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José Carlos Romero
Pedro Linares
Xiral López-Otero

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The policy implications of energy poverty indicators

José Carlos Romero[a], Pedro Linares, Xiral López

[a]*Institute for Research in Technology, School of Engineering (ICAI), Universidad Pontificia Comillas, Madrid, 28015, Spain*

Abstract

The methodologies and indicators that have been proposed in the literature to measure energy poverty are quite diverse. Some are subjective approaches based on personal or third parties' perceptions of affordable warmth at home; whereas others calculate objective indicators. Although these different proposals have already been theoretically compared, an empirical comparative analysis that measures in a real case study the practical impact of the theoretical limitations detected for the different indicators was still pending. The goal of this paper is thus to contribute to this debate by comparing critically the different approaches used to measure energy poverty in a real case (Spain in 2015), and to propose a new methodology that might be able to overcome some of the major problems that affect current methods.

Keywords: Energy Poverty; Minimum Income Standard; Policy Implications

Nomenclature

- AFCP After Fuel Cost Poverty
- ECV Spanish Survey on Living Conditions
- EHCS English Housing Condition Survey
- EHS English Housing Survey
- EPF Spanish Household Budget Survey

Email addresses: jose.romero@iit.comillas.edu (José Carlos Romero), pedro.linares@comillas.edu (Pedro Linares), xiral@uvigo.es (Xiral López)

- LIHC Low Income High Cost
- MIS Minimum Income Standard
- RMI Minimum Income Allowance provided by Spanish regions

1. Introduction

25 years after the publication of Brenda Boardman's book about Fuel Poverty[1] (Boardman, 1991), the debate in Europe regarding this important issue is probably more alive than ever. In 2012, a special issue of Energy Policy introduced by Liddell's editorial (Liddell, 2012), helped summarize some of the most relevant achievements to date, together with the pending issues. Five years later, some of them are still open, in particular those regarding the proper definition of energy poverty and the right methodology to obtain a comprehensive indicator. Although the most relevant contributions come from the UK (Boardman, 2012; Hills, 2011; Moore, 2012a; Guertler, 2012; Healy and Clinch, 2004; Hutchinson et al., 2006; Day et al., 2016) some other assessments can be found in the literature coming from other European countries as well (Bouzarovski et al., 2012; European Commission, 2015; Brunner et al., 2012; Fabbri, 2015; González-Eguino, 2015; Lacroix and Chaton, 2015; Santamouris et al., 2013; Scarpellini et al., 2015; Thomson and Snell, 2013; Tirado Herrero and Ürge Vorsatz, 2012). In addition, projects like EPEE, INSIGHT-E, or the EU Fuel Poverty Network and the recent report by Trinomics (Rademaekers, 2016) have also contributed significantly to the understanding of this complex issue.

Energy poverty and the concept of vulnerable consumers have also been recently recognized explicitly in European legislation. The so-called Clean Energy Package (European Commision, 2016a) sets out a new approach to protect vulnerable consumers, including provisions such as (1) the requirement that a share of energy efficiency measures are applied primarily to households living in energy poverty, (2) the obligation on Member States to monitor and report the situation of energy poverty, or (3) the creation of an energy poverty observatory to obtain better data about the problem and its solutions, and to assist Member States in combating it. In addition, the proposal for the revision of the Directive on the internal market for

[1] In this survey, the term Energy Poverty instead of Fuel Poverty has been used. A discussion about the difference between them can be found in (Li et al., 2014)

electricity (European Commision, 2016b) makes a distinction between vulnerable consumers and energy poverty, requiring Member States to define both concepts.

The methodologies proposed in the literature to identify energy poverty and vulnerable consumers are quite diverse (see Table 1). Some are subjective approaches based on personal or third parties' perceptions of affordable warmth at home; whereas others calculate objective indicators. Although these different proposals have already been theoretically criticized (Fahmy, 2011), (Heindl, 2015) or (Schuessler, 2014), an empirical comparative analysis that measures in a real case study the practical impact of these theoretical limitations, and their policy implications, is still pending.

Thus the goal of this paper is to contribute to this debate by comparing critically, in a real setting, the different approaches used to measure energy poverty on an objective basis, and to propose a new methodology that might be able to overcome some of the major problems that affect current proposals, i.e. (1) excessive sensitivity to energy prices and housing costs, (2) arbitrariness in the choice of the thresholds and (3) relative approaches that measure inequality rather than poverty. This third drawback will be further elaborated in Section 2.

However, defining a more accurate indicator that is able to show better the extent of the incidence of energy poverty in a country in aggregate terms is not enough. If energy poverty is to be solved, we must be able to identify the characteristics of those households most affected by it, so that they can be targeted correctly by the policies devised. Again, although some proposals have been made regarding the identification of vulnerable households (Middlemiss and Gillard, 2015), (Legendre and Ricci, 2015), there is still room for improvement. In the present study, we analyze the major factors that determine the vulnerability of households to energy poverty, and we present the main policy implications of these results.

We apply our methods to Spain, a country that, although features a rather benign climate (and would therefore be assumed to suffer less from this problem), has also been severely affected by the economic crisis, and in which energy prices have also increased very much recently (placing it among the most expensive countries for energy in households). As a result, Spain presents energy poverty rates comparable to other European countries and is therefore a good reference to test the different indicators.

The structure of the paper is as follows: Section 2 presents a brief state of the art of energy poverty indicators. Section 3 applies the methodology proposed to the case study and calculates the indicators, focusing on the search for their limitations and strengths. Additionally, Section 4 describes our study of vulnerable households based on the energy poverty indicator chosen. Finally, Section 5 presents the conclusions and some policy recommendations in the light of the empirical results.

2. Measuring energy poverty

The first studies about energy poverty were carried out in the early 80s in the UK. They were conducted by Bradshaw and Hutton (Bradshaw and Hutton, 1983), and were the prelude to Boardman's study (Boardman, 1991), also in the UK, where the first formal definition of energy poverty was presented: a home would be energy poor if its expenditure in energy services exceeded 10% of its total income.

In 1991, the English Housing Condition Survey (EHCS), that became in 2008 the English Housing Survey (EHS), used this threshold proposed by Boardman to measure the "affordable warmth", i.e. the ability of households to ensure a comfortable temperature in winter. Since then some other definitions of energy poverty have been proposed (Fahmy, 2011), (Price et al., 2012). Among them, Heindl's (Heindl, 2015) classification of energy poverty indicators is particularly interesting:

1. Subjective and qualitative, developed by the individuals themselves.
2. Subjective and qualitative, developed by third parties.
3. Objective and quantitative indicators, not income-expenditure based (eg, humidity, incidence of mold in the household or epidemiological data).
4. Objective, quantitative and income-based indicators.

Ideally, as Heindl points out, all these indicators should be taken into account when addressing the study of energy poverty in a country. However, we acknowledge that in essence, the fourth group somehow incorporates, at least partly, the others, therefore being more informative about all aspects of energy poverty. Therefore, while recognizing the need to consider all approaches, and indeed using a subjective measure to test the robustness of our results, the present study mainly focuses on objective, income-based measures.

There are basically three types of objective, income-based energy poverty indicators: those based on the share of income required to pay for energy expenses (2M indicators, which include the 10% approach); those based on the Minimum Income Standard (MIS) approach[2]; and finally, a third approach, the Low Income High Cost (LIHC) indicator (Hills, 2011), combines both aspects, i.e. energy costs and household income.

In Table 1 a selection of studies in Europe in recent years is presented which highlights the great deal of variability, even within the same study, depending on the type of energy poverty indicator used.

Table 1: Energy Poverty Indicators in Europe

Indicator	Country	Year	Sample size	Value	Reference
10%	Germany	2011	10,193	27.6-29.5%	(Heindl, 2015)
	France	2013	43,000	16.6%	(Legendre and Ricci, 2015)
	UK	1997-2008	61,355	18-18.2%	(Roberts et al., 2015)
	England	2014	11,851	11.6%	(DECC, 2016)
	France	2006	50,000	11-13%	(Imbert et al., 2016)
	Greece	2015	400	58%	(Papada and Kaliampakos, 2016)
	Spain	2013	22,057	18.24%	(Economics for Energy, 2015)
LIHC	England	2009	16,000	9%	(Hills, 2011)
	Austria	2013	931	2.5%	(Boltz and Pichler, 2014)
	Germany	2011	10,193	11.1-15.6%	(Heindl, 2015)
	France	2013	43,000	9.2%	(Legendre and Ricci, 2015)
	England	2014	11,851	10.6%	(DECC, 2016)
	France	2006	50,000	10%	(Imbert et al., 2016)
	Spain	2013	22,057	8.71%	(Economics for Energy, 2015)
MIS	England	2008	15,523	25.5%	(Moore, 2012b)
	Italy	2011	19,000	8.4%	(Valbonesi et al., 2014)
	Germany	2011	10,193	9.9-10.6%	(Heindl, 2015)
	Spain	2013	22,057	9.88%	(Economics for Energy, 2015)
AFCP	France	2013	43,000	20.9%	(Legendre and Ricci, 2015)
2M	Hungary	2005-2008	10,000	4-8%	(Tirado Herrero and Urge Vorsatz, 2012)

Let us summarize now briefly the main advantages and drawbacks of each of these three groups of objective income-based indicators according to the literature.

2.1. 10% indicator

According to this indicator, a household is energy poor if it has to spend more than 10% of its income in adequate energy services. This definition by

[2]According to Bradshaw et al. (Bradshaw et al., 2008), a minimum income standard (MIS) is the one required in order to enjoy the opportunities and choices necessary to participate in society.

Boardman (Boardman, 1991) became the official energy poverty indicator in the UK from 2001 to 2013, when the whole strategy was revised and the LIHC was chosen as the new indicator (Hills, 2012).

The 10% indicator has several advantages. It is simple to calculate, easy to communicate, and relatively versatile from a pragmatic point of view. However, it also suffers from significant limitations which have been clearly highlighted in the literature (Schuessler, 2014) and (Heindl, 2015).

These limitations are mainly due (1) to the excessive sensitivity to energy prices, underestimating the scale of the problem when prices are low and overestimating it when they are high; (2) to the arbitrary selection of the threshold at 10%, which could be justified on the socio-economic situation in the UK in the early 90s, but cannot be directly extrapolated to other spatial and temporal situations; and finally, (3) to the lack of any reference to the household income.

In fact, it has been shown that this threshold of 10% calculated for different countries may include a significant number of households that are not energy poor, e.g. high-income households with inefficient homes or with an otherwise excessive energy consumption. In Heindl's analysis (Heindl, 2015) the 10% indicator is considered an outlier, as it places the extent of energy poverty above 25%, much higher than what other indicators show.

In order to better understand these criticisms we should analyze the initial justifications that led to the election of the 10% as the threshold for the UK. In the pioneering work of Boardman (Boardman, 1991), which used data from 1988, the 10% indicator represented, on the one hand, the average energy expenditure of the 30% poorest households in Britain, and on the other hand, approximately twice the median percentage of energy expenditure of all households. At first, as Schuessler points out (Schuessler, 2014), this second fact was considered the most relevant and it served to consolidate the indicator. Nevertheless, if we highlight this capability of the 10% indicator to approximate the average cost of a specific percentage of the poorest households in the country distinctly from the entire population, the indicator takes on a new dimension, although with problems also. It is worth noticing that the first justification is referred to an absolute limit of poor households, whereas the second relies on a relative level of consumption.

This reflection by Schuessler opens the debate between the convenience of using relative or absolute indicators when dealing with energy poverty issues. In our opinion, and in line with the most accepted definition, the problem of energy poverty, as a social justice and not a welfare issue, is essentially normative, or in other words, is a problem of absolute limits. The fact that the whole society improves or worsens its aggregate behavior in this matter should not bring a concrete home in or out of energy poverty. Hence, a relative measure of poverty reflects inequality rather than poverty as such [3]. Therefore, we consider absolute measures more appropriate. Needless to say that these measures would be very much enriched with an specific analysis of energy inequality.

2.2. MIS based indicator

Applying this approach to the case of energy poverty, a household would be energy poor if it does not have enough income to pay for its basic energy costs, after covering housing and other needs. This indicator specifically identifies households which would be above the poverty threshold but fall below it because of their energy expenditure.

To find the first study of energy poverty indicator based on the MIS, we must go once again to the UK, and specifically to the work of Moore (Moore, 2012b). According to this researcher, the MIS provides a consistent and accurate measure of energy poverty, and at the same time it is easily adaptable to different standards of living in Europe. He also suggests that a scale of energy poverty based on MIS would help measure the level of vulnerability of different households. Other examples of energy poverty analysis based on MIS are Heindl's in Germany (Heindl, 2015) or Valbonesi's in Italy (Valbonesi et al., 2014).

The MIS-based indicator of energy poverty is undoubtedly one of the most robust when measuring objective, income-based energy poverty, because it addresses the problem from its very economic root: the income available for energy needs after the basic needs have been met. Unfortunately, it also presents a technical difficulty: the determination of the minimum income on an objective basis.

[3] We are aware that there is a broad consensus about the appropriateness of using relative rather than absolute methodologies to analyze general poverty issues (Townsend, 1980). The soundest arguments to defend that position are rooted on the ability of relative measures to be extrapolated to different geographical and temporal situations and, at the same time, to reflect the impact of inequality on welfare.

2.3. Low Income/High Cost indicator

The LIHC was proposed by Hills (Hills, 2012) and constitutes the basis of the new strategy in the UK in the fight against energy poverty.

According to the LIHC indicator, a household is defined as energy poor when income is below a certain (relative) poverty threshold and when its energy costs are higher than an energy expenditure threshold. Obviously, the use of this indicator requires the definition of both thresholds, which is not an easy task. Regarding the first, the approach used by Hills is the 60% of the median equivalent income after subtracting housing and modeled energy costs. For the second threshold, Hills used the median equivalent energy expenditure calculated over the total households.

This proposal is not exempt of criticism either. Moore (Moore, 2012b) criticizes the LIHC for different reasons: (1) because it is an overly complex and not transparent indicator, mainly by the problems of modeling the energy equivalent indicator; and (2) because setting the threshold of energy expenditure does not take into consideration the effect of energy efficiency of homes, and makes it difficult at the same time to find out those households that can come out of energy poverty by way of reducing their energy costs.

In addition to these two points highlighted by Moore, another negative factor is its doubly-relative character (being the quotient of two relative measures), which, besides from the conceptual problem about relative indicators pointed out before, makes very difficult to isolate causes and effects in the analysis of their results, especially when analyzing time series, and produces some odd dynamic behavior (Heindl and Schuessler, 2015).

Table 2 summarizes the pros and cons of the indicators presented.

After the major theoretical drawbacks of the three different groups of objective and income-based energy poverty indicators have been explained, the following section summarizes the results of an empirical analysis based on a real case, i.e Spain, in which these limitations are put at stake.

3. Energy Poverty indicators for Spain

In the previous section we have presented the pros and cons of the three families of objective and income-based energy poverty indicators consolidated in the literature. Now we estimate them in a real case: Spain in 2015 (the most recent year with available data). This analysis will allow us to detect the practical problems behind the implementation of these indicators, and in

Table 2: Summary of pros and cons of income-based energy poverty indicators

Indicator	**Pros**	**Cons**
10%	1. Simple to calculate 2. Easy to communicate 3. Relatively versatile from a pragmatic point of view	1. Excessive sensitivity to energy prices 2. Arbitrary selection of the threshold at 10% 3. Lack of any reference to the household income
MIS	1. Robust when measuring objective income-based energy poverty by addressing the problem from its very economic root	1. Difficulty to determine the minimum income on an objective basis
LIHC	1. Corrects the 10% indicator by considering not only the expenditure on energy but also an income threshold	1. Overly complex and not transparent indicator 2. Difficulty to find out those households that can come out of energy poverty by way of reducing their energy costs 3. Doubly-relative character which makes very difficult to isolate causes and effects when analyzing time series

particular, the amount of false positives and negatives that they can generate, and their sensitivity to the assumptions.

3.1. Data and methodology

The data source was the Spanish Household Budget Survey (EPF) in 2015. This is a database compiled by the Spanish National Statistics Institute (INE) which provides annual information on the nature and destination of consumption expenditure, as well as on various characteristics relating to the living conditions of households. This survey is carried out annually, interviewing households for two weeks. These households remain in the sample for two years, and are replaced by similar households in order to maintain the significance both at national and regional level. This is a survey of high statistical quality and very complete in terms of consumption (monetary and physical) and characteristics of households, covering the entire Spanish territory and is representative. Nevertheless, with regard to decisions related to the behaviour of households in energy matters, it lacks information to study in more detail energy poverty. Thus, it does not include information on the type of heating in the home (central or individual) or on the consumption of household appliances, issues that could be interesting for analyzing the vulnerability of Spanish households.

The EPF in 2015 was developed over 22,130 observations, although the spatial elevation factors included in the survey allow us to obtain representative results for Spanish households. As an equity variable, it has considered the exact amount of the net monthly annualized household income, while energy expenditure is the result of adding the annual expenditure on electricity, natural gas, liquefied gas, liquid fuels, solid fuels, and central heating and hot water, steam and ice in the main dwelling. With regard to housing costs, we have used the actual rents for rental homes and imputed rents for mortgage-owned homes.

The methodology to calculate the 10 % indicator is exactly the same of that proposed by Boardman (Boardman, 1991). Nevertheless, the methods to calculate the LIHC and MIS-based were slightly different to those proposed by Hills (Hills, 2012) and Moore (Moore, 2012b) respectively.

The LIHC has been calculated so that energy poor households are those that verify Eq.1 and Eq.2.

$$[Household\ expenditure\ on\ energy] > [Median\ expenditure\ on\ energy] \tag{1}$$

$$[Household\ income] - [Household\ expenditure\ on\ energy] < 60\%[Median\ Household\ income - Mean\ expenditure\ on\ energy] \quad (2)$$

The difference with Hills' approach (Hills, 2012) is located in the latter equation. Hills proposed using Eq.3 instead of Eq.2

$$[Household\ income] - [Household\ expenditure\ on\ energy] < 60\%[Mean\ Household\ income] \quad (3)$$

In our proposal the mean expenditure on energy was subtracted from the mean household income in Spain in order to be consistent with the first term of the equation in which we consider the income of the household after energy costs.

Regarding the MIS-based indicator, Moore proposed that a house is energy poor when Eq.4 was verified.

$$[Fuel\ Costs] > [Net\ household\ income] - [Housing\ costs] - [MIS] \quad (4)$$

In Moore's calculations the three first elements were taken from the English Housing Survey whereas the MIS was taken from Bradshaw et al. (Bradshaw et al., 2008). This MIS covers all needs, other than Council Tax, rent/mortgage payments and fuel.

Unfortunately, in Spain there is neither a similar study to Bradshaw's that calculates a MIS in different regions by a participatory process, nor a similar survey to EHS, which includes not only data of actual energy expenditure but also theoretical energy needs depending on the characteristics of the household. In Spain, neither the Household Budget Survey (EPF), nor the Survey on Living Conditions (ECV) collect information about the physical characteristics of houses. For this reason, a different strategy was chosen to estimate a MIS-based indicator for Spain. Since in some Spanish regions a minimum income allowance is available (RMI), the MIS was assimilated to the average RMIs in the territory, weighted by population.

From these data a MIS of €415.2 for the whole country was obtained. It should be noted that, by proposing this MIS, we are assuming that it is enough to cover all the household needs, something that, as will be seen later, is not necessarily right.

Subsequently, given that the RMI is received only by the household reference person, we transform a person-based MIS to a household-based MIS based on the equivalence rules recommended by the OECD. Hence, the equivalent MIS-based energy poverty indicator for Spain was calculated using the following Eq.5.

$$\begin{aligned} & [Actual\ Household\ expenditure\ on\ energy] > \\ & \qquad [Net\ household\ income] - [Housing\ costs] - \\ & - [MISeq. - Average\ energy\ expenditure - Average\ housing\ costs] \end{aligned} \quad (5)$$

where the average energy expenditure and the average housing costs in Spain in 2015 were €1,045 and €2,584 respectively, as taken from the EPF.

3.2. Results

Table 3 includes the three energy poverty indicators calculated for Spain in 2015.

Table 3: Energy Poverty Indicators. Spain. 2015

Indicator	**2015**
10%	14.96%
Minimum Income Standard (MIS)	8.70%
Low income/ High cost (LIHC)	8.10%

Additionally, the LIHC value for Spain using the original Hills' methodology was also calculated: 9.71% of Spanish households are energy poor according to this indicator, i.e. 1.61% more that with the modified LIHC. It means that Hills' original methodology could be slightly overestimating the extent of energy poverty, by not including the energy component in the right hand side in Eq.2.

It is worth noticing the great divergence between these indicators, which makes it difficult to obtain a clear picture of the actual situation of energy poverty in Spanish households. According to the 10% indicator, 14.96% of Spanish households would be energy poor, whereas just 8.10% of Spanish households are considered energy poor according to the LIHC indicator and 8.70% according to the MIS based indicator.

To try to shed some light on this issue, a comparative study looking for the intersections between them was carried out. Fig. 1 represents the overlap of households that are energy poor according to the three indicators. The figure shows the share of energy-poor households according to two or more indicators. As can be seen, 67% and 59% of households considered energy poor according to the 10% indicator are not so according to the MIS-based and LIHC indicator respectively. Besides, 58% of the households that the LIHC classifies as energy poor are not considered as such according to the MIS based indicator.

Two main findings may be highlighted from this exercise. First, 3% of Spanish households are energy poor for any of these three indicators. This would set the indisputable minimum of energy poor households in Spain in 2015. Second, the three indicators are clearly identifying different households, i.e. they do not measure the same problem.

The 10% indicator, which does not account for income levels, is probably measuring an excessive energy expenditure rather than energy poverty. This fact is clearly highlighted when we disaggregate the indicators by household income deciles. Table 4 summarizes the percentage of energy poor households (according to each indicator) that belong to each decile of income.

This analysis shows very clearly the weakness of the 10% indicator. By not accounting for income levels, it identifies as energy poor households in all income deciles, what is clearly inconsistent. It seems sensible to say that all households considered to be energy poor above the 4th or 5th decile of income are probably false positives, since their income is clearly sufficient to pay for reasonable energy expenses, even if they exceed 10%. The other two indicators, which do account for income levels, do not present this behavior, thus pointing out to the relevance of incorporating income levels to any reliable energy poverty indicator.

It should also be noted that there are no significant differences in the disaggregation of LIHC results according to the new methodology presented and the original Hills' proposal. In both cases, energy poor households are concentrated in the first three deciles.

Additionally, it should be noted that the range of 8-10% of energy poverty in Spain highlighted by the LIHC and the MIS indicators is well aligned with other subjective measurements like the inability to keep home adequately warm[4], which affected 8.0% of Spanish households.

However, that does not mean, as mentioned earlier, that the three indicators are measuring the same issue. By definition, 10% will still measure high energy expenditures, but not energy poverty. And as such, it will al-

[4]This indicator is included in the EU-SILC statistics on income and living conditions (Eurostat, 2017)

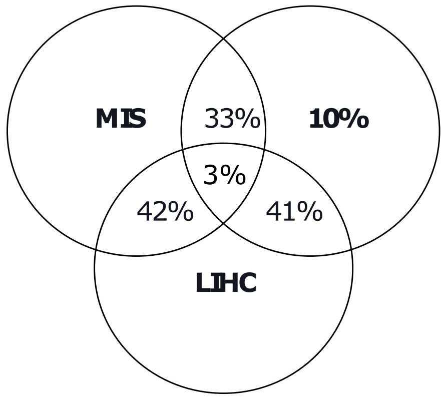

Figure 1: Share of energy-poor households according to two or more indicators

Table 4: Energy-poor households per income decile

	10%	LIHC	"Original" LIHC	MIS
1st Decile	37.06%	41.59%	41.59%	74.73%
2nd Decile	18.34%	51.71%	54.39%	20.41%
3rd Decile	13.33%	6.39%	2.64%	2.89%
4th Decile	10.96%	0.29%	1.17%	1.06%
5th Decile	7.80%	0.02%	0.06%	0.43%
6th Decile	4.39%	0%	0%	0.25%
7th Decile	4.27%	0%	0%	0.10%
8th Decile	1.93%	0%	0%	0.02%
9th Decile	1.31%	0%	0%	0.12%
10th Decile	0.62%	0%	0%	0%

ways feature a large degree of false positives. The LIHC does eliminate many of these, but its evolution is more difficult to interpret because of its doubly-relative nature, which makes it more suitable to measure energy inequality than energy poverty. Eventually, and in spite of its limitations, the MIS-based indicator seems to be the best available alternative for measuring energy poverty. In addition, it is the only one that provides an absolute measure of poverty, what is clearly another advantage.

It is also interesting to analyze the regional disaggregation of energy poverty by region, since that can also highlight the dependence of the results on climatic or income factors. Fig.2 presents the regional disaggregation of energy poverty in Spain in 2015 calculated over the 10% and the MIS-based indicators. Through this comparison, the importance of choosing the appropriate energy poverty indicator is highlighted once again. Ceuta, Canarias and Andalusia move from being the most energy poor regions using the MIS-based approach to be below the average value for Spain using the 10% indicator. Conversely, Galicia, Aragon or Castilla y Leon show higher values for the 10% but very low ones for the MIS-based. This apparent paradox is easily explained when climate or income factors are considered: Ceuta, Canarias and Andalusia feature a mild climate, with hence lower energy expenditures, but lower-than-average incomes, therefore showing much higher values for MIS-based than for the 10% indicator. Galicia, Aragon or Castilla y Leon, in turn, are colder regions but with much higher income. Interestingly, Castilla-La Mancha combines both a harsh climate and a low income, making it feature strongly both under the MIS and 10% approaches (leading in fact the latter). Again, the dichotomy between the indicator measuring mostly energy expenditures (10%) and the one that includes income effects (MIS) is clearly shown.

3.3. Practical limitations of the MIS-based indicator

As anticipated in the previous section, the main difficulty faced by MIS-based energy poverty indicators is how to determine the minimum income standard. A change in this value would mean a significant change in the indicators obtained. In order to analyze to what extent this factor influences the indicator, a sensitivity analysis was carried out.

As can be seen in Fig.3, the dependence on the MIS of the MIS-based indicator is very strong. For example, if instead of choosing the MIS from the average RMIs in the regions weighted by population, we choose the MIS proposed by Caritas, (85% of the inter-professional minimum wage, €550), the

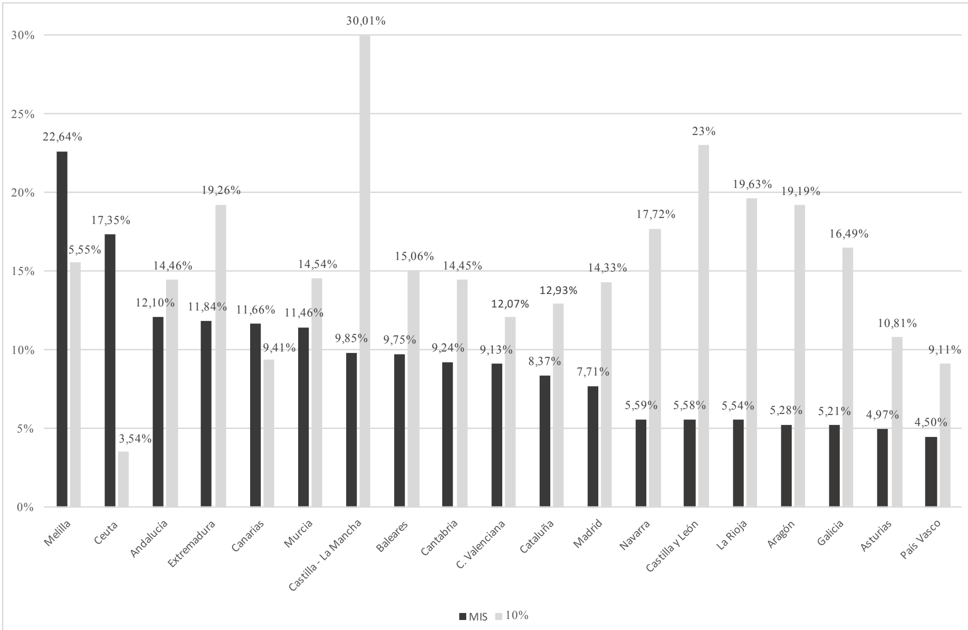

Figure 2: Regional energy poverty in Spain in 2015

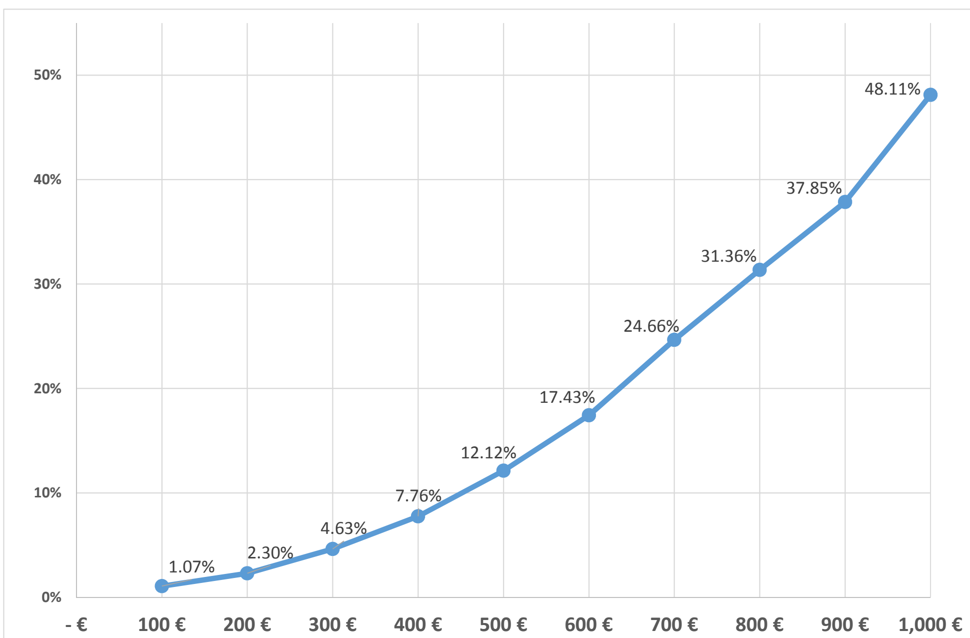

Figure 3: Sensitivity analysis to MIS

MIS-based indicator would have reached 15%, 72% higher than the original one.

This strong relationship led us to develop a more in-depth analysis to illustrate the possible deficiencies of the indicator and, at the same time, to propose strategies that would help to mitigate them. Ultimately, the question is whether the strong assumption that the MIS chosen covers the essential minimum expenses of any household is true.

Firstly, an analysis of the influence of housing expenditures was done. Given that this is the main expenditure in aggregate terms for households, the first step was to disaggregate the energy poverty indicator into two groups according to the tenure status of the household. On the one hand, the owners without mortgage and on the other hand those owners who were facing a mortgage and rented households. In this way we sought to isolate the influence that housing expenditures were having on the calculation of the indicator.

The first group is characterized by having zero housing expenditures, €1,075 average expenditure on energy and a 7.24% MIS-based energy poverty indicator. The average household expenditure of the second group is €5,518, their average expenditure on energy is €1,010 and their energy poverty indicator is 7.84%.

The results for the first group were coherent: their MIS-based energy poverty indicator is lower than the global indicator. Nevertheless, the results obtained for the second group were not. It did not seem coherent to us that the MIS-based energy poverty indicator of this group, whose expenditure on household is not zero, is lower than the MIS-based indicator of the complete set of households (7.84% versus 8.7%). The answer of this paradox was found analyzing the last component of Eq.5.

After subtracting the average household expenditures from the MIS in order to eliminate the influence of this factor in the calculation of the energy poverty indicator, the MIS equivalent obtained became zero or even negative for some households, specifically those constituted by only one person. This fact made them to be considered not energy poor when some of them actually could be. In other words, a problem of false negatives associated to the MIS-based indicator was found, and the reason for that is the MIS selected, which does not cover the total needs of the household in some cases.

In order to detect those false negatives, a particular analysis of households constituted by only one member was developed. Eq.5 was applied to this group and 52,000 households were revealed to be energy poor, i.e. 0.29% of total households in Spain. Thus a corrected MIS-based energy poverty figure for Spain in 2015 would be 8.99%.

The conclusion of this analysis is that, if a MIS-based indicator is to be used to measure energy poverty, this MIS has to be calculated in a manner in which its ability to cover the total needs of the household is absolutely guaranteed.

This would require defining a set of basic standard needs according to certain geographical and social characteristics of the household. For instance, regarding the basic energy needs, that component of the objective MIS would be calculated as the cost of the minimum energy needs of the household attending to the climate condition of its geographical area, to its energy efficiency and to the average cost of energy in the area. Similarly, the other components of the MIS (namely, food, clothes, shoes, health, education, etc) should be calculated attending to the typology of the household. It should be noted that one of these components is the housing expenditure, the most controversial and problematic component, as shown above, that will have to be managed carefully.

According to this methodology, there would be *indications* of energy poverty in a household when:

$$[Net\ household\ income] - [Actual\ Household\ expenditure\ on\ energy] > [non\ energy\ MIS]_{Type\ T} \quad (6)$$

where the $[non\ energy\ MIS]_{Type\ T}$ stands for the MIS of a household classified as type 'T' excluding its energy needs. In order to further analyze those indications of energy poverty the following two issues are to be checked:

1. If the income of the household is higher than the equivalent MIS of type 'T' households. If that is the case, the household can be considered specifically energy poor. Otherwise, that household is income poor, being energy only one of the factors contributing to this situation.

2. For those energy poor households, it should be verified if their energy expenditures are higher than the energy component of the MIS of the type 'T' household to which they belong. If so, the nature of the energy poverty of those households would be related to their energy bills, which are too high because of the inefficiency of the household or because of

sumptuous expenditures. Otherwise, the nature of their energy poverty would be related to structural high costs of energy in the area.

Of course, this methodology based on the calculation of an absolute MIS requires a complex previous process in which the different components of the MIS for the different typologies of households are properly designed and calculated. In addition, this methodology requires a data source that compiles household income and the actual and theoretical energy expenditures. Both the EHS (in the UK) and Phebus (in France) surveys already do so. Unfortunately, although the Spanish Institute for Energy Diversification and Saving (IDAE) provides statistics about theoretical energy expenditures in households, since neither the EPF nor the ECV in Spain currently collect this information, both sources cannot be related.

However, all this discussion about the right aggregate indicator is not enough to design energy poverty policies, since they do not allow us to identify vulnerable households, nor those elements that characterize them. Identifying vulnerable consumers also will help us to assess whether the indicator is correct or not, and its implications for policy-making.

4. From indicators to policies: defining vulnerable households

Once a global energy poverty indicator has been calculated, the second step in the way to design effective policies that are able to cope with this issue is to identify the characteristics of those households more vulnerable to energy poverty. This way, specific policies targeting specific criteria can be implemented.

4.1. Methodology of the vulnerability analysis

The methodology proposed in this study is an econometric analysis based on Legendre's proposal (Legendre and Ricci, 2015). We estimate a logit model in which the dependent variable is equal to one if the household is energy poor according to the MIS-based indicator, and zero otherwise. The variables from the EPF that have been used in the analysis are shown in Table 5.

Following the logit model methodology, we assume that there is a latent variable ($yi*$) so that

$$y_i^* = x_i^{'}\beta + \epsilon_i \tag{7}$$

x being the vector of explanatory variables and ϵ the error term. This variable y_i^* is unobservable, we only observe y_i, binary variable equal to 1 if the household i is in a situation of energy poverty according to the indicator based on MIS and equal to 0 if not. Thus, the probability that the household is vulnerable will:

$$P(y_i = 1) = P(y_i^* > 0) = P(\epsilon_i > -x_i^{'}\beta) \tag{8}$$

We assume that ϵ follows a standard logistic distribution, estimating a logit model.

The logit model presents the advantage of highlighting the direct relationship between the estimated coefficients and the probability ratios (Cameron and Trivedi, 2005). Thus, if the probability ratio is greater than one, it means a greater probability of energy poverty and viceversa with regards to the base or reference household type.

Table 5: Variables in the vulnerability analysis. Source: Spanish EPF in 2015

	Description	**Reference**
Type of household	Single person; Couple without children; Large family with high income; Large family with low income; Non-large family	Single
Tenure status of households	Property without mortgage; Property with mortgage; Rental; Free or semigratuary cession	Free or semigratuary cession
Type of house	Independent single family; Semi-detached house; Building with less than 10 dwellings; Building with 10 or more dwellings; Others	Others
Age of the property	More than 25 years old; Less than 25 years old	Less than 25 years old
Heating	Electricity; Natural gas; Liquefied gas; Liquid fuels; Solid fuels; Solar power; Housing without heating	Solar power
Type of employment of the main breadwinner	Directors and Managers; Technicians and professionals; Administrative employees and service and trade workers; Artisans and skilled workers from other sectors, operators and assemblers; Workers in elementary occupations; Others	Others
Employment of the main breadwinner	Worker; With work from which you are temporarily absent; Retired; Student; Household work; Permanent incapacity for work; Other	Other
Education level of the main breadwinner	Primary studies (or without studies); Secondary studies; Higher education	Higher education
Area of residence	Urban; Rural	Rural
Members of the family under 14 yrs	***	***
Members of the family over 65 yrs	***	***
Dummy low energy consumption	***	***

Note: We consider that a household has a very low energy consumption if its equivalent per capita energy consumption is below the first quartile. Large families with high income are defined as families with three or more dependent children (or two in certain circumstances, see Law 40/2003 of 18 November on the protection of large families) and an equivalent income above the fifth decile, with a large family with a low income that also has at least three dependent children but an income level below the fifth decile. Likewise, we consider as non large families those with fewer than 3 dependent children other than those formed by a single person or a couple.

As indicated above, we have a sample of 22,130 households by 2015. All the variables included in the model are dummies, including for each category as many dummies as there are alternatives except for one, known as a base or reference, and on which the probability coefficient is calculated.

4.2. Results

Table 6 summarizes the results of the vulnerability analysis. It is noteworthy that the configuration of the household significantly increases the likelihood of a household to be energy poor, although it is always linked to the income. Families with children and especially those with lower incomes are more likely to be energy poor than households formed by a single person, a couple without children or large families with high incomes. Besides, the larger the number of children in the home, the larger the likelihood that the household is energy poor; whereas the number of members over 65 years has a negative coefficient, reducing the likelihood of households to be energy poor.

All the above suggests that any measure taken to reduce energy poverty should have to take into account not only the income but also the configuration of the household.

The tenure status of the housing has also a big influence on the probability of a household to be energy poor. Households with home ownership without a mortgage show a lower probability to be energy poor than households living in rented flats or those with a mortgage. In fact, the former doubles the probability of being energy poor of the latter. One possible explanation for this phenomenon is that renting is an indication of lower income. Nevertheless, given the limitation of the MIS-based indicator highlighted above, i.e. the strong influence of the mortgage and the rent in the MIS, we should be cautious with these results.

A third element worth analyzing is the occupation of the main breadwinner of the household. There is a greater probability of the household being energy poor if the main breadwinner is unemployed, has an elementary occupation or is an administrative or service worker (though it is not the most important factor in relative terms). In addition, the educational level of the main breadwinner has an influence as well, so that a household whose main breadwinner has only primary studies or no education at all is more likely to be energy poor.

If we focus on households constituted by a single retired person (a specially sensitive group of population), according to the MIS-based energy poverty indicator calculated over the average values of the total population, 1.12% of those households would be energy poor (16,929 households).

Table 6: Vulnerability to Energy Poverty. Spain. 2015

	Coefficients	Probability ratios
Type of household		
Single	0.2325*	1.2618*
large family High income	-1.553	0.2116
Large family Low income	2.3852***	10.8608***
Normal family	1.0008***	2.7205***
Tenure status of households		
Without mortage	-0.898***	0.4074***
With mortage	0.9636***	2.621***
Rent	1.2661***	3.5468***
Type of house		
Detached house	-0.2885	0.7494
Terraced house	-0.496	0.6090
Condo less than10 apartments	-0.6464	0.5239
Condo more than 10 apartments	-0.7003	0.4965
Age of the property		
Older than 25 yrs	0.2254**	1.2529***
Heating		
None	-0.3282	0.7202
Electricity	-0.7226	0.4855
Natural gas	-0.8685	0.4196
GLP	-0.8465	0.4289
Liquified fuel	0.748	0.4733
Solid fuel	-0.6065	0.5452
Type of employment of the main breadwinner		
Manager	-0.100	0.9048
Professional	-0.3714*	0.6898*
Administrative employee	0.3390*	1.4036*
Craftman	0.1811	1.1985
Elementary jobs	0.8996***	2.4586***
Employment of the main breadwinner		
Employed	-1.9742***	0.1389***
Leave	-1.8607***	0.1556***
Unemployed	0.7416***	2.0992***
Retired	-1.4700***	0.2299***
Student	0.5341	1.7059
Household tasks	-0.7227**	0.4854**
Permanent disability	-0.8991***	0.4069***
Education level of the main breadwinner		
Primary	0.8554***	2.3523***
Secondary	0.4566***	1.5787***
Area of residence		
Urban	0.2043**	1.2267**
Members of the family under 14 yrs	0.1642***	1.1785***
Members of the family over 65 yrs	-0.7623***	0.4666***
Dummy low energy consumption	0.1717**	1.1873**

$R^2 = 0.3634$ Wald $c^2(53) = 4612.90(p - valor = 0.0000)$

Note: Asterisks indicate the level of significance of the parameters, so that *** indicates significance at 1%, ** at 5% and * at 10%

It is striking the little significance of the energy consumption indicator (contrary e.g. to the indicators used in the Spanish "bono social"); what tell us that simple measures such as those that try to identify vulnerable consumers based only on their level of consumption do not make much sense. Instead, the age of the dwelling does indicate a greater vulnerability, but its effect is not very relevant.

In summary, low-income households, with children and with job instability of their breadwinners, are the most vulnerable to energy poverty. Therefore, policies designed to deal with energy poverty issues should be primarily focused on them.

We also performed a sensitivity analysis of the previous results by restricting the consideration of households in a situation of energy poverty to those that, in addition to being considered energy poor according to the MIS-based indicator, have an equivalent level of income below the median. Therefore, possible false positives were excluded and the consistency of the previous results could be highlighted. The results of this new estimation, included in Appendix A, are similar to the previous ones and also have the same significant variables and with the same sign, which shows the robustness of the previous results.

4.3. Evaluating policies using a vulnerability analysis

Finally, and as an example of the policy implications of the analysis carried out in the paper, we can apply what we have learned from the analysis of vulnerability to the current social tariff in Spain, to check its alignment with the real problem it tries to solve.

The social tariff in Spain (similar to the one existing in other countries) allows some specific households belonging to certain categories, to apply for a discount of 25% or 40% of their electricity bill. Although its most recent version (RDL 7/2016, 23th of December, draft of April 29th, 2017) has incorporated an income criterion (which, according to our analysis of vulnerability, is essential), it still has certain shortcomings that prevent it from addressing efficiently and effectively the problem of energy poverty in Spain.

On the one hand, its use is still restricted to electricity, which only covers part of the energy consumption of households. Specifically, according to EPF microdata in 2015, electricity expenditure by Spanish households accounts for an average of 62% of their total energy expenditure, so the social tariff does not cover, on average, 38% of the household expenditure on energy.

H

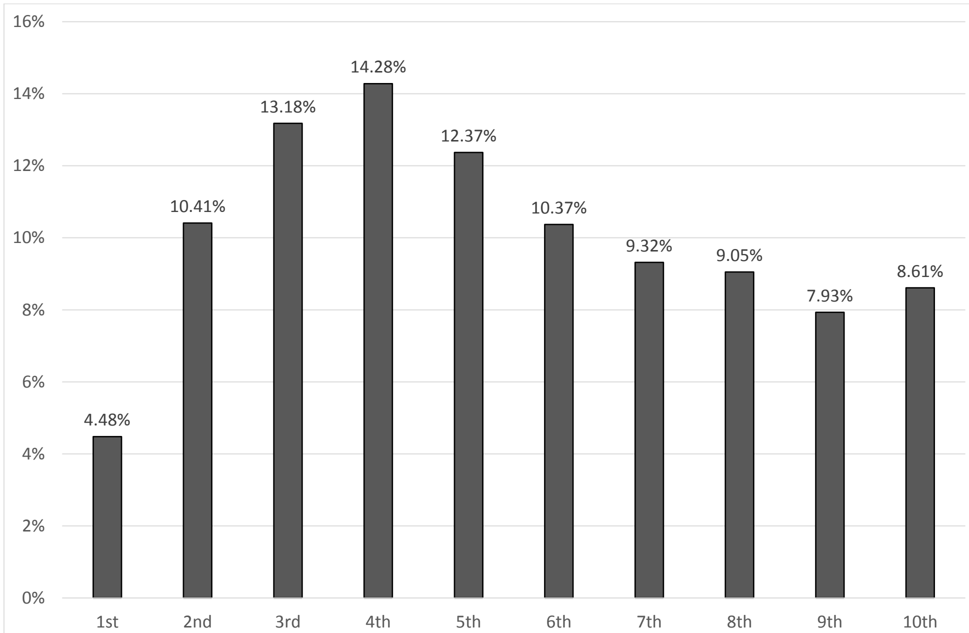

Figure 4: Distribution of households with members 65 years per decile of equivalent income

Since energy poverty is associated with total household energy consumption, mitigation measures should cover the different energy products.

On the other hand, the social tariff does not include considerations about housing tenure regimes, and it still includes some household typologies which do not necessarily correspond to vulnerable consumers: large families and pensioners. We now analyze whether these households really deserve the consideration of vulnerable consumers.

First, although in the EPF there is no information on households with pensioners, our results indicate that the presence of members aged 65 or over in the household reduces the probability of being energy poor and, in addition, if we observe the distribution of households with persons over 65 per decile of equivalent income (Fig.4), we see that in 2015 more than 45% of households belonged to one of the five highest deciles of equivalent income. Therefore, it does not seem that this is a vulnerable group.

Second, regarding large families, although the EPF does not directly indicate if a family is large, from its information we have calculated the distribution of large families by deciles of equivalent income. In this case we see

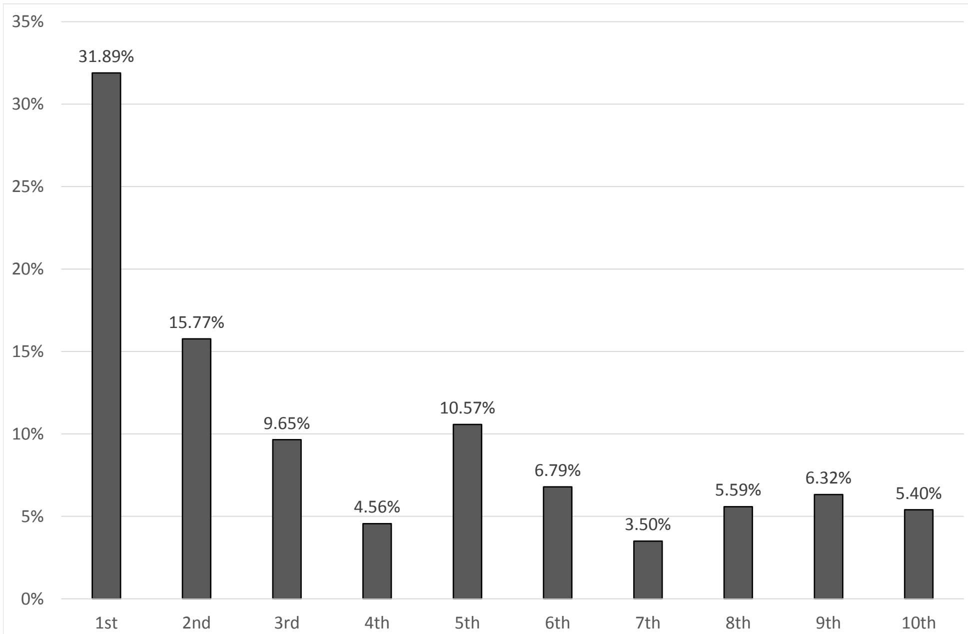

Figure 5: Distribution of large families by deciles of equivalent income

in Fig.5 that large families are included in the lower deciles, but it is also observed that more than 20% of large families have an equivalent level of income above the fifth decile and therefore should not be considered vulnerable.

Therefore, although the recent reforms of the Spanish social tariff do incorporate some of our findings (regarding the need to consider income levels) we see that there is still potential to design more efficient policies which better address vulnerable consumers. The development of better energy poverty indicators, and of vulnerability analyses based on them, is clearly required to advance in this direction.

5. Conclusions and Policy Implications

The results of our empirical analysis highlight that the most common objective, income-based, energy poverty indicator used so far, i.e. the 10% threshold, includes in most settings a high number of false positives. This fact, together with the relative nature of the LIHC indicator, which makes it more suitable to measure energy inequality than energy poverty, make us recommend the use of a MIS-based energy poverty indicator, calculated on an objective and absolute basis.

However, there are still some limitations regarding this indicator that need to be overcome: namely, the consideration of housing expenses, and also the correct definition of energy needs. And of course the definition of a MIS that includes all the basic expenses of the household.

Moreover, since as mentioned above, indicators only provide aggregate figures which do not allow us to clearly identify households at risk, something essential to design adequate policies, we also need to perform analysis of the factors that indicate vulnerability to energy poverty. In the Spanish case, these are households with low incomes, with children and with employment instability of their breadwinners. Interestingly, the Spanish social tariff only includes the income criterion, but at the same time includes population groups that do not seem to be vulnerable: large families and pensioners.

In light of these results, the following policy recommendations are proposed:

1. To select a sound and robust global energy poverty indicator together with the right methodology for its calculation. After the analysis presented in Section 2, a suitable objective and income-expenditure based energy poverty indicator would be one that (1) takes into account both incomes and expenditures of the household (thus avoiding a big number of false positives) and (2) can be calculated using an absolute strategy so that it measures actual energy poverty instead of energy inequality. Thus a MIS-based energy poverty indicator is probably the most suitable alternative. Nevertheless, a new approach able to overcome the current flaws is still needed. A possible alternative has been presented in Section 3.

2. To provide a definition of the vulnerable consumer which is aligned with the profile identified. Providing this definition is also mandatory according to the European Commission Directives 2009/72 and 2009/73 on the Electricity Market and the Gas Market, in which member states are urged to establish a clear definition of the "vulnerable consumer" as a preliminary step in drafting legislation to protect them. The results of the vulnerability analysis of this paper can help to establish that vulnerable consumer profile. As can be seen in Table 6, low-income households with children, paying rent, and with an unstable employ-

ment situation are clearly those that are most vulnerable to situations of energy poverty.

3. To design an appropriate support system. A support system aligned with the results of our previous analysis could be a social tariff that (1) covered the costs of all energy sources (Bouzarovski and Petrova, 2015), not just electricity and (2) were available to vulnerable consumers and only them: i.e. low-income families with children under their care, and with unstable employment status, as explained in Section 4.3

Other measures that could be implemented are those energy efficiency measures which have, in theory, great potential to alleviate energy poverty by reducing the energy expenditure required to achieve basic energy services. However, as in the case of the social tariff, for these measures to actually have the right effects, the recipients should be only the vulnerable households. In all cases, as with any other policy measures, they should be based in strong evidence.

Eventually, we hope that the analysis presented in this paper provides sound reasons for improving energy poverty measures adopted so far (Imbert et al., 2016), specially in the European context.

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Appendix A. Sensititity of vulnerability analysis

Table A.7: Sensitivity analysis. Vulnerability. Spain. 2015

	Coefficients	**Probablity ratios**
Type of household		
Single	0.2371*	1.2675*
large family High income	2.4035***	11.0623***
Large family Low income	1.0101***	2.7458***
Normal family		
Tenure status of households		
Without mortage	-0.8962***	0.4081***
With mortage	0.9551***	2.5989***
Rent	1.2606***	3.5275***
Type of house		
Detached house	-0.3176	0.7279
Terraced house	-0.5042	0.6040
Condo less than10 apartments	-0.6353	0.5298
Condo more than 10 apartments	-0.6855	0.5039
Age of the property		
Older than 25 yrs	0.2269***	1.2547**
Heating		
None	-0.3416	0.7107
Electricity	-0.7449	0.4748
Natural gas	-0.8877	0.4116
GLP	-0.8550	0.4253
Liquified fuel	-0.7854	0.4559
Solid fuel	-0.6107	0.5430
Type of employment of the main breadwinner		
Manager	-0.1519	0.8591
Professional	-0.3896*	0.6773*
Administrative employee	0.3504*	1.4196*
Craftman	0.1885	1.2074
Elementary jobs	0.9029***	2.4667***
Employment of the main breadwinner		
Employed	-1.9774***	0.1384***
Leave	-1.8540***	0.1566***
Unemployed	0.7455***	2.1075***
Retired	-1.4799***	0.2277***
Student	0.5481	1.7300
Household tasks	-0.7241**	0.4848**
Permanent disability	-0.8911***	0.4102***
Education level of the main breadwinner		
Primary	0.8499***	2.3394***
Secondary	0.4479***	1.5651***
Area of residence		
Urban	0.1938**	1.2139**
Members of the family under 14 yrs	0.1630***	1.1771***
Members of the family over 65 yrs	-0.7542***	0.4704***
Dummy low energy consumption	0.1756**	1.1919**

$R^2 = 0.3636$ Wald $c^2(53) = 4586.50(p - valor = 0.0000)$
Note: Asterisks indicate the level of significance of the parameters, so that
*** indicates significance at 1%, ** at 5% and * at 10%