Characterization of the Energy Consumption in Portugal's Residential Sector

(Master Thesis Extended Abstract)

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Abstract

In Portugal, the residential sector is one of the major contributors to the final energy consumption. Highly dependence on fossil fuels is one of the major concerns that have leaded this sector under energy efficiency monitoring measures. Thus, over the last decade, several reports about energy consumption in the residential sector have been published. However, some of them lack consistency between different information sources. This work aims to contribute to a detailed characterization of the energy consumption in the Portuguese residential sector. Therefore, energy consumption values by end-use and energy source were estimated based on comparison and inter-validation between collected data from the various information sources. The results obtained with the fore mentioned detailed level were projected to national consumption, in order to be compared to the final energy consumption of the domestic sector, published in National Energy Balance. Regarding that the estimated results do not present significant disparity, it is possible to assume them to be representative of a detailed characterization of the residential sector consumption in Portugal.

Keywords: residential sector, final energy consumption, useful energy, Portuguese households' energy profile.

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1. Introduction

1.1 Context

Over the last few years, energy policies' concerns regarding the residential sector have been increasing. In European Union Member States, this sector is responsible for about one third of the final energy consumption. Electricity is one of the main used energy sources and half of its production relies on fossil fuels [1]. Thus, the residential sector is also one of the major contributors to total greenhouse gases emissions [2]. Moreover, the increasing number of the dwellings as well as the increasing number of electronic appliances as well as their usage time and the increment of thermal comfort needs, are some of the reasons that have lead this sector to strive for energy efficiency monitoring measures [3]–[6]. Nonetheless, one of the most important goals under energy efficiency policies is to reduce the vulnerability to the main energy sources' oscillating prices and the insecurity of being highly dependent on other countries for energy supply [4].

In addition to the adverse effects associated with the use of fossil fuels, Portugal lacks such resources, which causes a high dependence on primary energy importation from other countries [7]. Even though it has been declining over the past few years [7], the energy dependence in 2014 was still 71%, which is fairly above the EU average [8]. At European level, energy demand moderation has been advocated as one of the most effective tools for achieving the reduction of external energy dependence and exposure to rising prices [3].

In fact, total gross energy consumption in European Union's Member States has been declining among the last 10 years [3]. However, it is suggested that this evolution may be a reflection of the economic and financial crises that has been driving changes in energy consumption patterns, rather than efficiency measures results [9].

Moreover, despite the great interest in energy efficiency measures implementation [10], the actual impact was below the expectations, since it was verified the existence of a gap, above 50%, between projections for the global energy demand and actual results over the last 20 years [11]. The main pointed reason to justify this gap is based on the lack of appropriated data, in which consistent energy indicators should be developed [11]. The absence of such indicators is then an important obstacle to an adequate assessment of the actual situation and subsequent improvements projections [11]. Therefore, detailed knowledge regarding each end-use sector has been turning imperative.

The recognition of this issue is not recent and that is why the majority of developed countries have quality statistical data regarding energy consumption. Regarding this aspect, European Commission has provided efforts in order to produce quality and accurate information related to energy consumption [5].

Furthermore, in order to fill the gaps in statistical information and improve its quality, the most recent Regulation (EU) 431/2014, published on 24 April 2014, and amending the previous regulation (no. 1099/2008) on energy statistics, establishes a common framework for the production, transmission, assessment and dissemination of the European Commission's statistical data, concerning the annual energy consumption statistics. National Energy Balance (NEB) follows this regulation [5]. NEB should then provide an overview of the national consumption, showing information about the country's energy structure and the evolution of consumption, such as the evolution of energy consumption in the residential sector over time.

However, this information is not disaggregated with enough detail in which the fore mentioned indicators can be built. Thus, extensive data dissociation is required in order to assess which are the end-uses that have the most influence within each sector [11]. For the specific case of households' consumption, energy consumption only at sector level is provided in NEB.

Therefore, over the last decade, several reports about the Portuguese residential sector have been published, provided by national entities as ADENE, QUERCUS, DGEG, INE, among others. Nonetheless, available data included on these and other sources lack overall consistency and there are also found nonconformities that can be based on different used methodologies.

Thus, it is necessary to conduct a systematic study, crossing data between the various information sources, in order to characterize, in more detail, the energy consumption in the residential sector.

1.2 Objectives

This work aims to contribute to a detailed characterization of the Portuguese residential sector, which can be used as an instrument for planning the most appropriate energy efficiency measures for this sector.

Thus, the first objective is to provide typical dwelling profiles that can be used to characterize the final energy consumption.

Secondly, it is pretended to develop national energy consumption indicators based on the breakdown of the energy consumption by end use and source.

1.3 Methodology

From an energy consumption characterization stand point of view, this analysis follows, therefore, the studies carried out in order to collect data about energy indicators in the residential sector: *Energy efficiency in equipment and electrical systems in the residential sector* (hereafter EEESE) [12], the survey results under *EcoFamilias* project (EF225 and EFII) [13], [14], *Survey on Energy Consumption in Households* (SECH), *Characterization of thermal performance and nominal heating gap of the residential building stock using the EPBD-derived databases: The case of Portugal mainland* (M&L) [15], the survey under *Fair Renewable Heating and Cooling Options and Trade* (FROnT) [16]. In addition, data from a recent project, *A sua casa, A sua energia (in portuguese, Your home, Your Energy)* [17], was also analyzed.

The methodology used in order to address the proposed objectives comprises two main approaches, based on available data provided by the several studies in this field.

1) To analyze the collected data from Census and SECH in order to build typical household profiles;
2) To compare and cross the energy consumption values provided from all information's sources, inter-validating them, to develop detailed energy consumption indicators.

2. Overview of energy consumption by final use and source

The average final energy annual consumption by source per dwelling was obtained based on SECH, NEB, EFII and ASCASCE' data and these values are represented in Figure 1. Values published in NEB were disaggregated into consumption per dwelling level, based on the number of dwellings supplied by each source of energy (regarding data published in SECH's report). In this way, the consumption of each energy source was divided by the number of households that are supplied by a certain type of source (for instance, final energy consumption of natural gas was divided by the number of dwellings that are supplied by this source). It is then possible to identify some differences between values concerning the consumption of some specific energy sources.

The values regarding oil consumption are the ones that stand out. However, in 2012, NEB's data show a huge reduction (over 100%) related to this fuel.

Considering all energy sources, values obtained from SECH's report are the most similar to the NEB's values, published in 2010. This was expected, since projections to NEB are based on SECH's data since that year.

Comparison between EFII and extrapolated NEB values, during the period 2009 – 2011, shows that the average consumption estimated by the first is slightly higher (8 to 16%) than NEB values. This variance may be based in the fact that 8.7% of the sample observed by EFII does not have another energy source supply besides electricity. As result, all energy services used in these dwellings are provided exclusively by electricity.

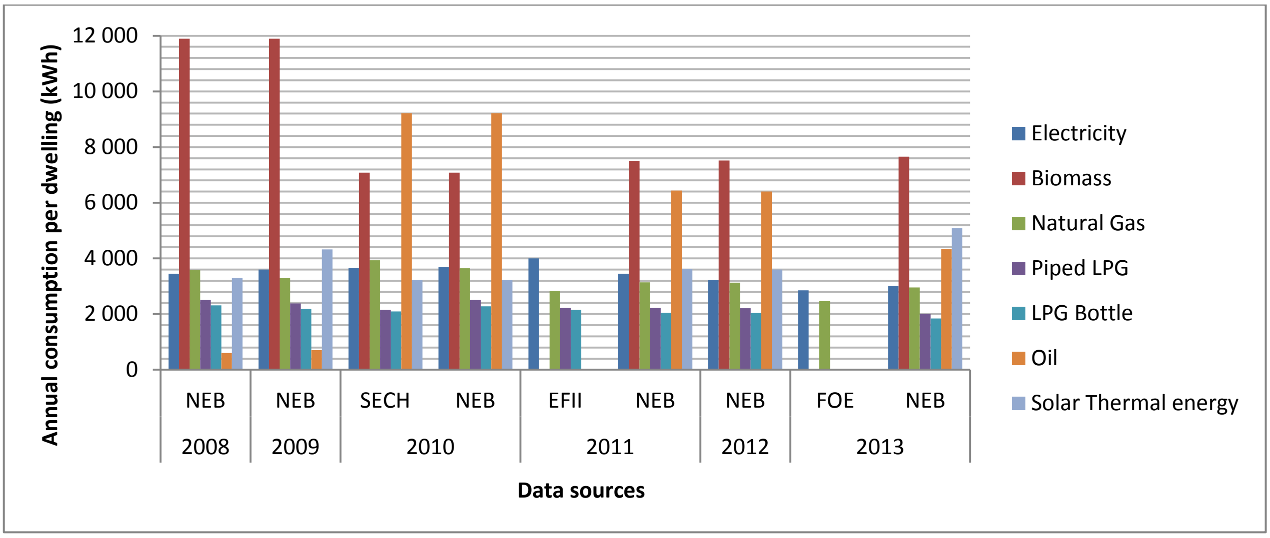

Figure 1 – Final energy consumption (kWh) per dwelling.

Figure 2 depicts the average electricity consumption values, which are provided in all information's sources concerning the consumption of energy in the residential sector. It is then observed that electricity consumption is the end use most well characterized, given the fact there is available data concerning this energy source since 2004, provided from different information's sources.

In general, it is observed that the values from different sources of information do not present significant variances. Thus, an averaged value of 3500 kWh per dwelling is obtained between 2004 and 2010. Nonetheless, NEB's values show a decrease of the electricity consumption in order of 18% since 2010, in the specific case of domestic sector.

On the other hand, values from EFII and ASCASE's data are above (around 17%) NEB's values. EFII data indicates an average annual electricity consumption of 4002 kWh per dwelling. The analyzed sample within this project is overestimated regarding several aspects, such as households' characteristics as well as geographical areas. ASCASE provides an average consumption of 4209 kWh per dwelling in 2013, meaning a difference of 28% compared to the extrapolated values from NEB published in the same year. The average value obtained from the same study for the year 2012 is also above (about 20%) the value published in NEB. Considering the sample of this project, there are two factors that might justify a possible overestimation of electricity consumption: the first one concerns the way of measuring the consumption that included reactive energy measurements; the second one regards the average floor area, which is above the Portuguese households average (109 m^2) obtained in Census of 2011.

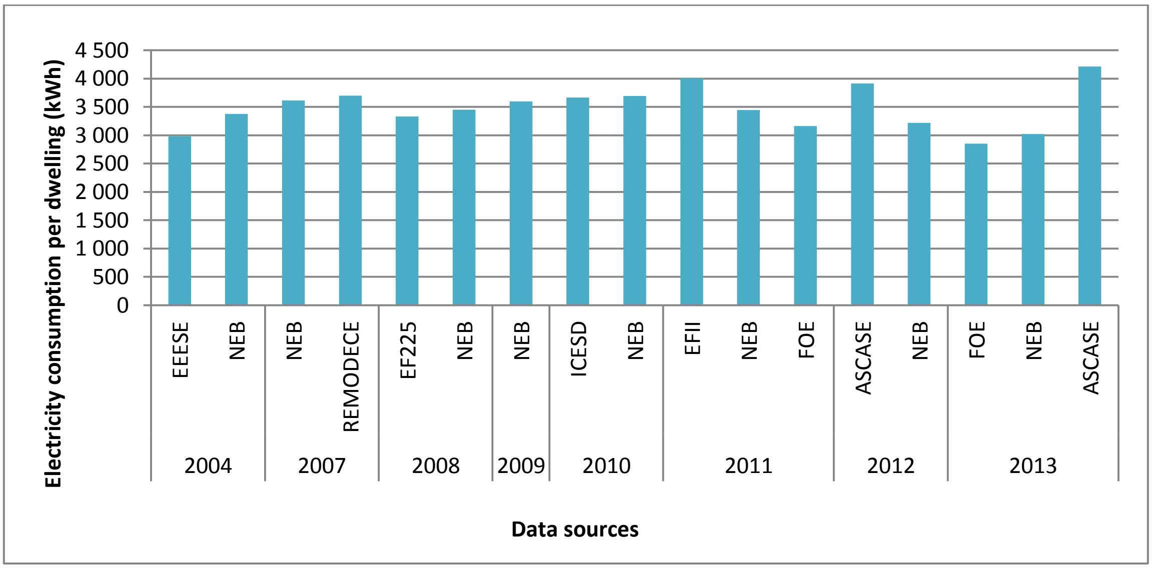

Figure 2 – Average annual electricity consumption per dwelling, based on the several information's sources.

In Table 1 the main elements collected from the studies that were the basis for this work are identified. The main following elements are identified: the holding period, the number of households analyzed within each study, the type of used methodology to collect data as well as the categories in which information is available.

Table 1 – Type of data collected from the information sources related to the residential sector.

Study		*EEESE*	*REMODECE*	*EF225*	*SECH*	*EFII*	*Census*	*M&L*	*FROnT*	*ASCASE*
Period		2000-2002	2006 - 2008	2007-2008	2009-2010	2009-2011	2011	2013	2015	2012-2015
Sample (number of dwellings)		150	642	206	7468	968	3991112	259277	900	53
Methodology	Surveys		✓	✓	✓	✓	✓		✓	✓
	Administrative Source				✓		✓			
	In situ measurements	✓	✓	✓		✓				✓
	Modelling		✓					✓		
Categories	Construction of the dwelling and households' characteristics		✓	✓		✓	✓		✓	✓
	Consumption/ Expenditure on Energy Commodities	✓	✓	✓	✓	✓				✓
	Energy Consumption by End-Use	✓	✓	✓	✓			✓		
	Space Heating				✓	✓	✓		✓	
	Space Heating				✓	✓			✓	
	Domestic Water Heating				✓	✓			✓	
	Electrical appliances	✓	✓	✓	✓	✓				✓
	Lighting		✓	✓	✓	✓				

3. Disaggregation of energy consumption

Final energy consumption is split into several sectors and, within each sector, various end-uses are provided. Accordingly, energy end-uses are defined as the use of energy commodities, in order to obtain certain energy service [5]. In the residential sector, the following major energy end-uses can be distinguished: space heating, space cooling, domestic water heating (DWH), cooking, lighting and electrical appliances.

In order to characterize the energy consumption in households, by end-use, a comparison regarding several parameters provided in data from the fore mentioned studies was taken. Subsequently, for each energy service category, data supplied from each information source were inter-validated. This validation procedure tried to achieve a coherent disaggregation of energy consumption values, at the most possible detailed level and, at the same time, to be representative at a national scale.

Figure 3 represents, in a hierarchical form, the levels of used information split into appropriate categories. Activity data was mainly obtained from INE's data base while energy data was collected from the several studies' reports as previously referred.

In order to further provide a detailed characterization of energy consumption in the residential sector, both data were considered. Activity data regards characteristics of households, such as the occupation intensity of dwellings, the average useful area, the house typology, among other aspects. Parameters included in this type of data influence the energy consumption in several ways. For instance, depending on the solar orientation of the building [18] as well as the materials' properties of the construction [12], these will influence the heat fluxes that imply changes in the interior equilibrium temperature and, consequently, in the heating energy needs. Therefore, minimum requirements related to these and other relevant parameters related to dwellings' characteristics were established under the National Energy Certification of Building System (SCE). Energy data concerns all type used sources per dwelling, energy supply systems, appliances (their usage time, efficiency, age, among others aspects are relevant). This type of information is then organized by energy services' categories. It is highlighted that the disaggregation of energy consumption by end-use and source, used in the presented methodological approach (see Figure 3), took into account the recommendations from both IEA and Eurostat, concerning statistics on energy consumption in households.

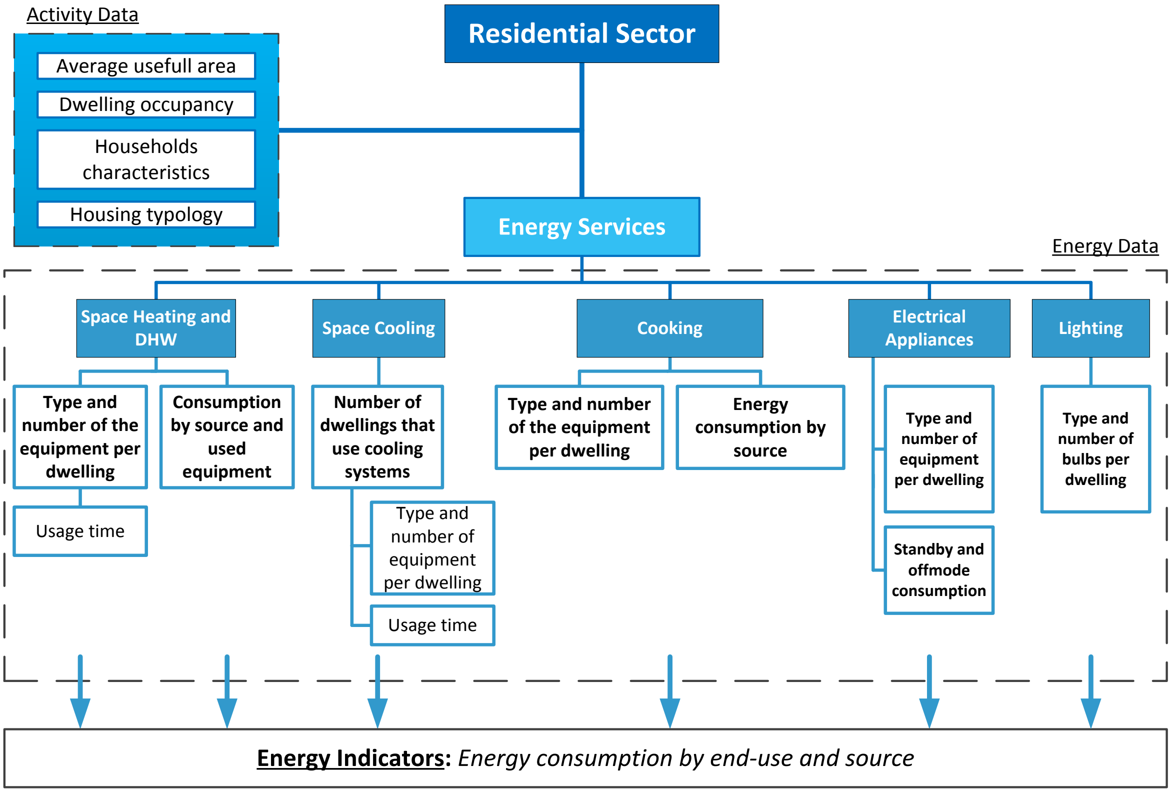

Figure 3 - Schematic representation of the methodology for the disaggregation of energy consumption by end-use and source.

3.1 Space Heating

The main used equipment encompass independent electric appliances, fireplaces, central heating boilers and air conditioning (heat pumps). Energy consumption per dwelling associated to space heating was estimated based on the type of used equipment (and subsequently, their efficiency rate), energy source and usage time. Assuming dwellings have similar energy needs (since it is here considered a representative house, with average characteristics at national scale), useful energy values were converted to final energy (through efficiency rates of the used system). Particularly, it was assumed that households using similar equipment also use equivalent useful energy.

In addition, based on statics' data, it was assumed that households using fireplaces also own independent equipment (and the total heating useful energy that both provide equals to the useful energy provided by a boiler or heat pump).

3.2 Space Cooling

Only 20% of the Portuguese dwellings use cooling systems. Air conditioning and ventilators are the most common used equipment. The estimation of energy consumption per dwelling associated to space cooling was done through a similar way as referred for Space Heating. In this case, useful energy and consumption energy values were estimated also through energy label assumptions established under Regulation 626/2011 which supports the Directive 2010/30/EU on the energy labeling of air conditioners.

3.3 DHW

The main used energy source to heat domestic water is LPG, followed by natural gas, and the most common used equipment is the heater (being used by around 60% of the total dwellings).

Useful energy needed to heat domestic hot water depends particularly on the number of persons per household. Since a reference house is here considered, it was assumed equal energy needs between the households. Thus, energy consumption per dwelling associated to DWH was also estimated though the iterative proceeding, starting with an input of useful energy value in order to obtain the final energy consumption of the considered system

Considering space heating and cooling and DHW services, the approached methodology to estimate the energy consumption by these end-uses was similar.

The conversion from useful energy to final energy per dwelling was obtained through equation 1:

$$Ef_{(s,i)} = \frac{Eu_{(s,i)}}{\eta_{(s,i)}} \quad (1)$$

where $Ef_{(s,i)}$ represents the final energy per dwelling (kWh/year) using a system s and a source i, $Eu_{(s,i)}$ represents the useful energy per dwelling (kWh/year) and η is the efficiency rate of the system. In Figure 4 there is a representation of the iterative proceeding used.

The error is calculated based on comparison between the value obtained in (3) and a reference value (energy consumption of the considered source), generally assumed trough more than one value provided by the fore mentioned studies.

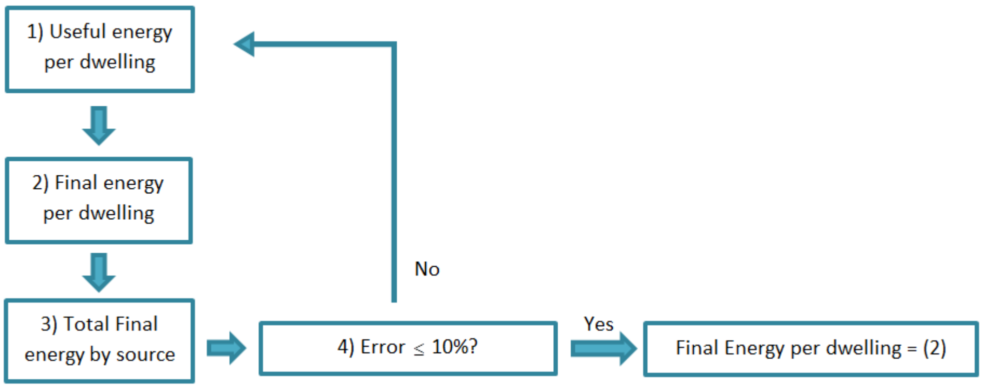

Figure 4 - Description of the proceeding used to estimate the energy consumption (final energy) per dwelling, based on actual energy use (useful energy).

3.4 Cooking

The cooking devices are summarized in ovens (mainly electric) and stoves (the majority use LPG or natural gas). The specific value for gas consumption per dwelling in this category is obtained only from SECH's data. Electric consumption per dwelling, associated to the oven use, was estimated through REMODECE's data, *EDP Power and Consumption Simulator* [19] and energy labels. In REMODECE's report an electric consumption value for cooking is already included; in the other cases energy consumption was estimated by assuming that the total annual period for using the oven by a typical household is 96 hours.

3.5 Electrical Appliances

Electrical appliances comprise two main categories: large (or white) appliances and other (smaller) appliances. The first categories include the refrigeration appliances and washing machines. A typical household owns a fridge, a clothes washing machine and a dishwashing machine. The specific energy consumption associated to these appliances was estimated. Other appliances include mostly audiovisual and entertainment equipment. TVs, DVDs, computers, modems, printers, irons, vacuums and microwaves are the most common devices found in Portuguese dwellings (usually one unit of each).

3.6 Lighting

The average number of bulbs per dwelling is 14. Fluorescent light bulbs are the predominant type (almost half of the total), followed by the incandescent and halogen light bulbs that still have a considerable weight in dwellings' lighting. The weight of the most efficient bulbs (LEDs) has been slowly increasing but it still owns a small proportion of the total number (1-3%).

4. Results Summary

Tables 2-4 show the results (on an annual basis) from the proceedings mentioned in section 3.

Values presented in Table 2 in italic aim to show the gap (around 80%) between results obtained for the same type of equipment (in this case, boilers) using different fuels. It is then worth to mention that these values were obtained through different methodologies.

Table 2 - Final and useful energy values associated to the various space heating systems.

Equipment	Energy Source	Final Energy (kWh/ dwelling)	Useful Energy (kWh/ dwelling)
Open fireplace	Biomass	6 200	620
Closed fireplace		2 000	1 500
Boiler		2 800	2 100
	Piped LPG	*633* - 1800	*475* - 1350
	Natural Gas	*967* - 1900	*726* - 1425
	Heating Oil	*6 159*	*4 619*
Air conditioning (Heat pump)	Electricity	658 - 1000	2 500
Independent heater		600	600
	LPG Bottle	554	333

Regarding the results for LPG and natural gas boilers, the maximum and minimum values were estimated through EFII and SECH's data, respectively. Nonetheless, it is possible to observe that those maximum values are similar to biomass boiler and heat pump's estimates.

On the other hand, values obtained for a household where oil boiler is used are highly above the fore mentioned ones. This discrepancy may be based on dwellings' areas of this sample above the average (and, consequently, greater heating area). Thus, in case of households using boilers for space heating, an average value was estimated, considering the most coherent values (from biomass boiler and from the maximum values for LPG and natural gas boilers). This value (2167 kWh per dwelling) is used in the further section, in order to characterize a household using boiler, independently on the supplying energy source.

Moreover, the estimates for both independent heating equipment and fireplaces show consistency, given the fact that the estimated values are similar for households using the same type of equipment. This observation regards an exception to open fireplaces: the average consumption of the households using open fireplaces implies 1.5 tons per year (which is almost three times the consumption of households using closed fireplaces). Still, due to higher levels of efficiency, households that use closed fireplaces obtain twice the useful energy.

Furthermore, when the fore mentioned useful energy values are complemented with those obtained for independent appliances, it is possible to confirm one of the assumptions made in section 3: households that use fireplaces also have independent equipment. The sum of the useful energy values estimated for both is around 2 000 kWh per dwelling, which is similar to the one estimated through centralized heating (boilers or heat pumps).

Table 3 includes the results for final and useful energy per type of cooling equipment. These were estimated from SECH and ASCASE's data.

Table 3 - Final and useful energy values associated to the various space heating systems.

Equipment	Final Energy (kWh/dwelling)	Useful Energy (kWh/dwelling)
Ventilator	20 - 22	1 – 1.5
Air Conditioning	336 - 416	1050 – 1300

The average final energy value is highly similar with the one obtained through an independent study [39], which was also based on SECH's data.

Nonetheless, it must be observed that the useful energy value estimated for households using air conditioning systems is twice the obtained value for some heating equipment (see Table 2). Considering this comparison, it is reasonable to admit uncertainty regarding the estimated values for air conditioning systems, since nominal energy needs established in REH's Regulation implies that heating nominal useful energy needs are twice the cooling nominal energy needs [20].

However, it is verified that annual final energy consumption values are similar to those estimated through values established in energy labels of air conditioning (399 kWh per dwelling) and ventilation systems (22 kWh per dwelling).

Results included in Table 4 show the final and useful energy for DHW in households using different types of equipment and energy sources.

Table 4 - Final and useful energy values associated to the various DHW systems.

Equipment	Energy Source	Final Energy (kWh/dwelling)	Useful Energy (kWh/dwelling)
Heater	Natural Gas	1 500 – 2 653	1 125 – 1 990
	Piped LPG	1 500 – 1 533	1 125 – 1 150
	Propane Bottle	1 500 – 1 562	1 125 – 1 172
	Butane Bottle	1 395 – 1 400	1 046 – 1 050
Boiler	Natural Gas	1 500 – 2 667	1 125 – 2 000
	Piped LPG	1 500 – 1 733	1 125 – 1 300
	Biomass	4723	3542
	Heating Oil	4015	3012
Electrical water heater	Electricity	1333	1200
Heat pump		800	2000

Results obtained for dwellings that use heaters supplied by different fuels are coherent between them. Estimated values for the electrical water heater, heat pump and natural gas and LPG boilers are also similar to the fore mentioned ones. Regarding this interval, energy used for DHW can be ranged from 1046 to 2000 kWh per dwelling.

Energy consumption of biomass and heating oil boilers are above that interval. Nonetheless, this dissimilarity can be based on intensity of occupation of the dwellings (which in these cases may be above average). Results obtained for space heating have also shown high values for the oil boiler, implying an overestimation for this sample.

Table 5 encompasses the specific energy consumption per dwelling attributed to white appliances and others electric appliances, including standby and offmode consumption.

Table 5 – Energy consumption of electric appliances.

Appliances	Energy Consumption (kWh/dwelling)
Refrigeration	754
Dishwashing machine	292
Clothes washing machine	330
Others	1 267
Total (kWh/dwelling)	2 643

5. Characterization of the Energy Consumption in the Portuguese Residential Sector

In order to present the breakdown of energy consumption per dwelling, results from the last Portuguese Census report were analyzed. Through this analysis, the average characteristics of the Portuguese residential building stock were obtained. Moreover, it was collected information concerning energy certificates. As result, a typical dwelling considered in the following sections covers these main characteristics:

- 3 bedroom apartment;
- average useful area of 109 m2;
- coated ceramic tiles or concrete roof;
- traditional plaster coating;
- intensity of occupation between 2 to 3 elements;
- Energy Certification C.

5.1 Energy Consumption per dwelling

This subchapter aims to represent the distribution of energy consumption in the most typical housing profiles. Through data gathered from different information's sources, it was possible to assess the most common used space heating and domestic hot water systems are fireplaces.

Based on the predominance of space heating and DWH systems, five dwellings' profiles were considered, presented in Table 6. For each one, there is provided a detailed characterization of the final consumption by energy service and source.

It must be highlighted that for all housing profiles, the consumption attributed to lighting, cooking and electrical appliances is considered equivalent, since it is assumed similar dwellings regarding representative characteristics, previously described. Consequently, the differentiation of energy consumption per household is based on the different types of equipment used for space heating and domestic hot water supply.

Table 6 – Housing profiles and their coverage of the residential building stock.

	Space Heating	DHW	Coverage (%)
Profile 1	Closed fireplace and independent electric equipment	Heater	40 – 50
Profile 2	Open fireplace and LPG heater	Heater	
Profile 3	Independent electric equipment	Heater	25 – 30
Profile 4	Boiler for central heating	Boiler	10 – 15

Figure 5 show the energy consumption distribution in the various housing profiles, presented in Table 6.

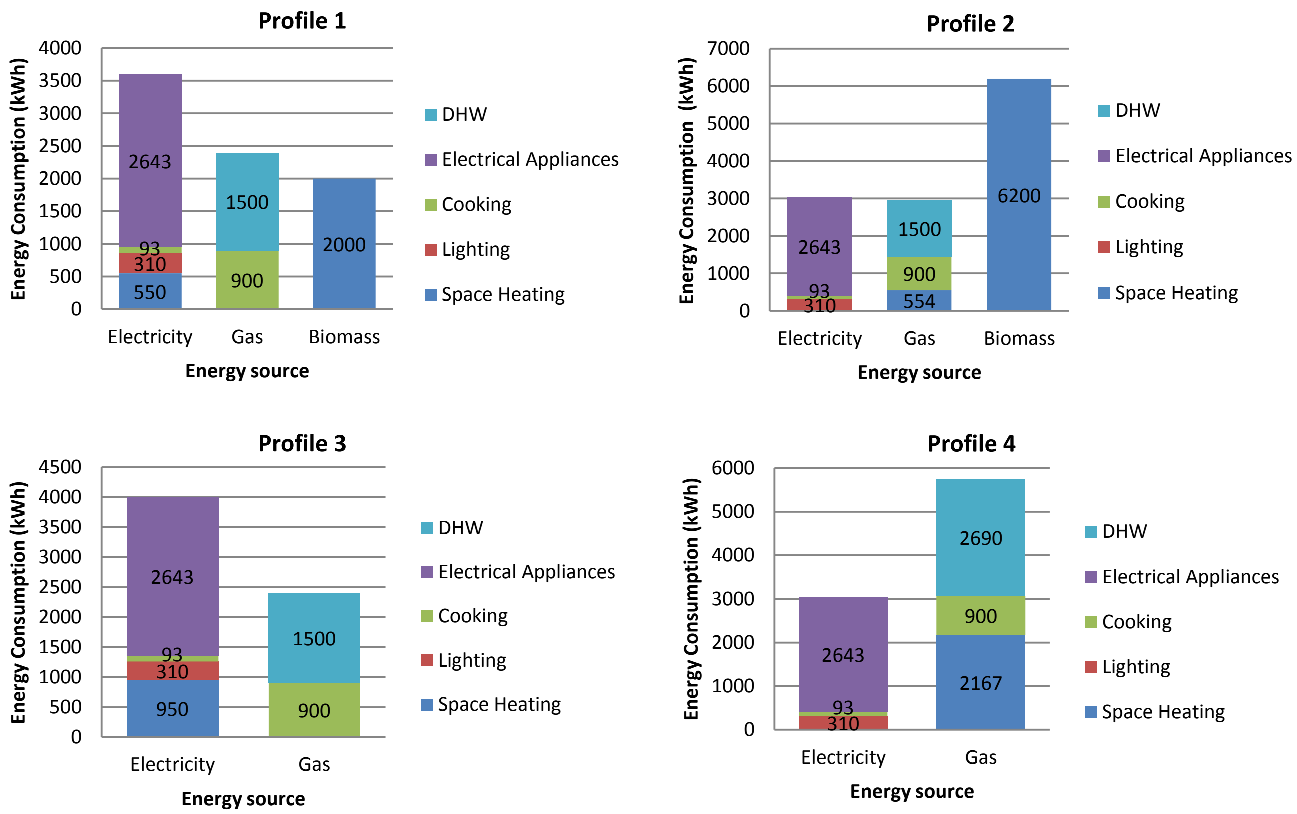

Figure 5 – Distribution of the energy consumption (kWh per dwelling) by end-use and source in four housing profiles.

5.2 National indicators of energetic consumption

In this subchapter final energy consumption values are presented by source type, projected for the national scenario, based on estimations given in the previous subchapter. The projected values are compared with domestic energy consumption values published in NEB. CO_2 emissions associated with each source are also estimated.

Table 7 depicts briefly the annual average consumption, by energy source, in different housing profiles.

Table 7 - Annual average consumption (kWh per dwelling) for the main energy sources.

	Electricity (kWh/dwelling)	Gas (kWh/dwelling)	Biomass (kWh/ dwelling)
Profile 1	3 596	2 400	2 000
Profile 2	3 046	2 954	6 200
Profile 3	4 024	2 400	-
Profile 4	3 046	5 757	-

In general, the results reveal that the consumption of energy in households with central heating systems (such as heat pump and boiler) is superior to that of households with independent appliances. It is noted that the electric consumption of a profile 2 residence (that only uses independent heating equipment) is similar to the consumption of profile 3 houses, in which the heating is provided by a heat pump (which has an efficiency rate three times larger).

Regarding gas consumption, it is observed that the annual average consumption of a household supplied by natural gas or LPG for heating, through a boiler system, is greater (above 50%) than that of a household which uses gas only for cooking and heating water (and uses a heater). Then, it is noted that households with boiler systems are the ones that have the higher final energy consumption.

Based on the predominance of housing profiles, the national average consumption was estimated and the units were converted to tons of oil equivalent (toe), in order to enable the comparison between them and values published in the energy balances of 2010 and 2013.

Table 8 presents the national consumption projections and respective differences regarding the NEB values, as well as the estimates for the CO_2 emissions, in tones (ton), associated with used energy sources in the residential sector.

By analyzing the results, it is possible to conclude that the estimate of CO_2 emissions associated to the final energy consumption in the residential sector is over 7.7 million tons.

In comparison to the values of NEB, the projected consumption for electricity, LPG and natural gas present very few disparities (less than 5%) for the year of 2010. Regarding the year 2013, a slight increment on these differences is observed, since the final energy consumption has been decreasing since 2010, according to the NEB records. Moreover, the results of the disaggregated consumption, in which the national projections were based, concern data collected until 2011 (with the exception of electricity).

Table 8 - Projected values of the national consumption by type of source associated CO_2 emissions and percentage variation (%) in comparison to the NEB's values.

	Consumption (toe)	CO_2 emissions (ton)	ΔNEB (%)	
			2010	2013
Electricity	1 234 664	4 859 546	-1.1	18.9
Heating Oil	124 328	433 278	-0.3	107.2
LPG	583 440	1 537 241	5.2	29.7
Natural Gas	292 213	614 509	-2.7	21.2
Biomass	365 355	440 000	-48,2	-43.6
Total	2 600 000	7 729 526		

Regarding heating oil consumption, a very considerable discrepancy is verified concerning the value published in the NEB of 2013, whereas the 2010's value is very similar. In this case, the only source of information about oil consumption was the SECH, explaining the coherence with the NEB of 2010. However, according to NEB's values evolution, oil consumption has been decreasing remarkably, with a difference of 107% between 2010 and 2013 (values of similar order to the ones in table 12 referred to oil consumption). Besides, it is noted that the values published before 2010 were significantly lower (in 2009 the consumption was 9 455 toe while in 2010 it reached 124 636 toe). Subsequently, it is supposed that the value estimated by the SECH, which was the basis for the results published in NEB since 2010, may be overestimated. This hypothesis explains the verified divergence regarding the energy consumption of households which use boiler fueled by heating oil.

Concerning biomass consumption, the projection for the national scenario is lower (than 40%) comparing to the values published in the NEB. This disparity is justified by the fact that the usage of firewood for cooking (included in SECH's report) was not taken into account. This assumption was taken due to the lack of data from other information's source concerning this aspect.

6. Conclusions

The main goal of this work was to characterize, in a detailed level, the energy consumption in the Portuguese residential sector, based on data from various information sources. Accordingly, the intent was to solve some inconsistencies presented within the available data and dissociate energy consumptions values in a sufficiently detailed level, in order to develop energy efficient indicators, as recommended by AIE and Eurostat.

In general, it was observed that electronic appliances represent the overwhelming majority of the electricity consumption. As for gas, the biggest consumption corresponds to the DHW final use. In the majority of the characterized housing profiles this service is responsible for 60% of the total gas consumption, with LPG bottles being the most used (65%).

Despite the drop in consumption over the last years, firewood still has a considerable weight in the residential sector's energy consumption, being mainly used for space heating.

It is worth to mention that, regarding the comparison between final energy consumption values presented in this work and the ones published in the national energy balances, these presented considerable similarities. Therefore, it is possible to affirm that the values resulting from this work are representative of the residential sector's energy consumption in Portugal.

Nevertheless, it is important to underline the fact that these estimates were based on several information sources, with different levels of detail and consumption dissociation. Due to that, in some cases hypothesis based on different sources were assumed in order to estimate consumption with the desired detail level. Additionally, it is noted that not all of the estimated values have the same validation level. An example of this is the fact that the gas consumption for cooking, as well as the general oil consumption, were estimated using data only from SECH, while the rest of the estimates were based on the information crossing from at least two sources.

Moreover, it is highlighted that the values of useful energy, from which the final energy consumption for the different appliances were estimated, are from an inferior order to the nominal energy needs, established by the REH Regulation [21]. Therefore, in a future work, it would be important to focus the specific consumption associated to space heating, as well as the actual use energy (useful energy). In this context, it is highlighted the fact that the estimated results from this work related to that end-use are the ones with higher uncertainty level, due to numerous assumptions that had to be taken in order to estimate them.

To finish, it is important to note the fact that every estimated value, as well as the final characterization of the housing profiles, are based on data regarding primary residences. However, it must be underlined that a considerable weight (19%) of the residential sector in Portugal corresponds to second residences. Gathering data on this type of residence is more difficult, due to the fact that the occupation time is short. Still, a high degree of influence on the energy consumption should be expected from these residencies.

Nomenclature

ADENE	Agency for Energy
ASCASE	A Sua Casa, A Sua Energia
DGEG	General Directorate of Energy and Geology
DHW	Domestic Hot Water
EDP	Energies of Portugal
EEESE	Energy efficiency in equipment and electrical systems in the residential sector
EF225	EcoFamilias225
EFII	EcoFamilias II
EU	European Union
FROnT	Fair Renewable Heating and Cooling Options and Trade
GEE	Greenhouse gas
GPL	Liquefied Petroleum Gas
INE	National Instituteof Statistics
LED	Light Emitting Diode
NEB	National Energy Balance
REMODECE	Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe
SECH	Survey on Energy Consumption in Households
SCE	National Energy Certification System

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