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Revista Hábitat Sustentable Vol. 10, N°. 1. ISSN 0719 - 0700 / Págs. 8 -21
https://doi.org/10.22320/07190700.2020.10.01.01

Recibido 06/05/2020
Aceptado 30/06/2020

MIDIENDO LA POBREZA ENERGÉTICA. UNA REVISIÓN DE INDICADORES

MEASURING FUEL POVERTY. A REVIEW OF INDICATORS

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RESUMEN
Identificar aquellos hogares en una situación de vulnerabilidad a la pobreza energética es el primer paso para abordar una problemática social a nivel mundial asociada a la falta de servicios energéticos mínimos, conocido por los términos anglosajones–Fuel Poverty y Energy Poverty, FP y EP, respectivamente. El concepto FP, definido en el Reino Unido como "la incapacidad para obtener un adecuado confort térmico debido a la ineficiencia de la vivienda", mientras que el concepto EP refleja la imposibilidad de tener acceso a un servicio energético mínimo en países en desarrollo. La falta de un consenso a la hora de definir una ruta clara ha originado que algunos países no la reconozcan como un problema social. La investigación se basa en la revisión de ambos conceptos, a través del análisis conceptual de los términos FP y EP, revisión de indicadores utilizados, estudio de la capacidad de los indicadores para identificar y proponer soluciones a la problemática. Todo ello en relación a los objetivos incluidos: infraestructuras disponibles, eficiencia energética, pobreza social y económica, bienestar y salud social. El resultado es la revisión desde una perspectiva técnica en el sector residencial que ayude a desarrollar soluciones que cubran las carencias encontradas.

Palabras clave
eficiencia energética, exclusión social, higiene, pobreza

ABSTRACT
Identifying those households in an energy poverty vulnerability situation is the first step towards addressing a global social problem associated with the lack of minimum energy services, known as Fuel Poverty and Energy Poverty, FP and EP, respectively. The FP concept is defined in the United Kingdom as "the inability to obtain adequate thermal comfort due to the inefficiency of the house", while the EP concept reflects the impossibility in developing countries of having access to a minimal energy service. The lack of consensus when defining a clear path has meant that some countries have not recognized it as a social problem. The research is based on the review of both concepts, through the conceptual analysis of the terms, FP and EP, a review of indicators used, and the study of the capacity of the indicators to identify and propose solutions to the problem. All this regarding the objectives included: available infrastructures, energy efficiency, social and economic poverty, well-being and social health. The result is a review from a technical perspective in the residential sector, that helps develop solutions that cover the deficiencies found.

Keywords
energy efficiency, social exclusion, hygiene, poverty

INTRODUCTION

Energy Poverty (EP), commonly conceived as the inability of a home to satisfy a minimum amount of energy services for its basic needs (Castaño-Rosa, Solís-Guzmán, Rubio-Bellido & Marrero, 2019) like, for example, keeping the dwelling in climatization conditions that are suitable for health (Sokołowski, Lewandowski, Kiełczewska & Bouzarovski, 2020), has stirred the interest of governments and political parties, thus achieving a greater public impact. There have been several definitions and indicators developed by some countries to analyze the situation of the most vulnerable homes, including those of the United Kingdom, Ireland, France, Slovakia, Italy or Austria (Thomson, Snell & Liddell, 2016). It is estimated that almost 20% of the entire European Union population would fall into this category ((EnAct), n.d.). However, there is no official common concept in Europe that allows analyzing the situation of energy poverty in member states and that could facilitate comparing the results obtained, to identify effective measures for an eventual eradication.

The European Commission (EC) uses three basic criteria to evaluate an EP situation: the inability to keep dwellings suitably conditioned, the delay in paying utility bills and living in unhealthy dwellings (leaks in roofs, walls or floors, appearance of mold and rot). This information was collected through the EU Energy Poverty Observatory (European Commission, 2018). The concept of EP is not just the difficulty of keeping a dwelling at a suitable temperature in the different seasons of the year, or to face the payment associated to a given energy consumption or to finance a high price of the energy consumed, but rather is a multidimensional concept that has been evolving. It is currently being defined as a situation that can deprive homes of not just heating or cooling, but also of hot water, electricity and other essential household needs (Bouzarovski & Petrova, 2015).

Currently FP and EP are the two main concepts used to identify one of the major social problems associated to the lack of minimal energy services in homes to cover their basic needs, like food, personal hygiene, comfort areas, safety at home, etc. Ultimately, minimal energy services that guarantee health and social wellbeing, regardless of the area where the dwelling is located, their social and economic situation, health or country of origin (foreigners). The main goal of this work is to review the most used international projects and works to effectively identify those homes at risk or those that are already in a FP or EP situation.

METHODOLOGY

To analyze the concept of EP, the state of the matter needs to be developed from an international perspective, beginning by 1) the analysis of the terms: Energy Poverty (EP) and Fuel Poverty (FP); continuing with 2) the revision of the indicators used to analyze an energy poverty situation; and ending with 3) the identification of the ability of the indicators to solve the issue regarding the proposed goals: available infrastructures, energy efficiency, social and economic poverty, social welfare and health, etc. These goals are set out based on the energy vulnerability factors defined by Bouzarovski, Petrova and Tirado-Herrero (2014). The result is a revision of EP and FP concepts from a technical perspective related to the residential sector, which will allow developing solutions that cover the shortfalls found.

On examining the indicators used to analyze an energy poverty situation, these are grouped into two categories: those based on expenses and incomes of the home and those based on perception surveys and statements of homes. In addition, there are indicators and methodologies that describe the most vulnerable consumers, like the econometric analysis, the overcrowding of shared dwellings, thermal comfort and those based on the energy efficiency rating of dwellings. The indicators gathered in Table 1 will be discussed in the following sections of the article.

REVIEW OF THE RELATED INDICATORS

To analyze EP, it is necessary to develop the state of the matter from an international perspective and, in particular, the analysis of the terms: Fuel Poverty (FP) and Energy Poverty (EP). This article analyzes and reviews the concepts of EP and FP, as well as the most used available indicators, given their capacity to identify homes at risk of EP starting from a technical perspective related to the residential sector. The concept of FP was introduced by Isherwood and Hancock in 1979 after the forced increase of energy prices, due to the oil crisis (1973-1974). However, it is not until 1991 when Brenda Boardman (2010) defines the concept of FP for the first time, referring to the United Kingdom as: "the inability to obtain a suitable thermal comfort due to the inefficiency of the dwelling", establishing the possibility that those who are energy poor, do not have to be economically so.

Currently, there are different official definitions of FP developed in countries like the United Kingdom,

Category	Type of Evaluation
Based on home's expenses and incomes	Energy consumption expense above 10% of the family income (10%) (Boardman, 2012)
	Energy consumption expense over double the national average (2M) (Schuessler, 2014)
	Family income below the Minimum Income Standard (MIS) (Moore, 2012)
	Family income below the monetary poverty threshold and energy consumption expense above the established threshold (LIHC) (Hills, 2012)
	Family income after fuel cost below the established threshold, where the average fuel cost of the analyzed area is excluded (AFCP) (Romero, Linares, López Otero, Labandeira & Pérez Alonso, 2015)
	Absolute energy consumption expense below the established threshold (HEP) (Rademaekers et al., 2016)
Based on surveys of perceptions and statements of the homes	Possibility of a home to maintain a suitable temperature during the cold season (European Commission, 2014)
	Delays in paying energy bills appear (European Commission, 2014)
	Deficiencies in the dwelling appear, like leaks, damp walls, floors, roofs or foundations, or rot in floors and window or door frames (European Commission, 2014)
	Ability of a home to keep a fresh temperature during summer months (Spanish National Statistics Institute, 2014)
Based on econometric analysis	Influence of given demographic, socioeconomic and physical conditions on suffering EP (Legendre & Ricci, 2014)
Based on thermal comfort	Percentage of hours where the residence is in a thermal comfort situation (Sánchez-Guevara, Neila Gonzalez & Hernández Aja, 2014)
Based on dwelling's energy efficiency	Influence of the quality of the dwelling (energy consumption) with an EP situation. Poor quality of the dwelling causes a higher energy consumption and, at the same time, an EP situation (Fabbri, 2015)decision-makers, technicians, researchers, etc. In Italy, a strategy to solve fuel poverty involves action in order to reduce energy prices, the AEEG (Italian regulatory authority for electricity gas and water
Based on combined criteria	Vulnerable Home Index. Allows assessing a home, whether identified or not in a situation of energy poverty, identifying which variable requires greater attention: economic, energy or thermal comfort. It makes it possible to include the economic and technical viability of energy retrofitting (Castaño-Rosa, Solís-Guzmán & Marrero, 2018)and assesses the home vulnerability situation regardless of whether or not it is in fuel poverty by using three dimensions: monetary cost, energy and thermal comfort. The monetary dimension analyses vulnerability in relation to the available net income to face everyday life. The energy variable assesses the vulnerability related to the constructive characteristics of the dwelling. Finally, the introduction of the thermal-comfort variable enables the evaluation of the vulnerability related to the inner temperature of the dwelling and its perception by occupants. The combination of the different resulting values in each dimension and its relationship to the quality of life of occupants establishes a hierarchy of vulnerable levels. As a result, a multi-dimensional index is defined which relates technical aspects (characteristics of the dwelling
	Fuel Poverty Potential Risk Index. Allows assessing the risk of a home from suffering EP, in relation to the place their dwelling is located in the context of Chile, using the adaptive comfort model (Castaño-Rosa, Solís-Guzmán & Marrero, 2018)and assesses the home vulnerability situation regardless of whether or not it is in fuel poverty by using three dimensions: monetary cost, energy and thermal comfort. The monetary dimension analyses vulnerability in relation to the available net income to face everyday life. The energy variable assesses the vulnerability related to the constructive characteristics of the dwelling. Finally, the introduction of the thermal-comfort variable enables the evaluation of the vulnerability related to the inner temperature of the dwelling and its perception by occupants. The combination of the different resulting values in each dimension and its relationship to the quality of life of occupants establishes a hierarchy of vulnerable levels. As a result, a multi-dimensional index is defined which relates technical aspects (characteristics of the dwelling
	Energy Poverty Vulnerability Index. Applied in Portugal, it provides a spatial analysis of EP by combining several indicators: socioeconomic, climate, energy (Gouveia, Palma & Simoes, 2019)

Tabla 1. Summary of the measures-indicators analyzed.
Fuente: Preparation by the authors.

France, Ireland and Slovakia (Thomson *et al.*, 2016), as well as a diverse set of indicators for its analysis, none of which are officially recognized by the EC. However, while seeking to mitigate this issue, in the Energy Roadmap 2050 strategy (European Commission, n.d.) implemented by the Commission, the vulnerable energy consumer is defined as the family supplied by electricity and formed by people whose age, state of health and low income present a risk of social exclusion, as well as the risk of the supply being cut, and also being benefitted by social protection measures to have the minimum electricity supply required (Peneva, 2016).

The concept of EP has gained relevance thanks to diverse research projects (Bouzarovski y Petrova, 2015; Shonali Pachauri, 2004). This is associated to a lack of energy supply, caused by problems related to distribution infrastructures. The use of the EP concept has allowed identifying areas with limited and old infrastructures and those in an inefficient state, like those of historic hubs, rural areas and/or social exclusion areas, which, together with their limited economic activity, continued depopulation and loss of investor attraction, have led to a continued abandonment, resulting in their residents having a worse quality of life.

A good example of EP is the study carried out in Hungary (Tirado Herrero & Ürge-Vorsatz, 2012), where the buildings analyzed had an excessive expense in energy consumption, complications to change supplier or fuel type due to technical and institutional restrictions, or the impossibility of reducing heating expenses through individual energy efficiency actions. This type of situations causes delays in or the impossibility of paying energy bills, supplies being cut by the energy supplier or the reduction of the use of other needs and basic services, and is mainly associated to poor countries, located especially in central and southern America, Africa and Asia (Bazilian, Sagar, Detchon & Yumkella, 2010; Birol, 2007).

Beyond the notions of FP and EP, the reality is that both define a situation where a home cannot satisfy its basic energy needs (like heating, cooling, lighting or cooking) (Gatto & Busato, 2020), whether this is because of a material or a social matter. From here arises the current trend to identify, more than an EP or FP situation, the vulnerable consumer, which calls upon the concepts of "resilience" – capacity to adapt on facing an adverse situation or status - (Bouzarovski *et al.*, 2014; O'Brien & Hope, 2010; Welsh, 2014) and "precariousness" – lack of sufficient resources or means - (Paugan, 1995). A review is made below of the most internationally recognized and used EP indicators (ASSIST 2GETHER, 2018; Herrero, 2017; Rademaekers *et al.*, 2016; Meszerics, 2016; Thomson *et al.*, 2016), using the European Energy Poverty Observatory (European Commission, 2018), the Mexican Energy Poverty Observatory ("Observatorio de Pobreza Energética en México," n.d.), and the Chilean Energy Poverty Network ("Red de Pobreza Energética (RedPE), Universidad de Chile", 2017) as a base. The analysis of weaknesses and threats of the indicators is made starting from the energy vulnerability factors defined by Bouzarovski et al. (2014).

10% INDICATOR

This indicator defines that a home is in energy poverty if it has to dedicate more than 10% of its income to pay for suitable energy services (like heating, cooling, lighting or cooking) (Boardman, 2010). Defined by Boardman, it is simple indicator, easy to communicate and relatively versatile, which allows establishing a clear political goal. The criticism comes fundamentally from, on one hand, its excessive sensitivity to energy prices, underestimating the scale of the problem when prices are low and overestimating it when these are high, and, on the other, from the arbitrary nature of fixing the threshold at 10%, a threshold which was justified given the socioeconomic situation of the United Kingdom at the beginning of the 90s. Experience of years of application has shown that this 10% threshold included a significant number of homes that were not energy poor, like high-income homes with inefficient houses.

2M INDICATORS

These include: double the median energy expense of the home, double the mean energy expense of the home, double the median energy expense percentage of the home and double the mean energy expense percentage of the home (Schuessler, 2014). Only the third of these indicators has its justification in the pioneering works of Boardman, where it was detected that the median energy expense percentage in respect to the total incomes in British homes was around 5% in 1988. After this, the assessment provided by these indicators indicates that "A home is under energy poverty if, out of their income, more than double the median energy expense percentage has to be used to pay for suitable energy services" (Schuessler, 2014, p. 11). The EP threshold is established in relation to the national mean, making it possible to recalculate it every year. In this sense, it is not a static measurement. As strong points of the indicator, one can highlight: that high-income homes are rarely included as energy poor and it considers the specific features of the country.

MINIMUM INCOME STANDARD (MIS)

MIS, defined by Moore (2012), considers the minimum income of a home as that which allows its members to opt for the opportunities and choices that, at the same time, make an active integration in society possible. The project, "A minimum income standard for Britain", developed by Bradshaw et al (2008), represents a good example of what this methodology intends to do. The first thing to underline is that it is limited project, as it establishes an MIS that is always associated to a concrete social collective and it is the people chosen as representatives, who come from diverse social collectives, who will take part in the entire deliberation process and in the preparation of the conclusions. Defining what is understood by an "acceptable minimum income" is the main limitation. This project is based on the UN's Convention of Human Rights and the works of a committee of experts in the US who reviewed the family budgets in 1980, and who developed the concept of Prevailing Family Standard. To keep in mind the particularly vulnerable collectives, a set of socioeconomic parameters of the home were established: the makeup of the home, employment situation, disability, health, ethnicity and accessibility. In this way, "a home would be in a situation of energy poverty if its total income minus its energy costs does not exceed the MIS corresponding to the characteristics of their home" (Moore, 2012, p. 21).

LOW INCOME HIGH COST (LIHC)

Starting from the studies made by Hills (2012), a home is considered as energy poor if its income is below a given poverty threshold and when its energy expenses are above another energy expense threshold. For this, it is necessary to establish both thresholds: the first is defined at 60% of the equivalent income median after discounting the expenses of the dwelling and the energy expenses. For the second threshold, the equivalent energy expense median calculated over all homes was used (see Figure 1).

The strong point of this indicator is based on the possibility of distinguishing between EP and general poverty, clearly reflecting that EP depends on the income of the home. In the same way, the use of this indicator leaves outside of a EP situation, those groups considered as the most vulnerable (elderly, chronically ill, disabled and small children) (Middlemiss, 2016), since the home defined as energy poor is formed by some low income families and an energy inefficient dwelling. This leads to an improvement of the energy efficiency of the dwelling is considered as the main measure to reduce EP, forgetting that low income homes will continue, to a certain extent, having problems to pay their bills and experiencing health issues on living with an inadequate comfort.

AFTER FUEL COST POVERTY (AFCP)

Based on the initial MIS indicator proposed by Moore, the development made by Heindl (2015) and the applications made in Spain by Romero et al. (2015) and in the United Kingdom by Hills (2012), consider that a home is in energy poverty when its income, once the housing and domestic energy expenses are discounted, falls below the minimum income standard (adjusted to the size and makeup of the home by means of the modified OECD equivalence scale). In short, this approach is based on the existence of a minimum income level that guarantees the wellbeing of a person, making it possible that a home is not excluded from society it is part of (social exclusion) by an economic factor.

HIDDEN ENERGY POVERTY INDICATOR (HEP)

HEP identifies those homes whose energy expense is too low, in such a way that where there will be an EP situation if the total energy expense is below the median energy expense (Rademaekers *et al.*, 2016).

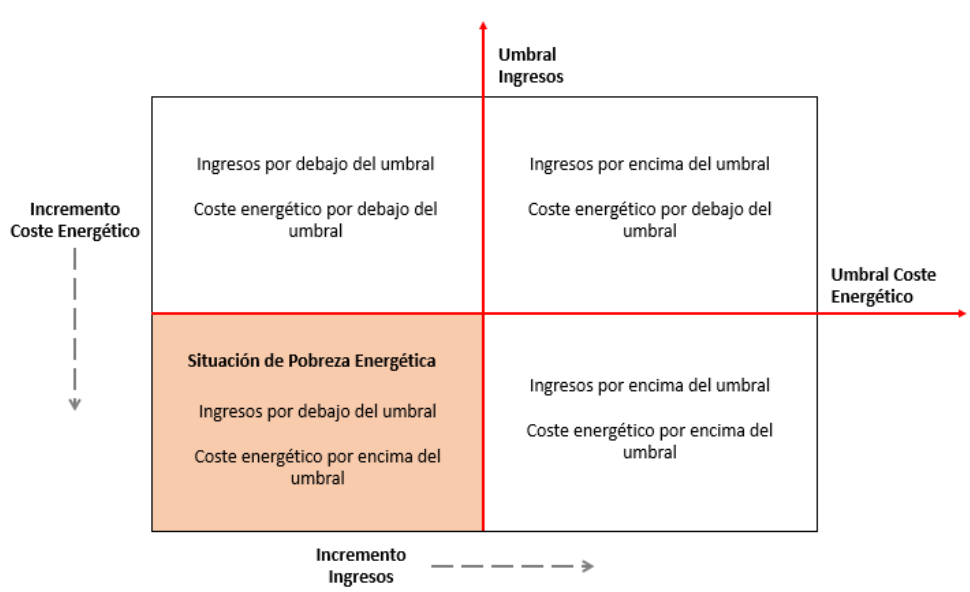

Figure 1. Low Income High Cost (LIHC) Indicator.
Source: Prepared using (Hills, 2012).

This indicator allows distinguishing those homes whose income does not allow having a minimum energy consumption on having to prioritize food expenses, responding to the effect known as "heating or eating". However, it is only valid if the absolute monetary expense is used, as generally high-income homes spend more on energy in absolute terms, but less as a proportional part of their income. On the contrary, homes with a very low expense regarding their income, on having elevated incomes, would be considered in an EP situation. Likewise, the use of the expense in absolute terms allows providing an absolute assessment of the consumption of energy services made, identifying those homes that have an expense below normal levels, abstaining from a basic consumption level. Among its limitations, it is necessary to mention HEP does not consider the characteristics of the dwelling, or its energy efficiency.

PERCEPTION AND STATEMENT SURVEYS OF THE HOMES

The goal of the European Union's survey about income and living conditions (EU-SILC) (European Comission, 2014) is providing a reference source about comparative statistics in Europe about income and social exclusion. From all the aspects of the daily lives of homes that this survey analyzes, the three questions generally used for the EP analysis are related to: inability of a home to maintain a suitable temperature during the cold season; delays in paying bills; and deficiencies in the dwelling, like leaks, damp walls, floors, roofs or foundations, or rot in the floor, window or door frames.

The perceptions and statements of the home surveys (ECV) (Spanish National Statistics Institute, 2014; Tirado Herrero, Jiménez Meneses, López Fernández, Martín García & Perero Van Hove, 2014) study the warm weather situation experienced in countries like Spain, made by the National Statistics Institute, enabling an assessment of the living conditions of people in excessively hot periods, on asking about the ability of a home to maintain a fresh temperature during summer months. The main weakness here is based on its subjective nature, that is susceptible to creating uncertainty in the results.

In brief, it must be clarified that these indicators were not created to analyze the problem associated to EP, so it is necessary to include new variables that allow establishing a difference between the problems associated to the impossibility of a minimum energy consumption and those related to the features of the dwelling or the heating systems.

ECONOMETRIC ANALYSIS

The goal of this analysis is explaining one variable starting from others, as well as the possible disturbances this may be subjected to, analyzing its behavior. Through this, it is intended to identify the collectives that are in a situation of greater vulnerability to experiencing an EP situation, which is why they do not identify an EP situation in themselves. The studies of Legendre & Ricci (2014) for France and of Minaci, Scarpa and Valbonesi (2014) for Italy are good examples of this type of analysis, where the goal is to quantify the influence that given demographic, socioeconomic and physical conditioning factors exercise on the likelihood that a home, that a priori is not in energy poverty, falls below its threshold.

The models developed by Walker, McKenzie, Liddell & Morris (2012) and Walker, Liddell, McKenzie & Morris (2013), which introduce techniques based on Geographic Information Systems to prepare an EP risk, stand out, evaluating: family size, electricity consumption, occupation level, price of the fuel used, etc. (Walker, McKenzie, Liddell y Morris, 2014).

THERMAL COMFORT

Thermal comfort can be understood as "that condition of the mind which expresses satisfaction with the thermal environment" (BS/EN 15251:2007, n.d.). The inclusion of the vulnerable consumer has led to the study of the thermal comfort of the dwelling, mainly due to its close relationship with people's health (Butcher, 2014; Kolokotsa & Santamouris, 2015), as well as its capacity to permit a reduction of the energy consumption of the dwelling (Hatt, Saelzer, Hempel & Gerber, 2012; Martínez & Kelly, 2015; Van Hooff, Blocken, Hensen & Timmermans, 2015), given that a suitable comfort in the dwelling means, in fact, the control of said energy consumption (Vilches, Barrios Padura & Molina Huelva, 2017).

The evaluation of thermal comfort in a dwelling is very complicated (der Perre, Ness, Thoen, Vandenameele & Engels, 2002; Heijs & Stringer, 1988; M. Bluyssen, 2014), mainly because of the great diversity of factors involved (Bienvenido-Huertas, Rubio-Bellido, Pérez-Fargallo & Pulido-Arcas, 2020). In this sense, it is worth highlighting the work of Sánchez-Guevara et al. (2014), where they use the comfort evaluation of dwellings as an indicator of the most vulnerable homes. Starting from the analysis of data obtained from the simulation, and using adaptive models to evaluate thermal comfort (ASHRAE (2013) ANSI/ASHRAE Standard 55-2013, 2013)(BS/EN 15251:2007, n.d.), they identify the number of hours that the home under study is outside

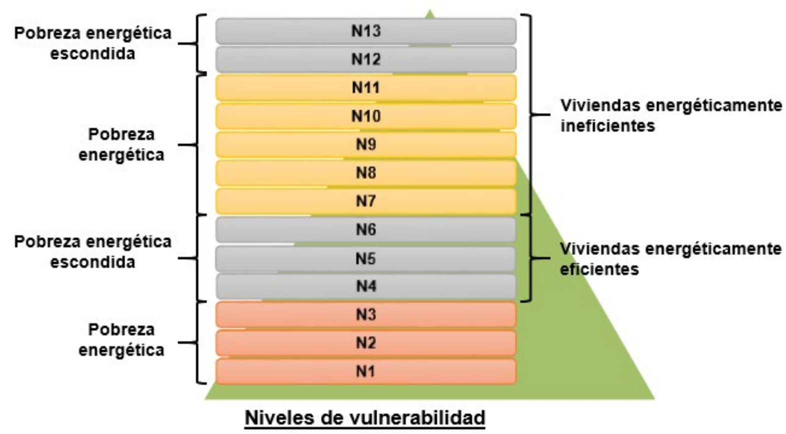

Figure 2. Vulnerability levels from the Index of Vulnerable Homes (IVH).
Source: Castaño-Rosa (2018, p. 55).

the established comfort zone. Those homes with a higher number of hours outside the comfort zone will be considered as the most vulnerable.

ENERGY EFFICIENCY OF THE BUILDING

Due to the relationship established between the energy efficiency of the dwelling, represented by its energy consumption and the EP, there are several researchers who promote reducing this situation by reducing the energy consumption of the dwelling (Braubach & Ferrand, 2013; Rosenow, Platt & Flanagan, 2013; Boardman, 2012). The case carried out in France by Florio and Teisser (2015) follows this line, where an energy efficiency certificate is prepared that, starting from the estimated energy expense of the dwelling, allows evaluating the characteristic housing stock in that country. Another case is the one made in Italy by Fabbri (2015), where an EP indicator is proposed, based on the energy performance of the dwelling using three variables: energy efficiency certification database, monitoring of actual energy consumption and the energy performance standard of the dwelling based on its age. The relationship established between the energy consumption data of the dwellings and the low-income homes (excessive energy consumption and low income), makes it possible to point out the homes in an EP situation that do not have enough income to carry out energy efficiency measures, even when receiving economic incentives. Recently, Porras-Salazar, Contreras-Espinoza, Cartes, Piggot-Navarrete & Pérez-Fargallo (2020), in their latest study on social dwellings in central-southern Chile, demonstrate that a third of those interviewed cannot maintain an adequate temperature in their home and, as a result, have respiratory problems and higher medical expenses. It concludes that improving the energy efficiency of these dwellings to thus reach a suitable temperature during a greater period, would allow reducing the number of families with respiratory issues, and the associated medical expenses.

VULNERABLE HOMES INDEX

The Index of Vulnerable Homes (IVH) (Castaño-Rosa *et al.*, 2018) has been proposed in a combination of the indicators described in the previous sections. This allows making an analysis of the vulnerability situation regarding its consequences and intensity, as well as the possibility of evaluating the optimal energy retrofitting measure to improve the quality of life of the homes. Figure 2 graphically shows the IVH composition: 13 levels (N1: level 1 of vulnerability and least unfavorable; to N13: level 13 of vulnerability and most unfavorable), and the equivalence to a situation of energy poverty or hidden energy poverty. Its latest application, in six neighborhoods in the Northern Hub of Seville, that received financing from the Ministry of Andalusia to carry out an energy efficiency improvement intervention, shows how it is possible to estimate both the cost of the National Health Service associated to an energy poverty situation, and the saving achieved after an energy retrofitting intervention (Castaño-Rosa, Solís-Guzmán & Marrero, 2020). IVH has been adapted and applied to the British context (Castaño-Rosa, Sherriff, Thomson, Guzmán & Marrero, 2019), suggesting that there still is an important margin for improvement in the definition of indicators. IVH is a new tool for the analysis and identification of homes vulnerable to experiencing EP, providing an exhaustive analysis in the identification of the different vulnerability situations that a home may experience (Castaño-Rosa, Sherriff, Solís-Guzmán & Marrero, 2020; Castaño-Rosa *et al.*, 2019).

FUEL POVERTY POTENTIAL RISK INDEX

In order to evaluate the risk a home has of suffering EP, depending on the location where its dwelling is, in the context of Chile, the Fuel Poverty Potential Risk Index (FPPRI) (Pérez-Fargallo *et al.*, 2017) is added. The use of the adaptive comfort model allows, starting from the application of the FPPRI, to consider the relationship between the occupants and the dwelling in the assessment of the risk of suffering from EP, especially for template climates like the central regions of Chile. The use of adaptive comfort covers, in part, the subjective aspect of the interactions of the occupants with the dwelling, reducing the possibility of overestimations. However, the main limitation of the FPPRI is that it must be applied in the design phase of the dwelling and not in already occupied homes. In this context, it is worth highlighting the work done by Bienvenido-Huertas et al. (2020) where the application of the FPPRI is carried out in the three most populated cities of Chile (Santiago, Concepción and Valparaíso), to predict the risk that a home would have of experiencing energy poverty in social housing, depending on the socioeconomic characteristics of the occupants and the technical characteristics of the dwelling (Bienvenido-Huertas, Pérez-Fargallo, Alvarado-Amador & Rubio-Bellido, 2019). This work shows the potential of FPPRI to reduce the risk of a home of suffering an EP situation in the near future.

ENERGY POVERTY VULNERABILITY INDEX

The energy efficiency of dwellings, the possibility of homes to implement measures and the difficulties in heating and/or cooling dwellings, are the different aspects analyzed by the Energy Poverty Vulnerability Index (EPVI), applied in Portugal (Gouveia *et al.*, 2019). In the case study defined for its application, where 3092 districts were analyzed, the potential of EPVI to identify the areas with the highest risk of suffering EP is shown, permitting a later detailed analysis at a local level. Ultimately EPVI is an effective application tool in Portugal, for the preparation of local and national energy efficiency policies. The main limitation of this index is the availability of the data needed for its application, which makes it impossible to apply in other countries where access to information is more restricted.

DISCUSSION

The quality of the dwelling is complex to evaluate and is possibly the most influential factor in the EP of a home, which is why energy efficiency may be a decisive and effective instrument in reducing EP, just as Porras-Salazar *et al.*, 2020 show, having an influence on the energy rating, energy envelope, installations, ventilation level, state of conservation and age of the home. This assessment is made using energy consumption data, so all the analyzed indicators are capable, in one way or another, of establishing a relationship, be this direct or indirect, between the energy efficiency of a dwelling and the EP. Another methodology that allows connecting the quality of the dwelling with EP consists in the thermal comfort assessment, as shown in the works developed by Sánchez-Guevara, Neila González & Hernández Aja (2018); Boemi & Papadopoulos (2019) and Porras-Salazar *et al*. (2020).

One of the most widely used assessment factors is the social impact that EP causes, for example, social exclusion. The relationship between EP and social exclusion is because families reduce social activities with friends and acquaintances on fearing being considered poor and/or on not being able to provide suitable conditions in their dwelling to hold social activities (Longhurst & Hargreaves, 2019). The inclusion of family income by the indicators based on the expenses and income of the home, and those based on surveys of perceptions and statements, allow connecting EP with the situation of economic and/or social poverty.

Health is another important aspect, confirming that living in a house with inadequate temperatures leads to higher hospital admission rates and a higher incidence and severity of asthmatic symptoms (Liddell & Morris, 2010). It has also been identified that the probability of suffering from depression or stress among teenagers who live in an insufficiently conditioned house is greater than 25%, while in homes that do not experience this issue, it reaches only 5% (Howden-Chapman, Viggers, Chapman, O'Sullivan, Telfar Barnard & Lloyd, 2012). Although it is the elderly, children and pregnant women, considered as the vulnerable population, are those who have a higher probability of being affected by these illnesses (Dear & McMichael, 2011). Aside from mental health problems, living in a dwelling with inadequate temperatures in winter is a cause associated to having physical health issues like the flu or colds; it is even accredited with the worsening of the situation of people who suffer from arthritis and rheumatism (Ortiz, Casquero-Modrego & Salom, 2019). Table 2 below, summarizes the capacities identified during the revision of the indicators.

CONCLUSION

The main goal of this document has been to provide a review of the currently most used and internationally recognized energy poverty indicators, following the criteria defined by the European Energy Poverty Observatory, the Mexican Energy Poverty Observatory and the Chilean Energy Poverty Network, with regard to their ability to identify those homes at risk of suffering from this (see

Revista Hábitat Sustentable Vol. 10, N°. 1. ISSN 0719 - 0700 / Págs. 8 -21
https://doi.org/10.22320/07190700.2020.10.01.01

Analysis	10%	2M	MIS	LIHC	AFCP	HEP	Perception surveys	Econometric	TC CT	EE	IVH	FPPRI	EPVI
Considers the "heating or eating" effect	X	X	✓	✓	✓	✓	X	X	X	X	✓	X	X
Prioritizes low income over high income	✓	✓	✓	X	✓	✓	✓	✓	X	X	✓	✓	✓
Only considers the energy consumption required to achieve a suitable comfort	✓	✓	X	X	X	X	✓	X	X	X	X	X	X
Includes the characteristics of the dwelling in the analysis	X	X	X	X	X	X	✓	✓	✓	✓	✓	✓	✓
Includes the compliance of the minimum thermal comfort	X	X	X	X	X	X	X	X	X	✓	✓	✓	X
Includes the energy efficiency of the dwelling in the analysis	X	X	X	✓	X	X	X	X	✓	✓	✓	✓	✓
Includes the suitable use of the home's facilities	X	X	X	✓	X	X	X	X	X	X	✓	X	X
Considers the income distribution in the study area	X	X	✓	✓	✓	✓	X	✓	X	X	✓	X	X
Includes actual expense and consumption information of the homes	✓	✓	✓	X	✓	✓	✓	✓	X	X	✓	X	✓
Excludes from the analysis the groups considered as the most physically vulnerable (elderly, chronically ill, disabled and young children)	X	X	X	✓	X	X	✓	✓	✓	✓	X	✓	✓
Prioritizes energy efficiency as a measure against EP, hiding the origin of the problem: the home is in a monetary poverty situation	X	X	X	✓	X	X	X	X	✓	✓	X	✓	✓

Table 2. Critical analysis of the analyzed indicators.
10% (10% indicator); 2M (2M indicators); MIS (Minimum Income Standard); LIHC (Low Income High Cost; AFCP (After Fuel Cost Poverty); HEP (Hidden Energy Poverty); TC (Thermal Comfort); EE (Energy Efficiency); IVH (Index of Vulnerable Homes); FPPRI (Fuel Poverty Potential Risk Index); EPVI (Energy Poverty Vulnerability Index). Source. Preparation by the authors.

Table 2). With this in mind, the energy vulnerability factors (available infrastructure, energy efficiency, monetary and social poverty, welfare and health), provided by Bouzarovski et al. (2014) have been used to analyze the effectiveness of current FP indicators, which can be grouped following the indicators they are based upon: income-expenses; self-reported conditions; econometric analysis; thermal comfort; and energy efficiency.

The main weakness of all these indicators is based on the impossibility that a single indicator considers all the possible factors that have an impact on the daily activities of the homes, like thermal comfort, health, and wellbeing. As a result, an incomplete analysis is provided if they are used in isolation, mainly due to inaccuracies of exclusion (reason why the homes that should receive benefits are not recognized by the government strategies) and inclusion (where homes that are not at risk of suffering from energy poverty comply with the eligibility criteria and, therefore receive support). Therefore, it is necessary to combine several indicators and analyze their results to determine whether a holistic analysis is achieved, both of the technical characteristics of the dwelling and the situation of the home.

The discussion presented in this document exposes the weaknesses of existing EP indicators in the identification of homes at risk and leads to the definition of a multiple indicator approach that brings together as many factors as possible. In addition, due to the complexity of extrapolating the indicators defined to other countries, or climate zones, with different social and economic context, the need is argued that each country defines EP considering the circumstances of the context to develop concrete and effective policies. Finally, in the particular case of the European Union, the lack of suitable definitions and indicators in most of the member states leads this research to providing a starting point.

ACKNOWLEDGMENTS

This research is part of the New Integrated Analysis of Energy Poverty in Andalusia (NAIPE). Prediction, assessment, and adaption to climate change of vulnerable homes from an economic, environmental, and social perspective. Reference US-1255465. Financed from the call of R&D+I Projects FEDER Andalusia 2014-2020 for the Economy and Knowledge Council of the Regional Andalusian Government (Spain).

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