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Analysis of the distribution of energy poverty in southern Spain: the relevance of working at the neighbourhood level

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Abstract This article proposes a hybrid methodology to represent the energy poverty situation in neighbourhoods with high vulnerability indices, using public data sources and surveys designed for local contexts. As an innovation, the method includes aspects of feminisation poverty, household health and information collected directly from the case study population. The San Pablo neighbourhood, in southern Spain, has been taken as a case study, to extrapolate the strategy to similar European neighbourhoods. The research has made it possible to identify new factors affecting the energy poverty situation, such as the domestic burden associated with households or the lack of accessibility to dwellings. The incorporation of this type of indicators, which have been analysed according to sex, has made it possible to highlight the process of feminisation of energy poverty in the territory under study. Based on the groups identified as the most vulnerable, new lines of research are opened to define actions and best practices that can be implemented to improve household energy vulnerability.

Keywords Energy poverty · Decentralised studies · Vulnerable groups · Gender perspective

Introduction

In order for people to live their lives fairly and without limitations, they need access to affordable and reliable energy services (United Nations, n.d.). When access to these is lacking, human development is hindered. The energy system should service all sectors: from industry to transport to homes (Pelz et al., 2018).

Nevertheless, within Europe, and more specifically in Spain, there are numerous cases of households that

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do not have access to a basic energy service. There are several reasons for this: from power cuts to the prohibitively high prices of electricity or gas (Middlemiss et al., 2019). In 2022, 9.3% of European households were unable to maintain their homes at comfortable temperatures. In Spain, this figure rose to 17.1% of the population (Eurostat, 2023). Price increases and a high dependency on gas alongside rises in the price of CO_2 emission allowances are the main reasons behind the growing energy crisis (Fariza & Sahuquillo, 2021).

Today's context of depletion in fossil fuel resources, increase in energy consumption, climate change and the growth in energy poverty, explains the need to consider energy as a Human Right (A. Hernández et al., 2009). Advances in the defence of this right must also respond to fair energy transition processes. Gains should not lead to other social inequalities or environmental impacts (Calvo et al., 2021, Bertinat, 2016).

In this context of the right to domestic energy, the need to identify the most vulnerable groups and collectives and their main deficiencies regarding energy emerges. Thus, the concept of energy poverty arose to define those households "incapable of reaching the necessary social and material level of domestic energy services" (Bouzarovski & Petrova, 2015).

This situation poses a greater risk to collectives facing other systematic inequalities such as immigrants, children, the elderly, or women (Sánchez, 2018). Furthermore, energy vulnerability has implications in different development areas for these collectives: from economic welfare to public health. Living in unhealthy houses with low energy efficiency leads to higher expenses, more probability of falling ill, and a greater risk of suffering from mental health problems (Pollard et al., 2019).

National policies are often proposed to deal with these situations of energy poverty. Nevertheless, as this is an issue that depends on so many factors, it is experienced very differently depending on the territory. Policies for tackling energy poverty should be comprehensive and should include the multiple inter-connected factors relating to the issue of energy access (Sovacool, 2012). The descentralization of energy policies may lead to strategies that can adapt to the needs of each region (Gallicchio, 2010). There should be a move towards decentralised studies of regions that share economic, climate, and cultural factors, to create a base of information and data upon which energy strategies can be designed (Costa-Campi et al., 2019). In the face of such complex issues, universal policies are simply not efficient enough to tackle the issue at hand (Primc & Slabe-Erker, 2020).

These decentralised strategies can be adapted and replicated in obsolete territories with similar deficiencies. This capacity to extrapolate methodologies and good practices is particularly relevant in the European context, where after the Second World War there was a proliferation of social neighbourhoods that are now obsolete. These low-quality building parks are usually inhabited by people on low incomes and are generally areas with high levels of energy poverty. Some of these decentralized strategies, such as the one carried out by the Aura Team of the University of Seville in the international sustainable habitat competition Solar Decathlon Europe 2019, have obtained very positive results. This strategy was applied to two residential neighbourhoods with similar conditions: San Pablo (Seville, Spain) and Havanna (Budapest, Hungary), to extend the methodology to other European neighbourhoods through the network of participating Universities.

This study aims to propose a methodology to represent the energy poverty situation in neighbourhoods with high vulnerability indices. Based on the method proposed by Sánchez-Guevara, a hybrid methodology is presented that combines statistical databases, with the novelty of including aspects related to household health and female tasks, and information collected through surveys of the neighbourhood population. Specifically, the article focuses the case study on Seville's Polígono San Pablo, although the methodology presented can be extrapolated to other European neighbourhoods with similar characteristics and high vulnerability rates.

It is important to highlight the importance of using hybrid methodologies to analyse problems as heterogeneous as energy poverty. The innovation of including citizen consultations makes it possible not only to analyse households' deprivation but also to reflect on the specific ways in which they face energy vulnerability. Public databases are a very useful source of information, but when carrying out decentralised research, it is deemed necessary to include other data sources designed for the territory itself. This advantage has been presented by other authors such as Ntaintasis et al. (Ntaintasis et al., 2019) for a case study in Greece where they surveyed 451 households.

This study concluded that the use of composite indicators adapted to local conditions allows for a more realistic representation of energy poverty and can provide information on its intensity. The research by Camboni et al. (Camboni et al., 2021) on energy poverty in Italian municipalities concludes similar reflections, as it shows how the combination of several data sources can compensate for the lack of information on energy conditions in limited territories. It is also possible to find multiple examples in Spain, such as the study developed by Gómez-Navarro et al. (Gómez-Navarro et al., 2021), where through surveys carried out in the city of Valencia, relevant results are obtained that include factors such as tenure status or energy illiteracy. Other Spanish studies have developed hybrid methodologies to analyze programs to combat energy poverty. This is the case of the study developed by Barrella et al. where they analyze a set of homes in Catalonia that have been renovated and can concretely identify improvements in these homes (Barrella et al., 2023).

The method used is part of the University of Seville Research Project: "Direct Application of the Aura Strategy in the Rehabilitation of Obsolete Andalusian Neighbourhoods" US.20–11, financed by the Regional Government of Andalusia's Department of Development, Infrastructures and Urban Planning. This method focuses on the sustainable rehabilitation of obsolete Andalusian neighbourhoods through interventions in residential mass housing. One of its key points is the conservation and regeneration of the existing urban fabric according to the needs identified by local residents themselves.

The article is structured as follows: Firstly, to justify the choice of the neighbourhood for this case study, a brief description of the Polígono San Pablo defines the buildings and demographic and socio-economic factors. Secondly, the two procedures employed to collect data for the measurement of energy vulnerability in the neighbourhood are defined: surveys carried out in the neighbourhood itself and databases from the Institute of National Statistics (hereinafter INE[1]). The data obtained in the surveys gives further results that would not be possible from the national databases alone. From the INE data, four levels of vulnerability are defined for the case study San Pablo A and B neighbourhood and each of Seville's districts. This will lead to a better understanding of the situation in the Polígono San Pablo neighbourhood compared to the rest of the city of Seville.

Finally, there is a reflection on the principal findings and a discussion about future research, improvements to include in the method, and the processes required to promote strategies to fight against energy poverty in Seville.

Theoretical framework

Energy vulnerability can be defined as a home's exposure to the risk of not being able to afford an adequate quantity of energy services (Desvallées, 2021). This concept is therefore temporary and probabilistic. Homes identified at a given moment as being in a situation of energy vulnerability can change their circumstances and no longer be vulnerable, and vice versa(Sánchez, 2018). Energy poverty is a manifestation of energy vulnerability in a given space and time (Bouzarovski, 2014, Tirado Herrero et al., 2018).

While the term energy poverty is increasingly present in the media and politics, there is currently debate as to how to measure this situation or which indicators to use (Faiella & Lavecchia, 2021). This lack of consensus can be explained by the wide range of factors that affect energy poverty in homes such as political and economic factors, geographical factors, individual household factors, cultural characteristics, (Bouzarovski & Petrova, 2015, Rademaekers et al., 2016) and factors related to energy literacy in homes.

Given its multidimensional character, the issue of energy poverty can be tackled with different strategies: public health, the transformation of the energy market, the mitigation of climate change, social security, or an ethical question, among others (Creutzfeldt et al., 2020). This complex nature means that a number of stakeholders are involved from local, regional, and national governments to tertiary sector entities. Networks such as The Energy Poverty Advisory Hub (EPAH) have emerged to share strategies and knowledge at the local level to combat energy poverty in Europe (European Commission, 2023).

[1] The Institute for National Statistics (INE) is the Spanish body responsible for public statistic activity that coordinates and manages large scale statistical operations such as the national census, economic and social indicators, the electoral roll, etc.

Some of these stakeholders have chosen to develop projects in limited areas where the factors that affect household vulnerability are more homogenous. This is the case in the research carried out by the Polytechnic University of Madrid which used the "High Energy Requirements Index" (Sánchez-Guevara Sánchez et al., 2020a) to assess the distribution of energy poverty in Madrid's different districts. Different studies analyse the situation in Catalonia, such as the EmpowerMed project which aims to mitigate the effects of energy poverty and improve the health of the affected population in Mediterranean coastal areas (Tirado Herrero, 2020). In the city of Seville, research such as the study led by the University of Seville's School of Building Engineering has been carried out to fight energy poverty in its buildings. This study proposes an assessment model for energy rehabilitation projects that takes energy consumption, comfort in homes, and economic status into consideration (Alba-Rodríguez et al., 2021).

While there have been significant advances in European research into this subject matter, it is still necessary to work on studies that include an intersectional approach as energy vulnerability is defined by other social differentiations such as class, gender, race, ethnicity, etc. (Cubillos Almendra, 2015). It is women who are still to a greater extent responsible for caregiving and household upkeep. It is women who have been affected to a greater extent throughout history by insecurity in basic services, as well as having to sustain household responsibilities and issues such as the non-payment of energy bills (Mcdowell, 1999). Consequently, previous national studies have identified women as a particularly affected group (Sánchez-Guevara Sánchez et al., 2020b, González Pijuan, 2016, González Pijuan, 2020a, González Pijuan, 2020b). In this way, reducing energy poverty will contribute to gender equality, above all in relation to socio-economic rights and education (Nguyen & Su, 2021).

Energy poverty is going to have a greater impact on the health of more vulnerable groups such as women, the elderly, immigrants, or the young. Not having access to a healthy and comfortable home is directly linked to respiratory and pulmonary illnesses. Not only is the physical health of a household affected. There is also a close link with mental health problems which range from stress or depression related to the inability to pay energy bills to loneliness and confinement (Zhang et al., 2021, Malgesini et al., 2018).

Energy Poverty in Andalusia

In the last few years, advances have been made in the fight against energy poverty in Spain. For example, in 2019 the government passed the National Strategy against Energy Poverty. However, most studies and programs continue to be developed at the national level and are not adaptable to the different contexts of the Spanish territory.

Although there is scarce documentation for the case study of Andalusia, there are national reports, such as that of the Environmental Science Association, in which indicators are broken down by autonomous communities. In the four studies presented since 2012, Andalusia has headed the list of communities with higher levels of energy poverty, always ranking among the top four rates (Tirado Herrero et al., 2012, 2014, 2016, 2018). Similarly, the data presented by the National Strategy against Energy Poverty places Andalusia as one of the regions most impacted by energy poverty. According to its latest published report, Andalusia is one of the regions with the highest values in the case of the disproportionate expenditure indicator and the indicator of inadequate temperature in the home in winter (Ministerio para la Transición Ecológica y el Reto Demográfico, 2022). These results are consistent with other academic studies that place this territory as one of those with the highest values in indicators such as arrears on utility bills or the MIS indicator (Romero et al., 2023).

In previous studies by the authors of this article, it has been shown that Andalusia has a high rate of energy poverty, above the national average in the various indicators, and in particular the indicator which measures the capacity to homes at an adequate temperature in winter and the indicator for the late payment of energy bills (Clavijo Núñez, 2020). Nevertheless, there is inadequate data on which to build indicators that can represent this issue at the local level, and above all, identify the most vulnerable groups or the most efficient measures to introduce. Carrying out research that studies the levels of energy poverty in a decentralised manner within Andalusia is deemed necessary.

Case study: San Pablo A and B Neighbourhood, Seville

The case study focuses on the San Pablo-Santa Justa District in the city of Seville, in particular the A and B neighbourhood of the Polígono San Pablo. Homes within the case study will be delimited to be able to create personalised processes with the local residents, and then extrapolate these results to the Polígono San Pablo as a whole.

The different factors that lead to a better understanding of the Polígono San Pablo, as well as the reasons for working on this territory, are outlined below:

– Characteristics of the buildings

This housing estate was built in five stages during the 1960s. It was made up of modest small-scale homes with generally low-quality construction (Departamento de Urbanística y Ordenación del Territorio, 2011). Most of the Polígono de San Pablo is made up of five storey open blocks with approximately 10 homes per block. The majority of the blocks do not have lifts. There are also some nine and thirteen storey tower blocks which are usually found at the end of main streets. These blocks are identified as higher income households (Departamento de Urbanística y Ordenación del Territorio, 2011).

In the central area of the District, found between the three neighbourhoods of San Pablo A and B, San Pablo C and San Pablo D and E, there is an area of average urban residential vulnerability that does not qualify as a slum (Estivill Baena et al., 2018). These three neighbourhoods are depicted in Fig. 1.

– Socio-economic and cultural characteristics.

There are currently 7,348 residents in the San Pablo A and B neighbourhood. 3,466 of these are men and 3,882 are women (Servicio de Estadística del Ayuntamiento de Sevilla, 2021). The aging population in this neighbourhood is generalised throughout the whole San Pablo-Santa Justa District. As can be seen in Table 1, the Aging Population Rate, which represents the percentage of the population over the age of 65, is 22.2% (Rodríguez Pérez, 2019). In the San Pablo A and B neighbourhood the rate of dependency, which is calculated as the ratio between the inactive and active population, is 52.1% (Rodríguez Pérez, 2019). It stands out that in both rates, the situation of women is worse, above the neighbourhood average.

The San Pablo A and B neighbourhood has a mortality rate of 13.99 which is higher than the 8.86 average in the city of Seville. It is the highest mortality rate among the neighbourhoods in the district (Servicio de Estadística (Ayuntamiento de Sevilla), 2016).

According to Seville's Local Health Plan 2019/2023 for the San Pablo-Santa Justa District, the district has three vulnerable areas, among which can be found the San Pablo A and B neighbourhood. This study uses Basic Urban Vulnerability Indicators (IBVU) to define vulnerable zones. In contrast, the Atlas of Urban Vulnerability in Spain 2011, catalogues the San Pablo A and B neighbourhood with a medium level of urban vulnerability (Ministerio de Transportes Movilidad y Agenda Urbana, 2011).

According to the results of the 2011 census, the San Pablo-Santa Justa district is one of the Vulnerable Territories in the city of Seville (Hernández Aja et al., 2018). As shown in Table 2, the San Pablo A and B neighbourhood has higher than average rates in Seville for indicators that classify this vulnerability: education, unemployment, and housing. The result for the education indicator is particularly worrying. Figure 2 also highlights this vulnerability. It can be seen that in the three studies carried out in 1991, 2001 and 2011, the San Pablo A and B neighbourhood has always been classified as vulnerable. This longstanding condition of vulnerability justifies the choice of the Polígono San Pablo as a case study.

With regard to culture, local residents have a strong sense of belonging to the neighbourhood. A large part of life takes place on the streets as it is a district divided into neighbourhoods that share cultural and economic characteristics. Nevertheless, the population has a low socio-cultural level (Rodríguez Pérez, 2019).

All of the above highlights the need for improvement in the quality and comfort of residents in this zone where there is a high rate of vulnerability and health problems among the population.

Fig. 1 Delimitation of San Pablo A and B in the Polígono de San Pablo. Author's own

Table 1 Aging population rates and level of dependency in the San Pablo A and B neighbourhood. Source: Rodríguez Pérez, 2019. Author's own

	Aging Population Rate	Dependency Ratio
Total Population	22.18%	52.07%
Men	16.45%	41.76%
Women	27.31%	62.63%

Table 2 Vulnerability rates for San Pablo A and B and the city of Seville. Source: (Hernández Aja et al., 2018). Author's own

Territory	I education	I unemployment	I housing
San Pablo A and B	17.71%	31.60%	15.67%
Seville	9.38%	31.08%	7.57%
Reference Value	16.38%	42.33%	17.50%

– The Aura Strategy in the Polígono de San Pablo

Work on the San Pablo A and B neighbourhood focuses on the application of the University of Seville's Solar Decathlon Team's Aura Strategy. This is based on the rehabilitation of obsolete Andalusian neighbourhoods through interventions in residential collective housing. A method is being developed to detect housing obsolescence in the neighbourhood, and based on this analysis, propose the practical application of the Aura Strategy. The main intervention concept is the juxtaposition of a technological-structural system on linear blocks of houses which

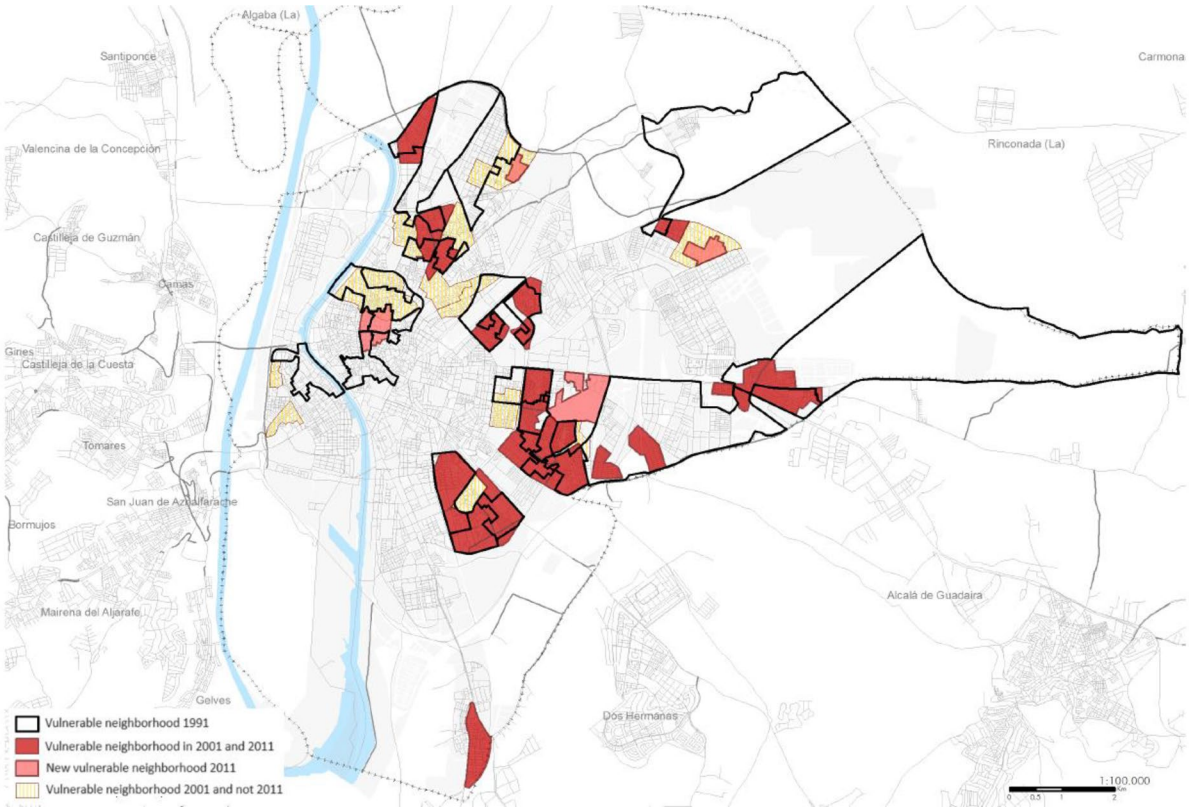

Fig. 2 Seville. Delimitation of Vulnerable Neighbourhoods according to the 1991, 2001 and 2011 Censuses. Source: (Hernández Aja et al., 2018)

incorporates new means of providing energy, technology, and space to the housing. It also responds to the care and self-determination of social, material, and energy identity giving rise to greater comfort, health, and quality of life for residents (Herrera-Limones et al., 2020, 2023).

Method

In order to represent and understand the situation of energy poverty in the Polígono de San Pablo, it is necessary to characterise energy vulnerability in each of the districts in the city of Seville. This way, the neighbourhood's situation can be understood and compared to the different levels of energy vulnerability throughout the city. A study method will be carried out in three phases as shown in Fig. 3. A hybrid methodology combining public data sources and surveys designed for the case study is proposed.

The most usual data sources for energy poverty studies in Spain, such as Living Conditions Surveys and Household Budget Surveys, are not disaggregated by neighbourhood or district. Moreover, samples are sometimes scarce even for analysing autonomous communities (Clavijo-Núñez et al., 2022). It is therefore important to complement statistical sources with other sources of information. Specifically, citizen consultations represent a very interesting opportunity as they can be adapted to the reality of each territory and bring research closer to the citizens.

Phase I. Analysis of databases

As there are no decentralised databases to calculate the main indicators which are used to measure energy poverty, two sources of data are used: databases from the Institute for National Statistics (INE) and responses to surveys carried out in the Polígono de San Pablo itself.

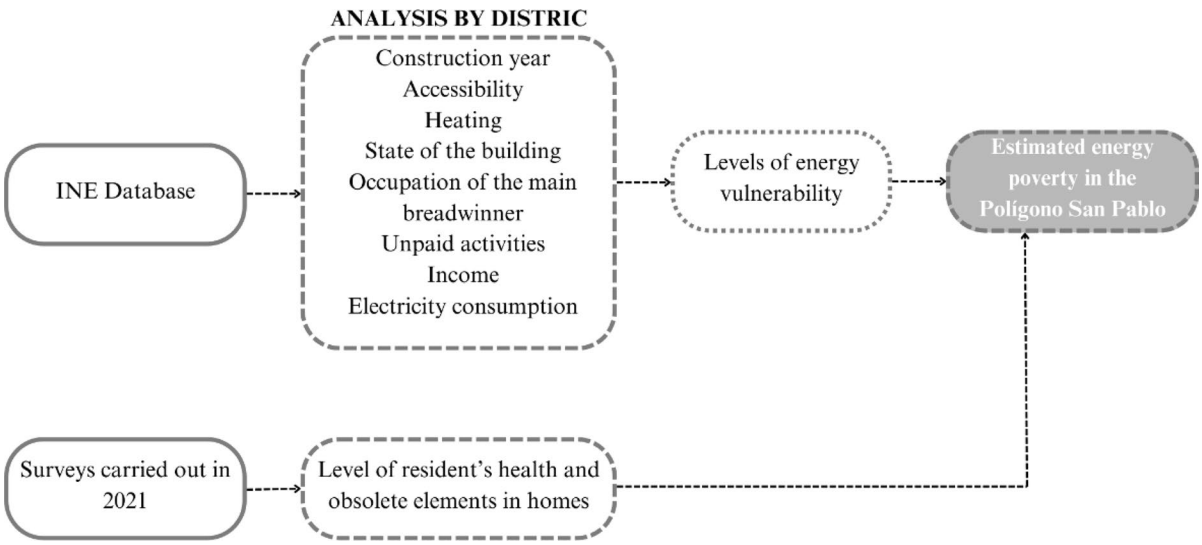

Fig. 3 Study method. Author's own

INE Databases

Firstly, analysis is carried out of indirect variables which help estimate zones with a high probability of suffering energy poverty (Sánchez-Guevara Sánchez et al., 2020a) through data provided by the Institute for National Statistics regarding districts and census sections. However, it should be highlighted that these databases do not allow analysis of some key variables for households, which hinders analysis of the results.

As can be seen in Table 3, eleven factors divided into eight categories were chosen to provide an image of the difficulty for a household to dispose of basic, affordable, and reliable energy services. These factors were chosen after being identified in previous studies as indicators that affect household energy vulnerability (Castaño-Rosa et al., 2020, Tirado Herrero, 2017, Pelz et al., 2018, Sánchez-Guevara Sánchez et al., 2020a) Although the factors in the "Accessibility of the home" and "non-paid activities" categories are not indicators that are usually analysed, it was decided they should be included as they allow studying how this situation affects two of the groups most vulnerable to energy poverty: the elderly and/or dependent, and women.

With respect to these indicators, it is worth highlighting the potential and limitations of the indicator that counts households with electricity consumption below 50% of the percentile. This metric is similar to the Low absolute energy expenditure indicator (M/2), which is widely used in the literature and research on energy poverty. This type of indicators based on energy expenditures allow obtaining reliable estimates, by avoiding weaknesses linked to "self-reporting" (Thomson et al., 2017a, 2017b, Waddams Price et al., 2012). However, there is a wide discussion about the 50% threshold, as in many territories this range leads to exclusion errors, i.e. a proportion of households incorrectly excluded from the fuel poverty measurement (Betto et al., 2020). The regional adaptation of this indicator is also discussed, as it depends on key factors such as climate, income, household size, energy efficiency or housing tenure (Barrella et al., 2022, Antepara et al., 2020). However, by not including references to these factors, such as income or energy efficiency in their calculations, high-income households with good quality housing may be wrongly classified as energy por (Barrella et al., 2022).

Despite the limitations it presents and the different thresholds it may adopt, research points to the great complementarity provided by this indicator, which makes it possible to detect situations of energy consumption rationing that cannot be perceived by other objective measurements (Meyer et al., 2018).

Through data from the 2011 and 2021 census (National Institute of Statistics, 2011, 2021a) and

Table 3 Factors analysed for each district in Seville. Author's own

Categories of the analysed factors	Description	Source and year of data
Construction year	The number of homes built before 1980, previous to the first technical regulation NBE-CT-79 is measured	Year of Construction. Population and Housing Census, 2021 (INE)
Accessibility of the home	The number of homes without lifts, leading to isolation of the elderly or dependent above all in older neighbourhoods, is counted	Building facilities (Lift). Population and Housing Census, 2011 (INE)
Heating	The number of homes without heating is measured	Heating type. Population and Housing Census, 2011 (INE)
State of the Building	Three indicators are calculated: (i) Number of dilapidated homes (ii) Number of dilapidated or deficient homes (iii) Homes with an area of less than 30 m^2 per occupant	(i) Building condition. Population and Housing Census, 2011 (INE) (ii) Building condition. Population and Housing Census, 2011 (INE) (iii) Construction record (surface area per occupant). Population and Housing Census, 2021 (INE)
Occupation of the main breadwinner	The number of homes with unemployed people, previously in employment or unemployed, first-time job seekers	Economic activity. Population and Housing Census, 2021 (INE)
Unpaid activities	Two indicators are calculated which provide information on inequalities in non-paid activities: (i) Responsibility for the greater part of domestic chores (ii) Care for a person with health issues	Unpaid work. Population and Housing Census, 2011 (INE)
Income	Median income per consumption unit (euros)	Atlas of the distribution of household income, 2021 (INE)
Electricity consumption	Homes below the 50th Percentile of electricity consumption	Households by intensity of use based on electricity consumption. Population and Housing Census, 2021 (INE)

income indicators from the INE (National Institute of Statistics, 2021b), the following factors will be studied for homes in the city of Seville:

All of these factors have been analysed separately for different household structures. Households with single women over the age of 65 and single-parent families have been analysed as they were identified as being especially vulnerable in various studies (Sánchez-Guevara Sánchez et al., 2020b, González Pijuan, 2016).

Data gathered from the surveys carried out in the Polígono de San Pablo

Secondly, data gathered in a survey carried out in May 2021 is used. This survey was carried out by the University of Seville's HUM-965 TRAnSHUMANCIAS research group, within the framework of the optional subject "Energy and Sustainability: Solar Decathlon 2020" at the School of Architecture, University of Seville. This process was the identification stage to gather the necessary data and apply the Aura Strategy in the neighbourhood. The main issues presented and possible outcomes are summarized in Annex 1.

Information about the different neighbourhoods that make up the Polígono de San Pablo was gathered via two surveys of a random sample. An initial analysis of the neighbourhood was carried out in which factors such as building accessibility, height, facades, and openings or materials and neighbourhood factors such as green zones, transport routes, roads, and bicycle lanes were studied. Based on this initial study, it is decided that the data to be gathered in the survey should be grouped into five categories: health and comfort, architectural aspects, energy parameters,

thermal-acoustic comfort, and cultural identity. These five categories make it possible to gather the information necessary to identify the obsolete aspects of the neighbourhood on which action should be taken. Furthermore, this method was also used to analyse both the physical and mental effects of the Covid-19 lockdown on households in the neighbourhood.

In particular, the results for the categories of "energy parameters" and "health and comfort" have been used for the present study. The questions "Changes that you would make in your home" and "Psychological and neurological problems" have been vital to understand the energy vulnerability situation in the neighbourhood and have served to identify areas for improvement in the neighbourhoods.

Phase II. Calculation of energy vulnerability levels

As a result of the data provided by the INE and the rationale proposed by Sánchez-Guevara (Sánchez-Guevara Sánchez et al., 2020a), energy vulnerability in the different districts in this case is defined by two possible situations:

- For various determining factors the territory exceeds the city average.
- Critical values (the worst value among all the districts analysed) for some of the indicators.

Four possible situations are established in this study to define the levels of energy vulnerability:

- **Very high vulnerability (VHV)** will be assigned to those homes that exceed the municipal average in all the categories or those homes that present critical values for more than one indicator.
- **High vulnerability (HV)** will be given to those homes that exceed the municipal average in more than one indicator and some of these indicators show critical values.
- **Medium vulnerability (MV)** will be given to those homes that exceed the municipal average in at least two indicators, none of them being critical values.
- **Low vulnerability (LV)** will be given to those homes that exceed the municipal average in one or no indicator.

With regard to the surveys in the Polígono de San Pablo, responses related to the factors that affect the level of energy poverty in homes are considered, in particular those responses related to the psychological and neurological health of the residents and the main changes to homes that are deemed necessary.

Phase III. Analysis of the results

After calculating the different levels of vulnerability for the districts in the city of Seville and the San Pablo A and B neighbourhood, an analysis and comparison of the results obtained is carried out. Specifically, a statistical comparison is made between the different districts of the municipality. This is to reflect which territories are more sensitive to energy vulnerability and require urgent action as well as those aspects which need improvements in these districts.

Complementarily, the results obtained for the San Pablo neighbourhood are analyzed in comparison with the results of the district where it is located (San Pablo-Santa Justa District). This analysis is complemented with the results of the surveys in the San Pablo neighbourhood to obtain a more complete study of the energy poverty situation in the district.

Results

The results for the analysis of the energy poverty situation in the different districts in the city of Seville and the specific case of the San Pablo A and B neighbourhood are set out below:

Results by district

This section provides an analysis of the results obtained as seen in Table 4 and Fig. 4. Table 4 shows the results of the indicators for each study area, the critical values of the districts (i.e., the worst value among all the districts analyzed), as well as those cases that present a result higher than the municipal average. This concludes the different levels of energy vulnerability for each district (lines 1 to 11), for the study neighbourhoods (lines 12 to 14) and the city average of Seville (line 15) are presented.

Table 4 Results of the factors which determine the level of energy vulnerability by district, San Pablo neighbourhoods, and the city of Seville. Authors' own

	Construction year	Accessibility	Heating	Building state			Occupation	Unpaid activities		Income	Electricity consumption	
Name of the territory	% Homes built before 1980	% People with homes without a lift	% People with homes without heating	% People with dilapidated homes	% People with dilapidated, deficient or poor homes	% Homes with an area < 30 m2 per occupant	% Unemployed people	% People with high levels of domestic responsibility	% People who care for others with health issues	Median income per unit of consumption (euros)	% Homes below the 50th Percentile of electricity consumption	Level of Energy Vulnerability
1. Casco Antiguo	67.99	55.36	7.96	**0.85**	4.99	33.16	8.69	**43.76**	8.61	22,750	17.21	VHV
2. Macarena	80.2	48.5	15.11	0.45	6.92	49.14	14.12	42.09	8.42	14,350	19.87	VHV
3. Nervión	59.1	25.18	8.19	0	2.62	32.17	7.07	39.05	8.24	24,850	18.97	LV
4. Cerro-Amate	69.7	**65.16**	**16.03**	0.43	**16.79**	**55.81**	**18.65**	41.73	8.43	**12,250**	18.88	VHV
5. Sur	63.7	36.67	13.48	0.14	8.66	44.88	15.26	38.43	**9.06**	15,750	19.08	HV
6. Triana	77.81	54.36	10.69	0.65	2.63	40.71	9.82	42.75	8.53	19,250	18.97	MV
7. Norte	35.75	32.72	15.97	0.41	2.62	51.75	15.53	39.48	8.99	14,350	**21.12**	HV
8. San Pablo-Santa Justa	69.22	36.07	11.13	0.16	3.27	43.43	12.04	42.22	8.72	17,850	19.93	MV
9. Este	27.55	39.02	12.23	0.35	2.98	51.22	14.58	37.79	7.18	15,750	20.65	MV
10. Bellavista-La Palmera	41.15	39.31	11.62	0	1.19	44.83	10.72	38.8	7.36	19,950	19.68	LV
11. Los Remedios	**84.46**	13.78	8.16	0	2.65	28.06	6.68	36.6	7.99	25,550	18.47	LV
12. San Pablo A y B	100	76.95	9.71	0	12.74	61.33	18.79	50.53	12.27	12,250	-	VHV
13. San Pablo C	100	51.77	17.01	0	0	39	16.44	49.69	11.75	12,950	-	VHV
14. San Pablo D y E	100	67.21	16.02	0	14.46	51.79	17.87	42.97	10.76	11,550	-	VHV
15. Sevilla	59.46	42.88	12.52	0.34	5.8	45.31	12.11	40.38	8.33	16,450	19.32	-

Value above the average of Seville in the districts and in the neighbouhoods

number Critical value in the districts

Analysis of the determining factors

To calculate the levels of energy vulnerability in Seville's eleven districts, indicators have been used that provide a variety of information regarding habitability. On the one hand, factors related to the quality of the house itself such as the year of construction, accessibility of the home, heating installation, and building state have been included. On the other hand, factors related to the people who inhabit these homes such as employment status, dedication to non-paid activities, or income have been included.

With regard to these house factors, it should be highlighted that a large number of districts have high rates of homes built before 1980. In terms of accessibility, only four districts are above the average in Seville. Nevertheless, this average is relatively high given that for 42.8% of people access to the street is difficult. This means that the elderly and dependent people may have to spend long periods in homes that do not have good comfort and health conditions. With regards to the number of people who do not have heating systems and can therefore not maintain their homes at an adequate temperature, there are three districts above the municipal average. Analysis of the number of people who live in dilapidated, poor, or deficient homes shows a noteworthy situation in the Macarena, Cerro-Amate, and Sur Districts. These three districts have a high percentage of people inhabiting homes with issues related to energy efficiency (for example, difficulty in maintaining adequate temperatures throughout the year) and health (damp or leaks). In terms of dwellings with a surface area per occupant of less than 30 m^2, four districts show worrying values: Macarena, Cerro-Amate, Norte, and Este Districts. This indicator reflects those households with the highest risk of housing an overcrowded population.

Concerning the factors related to residents' economic situation or employment status, five of the districts have a high rate of unemployment. Regarding non-paid activities, two important factors are introduced that aim to give a gender focus to the analysis, as it is traditionally women who have employed more of their time to caregiving and family matters. Consequently, it is women who spend a larger proportion of time in the home and who suffer to a greater extent the lack of access to basic energy services or

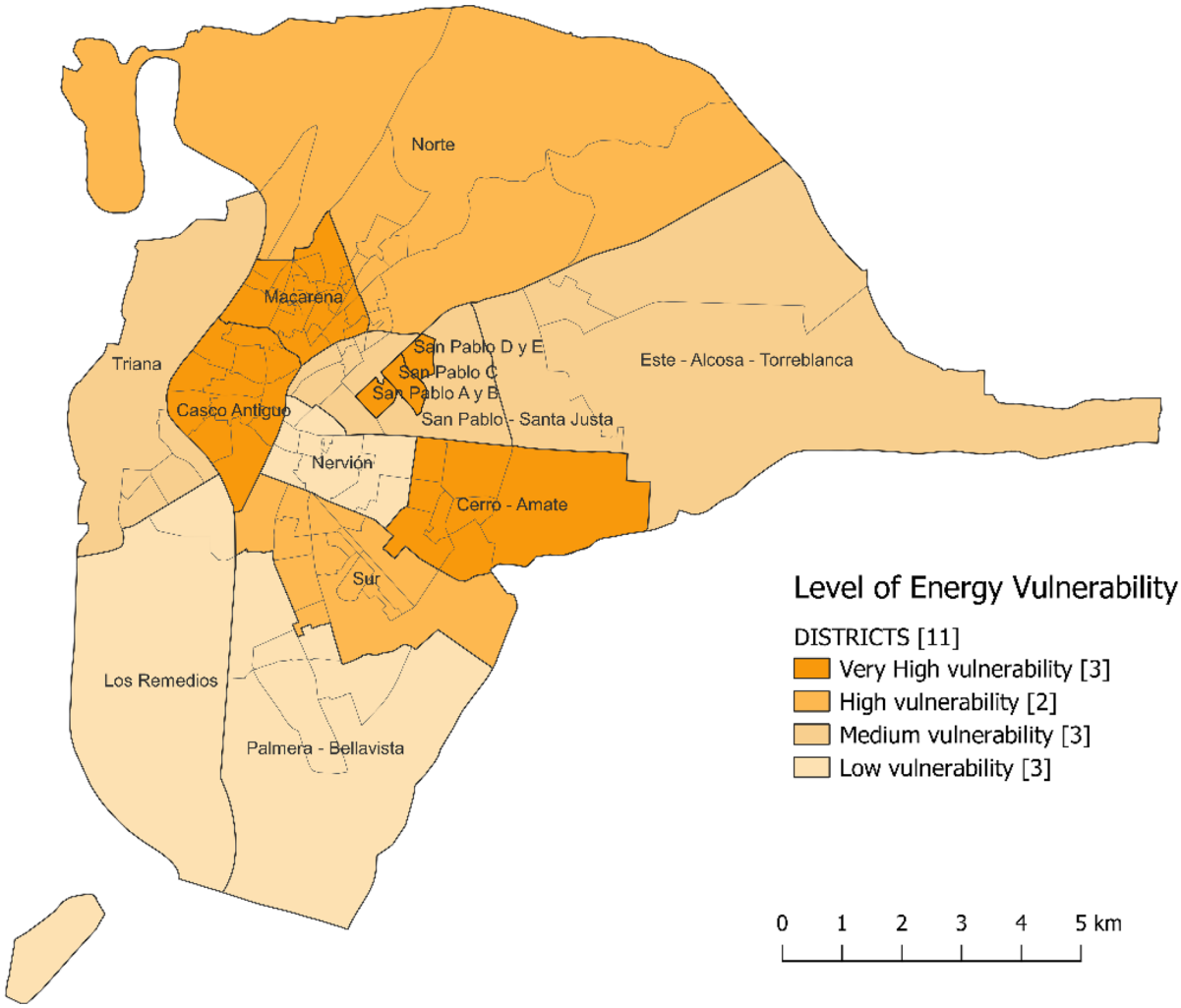

Fig. 4 Level of energy vulnerability by district and San Pablo neighbourhoods. Author's own

who have to deal with unpaid bills (Robinson, 2019). Seven of the eleven districts have a high percentage of people who care for others with health problems. The median income per unit of consumption is also established as a determining factor as it supposes that in any situation of poverty, those homes with lower incomes will find it harder to make their energy payments. There is also a correlation between households with lower incomes, dwellings with a floor area per occupant of less than 30 m^2, 0and households with people caring for members with health problems.

Finally, it is worth mentioning the results associated with energy consumption, an indicator included in the last census published in 2021. Five of the eleven districts have a high percentage of households with an average electricity consumption below the 50th percentile threshold. The results are particularly worrying for the North district, where 21.12% of households have a very low energy consumption, with which it is assumed that they are not able to meet their basic energy needs.

Analysis of energy vulnerability levels

Analysing the results of the different levels of vulnerability in line with the conditions described in the

method, it is concluded that three of Seville's eleven districts have a very high probability of suffering energy poverty. These are the Casco Antiguo, Macarena, and Cerro-Amate Districts. The case of the Macarena District stands out because all of its results exceed the average for the city of Seville. The results in the Cerro Amate District are equally worrisome, since in five of the eleven indicators analyzed, the results are critical.

Sur and Norte Districts are next on the list with high levels of energy vulnerability. In particular, the results for these districts identify these areas as having a high probability of suffering energy poverty, as they exceed the municipal average in six of the eleven indicators.

There are three Districts with medium levels of vulnerability: Triana, San Pablo – Santa Justa, and Este Districts. It is worth noting that these four neighbourhoods are made up of a diverse population, where different socioeconomic strata coexist.

Finally, three districts are categorized as having a low probability of suffering energy poverty, Los Remedios, Nervion, and Bellavista-La Palmera Districts. These areas present one or no indicator with results higher than the average for Seville, so it is assumed that the proportion of households suffering from energy poverty in these districts will be much lower than in other areas of Seville.

Results for the Polígono de San Pablo

Results according to the INE databases

Firstly, the level of energy vulnerability assigned to the San Pablo A and B neighbourhood is analysed in line with the same method applied to Seville's districts.

As can be seen in Table 4 and Fig. 4, San Pablo A and B exceed the municipal average in eight of the ten categories analysed, reaching critical values in comparison with the average of the districts. The three neighbourhoods analyzed (San Pablo A and B, San Pablo C and San Pablo D and E) present a very high level of vulnerability, as they have critical results with respect to the district indicators and exceed the municipal average in most of the factors analyzed. The following are among the most noteworthy results set out in Table 4:

- 100% of the houses in the INE data were built before 1980.
- 76.96% of homes do not have a lift. As this is a neighbourhood with an aging population, this lack of accessibility is an important issue for the health of local residents.
- Of the areas analyzed, the San Pablo A and B neighbourhood is the one with the highest proportion of households with an average area per occupant of less than 30 m^2. This translates into small homes where the aging population, since most of them do not have elevators or good access to the building, is crammed into their dwellings.
- 50.5% of people in San Pablo A and B have a high level of domestic responsibility. Analysing the data in terms of gender, it can be seen that 68.1% of people responsible for the majority of household chores are women, 34.41% of local residents. Furthermore, 8% of the people with high levels of domestic responsibility are single women over the age of 65, in comparison to 2% of homes made up of single men over the age of 65.
- All the single-parent households that have a high level of domestic responsibility are headed by women – in other words, 100% of homes with an adult and children are single-mother households.
- Almost 7% of the people in the neighbourhood without heating systems are women over the age of 65 who live alone and nearly 13% are single-parent families.
- The average and median income is considerably lower than the average in Seville which means it is more difficult for these families to pay energy bills and other basic services.
- The three neighbourhoods that make up the Polígono San Pablo (San Pablo A and B, San Pablo C and San Pablo D and E) have very high levels of vulnerability. These results contrast with the level of the district in which they are located, the San Pablo-Santa Justa District, which has a low level of energy vulnerability.
- Unfortunately, no data on energy consumption at the neighbourhood level have been published so far.

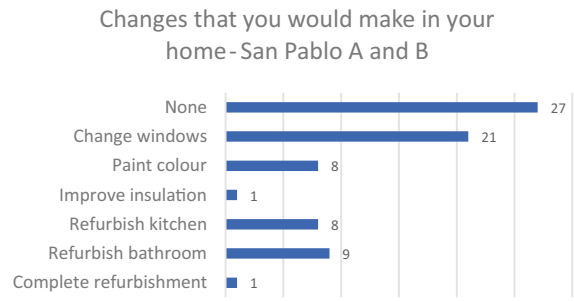

Fig. 5 Responses to the surveys regarding changes to homes carried out in the San Pablo A and B neighbourhood and the Polígono de San Pablo. Author's own

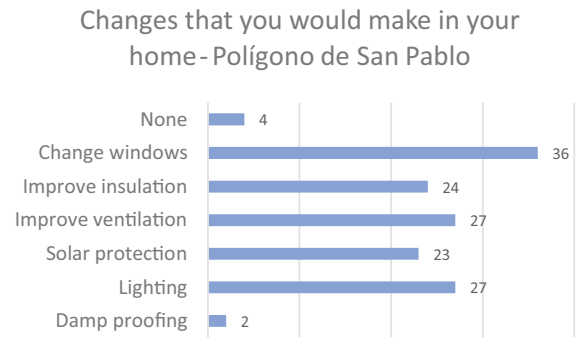

Fig. 6 Responses to the surveys regarding changes to homes carried out in the San Pablo A and B neighbourhood and the Polígono de San Pablo. Author's own

Results of the surveys

The surveys for the Polígono de San Pablo were carried out in two phases. The first phase was a 75-question survey only for the residents of San Pablo A and B (the main topics of these questions can be found in Annex 1). With 70 respondents, the following results for San Pablo A and B should be mentioned:

- 77.4% of people surveyed suffer from some form of psychological or neurological disorder such as anxiety, depression, or insomnia. These problems, alongside a lack of comfort in homes, are a result of the 2020 and 2021 lockdowns. As numerous studies show (Oliveras et al., 2020, D. Hernández et al., 2016, Thomson et al., 2017a, 2017b), one of the main problems of homes suffering from energy poverty is the knock-on effects it has on the physical and mental health of its inhabitants.
- With regards to changes to be made to homes (Fig. 5), the majority of those surveyed, 23.3%, opted for improving windows and enclosures. This highlights the lack of basic structures to maintain homes at an adequate temperature, or efficient ventilation. A large percentage of residents state that the enclosures in their homes are not airtight, which leads to huge energy losses.

For the second stage of the survey, the number of questions is reduced to 14 (the main topics of these questions can be found in Annex 1). In this case, the four sectors that make up the Polígono de San Pablo are analysed. With 81 respondents in the second survey, the following results stand out (Fig. 6):

- 66.7% of those surveyed state they have psychological or neurological problems (Fig. 7). Furthermore, 70% of the population has seen their pathologies worsen during lockdown as a result of poor conditions in their homes.
- About demands for thermal comfort (Fig. 6), 48% consider changing or improving windows or enclosures a priority. The main problems identified are related to a lack of thermal and acoustic insulation. Reference is also made to the lack of natural light in homes, with 36% of the population focusing on improving lighting. Another 36% of those surveyed found ventilation to be deficient in their homes. This is a fundamental aspect when creating healthy and comfortable spaces. 32% would change the insulation and 30% would invest in improving solar protection. All of these deficiencies lead to comfort and health issues as well as higher energy and economic spending on heating and lighting systems to combat them.

Discussion

This study has contextualised the situation of energy poverty in the city of Seville and in particular in the Polígono de San Pablo, presenting a methodology

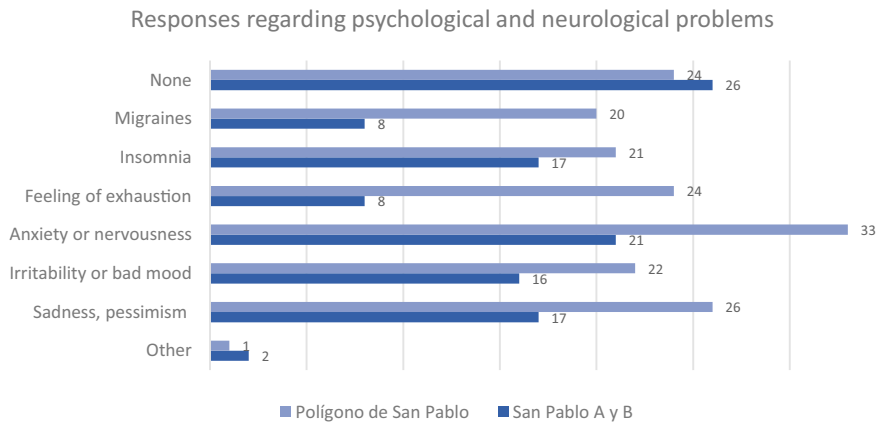

Fig. 7 Responses to the surveys regarding psychological and neurological problems carried out in the San Pablo A and B neighbourhood and the Polígono de San Pablo. Author's own

that can be extrapolated to other localities. Nevertheless, there are various conceptual and methodological aspects which require further reflection.

Firstly, there are limited sources of data from which to analyse the comfort conditions in homes and spending on energy services at the infra-municipal level. There is no local database from which to analyse the energy poverty of each territory and on which to apply the indicators used at the European level. Furthermore, the population and housing census of 2021 and 2011 have been used for this analysis, since some indicators that have been considered essential to analyze the energy vulnerability situation have not been updated in the last census. Thus, information is only available on issues such as unpaid domestic work or access to heating from databases more than 10 years old.

With regard to the method, while the data provided by the INE is not sufficient to calculate the main indicators for energy poverty, it does enable the definition of those districts and neighbourhoods with a higher probability of suffering from energy poverty, in other words, those territories with greater energy vulnerability. Furthermore, the proposed hybrid methodology using statistical databases and responses to surveys designed for the neighbourhood itself, enables a more realistic presentation of the energy poverty situation. The use of citizen consultations can enrich energy poverty studies, especially for more limited territories such as districts and neighbourhoods and thus be able to create policies for all people (Molina Molina, 2018).

About the analysis of the results obtained, it is worth highlighting the different levels of energy vulnerability of the neighbourhoods analysed and the District of San Pablo-Santa Justa. The three neighbourhoods analysed, San Pablo A and B, San Pablo C, and San Pablo D and E, have high levels of energy vulnerability. Nevertheless, the San Pablo-Santa Just District, where the three neighbourhoods mentioned are located, has a medium level of energy vulnerability with the same factors analysed. This is due for the most part to the fact that in the same district more vulnerable residents live side by side with those of a higher economic status. The fact that within such a delimited territory as a district, the issue of energy poverty is experienced from different needs and requires specific solutions, highlights the necessity to continue developing decentralised research and analysis.

To deal with the situation of energy vulnerability in the San Pablo A and B neighbourhood, improvements must be made to the accessibility of buildings, given that 77% of housing does not have a lift. As this is a neighbourhood with an aging population, this shortage supposes a huge limitation for residents who are forced to spend longer periods in their homes, affecting their mental and physical health.

It is also necessary to act on the state of the building as 13% of them are in a dilapidated, poor, or deficient state. As the surveys show, 23.3% of local residents consider improving windows and enclosures a priority. This improvement would make it easier for

homes to maintain an adequate temperature, thus avoiding increases in energy bills due to having to heat or cool rooms.

Concerning the economic character of the neighbourhood, both the high unemployment rate, around 17% of the population, and the low average income make it difficult for local residents to access reliable and safe energy services.

Concerning the data that analyses access to heating systems, it is to be expected that the current situation has worsened since the 2011 Census. Data regarding the current increases in energy prices needs to be reviewed. In 2011, the final purchase price of energy from the electricity market was €60.15/MWh (Red Eléctrica de España, 2012). By December 2021 this price had increased to €252.51/KWh (Red Eléctrica de España, 2021). The price of energy has potentially contributed to the energy poverty situation in Spain.

Another point to highlight would be the results associated with energy consumption, an indicator included in the last census published in 2021. This indicator is relevant in the proposed methodology, as it is an indirect metric in which households are not classified based on a single indicator. However, as discussed in the Theoretical framework section, it would be necessary to adapt this indicator to make its results more representative. For example, it would be necessary to have the necessary data to perform per capita calculations.

As set out in the introduction, another key point for creating strategies in the fight against energy poverty is to include a gender analysis. It has been proven that the processes of the feminisation of poverty also affect the right to energy. In the case of the San Pablo A and B neighbourhood, the results show that 68% of people with high domestic responsibilities are women, which makes them more vulnerable to shortages in energy services or even health problems (such as an increase in stress or depression).

Furthermore, an especially vulnerable group has been identified within the neighbourhood: single-parent homes headed by women. All the households with a single breadwinner who claim to have a high level of domestic responsibility are headed by women. 13% of households without heating systems are also single-parent families headed by women.

The proposed hybrid methodology, which includes innovative factors such as the domestic burden associated with households or the lack of accessibility to dwellings, makes it easier to identify vulnerable groups and social processes such as the feminisation of energy poverty.

It is necessary to highlight the repercussions of energy poverty on the population's physical and mental health. As the surveys carried out in the case study neighbourhood show, 77% of local residents state that they suffer from psychological or neurological disorders such as anxiety, depression, or insomnia. Further studies have already investigated how these trends are worsened when people do not possess a healthy and comfortable home (Thomson et al., 2017a, 2017b, D. Hernández et al., 2016, Malgesini et al., 2018).

Finally, it is important to highlight the importance of developing hybrid methodologies in local studies that address heterogeneous and complex problems such as energy poverty. As has been presented, energy poverty is a problem that depends on a multitude of factors, so energy strategies must be able to respond to the different local contexts and the needs of citizens (Sovacool, 2012, Creutzfeldt et al., 2020).

Conclusions

The Autonomous Community of Andalusia is a territory with a high level of energy poverty, exceeding the national average in the majority of energy vulnerability indicators (Tirado Herrero et al., 2018, Clavijo Núñez, 2020). This research concludes that the issue varies substantially between territories and populations. Even within the same district, homes in each neighbourhood have very different needs which require a response.

Even when there are no relevant databases available, studies on energy poverty should be able to understand the complexity and intersectionality of this phenomenon and employ the data available to reflect the reality of energy vulnerability in a territory. Even with estimates, results can be useful for the advancement of government energy policies and programmes if there is adequate knowledge of the problem.

The results presented by districts help to understand how energy vulnerability manifests itself in the city of Seville and what are the main priorities on which to act. For example, the percentage of

buildings constructed before 1980 is evidence of the need to promote programs to improve energy savings and efficiency. On the other hand, the indicators obtained for unpaid work, or the results disaggregated by gender show the need to create strategies from a feminist perspective.

To delve deeper into this problem, the research carried out in the San Pablo A and B neighbourhood uses surveys as a tool for generating a process adapted to the neighbourhood. As a result, data is obtained regarding lifestyles and household habits in the neighbourhood. It is interesting to note how the level of vulnerability of the neighbourhood and the Santa Justa-San Pablo district are different, thus making visible the multiple realities in which energy poverty manifests itself even in such limited territories. It is deemed necessary to continue working in this line, employing techniques that enable up to date information to be gathered for the case study itself.

The next steps to be taken in the fight against energy poverty in the Polígono de San Pablo focus on the development of participatory dynamics to create meeting places and continue gathering information about the needs and potential of the neighbourhood together with local residents themselves. The process to define the state of vulnerability must be intersectional, multidisciplinary, and participatory so at to enable the population's inequalities, problems or needs to be identified (Valverde Arbizu, 2017). The focus will be on social inclusion so that the effects on the population are analysed depending on gender or age.

Once these participatory spaces are created, efforts will centre on designing a strategy to improve the comfort and health conditions in these homes. It will be necessary to develop tools that search for models that minimise the environmental impact and improve public health (Herrera-Limones et al., 2019). These strategies and tools should also encourage the simple, direct, and rigorous transfer of scientific knowledge to citizens (Borrallo-Jiménez et al., 2020). To do so, it will be essential to incorporate processes of returns for the neighbourhood once the participatory dynamics have been carried out. These processes will be understood as the "restoration to the people of something alienated in the research process" in forms and languages that are useful for the population (Nevado, 2019).

The aim is to advance the constitution of a more sustainable and healthier city where access to energy is considered a right and a basic service for all homes.

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Declarations

Ethical approval Citizen surveys and interviews have been ethically evaluated and the consent of all participants has been obtained.

Conflict of interest There are no conflicts of interest related to the article.

Annex 1 Surveys carried out in the neighbourhood

0. Identification
- Age
- Gender
- Address
- Type of building
- Educational level

QUESTIONS INCLUDED IN PHASE 1

1. Elements and exterior spaces available in your homes
- Balcony
- Own terrace
- Common terrace
- Garden area
- Own courtyard
- Not applicable

2. External noise
- Rate it from 1 to 5, with 5 being a lot of noise and 1 being a little noise in the neighbourhood

3. Changes that would be made to the home
- Paint color
- Furniture
- Windows
- Bathroom renovation
- Kitchen renovation
- Insulation
- Integral reform
- Not applicable

4. Services or aspects of the neighbourhood that are deficient or undesirable
- Location
- Cleanliness
- Infrastructure
- Safety and security
- Neighbors
- Al lof the above

5. Improvements to be implemented in the public space
- Vegetation
- Children's playgrounds
- Sports areas
- Street repairs
- Areas that attract crime
- Public swimming pool
- Not applicable

6. Improvements to be implemented on public transportation
- More bus stops
- More bus lines
- More cabs stands
- More bike rental points
- Subway
- Not applicable

7. Sense of belonging and identity with respect to the neighbourhood.
- Yes
- No

8. Neurological or psychological problems during confinement
- Low self-esteem
- Sadness, pessimism or apathy
- Irritability or moodiness
- Symptoms of anxiety or nervousness
- Feeling of exhaustion
- Insomnia problems
- Headache or migraine
- None

9. Views from your windows during the quarantine
- Public park
- Own courtyard
- Inner courtyard
- Other buildings
- Trees
- Road

ADDITIONAL QUESTIONS INCLUDED IN PHASE 2

10. Type of buildings
- Low-rise building (5 floor o less)
- Medium-rise building (between 6 and 9 floor)
- High-rise building (more than 9 floor)

11. Pathology presented by the respondent
- Headache or migraine
- Insomnia
- Exhaustion
- Anxiety
- Bad mood
- Sadness
- Breathing problems
- None

12. Demand for improvements on thermal comfort in dwellings
- Insulation
- Ventilation
- Windows
- Lighting
- Solar protection
- Renovation of dampness
- None

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