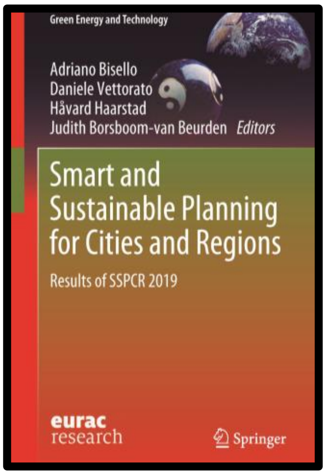

MARCH 2021

Exposure and Vulnerability Toward Summer Energy Poverty in the City of Madrid: A Gender Perspective

Miguel Núñez-Peiró; Carmen Sánchez-Guevara Sánchez; Ana Sanz Fernández; Marta Gayoso-Heredia; J. Antonio López-Bueno; F. Javier Neila González; Cristina Linares; Julio Díaz; Gloria Gómez-Muñoz

published in:

Smart and Sustainable Planning for Cities and Regions – Results of SSPCR 2019

Please cite this document as:

Núñez-Peiró, M., Sánchez-Guevara Sánchez, C., Sanz Fernández, A., Gayoso-Heredia, M., López-Bueno, J.A., Neila González, F.J., Linares, C., Díaz, J., Gómez-Muñoz, G. (2021). Exposure and Vulnerability Toward Summer Energy Poverty in the City of Madrid: A Gender Perspective. In: Bisello, A., Vettorato, D., Ludlow, D., Baranzelli, C. (Eds.), *Smart and Sustainable Planning for Cities and Regions*. Springer: pp. 481–495. doi:10.1007/978-3-030-57332-4_34.

Link to the document:

https://link.springer.com/chapter/10.1007/978-3-030-57332-4_34

Exposure and Vulnerability towards Summer Energy Poverty in the City of Madrid: A Gender Perspective

Miguel Núñez-Peiró[1], Carmen Sánchez-Guevara Sánchez[1], Ana Sanz-Fernández[1], Marta Gayoso-Heredia[1], J. Antonio López-Bueno[1,2], F. Javier Neila González[1], Cristina Linares[2], Julio Díaz[2] and Gloria Gómez-Muñoz[3]

Abstract

Recent research has addressed the special relationship between energy poverty and women. Despite that not many studies are yet available, results show that there might be strong gender inequalities connected with household's energy deprivation. Furthermore, differentiated health impacts have been detected between men and women, putting women into a more vulnerable position. In this sense, the so-called feminization of energy poverty is urging a revision of the existing studies from a gender perspective to foster its inclusion within energy poverty alleviation policies. The present study explores the links between summer energy poverty and gender in the city of Madrid. Summer energy poverty is considered another variety of energy deprivation particularly relevant within mid- and low-latitude countries, in which energy consumption for cooling is heavily increasing. It also seems to be particularly relevant in cities in which the urban heat island introduces relevant variations in the microclimatic conditions that might increase the housing-cooling demand. Following the methodology developed in previous studies, the risk of suffering from summer energy poverty is, in this paper, explored considering the household's gender composition. The geospatial distribution of their vulnerability is compared with other indicators related to their exposure to high temperatures: the housing energy efficiency and the cooling degree hours. The evaluation at the sub-municipal scale is carried out among the different subgroups in which a woman is the main breadwinner: single women with children and single women over 65 years old. Their situation is also compared to those households in which a man is the main breadwinner. The analysis of the selected variables is conducted using a *hotspot* analysis, which evaluates the autocorrelation of each variable according to its spatial distribution. Results show that women living alone and above 65 years old seem to be under the highest risk. They concentrate in areas with low energy-efficient housing stock and strong urban heat island intensities. On a general basis, the income gap between women and men makes it advisable to address energy poverty with a gender perspective.

Keywords: summer energy poverty, gender perspective, intra-urban variations, feminization, urban heat island

---

[1] School of Architecture, Universidad Politécnica de Madrid. Avda. Juan de Herrera 4, 28040, Madrid, Spain, miguel.nunez@upm.es

[2] National School of Public Health, Carlos III Institute of Health, Avda. Monforte de Lemos 5, 28029, Madrid, Spain.

[3] Fundación Arquitectura y Sociedad, Calle Babina Valverde 17, 28002, Madrid, Spain.

1 Introduction

Climate change projections for Europe suggest that the current temperature rise will continue throughout this century (IPCC 2013), which will coincide with an increase in the frequency and intensity of heat waves (Tebaldi et al. 2006). These temperatures will be higher in urban areas, where the urban heat island (UHI) phenomenon produces temperature increases that can exceed 12 ºC in comparison to their immediate rural areas (Gago et al. 2013; Oke et al. 2017). In that sense, and despite having focused its development on the inability to keep households at an adequate temperature during winter, the analysis of energy poverty is beginning to extend beyond under-heated months (Moore 2012). This new dimension of fuel poverty is known as *summer energy poverty.*

1.1 Summer Energy Poverty

Despite that there is not a specific definition, summer energy poverty can be understood as the inability to keep the house at an adequate temperature during the hottest months. According to the Energy Poverty Observatory (European Commission 2020), households might experience this situation due to a combination of factors: low income, inefficient building and appliances, high energy expenditures and specific energy needs. Although the definition of energy poverty includes heating and cooling needs in both the European and Spanish context (European Commission 2020; Ministerio para la Transición Ecológica 2019), the statistical databases do not reflect these situations equally. An example of this is that the last (and only) time European citizens were asked about their inability to keep their homes at a comfortable temperature during summer was back in 2012 (European Commission 2012). In a similar way, the last time Spanish households were asked about the availability of cooling systems was in the 2001 Census (Instituto Nacional de Estadística 2004).

However, the lack of statistical information has not prevented researchers from incorporating the summer energy perspective into the study of energy poverty. Several studies from around the world, such as in Australia (Moore et al. 2017), the UK (Mavrogianni et al. 2015; Wolf et al. 2010), Chile (Rubio-Bellido et al. 2017) and Italy (Pisello et al. 2017), have evaluated the resilience of vulnerable homes to high temperatures. Others have worked on the identification of summer energy poverty in the European context (Sánchez-Guevara et al. 2019; Santamouris and Kolokotsa 2015; Thomson et al. 2019). Researchers have even begun to explore various strategies to provide fresh and safe spaces for the population (Pearsall 2017; Sanchez and Reames 2019) or to improve the local and intergenerational connections and provide community assistance to the most vulnerable people (Sampson et al. 2013). A wide range of studies is, thus, beginning to be carried out to analyze the causes, consequences and possible solutions to alleviate summer energy poverty.

1.2 The Feminization of Energy Poverty

In recent years, several studies have mainstreamed a gender perspective into energy poverty (e.g., Clancy et al. 2017; Clancy and Feenstra 2019; Gonzalez Pijuan 2017; Robinson 2019). Continuing with this work, the FEMENMAD Project (Universidad Politécnica de Madrid 2019) has evaluated the feminization of energy poverty in the city of Madrid (Sánchez-Guevara et al. 2020; Sanz Fernández et al. 2016). The results show that, while 23% of total households of Madrid suffer from energy poverty, it rises to 29% in the case of those households where a woman is the main breadwinner. These values increase even more for the situation of a single woman over 65 (39%) or a single mother with children (41%) is assessed. In other words, single mothers with children are almost twice as likely to suffer from energy poverty as the average of the household of Madrid.

Risks associated with a different physiological response to high temperatures are also relevant between the sexes (Díaz et al. 2018; López-Bueno et al. 2019). Within the framework of the FEMENMAD project, the differences in terms of mortality and emergency hospital admissions were also analyzed. Although the differences found in mortality are explained by the difference in life expectancy between men and women, it was found that, with each degree exceeding 36 ºC, older women corresponding to the group from 65- to 74-years old experienced an attributable risk increase of 4.6% in admissions for natural causes. In the case of mortality due to circulatory causes, this percentage increased by 11.8% with each degree, while no significant statistical association was found for men during heat waves.

Given the higher incidence of energy poverty among households in which a woman is the main breadwinner and the higher vulnerability that some of these households might experience towards high temperatures, the present study explores their risk of suffering from summer energy poverty using the following approach.

2 Methodological Approach

The risk of suffering from energy poverty can be assessed through the spatial analysis of proxy indicators, as several studies have shown in recent years (Gouveia et al. 2019; März 2018; Tomlinson et al. 2011). These indicators are mapped and analyzed in order to find those areas where energy poor are more likely to be found. In this study, the risk of summer energy poverty is defined by the following expression:

$$Risk = Exposure \cap Vulnerability$$

Here, the risk depends on the intersection of households' exposure with households' vulnerability to high temperatures. Both exposure and vulnerability to high temperatures were measured through several indicators that were represented and treated spatially. Their degree of autocorrelation helped determine the areas where the highest values of each one of these indicators were concentrated (ESRI 2016a). These areas of concentration, called *hotspots*, were determined with a 90% confidence interval. Then, from the overlap of these *hotspots*, the areas with a higher risk were obtained together with the elements that characterize each one of them. To facilitate the comparison between the different cases, all indicators were presented by deciles. The spatial unit of the results is the census section of 2018.

2.1 Households Exposure to High Temperatures

The indicators used in Sánchez-Guevara et al. (2019) were taken as representative of those areas where a greater expenditure of energy could be given to keep home at an adequate temperature. These are, on the one hand, the energy performance of the building during the summer and, on the other hand, the cooling degree hours (CDH), which were estimated for both day and night. Since all domestic active cooling systems rely on electricity, the price of energy was not considered.

2.1.1 Energy Performance of the Housing Stock

The energy performance of buildings during summer was indirectly derived from the year of construction, in a similar way as was done in the *Technical Study on Energy Poverty in the City of Madrid* (Sanz Fernández et al. 2016). The year of construction reflects on a general basis both the construction characteristics of buildings and the regulations in force in that time (Instituto para la Diversificación y Ahorro de la Energía 2011). It was obtained from the Spanish Land Registry (Ministerio de Hacienda

2019) for each residential building in the city of Madrid. **Table 1** shows the relationship between the year of construction and the estimated energy performance of the buildings, while **Figure 1** shows the delimitation of the *hotspot* for the energy performance indicator. The housing with the worst energy performances during summer seems to concentrate around the central area of the city. These buildings, mostly constructed during the 1960s and 1970s, are characterized by the low quality of the construction, with low thermal inertia and the absence of thermal insulation.

Table 1 Energy performance of buildings during summer

	Year of construction	Percentage of total buildings	Construction characteristics
High	Before 1940	11%	Built of masonry, characterized by high thermal inertia and the use of shading devices to protect the openings from solar radiation.
	After 2006	25%	Built after the adoption of the Spanish Building Code (Código Técnico de la Edificación, 2019). Energy-saving and energy-efficiency criteria were introduced.
Average	1981 to 2006	7%	Built after the approval of the basic building regulation on thermal conditions (Gobierno de España, 1979), which introduced minimum insulation requirements.
Low	1941 to 1960	17%	Built of the post-Civil War period, no regulations applied. It is characterized by cheap materials with no quality standards.
	1961 to 1980	40%	Constructed during an expansive economic cycle, no regulations applied. Low-quality construction. Low thermal inertia. Absence of thermal insulation.

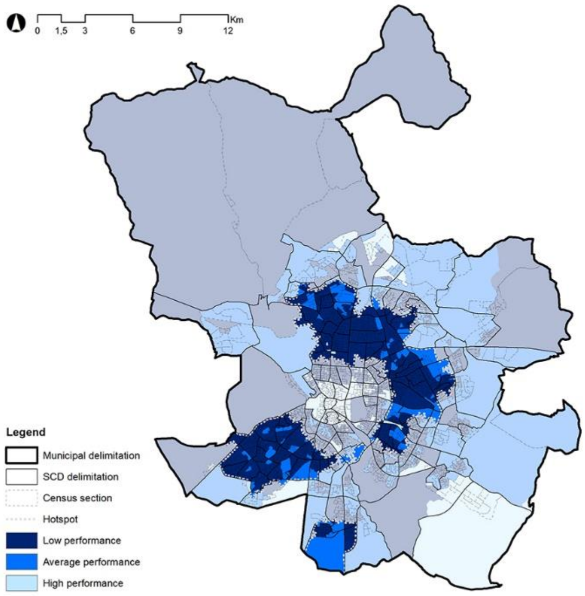

Fig. 1 Spatial distribution of the indicator associated with the energy performance of buildings during summer

2.1.2 CDH on the Microclimatic Scale

Cooling degree hours were estimated as the number of degrees that, for each hour of the day, the outdoor air temperature is above a certain reference temperature. Given the significant temperature differences that can be recorded in Madrid due to the UHI (Núñez Peiró et al. 2017), the data collected by a network of 20 sensors deployed during the MODIFICA Project (Universidad Politécnica de Madrid 2014) was used to determine the outdoor air temperature of each urban area. These sensors were distributed throughout the municipality following contextualization criteria that would guarantee their representativeness of the urban environment (Núñez Peiró et al. 2019) and were complemented with the records of three observatories from the Spanish Meteorological Agency (AEMET). The reference temperature, on the other hand, was defined as the comfort temperature established by the ASHRAE adaptive comfort standard (ASHRAE 2013; de Dear and Brager 1998). Since this standard does not contemplate sleeping hours (11 pm to 7 pm), two different reference temperatures, daytime and nighttime, were used. The daytime reference temperature was, thus, fixed at 28.3 ºC for June and at 28.4 ºC for July and August. On the other hand, a temperature of 27 ºC was established for the nights, in accordance with the criterion of the Spanish Building Code (Código Técnico de la Edificación, 2019). Finally, the day and nighttime CDHs were spatially interpolated for the entire city using a *kriging,* a tool available in the geostatistical analysis module of *ArcGIS* (ESRI 2016b; Oliver and Webster 1990).

Figure 2 shows the corresponding *hotspots* for high temperatures on the microclimatic scale. The concentration of a higher amount of CDH in the city center during the night corresponds to the typical concentric distribution of the UHI, while during the day the highest temperatures take place in the south-central area of the city. Despite the obvious differences between the day and nighttime CDH, there are some southern areas of the city in which high temperatures might be concentrated 24 hours a day.

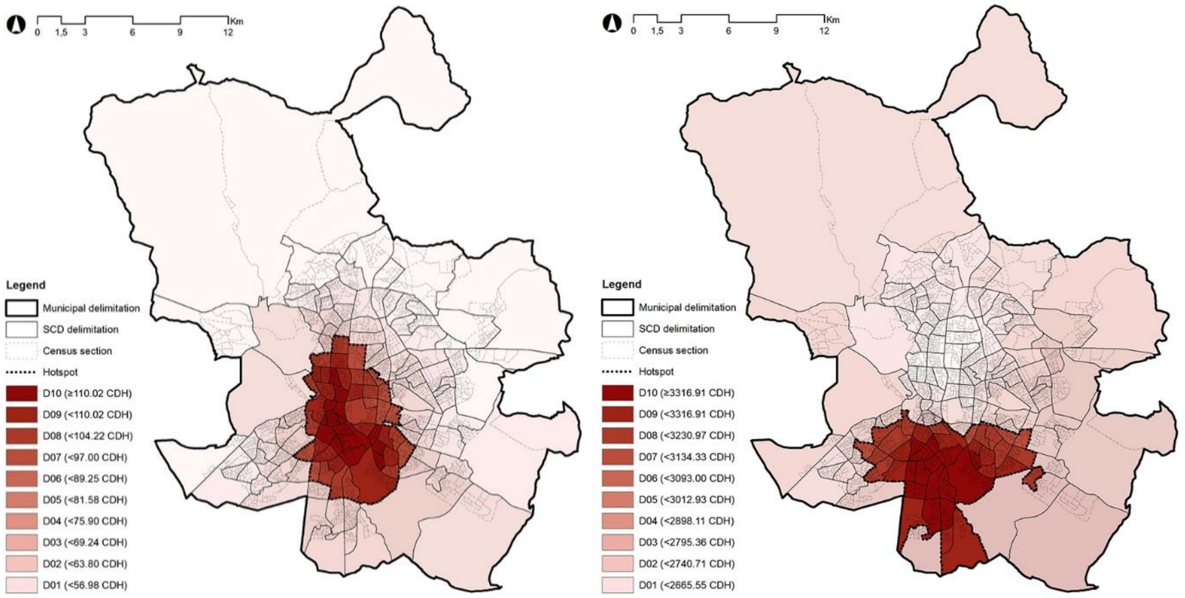

Fig. 2 Spatial distribution of CDH during the night (left) and during the day (right)

2.2 Gender-related Vulnerability of Households

To incorporate the gender perspective in this study, the indicators of vulnerability to high temperatures were defined in relation to the concentration of households in which women are the main breadwinners. Households with a single woman over 65 and with a single woman with children were, therefore, used as indicators of vulnerability. The data used in this study was extracted from the municipal statistical database (Ayuntamiento de Madrid 2018), which provides the total number of households according to their composition and by census section. The situation of each one of these vulnerable households was compared with their male counterparts, aiming at detecting differences in their spatial distribution, degree of exposure to high temperatures and any relationship with other relevant indicators. All these indicators were treated using the same statistical analysis tools as done with the exposure indicators, thus generating *hotspots* for the identification of areas with the greatest concentration of vulnerable households.

2.2.1 Households with a Single Women over 65

The concentration of households with a single person over 65, both men and women, is shown in **Figure 3**. While single men over 65 tend to inhabit the north-central part of the city, women are distributed in a ring around the city center, living in the northern, eastern and southern areas of the city. Although *hotspots* of both men and women seem to have a similar dimension, the total number of households concentrated in these areas are different. Single women over 65 represent 10% of the total households of Madrid, while this percentage reduces to 3% in the case of men.

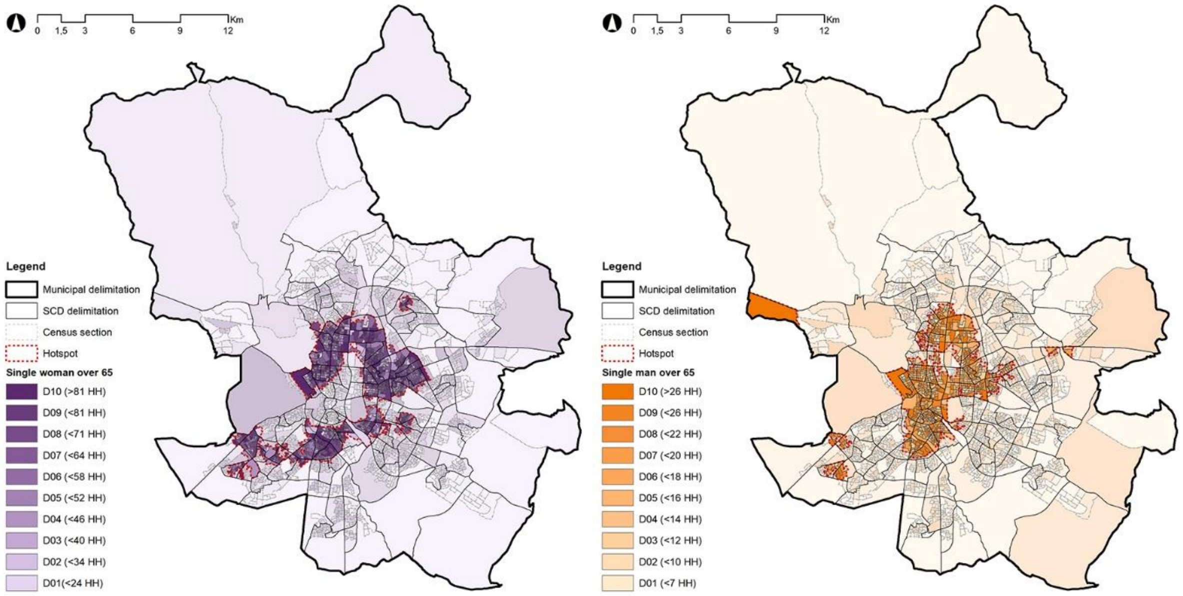

Fig. 3 On the left, the spatial distribution of the vulnerability indicator associated with single women over 65 years old. On the right, the situation of their male counterparts

2.2.2 Households of a Single Woman with Children

Figure 4 shows the concentration of single-parent households led by women and men. Both *hotspots* concentrate on the outskirts of the city. Male single-parent households are mostly found in the northern part of the city, while female single-parent households are distributed as well in the eastern and southern parts. In comparison with the total amount of households of the city, single-parent households account for 2.5% and, again, women comprise most of them (83% of single-parent households).

3 Results

Table 2 summarizes the result of overlapping the indicators associated with a greater exposure to high temperatures with the indicators of greater vulnerability in the city of Madrid. Among single women over 65, 41.1% live in areas where there is at least one overlap with an exposure indicator. In the case of their male counterparts, this percentage drops to 33.9%. This situation is repeated when analyzing the overlaps with two (12.6% vs 7.2%) and three (2.5% vs 0.7%) indicators. Similarly, and even though this is not an indicator of exposure but related with the expenditure capacity, women are more concentrated in the areas of Madrid where the lowest incomes concentrate (7.7% vs 1.0%).

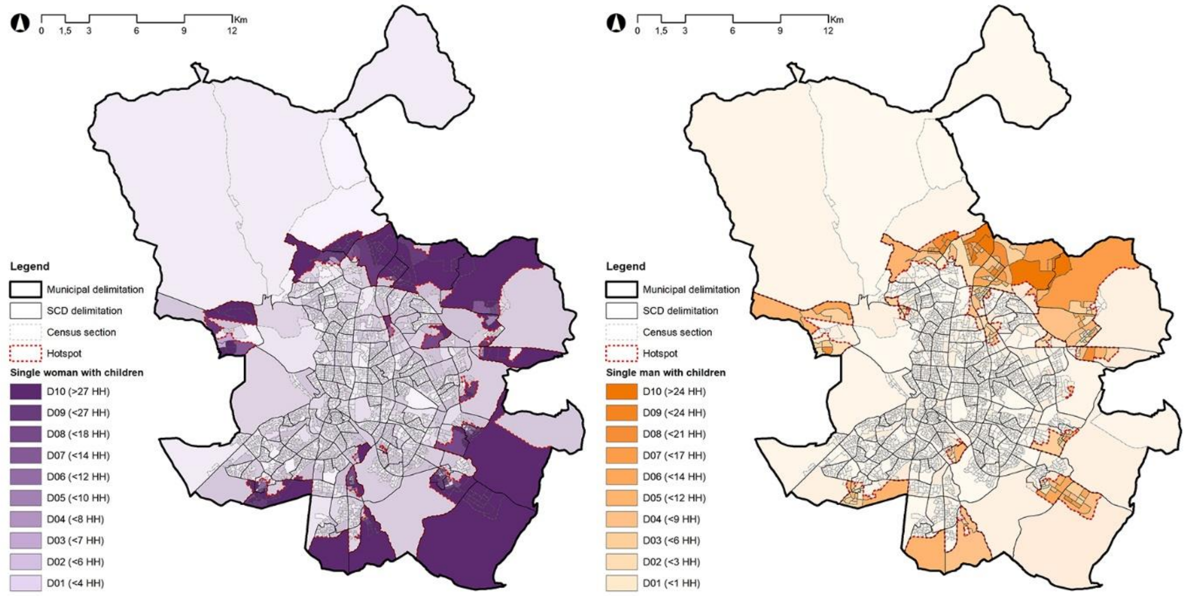

Fig. 4 On the left, the spatial distribution of the vulnerability indicator associated with single-parent households led by women. On the right, the situation of their male counterparts

Table 2 Percentage of households living in areas with a higher risk of suffering from summer energy poverty

	Single women		Single men	
Exposure indicators	over 65	with children	over 65	with children
One overlap	**41.1%**	**4.7%**	**33.9%**	**3.7%**
Daytime CDH	9.8%	3.3%	5.6%	1.1%
Nighttime CDH	21.3%	1.1%	23.4%	0.7%
Buildings performance	25.0%	1.8%	12.8%	2.8%
Two overlaps	**12.6%**	**1.3%**	**7.2%**	**0.7%**
Daytime and nighttime CDH	7.3%	1.1%	5.5%	0.7%
Daytime CDH and buildings performance	4.8%	0.4%	0.7%	0.3%
Nighttime CDH and building performance	5.4%	0.2%	2.4%	0.3%
Three overlaps	**2.5%**	**0.2%**	**0.7%**	**0.3%**
Daytime CDH, nighttime CDH and building performance	2.5%	0.2%	0.7%	0.3%
Low income indicator	**7.7%**	**1.0%**	**3.6%**	**0.0%**

Regarding their exposition to high temperatures, the situation of single women over 65 also differs from men: While both groups tend to suffer from high nighttime temperatures (21.3% vs 23.4%), women are more prone to concentrate in areas with less efficient buildings (25.0% vs 12.8%). **Figure 5** also shows that women tend to occupy more areas to the south, where several exposure indicators overlap and, thus, where the highest risk areas are located. These, which seem to concentrate in the districts of Carabanchel, Usera and, to a lesser extent, Puente de Vallecas, Retiro and Tetuán, are coincident with other vulnerable population areas revealed in previous studies (Sánchez-Guevara Sánchez et al. 2017).

Fig. 5 On the left, the risk of suffering from summer energy poverty for single women over 65. On the right, results obtained for their male counterparts

As for single-parent households, **Figure 6** shows the distribution for both headed by a woman and those headed by a man. Despite the fact that these households tend to be concentrated in the outskirts of the city, where they are less likely to suffer the highest temperatures during summer or to inhabit buildings with the poorest energy performance, the situation of women is still relatively worse than the situation of men. Single women with children concentrate on 4.7% of occasions in areas with a certain degree of exposure and opposed to 3.7% in the case of single men with children. This situation is reproduced when analyzing higher risks, i.e., the overlap of two indicators (1.3% versus 0.7%).

Fig. 6 On the left, the risk of suffering from summer energy poverty for single women with children. On the right, results obtained for their male counterparts

4 Discussion

Despite that single women with children seem to face relatively low risks from summer energy poverty, almost half of them are under *general* energy poverty since most of them are below the monetary poverty line (Sánchez-Guevara et al. 2020; Sanz Fernández et al. 2016). While, in terms of exposure to high temperatures, these households might be relatively better than the rest of the municipality, their vulnerability puts them at a higher risk of suffering energy poverty during heat waves episodes, which are expected to become more frequent in the next decades due to climate change. In this scenario and given the increasing penetration of cooling systems in Spain (Idealista 2019), the use of social tariffs might help to reduce the risk within this group. Cooling centers, which provide air-conditioned spaces during heat waves, have proven to be effective as well (Sanchez and Reames 2019).

Although fostering the use of air conditioning among certain groups might be protective during heatwaves, it might be a maladaptive strategy in the long run. The challenge might be not to increase the cooling energy consumption but to lower indoor temperatures in the most efficient way. In that sense, since the risk of suffering summer energy poverty among single women over 65 seems to be associated with an inefficient housing stock, energy retrofitting of buildings seems to be a reasonable approach to alleviate their situation. When possible, retrofitting should be accompanied by interventions in the public space to help mitigate the UHI. Reducing the outdoor temperature would increase the effectiveness of passive strategies, such as natural ventilation or evaporative cooling, and enhance the attractiveness of ventilators, which are low-energy consumption cooling systems. Additionally, avoiding the use of air conditioners would help to not contributing to the increase in the outdoor temperature (Sampson et al. 2013).

Regarding the limitations of this study, these are mainly related with data availability and disaggregation barriers found both spatially and by gender. In that sense, socioeconomic indicators could not be included to further explore the characteristics of each vulnerable group at the various locations. Despite that these groups were derived from previous studies for the municipality of Madrid in which socioeconomic indicators were used, relevant socioeconomic variations could be expected and should be analyzed in future studies as soon as disaggregated data becomes available. Another source of uncertainty relates to the building's energy performance indicators, which is only based on the year of construction. Further research should incorporate other variables such as the orientation, the relative position within the same building or the glazing area of the thermal envelope of the building, which does certainly have an impact into the cooling loads.

Finally, and beyond the limitations of not including in the present study neither the intra-household differences (Haddad and Kanbur 1992; Ponthieux and Meurs 2015) nor the greater risks associated with a different physiological response to high temperatures (see Sect. 1.2), it should be noted that the combination of all single women over 65 and single-mother households in the city of Madrid accounts for only one third of the total households in which a woman is a breadwinner. Derived from a lack of disaggregation by gender, this situation could hide the vulnerabilities associated with other household compositions. Gender-disaggregated statistical data, together with a greater methodological interconnection between the different databases and greater consistency and frequency of the provided data would, consequently, not only facilitate mainstreaming the gender perspective into energy poverty studies but increase the robustness of the results and ensure that they are monitored over the years.

5 Conclusions

This study is a first exploration of the risks that households led by women might face regarding summer energy poverty. Two household typologies, single women over 65 and single women with children, were analyzed spatially at the sub-municipal scale. A methodology based on the intersection of vulnerability and exposure to high-temperature indicators was used, showing that households led by women, together with a greater vulnerability in comparison to those led by men, also tend to concentrate in areas in which a higher exposure to high temperatures can be expected.

Regarding the different household typologies, single women over 65 seem to accumulate the highest risk of suffering from summer energy poverty. This risk is mostly associated with the energy performance of their buildings during the summer months, but it is also related to high outdoor temperatures due to the UHI effect. Since reducing the outdoor temperature would promote the use of passive strategies, housing interventions should be coordinated with urban adaptation and mitigation strategies to improve microclimatic conditions. On the other hand, single women with children tend to concentrate on the outskirts of the city and live in relatively new housing stock. They seem to face a relatively low risk towards summer energy poverty, although they might encounter relevant risks during heatwaves given their limited economic capacity to cope with unforeseen energy expenditures. In this context, providing financial assistance might be protective for those households with air conditioning systems. For those without any cooling device, setting up cooling centers might be effective as well.

Despite the limitations of not including other related variables, such as socioeconomic indicators, intra-household differences or the different physiological response towards high temperatures, the geospatial analysis based on proxy indicators has proved to be a useful tool to evaluate the relative risk of suffering from summer energy poverty at the sub-municipal scale and integrate a gender perspective. In that sense, policies aiming at mitigating summer energy poverty should consider the intra-urban variability of the phenomenon, prioritizing the most vulnerable areas and mainstreaming a gender perspective. To do so, further gender-disaggregated data should be collected in order to explore the situation of all household typologies.

Acknowledgements

This research was funded by the Municipal Consumption Institute of Madrid City Council and the project FEMENMAD —*Feminización de la pobreza energética en Madrid. Exposición a extremos térmicos*— funded by Madrid City Council under the call *Subvenciones 2018 para la realización de proyectos de investigación en materia de ciudadanía global y cooperación internacional para el desarrollo*. It was also partially funded by an FPU research grant (FPU15/05052) from the Spanish Ministry of Science, Innovation and Universities. The Spanish Meteorological Agency (AEMET) provided weather data, and Madrid Local Council helped with the installation of the urban network.

References

ASHRAE, 2013. ANSI/ASHRAE Standard 55-2013. Thermal Environmental Conditions for Human Occupancy.

Ayuntamiento de Madrid, 2018. Hogares por tamaño, composición del hogar, nacionalidad y sección según distrito. Padrón Munic. Habitantes (explotación estadística).

Clancy, J., Daskalova, V., Feenstra, M., Franceschelli, N., Sanz Blomeyer, M., 2017. Gender perspective on access to energy in the EU. Brussels, Belgium.

Clancy, J., Feenstra, M., 2019. Women, Gender Equality and the Energy Transition in the EU.

Código Técnico de la Edificación, 2019. Documento Básico de Ahorro de Energía. Anejo D. Condiciones operaciones y perfiles de uso.

de Dear, R.J., Brager, G.S., 1998. ASHRAE RP-884: Developing an Adaptive Model of Thermal Comfort and Preference.

Díaz, J., López, I.A., Carmona, R., Mirón, I.J., Luna, M.Y., Linares, C., 2018. Short-term effect of heat waves on hospital admissions in Madrid: Analysis by gender and comparision with previous findings. Environ. Pollut. 243, 1648–1656. https://doi.org/10.1016/j.envpol.2018.09.098

ESRI, 2016a. ArcGIS Spatial Statistics Toolbox for ArcMap.

ESRI, 2016b. How Kriging works. https://desktop.arcgis.com/en/arcmap/10.5/tools/3d-analyst-toolbox/how-kriging-works.htm (accessed 1.22.20).

European Commission, 2020. What is energy poverty? EU Energy Poverty Obs.

European Commission, 2012. Share of population living in a dwelling not comfortably cool during summer time by income quintile and degree of urbanisation. Eurostat.

Gago, E.J., Roldan, J., Pacheco-Torres, R., Ordóñez, J., 2013. The city and urban heat islands: A review of strategies to mitigate adverse effects. Renew. Sustain. Energy Rev. 25, 749–758. https://doi.org/10.1016/j.rser.2013.05.057

Gobierno de España, 1979. Real Decreto 2429/1979, de 6 de julio, por el que se aprueba la norma básica de edificación NBE-CT-79, sobre condiciones térmicas en los edificios.

Gonzalez Pijuan, I., 2017. Desigualdad de género y pobreza energética.

Gouveia, J.P., Palma, P., Simoes, S.G., 2019. Energy poverty vulnerability index: A multidimensional tool to identify hotspots for local action. Energy Reports 5, 187–201. https://doi.org/10.1016/j.egyr.2018.12.004

Haddad, L., Kanbur, R., 1992. Intrahousehold inequality and the theory of targeting. Eur. Econ. Rev. 36, 372–378. https://doi.org/10.1016/0014-2921(92)90093-C

Idealista, 2019. Solo una de cada tres casas en España tiene aire acondicionado.

Instituto Nacional de Estadística, 2004. Censo 2001. Resultados definitivos. Censos Población y Viviendas.

Instituto para la Diversificación y Ahorro de la Energía, 2011. Proyecto Sech-Spahousec. Análisis del consumo energético del sector residencial en España. Informe final. Madrid.

IPCC, 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

López-Bueno, J., Díaz, J., Linares, C., 2019. Differences in the impact of heat waves according to urban and peri-urban factors in Madrid. Int. J. Biometeorol. https://doi.org/10.1007/s00484-019-01670-9

März, S., 2018. Assessing the fuel poverty vulnerability of urban neighbourhoods using a spatial multi-criteria decision analysis for the German city of Oberhausen. Renew. Sustain. Energy Rev. 82, 1701–1711. https://doi.org/10.1016/j.rser.2017.07.006

Mavrogianni, A., Taylor, J., Davies, M., Thoua, C., Kolm-Murray, J., 2015. Urban social housing resilience to excess summer heat. Build. Res. Inf. 43, 316–333. https://doi.org/10.1080/09613218.2015.991515

Ministerio de Hacienda, 2019. Catastro inmobiliario. Dir. Gen. del Catastro.

Ministerio para la Transición Ecológica, 2019. Estrategia nacional contra la pobreza energética 2019-2024.

Moore, R., 2012. Definitions of fuel poverty: Implications for policy. Energy Policy 49, 19–26. https://doi.org/10.1016/j.enpol.2012.01.057

Moore, T., Ridley, I., Strengers, Y., Maller, C., Horne, R., 2017. Dwelling performance and adaptive summer comfort in low-income Australian households. Build. Res. Inf. 45, 443–456. https://doi.org/10.1080/09613218.2016.1139906

Núñez Peiró, M., Sánchez-Guevara Sánchez, C., Neila González, F.J., 2019. Source area definition for local climate zones studies. A systematic review. Build. Environ. 148, 258–285. https://doi.org/10.1016/j.buildenv.2018.10.050

Núñez Peiró, M., Sánchez-Guevara Sánchez, C., Neila González, F.J., 2017. Update of the urban heat Island of Madrid and its influence on the building’s energy simulation, Sustainable Development and Renovation in Architecture, Urbanism and Engineering. https://doi.org/10.1007/978-3-319-51442-0_28

Oke, T.R., Mills, G., Christen, A., Voogt, J.A., 2017. Urban climates. Cambridge University Press. https://doi.org/https://doi.org/10.1017/9781139016476

Oliver, M.A., Webster, R., 1990. Kriging: a method of interpolation for geographical information systems. Geogr. Inf. Syst. 4, 313–332. https://doi.org/10.1080/02693799008941549

Pearsall, H., 2017. Staying cool in the compact city: Vacant land and urban heating in Philadelphia, Pennsylvania. Appl. Geogr. 79, 84–92. https://doi.org/10.1016/j.apgeog.2016.12.010

Pisello, A.L., Rosso, F., Castaldo, V.L., Piselli, C., Fabiani, C., Cotana, F., 2017. The role of building occupants’ education in their resilience to climate-change related events. Energy Build. 154, 217–231. https://doi.org/10.1016/j.enbuild.2017.08.024

Ponthieux, S., Meurs, D., 2015. Gender inequality, 1st ed, Handbook of Income Distribution. Elsevier B.V. https://doi.org/10.1016/B978-0-444-59428-0.00013-8

Robinson, C., 2019. Energy poverty and gender in England: A spatial perspective. Geoforum 104, 222–233. https://doi.org/10.1016/j.geoforum.2019.05.001

Rubio-Bellido, C., Fargallo, A., Pulido Arcas, J., Trebilcock, M., 2017. Application of adaptive comfort behaviors in Chilean social housing standards under the influence of climate change. Build. Simul. 10.

Sampson, N.R., Gronlund, M.A., Buxton, L., Catalano, J.., White-Newsome, J.L., Conlon, M.S., O’Neill, S., McCormick, E.., 2013. Staying cool in a changing climate: Reaching vulnerable populations during heat events. Glob. Environ. Chang. 23, 475–484. https://doi.org/10.1016/j.gloenvcha.2012.12.011

Sánchez-Guevara, C., Núñez Peiró, M., Taylor, J., Mavrogianni, A., Neila González, J., 2019. Assessing population vulnerability towards summer energy poverty: Case studies of Madrid and London. Energy Build. 190, 132–143. https://doi.org/10.1016/j.enbuild.2019.02.024

Sánchez-Guevara, C., Sanz Fernández, A., Núñez-Peiró, M., 2020. Feminisation of energy poverty in the city of Madrid. Energy Build. [Under.

Sánchez-Guevara Sánchez, C., Núñez Peiró, M., Neila González, F.J., 2017. Urban Heat Island and Vulnerable Population. The Case of Madrid, in: Mercader-Moyano, P. (Ed.), Sustainable Development and Renovation in Architecture, Urbanism and Engineering. Springer International Publishing, Seville, pp. 3–13. https://doi.org/10.1007/978-3-319-51442-0_1

Sanchez, L., Reames, T.G., 2019. Cooling Detroit: A socio-spatial analysis of equity in green roofs as an urban heat island mitigation strategy. Urban For. Urban Green. 44, 126331. https://doi.org/10.1016/j.ufug.2019.04.014

Santamouris, M., Kolokotsa, D., 2015. On the impact of urban overheating and extreme climatic conditions on housing, energy, comfort and environmental quality of vulnerable population in Europe. Energy Build. 98, 125–133. https://doi.org/10.1016/j.enbuild.2014.08.050

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, Madrid.

Tebaldi, C., Hayhoe, K., Arblaster, J.M., Meehl, G.A., 2006. Going to the extremes: An intercomparison of model-simulated historical and future changes in extreme events. Clim. Change 79, 185–211. https://doi.org/10.1007/s10584-006-9051-4

Thomson, H., Simcock, N., Bouzarovski, S., Petrova, S., 2019. Energy poverty and indoor cooling: An overlooked issue in Europe. Energy Build. 196, 21–29. https://doi.org/10.1016/j.enbuild.2019.05.014

Tomlinson, C.J., Chapman, L., Thornes, J.E., Baker, C.J., 2011. Including the urban heat island in spatial heat health risk assessment strategies: a case study for Birmingham, UK. Int. J. Health Geogr. 10, 42. https://doi.org/10.1186/1476-072X-10-42

Universidad Politécnica de Madrid, 2019. FEMENMAD Project: Feminisation of energy poverty in the city of Madrid. Exposure to temperature extremes = Feminización de la pobreza energética en Madrid. Exposición a extremos térmicos. Madrid City Counc. http://abio-upm.org/project/proyecto-femenmad/

Universidad Politécnica de Madrid, 2014. MODIFICA Project: Predictive model for dwellings energy performance under the urban heat island effect. Minist. Econ. Compet. BIA2013-41732-R

Wolf, J., Adger, W.N., Lorenzoni, I., 2010. Heat waves and cold spells: An analysis of policy response and perceptions of vulnerable populations in the UK. Environ. Plan. A 42, 2721–2734. https://doi.org/10.1068/a42503