



Energy poverty in Andalusia. An analysis through decentralised indicators

Susana Clavijo-Núñez^{a,*}, Rafael Herrera-Limones^a, Julia Rey-Pérez^a, Miguel Torres-García^b

^a Instituto Universitario de Arquitectura y Ciencias de la Construcción, Escuela Técnica Superior de Arquitectura, Universidad de Sevilla, Av. Reina Mercedes 2, 41012, Sevilla, Spain

^b Departamento de Ingeniería Energética. E.T.S. de Ingeniería, Universidad de Sevilla, Camino de los Descubrimientos, s/n, 41092, Sevilla, Spain

ARTICLE INFO

Keywords:

Energy poverty
Vulnerable households
Decentralised studies

ABSTRACT

Interest in energy poverty has increased in recent years and has made it possible to define the lack of energy resources in households and the importance of energy as a right. The research carried out in this work shows the importance it acquires in the current context, where a large part of the population lives confined to their homes due to the global COVID-19 pandemic and has to face higher energy costs, which affects their health and safety. This paper focuses on showing the need to study and take action on energy-poor households in Andalusia, which has been identified as one of the Spanish communities with the highest level of energy poverty. To this end, the main indicators are calculated for Andalusia. The research is transdisciplinary and has been developed by the Aura team of the University of Sevilla, which participates in the Solar Decathlon university competition. A high degree of energy vulnerability is concluded, with all the main indicators exceeding the national average. Finally, the conclusions section shows the need to modify the current methodology that defines vulnerable households and develop local databases in territories where the factors that affect energy vulnerability are homogeneous and evolving towards decentralised studies.

1. Introduction

The energy sector is present in all current human activities in the form of electricity to drive systems, in the form of fuel for transport or heat to achieve comfort conditions. Of the total amount of final energy consumed in Spain, 18% goes to the residential sector (European Union, 2018). The way in which energy is managed in homes, the knowledge of citizens in this sector and public energy policies are of vital importance in order to keep homes under basic care (Alem and Demeke, 2020).

It is therefore important to register and study households that do not have sufficient or healthy energy conditions (Thomson et al., 2017). That is to say, those households that do not have adequate temperatures in the months with the most extreme climatic conditions, and those that do not have energy sources for the use of household appliances or for cooking, according to socially perceived needs (Tirado Herrero, 2017). This is where the use of the term energy poverty begins. It is a manifestation of energy vulnerability in a given space and time (Tirado Herrero et al., 2018) (Bouzarovski, 2014), which affects a large number of households globally and which needs to be investigated in order to reduce the social impact and to develop adequate energy policies

(Sovacool et al., 2012).

This task is not only based on implementing energy-saving measures or supplying buildings with renewable energy. The concept of energy poverty defends the human right to energy and promotes a citizenry trained in responsible energy consumption and production (Billi et al., 2018; Sánchez, 2018). This idea contrasts with the dominant vision of the European Union's energy policies, where energy services are governed by market criteria and the maximisation of private profits for energy companies (Tirado Tirado Herrero et al., 2018).

The elimination of energy poverty is starting to be considered in current policies, such as the United Nations Agenda 2030; concretized in Sustainable Development Goals (SDG) 7: affordable and clean energy. According to this goal, the aim is to "ensure access to affordable, reliable, sustainable and modern energy for all" (United Nations, n.d.).

The process of loss of energy resources affects households in very different ways and depends on their social category, be it gender, ethnicity, class, etc. (Viveros Vigoya, 2016). This is why the right to energy and to decent housing can only come about without confronting the current economic and social crisis (Hernández et al., 2009), contributing to the transformation towards a critical, informed and

* Corresponding author.

E-mail addresses: susclanun@alum.us.es (S. Clavijo-Núñez), herrera@us.es (R. Herrera-Limones), jrey1@us.es (J. Rey-Pérez), migueltorres@us.es (M. Torres-García).

<https://doi.org/10.1016/j.enpol.2022.113083>

Received 25 February 2021; Received in revised form 23 March 2022; Accepted 23 May 2022

Available online 3 June 2022

0301-4215/© 2022 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

responsible global citizenship (Gillard et al., 2017).

This research paper aims to advance in the analysis of energy poverty in Andalusia through the calculation of the main indicators of energy poverty. To do so, it has been counted on the collaboration of the Andalusian Energy Agency. Specifically, the research results have contributed to the European POWERTY project (Interreg Europe, 2019), led by the Agency. At the same time, the study has been developed in relation to the Aura project within the Solar Decathlon Europe 19, Solar Decathlon Latin America and Caribbean 15 and 19 university competitions. The Aura Strategy and participation in the Solar Decathlon are presented as a tool for innovation through project resolution, allowing students to approach new holistic transversal approaches, while acquiring international experience (Herrera-Limones et al., 2020b). The results and conclusions presented by the Aura project are particularly interesting in terms of the conditions of comfort, health and habitability of the prototype developed by the University of Seville team, given that this competition promotes energy-efficient designs that contribute to improving the health of the occupants (Herrera-Limones et al., 2020a).

The work is organised in three blocks. First, the situation of energy poverty in the European context is presented, from the main definitions to the indicators used to measure energy vulnerability. The case of Andalusia is specifically analysed as one of the communities with the highest degree of energy poverty in Spain.

The methodology for calculating the indicators in the Andalusian community is presented below, based on the Living Conditions and Household Budget Surveys carried out by the National Institute of Statistics. This allows for energy costs and the lack of comfort and habitability in Andalusian households to be addressed, which will have a direct impact on the physical and mental health of these families (Hernández et al., 2016).

Based on this methodology, a section is presented with the energy poverty rates and with the analysis of the answers on the deficiencies obtained from the surveys. This shows that Andalusia continues to be one of the regions with the highest levels of energy poverty, as the main indicators continue to exceed the national average.

Finally, a reflection on the main results obtained is included and a discussion on future research, possible improvements in the methodology and processes to improve energy poverty in the community is presented.

This research paper becomes more relevant when it is presented as one of the first specific studies on energy poverty indicators for the Andalusian territory. The collected results and contributions will serve as the basis for continuing the investigation of this problem that affects people's health on a daily basis.

2. Theoretical framework

Currently there is no single methodology or definition to measure energy poverty in a territory. Historically, it has been related to the inability to keep the home at an adequate temperature, or the inability to pay for electricity bills (Thomson et al., 2017). Although there is a direct relationship with the above, energy poverty is a much more complex term.

Many countries within the European Union have chosen a specific definition of energy poverty according to their specific problems (Rademaekers et al., 2016). Since it is such a multifaceted phenomenon, some distortion in the analysis of data at national level is inevitable. However, this methodology based on precise definitions neglects the diversity and context of each community (Sareen et al., 2020). Other institutions have opted for more generalised definitions, without limiting themselves to specific indicators (Tirado Herrero, 2017).

One of the earliest definitions was provided by Brenda Boardman in the UK, defining it as "the inability [for a household] to obtain an adequate amount of energy services for 10% of disposable income" (Boardman, 1991).

Other authors, such as Healy and Clinch, have incorporated

assessments of the ability of households to maintain adequate temperatures in winter. They included interesting factors such as the family configuration (in the case of single parent families) or the educational level of the household members. Thus, social factors appear apart from economic or technical ones (Healy and Clinch, 2004).

For his part, Buzar introduces the complexity of the context in which energy poverty in a household is measured. He underlines the importance of defining what is meant by a "sufficient level of energy needs" (Buzar, 2007).

A breakthrough in this terminology comes in the form of Bouzarovski and Petrova's proposal that energy poverty is the "inability [of a household] to achieve a socially and materially necessary level of household energy services" (Bouzarovski and Petrova, 2015). Thus, the same concept encompasses both economic incapacity, related to territories in the global north, and lack of access to energy resources, related to territories in the global south (Tirado Tirado Herrero et al., 2018).

The EU Energy Poverty Observatory (EPOV) states that adequate heating, air conditioning (cooling), lighting and energy for household appliances are essential services needed to ensure a decent standard of living and the health of citizens; in addition to access to energy services. According to the Observatory, energy poverty begins when a household lacks one of these services (EU Energy Poverty Observatory, n.d.).

The different definitions of energy poverty have been analysed and understood as a basic need. There are different international agreements and instruments that refer to the right to basic energy services, such as the Universal Declaration of Human Rights (UDHR) or the International Covenant on Economic, Social and Cultural Rights (ICESCR) (García and Mundó, 2014; Sánchez, 2006). Over the years, numerous international conferences have been held on the issue of energy, especially since the 1990s. However, there is one key milestone in the struggle for global rights that did not explicitly include the right to energy (Salvador Villà and Sneij Oriá, 2006). This is the Millennium Development Goals (MDGs), agreed at the UN Summit in New York in 2000 (United Nations, 2015a).

Thanks to the United Nations Framework Convention on Climate Change held in Lima in December 2014, the right to energy and its involvement in the climate emergency acquired greater relevance among the priorities of human development. This impulse on the right to energy ended up being materialized at the 2015 United Nations Summit, where the 2030 Agenda for Sustainable Development and the 17 Sustainable Development Goals were adopted. His new Agenda establishes more ambitious, participatory and universal challenges. (Agencia Española de Cooperación Internacional para el Desarrollo, n.d.). For the first time, a specific goal on energy is included, embodied in SDG 7 for Affordable and Clean Energy (United Nations, 2015b).

As shown in Fig. 1, this Goal focuses on guaranteeing universal access to affordable and non-polluting energy services, increasing renewable energies or promoting research into clean energy technologies with a view to 2030 (United Nations, n.d.) (see Fig. 2).

However, in this work universal access to energy services is focused on different objectives depending on the territory and its citizens. This is based on the fact that energy poverty is a complex concept and depends on many factors, both on a global-local and territorial scale (see Fig. 2). Global-local factors are those that affect the quality of life and the energy capacity of other geographically distant territories. The type of energy production and the great dependence on fossil sources, the natural resources used, the extraction of which is usually linked to serious violations of human rights and serious environmental impacts, or the commercialisation of energy itself, are some of them (Ávila et al., 2018; Cotarelo and Riutort, 2017).

This point highlights the great energy dependence that exists from the north to the global south, under a process of resource exploitation in which wealth is concentrated in the north and the rest of the territories are impoverished (Argibay and Celorio, 2005; Roberts and Parks, 2006).

On the other hand, the factors on a territorial scale are those that affect the studied territory itself. They can be grouped into five main

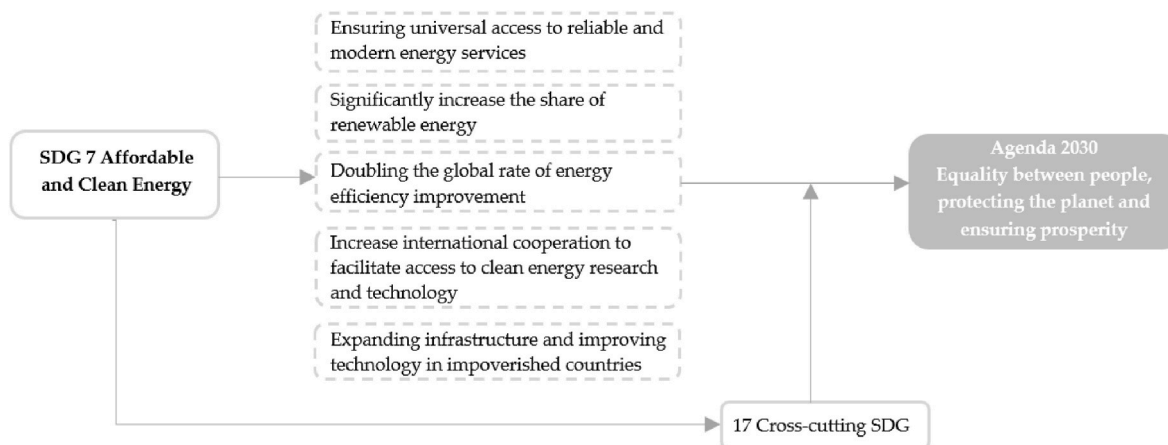


Fig. 1. SDG 7 targets and mainstreaming of Agenda 2030 goals.

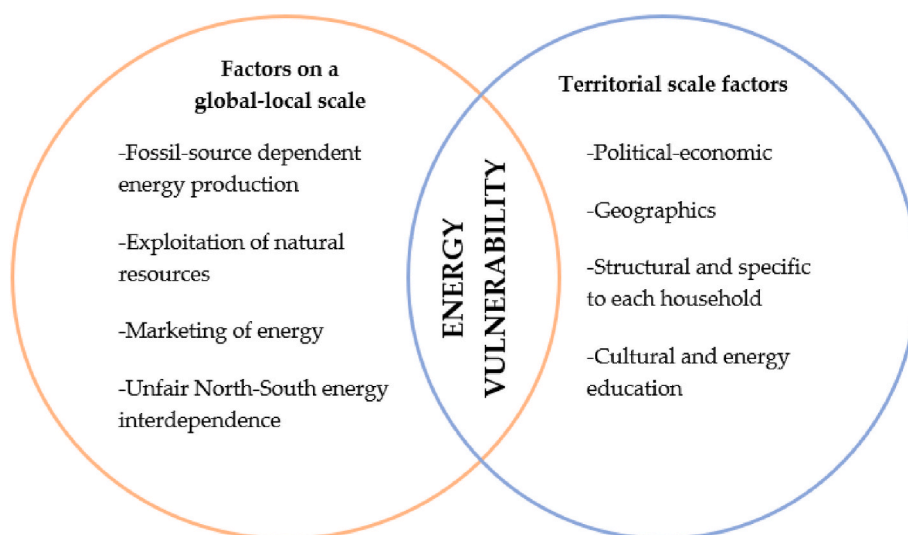


Fig. 2. Relationship between energy vulnerability and the factors on which it depends.

groups: political-economic factors (such as the state of the economy), geographical factors (such as climate), dwelling characteristics (such as insulation standards), household characteristics (such as income or expenditure), cultural factors and those related to the energy education of households (Bouzarovski and Petrova, 2015; Del Campo, 2016; Rademaekers et al., 2016). This last point is not usually considered in this type of study. However, it is considered essential as families are often unaware of possible alternatives.

The indicators are obtained in relation to different factors and are crucial in the definition of energy poverty, as they allow the number of families living under these circumstances in a territory to be quantified. However, there is currently no unified set of indicators. This is partly because establishing a set of indicators risks silencing certain significant aspects but difficult to measure (Sareen et al., 2020).

The list of the most commonly used indicators in the European Union is very long, depending on the country or body applying it. The main indicators at national level are listed below, grouped according to their calculation. The indicators obtained through the Living Conditions Surveys (LCS) and the Household Budget Surveys (HBS) are particularly noteworthy. These are two data sources developed by the National Institute of Statistics (INE in Spanish) that are published annually for the national and regional level.

LCSs present a reference source of income distribution and social exclusion. These surveys are essential for studying the needs of the

population and the collected data is presented disaggregated per person and consumption unit, depending on variables such as age, level of training, type of household, etc. (Instituto Nacional de Estadística, 2019a).

Three indicators emerge from this survey (Tirado Tirado Herrero et al., 2018):

- Inability to maintain the home at an adequate temperature during the cold months. In particular, the variety of climates in a country or the sensitivity of the people surveyed makes it difficult to obtain objective results for this indicator.
- Delayed payment of housing bills (water, gas, heating, electricity, community, etc.) due to financial difficulties. In this case, delays are counted against non-energy bills (Instituto Nacional de Estadística, 2019a). In addition, it has a strong dependence on the contracted tariffs. Nevertheless, it is a very useful indicator when measuring the capacity to maintain basic supplies in the home.
- The household lost some of its usual energy resources during the last 12 months due to financial difficulties. In the survey, this question does not take into account whether the lack of service was forced (such as a power cut) or whether it was due to economic hardship (Instituto Nacional de Estadística, 2019a).

On the other hand, the Household Budget Survey includes annual

data on the destination of consumer spending (Instituto Nacional de Estadística, 2016). The main indicators related to HBS are:

- Twice the median (2M). It is met when the energy load of a household (percentage of household energy expenditure on income, both in units of equivalent consumption) is more than twice the national median. The median of a year or a specific period can be used (Tirado Tirado Herrero et al., 2018). Most researches agree that indicators based on the median are more appropriate than those based on the average, from a statistical approach (Castaño-Rosa, 2018).
- Hidden Energy Poverty (HEP). It is defined as those households “whose energy expenditure is less than half the national average” (Ministerio para la Transición Ecológica y el Reto Demográfico, 2019). In order to avoid a distortion in the comparison between households of different sizes, expenses per person are used. Thus, the energy expenditure of each household is divided by the number of consumption units in the household (Ministerio para la Transición Ecológica y el Reto Demográfico, 2019).

The main problem with these two indicators is the dependence on statistical means (Schuessler, 2014), so changing the sources would lead to results that differ greatly from each other.

3. Analysis of Andalusia

In the case of Europe, as occurs in enriched territories or in the “global north”, the situation of energy poverty is related to the inability to face energy bills and maintain comfortable housing; compared to other territories, such as impoverished countries or those in the “global south”, where energy poverty refers to a lack of access to energy resources (Castelao Caruana and Méndez, 2019) (Bouzarovski, 2018).

Although it is not a priority on the Spanish political and social scene, there are several bodies working to tackle this poverty. Among these, we should highlight the European Union Energy Poverty Observatory (EPOV), the Platform for a New Energy Model (Px1NME), the Andalusian Energy Agency (AAE) and the Environmental Sciences Association (ACA). The values presented by the Observatory place Spain in an intermediate position with respect to the Member States of the European Union affected by energy poverty. In the case of the indicator of inadequate temperature in winter, Spain exceeds the European average with 9.1% of the population unable to maintain their homes at comfortable temperatures during 2018 (EU Energy Poverty Observatory, 2018). With regard to the indicator of twice the median, the Spanish average reaches 14.2% of households according to data calculated for 2015 (EU Energy Poverty Observatory, 2015).

While there are few studies that address energy poverty at a national level, even fewer provide results for provinces or autonomous regions. This is a major problem in terms of strategy development and action, as there is no theoretical analysis of the main shortcomings. It is important to re-emphasise the importance of developing studies in communities that share economic, climatic, cultural and other factors, so that there is a solid basis on which to work (Castaño-Rosa et al., 2020; Costa-Campi et al., 2019).

This study will focus on the specific case of Andalusia, given the collaboration with the Andalusian Energy Agency, with the *Aura* project of the University of Seville and the previous work carried out by the same author on this territory. It is a starting point for decentralised research in this region.

Despite the fact that there is hardly any bibliography for the case study of Andalusia, there are national reports in which the indicators are studied by the autonomous region, as in the case of the Environmental Sciences Association. In the four studies presented since 2012, Andalusia heads the list of regions with the greatest number of cases of energy poverty in homes (Tirado Tirado Herrero et al., 2018; 2016, 2014, 2012).

Table 1 below shows the indicators for the Andalusian region

Table 1

Results of the main indicators for Andalusia. Fuente (Tirado Tirado Herrero et al., 2018):

Territory	2M	HEP	Inadequate temperature	Invoice delay	Lack of supply
Spain	17%	12%	10%	7%	2%
Andalusia	18%	16%	12%	10%	3%

calculated in its latest study “Energy poverty in Spain: towards a system of indicators and a strategy for state action” in 2018 (Tirado Tirado Herrero et al., 2018), using the INE’s databases for 2016 (see Table 2).

These results show that Andalusia has higher energy poverty rates than the national average, and furthermore, it is the second most affected autonomous region, being preceded only by Castilla-La Mancha (Tirado Tirado Herrero et al., 2018).

All this shows the need to apply measures on Andalusian territory immediately. This study is one of the first specific studies on energy poverty indicators in Andalusia.

4. Methodology

Once the situation of energy poverty has been analysed at Spanish level in general and in Andalusia in particular, it becomes clear that the main characteristics need to be analysed in depth. For this purpose, the following methodology (see Fig. 3) of three different phases is proposed:

4.1. Phase I. Analysis of databases

At national level, the statistical resources that can provide the most relevant data are those produced by the National Institute of Statistics (INE). Specifically, the Living Conditions Surveys and the Household Budget Surveys for 2018¹ have been analysed (Instituto Nacional de Estadística, 2019b, 2019c). Both surveys are carried out at a national level and their results are presented broken down by region.

4.2. Phase II. Living Conditions Survey (LCS) and Household Budget Survey (HBS) calculations

Based on these surveys, the main indicators of energy poverty have been calculated. For the LCS, 13,368 households were interviewed of which 1,363 were Andalusian. Although it is true that the sample of 1,363 households cannot be considered a true reflection of Andalusian society, these data can give a general idea of the situation in which they live. As shown in Table 2, the following household responses have been analysed:

In the case of the HBSs, they were carried out for 21,395 households, of which 2,322 are Andalusian. These results make it possible to create a basic context for the energy expenditure of Andalusian families. Table 3 shows the data used to calculate the two indicators of interest, twice the median (2M) and hidden energy poverty (HEP):

It is important to note that each expenditure figure is associated with a spatial elevation factor. These factors are used to raise the sample data and obtain population results. However, the calculations have been made without this elevation, as the elevation factor is calculated by the INE at a national level and cannot be broken down by community.

4.3. Phase III. Analysis of the results

The calculation of the main indicators is essential to understand the situation of Andalusia versus the Spanish context, from the perspective. However, it is necessary to study the rest of the answers included in

¹ It should be noted that all the asked questions refer to the year before the survey, i.e. 2017.

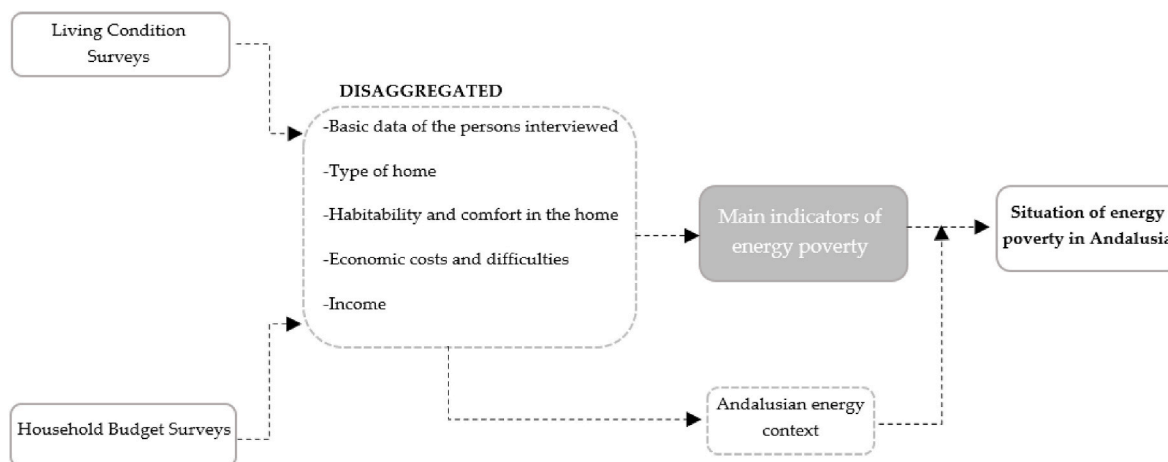


Fig. 3. Study methodology.

Table 2
Indicators analysed from the Living Conditions Survey.

Source of information	Indicators analysed
People's basic data	-Risk of poverty
Household files	-Delays in payment of electricity, water, gas, etc. bills in the last 12 months -Household's ability to make ends meet -Total costs (including rent or mortgage, electricity, community fees, etc.) -Lack of natural light -Problems of pollution, dirt, or other environmental problems in the area caused by industry or traffic -Problems with leaks, dampness in walls, floors, ceilings or foundations, or rot in floors, window or door frames -If the household can afford to keep the home at an adequate temperature during the winter months -If in the last 12 months there was any occasion when, due to financial difficulties, the household no longer had any of its usual sources of energy

Table 3
Indicators analysed from the Household Budget Survey.

Analysed indicators
-Energy expenditure, which includes expenditure on electricity, gas and other fuels linked to the main dwelling
-Unit of consumption, measuring the equivalent size of the household according to the modified OECD scale
-Income, as the exact amount of total net monthly household income, then converted to annual income
-Type of household, depending on whether it is a single-adult household, a couple without children, a couple with children under 16, or other households
-Gender of main breadwinner

these surveys in relation to habitability, comfort or mental health in order to understand this situation of poverty.

5. Results

In Andalusia, in 2018 there was a census of 8,384,408 people, of which 4,133,898 were men and 4,250,510 were women. These people had their habitual residence in some of the 3.2 million households registered in Andalusia (Instituto de Estadística y Cartografía de Instituto de Estadística de Andalucía, 2018).

Based on the defined methodology, the most significant results for the study are presented. Firstly, results provided by the Living

Conditions Surveys and the Household Budget Surveys are included. Based on these results, calculations have been made to obtain the five main indicators for measuring energy poverty proposed in the methodology.

5.1. Results of the Living Conditions Surveys

The results provided by the basic data of the persons interviewed and the data from the LCS files will be analysed in detail, as the latter are presented by Andalusian household and not by person.

This survey was carried out in 2018 for a total of 3,634 people living in Andalusia, of whom 1,856 were women and 1,778 were men. As for the results of the basic data of the interviewed people, the "people at risk of poverty or social exclusion" stands out. Thus, although this result is not specific to the case of poverty, it serves as a reference for knowing the situation of Andalusian households.

There is a high rate of people at risk of poverty in Andalusia, with 36.82% of the population (see Table 4). The number of women who are vulnerable to poverty is higher than the rate for men and, in addition, of the 695 women who have been identified as vulnerable, 110 were over 65 years of age at the time of the survey.

In terms of LCS household files, the 1,363 households surveyed were analysed. The main results related to energy poverty are presented in Table 5.

One of the main problems focuses on the last question on energy resource loss in the last 12 months, as only those households that have declared inadequate temperatures in winter are asked. This leads to a very limited sample of households, with only 179 Andalusian households responding. Even so, all these results allow the construction of the main indicators presented in this point.

5.2. Results of the Household Budget Surveys

In particular, the results necessary to calculate the indicators of twice the median (2M) and hidden energy poverty (HEP) have been chosen.

With all this, it has been obtained that the median energy expenditure per unit of consumption in Andalusia is 504 euros per household and that the median energy charge, measured as a percentage of annual energy expenditure over annual income (both measured per unit of

Table 4
LCS results.

People's basic data result	Total number of people	No. of women	No. of men	% of people in Andalusia
Risk of poverty	1.338	695	643	36,82%

Table 5
Results of Living Conditions Surveys.

Household outcome	No. of households	% of households
Delayed payment of invoices 1 time	20	1,47%
Delayed payment of invoices 2 times or more	120	8,80%
There was no delay	1.218	89,36%
Not stated	5	0,37%
Very difficult to reach the end of the month	227	16,65%
Difficulty in making ends meet	688	50,48%
Easy to make ends meet	439	32,21%
Very easy to reach the end of the month	9	0,66%
Costs are a heavy burden	807	59,21%
The costs are a reasonable burden	511	37,49%
The costs are not a burden	45	3,30%
Lack of natural light	69	5,06%
Environmental issues	127	9,32%
Presence of leaks, humidity ...	288	21,13%
Unsuitable temperature in winter	179	13,13%
Lack of energy source at least once	27	1,98%
There was no lack of energy source	152	11,15%
Not applicable	1184	86,87%

consumption) is 4.23%.

5.3. Main indicators of energy poverty

Table 6 shows the results of the energy poverty indicators for the Andalusian territory. As can be seen, the sample of analysed households is very small. This only highlights the need to carry out decentralised surveys and studies, as well as national ones.

If these results are compared with those calculated by Environmental Sciences Association for 2016 (Table 1), a discrepancy is observed in terms of the hidden energy poverty indicator, which goes from 16% to 9.77%, and the lack of supply or loss of energy source, which was 3% of the population under this problem in comparison with the current calculation for 2018 which evaluates it at 15.08%. This discrepancy can be explained, as mentioned above, by the very small sample of households for which information has been available.

Comparing the results obtained with those contained in the latest report produced by the Ministry for Ecological Transition (Ministerio para la Transición Ecológica y el Reto Demográfico, 2020), it can be seen that Andalusia continues to exceed the national average on most indicators (see Table 7), constituting a community with a high level of energy poverty. However, it can be seen that this study does not include the indicator of loss of usual sources as one of the main ones to be calculated and updated.

Table 6
Main indicators of energy poverty in Andalusia.

Data source	Indicators	No. of households affected	No. of households shown	% of households affected
LCS	Inability to maintain the home at an adequate temperature in winter	179	1.363	13,13%
LCS	Late payment of energy bills	140	1.363	10,27%
LCS	Loss of a regular source of energy in the last 12 months	27	179	15,08%
HBS	Twice the median (2M)	232	1.249	18,57%
HBS	Hidden Energy Poverty (HEP)	122	1.249	9,77%

Table 7
Comparison of results at Andalusian and national level based on 2018 data.

Indicators	% of households in Andalusia	% of households in Spain
Inability to maintain the home at an adequate temperature in winter	13,13%	9,10%
Late payment of energy bills	10,27%	7,20%
Loss of a regular source of energy in the last 12 months	15,08%	–
Twice the median (2M)	18,57%	19,90%
Hidden Energy Poverty (HEP)	9,77%	11%

6. Discussion

From this study, it has been possible to quantify and analyse the situation of energy poverty in Andalusia, obtaining the main indicators for this Autonomous Community. However, several methodological aspects are presented which need to be reflected upon.

Energy poverty is presented as the inability to access energy services that allow for a decent standard of living and good health of the community. For its elaboration, the statistical bases and the main indicators most used at national level have been chosen. INE's databases are one of the few sources currently available. However, it has been shown that these surveys are not sufficient to generate a detailed study of energy poverty, as the sample of households they provide is small. This can be seen in particular through the indicator of loss of a regular source of energy. As this is a question that is only asked to households that have declared that they do not have an adequate temperature in winter, only 179 households have been surveyed, a very small sample to understand the Andalusian energy poverty situation. It is necessary to develop surveys that incorporate specific questions for the calculation of energy vulnerability, which are carried out to a larger population sample by communities and provinces and which introduce a gender focus.

With regard to the indicators, the results are appropriate to the studies previously carried out. In spite of the small sample of surveys for Andalusia, the obtained results are very much in line with the reports made by the Association of Environmental Sciences for previous years. The main conclusion of the results is that Andalusia continues to constitute a community with a high degree of energy poverty. It can be seen that a large part of the Andalusian population is at risk of suffering some kind of poverty, specifically 36.82% of households. However, it is shown that by analysing only the main indicators it is not possible to understand the situation. For this reason, other responses collected in the surveys have been studied. It is worth noting that many of the surveyed households do not have comfortable homes, claiming to live with the presence of leaks, humidity (21.13% of households) or in areas with environmental problems of dirt or pollution (9.32% of respondents). There is also a lack of objective indicators to measure energy poverty, as the energy culture of households, how they manage the efficiency of their homes or even how many hours vulnerable people may spend in their homes are unknown (Jacques-Aviñó et al., 2019).

It can be seen that these calculations have only allowed the application of a quantitative methodology which, although necessary and providing knowledge of the energy poverty situation in Andalusia, is not sufficient to tackle the problem. It will be necessary to create a methodology that combines both a quantitative and qualitative perspective (Middlemiss et al., 2019). Qualitative techniques can be more easily adapted to an equality and human rights approach, which would allow for a more realistic identification of vulnerable groups (Luxán Serrano, 2020). It will be necessary to build a methodology that contributes to social change on the basis of both techniques (Bassi Follari, 2014), since the groups classified as being in energy poverty are built on the basis of the data and the way in which these are analysed (Sareen et al., 2020). It is necessary, therefore, to develop databases from local governments that incorporate these issues. In particular, these sources should incorporate data on cultural habits and how energy is managed in homes

(Thomson et al., 2017). These aspects are essential to create plans and strategies that promote responsible energy management. In this way, the aim is to minimize the impact of pollutant emissions from the energy sector in the global north on territories of the global south. All this shows a real problem of the Andalusian community. Although these results could not be taken as accurate, they reflect the situation of vulnerability of this society and the need to act immediately. To do this, it will be necessary to develop decentralised databases and methodologies that contribute to social change and to identify and contextualise this problem with the participation of public, private and civil society actors (Moore, 2012).

7. Conclusions and policy implications

From the present study it is understood that the situation of energy poverty in Spain is a complex problem that affects a large number of households. It is necessary to continue generating studies that identify the groups of households that are sensitive to this problem, effective measures to be applied and to generate knowledge transfer networks between all the involved actors, from governments to private companies or citizens. By working with all sectors of society, more objective research results could be developed to quantify the extent of poverty in households and, ultimately, of people's health.

From this study, new lines will be opened in the future to develop more specific research, since it is found that there is a need to develop decentralised strategic plans, where the factors of households and communities are more homogeneous. There is also a need to redefine sample surveys and to develop new indicators used to measure energy poverty. In order for the studies to faithfully represent this reality and develop a series of effective measures or strategies, it will be necessary to implement participatory processes where the community itself has a voice, identifying existing problems and needs. This will allow for the construction of more representative indicators. In particular, it would be necessary to incorporate the gender perspective, having been identified as one of the most vulnerable group (González Pijuan, 2016; Sánchez-Guevara Sánchez-Guevara Sánchez et al., 2020).

It will also be necessary to continue studying the relationship between energy poverty, health, both physical and mental, and well-being in a decentralised way for the different neighborhoods and localities. Households suffering from energy poverty are more vulnerable to respiratory diseases, viruses, chronic diseases, influenza and even social problems (Hernández et al., 2016), leading to morbidity and mortality related to the absence of a healthy environment (Pollard et al., 2019). In order to study the relationship between sustainable housing and health, in other words, between the medical and architectural disciplines, the most promising advances are aimed at transdisciplinarity. Applying this strategy, the Aura team from the University of Seville has won first prize in the Comfort Conditions tests at the SDLAC15 and SDEU19, developing active and passive comfort strategies to create a sustainable and healthy habitat (López-Escamilla et al., 2020). It is essential to continue working on projects such as Aura and Solar Decathlon, which constitute practical research tools for public health and sustainability (through the development of methodologies that combine a qualitative and quantitative approach) (Luna-Tintos et al., 2020). This will require the application of tools, such as the Solar Decathlon competitions, which allow minimised and public health to be improved (Borralló-Jiménez et al., 2020; Herrera-Limones et al., 2019).

Data availability

Datasets related to this article can be found at Instituto Nacional de Estadística España, hosted at https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176807&menu=ultiDatos&idp=1254735976608 and https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176806&menu=ultiDatos&idp=1254735976608.

CRedit authorship contribution statement

Susana Clavijo-Núñez: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing - review & editing. **Rafael Herrera-Limones:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing - review & editing. **Julia Rey-Pérez:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing - review & editing. **Miguel Torres-García:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

Research Project: "Direct application of the Aura Strategy by the SD-US Team for the regeneration of outdated Andalusian neighbourhoods", as well as a methodological approach for the estate of San Pablo, Seville (as a case study for the extrapolation of results to similar environments, through the implementation of sustainable regeneration in the working-class residential area). Part of the information used in the article comes from the development of the project.

The project was granted in the resolution of July 28th, 2021 by the Ministry of Development, Infrastructure and Territorial Planning (Local Andalusian Government), within the 2020 call for grants for carrying out research projects in the areas of housing, rehabilitation and architecture.

References

- Agencia Española de Cooperación Internacional para el Desarrollo, n.d. La agenda 2030. El reto de los Objetivos de Desarrollo Sostenible [WWW Document]. URL https://www.aecd.es/ES/Paginas/Sala_de_Prensa/ODS/01-ODS.aspx (accessed 12.6.2020).
- Alem, Y., Demeke, E., 2020. The persistence of energy poverty: a dynamic probit analysis. *Energy Econ.* 90, 104789. <https://doi.org/10.1016/j.eneco.2020.104789>.
- Argibay, M., Celorio, G., 2005. Origen y evolución de la educación para el desarrollo, in: Servicio Central de Publicaciones del Gobierno Vasco Donostia-San Sebastián (Ed.), *La Educación Para El Desarrollo*. Vitoria-Gasteiz, pp. 13–41.
- Ávila, S., Berdié Rabanaque, L., Botella, J., Camarasa Pfefferkorn, I., Campuzano Guerra, M., Coll, C., Del Bene, D., D'Elia Lullí, G., Guiteras Blaya, M., Nualart Corpas, J., Pérez López, A., Piqué i Magdalena, A., Presas Renom, O., Vives Ingla, M., 2018. Por la soberanía energética desde una democracia de raíz, *Icaria editorial, ¡Tenemos Energía! Retos de La Transición Hacia La Soberanía Energética*, pp. 19–46. Barcelona.
- Bassi Follari, J., 2014. Quantitative/qualitative : the paleozoic debate. *Forum Qual. Soc. Res.* 15, 7. <https://doi.org/10.17169/fqs-15.2.1993>.
- Billi, M., Amigo, C., Calvo, R., Urquiza, A., 2018. Economía de la Pobreza Energética ¿Por qué y cómo garantizar un acceso universal y equitativo a la energía? *Econ. y política* 5, 35–65. <https://doi.org/10.15691/07194714.2018.006>.
- Boardman, B., 1991. *Fuel Poverty: from Cold Homes to Affordable Warmth*. Belhaven Press, London, New York.
- Borralló-Jiménez, M., LopezdeAsiain, M., Herrera-Limones, R., Arcos, M.L., 2020. Towards a circular economy for the city of seville: the method for developing a guide for a more sustainable architecture and urbanism (GAUS). *Sustainability* 12, 7421. <https://doi.org/10.3390/su12187421>.
- Bouzarovski, S., 2014. Energy poverty in the European union: landscapes of vulnerability. *WIREs Energy Environ.* 3, 276–289. <https://doi.org/10.1002/wene.89>.
- Bouzarovski, S., 2018. Understanding energy poverty, vulnerability and justice. In: *Energy Poverty*. Palgrave Macmillan, pp. 9–39. https://doi.org/10.1007/978-3-319-69299-9_2.
- Bouzarovski, S., Petrova, S., 2015. A global perspective on domestic energy deprivation: overcoming the energy poverty-fuel poverty binary. *Energy Res. Social Sci.* 10, 31–40. <https://doi.org/10.1016/j.erss.2015.06.007>.
- Buzar, S., 2007. *Energy Poverty in Eastern Europe. Hidden Geographies of Deprivation*. Ashgate.

- Del Campo, A., 2016. Soberanía energética y democratización de la energía. Plataforma por un Nuevo Modelo Energético.
- Castano-Rosa, R., 2018. Identificación De Hogares Vulnerables a Partir Del Concepto Pobreza Energética. Indicador Y Modelo De Evaluación. Universidad de Sevilla.
- Castano-Rosa, R., Solís-Guzmán, J., Marrero, M., 2020. Energy poverty goes south? Understanding the costs of energy poverty with the index of vulnerable homes in Spain. *Energy Res. Social Sci.* 60, 101325. <https://doi.org/10.1016/j.erss.2019.101325>.
- Castelao Caruana, M.E., Méndez, F.M., 2019. La pobreza energética desde una perspectiva de género en hogares urbanos de Argentina. *SaberEs* 11, 133–151. <https://doi.org/10.35305/s.v11i2.186>.
- Costa-Campi, M.T., Jové-Llopis, E., Trujillo-Baute, E., 2019. Caracterización de la pobreza energética en España. In: Naturgy, Fundación (Ed.), *La Pobreza Energética En España. Aproximación Desde Una Perspectiva de Ingresos*, Madrid, pp. 37–44.
- Cotarelo, P., Riutort, S., 2017. Energía local, democracia real: una reflexión sobre la democracia energética. *La Energía. Retos y Problemas*.
- EU Energy Poverty Observatory, 2015. Indicator. Low absolute energy expenditure (M/2) [WWW Document]. URL <https://www.energy-poverty.eu/indicador?primarilyd=1463> (accessed 12.6.2020).
- EU Energy Poverty Observatory, 2018. Indicator. Inability to Keep Home Adequately Warm [WWW Document]. URL <https://www.energy-poverty.eu/indicador?primarilyd=1461>. (Accessed 12 June 2020).
- EU Energy Poverty Observatory, n.d. What is energy poverty? [WWW Document]. URL https://energy-poverty.ec.europa.eu/energy-poverty-observatory/what-energy-poverty_en. (Accessed 12 June 2020).
- García, M., Mundó, J., 2014. La energía como derecho. Cómo afrontar la pobreza energética.
- Gillard, R., Snell, C., Bevan, M., 2017. Advancing an energy justice perspective of fuel poverty: household vulnerability and domestic retrofit policy in the United Kingdom. *Energy Res. Social Sci.* 29, 53–61. <https://doi.org/10.1016/j.erss.2017.05.012>.
- González Pijuan, I., 2016. Desigualdad de género y pobreza energética. Un factor de riesgo olvidado.
- Healy, J.D., Clinch, J.P., 2004. Quantifying the severity of fuel poverty, its relationship with poor housing and reasons for non-investment in energy-saving measures. *Energy Pol.* 32, 207–220. [https://doi.org/10.1016/S0301-4215\(02\)00265-3](https://doi.org/10.1016/S0301-4215(02)00265-3).
- Hernández, A., Ferriz, Á., Herrero, Y., González, L., Morán, C., Brasero, A., Ortega, A.M., 2009. Insostenibilidad global. Las amenazas del planeta. In: FUHEM, Centro de Investigación para la Paz La Crisis Ecosocial En Clave Educativa. Guía Didáctica Para Una Nueva Cultura de Paz, Madrid, pp. 11–31.
- Hernández, D., Phillips, D., Siegel, E.L., 2016. Exploring the housing and household energy pathways to stress: a mixed methods study. *Int. J. Environ. Res. Publ. Health* 13, 916. <https://doi.org/10.3390/ijerph13090916>.
- Herrera-Limones, R., León-Rodríguez, Á.L., López-Escamilla, Á., 2019. Solar Decathlon Latin America and Caribbean: comfort and the balance between passive and active design. *Sustainability* 11, 3498. <https://doi.org/10.3390/su11133498>.
- Herrera-Limones, R., Millán-Jiménez, A., López-Escamilla, Á., Torres-García, M., 2020a. Health and habitability in the solar decathlon university competitions: statistical quantification and real influence on comfort conditions. *Int. J. Environ. Res. Publ. Health* 17, 5926. <https://doi.org/10.3390/ijerph17165926>.
- Herrera-Limones, R., Rey-Pérez, J., Hernández-Valencia, M., Roa-Fernández, J., 2020b. Student competitions as a learning method with a sustainable focus in higher education: the University of Seville “Aura Projects” in the “Solar Decathlon 2019. *Sustainability* 12, 1634. <https://doi.org/10.3390/su12041634>.
- Instituto de Estadística y Cartografía de Andalucía, 2018. Padrón Municipal de Habitantes. Cifras oficiales de población municipal [WWW Document]. URL https://www.juntadeandalucia.es/institutodeestadisticaycartografia/badea/operacion/es/consulta/anual/6782?CodOper=b3_128&codConsulta=6782 (accessed 12.6.2020).
- Interreg Europe, 2019. POWERTY [WWW Document]. URL <https://www.interregeurope.eu/powerity/> (accessed 12.7.2020).
- Jacques-Aviñó, C., Dvorzak, J.L., Arjona, D.R., Carrere, J., Benach, J., Ramos, C., Plana, M., López, M.J., 2019. Evaluación cualitativa de una intervención para reducir la pobreza energética. *Rev. Saude Publica* 53, 62. <https://doi.org/10.11606/s1518-8787.2019053001212>.
- López-Escamilla, Á., Herrera-Limones, R., León-Rodríguez, Á.L., Torres-García, M., 2020. Environmental comfort as a sustainable strategy for housing integration: the aura 1.0 prototype for social housing. *Appl. Sci.* 10, 7734. <https://doi.org/10.3390/app10217734>.
- Luna-Tintos, J.F., Cobreros, C., Herrera-Limones, R., López-Escamilla, A., 2020. Methodology comparative analysis” in the solar decathlon competition: a proposed housing model based on a prefabricated structural system. *Sustainability* 12, 1882. <https://doi.org/10.3390/su12051882>.
- Luxán Serrano, M., 2020. Apuntes sobre metodología cuantitativa en investigación feminista.
- Middlemiss, L., Ambrosio-Albalá, P., Emmel, N., Gillard, R., Gilbertson, J., Hargreaves, T., Mullen, C., Ryan, T., Snell, C., Tod, A., 2019. Energy poverty and social relations: a capabilities approach. *Energy Res. Social Sci.* 55, 227–235. <https://doi.org/10.1016/j.erss.2019.05.002>.
- Ministerio para la Transición Ecológica y el Reto Demográfico, 2019. Actualización de Indicadores de la Estrategia nacional contra la Pobreza energética. Medida 2.
- Ministerio para la Transición Ecológica y el Reto Demográfico, 2020. Actualización de Indicadores de la Estrategia Nacional contra la Pobreza Energética.
- Moore, R., 2012. Definitions of fuel poverty: implications for policy. *Energy Pol.* 49, 19–26. <https://doi.org/10.1016/j.enpol.2012.01.057>.
- Nacional de Estadística, Instituto, 2016. Encuesta de Presupuestos familiares. Metodología [WWW Document]. URL https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176806&menu=metodologia&idp=1254735976608. (Accessed 12 June 2020).
- Nacional de Estadística, Instituto, 2019a. Encuesta de Condiciones de Vida. Metodología [WWW Document]. URL https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176807&menu=metodologia&idp=1254735976608. (Accessed 12 July 2020).
- Instituto Nacional de Estadística, 2019b. Resultados de la Encuesta de Condiciones de Vida [WWW Document]. URL https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176807&menu=ultiDatos&idp=1254735976608 (accessed 12.6.2020).
- Nacional de Estadística, Instituto, 2019c. Resultados de la Encuesta de Presupuestos Familiares [WWW Document]. URL https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176806&menu=ultiDatos&idp=1254735976608. (Accessed 12 June 2020).
- Pollard, A., Jones, T., Sherratt, S., Sharpe, R.A., 2019. Use of simple telemetry to reduce the health impacts of fuel poverty and living in cold homes. *Int. J. Environ. Res. Publ. Health* 16, 2853. <https://doi.org/10.3390/ijerph16162853>.
- Rademaekers, K., Yearwood, J., Ferreira, A., Pye, S., Hamilton, I., Agnolucci, P., Grover, D., Karásek, J., Anisimova, N., 2016. Selecting Indicators to Measure Energy Poverty. *Trinomics*, Rotterdam, pp. 1–130.
- Roberts, J.T., Parks, B.C., 2006. Introduction: wet feet marching. In: *A Climate of Injustice : Global Inequality, North-South Politics, and Climate Policy*. MIT Press, pp. 1–43.
- Salvador Villá, I., Snej Oriá, J., 2006. La energía con relación a otros factores de desarrollo: WEHAB y Objetivos del Milenio. In: Asociación Catalana de Ingeniería Sin Fronteras. Energía, Participación y Sostenibilidad. Tecnología Para El Desarrollo Humano, pp. 287–294. Barcelona.
- Sánchez, T., 2006. Sistemas microhidráulicos: análisis de intervenciones a pequeña escala. In: Ingeniería Sin Fronteras Catalana Energía, Participación Y Sostenibilidad. Tecnología Para El Desarrollo Humano, pp. 173–186. Barcelona.
- Sánchez, C., 2018. De la vulnerabilidad energética al derecho a la energía.
- Sánchez-Guevara Sánchez, C., Sanz Fernández, A., Núñez Peiró, M., Gómez Muñoz, G., 2020. Feminisation of energy poverty in the city of Madrid. *Energy Build.* 223, 110157. <https://doi.org/10.1016/j.enbuild.2020.110157>.
- Sareen, S., Thomson, H., Tirado Herrero, S., Gouveia, J.P., Lippert, I., Lis, A., 2020. European energy poverty metrics: scales, prospects and limits. *Glob. Transitions* 2, 26–36. <https://doi.org/10.1016/j.glt.2020.01.003>.
- Schuessler, R., 2014. Energy Poverty Indicators: Conceptual Issues. Part I: the Ten-Percent-Rule and Double Median/Mean Indicators. *ZEW*.
- Sovacool, B.K., Cooper, C., Bazilian, M., Johnson, K., Zoppo, D., Clarke, S., Eidsness, J., Crafton, M., Velumail, T., Raza, H.A., 2012. What moves and works: broadening the consideration of energy poverty. *Energy Pol.* 42, 715–719. <https://doi.org/10.1016/j.enpol.2011.12.007>.
- Thomson, H., Bouzarovski, S., Snell, C., 2017. Rethinking the measurement of energy poverty in Europe: a critical analysis of indicators and data. *Indoor Built Environ.* 26 (7), 879–901. <https://doi.org/10.1177/1420326X17699260>.
- Tirado Herrero, S., 2017. Energy poverty indicators: a critical review of methods. *Indoor Built Environ.* 26 (7), 1018–1031. <https://doi.org/10.1177/1420326X17718054>.
- Tirado Herrero, S., López Fernández, J.L., Martín García, P., 2012. Pobreza Energética en España. Potencial de Generación de empleo derivado de la rehabilitación energética de viviendas. Asociación de Ciencias Ambientales, Madrid.
- Tirado Herrero, S., Gimarré Gallego, D., Irigoyen, V.M., Jiménez Meneses, L., López Fernández, J.L., Martín García, J., Perero Van Hove, E., 2014. Pobreza Energética en España. Análisis de tendencias. Asociación de Ciencias Ambientales, Madrid.
- Tirado Herrero, S., Jiménez Meneses, L., López Fernández, J.L., Perero Van Hove, E., Irigoyen Hidalgo, V.M., Savary, P., 2016. Pobreza, Vulnerabilidad Y Desigualdad Energética. Nuevos enfoques de análisis. Asociación de Ciencias Ambientales, Madrid.
- Tirado Herrero, S., Jiménez-Meneses, L., López-Fernández, J.L., Irigoyen-Hidalgo, V.M., 2018. Pobreza Energética en España. Hacia un sistema de indicadores y una estrategia de actuación estatales. Asociación de Ciencias Ambientales, Madrid.
- Union, European, 2018. Statistical Pocketbook in Figures. Publications Office of the European Union, Luxembourg. <https://doi.org/10.2833/105297>.
- United Nations. n.d. Goal 7: affordable and clean energy [WWW Document]. URL <https://sdgs.un.org/goals/goal7>. (Accessed 12 June 2020).
- United Nations, 2015a. Objetivos de Desarrollo del Milenio.
- United Nations, 2015b. Memoria del Secretario General sobre la labor de la Organización. New York.
- Viveros Vigoya, M., 2016. La interseccionalidad: una aproximación situada a la dominación. *Debate Fem.* 52, 1–17. <https://doi.org/10.1016/j.df.2016.09.005>.