urbanization and growth of urban populations, since they allow for an efficient management of a city's resources
	Automatic Measurement and Communication of Consumptions (Zhou et al, 2016)	A Smart Meter is useful since it allows for the immediate measurement and communication of energy consumptions to the suppliers
Value of Modernized Energy Grids and Smart Cities	Implementation Interest	What is your degree of interest in the construction of modernized energy distribution grids?

Author´s Elaboration

4.2.3 Conceptual Model – 3rd RQ

Hypotheses for the 3rd Research Question – **Is there value in the implementation of Peer-to-Peer projects for energy distribution, and if so, do companies and consumers recognize this value?**

H1a – The interest from international companies in P2P projects positively influences the possibility of implementing P2P systems in Portugal

H1b - The interest from international companies in P2P projects positively influences the interest from national consumers in P2P systems

H1c - The interest from international companies in P2P projects mediates between benefits of P2P systems and the possibility of implementing P2P systems in Portugal

H2a – The benefits of P2P systems positively influence the possibility of implementing P2P systems in Portugal

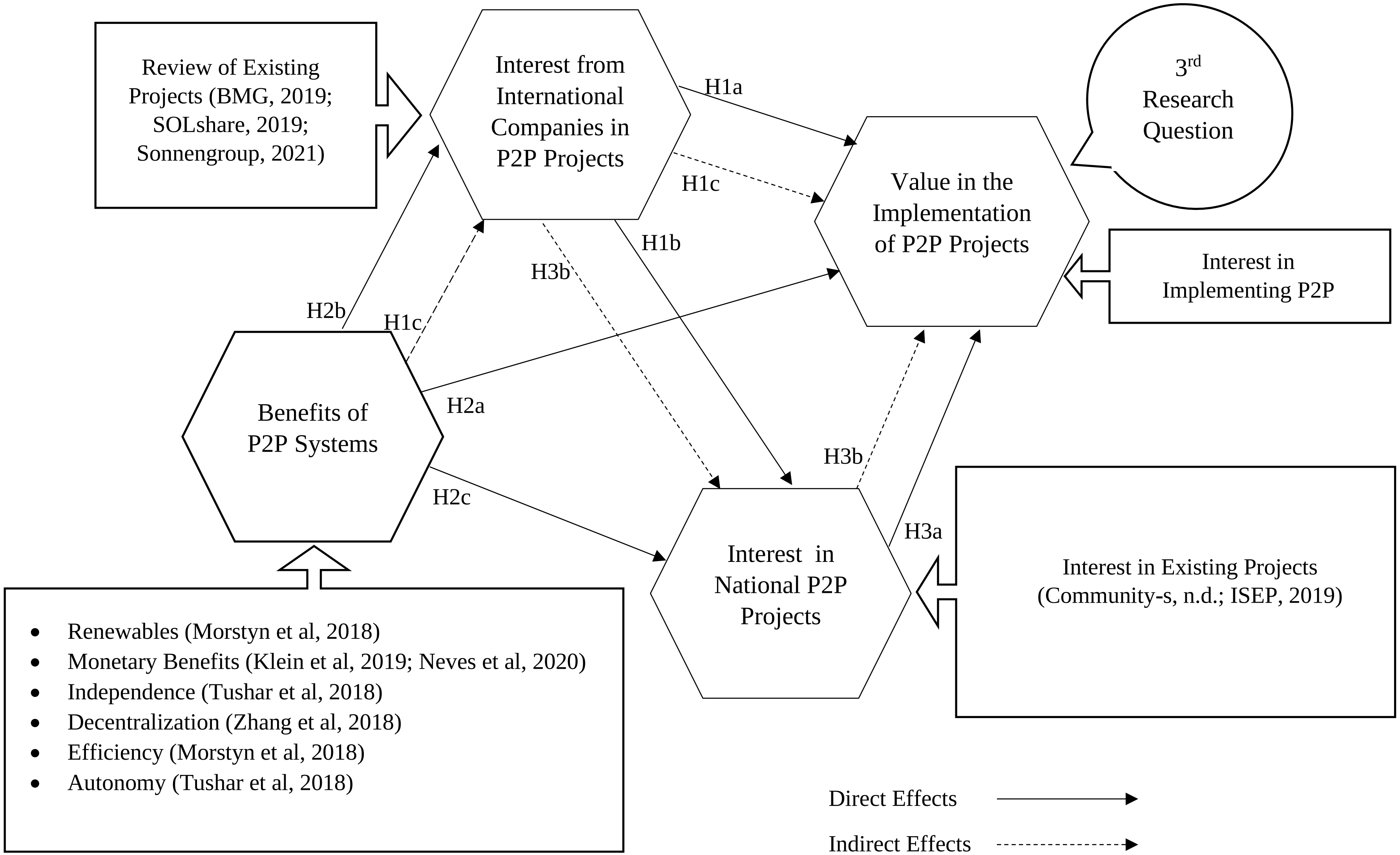
H2b – The benefits of P2P systems positively influence the interest from international companies in P2P projects

H2c - The benefits of P2P systems positively influence the interest from national consumers in P2P systems

H3a – The interest in national P2P projects positively influences the possibility of implementing P2P systems in Portugal

H3b – The interest in national P2P projects mediates between the interest from international companies in P2P projects and the possibility of implementing P2P systems in Portugal

Figure 4.3 - RQ3 Conceptual Model



Author´s Elaboration

Table 4.3 - RQ3 Variables, Indicators, and Questions

3. Is there value in the implementation of Peer-to-Peer projects for energy distribution, and if so, do companies and consumers recognize this value?		
Independent Variable	**Indicator**	**Questionnaire Questions**
Interest from International Companies in Implementing P2P Projects	Review of Existing Projects (BMG, 2019; SOLshare, 2019; Sonnengroup, 2021)	Projects that can provide renewable energy to remote areas through P2P systems, like the SOLbazaar in Bangladesh, are important
		A project like Sonnenbatterie, in which solar energy stored in batteries may be commercialized through P2P systems, seems positive
		I would like to participate in projects like the Brooklyn Microgrid (BMG), where energy is traded through P2P systems using Blockchain
Benefits of P2P Systems	Renewables (Morstyn et al, 2018)	A P2P system is positive because it allows for a greater integration of renewable energies in the distribution grid
	Monetary Benefits (Klein et al, 2019; Neves et al, 2020)	In Portugal, a P2P system may be useful because it allows for an energy price reduction (both from tax reductions and through the purchase and sale of energy at lower prices)
		A P2P project in Portugal that allows for energy cost savings seems attractive
	Independence (Tushar et al, 2018)	A P2P network that functions in and independent (or integrated) way regarding the normal distribution grid may bring benefits such as security, privacy and resilience
	Decentralization (Zhang et al, 2018)	In P2P systems, decentralization is positive since there is no longer a central authority confirming transactions, thus reducing costs and increasing efficiency
	Efficiency (Morstyn et al, 2018)	A P2P system is positive since it allows for an increase in the efficiency of renewable energy trading by using personalized information regarding the intervenient
		A P2P project in Portugal that promises to increase energetic efficiency and the autonomy of consumers seems attractive
	Autonomy (Tushar et al, 2018)	It would be useful to have an app in which a client could have access to its consumptions and production, and in which it could trade energy freely with its neighbours (automatically or not)
Interest in National P2P Projects	Interest in Existing Projects (Community-s, n.d.; ISEP, 2019)	I would like to participate in a project like Community-s, in which a solar energy based P2P network was built in two Portuguese villages
Implementation Value	Interest in Implementing P2P	What is your degree of interest in implementing P2P systems?

Author´s Elaboration

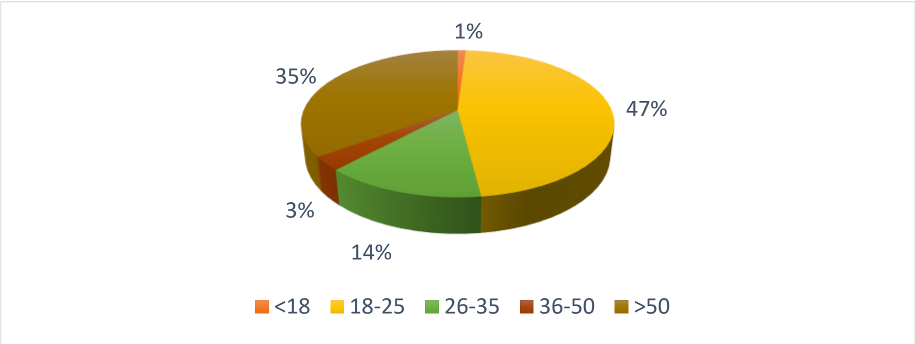
4.3 Sample Description

Personal information of every respondent was asked at the end of each questionnaire, regarding Age, Gender, and Education (and if the respondent owns a house for the survey referring to RQ3). The surveys are fully anonymous, and this information is useful to understand if the samples are sufficiently heterogeneous for the results to be valid.

RQ1 – Knowledge and Trust in Intelligent Systems

The presented sample includes 100 individuals. Regarding the respondent's age, 1 (1%) was "Under 18", 47 (47%) were "Between 18 and 25", 14 (14%) were "Between 26 and 35", 3 (3%) were "Between 36 and 50", and 35 (35%) were "Over 50". The following figure 4.4 shows the age distribution:

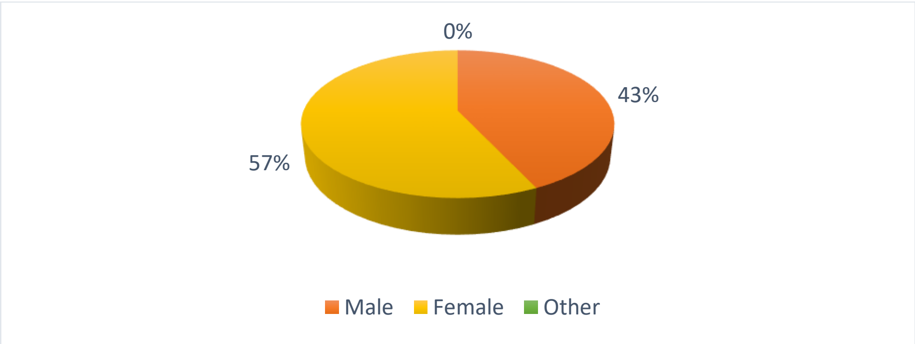
Figure 4.4 - RQ1 Survey's Age Distribution



Author´s Elaboration

Regarding the gender distribution, 43 (43%) were male and 57 (57%) were female. No respondent chose the option "Other". The following figure 4.5 shows the gender distribution:

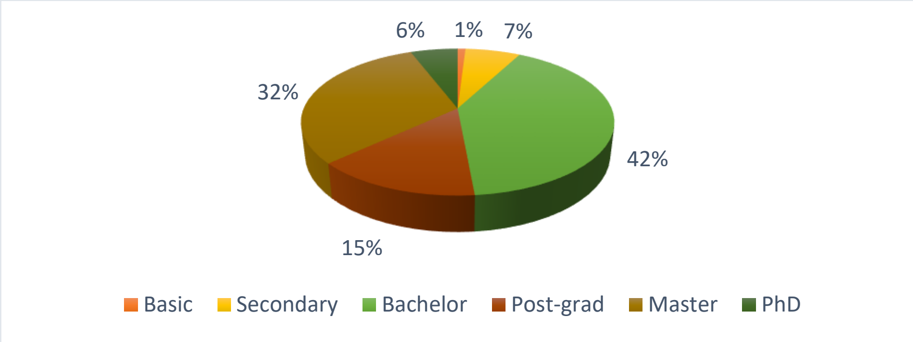
Figure 4.5 - RQ1 Survey's Gender Distribution



Author´s Elaboration

Regarding education, 1 (1%) had Basic Education, 7 (7%) had Secondary Education, 42 (42%) had a Bachelor´s Degree, 15 (15%) had a Post-graduate Degree, 32 (32%) had a Master's Degree, and 6 (6%) had a PhD. The following figure 4.6 shows the educational distribution:

Figure 4.6 - RQ1 Survey's Educational Distribution

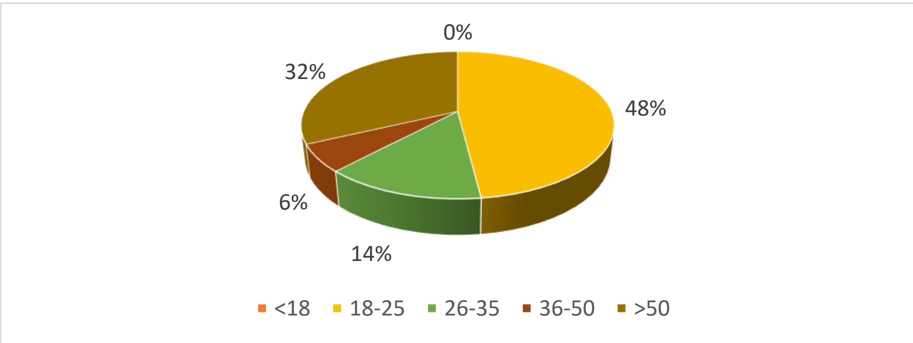


Author´s Elaboration

RQ2 – Smart Technologies to Modernize Energy Grids

The presented sample includes 100 individuals. Regarding the respondent's age, 0 (0%) were "Under 18", 48 (48%) were "Between 18 and 25", 14 (14%) were "Between 26 and 35", 6 (6%) were "Between 36 and 50", and 32 (32%) were "Over 50". The following figure 4.7 shows the age distribution:

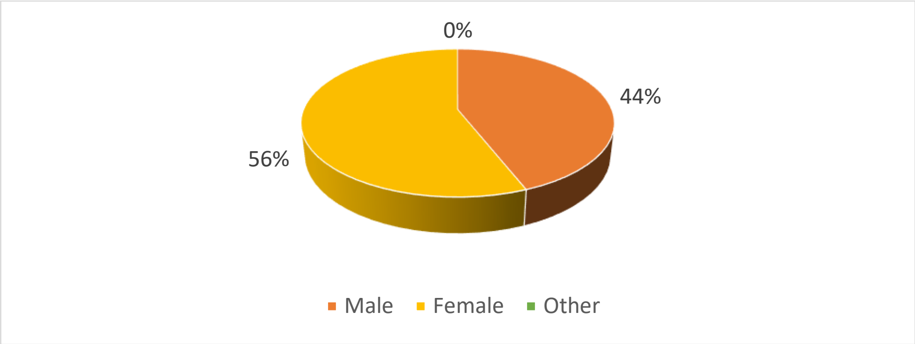
Figure 4.7 - RQ2 Survey's Age Distribution



Author´s Elaboration

Regarding the gender distribution, 44 (44%) were male and 56 (56%) were female. No respondent chose the option "Other". The following figure 4.8 shows the gender distribution:

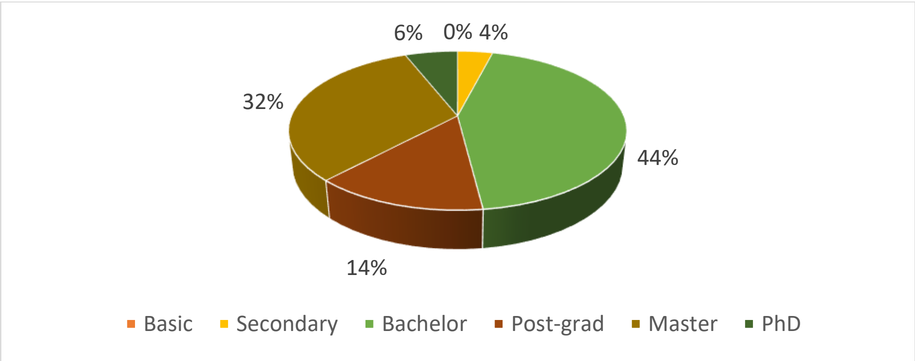
Figure 4.8 - RQ2 Survey's Gender Distribution



Author´s Elaboration

Regarding education, 0 (0%) had Basic Education, 4 (4%) had Secondary Education, 44 (44%) had a Bachelor´s Degree, 14 (14%) had a Post-graduate Degree, 32 (32%) had a Master's Degree, and 6 (6%) had a PhD. The following figure 4.9 shows the educational distribution:

Figure 4.9 - RQ2 Survey's Educational Distribution

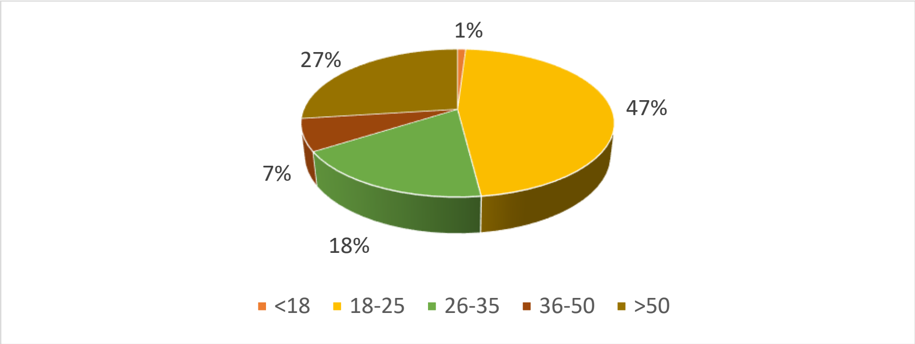


Author's Elaboration

RQ3 – Implementation of Peer-to-Peer Systems for Energetic Distribution

The presented sample includes 100 individuals. Regarding the respondent's age, 1 (1%) were "Under 18", 47 (47%) were "Between 18 and 25", 18 (18%) were "Between 26 and 35", 7 (7%) were "Between 36 and 50", and 27 (27%) were "Over 50". The following figure 4.10 shows the age distribution:

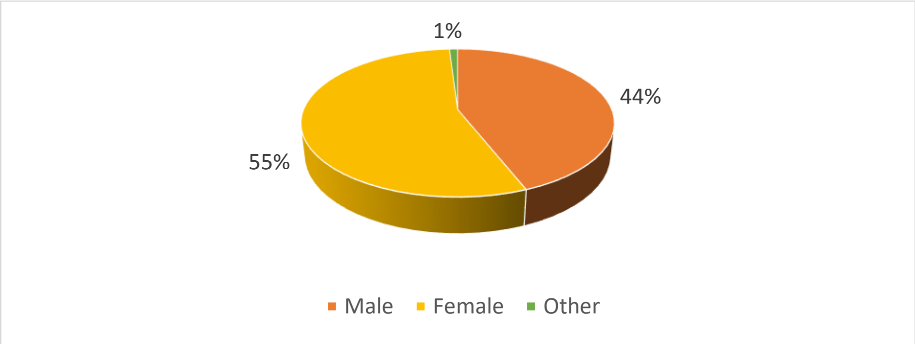
Figure 4.10 - RQ3 Survey's Age Distribution



Author´s Elaboration

Regarding the gender distribution, 44 (44%) were male, 55 (55%) were female, and 1 (1%) respondent chose the option "Other". The following figure 4.11 shows the gender distribution:

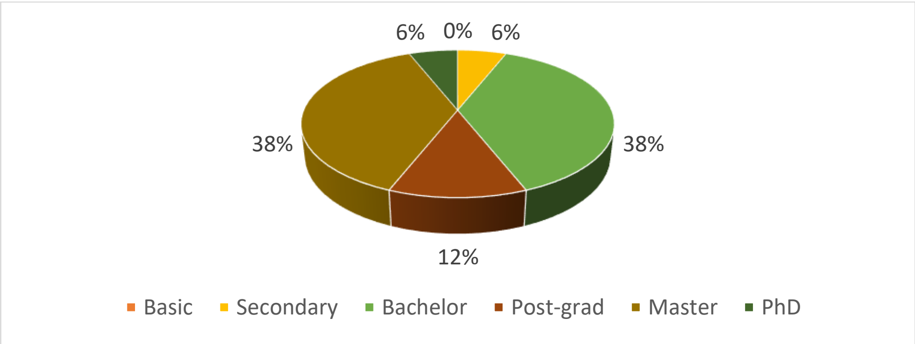
Figure 4.11 - RQ3 Survey's Gender Distribution



Author´s Elaboration

Regarding education, 0 (0%) had Basic Education, 6 (6%) had Secondary Education, 38 (38%) had a Bachelor´s Degree, 12 (12%) had a Post-graduate Degree, 38 (38%) had a Master's Degree, and 6 (6%) had a PhD. The following figure 4.12 shows the educational distribution:

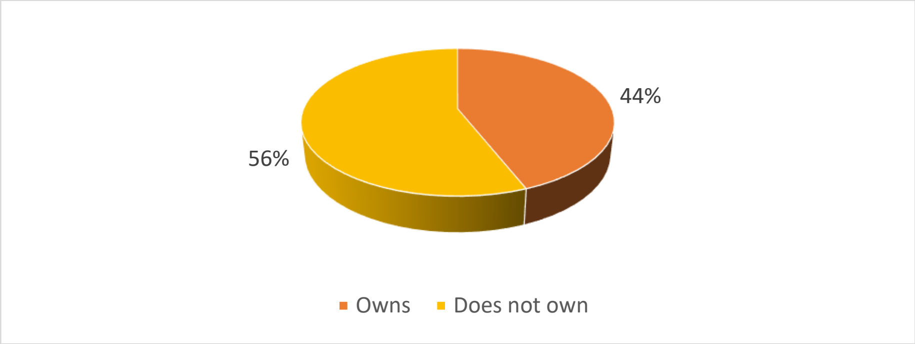
Figure 4.12 - RQ3 Survey's Educational Distribution



Author´s Elaboration

This survey has an additional question regarding the ownership of a house. 44 (44%) are the owners of their house, and 56 (56%) are not. The following figure 4.13 shows this distribution:

Figure 4.13 - RQ3 Survey's Home Ownership Distribution



Author´s Elaboration

Chapter V – Result Presentation and Discussion

5.1 RQ1 – Which factors influence the willingness to implement and develop Intelligent Systems that rely on Artificial Intelligence, Blockchain, and the IoT?

5.1.1 Statistical Analysis

For the online survey regarding *Knowledge and Trust in Intelligent Systems* [Annex A], a 5-point Likert Scale (Likert, 1932) was used. After the results were obtained, we tested our conceptual model using *Structural Equation Modelling* (SEM), more specifically a *Partial Least Squares* (PLS) path modelling approach, as previously mentioned. The Software SmartPLS 3 was used to complete these analyses. We start by evaluating both the reliability and the validity of the measurement model, and after those are confirmed we assess the structural model.

Starting with the measurement model, the individual indicators were checked for their reliability. Unfortunately, six indicators had to be removed since their standardized factor loadings were below 0.6 (Hair et al, 2017). The eliminated indicators were related with "Trust in IS" and "Benefits of IS". After the indicators were removed, reliability was assured since every individual indicator's standardized factor loading was above 0.6, and all were significant at $p < 0.001$ (Hair et al, 2017). The constructs showed a reliable internal consistency since all the constructs' Cronbach alphas (α) and Composite Reliability (CR) values were above 0.7 (Hair et al, 2017).

Convergent validity was also confirmed since the Average Variance Extracted (AVE) for each construct was above 0.5 (Bagozzi & Yi, 1988). To assess the discriminant validity, firstly the Fornell and Larcker criterion was used, which requires that the square root of every construct's AVE (in blue on table 5.1) is larger than the biggest correlation with every construct (Fornell & Larcker, 1981). Secondly, the Heterotrait-monotrait Ratio (HTMT) criterion was used, which states that all HTMT ratios should be below 0.85 (Hair et al., 2017; Henseler et al., 2015), as is shown in table 5.1 (in orange).

Table 5.1 - Composite Reliability, Average Variance Extracted, Correlations, and Discriminant Validity Checks

Latent Variables	α	CR	AVE	1	2	3	4
(1) Benefits from IS	**0,803**	**0,866**	**0,568**	**0,754**	**0,831**	**0,663**	**0,656**
(2) Factors to Implement IS	**1,000**	**1,000**	**1,000**	0,749	**1,000**	**0,844**	**0,750**
(3) Perception/Knowledge in IS	**0,801**	**0,871**	**0,629**	0,546	0,799	**0,793**	**0,613**
(4) Trust in IS	**0,877**	**0,915**	**0,731**	0,554	0,708	0,530	**0,855**

*Note: α-Cronbach Alpha; CR-Composite Reliability; AVE-Average Variance Extracted; **Blue**-Square roots of AVE; Below diagonal elements-correlations between the constructs; Above diagonal elements-HTMT ratios.*

Author´s Elaboration

The structural model was assessed by the use of sign, magnitude, and significance of the structural path coefficients; magnitude of R^2 value for each endogenous variable to measure predictive accuracy; and the Stone Stone-Geisser's Q^2 values to measure the predictive relevance (Hair et al, 2017). Before that, the inexistence of collinearity was checked using VIF values, which were all below the critical value of 5 (Hair et al, 2017). The values for R^2, the coefficient of determination for the endogenous variables ("Perception and Knowledge of Intelligent Systems", "Trust in Intelligent Systems", and "Factors to Implement Intelligent Systems") were 29.8%, 38.1% and 82.3%, respectively which all surpass the minimum value of 10% (Falk & Miller, 1992). Finally, the Q^2 values for each endogenous variable (0.176, 0.265, and 0.8 respectively) were all above zero, indicating the predictive relevance of the model (Hair et al, 2017).

5.1.2 Quantitative Results

Table 5.2 - Structural Model Assessment

Path	Path Coefficient	Standard Deviation	*t* statistics	*p* values
Benefits from IS -> Factors to Implement IS	0,345	0,054	6,348	**0,000**
Benefits from IS -> Trust in IS	0,376	0,105	3,587	**0,000**
Perception and Knowledge of IS -> Factors to Implement IS	0,469	0,054	8,665	**0,000**
Perception and Knowledge of IS -> Trust in IS	0,325	0,101	3,233	**0,001**
Trust in IS -> Factors to Implement IS	0,268	0,063	4,251	**0,000**

Author´s Elaboration

Table 5.3 - Bootstrap Results for Indirect Effects

Indirect Effect	Estimates	Standard Deviation	*t* statistics	*p* values
Benefits from IS -> Perception and Knowledge of IS -> Factors to Implement IS	0,256	0,043	5,907	**0,000**
Benefits from IS -> Trust in IS -> Factors to Implement IS	0,101	0,038	2,663	**0,008**

Author´s Elaboration

The results from table 5.2 show that the Benefits of IS has a significant positive effect on both the Factors to Implement IS (β=0.345, p<0.001) and the Trust in IS (β=0.376, p<0.001), thus supporting hypotheses H2a and H2b, respectively. The results also show that Perception and Knowledge of IS has a significant positive effect on both Factors to Implement IS (β=0.469, p<0.001) and Trust in IS (β=0.325, p<0.001), thus supporting hypotheses H1a and H1b, respectively. Finally, results show that Trust in IS has a significant positive effect on Factors to Implement IS (β=0.268, p<0.001), thus supporting the hypothesis H3a.

In order to test the mediation hypotheses, a bootstrapping procedure on SmartPLS 3 was used (Hair et al, 2017). Table 5.3 shows the results of the mediation effects, in which we can see that the indirect effects of the Benefits of IS on Factors to Implement IS via the mediator Perception and Knowledge of IS, and also via the mediator Trust in IS are significant (β=0.256, p<0.001 and β=0.101, p<0.01, respectively), thus supporting hypotheses H1c and H3b, also respectively.

5.1.3 Result Discussion

The conceptual model presented in this section intended to answer the Research Question *Which factors influence the willingness to implement and develop Intelligent Systems that rely on Artificial Intelligence, Blockchain, and the IoT?*. In order to do so, the model identified three main factors which were based on the Literature Review conducted for the dissertation. They are 1) the Perception and Knowledge of Intelligent Systems and their concepts (IA, ML, IoT, and Blockchain) (Zhang et al, 2021), 2) the Benefits generated by Intelligent Systems and their concepts (Gandomi and Haider, 2015; Kelleher et al, 2015; Li et al, 2018; Reyna et al, 2018; Russell & Norvig, 2010; Sethi and Sarangi, 2017; Singh et al, 2020), and 3) the Trust in Intelligent Systems and their concepts (Siau and Wang, 2018; Holliday et al, 2016; Rose et al, 2015; Abera et al, 2016; Lin and Dong, 2018; Fleischmann and Ivens, 2019). Another variable was added in order to test our model – Factors to Implement Intelligent Systems, which was based on the online surveys. These categories were latent variables in our model and were tested using SmartPLS 3 (Ringle et al, 2015). The validity of the model is shown in the previous section.

Several indicators were used for each variable. Regarding the perception and knowledge of Intelligent Systems, we used the indicator "Knowledge of Concepts" to study the general interest from people and institutions in IS (Zhang et al, 2021), which showed an increasing interest and knowledge of these systems. The survey provided answers which are concordant with the literature.

Regarding the importance of the benefits of IS for the possible implementation of IS, several were used as indicators. They are Environment Adaptation (Russel and Norvig, 2010), Pattern Learning Skills (Singh et al, 2020), Prediction Capabilities (Kelleher et al, 2015), Efficient Data Analysis (Gandomi and Haider, 2015), and Security and Privacy (Reyna et al, 2018). Our results show that these benefits are in fact important for the implementation of IS. The indicators Interconnectivity (Sethi and Sarangi, 2017) and Efficient Data Processing (Li et al, 2018) were removed from the model, as they were not contributing to the analysis.

Regarding trust in IS, there is some discomfort in accepting the IoT and Blockchain, which may be partially explained by their disruptive nature and the still relatively low levels of knowledge from the general public (Rose et al, 2015; Abera et al, 2016; Lin and Dong, 2018; Fleischmann and Ivens, 2019). For these reasons, some indicators were removed from our model ("Trust in the IoT" and "Trust in Blockchain"). Nevertheless, the indicator Trust in IS (Siau and Wang, 2018; Holliday et al, 2016) proved reliable enough, which allowed us to carry on with our model.

Having created the model with its variables and indicators, a final question was asked in the surveys regarding the willingness to implement IS. This question allowed us to better understand the intentionality to develop these systems, and was an indicator to our final variable Factors to Implement Intelligent Systems.

Having now identified the three main factors which may impact the implementation of IS, we proceeded to the testing of the previously formed hypotheses. The direct effects presented in our model were supported by the results. Firstly, we showed that the benefits generated by IS positively influence the possible implementation of IS, thus confirming the hypothesis H2a. This confirms that the benefits presented may be active factors for the implementation of IS, as was discussed in the literature (Gandomi and Haider, 2015; Kelleher et al, 2015; Li et al, 2018; Reyna et al, 2018; Russell & Norvig, 2010; Sethi and Sarangi, 2017; Singh et al, 2020).

The benefits of IS also positively influence the trust in IS, which validates our hypothesis H2b. This shows that the more people understand the possible benefits of IS, the more their trust may increase, and the confidence in using these systems is key to their development (Siau and Wang, 2018; Holliday et al, 2016).

Regarding the perception and knowledge of IS, the results show that there is a positive influence of perception in the possible implementation of IS, meaning that it may be a factor to their development and therefore supporting our hypothesis H1a. Also, hypothesis H1b was supported by the results since we show that perception on IS positively influences trust in these systems. Again, this is in line with our literature, where it is mentioned that interest and perception is growing (influencing the implementation) and that trust is directly affected by knowledge and confidence in these systems (Zhang et al, 2021; Holliday et al, 2016).

Our final direct effect concerns the positive influence of trust in IS in the possible implementation of IS, which is supported by our results and therefore validates our hypothesis H3a. What is shown is that the higher the trust levels in IS, the stronger the possibility of acceptance and usage of these systems, as is mentioned by several authors in our literature (Siau and Wang, 2018; Holliday et al, 2016; Rose et al, 2015; Abera et al, 2016; Lin and Dong, 2018; Fleischmann and Ivens, 2019).

Regarding the indirect effects, the first hypothesis to be mentioned is the possible mediator effect of perception of IS between the benefits and the possibility of implementing IS. The results show that this mediator effect exists, and therefore confirms our hypothesis H1c. This means that the benefits of IS are important in increasing the perception on IS, and therefore in increasing the possibility of implementing and developing IS. This is in line with our literature since the benefits of IS are important in the increasing interest in these systems (Zhang et al, 2021).

The final effect to be studied by this model is the mediator effect of trust in IS between the benefits and the possibility of implementing IS. The results show that this effect exists, which confirms our hypothesis H3b. Again, the benefits of IS are a major force in the presentation and trust in IS since they show that these systems and their underlying technologies may bring extremely positive consequences to our society. Our literature shows that it is important to understand the possible positive implications of these technologies in order to trust them, and eventually to develop and implement them (Siau and Wang, 2018; Holliday et al, 2016).

5.2 RQ2 – Do Smart Technologies and Intelligent Grids bring value to modernized energy grids, which may include P2P Systems and lead to Smart Cities

5.2.1 Statistical Analysis

For the online survey regarding *Intelligent Technologies to Modernize Energy Grids* [Annex B], a 5-point Likert Scale (Likert, 1932) was used. After the results were obtained, we tested our conceptual model using *Structural Equation Modelling* (SEM), more specifically a *Partial Least Squares* (PLS) path modelling approach, as previously mentioned. The Software SmartPLS 3 was used to complete these analyses. We start by evaluating both the reliability and the validity of the measurement model, and after those are confirmed we assess the structural model.

Starting with the measurement model, the individual indicators were checked for their reliability, which was assured since every individual indicator's standardized factor loading was above 0.6, and all were significant at $p < 0.001$ (Hair et al, 2017). The constructs showed a reliable internal consistency since all the constructs' Cronbach alphas (α) and Composite Reliability (CR) values were above 0.7 (Hair et al, 2017).

Convergent validity was also confirmed since the Average Variance Extracted (AVE) for each construct was above 0.5 (Bagozzi & Yi, 1988), except for one construct ("Advantage of

SGs/SCs”) in which it was slightly below 0.5 (0.461). However, the convergent validity is confirmed nonetheless since the composite reliability (0.808) is strong enough to mitigate this lower value (Fornell & Larcker, 1981). To assess the discriminant validity, firstly the Fornell and Larcker criterion was used, which requires that the square root of every construct’s AVE (in blue on table 5.4) is larger than the biggest correlation with every construct (Fornell & Larcker, 1981). Secondly, the Heterotrait-monotrait Ratio (HTMT) criterion was used, which states that all HTMT ratios should be below 0.85 (Hair et al., 2017; Henseler et al., 2015), as is shown in table 5.4 (in orange).

Table 5.4 - Composite Reliability, Average Variance Extracted, Correlations, and Discriminant Validity Checks

Latent Variables	α	CR	AVE	1	2	3	4
(1) Advantages of SGs/SCs	**0,708**	**0,808**	**0,461**	**0,679**	**0,757**	**0,549**	**0,833**
(2) Benefits of Intelligent Techs	**0,818**	**0,872**	**0,579**	0,605	**0,761**	**0,262**	**0,835**
(3) Value of Modernized Grids	**1,000**	**1,000**	**1,000**	0,478	0,243	**1,000**	**0,443**
(4) Willingness to Use Intelligent Techs	**0,810**	**0,866**	**0,568**	0,654	0,725	0,369	**0,753**

Note: a-Cronbach Alpha; CR-Composite Reliability; AVE-Average Variance Extracted; ***Blue****-Square roots of AVE; Below diagonal elements-correlations between the constructs; Above diagonal elements-HTMT ratios.*

Author´s Elaboration

The structural model was assessed by the use of sign, magnitude, and significance of the structural path coefficients; magnitude of R^2 value for each endogenous variable to measure predictive accuracy; and the Stone Stone-Geisser’s Q^2 values to measure the predictive relevance (Hair et al, 2017). Before that, the inexistence of collinearity was checked using VIF values, which were all below the critical value of 5 (Hair et al, 2017). The values for R^2, the coefficient of determination for the endogenous variables (“Advantages of SGs/SCs”, “Value of Modernized Grids”, and “Willingness to Use Intelligent Techs”) were 36.7%, 22.8% and 52.5%, respectively which all surpass the minimum value of 10% (Falk & Miller, 1992). Finally, the Q^2 values for each endogenous variable (0.152, 0.206, and 0.266, respectively) were all above zero, indicating the predictive relevance of the model (Hair et al, 2017).

5.2.2 Quantitative Results

Table 5.5 - Structural Model Assessment

Path	Path Coefficient	Standard Deviation	*t* statistics	*p* values
Advantages of SGs/SCs -> Value of Modernized Grids	0,478	0,087	5,512	**0,000**
Benefits of Intelligent Techs -> Advantages of SGs/SCs	0,605	0,073	8,264	**0,000**
Benefits of Intelligent Techs -> Willingness to Use Intelligent Techs	0,725	0,065	11,139	**0,000**

Author´s Elaboration

Table 5.6 - Bootstrap Results for Indirect Effects

Indirect Effect	Estimates	Standard Deviation	*t* statistics	*p* values
Benefits of Intelligent Techs -> Advantages of SGs/SCs -> Value of Modernized Grids	0,289	0,060	4,830	**0,000**

Author´s Elaboration

The results from Table 5.5 show that the Advantages of SGs/SCs has a significant positive effect on the Value of Modernized Grids (β=0.478, p<0.001), thus supporting hypothesis H1a. The results also support evidence to confirm hypotheses H2a and H2b, which respectively state that the Benefits of Intelligent Technologies have a significant positive influence in both the Advantages of SG and SCs (β=0.605, p<0.001), and in the Willingness to Use Intelligent Technologies (β=0.725, p<0.001).

In order to test the mediation hypotheses, a bootstrapping procedure on SmartPLS 3 was used (Hair et al, 2017). Table 5.6 shows the results of the mediation effects, in which we can see that the indirect effect of the Benefits of Intelligent Technologies on the Value of Modernized Grids via the mediator Advantages of SGs/SCs is significant (β=0.289, p<0.001), thus supporting hypothesis H1b.

5.2.3 Result Discussion

The conceptual model presented in this section intended to answer the Research Question *Do Smart Technologies and Intelligent Grids bring value to modernized energy grids, which may include P2P Systems and lead to Smart Cities?*. In order to do so, the model identified three main factors which were based on the Literature Review conducted for the dissertation. They are 1) the willingness to use intelligent technologies (Tounquet and Alaton,2019; Prettico, 2020), 2) the benefits of intelligent technologies (Wang et al, 2018; Shakeri et al, 2017; Viegas et al, 2016), and 3) the advantages of intelligent grids and Smart Cities (Sethi and Sarangi, 2017; Mohanty et al, 2016; Zhou et al, 2016). The variable Value of Modernized Energy Grids and Smart Cities was based on the online surveys and was added in order to test our model. These categories were latent variables in our model and were tested using SmartPLS 3 (Ringle et al, 2015). The validity of the model is shown in the previous section.

Several indicators were used for each variable. Regarding Willingness to Use Intelligent Technologies, the indicator “Implementation Status of Intelligent Technologies in the Energy Market” (Tounquet and Alaton,2019; Prettico, 2020) intended to show the state-of-the-art of intelligent technologies for energy management purposes, and the questions asked in our online survey show that there is a strong interest in these innovative technologies, proving that an increase in interest is occurring in the same line as what was found in the available literature.

Regarding the Benefits of Intelligent Technologies, the used indicators were “Consumption Prediction” (Wang et al, 2018), “Customer Characterization” (Wang et al, 2018), “Energetic Load Changing” (Shakeri et al, 2017), “Personalized Tariffs” (Viegas et al, 2016), and “Energy/Money Savings” (Viegas et al, 2016). These indicators retrieved from the literature review intend to represent the importance of these benefits in the possible development of intelligent and modernized energy grids.

Regarding the Advantages of Intelligent Grids and Smart Cities, the used indicators were “Efficiency” (Sethi and Sarangi, 2017), “Resilience” (Mohanty et al, 2016), “Renewables” (Sethi and Sarangi, 2017), “Sustainability” (Mohanty et al, 2016), and “Automatic Measurement and Communication of Consumptions” (Zhou et al, 2016). This last indicator was originally assigned to the Benefits of Intelligent Technologies variable and was changed due to the Cross Loadings value on SmartPLS 3 (Hair et al, 2017). These indicators intend to be an accurate representation of the importance of SGs and SCs.

Having created the model with its variables and indicators, a final question was asked in the surveys regarding the value of modernized energy grids. This question allowed us to better understand the intentionality and intrinsic value in the development of these grids, and was an indicator to our final variable Implementation Value of Modernized Energy Grids and Smart Cities.

After identifying the main factors that may contribute to the increased value of modernized energy grids and Smart Cities, the previously formed hypotheses were tested. As was shown before, the three direct effects proved significant. We start by showing that the Advantages of Intelligent Grids positively influence the Value of Modernized Energy Grids, supporting hypothesis H1a. This is in line with our literature, which showed that these advantages are important in the acceptance and possible development of modern energy distribution grids (Sethi and Sarangi, 2017; Mohanty et al, 2016).

Also supported by our model is the hypothesis H2a, which stated that the benefits of intelligent technologies positively influence the advantages of intelligent grids. Our literature suggests that there is an obvious relation between the benefits of these technologies and the advantages of the grids since the latter uses the former to be developed and implemented (Wang et al, 2018; Shakeri et al, 2017; Viegas et al, 2016; Sarangi and Sethi, 2017; Mohanty et al, 2016). Hypothesis H2b was also supported by the results in our model, stating that the benefits of intelligent technologies positively influence the willingness to use intelligent technologies. Literature suggests that this relation exists since the more people are familiarized with the possible benefits, the more willing they are to support and implement them (Tounquet and Alaton,2019; Prettico, 2020; Sarangi and Sethi, 2017; Mohanty et al, 2016).

Regarding indirect effects, we show that the advantages of SGs and SCs provide the mediation between the benefits of intelligent technologies and the value of modernized grids, which is our hypothesis H1b. An easy explanation is that although there is no evidence to support a direct link between benefits of intelligent technologies and modern energy grids, these benefits positively influence the development of intelligent grids and therefore influence the very value of these grids. Our literature suggests that the benefits from intelligent technologies are essential in the perception and existence of advantages for intelligent energy grids, and hence the possible increase in the value of the development and implementation of SGs and Smart Cities (Wang et al, 2018; Shakeri et al, 2017; Viegas et al, 2016; Sarangi and Sethi, 2017; Mohanty et al, 2016).

Finally, there were some more connections that could be tested in this model, namely the possible direct effect of the benefits of intelligent technologies on the value of modernized grids, or the direct effect of willingness to use intelligent technologies on the same value of modernized grids, along with some others. However, we believe that since on the one hand we are evaluating intelligent technologies, and on the other intelligent energy grids, the direct influences would not be relevant. Therefore, we chose to test only the indirect effects between intelligent technologies and advantages or value of intelligent grids, which were proven in the previous paragraph.

5.3 RQ3 – Is there value in the implementation of Peer-to-Peer projects for energy distribution, and if so, do companies and consumers recognize this value?

5.3.1 Statistical Analysis

For the online survey regarding *Implementation of Peer-to-Peer Systems for Energetic Distribution* [Annex C], a 5-point Likert Scale (Likert, 1932) was used. After the results were obtained, we tested our conceptual model using *Structural Equation Modelling* (SEM), more specifically a *Partial Least Squares* (PLS) path modelling approach, as previously mentioned. The Software SmartPLS 3 was used to complete these analyses. We start by evaluating both the reliability and the validity of the measurement model, and after those are confirmed we assess the structural model.

Starting with the measurement model, the individual indicators were checked for their reliability, which was assured since every individual indicator's standardized factor loading was above 0.6, and all were significant at $p < 0.001$ (Hair et al, 2017). The constructs showed a reliable internal consistency since all the constructs' Cronbach alphas (α) and Composite Reliability (CR) values were above 0.7 (Hair et al, 2017).

Convergent validity was also confirmed since the Average Variance Extracted (AVE) for each construct was above 0.5 (Bagozzi & Yi, 1988). To assess the discriminant validity, firstly the Fornell and Larcker criterion was used, which requires that the square root of every construct's AVE (in blue on table 5.7) is larger than the biggest correlation with every construct (Fornell & Larcker, 1981). Secondly, the Heterotrait-monotrait Ratio (HTMT) criterion was used, which states that all HTMT ratios should be below 0.85 (Hair et al., 2017; Henseler et al., 2015), as is shown in table 5.7 (in orange).

Table 5.7 - Composite Reliability, Average Variance Extracted, Correlations, and Discriminant Validity Checks

Latent Variables	α	CR	AVE	1	2	3	4
(1) Benefits P2P	0,890	0,912	0,569	**0,754**	0,662	0,810	0,610
(2) Implementation Value	1,000	1,000	1,000	0,651	**1,000**	0,788	0,747
(3) International Interest	0,708	0,829	0,623	0,698	0,725	**0,789**	0,856
(4) National Interest	1,000	1,000	1,000	0,605	0,747	0,760	**1,000**

Note: a-Cronbach Alpha; CR-Composite Reliability; AVE-Average Variance Extracted; ***Blue****-Square roots of AVE; Below diagonal elements-correlations between the constructs; Above diagonal elements-HTMT ratios.*

Author´s Elaboration

The structural model was assessed by the use of sign, magnitude, and significance of the structural path coefficients; magnitude of R^2 value for each endogenous variable to measure predictive accuracy; and the Stone Stone-Geisser's Q^2 values to measure the predictive relevance (Hair et al, 2017). Before that, the inexistence of collinearity was checked using VIF values, which were all below the critical value of 5 (Hair et al, 2017). The values for R^2, the coefficient of determination for the endogenous variables ("Implementation Value", "International Interest", and "National Interest") were 64.1%, 48.8% and 58.9%, respectively which all surpass the minimum value of 10% (Falk & Miller, 1992). Finally, the Q^2 values for each endogenous variable (0.588, 0.281, and 0.558 respectively) were all above zero, indicating the predictive relevance of the model (Hair et al, 2017).

5.3.2 Quantitative Results

Table 5.8 - Structural Model Assessment

Path	Path Coefficient	Standard Deviation	*t* statistics	*p* values
Benefits P2P -> Implementation Value	0,221	0,086	2,578	**0,010**
Benefits P2P -> International Interest	0,698	0,056	12,392	**0,000**
Benefits P2P -> National Interest	0,145	0,097	1,495	**0,136**
International Interest -> Implementation Value	0,249	0,104	2,388	**0,017**
International Interest -> National Interest	0,659	0,085	7,791	**0,000**
National Interest -> Implementation Value	0,424	0,115	3,692	**0,000**

Author´s Elaboration

Table 5.9 - Bootstrap Results for Indirect Effects

Indirect Effect	Estimates	Standard Deviation	*t* statistics	*p* values
Benefits P2P -> International Interest -> Implementation Value	0,174	0,079	2,201	**0,028**
International Interest -> National Interest -> Implementation Value	0,280	0,081	3,447	**0,001**

Author´s Elaboration

The results from Table 5.8 show that the Benefits of P2P has a significant positive effect on both the Implementation Value (β=0.221, $p<0.05$) and the International Interest (β=0.698, $p<0.001$), thus supporting hypotheses H2a and H2b, respectively. However, our model was unable to support hypothesis H2c, which stated that Benefits of P2P had a significant positive effect on National Interest, since our *p* value is higher than 0.05. The results also show that International Interest has a significant positive effect on both Implementation Value (β=0.249, $p<0.05$) and National Interest (β=0.659, $p<0.001$), thus supporting hypotheses H1a and H1b, respectively. Finally, results show that National Interest has a significant positive effect on Implementation Value (β=0.424, $p<0.001$), thus supporting the hypothesis H3a.

In order to test the mediation hypotheses, a bootstrapping procedure on SmartPLS 3 was used (Hair et al, 2017). Table 5.9 shows the results of the mediation effects, in which we can see that the indirect effects of the Benefits of P2P on Implementation Value via the mediator International Interest are significant (β=0.174, $p<0.05$), thus supporting hypothesis H1c. Also, the results show that the indirect effects of International Interest on Implementation Value via the mediator National Interest are significant (β=0.280, $p<0.01$), thus supporting hypothesis H3b.

5.3.3 Result Discussion

The conceptual model presented in this section intended to answer the Research Question *Is there value in the implementation of Peer-to-Peer projects for energy distribution, and if so, do companies and consumers recognize this value?*. In order to do so, the model identified three main factors which were based on the Literature Review conducted for the dissertation. They are 1) the interest from international companies in implementing P2P projects (BMG, 2019; SOLshare, 2019; Sonnengroup, 2021), 2) the benefits of P2P systems (Morstyn et al, 2018; Klein et al, 2019; Neves et al, 2020; Tushar et al, 2018; Zhang et al, 2018), and 3) the interest in national P2P projects (Community-s, n.d.; ISEP, 2019). The variable Implementation Value of P2P Systems was based on the online surveys and was added in order to test our model. These categories were latent variables in our model and were tested using SmartPLS 3 (Ringle et al, 2015). The validity of the model is shown in the previous section.

Several indicators were used for each variable. Regarding International Interest, the indicator "Review of Existing Projects" was used to understand how international projects may help in the development of new P2P projects (BMG, 2019; SOLshare, 2019; Sonnengroup, 2021), and our literature shows the possible benefits and advantages of each project.

Regarding Benefits of P2P Systems, the indicators were "Renewables" (Morstyn et al, 2018), Monetary Benefits (Klein et al, 2019; Neves et al, 2020), Independence (Tushar et al, 2018), Decentralization (Zhang et al, 2018), Efficiency (Morstyn et al, 2018), and Autonomy (Tushar et al, 2018). Our literature shows that these benefits are important in the development of P2P systems, and may therefore actively contribute to their implementation.

To assess National Interest in P2P projects, the indicator "Interest in Existing Projects" (Community-s, n.d.; ISEP, 2019) was used, which showed that there is not enough knowledge regarding P2P projects in Portugal. Two main reasons apply: there aren't sufficient projects in our country, and because the ones that already exist are relatively unknown to the population.

Having created the model with its variables and indicators, a final question was asked in the surveys regarding the willingness to implement P2P systems. This question allowed us to better understand the intentionality to develop these systems, and was an indicator to our final variable Implementation Value of P2P Systems.

After identifying the main factors that may contribute to the increased value of P2P systems' implementation, the previously formed hypotheses were tested. All but one of the direct effects presented in our model were supported by the results. We start by showing that the Benefits of P2P Systems positively influence the Implementation Value of P2P Systems, thus confirming the hypothesis H2a. This in in line with our literature, which showed that the benefits from P2P Systems are important in their development and acceptance (Morstyn et al, 2018; Klein et al, 2019; Neves et al, 2020; Tushar et al, 2018; Zhang et al, 2018).

Also, the Benefits of P2P Systems positively influence the International Interest in P2P projects, thus confirming the hypothesis H2b. This again is in line with our literature as most of what is shown and mentioned regarding international projects is directly related to the benefits brought by them (BMG, 2019; SOLshare, 2019; Sonnengroup, 2021). We were however unable to support our hypothesis H2c, which stated that the Benefits of P2P Systems would positively influence National Interest in P2P Projects. The reasons identified for this are shown in the literature, where it is mentioned that these projects are relatively new and still unknown to the general public.

Regarding the International Interest in P2P Projects, our results show that it has a positive influence on both the Implementation Value of P2P systems and in the National Interest in P2P projects, thus supporting hypotheses H1a and H2b, respectively. Again, this is in line with our literature as we show that these projects increase the value of P2P projects by showing their functionalities, advantages, benefits, and overall positiveness of their implementation (BMG, 2019; SOLshare, 2019; Sonnengroup, 2021).

Finally, the direct effect between National Interest and Implementation Value was supported by our results, which supports the hypothesis H3a. We show in our literature that if there is an increase in interest from national consumers in P2P projects, the value of these projects may increase in the future (Community-s, n.d.; ISEP, 2019).

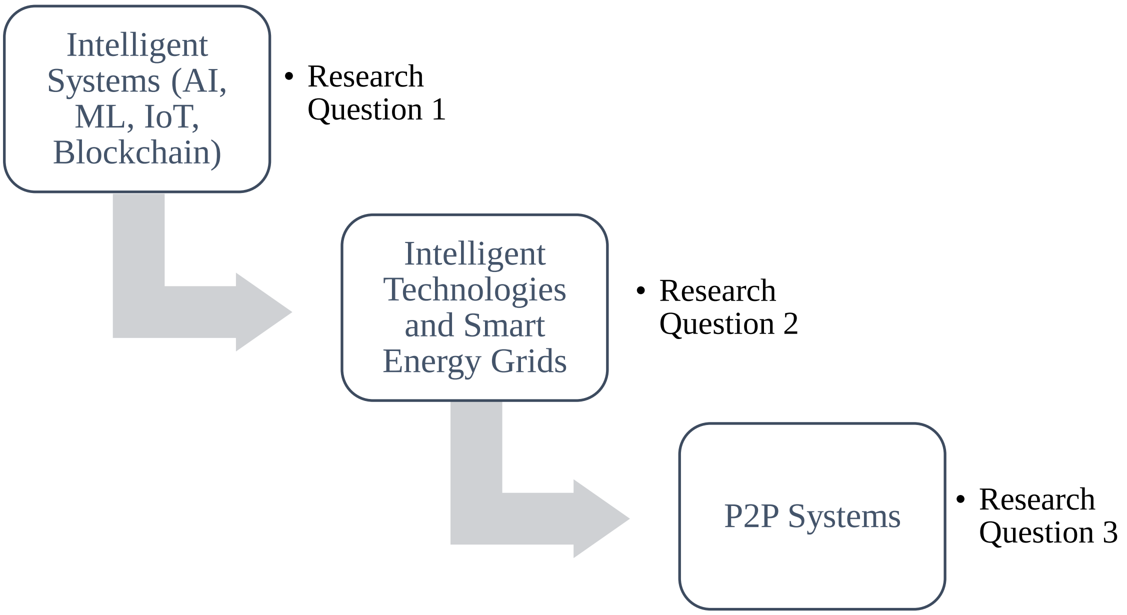
Regarding the indirect effects, we first show evidence that the International Interest mediates between the Benefits of P2P Systems and the Implementation Value of these systems, thus supporting hypothesis H1c. Our literature suggests that as the benefits become more apparent and more widely spread, International Interest increases and therefore the Implementation Value also increases (BMG, 2019; SOLshare, 2019; Sonnengroup, 2021; Tushar et al, 2018; Morstyn et al, 2018).

Finally, the mediator effect of National Interest between International Interest and the Implementation Value of P2P Systems is also supported by our results, thus validating hypothesis H3b. This means that as more international companies invest and increase their interest in these projects, the interest and knowledge in these systems will increase as well in the Portuguese public and will therefore increase the Implementation Value of P2P systems (BMG, 2019; SOLshare, 2019; Sonnengroup, 2021; Community-s, n.d.; ISEP, 2019).

5.4 Integrated Result Discussion

In order to reach the conclusions for this dissertation, an integrated result discussion of the three models is necessary. Figure 5.1 shows the links between the RQs and their topics. We try to show the relations between the three RQs and the influence they exercise on each other, in order to explain how Intelligent Systems and the technologies provided by them are useful to develop Smart Grids and potentially develop P2P systems for energetic distribution.

Figure 5.1 - Integrated Result Discussion



Author's Elaboration

The first model (regarding Intelligent Systems and their concepts) showed how perception, knowledge, benefits and trust are important factors for the development of these systems. The literature that supports this dissertation mentions how the integration of several benefits and capacities of intelligent systems and technologies may contribute to powerful and efficient solutions for data management and organization (Singh et al, 2020), which may be used in energy grids to provide reliable, low-cost, and sustainable systems for energetic distribution management (Yoldas et al, 2017).

By confirming the hypotheses present in our models regarding the first and second RQs, we try to prove the connections between Intelligent Systems and Smart Energy Grids, and the results show that there is in fact a positive and significant correlation between intelligent technologies and the implementation of modernized energy grids. This is in line with the literature mentioning that, for example, Smart Meters and the advantages provided by them are important in the development of modern grids and Smart Cities (Sethi and Sarangi, 2017). The same authors show that it is important to add intelligence at each step of the distribution network, and we believe this information is corroborated by the above-mentioned results of our models.

Mohanty et al (2016) state that smart technologies allow for the development of smart energy systems, and this information is supported by our model for RQ2, in which we see an indirect positive influence of these technologies in the increased value of modern energy grids. Regarding Smart Cities, we mention the importance of integrating intelligent technologies into grids to improve efficiency and sustainability (Silva et al, 2018), and again our models support this integration by showing the positive relations between benefits of smart technologies and value of SCs.

To show the relations between smart technologies, energy grids, and P2P systems, Zhang et al (2018) state that P2P trading is enabled by ICT-based online services, and that these services may be complemented with intelligent technologies to become more efficient. It is clear in the survey regarding P2P implementation that there is a strong connection between this type of projects and smart technologies, and this is supported by the model since there are clear positive correlations between the benefits of P2P systems (backed by smart technologies) and the value of their implementation.

Finally, in the literature review it is shown that P2P systems may benefit from technologies such as Blockchain (Tushar et al, 2018), Artificial Intelligence (Tushar et al, 2020), Machine Learning, and the IoT (Zhang et al, 2018). The results regarding intelligent technologies and willingness to implement them, together with the increase in value brought to SGs, supports the theory that Intelligent Systems may help in the development of efficient and sustainable P2P systems since these projects are not only integrated in more modern and intelligent energy grids, but also significantly benefit from smart technologies.

Chapter VI – Conclusions

6.1 Final Considerations

There were two objectives for this work. For the first one, *Understanding the possible role of intelligent systems in the development of Peer-to-Peer systems for energetic distribution management*, the presented study attempted to connect the recent developments of Intelligent Systems and several associated concepts with the development of intelligent technologies for the energy management industry, along with the possibility to include P2P systems in the energy distribution process.

After an extensive literature review, in which concepts of intelligent systems and technologies were presented and explained, surveys were conducted within the Portuguese population. The objective of these surveys was to evaluate the knowledge and interest of Portuguese respondents in these technologies, and to then compare and confirm several hypotheses formed from the literature review. The vast majority of the hypotheses were confirmed, showing a strong and positive relation between the possibility of developing intelligent systems and the willingness to modernize energy grids.

The formulation and validation of the proposed hypotheses was possible by performing a statistical analysis of the surveys' responses, which showed how the benefits of intelligent systems along with both trust and knowledge of them are important factors for their development. Also shown is the connection between the benefits of smart technologies (which, as indicated in our literature review, are strongly related to intelligent systems) and the advantages of smart grids and Smart Cities, which are in turn positively connected with the increased value of modernized energy grids.

More specifically, the hypotheses formulated for the first research question (*Which factors influence the willingness to implement and develop Intelligent Systems that rely on Artificial Intelligence, Blockchain, and the IoT?*) tried to verify if there are significant positive relations between the perception/knowledge, the benefits, and the trust in Intelligent Systems with the possibility of their development. What is shown by the analysis of the survey's (*Knowledge and Trust in Intelligent Systems*) responses is that these relations exist, and therefore that the three abovementioned ideas are factors for the possible implementation of IS in the Portuguese market. Indirect relations were also taken in consideration, showing that both perception and trust mediate between the benefits of IS and the possibility to implement them.

Still regarding the first objective of this study, to find answers for the second research question (*Do Smart Technologies and Intelligent Grids bring value to modernized energy grids,* *which may include P2P Systems and lead to Smart Cities?*), hypotheses were formulated that attempted to find positive and significant connections between the benefits of smart technologies and the advantages of smart grids with the possible implementation and development of modernized energy grids. These connections were supported by the analysis of the online survey (*Intelligent Technologies to Modernize Energy Grids*), which showed that both the benefits of smart technologies and the advantages of smart grids increase the value of modern energy distribution grids, which therefore may lead to their development and implementation. To confirm these connections, a positive relation between the benefits of smart technologies and the willingness to use these technologies was also established and supported.

For the second objective of this dissertation, *Analysing the Portuguese energy sector to understand if consumers and companies are ready and/or willing to implement Peer-to-Peer systems*, an attempt was made to connect existing projects, benefits, and Portuguese consumers' interest in national P2P projects with the value and possible development and implementation of these systems. The third research question, formulated specifically for this objective, was *Is there value in the implementation of Peer-to-Peer projects for energy distribution, and if so, do companies and consumers recognize this value?*, and was answered both with the literature review and the associated hypotheses for the model and online survey (*Implementation of Peer-to-Peer Systems for Energetic Distribution*).

What the statistical analysis of the model pertaining to this survey showed was that there are indeed positive and significant relations between the benefits of P2P systems and the interest from international companies (showing the existing projects) with the increase in value and the possibility of implementing P2P systems among Portuguese consumers. Also shown is the positive influence of the benefits of P2P systems in the interest from international companies, logically explained by the characteristics of implemented projects around the world. An attempt was made to understand if for Portuguese projects these benefits were also significant, and unfortunately this relation was not supported by our survey since there is insufficient information and knowledge available.

However, interest in national projects does positively influence the value of P2P systems, and also mediates between interest in international projects and the increase in value of P2P systems, which indicates that if more information and more projects exist in Portugal, this value will increase, and the implementation of P2P systems will be ever more present.

Having shown the positive influences between all the mentioned variables and their respective research questions, it is important to mention what these results implicate when analysed together. For this, an integrated result discussion was performed which intended to show the influence of each concept in the others. Resorting to the literature review and to the separate analysis of each model, conclusions were reached regarding the connections between Intelligent Systems, Modernized Energy Distribution Grids, and Implementation of P2P Systems.

What is shown is a significant relation between the factors and willingness to implement intelligent systems and the increased value of modernized energy grids, since these grids use smart technologies which are highly dependent on a positive and strong use of intelligent systems for their development. Therefore, the development and implementation of concepts related to intelligent systems is in fact important to bring value to smart grids, which are decidedly dependant on ICT advances and improvements, as well as on trust and knowledge from users in the technologies present in these modern grids.

In the case of the implementation of P2P systems, the integrated analysis shows how these systems not only benefit from being implemented in a scenario where intelligent grids are present, but also strongly benefit from the development of intelligent systems and technologies. This conclusion was reached since the benefits of P2P systems are highly related to the use of smart technologies, as is shown in our literature review, and we therefore extrapolate that consumers who are more interested, have more knowledge, and show more trust in intelligent systems and technologies, as well as those who show more openness and willingness in the use and development of intelligent energy distribution grids, are more likely to be interested in implementing P2P projects.

To summarise, this dissertation intended to show the relations between Intelligent Systems, Smart Grids and Intelligent Technologies for energy distribution, and the Implementation of Peer-to-Peer Systems. A wide-ranging literature review was performed, in which these technologies were addressed and explained, and where several projects and examples of each idea were mentioned. To complement the literature, three online surveys for the Portuguese population regarding each topic were made, which were later subjected to rigorous statistical analysis to show the existing connections and influences between them. Hopefully the conclusions reached by the integrated result discussion will prove helpful for the future development of these innovative technologies and projects, as well as for increasing trust and willingness from both consumers and companies in including these projects in their short-future plans.

6.2 Limitations

This study was performed resorting to literature and a quantitative analysis of survey answers. As such, some limitations were found. The nature of Intelligent Systems is understandably complex, Smart Energy Grids are extremely recent, and P2P projects are scarce and underdeveloped. As such, further studies and more time would be favourable for this study. Regarding the surveys, the limitations mostly concern the facts that the targeted population (although quite heterogenous) was strictly Portuguese, that the samples are relatively small, and the overall lack of information regarding some of the innovative technologies mentioned.

However, the study presented does show a positive intention of developing IS, SGs and P2P systems, thus increasing the confidence that this dissertation is able to show relevant results despite the abovementioned limitations. This does not mean in any way that further studies are not necessary, as they are essential for the continuous development of these technologies.

6.3 Suggestions for Further Studies

Given the limitations mentioned above, some suggestions for further studies are pressing. To begin, and as previously mentioned, given that the technologies considered for this study are innovative and recent, more time would be important to fully understand at least more of the almost limitless implications brought by intelligent technologies. Regarding the use of intelligent energy systems, more studies showing the implications and positive consequences of these grids would be welcome. As for P2P systems and projects, again more information on the real-life implications would be essential, along with an increase in the implementations of these projects that could show in more detail how relevant, exciting, and important P2P systems could become in the future.

Bibliography

Abera, T., Asokan, N., Davi, L., Koushanfar, F., Paverd, A., Sadeghi, A. R., & Tsudik, G. (2016, June). Things, trouble, trust: on building trust in IoT systems. In *Proceedings of the 53rd Annual Design Automation Conference* (pp. 1-6).

Abiodun, O. I., Jantan, A., Omolara, A. E., Dada, K. V., Mohamed, N. A., & Arshad, H. (2018). State-of-the-art in artificial neural network applications: A Survey. *Heliyon*, *4*(11), e00938.

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., & Airaksinen, M. (2017). What are the differences between sustainable and smart cities?. *Cities*, *60*, 234-245.

Alaton, C., & Tounquet, F. (2019). Benchmarking Smart Metering Deployment in the EU-28. *European Commission*.

Allam, Z., & Dhunny, Z. A. (2019). On big data, artificial intelligence and smart cities. *Cities*, *89*, 80-91.

Arasteh, H., Hosseinnezhad, V., Loia, V., Tommasetti, A., Troisi, O., Shafie-khah, M., & Siano, P. (2016, June). Iot-based smart cities: A survey. In *2016 IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC)* (pp. 1-6). IEEE.

Ashton, K. (2009). That 'internet of things' thing. *RFID journal*, *22*(7), 97-114.

Bagozzi, R. P., & Yi, Y. (1988). On the evaluation of structural equation models. *Journal of the academy of marketing science*, 16(1), 74-94.

Brooklyn Microgrid (2019) Retrieved from https://www.brooklyn.energy/

Chowdhury, S., Chowdhury, S.P., Crossley, P. (2009). *Microgrids and active distribution networks*. London, UK: The institution of Engineering and Technology.

Community-s (n.d.). Community-s. Retrieved from http://community-s.vps.energy/#inovacao

DGEC; OE; ADENE (2021) Energia em Números - Edição 2021, ADENE – *Agência para a Energia*. Lisboa, Portugal

Drescher, D. (2017) *Blockchain Basics: A Non-Technical Introduction in 25 Steps*. Frankfurt, Germany: Apress

Energias De Portugal (2018a, September 25) *EDP investe em startup que leva eletricidade a zonas isoladas do Bangladesh*. Retrieved from https://www.edp.com/pt-pt/noticias/2018/09/27/edp-investe-em-startup-que-leva-eletricidade-a-zonas-isoladas-do-bangladesh

Energias De Portugal (2018b) *Smart4RES: Ciência de Dados para Previsão de Energia Renovável*. Retrieved from https://www.edp.com/pt-pt/inovacao/smart4res-como-atingir-100-de-energia-renovavel

Energias De Portugal (2018c) *Blockchain Aplicada ao Mercado de Energia Solar*. Retrieved from https://www.edp.com/pt-pt/inovacao/blockchain-aplicada-ao-mercado-de-energia-solar

Eurostat(a) (13/04/2021) Artificial Intelligence (ISOC_EB_AI) Retrieved from https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210413-1?redirect=%2Feurostat%2Fweb%2Fmain%2Fhome

Eurostat(b) (11/03/2021) Internet of Things (ISOC_EB_IOT) Retrieved from https://ec.europa.eu/eurostat/web/products-datasets/-/isoc_eb_iot

Fadlullah, Z. M., Fouda, M. M., Kato, N., Takeuchi, A., Iwasaki, N., & Nozaki, Y. (2011). Toward intelligent machine-to-machine communications in smart grid. *IEEE Communications Magazine*, *49*(4), 60-65.

Falk, R. F., & Miller, N. B. (1992). A primer for soft modeling. University of Akron Press.

Fleischmann, M., & Ivens, B. (2019, January). Exploring the role of trust in blockchain adoption: an inductive approach. In *Proceedings of the 52nd Hawaii international conference on system sciences*.

Fornell, C., & Larcker, D. F. (1981). Structural equation models with unobservable variables and measurement error: Algebra and statistics.
Gandomi, A., & Haider, M. (2015). Beyond the hype: Big data concepts, methods, and analytics. *International journal of information management*, *35*(2), 137-144.
Hair Jr, J. F., Sarstedt, M., Ringle, C. M., & Gudergan, S. P. (2017). Advanced issues in partial least squares structural equation modeling. *saGe publications*.
Hatziargyriou, N., Asano, H., Iravani, R., & Marnay, C. (2007). Microgrids. *IEEE power and energy magazine*, *5*(4), 78-94.
Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the academy of marketing science*, 43(1), 115-135.
Holler, J., Tsiatsis, V., Mulligan, C., Avesand, S., Karnouskos, S., & Boyle, D. From Machine-To-Machine to the Internet of Things (2014).
Holliday, D., Wilson, S., & Stumpf, S. (2016, March). User trust in intelligent systems: A journey over time. In *Proceedings of the 21st International Conference on Intelligent User Interfaces* (pp. 164-168).
Instituto Superior de Engenharia do Porto (ISEP9 (31/05/2019) Retrieved from https://www.isep.ipp.pt/new/viewnew/6034
IRENA (2020), Innovation landscape brief: Peer-to-peer electricity trading, International Renewable Energy Agency, Abu Dhabi
Ismagilova, E., Hughes, L., Dwivedi, Y. K., & Raman, K. R. (2019). Smart cities: Advances in research—An information systems perspective. *International Journal of Information Management*, *47*, 88-100.
Kelleher, J. D., Mac Namee, B., & D'Arcy, A. (2015). Fundamentals of Machine Learning for Predictive Analytics.
Klein, L.P., Krivoglazova, A., Matos, L., Landeck, J., & de Azevedo, M. (2020). A Novel Peer-To-Peer Energy Sharing Business Model for the Portuguese Energy Market. *Energies*, *13*(1), 125.
Leikas, J., Koivisto, R., & Gotcheva, N. (2019). Ethical framework for designing autonomous intelligent systems. *Journal of Open Innovation: Technology, Market, and Complexity*, *5*(1), 18.
Li, H., Ota, K., & Dong, M. (2018). Learning IoT in edge: Deep learning for the Internet of Things with edge computing. *IEEE network*, *32*(1), 96-101.
Likert, R. (1932). A technique for the measurement of attitudes. *Archives of psychology*.
Lin, I. C., & Liao, T. C. (2017). A survey of blockchain security issues and challenges. *IJ Network Security*, *19*(5), 653-659.
Lin, J., Yu, W., Zhang, N., Yang, X., Zhang, H., & Zhao, W. (2017). A survey on internet of things: Architecture, enabling technologies, security and privacy, and applications. *IEEE Internet of Things Journal*, *4*(5), 1125-1142.
Lin, Z., & Dong, L. (2018). Clarifying trust in social internet of things. *IEEE Transactions on Knowledge and Data Engineering*, *30*(2), 234-248.
McCarthy, J., Minsky, M. L., Rochester, N., & Shannon, C. E. (2006). A proposal for the Dartmouth summer research project on artificial intelligence, august 31, 1955. *AI magazine*, *27*(4), 12-12.
McCorduck, P., & Cfe, C. (2004). *Machines who think: A personal inquiry into the history and prospects of artificial intelligence*. CRC Press.
Mohanty, S. P., Choppali, U., & Kougianos, E. (2016). Everything you wanted to know about smart cities: The internet of things is the backbone. *IEEE Consumer Electronics Magazine*, *5*(3), 60-70.

Mohri, M., Rostamizadeh, A., & Talwalkar, A. (2012). *Foundations of machine learning*. MIT press.
Molina, M. (2020). What is an intelligent system?. *arXiv preprint arXiv:2009.09083*.
Morstyn, T., Farrell, N., Darby, S. J., & McCulloch, M. D. (2018). Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants. *Nature Energy*, *3*(2), 94-101.
Nakamoto, S., & Bitcoin, A. (2008). A peer-to-peer electronic cash system. *Bitcoin.–URL: https://bitcoin. org/bitcoin. pdf*, *4*.
Neves, D., Scott, I., & Silva, C. A. (2020). Peer-to-peer energy trading potential: An assessment for the residential sector under different technology and tariff availabilities. *Energy*, *205*, 118023.
Newell, A., & Simon, H. A. (1961). *GPS, a program that simulates human thought*. RAND CORP SANTA MONICA CALIF.´
Nielsen, M. A. (2015). *Neural networks and deep learning* (Vol. 25). San Francisco, CA: Determination press.
Ning, H., & Wang, Z. (2011). Future internet of things architecture: like mankind neural system or social organization framework?. *IEEE Communications Letters*, *15*(4), 461-463.
Oussous, A., Benjelloun, F. Z., Lahcen, A. A., & Belfkih, S. (2018). Big Data technologies: A survey. *Journal of King Saud University-Computer and Information Sciences*, *30*(4), 431-448.
Park, C., & Yong, T. (2017). Comparative review and discussion on P2P electricity trading. *Energy Procedia*, *128*, 3-9.
Prettico, G., Marinopoulos, A., Vitiello, S., Distribution System Operator Observatory 2020: An in-depth look on distribution grids in Europe, EUR 30561 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-28430-7, doi:10.2760/311966, JRC123249.
PricewatherhouseCoopers (2016) *Blockchain – an opportunity for energy producers and consumers?* PWC. https://www.pwc.com/gx/en/industries/assets/pwc-blockchain-opportunity-for-energy-producers-and-consumers.pdf
Proserpio, D., Hauser, J. R., Liu, X., Amano, T., Burnap, A., Guo, T., ... & Yoganarasimhan, H. (2020). Soul and machine (learning). *Marketing Letters*, *31*(4), 393-404.
Reyna, A., Martín, C., Chen, J., Soler, E., & Díaz, M. (2018). On blockchain and its integration with IoT. Challenges and opportunities. *Future generation computer systems*, *88*, 173-190.
Ringle, C., Da Silva, D., & Bido, D. (2015). Structural equation modeling with the SmartPLS. Bido, D., da Silva, D., & Ringle, C.(2014). Structural Equation Modeling with the Smartpls. *Brazilian Journal Of Marketing*, 13(2).
Rose, K., Eldridge, S., & Chapin, L. (2015). The internet of things: An overview. *The internet society (ISOC)*, *80*, 1-50.
Russell, S., Norvig, P. (2010) *Artificial Intelligence: A Modern Approach* (3rd ed.) New Jersey, USA: Pearson Education, Inc.
Schmidhuber, J. (2015). Deep learning in neural networks: An overview. *Neural networks*, *61*, 85-117.
Segaran, T. (2007). *Programming collective intelligence: building smart web 2.0 applications*. " O'Reilly Media, Inc.".
Sethi, P., & Sarangi, S. R. (2017). Internet of things: architectures, protocols, and applications. *Journal of Electrical and Computer Engineering*, *2017*.
Shakeri, M., Shayestegan, M., Abunima, H., Reza, S. S., Akhtaruzzaman, M., Alamoud, A. R. M., ... & Amin, N. (2017). An intelligent system architecture in home energy management systems (HEMS) for efficient demand response in smart grid. *Energy and Buildings*, *138*, 154-164.

Siau, K., & Wang, W. (2018). Building trust in artificial intelligence, machine learning, and robotics. *Cutter Business Technology Journal*, *31*(2), 47-53.
Silva, B. N., Khan, M., & Han, K. (2018). Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities. *Sustainable Cities and Society*, *38*, 697-713.
Singh, S. K., Rathore, S., & Park, J. H. (2020). Blockiotintelligence: A blockchain-enabled intelligent IoT architecture with artificial intelligence. *Future Generation Computer Systems*, *110*, 721-743.
SOLshare (2019) Retrieved from https://me-solshare.com/what-we-do/
Sonnengroup (2021) *What is the sonnenCommunity?* Retrieved from https://sonnengroup.com/sonnencommunity/
Sustainable Energy Development Authority (2020, November 5) *Malaysia's 1st Pilot Run of Peer-to-Peer (P2P) Energy Trading*. Retrieved from http://www.seda.gov.my/2020/11/malaysias-1st-pilot-run-of-peer-to-peer-p2p-energy-trading/
SWECO (2015) Study on the effective integration of Distributed Energy Resources for providing flexibility to the electricity system (Report for the European Comission) https://ec.europa.eu/energy/studies/study-effective-integration-distributed-energy-resources-providing-flexibility-electricity_en
Tarka, P. (2018). An overview of structural equation modeling: its beginnings, historical development, usefulness and controversies in the social sciences. Quality & quantity, 52(1), 313-354.
Turing, A., & Haugeland, J. (1950). *Computing machinery and intelligence* (pp. 29-56). Cambridge, MA: MIT Press.
Tushar, W., Saha, T. K., Yuen, C., Smith, D., & Poor, H. V. (2020). Peer-to-peer trading in electricity networks: An overview. *IEEE Transactions on Smart Grid*, *11*(4), 3185-3200.
Tushar, W., Yuen, C., Mohsenian-Rad, H., Saha, T., Poor, H. V., & Wood, K. L. (2018). Transforming energy networks via peer-to-peer energy trading: The potential of game-theoretic approaches. *IEEE Signal Processing Magazine*, *35*(4), 90-111.
Ullman, J. B., & Bentler, P. M. (2012). Structural equation modeling. Handbook of Psychology, Second Edition, 2.
United Nations, Department of Economic and Social Affairs, Population Division (2019). *World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420)*. New York: United Nations.
Varghese, B., & Buyya, R. (2018). Next generation cloud computing: New trends and research directions. *Future Generation Computer Systems*, *79*, 849-861.
Viegas, J. L., Vieira, S. M., Melício, R., Mendes, V. M. F., & Sousa, J. M. (2016). Classification of new electricity customers based on surveys and smart metering data. *Energy*, *107*, 804-817.
Wang, Y., Chen, Q., Hong, T., & Kang, C. (2018). Review of smart meter data analytics: Applications, methodologies, and challenges. *IEEE Transactions on Smart Grid*, *10*(3), 3125-3148.
Yli-Huumo, J., Ko, D., Choi, S., Park, S., & Smolander, K. (2016). Where is current research on blockchain technology?—a systematic review. *PloS one*, *11*(10), e0163477.
Yoldaş, Y., Önen, A., Muyeen, S. M., Vasilakos, A. V., & Alan, İ. (2017). Enhancing smart grid with microgrids: Challenges and opportunities. *Renewable and Sustainable Energy Reviews*, *72*, 205-214.
Zhang, C., Wu, J., Zhou, Y., Cheng, M., & Long, C. (2018). Peer-to-Peer energy trading in a Microgrid. *Applied Energy*, *220*, 1-12.

Zhang, D., Mishra, S., Brynjolfsson, E., Etchemendy, J., Ganguli, D., Grosz, B., Lyons, T., Manyika, J., Niebles, J.C., Sellitto, M., Shoham, Y.,Clark, J., and Perrault, R. “The AI Index 2021 Annual Report,” AI Index Steering Committee, Human-Centered AI Institute, Stanford University, Stanford, CA, March 2021.

Zhang, X. D. (2020). Machine learning. In *A Matrix Algebra Approach to Artificial Intelligence* (pp. 223-440). Springer, Singapore.

Zheng, Z., Xie, S., Dai, H. N., Chen, X., & Wang, H. (2018). Blockchain challenges and opportunities: A survey. *International Journal of Web and Grid Services*, *14*(4), 352-375.

Zhou, B., Li, W., Chan, K. W., Cao, Y., Kuang, Y., Liu, X., & Wang, X. (2016). Smart home energy management systems: Concept, configurations, and scheduling strategies. *Renewable and Sustainable Energy Reviews*, *61*, 30-40.

Annexes

Annex A. Survey for RQ1 – Knowledge and Trust in Intelligent Systems

Conhecimento e Confiança em Sistemas Inteligentes

Este questionário tem como objetivo entender os conhecimentos e a confiança em Sistemas Inteligentes. Para isso, em cada secção apresentamos uma breve descrição de vários conceitos associados a estes Sistemas, e pedimos que avalie a sua concordância com cada afirmação.

*Obrigatório

Sistemas Inteligentes	Sistemas Inteligentes (SI) são sistemas capazes de se aperceberem do seu ambiente através de sensores, e de atuarem sobre ele. Têm capacidades como perceção e raciocínio, e são capazes de se adaptar e de aprender com as suas experiências passadas. São também autónomos, sendo que podem tomar decisões baseadas no seu próprio conhecimento e independentemente da programação original feita pelos seus criadores, dentro de parâmetros previamente definidos.

1. Tenho conhecimento do que são Sistemas Inteligentes

Marcar apenas uma oval.

	1	2	3	4	5	
Não concordo						Concordo muito

2. Um SI que mostre transparência e boa performance é fidedigno

Marcar apenas uma oval.

1	2	3	4	5

3. Um SI autónomo que seja seguro e facilmente interpretável é fidedigno

Marcar apenas uma oval.

1	2	3	4	5

4. Um SI com um objetivo claro é fidedigno

Marcar apenas uma oval.

1	2	3	4	5

5. Um SI que explique os resultados que obtém é mais fidedigno

Marcar apenas uma oval.

	1	2	3	4	5	
	◯	◯	◯	◯	◯	

Inteligência Artificial e Machine Learning	Inteligência Artificial (IA) é a tecnologia que permite às máquinas terem as características que as tornam inteligentes. Essencialmente, é o que permite uma máquina passar de um simples programa para um dispositivo que aprende sozinho. IA é baseada na crença de que máquinas podem ser agentes racionais, capazes de escolher a resposta mais lógica e eficiente para problemas complexos. Machine Learning (ML) é um subsistema de IA, que através de algoritmos permite a um programa aprender a fazer previsões baseadas em dados obtidos previamente.

6. Tenho conhecimento dos conceitos e aplicações de Inteligência Artificial e Machine Learning

Marcar apenas uma oval.

	1	2	3	4	5	
Não concordo	◯	◯	◯	◯	◯	Concordo muito

7. Um Sistema Inteligente pode adaptar-se a qualquer situação e proporcionar a melhor solução disponível *Marcar apenas uma oval.*

1 23 4 5

8. Um Sistema Inteligente aprende com os dados que lhe são fornecidos e encontra soluções ideais para resolver transações complexas *Marcar apenas uma oval.*

1 23 4 5

9. Um Sistema Inteligente aprende com os dados que lhe são fornecidos e consegue prever futuros padrões de oferta e procura *Marcar apenas uma oval.*

1 23 4 5

10. Um Sistema Inteligente pode analisar enormes quantidades de informação, e retirar resultados que fornecem as melhores aplicações para cada utilizador *Marcar apenas uma oval.*

1 23 4 5

11. Um Sistema Inteligente, através de Smart Meters, pode pré-processar dados (como padrões de utilização ou previsões de futuras necessidades energéticas), e enviar informações simplificadas para os fornecedores.

Marcar apenas uma oval.

of

	1	2	3	4	5
	⬭	⬭	⬭	⬭	⬭

Internet

Things

A Internet of Things (IoT) refere-se à interconectividade entre dispositivos ligados à Internet, que trocam informações a velocidades extremamente elevadas e permitem o colecionamento e processamento de dados de múltiplas e variadas fontes.

12. Tenho conhecimento do conceito e aplicações da Internet of Things

Marcar apenas uma oval.

	1	2	3	4	5	
Não concordo	⬭	⬭	⬭	⬭	⬭	Concordo muito

13. Só confiaria na IoT se soubesse que os meus dados estão seguros e privados

Marcar apenas uma oval.

1 2 3 4 5

14. Confiaria mais na IoT se houvesse feedback sobre os sistemas e se os fornecedores do serviço tivessem uma reputação positiva *Marcar apenas uma oval.*

1 23 4 5

15. Na Internet of Things, os dispositivos conectados entre si podem completar tarefas altamente complexas

Marcar apenas uma oval.

1 2 3 4 5

Blockchain

Blockchain é uma tecnologia que permite trocar informação de forma segura e transparente. Não necessita de uma autoridade central que verifique cada transação, visto que todos os membros dentro de uma blockchain têm acesso aos dados transitados e podem verificar cada transação (ou seja, podem verificar que a troca de dados ocorreu, mas não o que os dados contêm ou a identidade dos intervenientes). A troca destes dados só ocorre se não houver nenhuma alteração ao longo da blockchain, o que permite um alto nível de segurança e fidelidade nas transações.

16. Tenho conhecimento do conceito e aplicações do Blockchain

Marcar apenas uma oval.

	1	2	3	4	5	
Não concordo	◯	◯	◯	◯	◯	Concordo muito

17. Confiaria nos outros utilizadores de uma Blockchain para verificarem os meus dados

Marcar apenas uma oval.

1	2	3	4	5
◯	◯	◯	◯	◯

18. A tecnologia do Blockchain garante a segurança das transações tanto ou mais do que o faria uma autoridade central *Marcar apenas uma oval.*

1	2	3	4	5
◯	◯	◯	◯	◯

19. Um Sistema Inteligente que registe transações através de Blockchain permite maior segurança, anonimidade e resiliência (visto que deixa de haver um ponto central de processamento de dados) *Marcar apenas uma oval.*

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

20. Tendo oportunidade, gostaria de implementar um Sistema Inteligente

Marcar apenas uma oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

Informação Pessoal

21. Idade *

Marque todas que se aplicam.

- ☐ <18
- ☐ 18-25
- ☐ 26-35
- ☐ 36-50
- ☐ >50

22. Género *

Marque todas que se aplicam.

- ☐ Feminino
- ☐ Masculino

Outro: ☐ ______________________

23. Escolaridade *

Marque todas que se aplicam.

- [ ] Ensino Básico
- [ ] Ensino Secundário
- [ ] Licenciatura
- [ ] Pós-graduação
- [ ] Mestrado
- [ ] Doutoramento

Annex B. Survey for RQ2 – Smart Technologies to Modernize Energy Grids

Tecnologias Inteligentes para Modernizar Redes Energéticas

Este questionário tem como objetivo entender se Tecnologias Inteligentes podem ser úteis para criar Redes Energéticas modernizadas. Para isso, apresentamos algumas descrições de conceitos relacionados com estas Redes e Tecnologias, e pedimos que avalie a sua concordância com cada afirmação.

*Obrigatório

Tecnologias Inteligentes	Tecnologias Inteligentes têm a capacidade de medir, interpretar, e comunicar dados automaticamente. Smart Meters (aparelhos que permitem uma medição de consumos energéticos automática e inteligente) são um excelente exemplo destas tecnologias, que podem ser usadas para medir e analisar, por exemplo, o consumo de energia de uma família e oferecer os melhores preços baseando-se nos seus hábitos e preferências.

Vantagens para um cliente

Nesta secção avaliamos as vantagens das Tecnologias Inteligentes do ponto de vista de um cliente de electricidade. As suas respostas são importantes independentemente do facto de ser ou não responsável pelos contratos de energia - queremos avaliar a perceção destas vantagens para qualquer pessoa.

1. Seria útil ter um Smart Meter (medidor inteligente) para o meu fornecedor de energia obter dados sobre o meu consumo *Marcar apenas uma oval.*

	1	2	3	4	5	
Não concordo	⬭	⬭	⬭	⬭	⬭	Concordo muito

2. Seria útil ter um Smart Meter para o meu fornecedor de energia conseguir oferecer preços baseados no meu consumo em real-time *Marcar apenas uma oval.*

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

3. Um Smart Meter é útil porque permite que um fornecedor ofereça tarifas mais atrativas e personalizadas a cada cliente *Marcar apenas uma oval.*

	1	2	3	4	5
	◯	◯	◯	◯	◯

4. Um Smart Meter é útil porque permite ao cliente poupar energia e dinheiro

Marcar apenas uma oval.

	1	2	3	4	5
	◯	◯	◯	◯	◯

5. Num futuro próximo, a maioria dos medidores de consumos de energia deveriam ser "inteligentes"

Marcar apenas uma oval.

	1	2	3	4	5
	◯	◯	◯	◯	◯

Tecnologias Inteligentes

Vantagens para um fornecedor

Nesta secção tentamos avaliar as vantagens das Tecnologias Inteligentes para um fornecedor de electricidade, do ponto de vista de um cliente.

6. Seria útil ter um Smart Meter para o meu fornecedor de energia prevenir fraudes e erros de leitura

Marcar apenas uma oval.

	1	2	3	4	5	
Não concordo	◯	◯	◯	◯	◯	Concordo muito

7. Havendo um benefício monetário para um fornecedor de energia, equipar um Smart Meter deveria ser uma prioridade *Marcar apenas uma oval.*

1 2 3 4 5

8. Um Smart Meter é útil porque permite medir e comunicar de imediato consumos de energia aos fornecedores *Marcar apenas uma oval.*

1 2 3 4 5

9. Um Smart Meter é útil porque permite a um fornecedor prever os consumos futuros dos seus clientes

Marcar apenas uma oval.

1 2 3 4 5

10. Um Smart Meter é útil porque permite que um fornecedor caracterize os seus clientes de uma forma eficiente *Marcar apenas uma oval.*

1 2 3 4 5

11. Um Smart Meter é útil porque permite que se altere a carga energética de cada cliente consoante os seus consumos (por exemplo ter uma carga mais baixa durante a noite)

Marcar apenas uma oval.

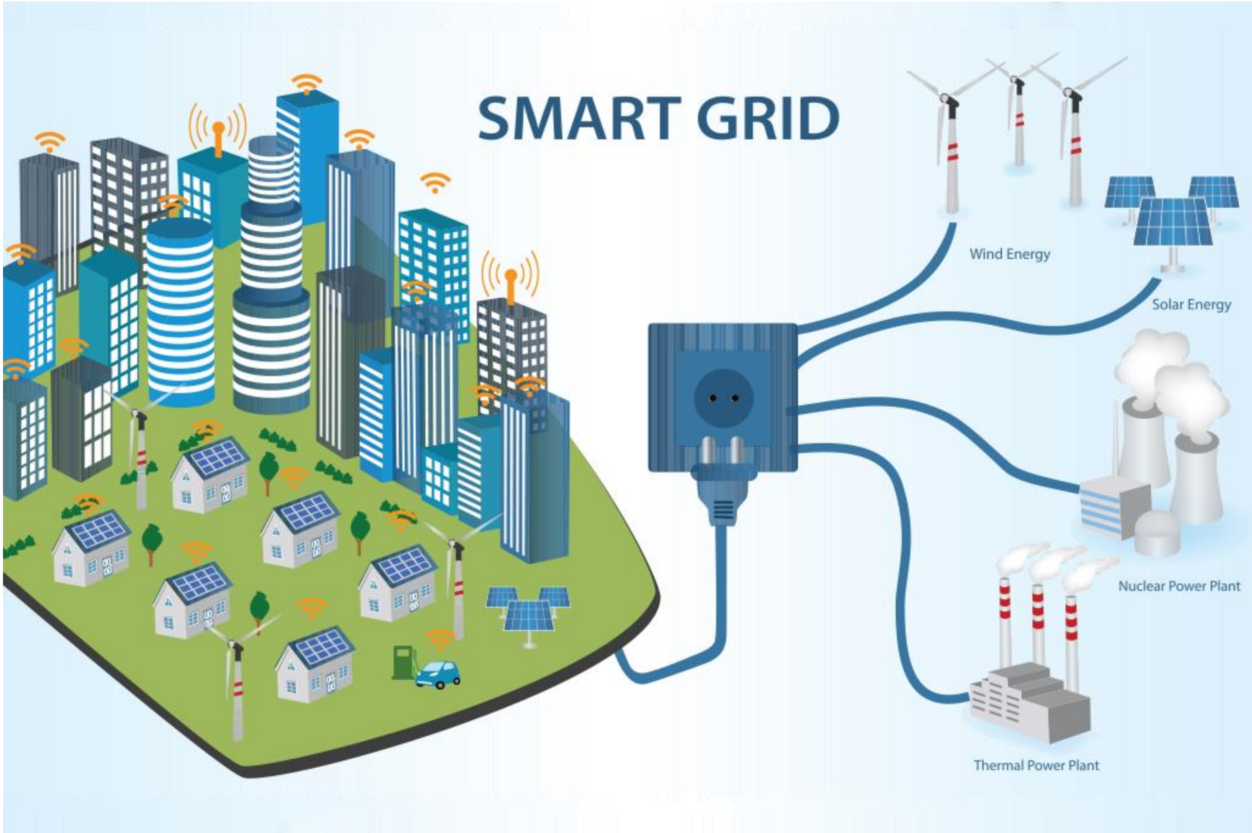
1 2 3 4 5

Redes Inteligentes (Smart Grids) são redes de energia com distribuição otimizada através de IA, baseadas em análises de dados que podem ser fornecidos por Smart

Redes Meters. Estas Redes podem-se basear na produção de energias renováveis, e tantopodem ser independentes da rede de distribuição normal como podem ser um

Inteligentes

complemento à mesma. Podem também ser aplicadas em grande escala, contribuindo para a criação de Smart Cities.



12. Redes Inteligentes são importantes porque, havendo "inteligência" em todos os passos da distribuição de energia, o processo torna-se mais eficiente *Marcar apenas uma oval.*

	1	2	3	4	5	
Não concordo	⬭	⬭	⬭	⬭	⬭	Concordo muito

13. Redes Inteligentes são mais seguras contra, por exemplo, riscos de segurança ou perdas de energia

Marcar apenas uma oval.

	1	2	3	4	5	
	⬭	⬭	⬭	⬭	⬭	

14. Redes Inteligentes permitem usar ao máximo fontes renováveis, visto que alteram autonomamente e de acordo com as melhores condições a fonte de energia a ser utilizada na rede

Marcar apenas uma oval.

	1	2	3	4	5	
	⬭	⬭	⬭	⬭	⬭	

15. Smart Cities são importantes para combater os efeitos da rápida urbanização e crescimento das populações urbanas, visto que permitem uma gestão eficaz dos recursos de uma cidade *Marcar apenas uma oval.*

	1	2	3	4	5	
	⬭	⬭	⬭	⬭	⬭	

16. Qual o seu nível de interesse na construção de redes de distribuição energéticas modernizadas?

Marcar apenas uma oval.

	1	2	3	4	5	
	⬭	⬭	⬭	⬭	⬭	

Informação Pessoal

17. Idade *

Marque todas que se aplicam.

- [ ] <18
- [ ] 18-25
- [ ] 26-35
- [ ] 36-50
- [ ] >50

18. Género *

Marque todas que se aplicam.

- [ ] Feminino
- [ ] Masculino

Outro: [ ] ____________________

19. Escolaridade *

Marcar apenas uma oval.

- ( ) Ensino Básico
- ( ) Ensino Secundário
- ( ) Licenciatura
- ( ) Pós-graduação
- ( ) Mestrado
- ( ) Doutoramento

Annex C. Survey for RQ3 – Implementation of Peer-to-Peer Systems for Energetic Distribution

Implementação de Sistemas Peer-to-Peer para Distribuição Energética

Este questionário tem como objetivo entender a viabilidade da implementação de sistemas Peer-to-Peer para distribuição energética. Para isso, após uma breve introdução ao funcionamento destes sistemas pedimos que avalie a sua concordância com as afirmações apresentadas.

*Obrigatório

Sistemas Peer-to-Peer

Distribuição de energia Peer-to-Peer (P2P) é um modelo de negócio em que um Prosumer (alguém que é ao mesmo tempo produtor e consumidor de energia), equipado com uma fonte de energia renovável (por exemplo painéis solares ou moinhos eólicos) pode formar uma rede de distribuição de energia com os seus vizinhos. Desta forma, o excesso de energia produzido por uma casa seria automaticamente disponibilizado a outra casa que necessite.

Existem várias vantagens para esta tecnologia, tais como (e entre outras):

Maior produção de energia de fontes renováveis

Menores custos para consumidores que evitem a rede de distribuição normal (preços oferecidos por vizinhos podem ser mais baixos)

Benefícios monetários para prosumers que vendam o seu excesso de energia (sem sistemas P2P, podem vendê-la a baixo custo ao seu distribuidor de energia, ou guardar o excesso através de baterias com elevados custos)

Providenciar energia renovável a áreas rurais (ou mesmo áreas onde não há fornecimento de energia)

Potenciais oportunidades de negócio para empresas novas ou já existentes

Vantagens de Sistemas P2P

Nesta secção, pedimos que indique o seu grau de concordância relativo às várias vantagens de Sistemas P2P que serão apresentadas.

1. Um sistema P2P é positivo porque permite uma maior integração de energias renováveis na rede de distribuição *Marcar apenas uma oval.*

	1	2	3	4	5	
Não concordo	⬭	⬭	⬭	⬭	⬭	Concordo muito

2. Uma rede P2P que funcione de forma independente (ou integrada) em relação à rede de distribuição normal pode trazer benefícios como segurança, privacidade e resiliência

Marcar apenas uma oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

3. Em sistemas P2P, a descentralização é positiva porque deixa de haver uma autoridade central a confirmar as transações, reduzindo custos e aumentando a eficiência

Marcar apenas uma oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

4. Um sistema P2P é positivo porque permite aumentar a eficiência na troca de energias renováveis, através de informações personalizadas sobre os intervenientes

Marcar apenas uma oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

5. Seria útil uma App na qual um cliente pode ter acesso aos seus consumos e produção, e na qual pode trocar energia livremente com os seus vizinhos (de forma automática ou não)

Marcar apenas uma oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

6. Em Portugal, um sistema P2P pode ser útil porque permite uma redução do preço da energia (tanto através da redução de impostos como através da compra e venda de energia a preços mais atrativos)

Marcar apenas uma oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

Vontade de Participar em Sistemas P2P

Nesta secção, pretendemos avaliar se existe interesse na população portuguesa em aderir a Sistemas P2P.

7. Gostaria de participar em projetos como a Brooklyn Microgrid (BMG), onde se troca energia através de sistemas P2P com recurso ao Blockchain *Marcar apenas uma oval.*

	1	2	3	4	5	
Não concordo	◯	◯	◯	◯	◯	Concordo muito

8. Projetos que consigam fornecer energias renováveis a áreas remotas através de sistemas P2P, como por exemplo o SOLbazaar no Bangladesh, são importantes *Marcar apenas uma oval.*

	1 2	2	3	4	5	
	◯	◯	◯	◯	◯	

9. Parece-me positivo um projeto como a Sonnenbatterie, em que energia solar guardada em baterias pode ser comercializada através de sistemas P2P *Marcar apenas uma oval.*

	1	2	3	4	5	
	◯	◯	◯	◯	◯	

10. Gostaria de participar num projeto como o Community-s, que consistiu em formar uma rede P2P baseada em energia solar em duas vilas portuguesas *Marcar apenas uma oval.*

	1	2	3	4	5	
	◯	◯	◯	◯	◯	

11. Um projeto P2P em Portugal que prometa aumentar a eficiência energética e a autonomia dos consumidores parece atrativo *Marcar apenas uma oval.*

	1	2	3	4	5	
	◯	◯	◯	◯	◯	

12. Um projeto P2P em Portugal que permita poupar dinheiro em energia parece atrativo

Marcar apenas uma oval.

	1	2	3	4	5	
	◯	◯	◯	◯	◯	

13. Qual o seu nível de interesse em implementar sistemas P2P?

Marcar apenas uma oval.

1 2 3 4 5

Informação Pessoal

14. Idade *

Marque todas que se aplicam.

- [ ] <18
- [ ] 18-25
- [ ] 26-35
- [ ] 36-50
- [ ] >50

15. Género *

Marcar apenas uma oval.

- Feminino
- Masculino
- Outro: ____________________

16. Escolaridade *

Marcar apenas uma oval.

- Ensino Básico
- Ensino Secundário
- Licenciatura
- Pós-graduação
- Mestrado
- Doutoramento

17. Tem casa própria? *

Marque todas que se aplicam.

- [ ] Sim
- [ ] Não
