

# SOCIOSPATIAL ASSESSMENT OF ENERGY POVERTY AND ITS GENDER DIMENSION IN VULNERABLE AREAS OF GRANADA, SPAIN

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## EVALUACIÓN SOCIOESPACIAL DE LA POBREZA ENERGÉTICA Y SU DIMENSIÓN DE GÉNERO EN ÁREAS VULNERABLES DE GRANADA, ESPAÑA

## AVALIAÇÃO SOCIOESPACIAL DA POBREZA ENERGÉTICA E SUA DIMENSÃO DE GÊNERO EM ÁREAS VULNERÁVEIS DE GRANADA, ESPANHA

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## ABSTRACT

Although energy poverty is a widely addressed issue, significant knowledge gaps persist regarding how it disproportionately affects women. This study analyses energy vulnerability and the gender dimension from a socio-spatial perspective, using the city of Granada as a case study. The methodology draws on publicly available census-level data to combine energy and gender indicators and examine their prevalence in areas categorized as vulnerable. The findings reveal a relationship between vulnerable areas, low-income levels, and energy-inefficient buildings. Older women living alone, female-led households, and foreign-born women are identified as at-risk groups, all presenting significantly reduced income levels. The study concludes that there is a need to redefine vulnerable areas, promote energy retrofitting, and incorporate a gender perspective to design comprehensive public policies that contribute to a fair energy transition.

### Keywords

energy, women, residential areas

## RESUMEN

A pesar de que la pobreza energética es un problema ampliamente abordado, aún persisten lagunas de conocimiento sobre cómo afecta de manera diferenciada a las mujeres. El estudio analiza la vulnerabilidad energética y la dimensión de género desde una perspectiva socioespacial, tomando como caso de estudio la ciudad de Granada. La metodología emplea datos públicos a escala censal para combinar indicadores energéticos y de género y analizar su prevalencia en áreas categorizadas como vulnerables. Los resultados evidencian una relación entre áreas vulnerables, bajos ingresos y construcciones energéticamente ineficientes. Se identifican como grupos de riesgo las mujeres mayores en hogares unipersonales, los hogares encabezados por mujeres y las mujeres extranjeras, que presentan ingresos significativamente reducidos. Se concluye que es necesario redefinir las áreas vulnerables, promover la rehabilitación energética e integrar el enfoque de género, a fin de diseñar políticas públicas integrales que contribuyan a una transición energética justa.

### Palabras clave

energía, mujeres, áreas residenciales

## RESUMO

Embora a pobreza energética seja uma questão amplamente abordada, ainda persistem lacunas de conhecimento sobre como ela afeta as mulheres de forma diferenciada. Este estudo analisa a vulnerabilidade energética e a dimensão de gênero sob uma perspectiva socioespacial, tomando como caso de estudo a cidade de Granada. A metodologia utiliza dados públicos em escala censitária para combinar indicadores energéticos e de gênero, com o intuito de analisar sua prevalência em áreas classificadas como vulneráveis. Os resultados evidenciam uma relação entre áreas vulneráveis, baixa renda e edifícios energeticamente ineficientes. São identificados como grupos de risco as mulheres idosas em domicílios unipessoais, os domicílios chefiados por mulheres e as mulheres estrangeiras com rendimentos significativamente reduzidos. Conclui-se que é necessário redefinir as áreas vulneráveis, promover a reabilitação energética e integrar a perspectiva de gênero, com o objetivo de elaborar políticas públicas integrais que contribuam para uma transição energética justa.

### Palavras-chave

energia, mulheres, áreas residenciais

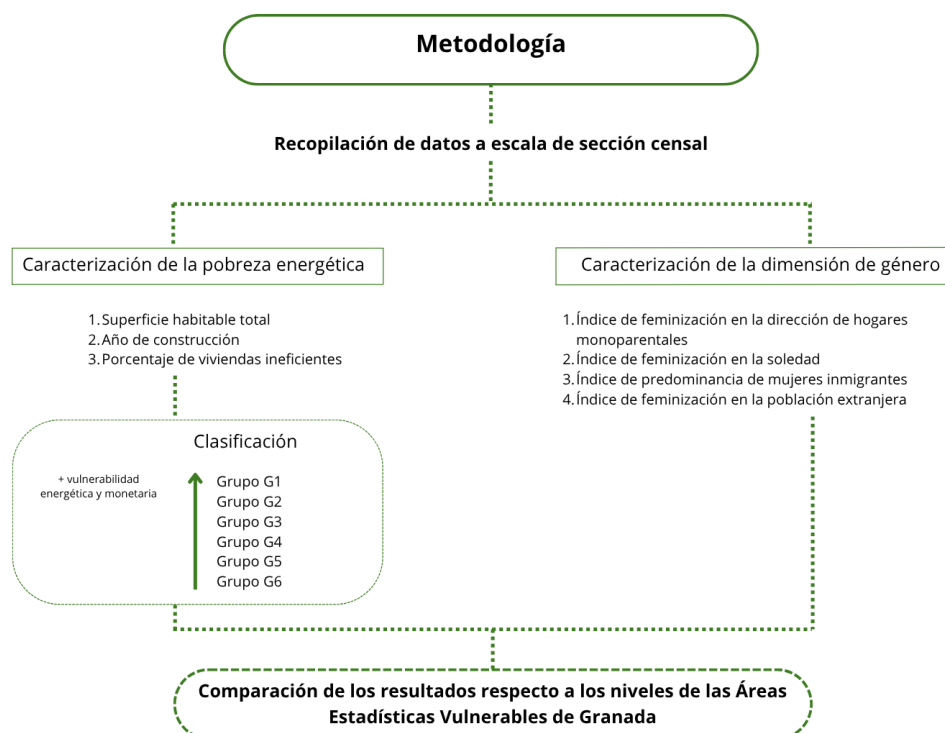


Figure 1. Outline of the applied methodology. Source: Prepared by the Authors.

## INTRODUCTION

Energy poverty (EP), a multidimensional problem located at “the intersection between household incomes, energy costs and the energy efficiency of the housing stock” (Faiella & Lavecchia, 2021), is linked to other dimensions of poverty and inequality, such as the gender gap. At the same time, the academic review of the feminization of energy poverty, although relevant, is lacking (Longhurst & Hargreaves, 2019). From a gender perspective, women continue to take on more of the tasks of caring for and maintaining the home. As a result, they have historically been the most affected by the lack of secure access to basic services, while also facing the burden of household responsibilities and difficulties paying energy bills (McDowell, 1999).

A key problem is the lack of data on the gender dimension in EP (Clancy, 2016). It was initially analyzed from technical aspects such as consumption and thermal perception (Cecelski, 2004), and subsequently in terms of its comprehensive impact on EP (Clancy et al., 2017). Currently, there are still limitations due to the lack of disaggregated data (Bradshaw, Chant & Linneker, 2017), as well as conceptualizations and prejudices about the feminization of EP (Listo, 2018). It is also evident that an intersectional approach is needed, in which factors such as gender, age, or social class are intertwined, generating both privileges and disadvantages (Viveros Vigoya, 2016).

In Europe and Spain, more than half of single-parent households are at risk of poverty or social exclusion, especially those supported by women, who earn 18.6% less than men and have a higher unemployment rate (Alguacil Denche, Llano Ortiz & Sanz Angulo, 2024; Technical Secretariat of European Anti-Poverty Network [EAPN-EN], 2024). Andalusia has one of the highest incidence rates of EP in Spain (Romero Mora, Barrella & Centeno Hernández, 2024), due to the combination of low wages, increased climatic severity, and a poor built environment (Castaño-Rosa, Solís-Guzmán & Marrero, 2020). Granada is one of the most affected cities, with documented structural problems, such as the continuous power cuts in the northern neighborhoods (Ramírez, 2023), a strong energy demand due to severe weather conditions (Bienvenido-Huertas et al., 2020), and poor energy performance in social housing from the point of view of adaptive comfort (Calama-González et al., 2024). However, the literature lacks studies that integrate the gender dimension from an intersectional approach in the analysis of EP in Granada.

It is necessary to incorporate this dimension through a socio-spatial approach, which examines the susceptibility of spatial environments (e.g., neighborhoods) to risks arising from specific dynamics. Using this analysis in social problems allows consideration of temporal factors and different input variables (Panda, 2017). In the case of EP, this approach allows detecting its unpredictability, as it can

vary with household characteristics and social inequalities within the same area (Pérez-Fargallo et al., 2026).

The general aim of the article is to determine the relationship between energy poverty and the gender dimension at the census scale in vulnerable areas in Granada. The findings, which incorporate an intersectional gender approach, enable analysis of the influence of the feminization of energy poverty in Granada and will serve as a basis for developing public policies that effectively advance a fair transition.

## METHODOLOGY

The proposed methodology combines a quantitative analysis of energy and gender variables in Granada, as detailed in the phases shown in Figure 1.

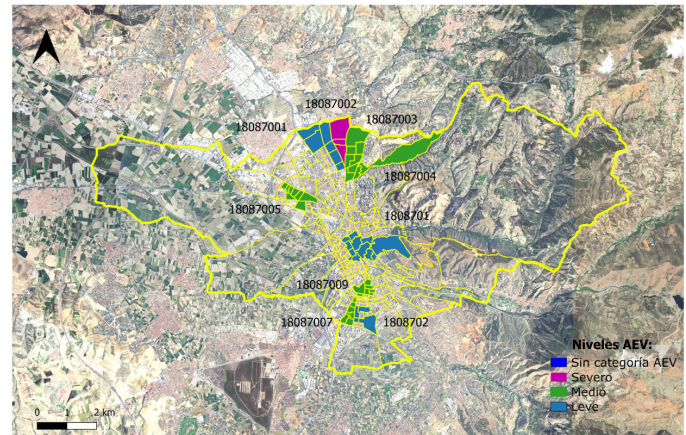
### CASE STUDY

The city of Granada (Spain) was selected as the study area, and vulnerable statistical areas (VSAs) from the Vulnerable Neighborhoods Catalog were included (Ministry of Transport, Mobility and Urban Agenda, 2021). The characterization of the VSAs allows the classification of the census sections into five levels (not vulnerable, mild, medium, severe, and critical) based on three indicators: unemployed population, population without studies, and housing in poor condition.

Granada has mild, medium, and severe VSA levels (Figure 2). In the case of mild, 3 VSAs are detected, with the Almanjáyar neighborhood standing out as one of the areas with the most reported cases of energy poverty in the city. The medium level has the majority of the city's VSAs (6 in total). They cover the neighborhoods of Cartuja, La Chana, Monteverde-Caserío de Montijo, Zaidín chico, and Zaidín-Vergeles. Finally, the La Paz-Rey Badis area has the most severe VSAs.

### MATERIALS

Firstly, technical and socio-economic public data on the real estate stock were collected from sources that



| Código   | Nivel de vulnerabilidad | Nº viviendas | Superficie (Ha) | Nº secciones censales |
|----------|-------------------------|--------------|-----------------|-----------------------|
| 1808701  | Leve                    | 10615        | 135,95          | 12                    |
| 1808702  | Leve                    | 2810         | 37,07           | 5                     |
| 18087001 | Leve                    | 4065         | 106,69          | 5                     |
| 18087003 | Medio                   | -            | 77,81           | 5                     |
| 18087005 | Medio                   | 5610         | 48,49           | 9                     |
| 18087004 | Medio                   | 2860         | 121,66          | 4                     |
| 18087007 | Medio                   | 3775         | 25,09           | 6                     |
| 18087009 | Medio                   | 3900         | 26,75           | 8                     |
| 18087002 | Severo                  | 1.555        | 64,20           | 4                     |

Figure 2. Location of the vulnerable statistical areas of Granada. Source: Prepared by the Authors.

provided disaggregated information (Table 1). In the databases of the National Institute of Statistics [INE] for 2021 and 2023, the disaggregated resolution was at the census section level, whereas for the energy certificates it was at the housing scale and was grouped into the corresponding sections to unify the unit of analysis. The data have been collected for 180 census sections of the city of Granada.

The energy certificates database underwent fine-tuning, including eliminating duplicate records, excluding certificates with empty fields, and discarding records with errors in the survey reference. After this process, the database comprised 27,484 residential energy certificates, with coverage by census section calculated as the ratio of available certificates to the total number of housing units (Table 2).

| Survey/database                        | Year | Spatial scale  | Reference                  |
|----------------------------------------|------|----------------|----------------------------|
| Household Income Distribution Atlas    | 2023 | Census section | (INE, 2025)                |
| Population and housing census          | 2021 | Census section | (INE, 2023)                |
| Andalusia energy certificates registry | 2025 | Housing        | (Junta de Andalucía, 2025) |

Table 1. Databases of socio-economic and technical character of the built environment used in the study. Source: Prepared by the Authors.

| Mean (%) | Median (%) | Q1 (%) | Q3 (%) | Min. (%) | Max. (%) |
|----------|------------|--------|--------|----------|----------|
| 16.3%    | 13.7%      | 8.8%   | 19.3%  | 2.5%     | 65.3%    |

Table 2. Coverage of energy efficiency certificates in Granada. Source: Prepared by the Authors.

## CHARACTERIZATION OF ENERGY POVERTY

An analysis was carried out using three energy indicators of the dwelling, selected according to the methodology of Aguilar, Guerrero-Rivera and de la Hoz-Torres (2025), and obtained from the available databases of building energy certificates. No additional indicators were incorporated because energy data sources were not available at the census level. The indicators used were total living area, year of construction, and the percentage of inefficient housing (Equation 1).

$$ID_i = \frac{D_{i,E} + D_{i,F} + D_{i,G}}{D_i} \cdot 100 \quad [\%] \quad (\text{Equation 1})$$

Where  $ID_i$  is the percentage of inefficient housing;  $D_{i,E}$  is the number of homes with an E label;  $D_{i,F}$  is the number of homes with an F label;  $D_{i,G}$  homes with a G-label; and  $D_i$  the total number of homes tagged.

These energy indicators were complemented by the EP indicator, based on the socio-spatial adaptation of the 2M indicator, which has been used in a variety of studies in the scientific literature (Antepara et al., 2020; Sánchez-Guevara Sanchez et al., 2020a). As these investigations indicate (Equation 2), given that the average energy expenditure in Spain is approximately 5%, a threshold of 10% is considered.

$$EPR = \frac{EC}{DI} \cdot 100 \quad [\%] \quad (\text{Equation 2})$$

Where EPR is the rate of EP; EC is the annual cost or expenditure of energy consumption obtained through energy certificates (€); and DI is the average annual net income of the dwelling (€).

The energy cost was calculated by breaking down the costs of the different energy vectors used by the dwelling: electricity, natural gas, liquefied petroleum gas (LPG), and biomass (Equation 3), based on the consumption data included in the energy certificate.

$$EC = ECC + NGCC + LPGCC + BCC \quad [€] \quad (\text{Equation 3})$$

Where ECC is the annual cost of the dwelling's electricity consumption (€); NGCC is the annual cost of natural gas consumption (€); LPGCC is the annual cost of LPG consumption (€); and BCC is the dwelling's annual cost of biomass consumption (€).

The cost of electricity consumption was calculated based on a series of considerations regarding the typical characteristics of Spain (Equation 4). In this sense, the Voluntary Price for the Small Consumer (PVPC, in Spanish) tariff was considered, without time discrimination (Royal Decree 216, 2014).

$$ECC = 1,21 \cdot ((C_e \cdot P_e) + CP) \cdot (1 + EIT) + RM \quad [€] \quad (\text{Equation 4})$$

Where  $C_e$  it is the energy consumption obtained from the dwelling's energy certificate (kWh);  $P_e$  is the price of the PVPC electricity tariff (€/kWh); CP is the cost of the contracted power (€); EIT is the electricity tax; and RM is the rental of the meter (€). The values associated with the tariffs were obtained from the average PVPC values for 2025. Regarding power, a 4.6 kW contract was considered, representative of the average contracted power in the country (ENDESA, 2025).

As for natural gas, billing under the last-resort tariff (TUR, in Spanish) was considered. The formulation used would be Equation 5:

$$NGCC = 1,21 \cdot ((C_{NG} \cdot P_{NG}) \cdot (1 + T) + FC + RM) \quad [€] \quad (\text{Equation 5})$$

Where  $C_{NG}$  is the natural gas consumption (kWh);  $P_{NG}$  is the price of the variable term of natural gas (€/kWh); T is the tax on hydrocarbons; FC is the fixed-term price of natural gas (€); and RM is the rental of the meter (€). Finally, the costs of LPG and biomass were obtained using Equation 6 and Equation 7.

$$LPGCC = C_{LPG} \cdot P_{LPG} \quad [€] \quad (\text{Equation 6})$$

$$BCC = C_B \cdot P_B \quad [€] \quad (\text{Equation 7})$$

Where  $C_{LPG}$  is the LPG consumption (kWh);  $P_{LPG}$  is the price of propane (€/kWh);  $C_B$  is the biomass consumption (kWh); and  $P_B$  is the biomass price (€/kWh).

## ENERGY POVERTY CLASSIFICATION

Once the EP results were available, the census sections were classified into different levels, following the methodologies proposed in previous studies of the Community of Madrid (Sanz-Fernández et al., 2016; Sánchez-Guevara Sánchez, Sanz Fernández & Núñez Peiró, 2020b). The methodology consists of the two-dimensional location of households when comparing the income variables (DI) and energy expenditure (EC).

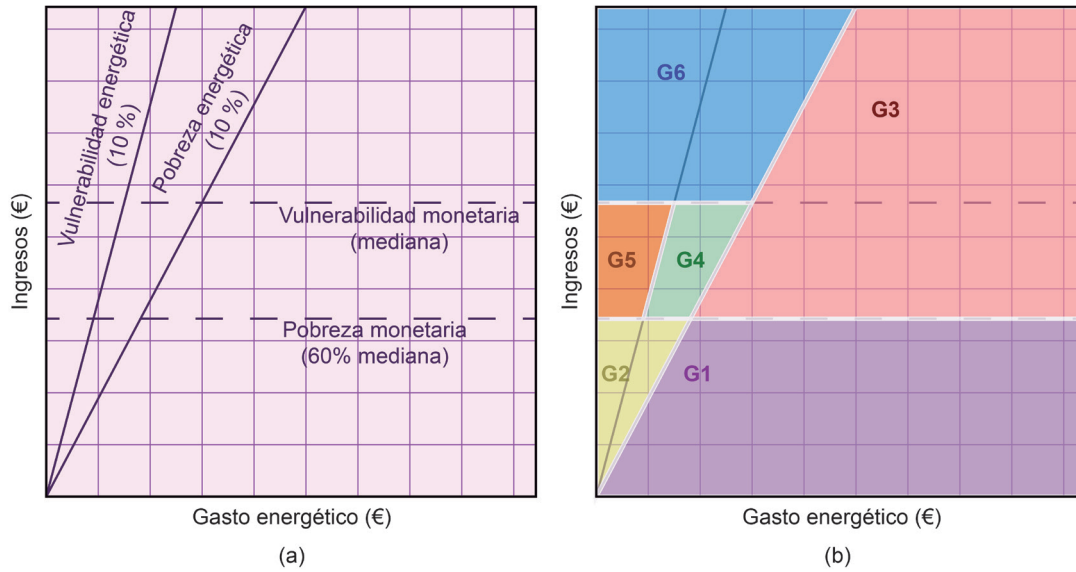


Figure 3. Classification of households: (a) thresholds and (b) groups. Source: Prepared by the Authors based on the methodology of Ana Sanz-Fernández (Sanz-Fernández et al., 2016) and Carmen Sánchez-Guevara Sánchez (Sánchez-Guevara Sánchez et al., 2020b).

This approach includes some lines-thresholds, which led to six different groups (Figure 3):

- Group G1: Census tracts with households suffering from both monetary poverty (60% of median income) and EP (10% of energy expenditure compared to income).
- Group G2: Census tracts suffering from monetary poverty.
- Group G3: Census tracts that suffer from EP, but not monetary poverty (they would be in monetary vulnerability, median income).
- Group G4: Census tracts with households in the energy vulnerability (5% of energy expenditure) and monetary vulnerability category.
- Group G5: Census tracts in the monetary vulnerability category.
- Group G6: Census tracts without energy or monetary vulnerability.

## CHARACTERIZATION OF THE FEMINIZATION OF ENERGY POVERTY

To analyze the feminization of energy poverty, four partial gender indicators were used based on disaggregated data from the INE and on the limitation of applying existing feminization indices in the literature (Capetillo-Ordaz et al., 2024). The partial indicators considered were: feminization index in the leadership of single-parent households (FHH<sub>i</sub>); index of feminization in loneliness (FL<sub>i</sub>); predominance index of immigrant women (PFoW<sub>i</sub>) and index of feminization in the foreign population (FFo<sub>i</sub>).

The reflects the predominance of single-parent households (Equation 8). This indicator is key, as

women earn lower wages, receive lower pensions, and experience higher unemployment rates, which structurally reduces their disposable income for energy bills.

$$FHH_i = \frac{H_{i,w<65} + H_{i,w>65}}{H_i} \cdot 100 \quad [\%] \quad (\text{Equation 8})$$

Where  $H_{i,w<65}$  is the total number of households headed by women under the age of 65;  $H_{i,w>65}$  is the total number of households headed by women over the age of 65; and  $H_i$  is the total number of households.

The feminization in the loneliness index (FL<sub>i</sub>) reflects the situation of women over the age of 65 who live alone and whose income depends on their pension. The calculation of this index was based on a comparison with respect to households composed of older men (Equation 9).

$$FL_i = \frac{H_{i,w,l>65}}{H_{i,m,l>65} + 1} \cdot 100 \quad [\%] \quad (\text{Equation 9})$$

Where  $H_{i,w,l>65}$  is the total number of households headed by women over the age of 65 living alone; and  $H_{i,m,l>65}$  is the total number of households headed by men aged 65 and older living alone.

The predominance index of immigrant women PFoW<sub>i</sub> was included to explore the relationship between immigration and gender inequalities in EP (Equation 10), as they often face socio-economic disadvantages, such as lower-paid jobs or higher unemployment rates.

$$PFoW_i = \frac{W_{i,Fo}}{W_{i,Fo} + W_{i,Sp}} \cdot 100 \quad [\%] \quad (\text{Equation 10})$$

Where  $W_{i,Fo}$  is the number of women born outside Spain who are residents in the area of analysis; and  $W_{i,Sp}$  is the number of women born in Spain in the area of analysis.

Finally,  $FFo_i$  reflects the gender composition of immigrant communities and can be used to identify groups of foreign women who might be disproportionately exposed to EP due to socio-economic disadvantages (Equation 11).

$$FFo_i = \frac{W_{i,Fo}}{M_{i,Fo} + 1} \cdot 100 \quad [\%] \quad (\text{Equation 11})$$

Where  $M_{i,Fo}$  is the number of men born outside Spain.

Finally, the Moran Index is applied to the analyzed variables to examine the spatial autocorrelation of these indicators across sections. Values close to 1 show strong positive spatial clustering, values close to 0 indicate a random distribution, and values close to -1 indicate high spatial dispersion. The statistical significance is evaluated using a pseudo-p-value obtained from 999 random permutations.

## RESULTS AND DISCUSSION

The analysis began with an evaluation of the energy indicators and their relationship to the VCAs of Granada; areas that were not classified as VCAs were also considered. As shown in Figure 4, there are clear coincidences among VCAs on some energy indicators, such as year of construction, living area, and annual energy expenditure, with a lower interquartile range in the higher-risk VCAs due to their smaller spatial size. The average construction year for these areas was 1974. The analysis of inefficient housing reveals a clear relationship between VCA severity and housing efficiency. The highest-risk VCA (11% of the vulnerable territory) shows a percentage close to 100% in all sections. For the other VCAs and risk-free zones, the percentages of inefficient housing are similar. Since there is a correlation between energy efficiency and living space (larger homes consume more energy), analyzing the EPR indicator is well-suited to the final evaluation of the EP risk. The 10% threshold for the 2M indicator was considered; 28% of the sections without VCA cataloging were in EP, a percentage that progressively increases with risk: 53% in VCA 1, 75% in VCA 2, and 100% in VCA 3.

The analysis continued with the risk groups of the methodology of Sánchez-Guevara Sánchez et al. (2020b). As shown in Figure 5, in the severe category of VCAs, 100% of the census units were in G1, more extreme cases of energy and monetary poverty. Both

in the lower-risk VCAs and in areas without VCA cataloging, census sections were observed within the G1. Although this implies a lack of correlation between VCA cataloging and the risk of EP, the associated percentage values for records in the G1 were dependent on the level of VCA: 0.8% in areas without VCA, 20% at the mild level, and 25% at the medium level. Thus, a relationship was again detected between VCA levels and the risk of EP. In the remaining groups, certain associations were observed between VCA and the predominant group. In this sense, the G3 group predominated in the mild and medium levels (Figure 5). These cases are characterized by low-to-middle income and a lack of energy efficiency in housing. G6 (zero energy and monetary risk) predominated in areas without VCA cataloging, mainly due to higher income levels than in vulnerable areas. However, even in areas without VCA cataloging, EP cases are registered, with percentage values as high as 27.6%. Figure 6 shows the spatial distribution of the sections in each group: G2 and G5 are more uniform, while the other categories group the census sections with greater coherence in their classification as VCAs.

The relationship between residential inefficiency, low income, and EP had already been documented in both Madrid (Sanz Fernández et al., 2016) and Barcelona (Delgado, 2018). The cases of EP in areas without VCA cataloging highlight the importance of using a combination of indicators.

It should be noted that most of the houses predate the basic regulation of 1979, which established the need to implement insulation solutions in building envelopes. However, this relationship may vary due to possible subsequent retrofits. In general, the percentage of sustainable, highly efficient homes in Granada is low, underscoring the need to adopt energy retrofit strategies. Regarding the relationship between energy efficiency and living space, evaluating only the consumption variable could lead to misleading conclusions, since the most severe VCAs had the lowest consumption values due to the smaller area of their housing.

These cases of EP are linked to housing energy inefficiency and low incomes in these VCAs. Although the VCA definition criteria did not originally consider EP criteria, their interrelation with economic and efficiency problems leads to a greater predominance of EP in the most vulnerable areas, including some without VCA cataloging, which may reflect the need to reclassify some census units.

Once the EP was characterized, the gender dimension was evaluated. In Figure 7, some similarity is observed across all zones, except in the severe category. The indicators of feminization

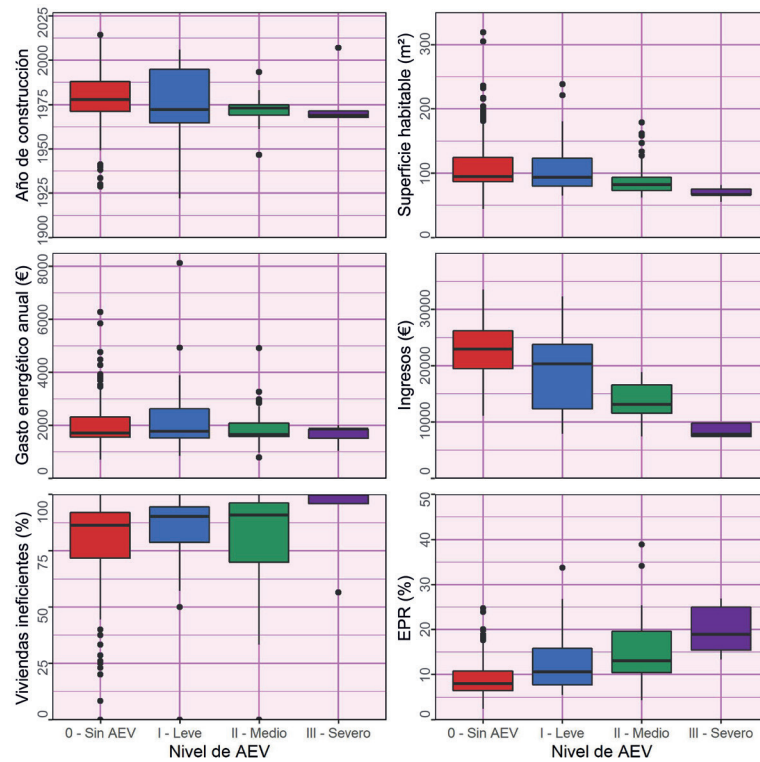


Figure 4. Box diagrams of the results obtained in the energy indicators. Source: Prepared by the Authors.

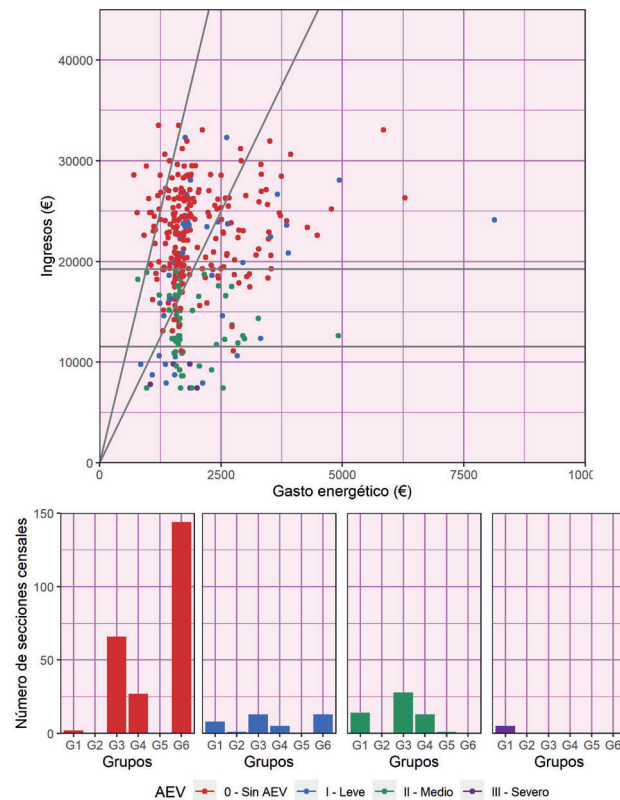


Figure 5. Location of households by energy poverty risk group, as classified by the VCA. Source: Prepared by the Authors.

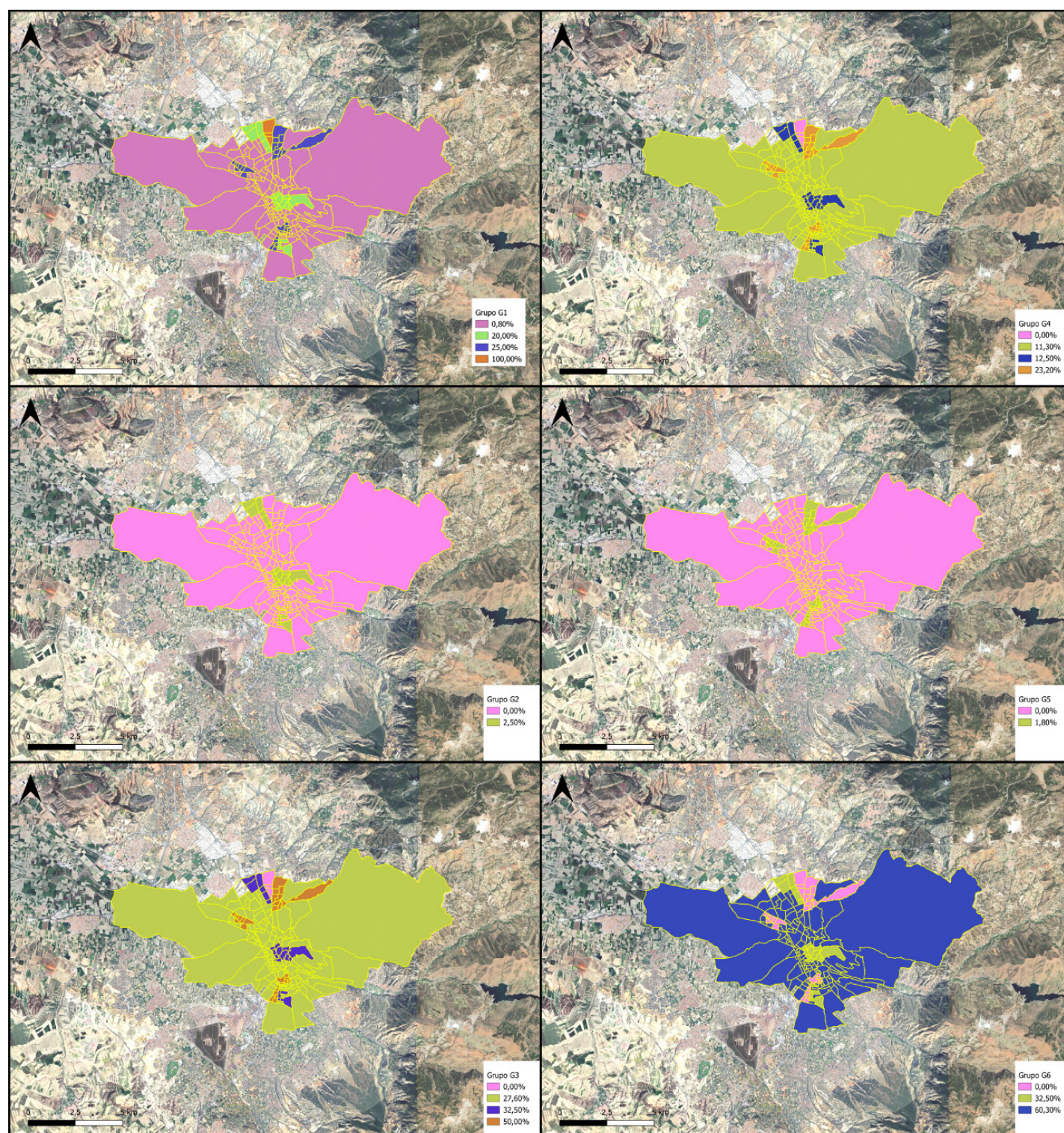


Figure 6. Spatial distribution of EP groups. Source: Prepared by the Authors.

in household management (FHH), feminization in solitude (FL) and foreign population (PFoW) and (FFo) were lower in the census tracts of La Paz-Rey Badis. The feminization index of loneliness shows values exceeding 100% in male-headed households. The feminization rate of the foreign population also

exceeds 100% in the vast majority of cases. Single-parent households are also predominant in the region.

The lower concentration of gender indicators in La Paz-Rey Badis may be associated with the limited extension of VCA 3 in Granada, resulting in a concentration of

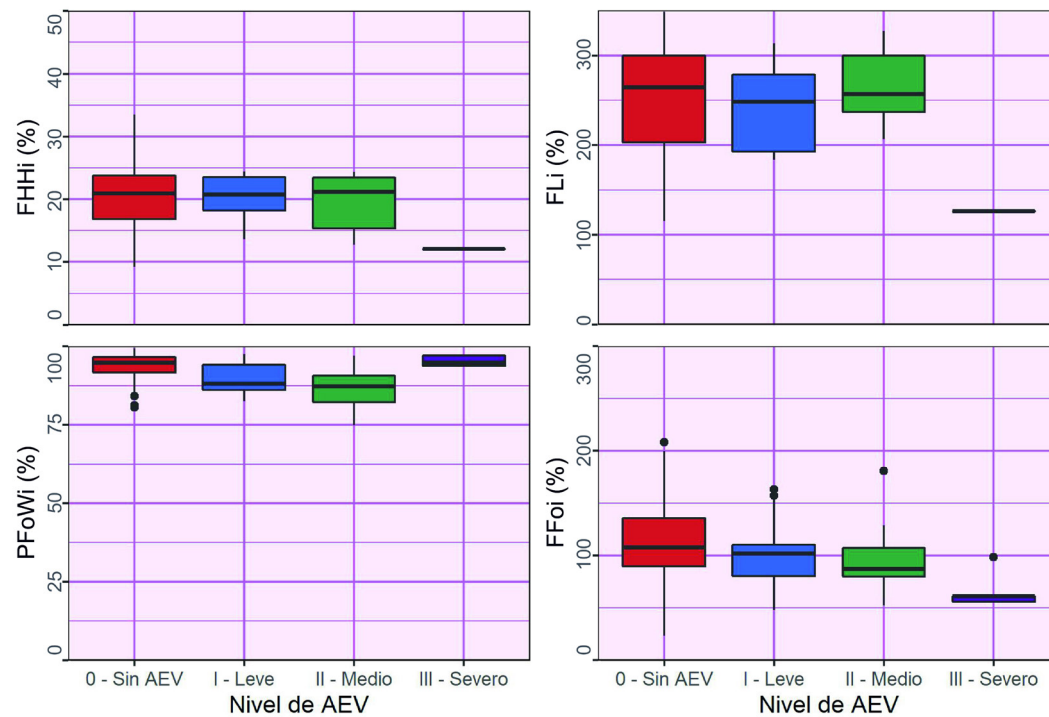


Figure 7. Box diagrams of the gender indicators, classified according to the VCA. Source: Prepared by the Authors.

results. On the other hand, there is a high proportion of vulnerable households headed by single older women, which could be explained by the fact that economic sustenance is usually pensions (which are lower than for men). In the same vein, single-parent households can lead to new EP situations if their incomes align with the usual trends in the business sector.

Regarding the spatial autocorrelation analysis, most indicators show moderate-to-high spatial clustering, with weak clustering in some cases, and are statistically significant in all cases. For example, the year of construction shows a Moran I of 0.455 ( $p$ -value=0.001), and the living area shows a Moran I of 0.468 ( $p$ -value=0.001), which reflects the residential segregation characteristic of cities. The index of feminization of the foreign population presents a weak positive autocorrelation ( $I=0.113$ ;  $p$ -value=0.005), a consequence of a more dispersed distribution in the territory.

The results show the need to complement official tools for defining vulnerable areas by incorporating energy and gender criteria, to represent the most vulnerable urban areas on which it is a priority to act. Among the study's limitations are the lack of individual-level data, the absence of actual consumption measurements, and the reliance on estimated average tariffs. Future research should incorporate more gender variables to expand the analysis of the feminization of EP.

## CONCLUSIONS

Although the city of Granada has been identified as having a high energy vulnerability, the interrelationships between the levels of vulnerable statistical areas, officially recognized in the city of Granada, and their energy-social reality had not been analyzed until now. As reflected in the results, there is a relationship between high levels of VCAs and energy poverty across different dimensions. The main cause of this relationship is low family income (a socio-economic factor), since the city's built environment is characterized by very poor energy performance. In this sense, even in areas that do not have a risk of VCA, significant percentages of cases of energy poverty appear. This raises a binomial in the course of the strategies: on the one hand, the need to redefine the methodology for cataloging VCAs if it is intended to serve as a reference for identifying the areas most at risk of energy poverty in the city. On the other hand, the commitment to energy rehabilitation aims to address one of the factors that drive the proliferation of energy poverty: the inefficiency of city housing. This is especially relevant in the city, since a large share of the city's census sections are not in monetary poverty (except for the cases indicated in the results section).

Similarly, the results have highlighted a possible association between the gender dimension and the city's energy poverty. In this sense, dimensions such as the feminization of loneliness and the foreign population being the majority in the city are usually associated with a lower level of income for families. As

a result of this study, it is expected that these findings will provide a starting point for integrating gender studies into cases of energy poverty, both in Granada and in other cities. Expanding the scale of analysis and incorporating disaggregated data at other levels will allow for the establishment of more robust correlations regarding the implications of energy poverty and gender.

## CONTRIBUTION OF AUTHORS CRediT

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## BIBLIOGRAPHIC REFERENCES

Aguilar, A. J., Guerrero-Rivera, M. F., & de la Hoz-Torres, M. L. (2025). Identifying urban energy-vulnerable areas: a machine learning approach. *Journal of Building Engineering*, 109, 113047. <https://doi.org/10.1016/j.jobee.2025.113047>

Alguacil Denche, A., Llano Ortiz, J. C., & Sanz Angulo, A. (2024a). 14º informe. *El Estado de la Pobreza. Seguimiento de los indicadores de la Agenda UE 2030 (2015-2023)*. European Anti-Poverty Network [EAPN]. <https://www.eapn.es/publicaciones/566/xiv-informe-sobre-el-estado-de-la-pobreza-seguimiento-de-los-indicadores-de-la-agenda-ue-2030-informe-estatal>

Antepara, I., Papada, L., Gouveia, J. P., Katsoulakos, N., & Kaliampakos, D. (2020). Improving energy poverty measurement in southern European regions through equalization of modeled energy costs. *Sustainability*, 12(14), 5721. <https://doi.org/10.3390/su12145721>

Bienvenido-Huertas, D., Rubio-Bellido, C., Farinha, F., Oliveira, M. J., & Pérez-Ordóñez, J. L. (2020). Evaluating the potential of adaptive comfort approach using historic data to reduce energy consumption in buildings in southern Spain. *Building and Environment*, 185, 107313. <https://doi.org/10.1016/j.buildenv.2020.107313>

Bradshaw, S., Chant, S., & Linneker, B. (2017). Gender and poverty: what we know, don't know, and need to know for Agenda 2030. *Gender, Place & Culture*, 24(12), 1667–1688. <https://doi.org/10.1080/0966369X.2017.1395821>

Calama-González, C. M., Escandón, R., Suárez, R., Alonso, A., & León-Rodríguez, Á. L. (2024). Household energy vulnerability evaluation in southern Spain through parametric energy simulation models and socio-economic data. *Sustainable Cities and Society*, 103, 105276. <https://doi.org/10.1016/j.scs.2024.105276>

Capetillo-Ordaz, N. B., Martín-Consuegra, F., Alonso, C., Terés-Zubiaga, J., & Koutra, S. (2024). Inclusivity in urban energy transitions: A methodological approach for mapping gendered energy vulnerability. *Energy Research and Social Science*, 109, 103426. <https://doi.org/10.1016/j.erss.2024.103426>

Castaño-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 Research and Social Science*, 60, 101325. <https://doi.org/10.1016/j.erss.2019.101325>

Cecelski, E. (2004). *Re-thinking gender and energy: Old and new directions*. ENERGIA/EASE Discussion Paper. <https://assets.publishing.service.gov.uk/media/57a08cccd915d3cfd001612/R8346-ConceptRev.pdf>

Clancy, J. S. (2016). *In the light of what we know: Gender and energy transformations*. University of Twente.

Clancy, J. S., Daskalova, V. I., Feenstra, M. H., Franceschelli, N., & Sanz, M. (2017). *Gender perspective on access to energy in the EU*. Publications Office of the European Union.

Delgado, L. (Coord.). (2018). *Radiografies de la situació del dret a l'habitatge, la pobresa energètica i el seu impacte en la salut a Barcelon*. Dilogic S.L. <https://www.aspb.cat/wp-content/uploads/2018/05/Informe1-Radiografies-DretHabitatge-PobresaEnergetica-Salut-Barcelona.pdf>

Endesa. (01 de diciembre de 2025). ¿Qué potencia necesitan los electrodomésticos de tu casa? Guía práctica con ejemplo y tabla. Endesa S.A. <https://www.endesa.com/es/blog/blog-de-endesa/luz/que-potencia-electrica-necesitas>

Faiella, I., & Lavecchia, L. (2021). Energy poverty. How can you fight it, if you can't measure it? *Energy and Buildings*, 233, 110692. <https://doi.org/10.1016/j.enbuild.2020.110692>

Instituto Nacional de Estadística [INE]. (30 de junio de 2023). *Censo de Población y Viviendas - 2021*. INE base. [https://www.ine.es/dyngs/INEbase/operacion.htm?c=Estadistica\\_C&cid=1254736177108&menu=ultiDatos&idp=1254735572981](https://www.ine.es/dyngs/INEbase/operacion.htm?c=Estadistica_C&cid=1254736177108&menu=ultiDatos&idp=1254735572981)

Instituto Nacional de Estadística [INE]. (21 de octubre de 2025). *Atlas de Distribución de Renta de los Hogares. Año 2023*. INE base. [https://www.ine.es/dyngs/INEbase/operacion.htm?c=Estadistica\\_C&cid=1254736177088&menu=ultiDatos&idp=1254735976608](https://www.ine.es/dyngs/INEbase/operacion.htm?c=Estadistica_C&cid=1254736177088&menu=ultiDatos&idp=1254735976608)

Junta de Andalucía. (01 de junio de 2025). *Registro de certificados energéticos de Andalucía*. Datos.gob.es. Gobierno de España - Ministerio para la Transformación Digital y de la Función Pública <https://datos.gob.es/es/catalogo/a01002820-registro-de-certificados-energeticos-de-andalucia>

Listo, R. (2018). Gender myths in energy poverty literature: A Critical Discourse Analysis. *Energy Research and Social Science*, 38, 9–18. <https://doi.org/10.1016/j.erss.2018.01.010>

Longhurst, N., & Hargreaves, T. (2019). Emotions and fuel poverty: The lived experience of social housing tenants in the United Kingdom. *Energy Research and Social Science*, 56, 101207. <https://doi.org/10.1016/j.erss.2019.05.017>

McDowell, L. (1999). *Gender, identity and place: Understanding feminist geographies*. University of Minnesota Press.

Ministerio de Transportes Movilidad y Agenda Urbana. (2021). *Catálogo de Barrios Vulnerables de España 2011*. Ministerio de Transportes, Movilidad y Agenda Urbana / Universidad Politécnica de Madrid. [https://cdn.mitma.gob.es/portal-web-drupal/vivienda/barrios\\_vulnerables/bbv\\_2011\\_01\\_andalucia.pdf](https://cdn.mitma.gob.es/portal-web-drupal/vivienda/barrios_vulnerables/bbv_2011_01_andalucia.pdf)

Panda, A. (2017). Climate change, drought and vulnerability. In S. Iradaya Rajan & R.B. Bhagat (Eds.), *Climate Change, Vulnerability and Migration*. Routledge India. <https://doi.org/10.4324/9781315147741-10>

Pérez-Fargallo, A., Clavijo-Núñez, S., Rubio-Bellido, C., Bienvenido-Huertas, D., & Serrano-Jiménez, A. (2026). Defining socio-climate-energy zones based on photovoltaic potential to support new standards for eliminating energy poverty in Chile. *Journal of Cleaner Production*, 554, 148127. <https://doi.org/10.1016/j.jclepro.2026.148127>

Ramírez, M. J. (14 de enero de 2023). *Granada, tercera capital andaluza que más padece la pobreza energética*. GranadaDigital. <https://www.granadadigital.es/granada-pobreza-energetica-tercera-capital-andaluz/>

Real Decreto 216 de 2014 [Ministerio de Industria Energía y Turismo]. Por el que se establece la metodología de cálculo de los precios voluntarios para el pequeño consumidor de energía eléctrica y su régimen jurídico de contratación. 28 de marzo de 2014. BOE, (77). <https://www.boe.es/buscar/act.php?id=BOE-A-2014-3376>

Romero Mora, J. C., Barrella, R., & Centeno Hernández, E. (2024). *Informe de Indicadores de Pobreza Energética en España 2023*. Cátedra de Energía y Pobreza. Escuela Técnica Superior de

Ingeniería [ICAI] – Universidad Pontificia Comillas. [https://www.iit.comillas.edu/documentacion/informetecnico/IIT-24-303I/Informe\\_de\\_Indicadores\\_de\\_pobreza\\_energ%C3%A9tica\\_en\\_Espa%C3%B1a\\_2023.pdf](https://www.iit.comillas.edu/documentacion/informetecnico/IIT-24-303I/Informe_de_Indicadores_de_pobreza_energ%C3%A9tica_en_Espa%C3%B1a_2023.pdf)

Sánchez-Guevara Sánchez, C., Sanz Fernández, A., Núñez Peiró, M., & Gómez Muñoz, G. (2020a). Energy poverty in Madrid: Data exploitation at the city and district level. *Energy Policy*, 144, 111653. <https://doi.org/10.1016/j.enpol.2020.111653>

Sánchez-Guevara Sánchez, C., Sanz Fernández, A., & Núñez Peiró, M. (2020b). Feminisation of energy poverty in the city of Madrid. *Energy and Buildings*, 223, 110157. <https://doi.org/10.1016/j.enbuild.2020.110157>

Sanz Fernández, A., Gómez Muñoz, G., Sánchez-Guevara Sánchez, C., & Núñez Peiró, M. (2016). *Estudio técnico sobre pobreza energética en la ciudad de Madrid*. Ayuntamiento de Madrid. <https://www.madrid.es/UnidadesDescentralizadas/Consumo/NuevaWeb/pobreza%20energ%C3%A9tica/Copy%20of%20Estudio%20Pobreza%20energ%C3%A9tica%204%20febrero%202017.pdf>

Secretaría Técnica de European Anti-Poverty Network [EAPN-ES]. (Coord.). (2024). *Informe Poverty Watch 2024*. European Anti-Poverty Network - España [EAPN-ES]. [https://www.eapn.es/ARCHIVO/documentos/documentos/1734609856\\_informe\\_poverty\\_watch\\_eapn2024.pdf](https://www.eapn.es/ARCHIVO/documentos/documentos/1734609856_informe_poverty_watch_eapn2024.pdf)

Viveros Vigoya, M. (2016). Interseccionalidad: Una Aproximación Situada a La Dominación. *Debate Feminista*, 52, 1–17. <https://doi.org/10.1016/j.df.2016.09.005>