How Much are Portuguese Residential Consumers Willing to Invest in Photovoltaic Systems?

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Abstract. This paper presents the main results of a survey conducted aiming at analysing and evaluating the citizen's perceptions and willingness to invest in the installation of residential photovoltaic systems. Data has been collected in Coimbra, an urban municipality of Portugal, through a questionnaire involving three groups of questions related to socio-economic characterization of the household and building characteristics, ownership of any type of renewable energy system and willingness to invest in residential photovoltaic systems. Regarding the investment cost of the different photovoltaic systems considered, and according to the type of housing, an individual technical and economic evaluation was performed. Most of the 88 respondents have a positive attitude towards the integration of renewable energy systems in the residential sector and some of them have good knowledge of these systems. However, only a few of the respondents own a solar system and about two-thirds of respondents expressed no interest in investing in PV systems. The study served as a starting point for the assessment of the integration of renewable energies in an urban context and the obtained results will serve as the basis for the definition of scenarios related to the penetration of solar photovoltaic systems in the residential sector. This type of results can also be considered by Policy-makers in defining future measures to support the installation of residential renewable energy systems.

Keywords: Photovoltaic systems · Renewable energy systems · Residential sector · Willingness to invest

1 Introduction

Renewable energies, being of infinite supply, decentralized, and uniquely suited to their location, are the solution for cleaner and safer energy production. Increasing the generation of electricity from renewable energies can contribute to reduce greenhouse gas emissions, to decrease dependence from fossil fuels and fuel imports, to increase the safety of energy supplies and to meet sustainable energy development targets.

Portugal has privileged natural conditions for the generation of renewable energy. However, most of the energy from renewable sources is nowadays generated from

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large wind and photovoltaic farms, despite the fact that the potential for new small-scale installations for the distributed production of electricity, namely in the residential sector, using endogenous renewable sources, is very considerable. Among the various renewable technologies, solar Photovoltaic, or (PV)-based electricity, is dubbed as the most environmentally friendly and sustainable technology for electricity production and it is believed to have the largest potential for the residential sector [1].

Although the Portuguese positive attitude towards investments in innovative renewable energy systems (RES), namely solar projects and new hydropower units is high [2], the number of residential consumers adopting solar PV technologies is still relatively low, despite the fact that this activity is licensed through specific laws and there may be support measures.

Increasing the installation of photovoltaic solar systems in the residential sector could contribute to the compliance with European Union (EU) legislation on the energy performance of buildings (Energy Performance of Building Directive, 2010/31/EU). According to this Directive, Member States shall ensure that from the year 2020 all new buildings will have to be 'Nearly Zero Energy Buildings' (NZEB), which means, "a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby".

However, despite the potential of PV systems as an energy option in the urban energy system, several factors affect PV deployment [3, 4]. Based on an extensive range of literature in the broader field of renewable energy, five main types of barriers that limit site suitability, economic viability, and social acceptance of large-scale deployment of the solar option are identified in [3]: (1) technical barriers – space constraints, intermittency, and grid connection limitations; (2) economic considerations – high investment costs and long payback period; (3) market factors – misplaced incentives, unpriced costs, insufficient information and difficulty in accessing reliable information; (4) access to finance and institutional regulations – the existence of vested interests against new energy options, difficulties in dealing with permission requirements; (5) social barriers – lack of public acceptance of new energy technologies and low perceived usefulness of a new energy technology.

The Feed-in-tariffs (FITs) scheme is the most common market driven instrument that governments, including the Portuguese Government, have been using to facilitate RES market development [5–7]. The central principle of FITs policies is to offer guaranteed prices for fixed periods, to enable a greater number of investors [8]. The scheme has rapidly increased the deployment of (PV) technologies at small scale since its introduction in 2008 (Portuguese Ministerial Order 201/2008). However, some researchers criticize the solar PV FITs used to incentivize consumers to acquire solar PV, because they are funded through increased electricity prices affecting lower income groups who are less capable of investing in solar technology [5]. The decline of the feed-in tariff rates is increasing the interest in self-consumption of PV electricity from residential systems (defined as the share of the total PV production directly consumed by the PV system owner) among PV system owners and in the scientific community [6, 9]. Moreover, the success of policies that encourage the uptake of solar PV in the residential sector requires consumer acceptance and engagement with new and emerging energy technologies, and their role is crucial to the implementation of energy policies [5].

In this context, the main objective of this paper is to analyse and evaluate the residential consumer's perceptions and willingness to invest in the installation of photovoltaic systems. The study is based on a survey of residential consumers conducted in a Portuguese city, used for this purpose. The paper is organised as follows: After the introduction the second section gives a brief overview of the evolution of photovoltaic systems' legislation and support measures. The third section presents the methodological framework and questionnaire design, while the main results are presented in the fourth section. Finally, some conclusions are drawn, including expected future developments in this field of research.

2 Residential PV Systems - The Portuguese Legal Framework and Support Measures

Some key findings of a study focused on residential prosumers in the European Energy Union [10], with prosumers as "energy consumers who also produce their own energy from a range of different onsite generators", using small scale solar PV to generate electricity, reveal that there is no harmonised regulatory framework for residential prosumers in the EU. Member States take different approaches, have simplified procedures for setting up residential prosumer installations and differ in terms of the financial incentives given to prosumers. Furthermore, in most Member States, the regulatory framework has evolved rapidly over time. The study also concludes that incentives have played an important role in promoting the development of self-generation, especially in the more mature solar PV markets.

In Portugal, renewable energy policy is in line with EU 2020 targets and Portuguese targets on renewable energy, that is, 31% of renewable energy in gross final energy consumption. The policies and measures to meet the targets were set out in the Portuguese National Renewable Energy Action Plan (NREAP) in July 2010. The Cabinet Resolution 20/2013 approved the new NREAP 2020, aiming to adjust the energy supply to the demand and to review the objective of each RES in the national energy mix, taking into account, namely, the maturity of the technology and its competitiveness [11].

Regarding electricity generation with residential PV in Portugal, Decree-Law 68/2002 initially regulated microgeneration: installations that use a single production technology and have a single-phase or three-phase load operating at a Low Voltage, and with a capacity of no more than 5.75 kW for single houses and 11.04 kW for condominiums. According to this law, at least 50% of the electricity produced by generators and solar panels should be consumed by the producer or by connected third parties. A Ministerial Order established the method for calculating the payment due for energy produced by microgeneration units. After five years of coming into effect, the number of microgeneration units did not achieve an expressive number.

In the end of 2007, a new law promoting the microgeneration of electricity was approved. Decree-Law 363/2007 defined a special and fast process of licensing where producers could register their installations via an electronic platform or SRM - System for the Registration of Minigeneration, and an interesting tariff - initial tariff of 650€/MWh for PV systems. The Ministerial Order 201/2008 introduced the FITs scheme and rapidly increased the deployment of PV technologies at small scale. As of October 2010, Decree Law 118-A/2010 modifies some aspects of the Microgeneration Law by simplifying the application procedure and by streamlining the access to the microgeneration regime for public, social, education, defence and local institutions. Moreover, access to the benefits regime was adjusted to the cost of the equipment used in the microgeneration and subject to certain conditions, namely the compliance with energy efficiency rules and the use of solar thermal collectors or biomass boilers. Decree Law 34/2011 and Decree-Law 25/2013 complement the microgeneration regime. This new regulation simplifies the licensing regime through the new SRM electronic platform managed by the Directorate-General for Energy and Geology (DGEG).

At this time, the microgeneration law defines two regimes: the general regime, applicable to any type of microgeneration up to a limit of 5.75 kW and the special regime, applicable to renewable electricity production up to a limit of 3.68 kW. For the special regime, a reference FIT was established and applied to each technology according to a different percentage. The reference FIT for new producers reduces each year and, once defined, is valid for 15 years divided into two periods, one period of eight years and another for the remaining seven years with different tariffs for each. In 2010, the tariffs were 400€/MWh for the first period and 240€/MWh for the second. The mechanism includes an annual reduction rate of 20€/MWh. In 2014, the reference FIT was 66€/145€ per MWh for PV technologies. By mid-2014, there were 25000 installations in the special regime and 900 in the general regime, delivering a total capacity of 93 MW and 4.0 MW, respectively [11].

The more recent legislation in Portugal, Decree-Law 153/2014, was designed to streamline distributed electricity production, ensuring the technical and economic sustainability of the electric grid, simplifying the old model of microproduction and miniproduction and enabling entities with less constant consumption profiles, to be also included in this scheme.

The new Portuguese legal framework is applicable to the installation of a generation unit (UP), which may take the form of a small-scale generation unit (UPP) or a generation unit for self-consumption (UPAC). It provides for the same simplified licensing procedures as the previous legislation and the potential producers could conduct their licensing using the Electronic System of Registration of Generation Units (SERUP). The procedure is similar for both generation units – UPP or UPAC. The producer must submit a request to the SERUP and pay the registration fee to the DGEG. Once the generation unit has been registered, the producer must install it using an authorised installation entity and submit a request for the inspection of the unit. If the unit has no defects nor irregularities, the exploitation certificate will be issued, the unit will be definitively registered and the generation unit can be connected to the grid – UPP or to the producer installation – UPAC.

However, there are different rules according to the type of generation unit. A UPP is applicable to any type of RES up to a limit of 250 kW, with grid injection and with a FIT for each primary energy used, according to a different percentage contained in Ministerial Order 15/2015. The reference FIT for new producers in 2015 is valid for 15 years, and has a value of 95€/MWh, to which 5.0€/MWh are added if there is 2 m^2 of solar thermal panels in the consumer's installation or of 10€/MWh if there is an electric vehicle charging power outlet connected to the mobility grid in the consumer facility [11]. A UPAC is applicable to any kind of source since it does not benefit from a FIT, and has the possibility of injecting the surplus into the grid, which if paid by the last-resort supplier at 90% of the average monthly market price. Optionally, a UPAC, either grid connected or off-grid, can also trade the electricity surplus or the generated electricity by green certificates [11].

3 The Methodological Framework and Questionnaire Design

Based on a survey supported in a questionnaire, our study proposes the analysis and evaluation of the consumers' willingness to invest in photovoltaic systems in the residential sector. As referred in [12], although there are several studies in the scientific literature on the estimation of the consumers' willingness to pay (WTP) for renewable energies, only a few of them focused on WTP for renewable energy technologies that may be installed in households. In [13] a survey of 200 Greek consumers was carried out, from December 2009 to January 2010, aiming to examine the determinants that affect consumers' intention towards the adoption of renewable energy sources in the residential sector in Greece. The work in [14] takes a closer look at the awareness regarding microgeneration and presents the results from a nationally representative study conducted in the Republic of Ireland. A survey was developed in March 2009 to identify the level of awareness for microgeneration technologies in Ireland, accessed a sample of 1010 adults aged above 15 years, and ensured representativeness by setting strict quotas for age, gender, social class and region. In this context, [12] also presents the results of a questionnaire survey carried out in order to identify the preferences on renewable microgeneration technologies in Lithuanian households and sharing thereof. Respondents were individual house owners living in Kaunas or in the Kaunas region and completed questionnaires in the period of April-June 2016. The study in [15] aims to do an in-depth analysis on how Swedish households search for and interpret information about PVs, as well as to discuss how to reach different groups with this information. The results of this work are based on three interview studies made between autumn 2013 and autumn 2016. The work in [16] presents a study aiming to explore how to motivate homeowners to adopt residential solar electric technology. This study is based on semi-structured interviews with homeowners throughout the state of Wisconsin, who have installed PV technology. Interviews were conducted between April and November 2011 and involved 48 individuals in 36 households.

3.1 Questionnaire Design and Respondents Profile

The questionnaire survey was made short (an expected total time of completion of 5 min maximum) and relatively simple, to increase the probability of receiving a higher number of respondents. It was prepared considering three groups of questions, all of multiple choice: the first group is related to the socio-economic characterization of the household; the second group deals with building characteristics; the third and last group considers the ownership of any type of residential renewable energy system and the willingness to invest in residential PV systems. We carried out the survey from July to September 2018. The questionnaire was made anonymous, distributed through Google Forms to a universe of 110 residential consumers and had 80% of the sent requests successfully answered.

All the 88 respondents to the online survey are residents of Coimbra, the Portuguese city chosen for this study. The average age of the respondents is 52, and their ages range from 25 to 78 years. Most respondents are between the ages of 25 and 40 years old (55.7%), 33% are between 40 and 60 years old, and only 11.7% above 70 years old. Regarding the educational level of respondents, the majority are university-educated where 68.2% hold a Bachelor's or a Master's Degree and 20.5% hold a PhD Degree. Only 11.4% have graduation from a secondary school as educational level.

Besides the age and educational level, residents have been questioned about the number of persons per household, net household income and house type. Almost half of the interviewed, 48.9% live in a three or four-person household. Another large share, 43.2%, live in a one or two-person household. Only for about 8% of the answers, the household composition is higher than 4 people. Half of the households have an income between 1,000 and 2,500 EUR/month, 11% have an income lower than 1,000 EUR/month and only 39% of households have an income higher than 2,500 EUR/month. The great majority of the respondents, 80.1%, own their house, 29.5% live in a single-family house, 12.5% live in a condominium with more than eighteen households and the majority, 58%, live in a condominium with a number of households between three and eighteen. Almost all the buildings in the sample are exclusively used for housing (85.2%).

3.2 Economic Analysis of Different Residential PV Systems

To support the questions related to residential consumers willing to invest in photovoltaic systems, as for example when defining the limits for the total investment costs, an economic analysis of different PV systems that can be installed in the residential sector had been conducted. This analysis took into account the local availability of solar radiation, existing market technologies and the new Portuguese legislation

Table 1. Economic analysis of different UPP units.

				UPP
Installed capacity	500 W	1500 W	3000 W	5000 W
Total investment cost (€)	725.00	1923.00	5247.00	9517.00
Annually electricity production (kWh)	825.00	2475.00	4952.00	8251.00
Net Present Value (€)	−102.98	1161.99	1535.42	2189.86
Internal rate of return	1.55%	8.12%	5.59%	5.06%
Payback (years)	19.93	10.13	12.84	13.56
O&M costs (€)	35.00	35.00	35.00	35.00
Discount rate	3.00%	3.00%	3.00%	3.00%
Reference tariff (€/kWh)	0.095	0.095	0.095	0.095

concerning the promotion of renewable energy sources in households [17–19]. The PVSYST® software has been used for the simulation of electricity production from the different PV systems considered.

The main results of the economic analysis for the different small-scale PV generation units, including the profitability of a PV system (see Net Present Value), are presented in Table 1.

According to the results presented in Table 1, one main conclusion is that the investment in a 500 W UPP is very appealing from the prosumer point of view, in what concerns the total investment cost. However, this system presents a negative NPV, meaning that it will be a non-economically viable project.

For UPAC units, the installed capacity considered for evaluation was decided according to the most frequent registrations in Portugal, in the SERUP platform, from March 2015 to July 2017. Table 2 presents the main results of the economic analysis for different PV generation units, for self-consumption.

Table 2. Economic analysis of different UPAC units.

				UPAC
Installed capacity	500 W	1500 W	3000 W	5000 W
Total investment cost (€)	1025	4189	9294	15111
Annually electricity production (kWh)	825	2475	4952	8251
Net Present Value (€)	499.25	1602.66	2903.95	5619.19
Internal rate of return	7.25%	6.34	5.75	6.24
Payback (years)	10.87	11.94	12.66	12.08
O&M costs (€)	35	35	35	35
Discount rate	3%	3%	3%	3%

An economic analysis for UPAC systems selling the surplus produced electricity to the national grid was not performed. This was because, for those cases, detailed knowledge is needed on the energy consumed in the dwelling and on the energy that is sold or not sold to the public grid.

4 Consumers Willing to Invest in PV Systems – Results and Discussion

To analyse and evaluate the residential consumer's perceptions and willingness to invest in the installation of photovoltaic systems, the focus of the results herein presented, additional questions were included in the questionnaire, regarding the ownership of renewable energy systems, renewable energy awareness, interest in investing in renewable energy systems and how much the household would be willing to invest in a PV system.

Only 31% of the houses surveyed here have a renewable energy system installed. Of these, 7% correspond to PV systems for electricity production, 6% to biomass units

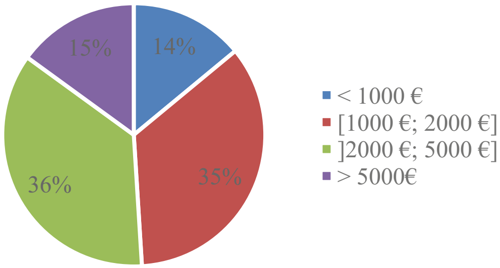


Fig. 1. Percentage of residential consumers willing to invest, by investment value range.

for heating and 18% to solar thermal systems for hot water production. Concerning these houses that already have a renewable energy system installed, 24 of the total enquires have confirmed energy related savings in their electric bill, corresponding to 89% of the consumers with an installed renewable energy system.

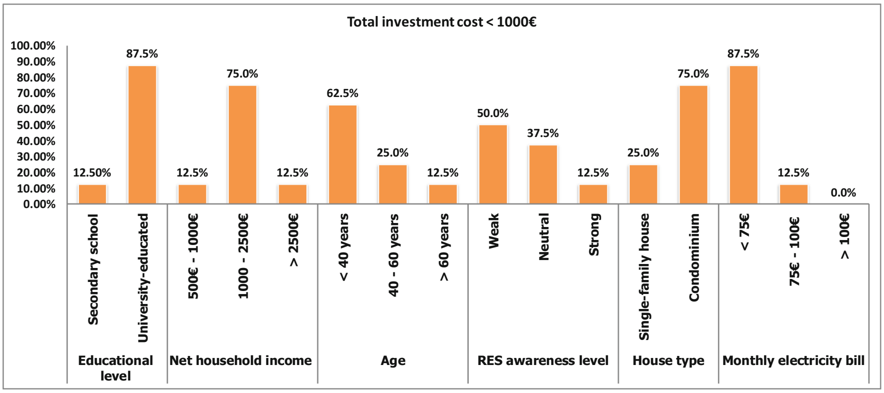
When questioned about the interest in investing in PV systems, about two-thirds of respondents (67%) expressed no interest in this investment. Figure 1 illustrates the results obtained regarding how many residential consumers are willing to invest in a PV system, expressed as a percentage, by investment value range considered. As it could be expected, the percentage of consumers willing to invest more than 5000 € is low. However, the percentage of consumers willing to invest up to 1000 € is the lowest. This result may be related to the pre-conceived idea of the cost associated with a photovoltaic system, together with the net household income of inquired consumers.

Figure 2a–d, depict how much residential consumers are willing to invest in a PV system according to the buildings' characteristics and according to their socio-economic characterization.

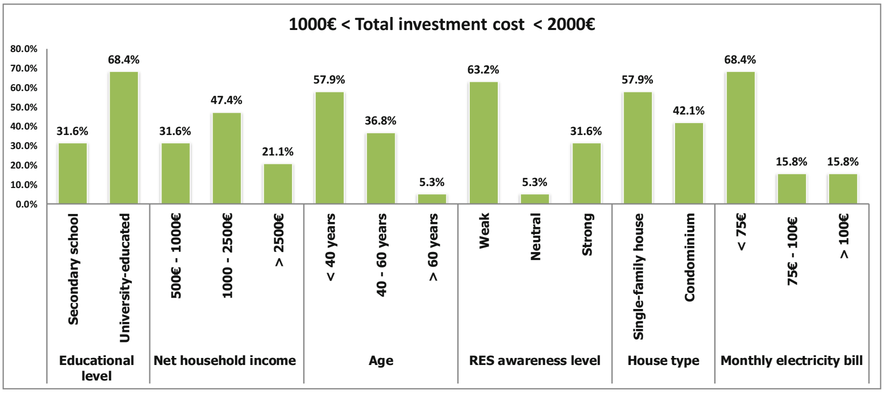
From the analysis of the results presented in the graphs of Fig. 2, as expected, there is a direct relationship between net monthly household income and investment in PV systems. 75% of respondents willing to invest more than 5000 € have a net monthly income of more than 2500 €. This percentage decreases as the income decreases reaching no responses to incomes less than 1000 €. Moreover, given the data on the economic evaluation of different PV systems, presented in Tables 1 and 2, the number of options for consumers who are willing to invest up to 1000 € is reduced. Of course, the options will increase as the amount the consumer is willing to invest increases. The same direct relationship exists regarding educational level. The totality of respondents who are willing to invest more than 5000 € are university-educated.

The younger respondents are more willing to invest. This is not surprising, as this group will correspond to consumers with greater knowledge regarding renewable energy and environmental concerns. The respondents aged over 60 represent the largest percentage of consumers willing to invest more than 5000 €.

There is no direct relationship between the amount of the monthly electricity bill and the amount willing to invest. The majority of respondents indicate a monthly electricity bill less than 75 €. Those with the highest monthly electricity bill (higher than 100 €) correspond to the highest percentage of respondents in the investment range between 1000 € and 2000 €. For consumers with monthly electricity bill between



a)



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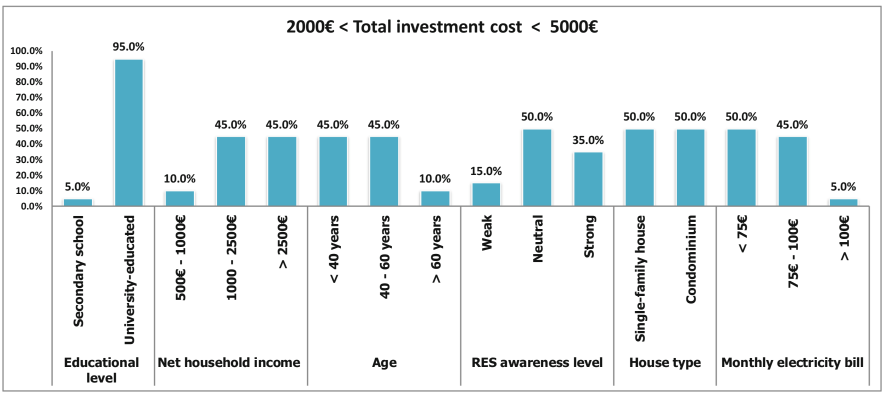
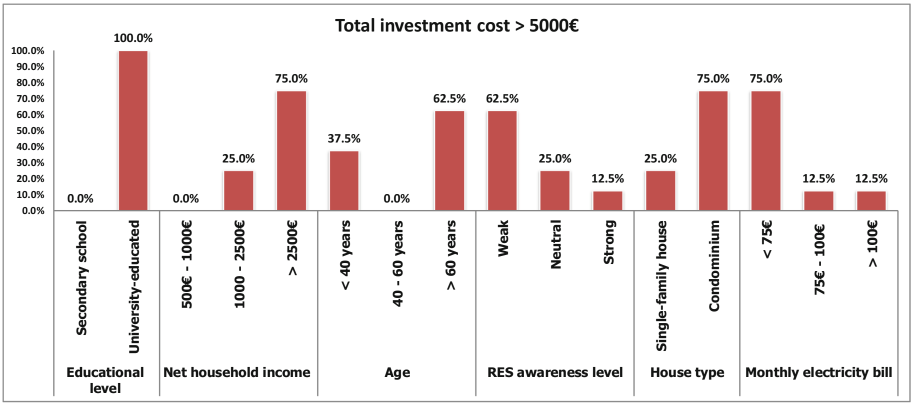


c)

Fig. 2. How much are residential consumers willing to invest in a PV system.



d)

Fig. 2. (*continued*)

75 € and 100 €, the largest number of responses (45%) corresponds to the investment range between 2000 € and 5000 €. Regarding the type of household involved in the survey, we can observe that, except for the investment range between 1000 € and 2000 €, the majority of respondents live in condominiums, where the installation of a PV system may be more difficult, requiring the acceptance of all condominium owners.

5 Conclusions

The main objective of the present study was to analyse and evaluate the residential consumer's perceptions and how much they are willing to invest in photovoltaic systems. This study is the starting point for a wider study, aiming at the assessment of the economic, social and environmental impacts of the integration of renewable energies in an urban context. Information about consumers' socioeconomic profile and about their willingness to adopt and to invest in renewable energies, namely in the installation of PV systems, will serve as the basis for the definition of different scenarios related to the penetration of solar photovoltaic systems in the residential sector, according to the buildings' characteristics and according to the consumers' socio-economic characterization and electricity consumption profile.

Data collected through an online questionnaire allowed to conclude that the willingness to adopt or invest in renewable energy systems in the residential sector is dependent on the consumer's age and knowledge about RES and, eventually, about existing legislation concerning RES. On the other hand, regarding the amount that consumers are willing to invest in residential RES, there is a strong relationship with the net monthly household income. This fact justifies some recommendations in line with [10]: an EU-level legal framework focused on the establishment of a portfolio of carefully designed incentives, tailored to the different situations and measures designed aiming at supporting the development and uptake of new technologies with an environmental objective.

Although the presented methodology has been developed in a national context, using a medium-sized Portuguese city as a decision-making scenario, and considering the applicable national and international legislation and support programs, it can be applied to other national municipalities, or in other countries, taking into account the specificities of each urban energy system and legal framework under analysis.

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