Energy solvency. A new concept to prevent energy poverty in Spain.

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Abstract

The new concept of energy solvency is defined as the ability of a person buying or renting a dwelling to meet the energy costs necessary to keep the dwelling comfortable, without falling into energy poverty. The energy efficiency certificate information is used to calculate the economic expenditure that is theoretically necessary to maintain the property comfortable. This is a more robust value for calculating the energy poverty indicator 2M than the available data on real expenditure. Dwellings' maximum surface may be determined in order to guarantee the energy solvency, depending on the climate zone, the energy class, the energy sources used, and the household's net income. The results indicate that in 15% of situations, it is not possible to have a dwelling that exceeds the minimum surface area stipulated by law without incurring an energy risk situation. It is also observed that in 86% of the cases, energy solvency is achieved for dwellings with energy class A, B, C, and D, up to 120 m^2. It is concluded that, by knowing the energy solvency before renting or buying a home, it is possible to prevent energy poverty by avoiding those operations in which it is known that this will happen.

Key words

Energy poverty, Energy performance certificates, Energy cost, Energy empowerment, Energy solvency

1. Introduction

When a person applies for a loan for the purchase of a home in Spain, the financial institution is obliged to check the applicant's financial solvency (Jefatura de Estado, 2019). Among other requirements, it checks the applicant's capacity to repay the loan. To do so, it verifies that the mortgage payment does not exceed 35% of the applicant's net monthly income.

Proper identification of bank customers' solvency is of paramount importance, as the default of payment on loans has serious repercussions in many areas. Increasing default rates threaten the solvency of credit institutions, but their vulnerability is also a major economic and political problem. No government can afford the collapse of its banks, given that each one of them is strongly intertwined with the rest of the financial institutions and with multiple other economic actors (companies and households). The collapse of one credit organization drags down other agents and may feed a more general state of panic, which is why governments are obliged to take all necessary measures to stop it.

The social costs associated with financial crises are of less academic relevance but of equal or greater real importance. At a macroeconomic level, they generate situations of high unemployment and significant cuts in social spending, which tend to be most damaging for the most vulnerable groups dependent on public resources. At a microeconomic level, financial insolvency has devastating consequences. Those who cannot repay their loan lose the value of their home, the value of the assets put up as collateral, the savings they invested in it, and their ordinary housing. At the end of the process, they often remain significantly indebted and registered as defaulting and insolvent, making it more difficult for them to access new loans, even if their economic situation improves in the future.

Likewise, when a person rents a property, landlords/ladies check the tenant's financial solvency to minimize the risk of non-payment, although in this case there is no legal requirement to do so. The same indicator is usually used: that the rent does not exceed 35% of the tenant's net monthly income.

The study of economic solvency aims, therefore, to ensure that the tenant has the economic capacity to pay the mortgage or the rent.

This paper proposes, as a novelty, the introduction of the concept of energy solvency. This might be defined as the ability of the person buying or renting a home to meet the energy costs necessary to maintain the home in a comfortable situation, without falling into a situation of energy poverty.

The concept of energy solvency aims to link two concepts widely consolidated in the literature: energy poverty and economic solvency. In this way, a concept of this nature would generate practices in economic agents and in the administration intended to prevent social situations of vulnerability while at the same time encouraging construction measures that promote energy efficiency.

In April 2019, the National Strategy against Energy Poverty 2019-2024 (ENCPE in Spanish) was approved. For the first time in an official Spanish document, energy poverty is defined as "the situation in which a household's basic energy supply needs cannot be met due to an insufficient level of income and which may be aggravated by having an energy-inefficient dwelling" (Ministerio para la Transición Ecológica, 2019). One of the indicators used to determine whether a household is in an energy poverty situation is the "Disproportionate expenditure (2M)" indicator, which considers under this situation those households whose energy expenditure in relation to their income exceeds twice the national median. In addition, the M indicator is used to determine whether a household is in a situation of energy vulnerability, which assesses the potential of a household to fall into energy poverty. It is reached when a household is at half the value of the 2M energy poverty threshold (Sánchez-Guevara, Propuesta metodológica de evaluación de la pobreza energética en España: indicadores para la rehabilitación de viviendas, 2015).

As well as net income is compared with the cost of the mortgage or rent to assess financial solvency, to reduce the risk of default, comparing net income with the cost of energy could reduce the risk of falling into energy poverty. This would be a preventive measure with higher effectiveness than conducting an intervention once the risk has materialized.

If the next mortgage law, in addition to requiring financial institutions to study economic solvency, also required them to study energy solvency, it could prevent future situations of energy poverty. It would be beneficial for: the people who would be prevented from entering a foreseeable situation of energy poverty; the healthcare system, which would avoid the consequences on the health of people suffering from this situation; and the State, whose results in the fight against energy poverty would not be worsened as a result of this issue. Although financial institutions could be harmed by placing an additional requirement on their mortgage business, they could improve their reputation by assuming greater social responsibility in their activity.

In the renting area, there is no legal requirement to carry out a financial solvency study. The consequences of non-payment of rents, as they are more spread out, do not affect the economy as a whole in the same way an increasing mortgage default rate may impact the banking sector. However, energy poverty does have an important effect on society as a whole, affecting a large number of people, with consequences on their health and on the rest of the vital activities they carry out, as they have a home that is not able to adequately meet their comfort needs.

This paper aims to apply the new concept of energy solvency to the socio-economic data of Spain to establish the limits that should not be crossed to avoid a situation of energy poverty when renting or buying a home.

2. Background

The enormous impact of the past real estate-financial crisis has generated widespread concern about economic solvency. Let us not forget that bank bailouts placed a very significant burden on public finances in Europe, as well as slowing down the subsequent recovery. It is estimated that 62 banks in 15 EU countries have received no less than 413 billion euros of taxpayers' money (Valera, 2019). In Spain alone, state aid amounted to 65.725 billion euros (Banco de España, 2019).

The social consequences were also very serious. The unemployment rate in the European Union rose from 8.8% to 10.3% between 2008 and 2013, when it peaked (Draghi, 2014). But in countries such as Spain, the impact of the crisis was much more intense. In the same period, the level of unemployment rose from 13.9% (4,010,700 unemployed) to 25.9% (5,904,700 unemployed) (Eurostat, 2013). On the other hand, "between 2008 and 2014, 604,489 foreclosure processes were initiated and 378,693 evictions were ordered, of which 244,267 were executed" (Raya, 2017). All this in a context in which people at risk of poverty and social exclusion went from representing 23% of the population to 27% (Eurostat, 2014).

Concern about economic solvency in the mortgage field, especially in the wake of the past crisis, has led to the development of bank-targeted rules that attempt to prevent default situations and their repercussions. The European Union established criteria (Unión Europea, 2013), (Unión Europea, 2013) that the states had to transpose into their national legislation (for Spain (Gobierno de España, 2013), (Gobierno de España, 2014)).

In the case of Spain, the new legislation also aims to ensure that small customers cannot be easily deceived by the complexity and technicality of credit contracts, unaware of the risks involved (Ministerio de Economía y Hacienda, 2011), (Banco de España, 2012). And to moderate the negative impact of insolvency, countries such as Spain were forced to modify legislation, facilitating the use of figures such as dation in payment (Jefatura del Estado, 2012) or, more recently, toughening the conditions for executing an eviction (Jefatura del Estado, 2020). Some have even considered Spanish credit regulation as an instrument of real estate dispossession for the most economically vulnerable sectors in favor of the banks (Yrigoy, 2019).

Although energy poverty was defined in the United Kingdom for the first time in 1983 as the inability to afford adequate heat in the home (Bradshaw & Hutton, 1983), it has not been defined in any official document in Spain until 2019. Over these 37 years, the concept has undergone a significant evolution. Intending to make it a measurable concept, Boardman in 1991 postulated that energy poverty affects households whose expenditure on all energy services exceeds 10% of their income (Boardman, 1991). In addition, he extended the scope of attention to include, along with heating, other energy services such as domestic hot water production or food refrigeration, among others.

Throughout this time, certain limitations have been detected in this definition and in the indicator used to measure the phenomenon. The arbitrary nature of the threshold has been highlighted (Heindl, 2015). To adapt the 10% threshold to local circumstances at any given time, the indicator "Disproportionate expenditure (2M)" is used: households whose energy expenditure in relation to their income exceeds twice the national median (Romero, Linares, López Otero, Labandeira, & Pérez Alonso, 2014).

The main strength of the 2M indicator is that it uses a readily available statistical data source: the Household Budget Survey (HBS) (Instituto Nacional de Estadística, 2020). Moreover, as it is a survey conducted annually in the European Union, it is possible to compare its historical evolution in the different member countries.

The two major weaknesses of the 2M indicator are that it excludes households that do not use energy services because they cannot afford them (Hills, Fuel Poverty: The problem and its measurement. Interim Report of the Fuel Poverty Review. (No. CASE Report 69), 2011), and it includes households with large energy bills because they waste energy, regardless of their income (Moore, 2012). Another weakness of the 2M indicator that does not directly affect Spain, but is relevant in Central and Eastern Europe, is the use of cheapest or even free fuels such as waste, boards or low-quality coal, wich mask energy poverty (Karpinska & Śmiech, 2020).

To avoid such situations, Hills introduces a new indicator: Low Income High Cost (LIHC): Households that require energy costs above the median; and if they were to spend that amount, they would be left with a residual income below the official poverty line (below 60% of median household income after subtracting housing costs and modeled equivalent energy costs) (Hills, Getting the measure of fuel poverty. Final Report of the Fuel Poverty Review. CASE report 72, 2012).

The more complete and precise the definition, the more complex it is to measure. This approach uses the energy expenditure required to achieve a given level of comfort, not the energy expenditure actually incurred. It is used in the United Kingdom, which has developed a specific survey to measure energy poverty, the English Household Condition Survey (EHCS). This survey is more comprehensive than the survey used in EU countries (EPF), which is not specific to measuring energy poverty. It obtains data on the number of people in the household, physical attributes of the dwelling, occupancy status, and energy use (DEFRA & BERR, 2008). The United Kingdom has also developed a tool that allows, with the data obtained in the EHCS survey, to find out the energy needed in each household to maintain comfort conditions: Building Research Establishment Domestic Energy Model (Tirado Herrero, Jiménez Meneses, López Fernández, & Irigoyen Hidalgo, 2018).

The actual energy consumed in households is less than the energy required to achieve comfort conditions. The actual energy expenditure of English households in 2009 was between 66% and 82% of the theoretical expenditure required to satisfy an adequate level of thermal comfort (Tirado Herrero, López Fernández, & Martín García, Pobreza energética en España. Potencial de generación de empleo derivado de la rehabilitación energética de viviendas, 2012).

To address the actual under-consumption detected, in cases where no theoretical consumption data are available, subjective indicators are introduced, such as the inability to keep the home adequately warm during the winter (European Economic and Social Committee, 2011). They can be obtained from an available statistical data source: Living Conditions Survey (LCS) (Instituto Nacional de Estadística, 2020), which is conducted in the European Union.

Subjective indicators exhibit significant variability depending on factors such as the severity of winter weather (Sánchez-Guevara, Sanz Fernández, & Hernández Aja, Income, energy expenditure and housing in Madrid: retrofitting policy implications, 2015). The subjective approach causes some mistrust in the academic world (Romero, Linares, López Otero, Labandeira, & Pérez Alonso, 2014).

The definition of energy poverty approved in Spain includes the three main factors to which Luxán attributes energy poverty: the high cost of energy bills, low household income, and low energy efficiency in housing (de Luxán García de Diego, Sánchez-Guevara, Román López, Barbero Barrera, & Gómez Muñoz, 2017). However, the quantitative indicators employed focus on household income and energy expenditure but do not take into account electricity prices, the energy efficiency of the dwelling, or the degree to which comfort conditions are achieved.

The study of energy poverty at the national level does not take into account regional differences due to climate, which in Spain differs significantly. Buildings in Las Palmas de Gran Canaria have a heating demand 20 times lower than those in Burgos (Grupo de Termotecnia de la Escuela Superior de Ingenieros Industriales de la Universidad de Sevilla, 2009).

In the absence of a specific survey and a model that is capable of taking into account all these variables, as in the UK case, this paper uses an alternative way to find out if a person who wants to buy or rent a home is going to be in a situation of energy poverty, if they are at risk of energy poverty or if they are energy solvent. To do this, it uses the data collected to draw up the Energy Performance Certificate, which is compulsory when a property is sold or rented (Ministerio de la Presidencia, Relaciones con las Cortes y Memoria Democrática, 2021).

The Energy Performance Certificate calculates, through a computer tool (Ministerio para la Transición Ecológica y el Reto Demográfico, 2021), the energy consumption of a dwelling under standard conditions of use to be able to compare the results. Therefore, it does not take into account how the dwelling is used. It does not provide actual consumption results, but theoretical results of the consumption needed to achieve comfort conditions (Marmolejo Duarte & Onecha Pérez, 2021).

The data that the Energy Performance Certificate does not provide to determine energy poverty is easier to obtain and operate, than the energy modeling of the building that allows the necessary energy consumption to be determined, which is more accurate in the assessment of energy poverty than the actual energy consumption.

In the Spanish context, there have been several attempts to economically quantify the expenditure necessary to maintain a dwelling in comfortable conditions.

Firstly, Martín Consuegra has studied energy poverty at the urban level (Martín-Consuegra, Hernández Aja, Oteiza, & Alonso, 2019). He starts from the heating energy demand values of the thermal envelope of a given building according to its age (Aksoezen, Daniel, Hassler, & Kohler, 2015). With these values, he assigns each census section an energy class. He transforms heating demand into energy consumption and he completes the rest of the energy consumption according to the data provided by the Institute for Energy Diversification and Saving (Instituto para la Diversificación y Ahorro de la Energía, 2011). Finally, he obtains the economic cost according to the method described by Alonso (Alonso, Martín-Consuegra, & Lucas, 2013). It obtains from the cadastre (Ministerio de Hacienda y Función Pública, 2021) the geometric data of the envelope and the age of the entire building stock. This is an important amount of data, necessary when knowing its geographical location is required, but which slows down its handling and makes its processing difficult due to its volume.

Secondly, the General Council of Technical Architecture has developed a tool for the indicative calculation of basic energy costs based on the indicators of the Energy Performance Certificate (Consejo General de la Arquitectura Técnica de España, 2021). It is an agile and easy-to-use tool. The values only consider consumption due to heating, domestic hot water, and cooling. It does not take into account consumption from lighting or household appliances (Payán de Tejada Alonso, López-Asiain Martínez, Fernández Castillo, & Luna González, 2020). Another limitation is that it handles data individually, so it is not agile for a large number of data.

Finally, Gallego studies the relationship between the energy cost and the rental cost of dwellings in the different climatic zones of Spain (Gallego Sánchez-Torija, Fernández Nieto, & Gómez Serrano, 2021). To do so, he complements the energy consumption data provided by the Energy Efficiency Certificate (heating, domestic hot water, and cooling) with the rest of the energy consumption based on the data provided by the Institute for Energy Diversification and Saving (Instituto para la Diversificación y Ahorro de la Energía, 2011). He goes further than Martín-Consuegra by differentiating these consumptions according to the type of energy used. To calculate the economic amount of energy consumption, he uses data from the National Commission for Markets and Competition (Comisión Nacional de los Mercados y la Competencia, 2021). He gives the results for a house of an average surface area located in different climatic zones and with different energy classes.

Due to the disaggregation of results offered by the latter author, our work is based on the results he offers.

Interventions aimed at reduce energy poverty once this has occurred present high levels of difficulty. Jacques Aviñó highlights that a more holistic approach, taking into account the importance of the structural determinants and social inequalities is key to provide a deeper understanding of the problem, as well as for the design of equitable policies to reduce the negative impacts of energy poverty (Jacques-Aviñó et al., 2022). Best points out the importance of increasing long-term assistance beyond short-term needs to alleviate the urgent needs related to the lack of affordable energy when in a situation of energy poverty (Best & Sinha, 2021).

Interventions aimed at preventing energy poverty before it occurs, such as the one proposed in this study, manage to reduce the public spending necessary to combat energy poverty (Nguyen & Su, 2022).

3. Methodology

Calculations are made using 2020 values, which are the latest published at the time this paper is written.

First, the net income per household grouped by deciles is calculated. The data is obtained from the Living Conditions Survey (LCS) conducted by the National Statistics Institute (Instituto Nacional de Estadística, 2020).

Next, the intensity of household energy expenditure (energy expenditure per square metre) is calculated. To do this, the energy expenditure calculated by Gallego (Gallego Sánchez-Torija, Fernández Nieto, & Gómez Serrano, 2021) is divided by the floor area of the dwelling used in his calculations. In the mentioned paper, the methodology used to obtain energy expenditure can be observed so that, following said methodology, it can be applied in other cases.

The energy expenditure intensity is calculated for dwellings with the characteristics shown in table 1.

Table 1. Characteristics of studied dwellings

Type of dwelling	Colective
Type of energy consumed	Type 1: Heating: gas; domestic hot water (DHW): gas; cooker: electric; air conditioning: no. Type 2: Heating: electric; domestic hot water (DHW): electric; cooker electric; air conditioning: no.
Energy classification	A, B, C, D, E, F, G
Climatic zone	α, A, B, C, D

Collective housing is selected as the type of dwelling to be studied, since it represents 67.9% of Spanish dwellings (Ministerio de Transportes, Movilidad y Agenda Urbana, 2020).

Regarding the type of energy consumed in the heating installation, we studied dwellings with the two most representative types of energy consumed: 53% of dwellings have a gas boiler and 18% have electric heating (Ministerio de Transportes, Movilidad y Agenda Urbana, 2020).

Regarding the type of energy consumed in the domestic hot water installation, we studied the dwellings with the two most representative types of energy consumed: 79% of dwellings have a gas boiler or gas water heater and 19% have an electric water heater (Instituto para la Diversificación y el Ahorro de la Energía, IDAE, 2019).

Only 30% of Spanish households have an air-conditioning system (Instituto para la Diversificación y el Ahorro de la Energía, IDAE, 2019), so only the consumption of dwellings without air-conditioning is studied.

Both the energy classification and the climate zone where the dwelling is located have a significant impact on the intensity of energy expenditure, so calculations are made for both variables in all cases. As the dwellings do not have an air-conditioning system, only the winter climate zone is taken into account. The summer climate zone is not taken into account, as there is no energy expenditure for cooling the dwelling.

Finally, the energy risk threshold is calculated: the maximum square metres of housing eligible without incurring energy poverty according to the 2M indicator. The energy solvency threshold is also calculated: maximum square metres of housing eligible without incurring energy vulnerability according to the M indicator.

Both indicators are calculated for different deciles of net household income, different climate zones, and different energy classes.

4. Results

Following the methodology described above, the results obtained are shown below.

First, table 2 shows the net income per household grouped by deciles for the year 2020.

Table 2. Net income per household.

Decile	Net income per household (€)
1	6.756,27
2	12.510,25
3	16.766,87
4	21.064,46
5	25.534,52
6	30.011,90
7	35.006,07
8	41.926,07
9	52.312,79
10	76.500,36

Hereunder, Table 3 displays the results of the intensity of household energy expenditure for collective dwellings of type 1 (Heating: gas; domestic hot water (DHW): gas; cooking: electric; air conditioning: no) and type 2 (Heating: electric; domestic hot water (DHW):

electric; cooking: electric; air conditioning: no) for the different climate zones and energy classes.

Table 3. Intensity of energy expenditure.

Energy cost intensity (€/m2)		**CLASS**													
		A		**B**		**C**		**D**		**E**		**F**		**G**	
		Type 1	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**
CLIMATE ZONE	α	11,09	10,29	11,09	10,29	11,09	10,29	11,09	10,29	11,09	10,29	11,09	10,29	11,09	10,29
	A	11,27	10,51	11,52	11,03	11,84	11,72	12,33	12,77	13,53	15,34	14,56	17,54	14,71	17,84
	B	11,35	10,63	11,72	11,43	12,23	12,51	12,98	14,12	14,55	17,48	15,87	20,30	16,08	20,73
	C	11,47	10,86	12,10	12,19	12,96	14,03	14,23	16,74	16,58	21,76	18,48	25,83	18,80	26,50
	D	11,67	11,16	12,61	13,17	13,90	15,93	15,80	20,00	19,13	27,10	21,77	32,73	22,22	33,70
	E	11,82	11,46	13,09	14,16	14,83	17,87	17,39	23,33	21,71	32,57	25,09	39,79	25,69	41,06

Finally, Table 5 shows the energy risk thresholds: maximum square metres of housing eligible without incurring in energy poverty according to indicator 2M. Table 6 shows the energy solvency thresholds: maximum square metres of housing eligible without incurring in energy vulnerability according to indicator M. Both indicators are shown for different deciles of net household income, different climate zones, and different energy classes.

Given the large number of values shown in tables 5 and 6, and to help understand the results obtained, these are grouped following a colour code portrayed in Table 4. Colour red is used for dwelling surfaces below the minimum surface area allowed by the regulations. Since the minimum surface area is regulated at the regional level, the median of the regional values has been adopted, which also coincides with the mode of these values (Kato, 2019).

Table 4. Colour coding for the different surface areas of dwellings available in Spain (Ministerio de Transportes, Movilidad y Agenda Urbana, 2020).

Dwelling surface	**Colour code**	**Percentage of available dwellings**
Below 38 m^2		12,7%
Between 38 and 60 m^2		
Between 60 and 75 m^2		17,6%
Between 75 and 90 m^2		28%
Between 90 and 120 m^2		23%
Between 120 and 150 m^2		8%
Above 150 m^2		10%

Table 5. Energy risk threshold: Maximum dwelling surface to not exceed 2M.

Dwelling surface (m2)	**CLASS**						
	A	**B**	**C**	**D**	**E**	**F**	**G**

CLIMATE ZONE			Type 1	Type 2	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2
	α	D1	30	33	30	33	30	33	30	33	30	33	30	33	30	33
		D2	56	61	56	61	56	61	56	61	56	61	56	61	56	61
		D3	76	81	76	81	76	81	76	81	76	81	76	81	76	81
		D4	95	102	95	102	95	102	95	102	95	102	95	102	95	102
		D5	115	124	115	124	115	124	115	124	115	124	115	124	115	124
		D6	135	146	135	146	135	146	135	146	135	146	135	146	135	146
		D7	158	170	158	170	158	170	158	170	158	170	158	170	158	170
		D8	189	204	189	204	189	204	189	204	189	204	189	204	189	204
		D9	236	254	236	254	236	254	236	254	236	254	236	254	236	254
		D10	345	372	345	372	345	372	345	372	345	372	345	372	345	372
	A	D1	30	32	29	31	29	29	27	26	25	22	23	19	23	19
		D2	56	60	54	57	53	53	51	49	46	41	43	36	43	35
		D3	74	80	73	76	71	72	68	66	62	55	58	48	57	47
		D4	93	100	91	95	89	90	85	82	78	69	72	60	72	59
		D5	113	121	111	116	108	109	104	100	94	83	88	73	87	72
		D6	133	143	130	136	127	128	122	118	111	98	103	86	102	84
		D7	155	167	152	159	148	149	142	137	129	114	120	100	119	98
		D8	186	199	182	190	177	179	170	164	155	137	144	120	143	118
		D9	232	249	227	237	221	223	212	205	193	171	180	149	178	147
		D10	339	364	332	347	323	326	310	300	283	249	263	218	260	214
	B	D1	30	32	29	30	28	27	26	24	23	19	21	17	21	16
		D2	55	59	53	55	51	50	48	44	43	36	39	31	39	30
		D3	74	79	72	73	69	67	65	59	58	48	53	41	52	40
		D4	93	99	90	92	86	84	81	75	72	60	66	52	65	51
		D5	112	120	109	112	104	102	98	90	88	73	80	63	79	62
		D6	132	141	128	131	123	120	116	106	103	86	95	74	93	72
		D7	154	165	149	153	143	140	135	124	120	100	110	86	109	84
		D8	185	197	179	183	171	168	162	148	144	120	132	103	130	101
		D9	230	246	223	229	214	209	202	185	180	150	165	129	163	126
		D10	337	360	326	335	313	306	295	271	263	219	241	188	238	185
	C	D1	29	31	28	28	26	24	24	20	20	16	18	13	18	13
		D2	55	58	52	51	48	45	44	37	38	29	34	24	33	24
		D3	73	77	69	69	65	60	59	50	51	39	45	32	45	32
		D4	92	97	87	86	81	75	74	63	64	48	57	41	56	40
		D5	111	118	106	105	99	91	90	76	77	59	69	49	68	48
		D6	131	138	124	123	116	107	105	90	91	69	81	58	80	57
		D7	153	161	145	144	135	125	123	105	106	80	95	68	93	66
		D8	183	193	173	172	162	149	147	125	126	96	113	81	112	79
		D9	228	241	216	215	202	186	184	156	158	120	142	101	139	99
		D10	333	352	316	314	295	273	269	228	231	176	207	148	203	144
	D	D1	29	30	27	26	24	21	21	17	18	12	16	10	15	10
		D2	54	56	50	47	45	39	40	31	33	23	29	19	28	19
		D3	72	75	66	64	60	53	53	42	44	31	39	26	38	25
		D4	90	94	84	80	76	66	67	53	55	39	48	32	47	31
		D5	109	114	101	97	92	80	81	64	67	47	59	39	57	38

		D6	129	134	119	114	108	94	95	75	78	55	69	46	68	45
		D7	150	157	139	133	126	110	111	88	91	65	80	53	79	52
		D8	180	188	166	159	151	132	133	105	110	77	96	64	94	62
		D9	224	234	207	199	188	164	166	131	137	97	120	80	118	78
		D10	328	343	303	290	275	240	242	191	200	141	176	117	172	114
	E	D1	29	29	26	24	23	19	19	14	16	10	13	8	13	8
		D2	53	55	48	44	42	35	36	27	29	19	25	16	24	15
		D3	71	73	64	59	57	47	48	36	39	26	33	21	33	20
		D4	89	92	80	74	71	59	61	45	49	32	42	26	41	26
		D5	108	111	98	90	86	71	73	55	59	39	51	32	50	31
		D6	127	131	115	106	101	84	86	64	69	46	60	38	58	37
		D7	148	153	134	124	118	98	101	75	81	54	70	44	68	43
		D8	177	183	160	148	141	117	121	90	97	64	84	53	82	51
		D9	221	228	200	185	176	146	150	112	120	80	104	66	102	64
		D10	324	334	292	270	258	214	220	164	176	117	152	96	149	93

Table 6. Energy solvency threshold: Maximum dwelling surface to not exceed M.

Area (m2)			**CLASS**													
			A		**B**		**C**		**D**		**E**		**F**		**G**	
			Type 1	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**	**Type 1**	**Type 2**
CLIMATE ZONE	α	D1	61	66	61	66	61	66	61	66	61	66	61	66	61	66
		D2	113	122	113	122	113	122	113	122	113	122	113	122	113	122
		D3	151	163	151	163	151	163	151	163	151	163	151	163	151	163
		D4	190	205	190	205	190	205	190	205	190	205	190	205	190	205
		D5	230	248	230	248	230	248	230	248	230	248	230	248	230	248
		D6	271	292	271	292	271	292	271	292	271	292	271	292	271	292
		D7	316	340	316	340	316	340	316	340	316	340	316	340	316	340
		D8	378	407	378	407	378	407	378	407	378	407	378	407	378	407
		D9	472	508	472	508	472	508	472	508	472	508	472	508	472	508
		D10	690	743	690	743	690	743	690	743	690	743	690	743	690	743
	A	D1	60	64	59	61	57	58	55	53	50	44	46	39	46	38
		D2	111	119	109	113	106	107	101	98	92	82	86	71	85	70
		D3	149	160	146	152	142	143	136	131	124	109	115	96	114	94
		D4	187	200	183	191	178	180	171	165	156	137	145	120	143	118
		D5	227	243	222	232	216	218	207	200	189	166	175	146	174	143
		D6	266	286	261	272	253	256	243	235	222	196	206	171	204	168
		D7	311	333	304	317	296	299	284	274	259	228	240	200	238	196
		D8	372	399	364	380	354	358	340	328	310	273	288	239	285	235
		D9	464	498	454	474	442	446	424	410	387	341	359	298	356	293
		D10	679	728	664	694	646	653	620	599	565	499	525	436	520	429
	B	D1	60	64	58	59	55	54	52	48	46	39	43	33	42	33
		D2	110	118	107	109	102	100	96	89	86	72	79	62	78	60
		D3	148	158	143	147	137	134	129	119	115	96	106	83	104	81
		D4	186	198	180	184	172	168	162	149	145	121	133	104	131	102

		D5	225	240	218	223	209	204	197	181	175	146	161	126	159	123
		D6	264	282	256	263	245	240	231	213	206	172	189	148	187	145
		D7	308	329	299	306	286	280	270	248	241	200	221	172	218	169
		D8	369	394	358	367	343	335	323	297	288	240	264	207	261	202
		D9	461	492	446	458	428	418	403	370	360	299	330	258	325	252
		D10	674	720	653	669	626	612	589	542	526	438	482	377	476	369
	C	D1	59	62	56	55	52	48	47	40	41	31	37	26	36	25
		D2	109	115	103	103	97	89	88	75	75	57	68	48	67	47
		D3	146	154	139	138	129	120	118	100	101	77	91	65	89	63
		D4	184	194	174	173	163	150	148	126	127	97	114	82	112	79
		D5	223	235	211	209	197	182	179	153	154	117	138	99	136	96
		D6	262	276	248	246	232	214	211	179	181	138	162	116	160	113
		D7	305	322	289	287	270	250	246	209	211	161	189	136	186	132
		D8	366	386	346	344	324	299	295	250	253	193	227	162	223	158
		D9	456	482	432	429	404	373	368	313	316	240	283	203	278	197
		D10	667	704	632	628	590	545	538	457	461	352	414	296	407	289
	D	D1	58	61	54	51	49	42	43	34	35	25	31	21	30	20
		D2	107	112	99	95	90	79	79	63	65	46	57	38	56	37
		D3	144	150	133	127	121	105	106	84	88	62	77	51	75	50
		D4	181	189	167	160	152	132	133	105	110	78	97	64	95	63
		D5	219	229	202	194	184	160	162	128	133	94	117	78	115	76
		D6	257	269	238	228	216	188	190	150	157	111	138	92	135	89
		D7	300	314	278	266	252	220	222	175	183	129	161	107	158	104
		D8	359	376	332	318	302	263	265	210	219	155	193	128	189	124
		D9	448	469	415	397	376	328	331	262	273	193	240	160	235	155
		D10	656	685	607	581	550	480	484	383	400	282	351	234	344	227
	E	D1	57	59	52	48	46	38	39	29	31	21	27	17	26	16
		D2	106	109	96	88	84	70	72	54	58	38	50	31	49	30
		D3	142	146	128	118	113	94	96	72	77	51	67	42	65	41
		D4	178	184	161	149	142	118	121	90	97	65	84	53	82	51
		D5	216	223	195	180	172	143	147	109	118	78	102	64	99	62
		D6	254	262	229	212	202	168	173	129	138	92	120	75	117	73
		D7	296	305	267	247	236	196	201	150	161	107	140	88	136	85
		D8	355	366	320	296	283	235	241	180	193	129	167	105	163	102
		D9	443	456	400	369	353	293	301	224	241	161	209	131	204	127
		D10	647	668	584	540	516	428	440	328	352	235	305	192	298	186

5. Discussion

5.1. Analysis of results

Monetary poverty of households is established when their income is below 60% of the median (Sánchez-Guevara, Sanz Fernández, Núñez Peiró, & Gómez Muñoz, 2020), which is the case for deciles 1 and 2. While all households in decile 1 are at risk of energy poverty regardless of the other conditions of their dwellings, only 20% of households in decile 2 would be at risk of energy poverty, if their dwelling does not exceed the floor area shown in table 5. This means that 40% of households in monetary poverty are not necessarily at risk of energy poverty.

9% of households in monetary poverty are in energy poverty regardless of other housing conditions. Sánchez-Guevara finds that 7% of households in monetary poverty are also in energy poverty in Madrid (Sánchez-Guevara, Sanz Fernández, Núñez Peiró, & Gómez Muñoz, 2020). If we extract the results of the present study for climate zone D, to which Madrid belongs, we observe that 6% of the households located in this climate zone that are in monetary poverty are also in energy poverty, regardless of the rest of their housing characteristics. It is therefore considered that the results of this research are similar to those obtained in the previously mentioned research.

When analysing the energy risk table, it is striking that 15% of the results are marked in red, which means that dwellings with the corresponding characteristics must have a floor area smaller than the minimum floor area allowed by law in order not to be in a situation of energy risk. The energy risk varies in each climate zone, from 10% of the dwellings in climate zone α to 26% in climate zone E. The phenomenon should therefore be monitored more intensively in the more severe climate zones.

When analysing the energy risk table, it is striking that 15% of the results are marked in red, which means that dwellings with the corresponding characteristics must have a floor area smaller than the minimum surface allowed by law in order not to be in a situation of energy risk. The energy risk varies in each climate zone, from 10% of the dwellings in climate zone α to 26% in climate zone E. The phenomenon should therefore be monitored more intensively in the most severe climate zones.

The energy poverty data according to the 2M indicator provided in the 2020 update (Ministerio de Transportes, Movilidad y Agenda Urbana, 2020) as well as this study show an increase in incidence from climate zone α to climate zone B. However, the incidence decreases from climate zone B to climate zone G n the 2020 update, contrary to the results of this research. This difference between the results obtained with the actual expenditure and those obtained with the theoretical expenditure is explained by the fact that dwellings are better prepared for the cold in the most severe climate zones: they have better thermal insulation and more efficient heating installations, as explained in the National Strategy Against Energy Poverty when obtaining the paradoxical results (Ministerio para la Transición Ecológica, 2019).

It is worth noting that in 99% of dwellings with energy class A, B, C and D, energy solvency can be achieved regardless of household income. If we consider dwellings up to 120 m^2, this percentage drops to 86%. This means that the fundamental problem of energy poverty is not so much household income, but the poor quality of housing. Current regulations do not allow the construction of new houses with poor energy performance. The problem lies in the building stock. 85% of dwellings that have been certified by 2019 belong to classes E, F or G (Ministerio para la Transición Ecológica, IDAE, Ministerio de Fomento, 2019). Energy rehabilitation is essential to reduce energy poverty.

5.2. Social consequences

Energy solvency is undoubtedly an important consideration for anyone buying or renting a house. Knowing their income and the climate zone in which they are located, by applying the methodology of this research, they could find out the square metres of housing of each energy class that they are eligible for without falling into energy poverty. Such information contributes to the energy empowerment of citizens. Without access to energy solvency information, it is possible to buy or rent a house and, once the transaction is completed, discover that there will be difficulties in meeting the energy bill.

The average dwelling in Spain has a surface of 90.2 m^2 (Instituto para la Diversificación y el Ahorro de la Energía, IDAE, 2019). For dwellings with such a surface of type 2 (electrically heated), in climate zone E (the coldest one), and with energy class F or G (33% of the available dwellings (Ministerio para la Transición Ecológica, IDAE, Ministerio de Fomento, 2019)), only 30% of the highest-income households are energy solvent. For the next energy class E, which accounts for 52% of available dwellings (Ministerio para la Transición Ecológica, IDAE, Ministerio de Fomento, 2019), only 50% of the highest-income households are energy solvent. Whereas for medium-sized dwellings of type 1 (with gas heating), and classes F or G, 60% of the highest-income households are energy solvent and 70% for class E. Only 10% of the highest-income households are energy solvent. Only 10% of the highest-income households would not be energy risky in dwellings of type 2, class E, F or G (85% of available dwellings (Ministerio para la Transición Ecológica, IDAE, Ministerio de Fomento, 2019)) and climate zone E and 30% of the highest income households for dwellings of type 1.

These results highlight the need for society to intervene in the worst energy performance housing. People with higher incomes are more able to choose housing with better energy performance, while people with lower incomes should not be forced to live in housing that leads to energy poverty.

If we analyse what happens in the different climate zones, we see that all dwellings located in climate zone α are energy solvent regardless of their income, thanks to the mild climate of the Canary Islands. In climate zone A, only households with the lowest 20% of income would not be energy solvent in a medium-sized dwelling. This figure rises to 30% in zone B, 40% in zone C and 50% in zone D.

These results show the need to tackle energy poverty not in the same way across the territory, but differently depending on the climate zone. Being energy solvent is easier in milder climates. This climatic inequality highlights the need to act differently in an attempt to achieve greater equity.

Another point to consider is the socially reasonable housing area. Spanish constitutional law stipulates that private property is limited by the social function to which it is subject. Limiting the maximum surface area of a dwelling could be considered from the perspective of sustainability, given that we are on a finite planet, with a limited surface area and finite material resources (Meadows, Meadows, Randers, & Behrens, 1972). Based on the results of this research, it is worth considering whether, as a society, it would be reasonable to set limits on the surface area of dwellings according to climate zone, energy class and income, in order to guarantee energy solvency.

The results obtained show, as highlighted by Sánchez-Guevara (Sánchez-Guevara, Sanz Fernández, Núñez Peiró, & Gómez Muñoz, 2020), that monetary poverty and energy poverty are two phenomena that, although related, do not coincide, and should therefore be studied separately in order to be able to address them adequately.

Finally, the implementation and use of energy solvency concept would have an effect on the market. Potential landlords or buyers with less purchasing power would not opt for the houses with the worst results. The decrease in demand for these dwellings would be an incentive to improve their energy efficiency or reduce their price, so that energy poverty would be reduced.

5.3. Policy implications

The energy solvency results show in red those housing energy classes that place households with a net income level belonging to decile 1 in a situation of energy poverty depending on the climate zone in which they are located. In these cases, it would be necessary for energy rehabilitation policies to promote action in these dwellings in order to obtain an energy class that would lift their inhabitants out of energy poverty. Such policies, in addition to taking into account the net income of households, should also consider the surface area of the dwellings, the climate zone and the energy class.

In order to prevent new cases of energy poverty, it would be desirable to include a requirement to analyse energy solvency when buying or renting a house. In the case of home purchase, the law 5/2019, which regulates real estate credit contracts, should be amended. In the case of renting, either Royal Decree 390/2021, which approves the basic procedure for the certification of the energy efficiency of buildings (Ministerio de la Presidencia, Relaciones con las Cortes y Memoria Democrática, 2021), should be amended to include the economic cost of energy consumption, as proposed by Gallego (Gallego Sánchez-Torija, Fernández Nieto, & Gómez Serrano, 2021), and energy solvency, as proposed in this article, or a new law should be passed to include this requirement.

With the data from the energy efficiency certificate (surface area of the dwelling, climate zone and energy class) and the household's net income data, using the methodology described in this article, it would be possible to identify those dwellings that are at risk of energy poverty. With this information, personalised monitoring policies and active measures could be put in place to ensure that the risk does not materialise into energy poverty. As stipulated in Royal Decree 390/2021 (Ministerio de la Presidencia, Relaciones con las Cortes y Memoria Democrática, 2021), it would be desirable that anonymised data from energy performance certificates be made available for statistical and research use. This has not been the case since the first Royal Decree on energy certification was passed in 2013. It is necessary to have access to such data in order to update the results of this research in the future and to be able to articulate policy measures in line with its evolution.

6. Conclusions

Analogous to the meaning of financial solvency in the field of bank lending, this paper has defined the new concept of energy solvency as the ability of the person buying or renting a dwelling to meet the energy expenditure necessary to keep the dwelling comfortable, without falling into energy poverty.

The recent phenomena of the financial crisis and the covid-19 pandemic have placed many households in a situation of social and economic vulnerability that would be highly desirable to improve. Sometimes the poorest families rent housing whose cost seems affordable but which, due to its lack of energy efficiency, ends up being disproportionately burdening or forces their users to minimise consumption at the cost of not being able to access sufficiently adequate material conditions.

In order to rent or sell a house, it is necessary to provide the energy efficiency certificate that shows the energy consumption necessary to maintain the house in a comfortable situation. From this information, the intensity of the energy consumption of the home has been obtained: the energy consumption per square metre.

This is a theoretical value that is considered more robust for calculating the energy poverty indicator "Disproportionate expenditure (2M)", as the data available with which this indicator is usually calculated are those of real expenditure. They overcome the limitations of actual expenditure, as they do not take into account under-consumption without achieving comfort and energy waste.

Using the calculated energy expenditure intensity values and the data on net household income in Spain, the maximum surface areas that dwellings can have to guarantee the energy solvency of their occupants, depending on the climate zone, the energy class, the energy sources used and the household's net income decile, have been determined. The same procedure has been used to detect the risk of energy poverty.

By knowing the energy solvency before renting or buying a house, energy poverty can be prevented by avoiding transactions where it is known that this situation will occur.

If the legal obligation to calculate energy solvency when buying or renting a flat is established, the appearance of new cases of energy poverty could be prevented before they occur. It would be a political decision that would have a significant impact on preventing new situations of energy poverty.

The results obtained in this research highlight other issues that remain open for future research, including the following:

- The concept of financial solvency has been presented in a static way at the moment of buying or renting a house. It would be possible to delve deeper into its dynamic behaviour over the duration of the rental or mortgage, despite the difficulties of any future prediction where complex factors come into play.
- Energy solvency indicator, as it has been proposed, offers data on whether energy poverty is encurred depending on the surface of the dwelling that is chosen. It would be desirable to offer the gap that is incurred in each case, so that in addition to reporting on whether or not there is a risk of energy poverty, the economic scope of said risk could be known.

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