Fuel poverty map of Valencia (Spain): Results of a direct survey to citizens and recommendations for policy making.

ABSTRACT:

Measuring Fuel Poverty is a requirement for the correct sizing and the better understanding of the problem. Valencia's city council (Spain) commissioned a study based on primary data, i.e. direct interviews to the inhabitants. The survey reached 595 valid answers and gave an accurate quantification of fuel poverty in the city. For a more complete approach, and to be able to benchmark the results, five fuel poverty indicators were measured, next the minimum income standard was chosen for a deeper analysis. This indicator presented a 23.1% of households in fuel poverty, clearly above the average value for the country.

Based on the survey results, the effect of different relevant factors is discussed, like energy prices, energy quality of the dwellings, tenure status or energy illiteracy. Then, conclusions and specific policy implications are put forward classified into four categories: economic support, housing retrofitting, training in energy, and deployment of new energy actors and markets.

KEY WORDS: Fuel poverty, Valencia, Minimum Income Standard

1. INTRODUCTION

During the twenty years following the first study on fuel poverty (hereinafter FP) by Boardman (1991), most of the actions (reports, news, measures, etc.) against FP came mainly from United Kingdom and Ireland. In this paper fuel poor are “households who are living in a cold climate and have difficulty in getting access to electricity or modern cooking facilities, and in supplying indoor heating with appropriate cost”, following the discussion on fuel poverty versus energy poverty of (Li et al., 2014). Lately, FP has become an emerging topic and numerous studies have been published, especially in the rest of Europe (Besagni and Borgarello, 2019; Chaton and Lacroix, 2018; Dagoumas and Kitsios, 2014; Romero et al., 2018). The outcomes of such research demonstrate that FP is a growing concern and is in fact severe in countries considerably affected by the latter economic downturn, or the current COVID-19 crisis.

Consequently, civil society organisations began to mobilise in defence of housing rights and the minimum basic needs of the people, contrasted with the energy oligopoly’s apparent lack of action. As a consequence, the demand for energy democracy and the “right to energy” is gaining ever more support (Becker and Naumann, 2017). This topic raised the question “which would be an appropriate energy demand to maintain an acceptable comfort level?”. On this regard, (Sánchez-Guevara Sánchez et al., 2017) propose minimal energy needs related to thermal habitability conditions through adaptative demand (versus energy demand). The full understanding for each building type, outdoors conditions, dwelling use, etc. of the minimum energy needs (heating, lighting, and refrigeration) to maintain an adequate comfort will help to better measure and overcome fuel poverty.

When the first reports on FP were published in Spain (Tirado Herrero. et al., 2012), only a minority of Spanish society had ever heard about this concept. There were few social actors working on the problem and few measures promoted by public policies (Pellicer and Lillo, 2014). Even so, after the municipal elections of May 2015, some Spanish public regional governments and city councils began to implement measures to combat FP, e.g. the social discount scheme (DOGV, 2015). Today, the situation is very different and the media and society normally acknowledge and condemn FP. Besides, there are a variety of social organisations, publicly and privately owned institutions and researchers that address the problem (Aristondo and Onaindia, 2018; Romero et al., 2018; Sánchez-Guevara Sánchez et al., 2018).

The latest release of the “Report on fuel poverty” from “Asociación de Ciencias Ambientales” (Tirado Herrero. et al., 2018) points out that FP affects around 15% of the Spanish population, based on the data of the Survey on Spanish Household Budgets (EPF) and on the Survey on Living Conditions (ECV), by the National Statistics Institute (INE). Hence, FP in Spain is relevant, and poses a real challenge since its inclusion in the public policy agenda is very recent.

The main causes of FP: i) low incomes, ii) high energy prices and iii) low energy efficiency of households, are widely discussed in the literature (Atanasiu et al., 2014; Dulac et al., 2019; Ntaintasis et al., 2019; Pye et al., 2015; Schleich, 2019; Ugarte et al., 2016). Many recent studies underpin the multidimensional approach of the concept (Day et al., 2016; Gillard et al., 2017; Poruschi and Ambrey, 2018; Sanz-Hernández, 2019) as FP has social, health,

environmental, economic and political implications (Papada and Kaliampakos, 2018). However, despite the number of papers published analysing different FP attributes and perspectives, there is still no consensus on its definition and measurement (Bouzarovski and Petrova, 2015; Thomson et al., 2016). In addition, only a few, recent studies have focused in measuring FP at the local level with primary data (Martín-Consuegra et al., 2019).

In contrast, a number of studies measuring FP have been conducted using secondary data such as statistics on family incomes, domestic energy consumption, energy efficiency of buildings, etc. (Aristondo and Onaindia, 2018; Costa-campi et al., 2019; Martín-Consuegra et al., 2019; Okushima, 2017; Papada and Kaliampakos, 2018; Tirado Herrero. et al., 2018). This has the disadvantage of using aggregated data and thus, neither knowing where the households are located, nor which the features of any particular household are, nor how its users are perceiving the lack of energy. On the other hand, precisely geo-located statistical data is difficult to obtain due to privacy protection.

Ad-hoc surveys use primary and geo-located data; this way, the family income, the energy costs, the type of building, etc. are directly linked to one located household. Besides, aggregating those primary data allows us to provide results for particular areas (i.e. streets, neighbourhoods, districts, etc.). This is very useful in order to implement specific policy actions for area-related problems.

According to (Tirado Herrero, 2017), three main approaches co-exist to measure FP:

- The income/expenditure approach, which measures the relation of energy expenditures with the household's income. The result is compared with special thresholds, see section 2 for more details.
- The households' self-reported approach, in which users self-assess their living conditions (e.g. inability to keep the house adequately warm, and/or arrears on utility bills, and/or bad preservation of walls, windows, etc.).
- The direct approach, which compares the affordable level of comfort with a pre-defined standard (e.g. World Health Organization's temperature standard: between 18-27ºC; and relative humidity: between 40%-60%). Families which are too often under 18ºC on average in winter or over 27ºC on average in summer, would be potentially fuel poor.

The EU Energy Poverty Observatory (EPOV) proposes 4 primary indicators: i) high share of energy expenditure in income (twice the median of data: 2M), ii) low absolute energy expenditure (or M/2), iii) the inability to keep the house adequately warm, and iv) arrears on utility bills. The first two are based on the income/expenditure approach and data is taken from the European Survey on Households' Budgets. The other two rely on the self-perception of households' approach and data coming from the European Survey on Income and Living Conditions (EU SILC). In addition, they also provide a variety of secondary indicators founded on structural factors and complementary aspects of the phenomenon. However, EPOV was recently created so neither a common definition of fuel poverty nor common indicators to measure it, have yet been officially adopted at EU level. The same holds true for Spain.

The objective of this paper is to estimate and assess FP in the city of Valencia analysing outcomes from ad-hoc surveys, in this case 595 valid surveys. Results are presented through FP maps per district since the location of each household respondent is available. This

research work compares results of five different FP indicators (introduced in section 2). It also informs on the proposal of strategies to fight and mitigate FP in Valencia.

The rest of the paper is organised as follows: Section 2 provides information on the methodology used to convey the surveys, the chosen indicators and how primary data were processed. Section 3 presents results of FP according to the FP indicators, and discusses them analysing other aspects beyond the main causes of FP. Finally, in section 4 conclusions are set together with policymaking recommendations for the case of the city of Valencia.

2. METHODOLOGY

2.1 Surveys

With the objective of estimating and understanding FP in the city of Valencia, 613 surveys were carried out. Initially, a pilot questionnaire was created requiring information about demographic characteristics of the dwelling, energy consumption and expenditure, energy certification of the household and economic situation of the family. Surveys were undertaken visiting homes randomly selected.

Based on the outcomes, the questionnaire was improved (see Annex 1 for its final form). The requirement of showing the energy bills was discarded because few interviewees would show them. And, due to the slow door-to-door process it was decided to conduct street-level surveys, combined with additional surveys through Google Forms®. As most of the respondents' profiles belonged to deciles of medium-high incomes, more surveys were carried out in municipal social services, counting on the collaboration of several local public and non-government organizations. The questionnaires included double-check questions with similar contents to contrast the information gathered.

As there is little information about the current situation, the common formula to calculate the sample size "n" was applied to the whole city (equation 1). Due to limitation of resources, the designed survey intended a confidence level of 97.5% (Z_α^2=2.24 in equation 1), a confidence interval of 3% (e=0.03 in equation 1) and p was set to a conservative 0.3 (and q=1-p=0.7). Thus, as the total number of first residences is 328,933 (see Table 2), the sample size must be of 500 interviews.

$$n = \frac{Z_\alpha^2 N p q}{e^2 (N-1) + Z_\alpha^2 p q} \quad (1)$$

In the end, there were 501 face-to-face and 112 on-line surveys carried out, from which a total of 595 were assessed as reliable. All respondents provided information about their main residence of Valencia. They were distributed among the different districts of Valencia ranging from 19 to 50 surveys per district (see Table 2). Therefore, the statistic quality levels are met for the city, although not for each district.

These 595 surveys included three biases, which were corrected with compensation factors. The first bias was related to income differences among districts so that results were weighted considering the number of households by income decile (according to the National Tax

Agency). The second bias detected consisted of differences of distribution of population per district, hence, results were weighted based on the number of first residences from each district according to the official register of inhabitants of Valencia (Ayto Valencia, 2020). The third bias corresponded to the quality of the house, and results were weighted based on the distribution of houses per decade of construction(Ayto Valencia, 2020). The aggregation of compensation factors ranged from 0.51 to 7.87, i.e. a given household found in FP could add 0.51 or 7.87 to the final number of FP households. It depended on whether it belonged to a district where more or fewer households than the corresponding number were surveyed, belonged to an income decile that included more or fewer households in that district, and the age of the building was more or less abundant than the rate in that district, Figure 1 shows the 595 compensation factors, as can be seen, most of them ranged between 0.75 and 1.5 which is acceptable based on the literature (Evans M., Hastings N., Peacock B., 2000).

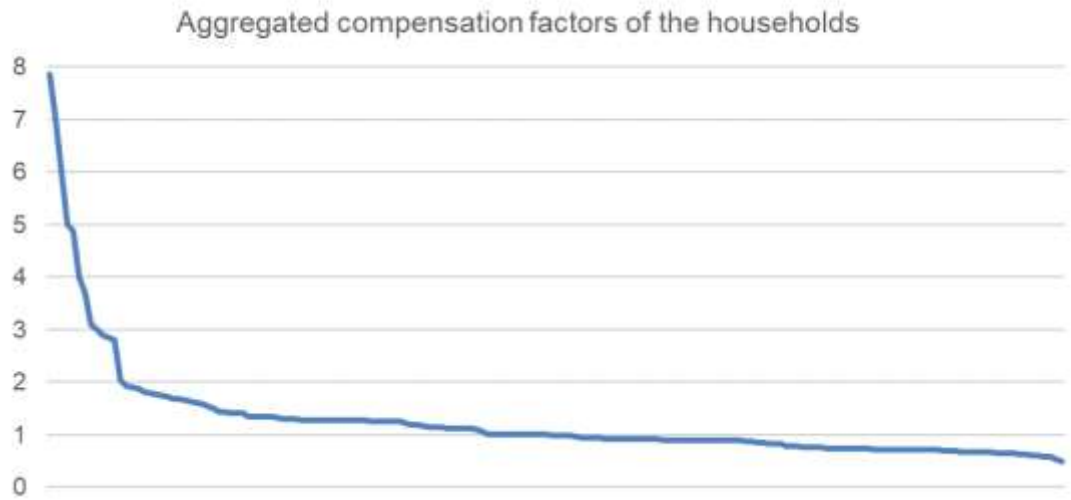

Figure 1. Aggregated compensation factors for the surveyed households

The characteristics of the sample compared to the average data for the city are shown in Annex 2, all city data are extracted from (Ayto Valencia, 2020). It can be seen that the sample is fairly aligned with the average characteristics of the city and can therefore be considered sufficiently representative. Each questionnaire collected was reviewed for consistency and completeness. To do this, related questions were crossed, such as A.7.1. with A.7.2, or B1 with B2 and B3, or with B12, B15, etc. Data were then incorporated into an MS-Excel® book in which the appropriate data were selected for the different calculations. These calculations were carried out by means of the pre-set functions of the software. The compensations for the sample to correspond to the population it represents were made from the statistical data of the Valencia City Council (Ayto Valencia, 2020).

2.2 The measurement of fuel poverty through five indicators

As previously stated, five widely recognized indicators have been used:

- 10% Rule (R10%). A household is fuel poor if more than 10% of the family incomes are used to pay appropriate energy service bills (Boardman, 2009, 1991). For this indicator, questions A7, B13, B17 and B18 in Annex 1 were used.

- Twice the median, 2M hereinafter. Likewise, a household is fuel poor if it needs to spend more than twice the median of the share of energy expenditures with respect to income of all data for households (Boardman, 1991; Tirado Herrero. et al., 2018). Considering that the surveys produced a share of energy expenditure of 4.1% for Valencia, the 2M threshold for Valencia was set to 8.2%. Again, this indicator is calculated with the outcomes of questions A7, B13, B17 and B18 of Annex 1.
- Low Income High Costs (LIHC). In this case, a dwelling is fuel poor if its income after energy expenditures is below a certain income threshold and the energy expenditure is above an energy expenditure threshold. To calculate such thresholds, the approach proposed by (Romero et al., 2018) was followed. The income threshold is set as 60% of the median of income after equivalent energy expenditure (in proportion to family size); the energy expenditure threshold is the median of the equivalent energy expenditure over the total number of households. To be able to work with expenditures of different household sizes, Spanish equivalence factors for domestic energy expenditure and income were used according to those of (Tirado Herrero et al., 2016), adapted from Hills (2012): one person gets a weight of 1, two people: 1.46, three people: 1.71, four people: 1.92 and five or more people: 2.00. Thus, for the city of Valencia and the LIHC indicator, the income threshold is 9,387.29 €/dwelling/year and the energy expenditure threshold 396.89 €/dwelling/year. For this indicator, the answers to the following questions were used: A6, A7, B13, B17 and B18 (see Annex 1).
- Minimum Income Standard (MIS). A “minimum income standard” is that one which allows the members of a household to afford the items required for a minimum-acceptable living standard (Bradshaw et al., 2008). That is, the minimum income which allows one to have the opportunities and choices needed to be actively integrated in society. Therefore, a dwelling is fuel poor if its income after having paid the house costs (rent or mortgage, and council taxes) and the energy services bills, is below a minimum income after subtracting the median of the energy expenditure of all the households and the median of all households’ energy expenditure. To consider economies of scale at domestic level, we have used the equivalence to units of consumption (uc) used by Eurostat, in which the first adult in the household is 1 uc, each adult thereafter (aged 14 and over) is 0.5 uc and each child is 0.3 uc. Therefore, MIS threshold changes with the different household sizes. For Valencia city, the mean of the minimum income of inclusion for the Valencian Community is 426€/month per uc (based on the city council’s statistics for Valencian family incomes). For this indicator, the answers to the following questions A6, A7, B13, B17 and B18 of Annex 1 were used.
- Perception and statements of people, P&S hereinafter (Tirado Herrero. et al., 2018; Tirado Herrero, 2017). This indicator includes information on households’ situations regarding appropriate/inappropriate temperatures, problems with payments of utility bills, and quality of life with regard to the previously mentioned. Due to the difficulty to measure this, residents are asked about their perceptions. The questions asked to Valencian citizens are those of Annex 1, section C. A specific index for “perception” was developed based on the questions:
    - During the last winter at your home, were you often cold because of the heating costs? (question C3 Annex 1)

- During the past summer in your home, were you often hot because of the air conditioning (or fan) costs? (question C5 Annex 1).
- Do you think your daily life (or that of any member of your household) has been negatively affected due to the energy situation at home? (question C11 in Annex 1).

Households whose response to two of these three questions were “Often” or “Too often” were considered to be in FP.

2.3 Reflections about the fuel poverty indicators

The 5 different FP indicators selected have from slightly to completely different FP approaches, starting by the way they are measured. Although widely discussed in the literature, see for example (Romero et al., 2018; Tirado Herrero, 2017), the most important differences are reviewed here for completeness (Table). In general, all indicators reflect FP indirectly, they do not measure directly comfort (i.e., if temperature or humidity are adequate in the household, although they do measure household incomes. Besides, neither acknowledge any of the three main causes of FP, nor its consequences (see section 1).

Table 1. Comparison of FP indicators features.

Indicator	Relative / Absolute thresholds	Application	False positives	False negatives
R10%	One relative	Simple	Household of enough income that expends too much on energy	Poor household that can only afford very little expenditure on energy
2M[1)]	One relative	Simple	Household of enough income that expends too much on energy	Poor household that can only afford very little expenditure on energy
LIHC[2)]	Two, both relative	Complex	No	Poor household that can only afford very little expenditure on energy
MIS[2)]	One absolute	Complex	No	No
P&S	None, absolute approach	Complex	Household of enough income that declares not to be able to keep the house comfortable	Household in FP that does not declare anything

Notes: [1)] R10% and 2M are very similar as the former is actually the latter applied at the beginning of measuring FP in United Kingdom, when 5% was approximately the median of the ratio of energy expenditure over incomes for any household.

[2)] MIS and LIHC consider the number and type of inhabitants of the house. Households with more inhabitants are more likely to be classified as fuel poor (as explained later).

The relative indicators are influenced by modifications of the performance of the other households with which they are compared: energy expenditure and incomes. Thus, a dwelling whose inherent conditions have not changed, could over time pass from an FP to a non-FP situation, or the opposite, based on the other households’ performance. The main strength of relative indicators is that they avoid the issue of defining an absolute threshold (there is not

yet an agreement) and approach FP as a relative problem. Furthermore, relative indicators are widely used because they were the first ones to measure FP and the easiest to be defined.

Indicators with absolute thresholds do not depend on the rest of the households' values. The thresholds are set based on economic and social limits decided by experts and tailored for each region, for example minimum wages, social rents, local comfort humidity and temperature, etc.

The P&S indicator allows us to identify and connect FP with its consequences, but it is very difficult to measure it correctly because the questions are subjective, and people may overestimate or underestimate their problems. In this research, this indicator tended to overestimate FP rates.

In this work, false negatives and positives have been carefully processed analysing the responses of the survey regarding energy consumption, energy cost, households' features and perceptions on the quality of life during winter and summer.

3. RESULTS AND DISCUSSION.

Table 2 shows the percentage of households in fuel poverty per district and per FP indicator. The last row corresponds to average values for the city, considering the amount of first residences of each district. The number of first residences and the average statement of income per district are also included in the first columns.

3.1 Results of fuel poverty in the city of Valencia

As can be seen in Table 1, Perception and Statements indicator gives the highest average values of FP, while LIHC the lowest. R10% performs similar to LIHC, and 2M and MIS on average have intermediate values. Based on answers as there are not enough surveys to deduce what happens in the districts, the minimum LIHC reaches 0% in districts like *Ciutat Vella* and *Eixample* and provided the maximum rate of 21.9% of FP to households in *Poblats del Nord*. At the other extreme P&S indicator reached a maximum of 43.68% of households in FP in *Poblats de l'Oest* and a minimum of 20.1% in *Extramurs*. MIS indicator gave a maximum of 32.83% in *Algiròs* and a minimum of 2.8 in *Eixample*. 2M indicator did not identify any household in FP in *Eixample* and provided a maximum of 42.66% in *Jesús*. R10% indicator gave a 0.0% of FP in *Ciutat Vella* and *Eixample* and a maximum of 19.0% in *Poblats del Sud*.

Table 2. Fuel poverty as percentage of total first residences, according to indicators R10%, 2M, LIHC, MIS and P&S per districts and for the city of Valencia.

				Fuel Poverty indicator				
DISTRICTS	# of valid surveys	# of 1st residences	Average income (€/residence·year)	R10%	2M	LIHC	MIS	P&S
Algiròs	50	15,853	32,848	17.8%	21.4%	12.5%	32.8%	37.6%
Benicalap	25	17,725	25,981	14.4%	23.71 %	18.5%	22.6%	36.1%
Benimaclet	40	12,085	32,633	6.5%	9.8%	6.5%	21.8%	26.1%

				Fuel Poverty indicator				
DISTRICTS	# of valid surveys	# of 1st residences	Average income (€/residence·year)	R10%	2M	LIHC	MIS	P&S
Camins al Grau	35	25,925	31,849	10.4%	13.0%	5.2%	23.5%	24.4%
Campanar	22	14,775	36,742	7.7%	7.7%	7.7%	19.2%	34.6%
Ciutat Vella	31	12,215	38,739	0.0%	5.0%	0.0%	15.4%	30.7%
El Pla del Real	30	12,345	49,592	9.4%	9.4%	9.4%	21.5%	28.0%
L'Eixample	27	19,345	49,478	0.0%	0.0%	0.0%	2.8%	33.6%
Extramurs	22	22,000	35,851	9.2%	9.2%	12.2%	15.3%	20.1%
Jesús	20	22,090	26,031	15.5%	42.7%	12.9%	23.2%	25.8%
La Saïdia	43	20,825	27,355	17.0%	18.9%	13.2%	30.2%	31.4%
L'Olivereta	32	20,355	25,903	15.4%	33.1%	7.6%	26.8%	34.5%
Patraix	38	23,075	29,618	16.1%	19.4%	9.7%	29.5%	39.5%
Poblats de l'Oest	21	5,480	24,124	14.1%	35.3%	14.1%	28.3%	43.7%
Poblats del Nord	19	2,365	26,748	21.9%	21.9%	21.9%	32.9%	23.4%
Poblats del Sud	24	8,040	27,951	19.0%	19.0%	19.0%	19.0%	41.0%
Poblats Marítims	39	24,255	25,046	15.0%	22.5%	10.0%	29.9%	40.9%
Quatre Carreres	38	29,700	29,375	8.8%	16.2%	13.2%	25.0%	36.0%
Rascanya	39	20,540	24,816	18.0%	24.4%	13.5%	28.9%	36.7%
CITY OF VALENCIA	**595**	**328,933**	**31,456**	**11.9%**	**18.2%**	**10.2%**	**23.1%**	**32.7%**

Based on answers to the survey, the districts with the highest average rate of FP were *Poblats de l'Oest*, *Jesús* and *Benicalap*. Districts with lowest FP were *Eixample*, *Ciutat Vella* and *El Pla del Reial*. According to the National Tax Agency, the districts with the highest average incomes are l'*Eixample*, *El Pla del Reial* and *Ciutat Vella*. The districts with the lowest average incomes are *Poblats de l'Oest*, *Rascanya* and *Poblats Maritims.* Hence, the results are consistent with the average incomes per districts, note that *Benicalap* and *Jesús* are also among the ones of lowest average incomes.

For the city, with the accuracy explained in section 3.1, the average share of FP in the city of Valencia varied from the minimum of 10.16% calculated with LIHC to the maximum of 32.69% with P&S, passing through 11.91%, 18.18% and 23.08% calculated with R10, 2M and MIS indicators, respectively. This would mean ranging from around 33,000 households up to 106,000 households in FP in Valencia.

Furthermore, although R10% and 2M have similar poverty thresholds, 10% and 8.16% respectively, for some districts (i.e. *Jesús*, *L'Olivereta* and *Poblats de l'Oest*) 2M gives FP values more than doubling R10% ones, which means there are many households between the two thresholds.

Compared with other studies, the obtained values in Valencia are higher. In the study by (Aristondo and Onaindia, 2018), for the Comunitat Valenciana (administrative region of which Valencia is the capital), FP rated between 6.4% and 9.0% measured by a combination of three indicators applied to the Spanish statistics on Living Conditions Survey (*Encuesta de Calidad*

de Vida in Spanish*, ECV*). In the study by (Tirado Herrero. et al., 2018), also for the Comunitat Valenciana and measured by four indicators applied to the ECV, the values rank between 9% and 20%. The study by (Romero et al., 2018) used the Spanish Household Budget Survey (*Encuesta de Presupuestos Familiares*, in Spanish, EPF) to calculate the MIS, and for Comunitat Valenciana obtained a value of 9.13% Finally, the study by (Costa-campi et al., 2019) based on the EPF, and applying LIHC, achieved a value between 6% and 9% for the Comunitat Valenciana.

Hence, this is the first study, based on direct surveys to households, and specific to the city of Valencia. The higher than expected FP rates may be due to three main reasons. Firstly, this study is based on direct surveys with a sample including all types of households by district and by income decile. Secondly, studies based on national statistics like ECV and EPF might not be reaching all the poor households as the poverty rate in Comunitat Valenciana is 30.2% based on the report by (Llano Ortiz, 2019). Thirdly, (Costa-campi et al., 2019) find higher rates of FP in urban areas than in rural areas, and Valencia is the largest city of the Comunitat Valenciana, which has only around 20% of its population in rural areas.

3.2 Analysis of indicators

Starting with the P&S indicator and its implementation, this was found unreliable. On the one hand, the perceptions and statements of people were influenced by variables different from the causes of fuel poverty. Too often, economic and energy data of apparently energy poor households contradicted the result, i.e., they seemed false positives, although they were not discarded because the P&S metrics were all consistent. On the other hand, the questions from the survey which built up the indicator and the way of analysing the answers were complex and subjective. Therefore, the P&S indicator was found to overestimate FP, and was finally discarded for further analysis. However, the authors believe such a P&S indicator, improved in design and application, should be considered in future political strategies for responding to fuel poverty.

Furthermore, since R10% and 2M are actually equivalent, and in line with the EPOV, 2M indicator was considered and the R10% was also discarded. Nevertheless, R10% calculations allow comparison with other studies.

Similar to the research by (Romero et al., 2018; Tirado Herrero. et al., 2018), a comparative analysis of the different FP indicators was carried out to study their characteristics, and the simultaneity of these indicators. The aim was to reveal to what extent they coincided in identifying a particular household as in a FP situation (see figure 2). The simultaneity of the 5 indicators only happened in 4.6% of the FP households (i.e. in the 45.1% of the FP households as per LIHC, or the 19.9% of FP households as per MIS).

As explained, P&S and R10% were discarded after the results of the survey, and the simultaneity of 2M, MIS and LIHC was then analysed. There is a 7.0% of households that classify as FP by the three indicators (see figure 2). These values are consistent when compared with the literature, although those studies use regional and secondary data (Romero et al., 2018). The low coincidence is due to the different approach to FP of the different indicators.

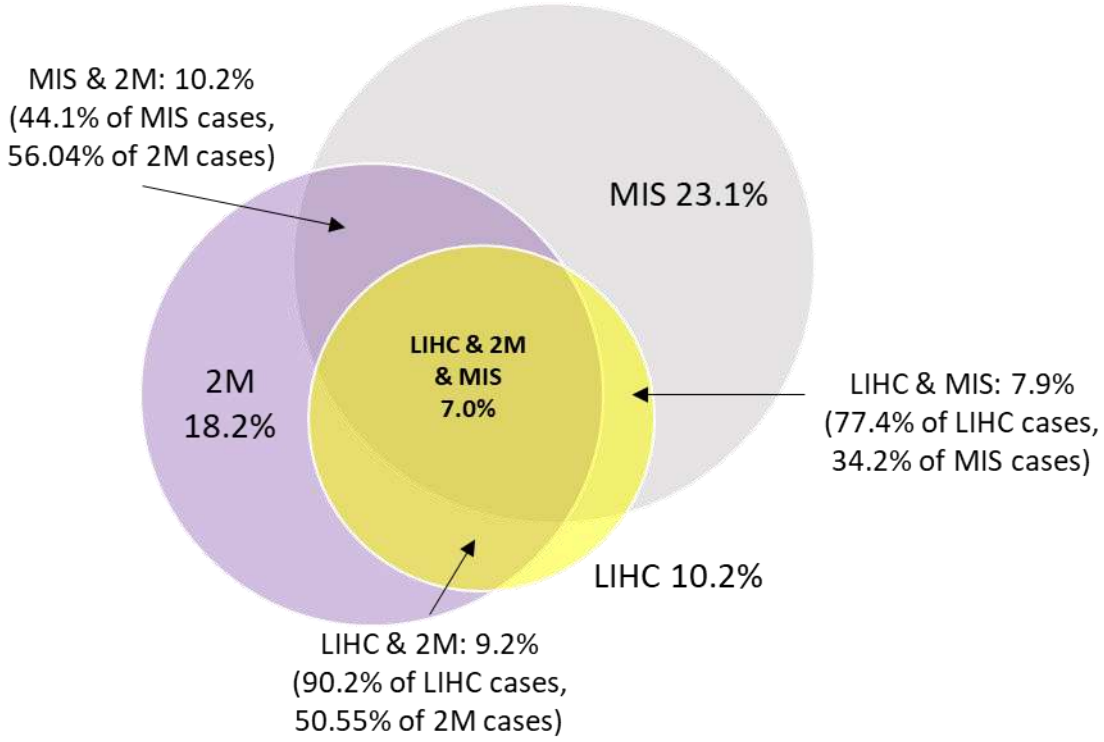

Figure 2. Simultaneity of indicators 2M, LIHC and MIS

As can be seen in the figure, between 7.9% and 10.2% of the households were in an FP situation according to at least 2 indicators simultaneously. This means 50.55% of the FP houses as per 2M are also in LIHC, and they amount to 90.20% of the houses in LIHC. 77,45% of the households in LIHC are also in MIS, while 55.73% of 2M cases are also FP as per MIS.

The simultaneity of the 3 indicators or of two of them, hence, can be considered as a higher certainty of identifying a household in FP. However, many households in FP may not be identified at the same time by the three approaches, and one must be chosen.

3.3 Selection of the most suitable fuel poverty indicator

Having to choose one approach and its indicator, 2M and LIHC were discarded because the analysis of the answers to the survey showed many poor families who gave false negatives. This was also due to its relative status (e.g. an improvement in some households could modify the FP status of other households in which nothing changed). Hence, the MIS indicator was finally selected.

Furthermore, LIHC gave six false positives, based on all the answers to the survey, while 2M gave 34 out of 595. MIS did not report false positives. Regarding false negatives of MIS, 10 cases were considered false negatives. They were all households of one inhabitant, or one adult and one child in a rented house or a mortgaged house. In those cases, the equation of MIS does not completely include all the expenses a household may incur (Romero et al., 2018). By comparison, 2M reported 45 false negatives and LIHC 69 out of 595. This is why around 20% was deemed a more accurate rate of FP households in Valencia, and MIS is more precise than 2M, although obtaining a similar rate of FP households.

Figure 3 shows results of the FP in Valencia according to MIS indicator per district. As can be seen in Table 2, all indicators gave a similar distribution per district, except for P&S, which behaved differently. The map shows a certain geographic correlation between districts and fuel poverty, as FP is higher in the northern districts and clearly lower in the central districts.

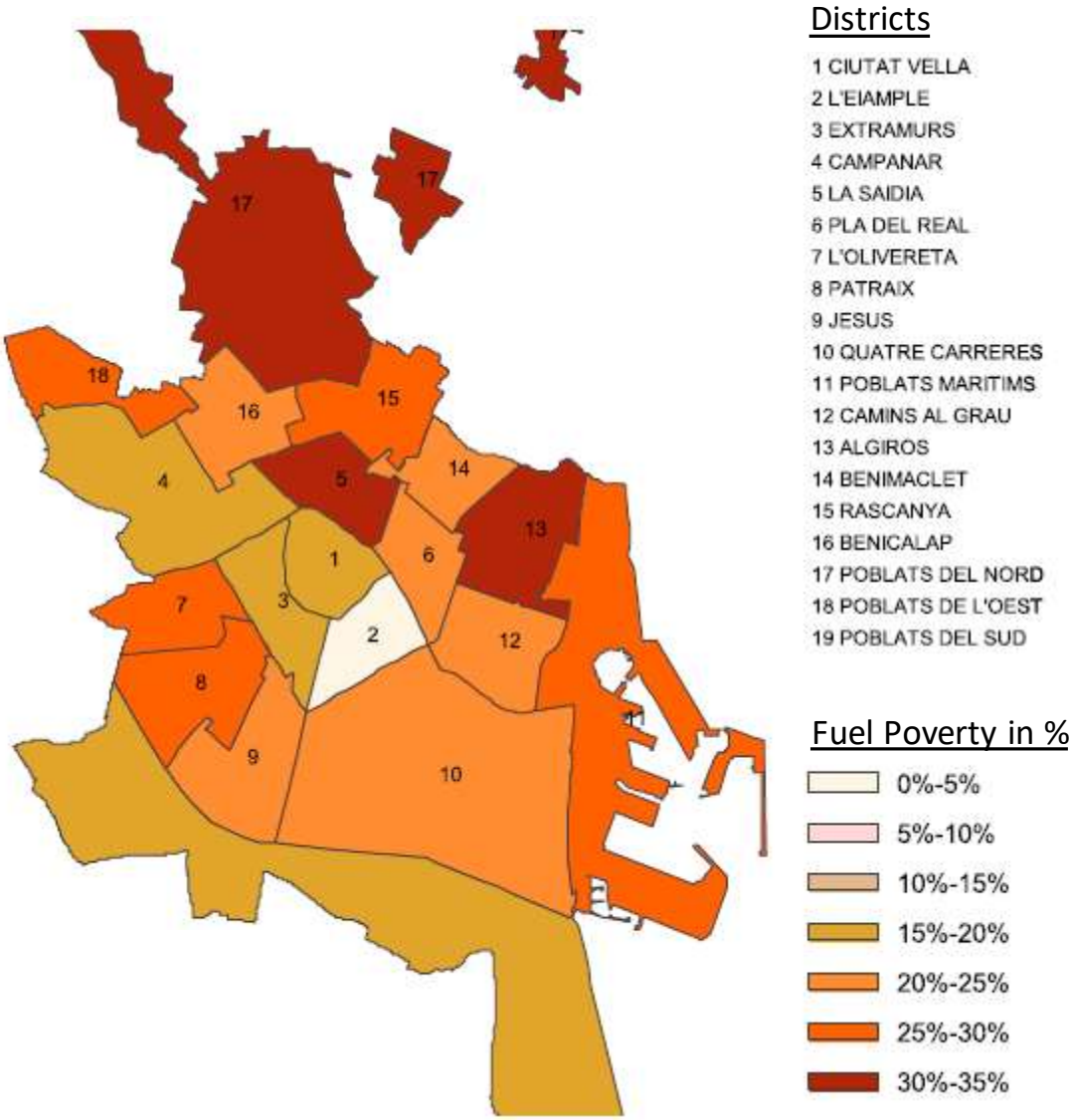

Figure 3. Fuel poverty map according to MIS indicator in Valencia city, per district

3.4 Vulnerability to fuel poverty

To study which households in Valencia are vulnerable to FP, i.e. are at risk of falling into FP, if their incomes dropped or their energy expenditures rose, some assumptions were considered:

- A decrease of 33% of the family incomes as a result of a financial crisis, due to a reduction of salary, or a change from employment to unemployment allowance situation, or due to the loss of a subsidy. FP households as per MIS FP (MIS-FP hereinafter) would be: 36.62%, a 59% higher rate.

- An increase of 33% of energy expenditure, due to climate worsening, a consumption increase because of preventive lockdown, or any other reason. MIS-FP households would be: 24.17%, a 5% higher rate
- A change in the family composition increasing up to 0.3 units of consumption (i.e. a new born). MIS-FP households would be: 30.96%, a 34% higher rate
- A simultaneous change of all the above assumptions. MIS-FP households would be: 43.97%, a 90% higher rate

After analysing how many households would pass from a non-FP to an FP situation by implementing these changes, it turns out that between 1% and 20.9% of Valencia's households are at risk of falling into fuel poverty.

Next, data are analysed regarding the main causes of Fuel Poverty: low incomes, high energy prices and low energy efficiency of households. Afterwards, other indirect causes of FP are discussed as well.

3.5 The effect of households' incomes on fuel poverty

Among the MIS-FP households, most of the interviewed household spokespersons reported incomes in the three lowest deciles of rent. Only 9 out of 595 cases had incomes belonging to the 4th lowest decile of rent, and 2 cases reported incomes in the 5th decile. However, all those households had 4 or more members at home and other features that confirmed them as FP. An analogous behaviour showed the other indicators. Hence, FP was closely related to the incomes of the household, as expected. This is consistent with the results of previous research (Tirado Herrero, 2017), and the sensitivity analysis previously explained.

More evidence of this obvious effect is that almost all households in MIS-FP had none or only one person with incomes, and the 27 households with 2 or more incomes were mainly retirement pensions or part-time wages, i.e. typical low incomes.

3.6 The effect of energy expenditure. Energy prices and the energy quality of the dwelling.

As expected, and confirmed with the vulnerability analysis, energy price and demand clearly influence the chances of being in fuel poverty. On the one hand, Spain belongs to the 5 countries with the most expensive electricity and gas in Europe, with an income per capita below the European average (Eurostat, 2020a, 2020b). In particular Valencia has average household income and energy prices in Spain (Ayto Valencia, 2020). Hence, a higher share of FP than the European average had to be expected.

About the energy demand, a household need is determined by outdoors weather conditions, the building's orientation, its envelope, the inhabitants, and the number, frequency and efficiency of the appliances used. Section B of the questionnaire in Annex 1 was intended to enable an analysis of the energy quality of the dwellings. Unfortunately, only 5 of the spokespersons of households in MIS-FP knew the energy certificate of their houses, and these were between level D and level F. All the others did not know the energy quality of their households (around 50%), or knew the house had no energy certificate (although by law, in Spain all rented houses must have an energy certificate). Hence, no correlation could be

analysed between the energy quality of the building and the probability of a family to be FP. On the other hand, no correlation could be analysed either between the energy quality of the building and its age, however, in this case the rule is poor energy efficiency as discussed in (IVE, 2020). However, there were some meaningful findings based on the types of energy systems the interviewees declared to have at home. Thus, of the households in MIS-FP, only 10.8% use heating efficient systems like gas powered hot water & heating, or heat pumps; but none of the FP-MIS households had a highly efficient shared system like a district heating or building heating system. Besides, half of the 10.8% MIS-FP households with apparently efficient energy systems, had a poor energy quality based on questions B2, B4, B5, B6 and section C about Perceptions. The other half of those MIS-FP families had almost no incomes. In conclusion, all surveyed FP households present energy systems of improvable efficiency. This, together with the poor energy efficiency of the buildings in Valencia, allow to conclude that house retrofitting has a great potential for decreasing the energy consumption while maintaining home comfort. The latter, provided the so-called Rebound Effect is avoided (Sorrell, 2009).

Finally, among MIS-FP households, 7.1% were found to be paying more than necessary solely because of the energy contract. Another 30.1% may also be paying more, but more data would be needed to be sure; and, as explained, later, the great majority of interviewees declared that their family energy bills were little or in no way understood. Then, optimisation of the bills (through reducing the power, changing to time-of-use tariffs or cancelling unnecessary services) could achieve relevant economic savings (Tirado, 2018).

3.7 Fuel poverty and tenure status of the household

Of the 595 valid answers to the survey, 207 (35%) are rented or different, and 388 owned by their inhabitants with or without a mortgage (65%). These rates are similar to those reported by the city council's statistical office (Ayto Valencia, 2020). However, among MIS-FP households, 62% are rented and 38% owned, and of the latter, 97% were paying a mortgage on the household. Hence, rents and ownership costs are closely related to FP. In fact, the correlation between rents or mortgages and MIS was advanced by Romero et al. (2018), although they did not distinguish between rented houses and mortgaged houses.

Actually, rented houses have clearly higher FP rates than owned houses. This is due to a higher incidence of precariousness among renting inhabitants. But, also, the research found a variety of interviewees in FP rented households complaining of landlords not caring about their situation. And among those interviewees, there were several that complained of not being allowed to introduce changes in their households, either to improve the house and appliance efficiency, or the energy supply and its contracts. Unfortunately, those were spontaneous comments, not always recorded, and the survey could not determine the percentage of FP rented houses under those circumstances.

3.8 Fuel poverty and the number of inhabitants in the household.

According to the survey, the average number of units of consumption (uc) per household is 1.87 uc/household, i.e. equivalent to a dwelling with two adults and a child under 14 years. However, for MIS-FP households, the figure is 2,12 uc, i.e. two adults, and three children under 14 years. Hence, in general terms, the more members in the households, the greater

probability of being fuel poor. Indeed, districts with higher FP rates coincide with those with greater number of residents per household (*Poblats del Nord, Rascanya, Poblats de L'Oest, Poblats Masrítims y L'Olivereta*). However, 33.3% of the MIS-FP households had less uc than the average, with a majority of them (62%) being composed of elderly people living off a pension. Besides, the households' size might play an important role on the energy consumption especially when this is not appropriate for the family size. It is the case of low-income elderly living alone or in pairs in big and inefficient houses with high energy costs. In addition, note that elderly occupy the home most of the time and days of the year, so they are especially vulnerable when the comfort conditions are not adequate (Healy and Peter Clinch, 2002).This relationship between the elderly living alone and fuel poverty was another of the findings when analysing household compositions.

3.9 Energy illiteracy

Energy illiteracy is the lack of understanding of the nature and role of energy in our daily lives, and the inability to apply it to everything from making energy efficiency decisions to understanding energy bills (Martins et al., 2020). In this study, 62.02% of the surveyed households declared knowing "nothing" or "little" about items from their energy bills (electricity, gas, butane, etc.). Interestingly, the relationship between energy illiteracy and FP was not significant, among MIS-FP households, the declared lack of understanding of the bills was 70.5%. However, clarifying item arrangement in the bills is by itself an effective way to fight against FP (Romero et al, 2014). Also, it facilitates the comprehension and decision-making capacity of vulnerable consumers regarding their type of contract. Hence, this finding served to interpret results from a different point of view: the majority of MIS-FP consumers have not learnt to understand their energy bills for optimising the energy costs related to tariffs, type of contract, method of payment, etc.

This conclusion was reinforced with responses from questions C9.2 to C9.8 of the survey (Annex 1). Of all the interviews, 27.4% of the households had improved their energy efficiency somehow and from these, only 12% were classified as MIS-FP. In conclusion, households in FP did not know how to save energy, or to decrease their expenditure on energy while keeping comfortable.

4. CONCLUSIONS AND POLICY IMPLICATIONS

Fuel poverty (FP) was measured in the city of Valencia from responses to 595 surveys. Rates of FP were 11.9% according to the 10% rule, 18.2% according to twice the median of the energy expenditure rate, 10.2% according to low income high costs, 23.1% according to Minimum Income Standard (MIS), and 32.7% according to residents' perceptions and statements. They are all above the typical values of other studies, and this may be due to the specificity of the study, and to the fact that Valencia is a relatively big city with around 800,000 inhabitants, and up to 2,500,000 people in its metropolitan area (Eurostat), and FP is higher in urban areas than in rural areas or mild temperature regions.

Due to its complexity, there is not an agreed indicator yet to measure FP in a simplified and automatic way. The different feasible indicators address it from different approaches, and none of them seem to perfectly distinguish FP families from the rest. Yet, to quantify the magnitude of FP is of great importance in order to understand the problem, to design comprehensive

policies and to measure progress. For this study, authors decided to adopt the Minimum Income Standard (MIS) because it is directly related to the household's available income after paying all necessary household expenses, it takes into account family size, and it is an absolute indicator.

According to MIS, Valencia has 23.1% of households in Fuel Poverty. From these, 16.9% have very low incomes and their poverty is structural and 6.2% are fuel poor due to their energy expenditure. In addition, up to another 15.5% of households are at risk of being fuel poor if their energy expenditure increased by 33%, or if their income decreased by 33%, or if the family increased with a new-born.

Beyond the known causes of fuel poverty, FP has been found in this research work to be also related to the tenure of the dwelling. Mortgaged dwellings present high FP rates, as expected. However, rented dwellings present even higher rates due to the precariousness of their inhabitants and, apparently, to the disinterest of many owners, in the context of a rental market of neglected underdeveloped housing. Furthermore, the size of the family also positively correlates with FP rates. Finally, energy Illiteracy was found to be very high in both fuel poor (slightly higher) and non-fuel poor households; families struggling to keep their homes at comfortable temperatures and humidity, are not better trained in getting the most out of their assets.

To conclude, based on the results of the study, recommendations for policy making in the local realm are put forward to mitigate fuel poverty (Table 3). They have been classified in i) Economic Support, ii) Energy Retrofitting, iii) Energy Literacy and iv) New Models of Energy Systems:

i. Economic support consists of managing energy expenditure costs. To manage costs means either to help to pay the higher energy bills, those of winter and summer in Valencia, or to flatten the higher bills by distributing the costs with the periods of less energy expenditure. But also, to review the contracts so that unnecessary costs would be discarded, or better prices found.

   Such subsidies can be used to combat social emergencies through temporary patches. Nevertheless, they do not attack FP causes and, if no other measures are implemented, an FP situation will occur again later. In addition, the energy consumption increases (and so does the environmental impact) since fuel poor households can now afford the costs. It may even lead to a Rebound Effect. Finally, this support creates an unwanted dependency on the public administration in families. Hence, it should be sparsely applied and only if no other measures are feasible.

ii. Housing retrofitting includes durable measures that improve the energy efficiency of the home through building insulation solutions, the use of efficient equipment in the home, or self-consumption of renewable energy. These are some of the most beneficial measures as they increase the energy efficiency of the dwelling, save environmental impacts (if the right insulation, equipment, etc. are chosen) and avoid dependency on the public administration. But they are among the most expensive and can become technically and administratively difficult to implement.

To mitigate the barrier of investment, funding programmes could be: zero profit loans, purchase discounts, funds paid with savings, etc. They could be applied to the substitution of inefficient heaters by heat pumps (that will also cool down the temperature in the hot Valencian summer), insulation of walls and roofs, or to use renewable energy micro power plants. For rented homes, owners must be involved, and an option could be to offer loans that would be repaid from energy savings, and/or from small increases in the cost of rent.

iii. Energy-trained consumers make better choices usually reducing consumption and costs. Such consumers know which habits at home achieve relevant energy savings, maintaining comfort. Practicing simple energy audits, they can measure their consumption, compare with the bills, understand the importance of energy certification of buildings, and estimate the benefits of improvements in room and water heating, the efficiency of appliances and lighting, etc. Overall, skilled energy consumers identify energy inefficiencies in the household and implement good practices to make a rational use of energy. Training should be addressed obligatorily to vulnerable families or to welfare workers dealing with such families. The most urgent goals are to understand the bills, to audit the energy practices and energy-related goods, to learn how to apply for subsidies, what to do to avoid disconnection, etc. In fact, Valencia's city council has just started to train their social workers in all those matters. Finally, in view of the little change in energy poverty over the last years, education for a new model of energy supply and demand should be included in official primary and secondary schools.

iv. To end up with the recommendations for policy, during the study, questions were frequently raised against the current energy model, in which consumers negotiate on their own with huge energy companies; those unable to pay are either disconnected or are ever more in debt, and public organizations and charities have to rescue them, paying their bills and debts. Currently, local governments can promote new energy market models in their aim to rationalize energy consumption, increase efficiency and promote clean energy generation in the cities. For example, local energy micro-markets or energy communities of shared self-consumption, at different levels (building, street, neighbourhood). These have great potential to mitigate FP as the energy has a lower price and the community takes better care of its members. For that, financing programmes and administrative reforms are needed in Valencia to facilitate renewable energy installations. Another example would be, the creation of public companies for trading energy, like in Cadiz or Barcelona, which allow the purchase of electricity with guarantee of origin (of zero emissions), enabling prosumers (producers and consumers of energy) to trade their energy, and guarantee the energy supply and fair treatment of vulnerable families (optimised tariffs, flexibility in payments, prevention of disconnection, exemption from commissions of unpaid bills, etc.). In Valencia, new energy systems would also include district heating/cooling, collective purchasing of insulation materials or energy equipment, and nature-based solutions for urban retrofitting to alleviate extreme temperatures in winter and summer (particularly the frequent so called tropical nights: temperature does not fall under 20 °C during the night time).

Table 3. Summary proposal of policy measures to mitigate fuel poverty in Valencia

Type of strategy	Action	Specific measures
Economic	Pay energy costs	Subsidy to energy expenditure
	Manage energy costs	Negotiate arrears
		Change of contract (tariffs, additional services, power, flat rates, etc.)
Retrofitting of housing	Insulation	Insulation emergency kit (weather strips, insulation panels, heat reflectors, etc.)
		Loans for housing insulation: insulation of walls and roofs, windows replacement, avoid thermal bridges, etc.
	Efficient household appliances	Improvement of heating and cooling equipment
		Improvement of electrical/combustion devices
		Individual renewable energy generation: heat, electricity, etc.
	Benefiting rented families	Involve landlords to refurbish and/or provide efficient appliances
Energy culture/ habits	Education/training	Energy awareness on consumption, housing conditions and appliances, understanding bills, energy analysis, etc.
		Change consumption habits (e.g. correct use of shutters, curtains, doors and windows and right selection and use of lights and appliances)
New energy markets and actors	New market actors	Public companies for trading energy Energy cooperatives and other socially driven actors
	Communities	Prosumer/energy communities (building, street, neighbourhood) District heating/cooling Collective purchasing
	Urban retrofitting	Nature based solutions: green and blue corridors, green rooftops and façades, etc.

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ANNEX 1 SURVEY

SURVEY

A. PERSONAL DATA:
A1. Address,
A2. Nationality,
A3. Gender,
A4. Age,
A5. Time of residence in the current dwelling,
A6. Household members detailed information
- A6.1. Number,
- A6.2. Age,
- A6.3. Breadwinners,
- A6.4. Occupation of the breadwinners
- A6.5. Members in charge.

A7. Economy
- A7.1. Total household yearly income
- A.7.2. Total household costs: rent or mortgage expenditure, taxes, community expenditure.

B. ENERGY MATTERS:

B1. How do you heat up your house? Electricity, gas, heat pump, local space heaters, butane, I do not heat up my house, others.

B2. Do you heat up the whole house or only the living space? Usually the whole house, only where we are (always the same room), only where we are (different rooms), not response/ do not know (NR/DK).

B3 Which type of energy do you use to heat water? Electricity, gas, butane, I do not heat water, others.

B4 Which is the year of construction of your house? Before 1979, between 1979 and 2006, after 2006, NR/DK.

B5 Which is the energy certification of your house? A, B, C, D, E, F, G, it does not have one., NR/DK.

B6 Which is the surface (m^2) of your house?

B7 Type of house. Singe family, flat/apartment.

B8 Tenancy regime. On property, rented (other, specify:_____)

B9 Do you understand all the items of the electricity bills? Nothing, a little, quite, a lot.

B10 Do you know your contracted tariff on electricity? Yes, no, I do not care.

B11 Do you know which electric power do you have? Yes (which is it?), no.

B12 How often do you pay electricity bills? Every month, every two months, NR/NK.

B13 How much do you pay in electricity bills (which period)?

B14 Do you understand all the items of the gas bills? Nothing, a little, quite, a lot.

B15 Do you know your contracted tariff on gas? Yes, no, I do not care.

B16 How often do you pay gas bills? Every month, every two months, NR/NK.

B17 How much do you pay in gas bills (which period)?

B18 Do you pay other types of energy bills: butane, wood pellets, etc. If yes, how much (period)?

C. PERCEPTION:

C1 Are you receiving any social subsidy?

C2 Does your dwelling have leaks or damps walls, ceilings or foundations or rotten floors, windows frames or doors?

C3 During the last winter in your home, were you often cold because of the heating costs?

Never, some odd times, Often, Too often

C4 Would you have turned on space heaters longer or in more rooms of your household, in case you had been able to?

C5 During the past summer in your home, were you often hot because of the air conditioning (or fan) costs?

Never, some odd times, Often, Too often

C6 Would you have turned on (or installed) air conditioning longer or in more places of your home, in case you had been able to?

C7 In the last twelve months, has the household been in arrears, i.e. has been unable to pay on time due to financial difficulties for utility bills (heating, electricity, gas, water, etc.)?

C8 In the last twelve months, have you quitted paying gas or electricity bills?

C9 In which of the next situations have you been in the last twelve months?

C9.1 I was shut off from any utility (electricity, gas, water, etc.)

C9.2 I have improved the isolation of my house (fixing windows, etc)

C9.3 I have reduced the contracted power

C9.4 I have changed habits regarding the use of equipment (restricting the use of heaters, washing machines, etc.)

C9.5 I have modified the type of energy tariff to a cheaper one

C9.6 I have contracted the Time Of Use (TOU) tariff

C9.7 I have applied for social subsidy.

C9.8 I have requested to pay in instalments

C9.9 I have connected illegally to the power grid

C9.10 I have asked family members for help to pay electricity or gas services.

C9.11 I have asked public services for help to pay utility bills.

C9.12 I have asked other social organisations for help to pay utility bills. Which one (Caritas, Red Cross, other)?

C10 In which of the next situations have you been in the last twelve months due to not having enough energy at home?

C10.1 Food: Has the quality of the food you eat been reduced due to the energy situation in your home (e.g. modification in the type of food acquired and the way of cooking it)?

C10.2 Education: Have you struggled to do the homework which required having access to computer, Internet, printing machines, etc. due to the energy situation in your home?

C10.3 Health/ body integrity: Due to the energy situation in your home, have you or any member of your home suffered any of these chronic illnesses: headaches, respiratory, cardiovascular, allergy.

C11. Do you think your daily life (or that of any member of your household) has been negatively affected due to the energy situation at home?

Never, some odd times, Often, Too often

ANNEX 2 SAMPLE CHARACTERISTICS COMPARED WITH THE POPULATION

	SAMPLE (with compensation factors)			Main residences of Valencia (Ayto Valencia, 2020)		
Average income per household	29.85 K€/household.year			31.46 K€/household.year		
Units of consumption per household	1.87 uc/household			1.69 uc/household		
Average Electricity consumption	3.05 MWh/household·year			3.35 MWh/household.year		
Average Gas consumption	2.25 MWh/household·year			2.23 MWh/household.year		
Average consumption of other energies	0.38 MWh/household.year			0.22 MWh/household.year		
Year of building construction	Before 1980	1980-2006	After 2006	Before 1980	1980-2006	After 2006
	65.1%	29.4%	5.5%	72.9%	20.5%	6.6%
Tenure status	Owned	Rented	Others	Rented	Owned	Others
	65.1%	29.4%	0%	72.9%	22.7%	4.3%