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Behavior Patterns, Energy Consumption and Comfort during COVID-19 Lockdown Related to Home Features, Socioeconomic Factors and Energy Poverty in Madrid

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Abstract: During spring 2020, the world was shocked at the imminent global spread of SARS-CoV-2, resorting to measures such as domestic confinement. This meant the reconfiguration of life in an unusual space; the home. However, not all households experienced it in the same way; many of them were vulnerable. A general increase in energy consumption and discomfort in many cases, led these families to suffer the ravages of confinement. This study analyzes the energy and comfort situation for the Madrid (Spain) population, according to the configuration of the homes, the characteristics of the dwellings, the vulnerability index by district, and energy poverty (measured with the 10% threshold of energy expenditure of home incomes). The results show a greater exposure, in confinement, of vulnerable and energy-poor households to scenarios of discomfort in the home, to which they could not respond, while energy consumption inevitably increased. Driven by need, energy-poor homes applied certain saving strategies, mainly resorting to thermal adaptation with clothing. This study shows the risk these households experienced in the face of an extreme situation, and invites reflection on preventive and containment measures that aim to avoid harming the disadvantaged in the future; harm that would also entail serious consequences on the health of their cohabitants.

Keywords: COVID-19; energy poverty; housing; lockdown; energy consumption; domestic hot water (DHW); HVAC; appliances; household behavior; vulnerability

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Highlights

- Almost a third of the participating households usually dedicate more than 10% of their income to energy expenses (and they can be considered energy-poor).
- General energy consumption increased without having a significant relationship with the situation of vulnerability, or with energy poverty.
- Of the participating households, 43.6% increased their consumption of hot water during confinement, while the use of heating was strictly necessary for half of the sample. None of the uses of these services indicated a significant relationship with energy poverty.
- Half of the sample did not apply energy saving measures in confinement, compared to a quarter who applied three or more measures, statistically related to energy poverty.
- Thermal discomfort, applying thermal adaptation measures on a daily basis, and having thermal preferences for heat in the home were related to being energy-poor.

1. Introduction

The public health measures established at the global level have been based, to a greater or lesser extent, on confinements to isolate the population and protect it against SARS-CoV-2. This situation has led to a concentration of household tasks, both daily and extraordinary, with housing becoming the nerve center of human activity for most households around the world [1]. This has brought with it numerous consequences on a social and economic, but also environmental, level. Cities avoided the pressure to which they are usually subjected, due to displacement, traffic, pollution and noise, moving to homes, and therefore, that pressure was borne mainly by the homes themselves [2].

Households usually have very different consumption profiles, depending on their composition and occupational habits [3–5]. In this sense, the greatest pressures are often borne by one-person households [6] and those headed by women [7,8]. Taking into account the unequal situation of these households in terms of economic income [9], quality of housing [10], and access to energy services [11], resources, and the internet, as well as other factors [12,13], they have had very different experiences depending on their possibilities [14].

According to the Energy Poverty Observatory from the European Commission, energy poverty consists of the inadequate levels of essential energy services that would allow warmth and cooling, lighting, and the energy to power appliances regarded as essential services needed for living. The lack of these adequate services results in adverse health and wellbeing consequences [15]. However, this definition differs from others that include certain nuances or gaps that should be noted, such as how to measure energy poverty [16], if it is universal [17] or if it should be applicable differently in developed countries [18] compared to countries under development [19,20], or what is meant by meeting basic human needs, and what are the possibilities of access to energy, including the real capacities for choosing the energy source, based on different criteria [21].

In less developed countries, the lack of choice of these energy sources, and the general scarcity of energy resources [22], leads to the environmental pollution of homes, due to the high exposure to volatile particles and other suspended compounds that favor the proliferation of diseases in their population, or the worsening of existing ones [23] and a challenge for investors and political decision-makers in these regions [17,24]. The influence of climate on the possible response of households in order to maintain comfort conditions is decisive in this regard [25].

One of the most common methods to measure energy poverty in the context of developed countries, and even more so in the European context, is the ten percent rule index (TPRI), by which the energy-poor would be defined as those who use more than this percentage of their total household income to pay energy bills. This method is widely used for its simplicity, and its origin dates back to the United Kingdom, where it was first defined by Brenda Broadman [26]. Other measurement methods are somewhat more complex, trying to accommodate the expenditure associated with these energy services, as well as the level of income, so that they are more easily comparable between countries, such as the Minimum Income Standard (MIS), proposed by Moore, 2012 [27], based on the minimum income necessary to cover energy costs once the rest of the expenses have been satisfied, and finally the Low Income High Cost (LIHC) indicator [28], which focuses specifically on households with a low level of income, and therefore on households with the lowest income distribution. Other methods are based on multidimensional indexes that try to address the complexity of the circumstances that lead to the home becoming potentially energy-poor, even taking into account other variables that have to do with the condition and quality of their homes, in addition to other socioeconomic issues [29–32].

The confinement due to the COVID-19 pandemic has forced the continued presence in homes, which has intensified the activity inside, so the energy demand has increased; the entire household within the home, with greater demands for eating, hygiene and cleanliness, for leisure, sports and free time, for sleeping, and for working and studying remotely [14] in homes, where possible. This in turn has led to a worsening of indoor environmental quality, and associated health risks [23], as well as a greater demand for indoor comfort, due to the increased presence in the house compared to what is usual. When the consequences of COVID-19 are still quantified in terms of environmental impacts and its effects on the transmission of the disease [33], as well as the influence on the achievement of the Sustainable Development Goals (SDG) set in the 2030 Agenda according to the UN, the lessons learned offer an uneven response on the epidemiological treatment of the pandemic and on the transversal policies aiming to support families and to minimize the different impacts that it caused [34,35].

In Spain, the existence of a residential stock mainly prior to the technical standards in matters of insulation, comfort and indoor air quality [36], has not made it easier for Spanish households to meet energy demands, especially linked to the achievement of comfort during confinement for COVID-19. Although strategies have been approved at both European [37] and Spanish [36] levels, the implementation of the energy and comprehensive rehabilitation of residential buildings is still one of the most important challenges for this country, and it is too late for what it has meant this extreme phenomenon of housing occupation.

Next, a study is presented on how the closure by COVID-19 has affected the city of Madrid, with multivariate analysis on energy consumption, broken down by service and equipment, perceived comfort, and the proportion of income allocated to pay energy bills, both before and during the confinement (which will be established in energy poverty thresholds following the TPRI index), according to the municipal vulnerability index.

2. Literature Analysis

Following the literature review on households, energy and COVID-19, the research results show very different areas of interest. On the one hand, the view from the energy sector and industry has been widely analyzed, highlighting the decrease in energy demand in global terms, despite the increase in the residential sector [38–40]. This would affect certain economies [41] of specific populations [42].

On the other hand, to mitigate the socioeconomic ravages of the pandemic, many studies have focused on the policies and strategies undertaken or necessary at the government level to alleviate the worsening vulnerability of the poorest [43–45]. This poverty may, in turn, stem from structural socioeconomic inequalities [46]. The vulnerability of households also causes a greater exposure to the disease linked to deprivation, due to the lack of access to minimum habitability and energy for life and comfort [47–49], and other possible risks derived from physical and psychological conditions due to the uncertainty that the situation itself has generated [50,51].

Some of the most recurrent aids have been based on, or have suggested, either direct monetary transfers to the most disadvantaged groups [52,53], or support to promote or continue the transition and access to cleaner energy at the household level [23]. Despite the political, cultural and ideological rejection of certain societies [54], aggravated by financial difficulties, the fall in household income and the increase in the prices of energy carriers, it has reversed decreasing trends in energy poverty in countries such as Poland [55]. Other countries, such as the United States, have seen their already very high energy bills worsen [56], and they are more pronounced for black or Hispanic families, those with young children, chronic diseases, or living in inefficient houses [57].

Other authors have focused their analysis based on secondary data, originating from official sources, to assess through models and predictive calculations, according to different lifestyles, possible consequences in the population, including per capita energy consumption, and energy structure and intensity [58]. However, among the economic recovery plans to respond to COVID-19, especially in developed countries, energy efficiency has not been specifically considered [59].

With the focus on the residential sector, this has been approached unevenly, with different scales of approximation (national, regional, urban), and different levels of detail (global population energy demand, demand at the home or community level, or consumption of various domestic energy systems).

Studies at the urban level establish that they address, with different levels of detail, the impact of energy consumption associated with households during this pandemic period. Some of them are close to global energy consumption, including transport, for example, which means that the level of detailed approximation in each of these energy areas is much lower [60], so that energy expenditure in housing it is offered globally.

Other studies delve into smaller scales, such as communities, with reduced samples, and they expose specific or highly focused problems, such as the energy needed to cook [61] or comparative perspectives of use, focused on various thermal services or specific facilities, such as domestic air conditioning [62].

Paradoxically, southern European countries, such as Spain, suffer severe indices of energy poverty, precisely because of the trap of mild winters. These, despite not being too harsh, lead to less investment in efficient heating systems, which creates a situation of even greater energy vulnerability [63].

In Spain, there are also studies at the sectoral energy demand level, including fluctuations for the non-residential and domestic sectors [64]. The unemployment benefits generated by the pandemic, and other subsidies, have served to reduce the pressure of energy expenditure suffered by families, who are confined and subjected to lower income and higher consumption by staying at home [65].

On the other hand, there are reports from different non-profit organizations that have evaluated the impact of COVID-19 on energy poverty, highlighting the global situation and the protection of policies and aid in a more qualitative way [66]. Financial and private entities have also reported insofar as they have had data on the consumers themselves [67].

Finally, other reports address the impact of COVID-19 on Spanish households, either at the regional or municipal level, by consumer sector, without giving details of the alterations in habits and therefore in the use of different energy services available at home, derived from the confinement itself [68].

As indicated by Fell et al. (2020), social research on energy issues during and after the COVID-19 pandemic should contain very varied aspects, to try to balance the research and the results offered, creating a panorama that covers the situation experienced as real as possible by the various homes. Among these considerations, the economic situation, behavior or changes in routines and the use of energy in the home should be evaluated, and in relation to that, intensity or change of uses, and changes in housing related to the pandemic or its context, among others [69].

Therefore, a general lack of studies is detected that globally analyze the behavior of households in the dwelling, linking the modification of habits and routines with compared energy consumption, separated by energy service, and perceived comfort, in order to be able to compose a joint picture of the energy response of the home to home needs. Understanding what happens in a globally unprecedented situation such as this requires a comprehensive disclosure of what happens in homes and how it translates into energy consumption patterns, compared to what could be regular pre-pandemic use. The research questions posed are: (Q1) what energy behaviors, in comparative terms with their pre-COVID-19 habits, have Madrid households followed? and (Q2) Have these behaviors been conditioned by a possible situation of vulnerability or energy poverty?

The aim of the study, therefore, is to know how the behavior and needs of confined households in the municipality of Madrid have led them to follow certain patterns of energy consumption, and to verify whether these patterns are related to indicators of vulnerability and energy poverty, understanding the latter according to the rule of ten percent of total household income.

Although this study was originally part of a project at the national level [1], approximations at the city level allowed for the establishment of another, different analysis by cross-referencing this information with variables from secondary data at the neighbourhood or district scale, compensating for the initial lack of home-income information. This would allow differences and nuances of the sample to be observed, therefore enriching the information obtained.

The main contribution of this article resides in offering direct information from the homes themselves, so that the real ways of inhabiting the home during confinement by COVID-19 are known and linked, with different patterns on the use of energy, as well as knowing if the need for comfort was satisfied during this period. Differentiating these behaviors according to indicators of the economic component for households would make it possible to verify whether, during this specific period, or in other extreme situations, families, and more specifically the most vulnerable, should be assisted with aid by governments and administrations in a more efficient way, and what may be the most appropriate strategies for establishing not only relief policies, but also preventive and contingency plans, in the face of similar future scenarios.

3. Materials and Methods

The study presented here is a result of the [COVID-HAB] project on COVID-19 confinement, housing and habitability. By means of a mixed and exploratory approach, the aim was to learn about the reality of Spanish households during lockdown and the conditions of their homes, and to assess the shortcomings and preferences detected in the face of such a singular and extreme situation, which in turn required a radical change in the use of spaces and domestic equipment. The study used two online questionnaires, one quantitative and the other qualitative, with questions on different aspects of household behaviour, changes in habits, quality of housing, and use of spaces and equipment in the houses, as well as their level of satisfaction in view of the new needs generated. Among all the questions in the quantitative questionnaire, the ones that stood out were those focused on the perception of comfort in the home, both environmental and thermal (based in turn on the comfort rankings described in the ASHRAE standard 55), as well as on the use of thermal systems (domestic hot water, heating, and cooling) and equipment, such as household appliances and electronic devices. To complete the information, sociodemographic data were collected from the participating sample. In this study, the data relating to the city of Madrid are presented.

3.1. Study Area

In order to work with certain variables, such as the municipal vulnerability index, the municipality of Madrid was chosen. This city is the most populated in Spain, with 3,334,730 inhabitants [70], distributed among 1,307,682 main dwellings, so the average household size is 2.55 people [71].

With a total surface area for the municipality of 60,445.52 Ha, the density of occupation in Madrid is about 55 inhab/Ha. The city is divided into neighbourhoods, which are in turn organised into municipal districts.

3.2. Data Collection and Recruitment

To find out users' perceptions of the comfort of their homes and usage patterns in relation to thermal services (domestic hot water and heating/cooling air conditioning systems), as well as energy-dependent electronic equipment and devices, in the context of lockdown, data obtained through the [COVID-HAB] project for the municipality of Madrid were used. The data came from the quantitative questionnaire that participants filled in anonymously between 30 April and 22 June 2020, coinciding with the social confinement decreed by the pandemic of COVID-19.

A non-probabilistic sampling was used. The strategy that was followed to disseminate the questionnaire and thus capture the responses of Spanish households was multi-channel: institutional websites, social networks, and email. To reach more people, web scraping techniques were used to access the contacts of neighbourhood and thematic groups (neighbourhood associations and federations, cultural associations and city councils) throughout Spain. For the municipality of Madrid, access was gained to the contacts of more than 200 groups and entities, which served as facilitators to spread the questionnaire among their communities, by email.

The online digital data collection tool SurveyMonkey® was used for this information collection, and a database was created with the variables collected using an online questionnaire.

Among the 58 questions in the online questionnaire, those regarding perceived comfort in the home were chosen, as well as habits and consumption related to thermal and air conditioning systems, household appliances and electronic devices, and the socio-demographic data of the participants.

3.3. Variables Chosen for the Study

There are five categories that encompass the variables used for the analysis in this study (see Table 1). These variables were obtained as results of the [COVID-HAB] project, except for those concerning the territorial vulnerability index of neighbourhoods and districts in the Madrid municipality. The vulnerability data are from the Madrid City Council, together with the Carlos III University [72].

Table 1. List of variables by categories of the study.

Category	Variables
Sociodemographic	Age, gender, employment status, education level and country of birth.
Characteristics of the household and cohabitants	Occupancy regime, vulnerability index quartile, useful surface area, number of cohabitants, useful surface area per cohabitant, cohabitation with children under 18 years of age and cohabitation with persons over 65 years of age.
Energy expenditure before and during lockdown (energy poverty)	Usual energy expenditure and estimated energy expenditure in confinement (ten per cent threshold).
Energy consumption and savings during lockdown	Comparative use of appliances and devices, comparative use of domestic hot water, use of heating, and savings measures.
Thermal comfort	Perceived thermal sensation, usual clothing, priority adaptation measure if there is thermal dissatisfaction, priority adaptation frequency, thermal preference.

Firstly, the socio-demographic variables are used to characterise the population distribution according to gender, age, employment status, educational level and country of birth.

Regarding the characteristics of the household nucleus and cohabitants, the variables selected were: occupancy regime; quartile corresponding to the municipal vulnerability index; usable surface area; number of cohabitants; usable surface area per cohabitant; cohabitation with children under 18 years of age; and cohabitation with people over 65 years of age.

The energy poverty variable was constructed with a question referring to the percentage of household income spent on energy bills, also referred to as energy expenditure (less than 5%, 5–10%, 10–15% and more than 15%). Therefore, energy poverty was defined as spending more than 10% of total household income to pay for energy consumption, in line with the TPRI indicator [26], which is widely used in the literature, although with certain limitations due to the very conception of the term [73]. This question was asked for before and during lockdown. However, many people did not have such invoices at the time of completing the questionnaire. In this case, an alternative question was asked about how participants expected their energy bills to change during lockdown, with Likert-type responses (not at all/a little/somewhat/quite a lot/a lot/totally).

The next category of variables was called energy consumption and savings during lockdown. This category in turn included: the use of household and electrical appliances; the use of domestic hot water and air conditioning (referring to heating, in this case, for Madrid); and the energy-saving measures adopted by households during this period. They were asked about 10 types of household appliances, whether they were used more, the same or less than usual during the period of confinement. The hot water and heating systems available and the source of energy used were reflected. For heating, the frequency of use during confinement was asked with a Likert-type response (never/almost never/strictly necessary/quite a lot/continuously). Ten energy-saving measures were also referred to, in order to indicate which ones were applied during lockdown. These were: turning off unused lights; changing to LED light bulbs; eliminating baths, and shortening shower times; adjusting/switching off heating; organising schedules; making full use of dishwashers/washing machines; unplugging unnecessary equipment; using energy at economical times; changing energy tariffs; and increasing the use of renewable energy.

Finally, in the category of thermal comfort, the variables relating to the perception of comfort/discomfort are grouped together: the perceived thermal sensation; the level of usual clothing; the priority adaptation measure if there is thermal dissatisfaction; the frequency with which priority adaptation is used; and the thermal preference in the home. These questions were developed taking into account, respectively, the definitions provided in ISO 7730 [74] and occupancy survey techniques to find out the different aspects of thermal comfort, thermal satisfaction, and adaptation (acclimatisation) of the participants, according to ASHRAE standard 55 [75].

Table 1 shows all the variables analysed in this study, grouped by category.

As for the variable corresponding to the municipal vulnerability index, given by quartiles, this was obtained from the website of Madrid City Council, who processed them in collaboration with the Carlos III University, applying a methodology available in [72]. This multidimensional variable of the vulnerability index is defined by the authors as "the potential for the population of a specific urban space to be affected by some adverse circumstance", based on certain conditions of risk, fragility, and disadvantage, which, in a critical situation, could lead to exclusion, and even consolidate it. This variable was adapted, following two guidelines. The first adaptation is due to the fact that the data are initially offered by district or neighbourhood, whereas the data in this survey are georeferenced by postcode, so the conversion to postcode was made, choosing the data source by district (there are 21) (55). This conversion was carried out graphically through the free software QGIS, version 3.16, applying geographic information of territorial delimitation by districts and postcodes from the NOMECALLES portal (Institute of Statistics of the Community of Madrid, n.d.) [76]. Although this adjustment is implemented, this article will refer to this variable in its original name, as "vulnerability index by district". As a second adaptation, we provide the resulting variable by postcodes divided into quartiles, to facilitate the interpretation of the data, especially when cross-referenced with other variables.

3.4. Data Analysis

On the basis of the variables presented in Section 3.3, a descriptive analysis was executed, stratified by gender of the sociodemographic variables of the sample and by quartile of the vulnerability index by district of the characteristics of the dwelling and household. This was followed by a descriptive analysis of the energy expenditure and poverty variables, and a bivariate analysis of the relationship of the latter with the sociodemographic variables and dwelling and household characteristics using the chi-square test. The same procedure was carried out for the energy expenditure and savings and thermal comfort variables, looking at their relationship with the energy poverty variable before lockdown using the chi-square test. All contrast analyses were performed for a 95% confidence level. Figure 1 shows the distribution of participation by district and postcode, with vulnerability quartiles highlighted in colour.

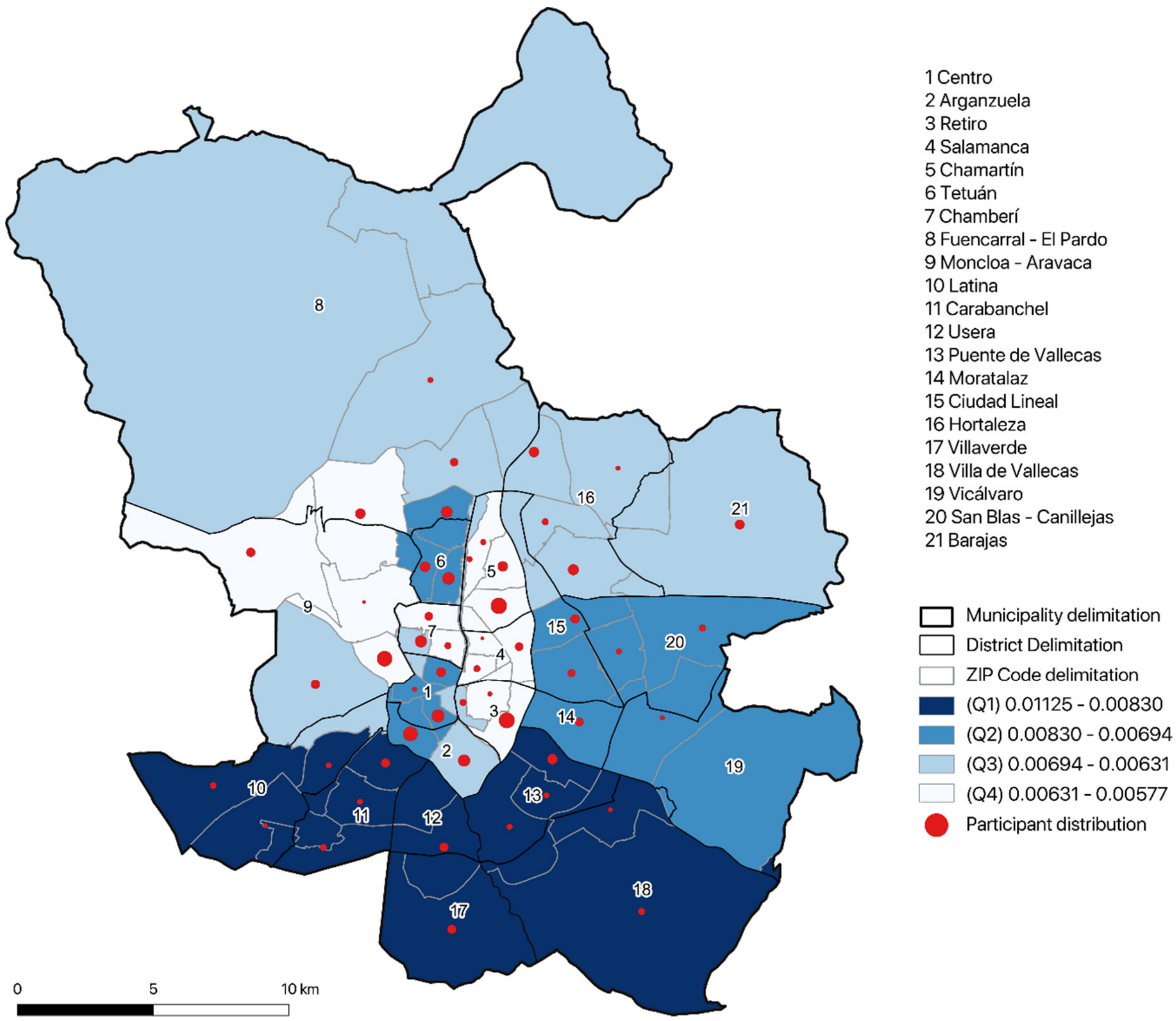

Figure 1. Total participants' distribution in the study for Madrid, according to the quartiles of the vulnerability index by district.

4. Results

4.1. Characteristics of the Participants in Madrid

The population participating in the survey for the municipality of Madrid was 367 people, as sole representatives of their households, in order to find the correspondence 1answer–1household. Of the participants, 68.9% were women. Table 2 shows the sociodemographic characteristics of the respondents stratified by gender.

The majority of the population is between 35 and 54 years of age (56.9%) and has a higher education level (86.1%). Regarding employment status, 45.3% work for the administration, 39.9% are employed and 14.7% are self-employed or entrepreneurs. This distribution differs statistically significantly by gender, with a higher percentage of female civil servants (50.3% vs. 33.7%) and a lower percentage of females who are self-employed/entrepreneurs (8.2% vs. 23.5%). The majority (95.7%) of the sample are of Spanish origin and more than half of them live in the least vulnerable districts (53.7%).

Table 2. Sociodemographic characterization of the respondents by gender.

Variable	Total *n* (% Column)	Male *n* (% Column)	Female *n* (% Column)	*p* *
General	367 (100)	114 (31.1)	252 (68.9)	
Age				
18–34	69 (19)	22(19.6)	47 (18.7)	0.857
35–54	207 (56.9)	65 (58.0)	142 (56.3)	
≥55	88 (24.2)	25 (22.3)	63 (25)	
Education level				
Up to High School/Vocat. Training	51 (14.0)	20 (17.5)	31 (12.4)	0.068
University	163 (44.7)	41 (36)	122 (48.6)	
Posgraduate	151 (41.4)	53 (46.5)	98 (39)	
Employment status				
Civil servant	126 (45.3)	28 (33.7)	86 (50.3)	0.001
Employee	111 (39.9)	33 (39.8)	71 (41.5)	
Self-employed/Entrepreneur	41 (14.7)	22 (23.5)	14 (8.2)	
Place of birth				
Spanish	346 (95.7)	108 (84.7)	238 (94.4)	0.909
Foreign	20 (4.3)	6 (5.3)	14 (5.6)	
Vulnerability index				
Quartile 1 (higher vulnerability)	58 (16.4)	16 (14.3)	42 (17.4)	0.745
Quartile 2	106 (29.9)	35 (31.3)	71 (29.3)	
Quartile 3	85 (24.0)	32 (28.6)	53 (21.9)	
Quartile 4 (lower vulnerability)	105 (29.7)	29 (25.9)	76 (31.4)	

* p value for the chi-square test of the relationship of the variable with gender. A $p < 0.05$ implies a significant relationship.

4.2. Characteristics of Participating Households' Dwellings

The characteristics of the participating households' dwellings are shown in Table 3, stratified by vulnerability index quartile by postcode of residence. The average floor area of the dwellings was 86.9 m^2 (SD: 37.75; Range: 25–300) with an average of 2.53 inhabitants (SD: 1.26; Range: 1–7), and an average of 42.2 m^2 per inhabitant (SD: 25.38; Range: 10.7–200).

In 25.5% of households there was only one person living, in 29.7% there were two people living and in 44.8% there were more than two people living. These distributions differed in a statistically significant way according to the vulnerability quartile: households in quartile 2 were more inclined to have one or two people living in them, and those in quartile 4 were more likely to have more than two people living in them than in the rest of the households. In 32.7% of households, there were children under 18 years of age living and in 16.4% of households there were people over 65 years of age. The usable surface area of the dwelling was also related to the vulnerability index quartile: there were significantly fewer dwellings over 100 m^2 and over 61–80 m^2 in the first quartile, and more dwellings up to 60 m^2 in the second and third quartile. Of the dwellings, 68.2% were owned, and 31.8% were rented. Again, these percentages varied significantly according to the vulnerability index, with ownership being associated with dwellings in the first quartile (higher vulnerability) and renting with dwellings in the fourth quartile (lower vulnerability).

4.3. Comparative Energy Expenditure (Energy Poverty)

Of the 326 households that provided information on the percentage of expenditure they spent on energy before lockdown, 83 (25.5%) spent less than 5%, 110 (33.7%) spent between 5% and 10%, 59 (16.1%) spent between 10% and 15%, 28 (8.6%) spent more than 15%, while 46 (14%) did not know. Excluding the latter, one third of the households that answered the question specifically (31.1%) spent more than 10% of their income on energy and were therefore classified as energy-poor according to Broadman's method.

Table 3. Characteristics of the participating households' dwellings by vulnerability index quartile.

Variable	Total N (% Col)	First Quartile N (% Col)	Second Quartile N (% Col)	Third Quartile N (% Col)	Fourth Quartile N (% Col)	*p* *
General	355 (100)	58 (16.3)	106 (29.9)	85 (23.9)	106 (29.9)	
People in the household						
One	84 (25.5)	13 (25)	31 (31)	19 (23.8)	21 (21.4)	0.052
Two	98 (29.7)	14 (26.9)	38 (38)	23 (28.8)	23 (23.5)	
More than two	148 (44.8)	25 (48.1)	31 (31)	38 (47.5)	54 (51.1)	
Cohabiting with children under 18						
No	222 (67.3)	30 (57.7)	77 (77)	56 (70)	59 (60.2)	0.03
Yes	108 (32.7)	22 (42.3)	23 (23)	24 (30)	39 (39.8)	
Cohabiting with people over 65						
No	276 (83.6)	44 (84.6)	80 (80)	73 (91.3)	79 (80.6)	0.168
Yes	54 (16.4)	8 (15.4)	20 (20)	7 (8.8)	19 (19.4)	
Usable surface area						
Up to 60 m^2	85 (25.8)	10 (18.9)	33 (33)	24 (30.4)	18 (18.4)	0.001
61–80 m^2	83 (25.2)	24 (45.3)	21 (21)	13 (16.5)	25 (25.5)	
81–100 m^2	100 (30.3)	15 (28.3)	28 (28)	30 (38)	27 (27.6)	
$\geq$100 m^2	62 (18.8)	4 (7.5)	18 (18)	12 (15.2)	28 (28.6)	
Usable surface area per person						
$\leq$24 m^2/person	83 (25.2)	19 (36.5)	19 (19)	21 (26.6)	24 (24.5)	0.523
>24–$\leq$35 m^2/person	91 (27.7)	11 (21.2)	28 (28)	23 (29.1)	29 (29.6)	
>35–$\leq$50 m^2/person	74 (22.5)	9 (17.3)	27 (27)	19 (24.1)	19 (19.4)	
$\geq$51 m^2/person	81 (24.6)	13 (25)	26 (26)	16 (20.3)	26 (26.5)	
Occupancy regime						
Own	217 (68.2)	39 (81.3)	67 (69.1)	51 (68)	60 (61.2)	0.111
Rented	101 (31.8)	9 (18.7)	30 (30.9)	24 (32)	38 (38.8)	

* *p*-value for the chi-square test of the relationship with the vulnerability index expressed in quartiles. A $p < 0.05$ implies a significant relationship.

At the time of answering the questionnaire during lockdown, 61.2% of the sample already had energy bills, so they were able to provide information on the percentage of household expenditure they made in this context. Of these, 32.6% spent more than 10% and were therefore classified as energy poor. Of the 126 people who had not yet received bills for the period of confinement and who answered the question about the expected impact of a possible increase in their energy bills during lockdown, 57.1% answered that it would have a significant impact. This percentage was higher among people in energy poverty (62.2% vs. 51.5%), although not statistically significant (*p*: 0.297).

Suffering from energy poverty before lockdown was statistically significantly related to the vulnerability index: the most vulnerable districts suffered almost twice as much as the least vulnerable (51.1% vs. 26.5%). It was also almost statistically significantly related (*p*: 0.052) to living with people over 65 years of age; 43.9% of people who did so suffered of energy poverty, compared to 28.7% of those who did not. The level of education had a non-statistically significant correlation (*p*: 0.114); 25.2% of people with postgraduate studies suffered from energy poverty, 33.9% of those with university studies and 42.4% with studies below the university level. Energy poverty indicator was found as statistically significative, with the unemployed representatives of the households (6.5%), whilst other unemployment situations linked to the pandemic did not show such a relationship with energy poverty.

Nor statistical association was found between the rest of the sociodemographic and housing characteristics and energy poverty.

4.4. Energy Consumption and Saving Strategies during Lockdown

During lockdown, the use of household appliances in the home, and therefore energy consumption, increased (Figure 2). The only one of these increases in consumption that was statistically significantly (p: 0.016) related to energy poverty was that of the use of computers; it increased by 75.3% in households in energy poverty and 86.5% in those without. Some of these increases in use were related to sample characteristics such as gender (women increased their use of oven, hoover, dishwasher and freezer more than men); employment status (female employees and civil servants increased their use of computers and mobile devices more than self-employed/entrepreneurs); and age (those aged 35–54 increased their use of oven, hoover and freezer more and those aged 55 and over increased their use of computers to a lesser extent). A statistically significant relationship was also found with some household characteristics such as the number of people living together (dishwasher and food processor use increased more in households with more than two people living together). Living with people over 65 years of age was related to a lower increase in the use of oven, food processor, vacuum cleaner, washing machine and dishwasher, while living with people under 18 years of age was related to a higher increase in the use of these appliances such as tumble dryer and freezer.

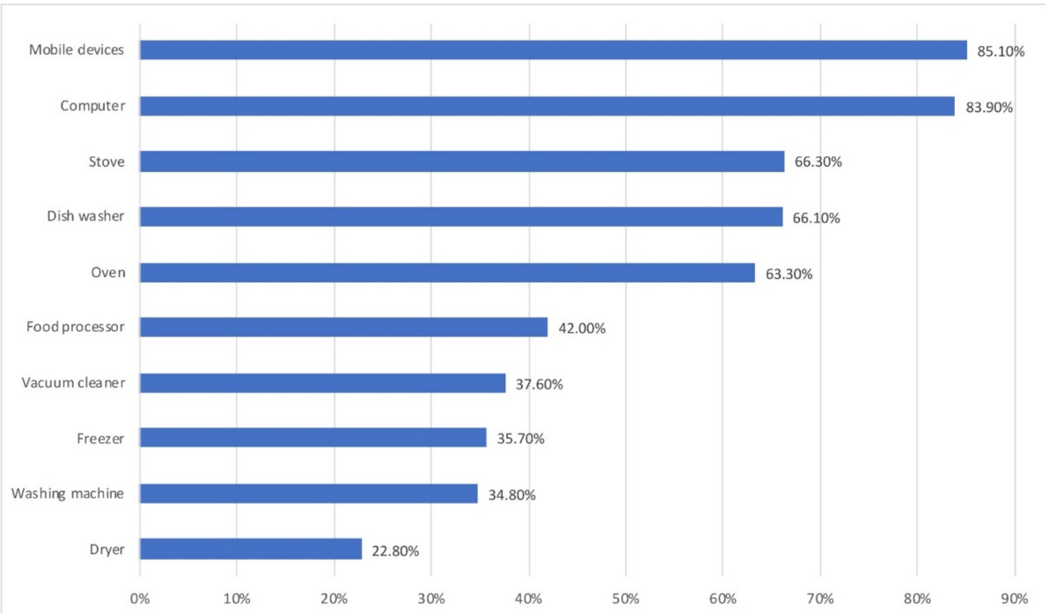

Figure 2. Increase of appliances and electronic devices during the lockdown.

In terms of generation sources, 80.2% of the sample use natural gas for water heating, 16% electricity and 3.8% diesel. Using gas is statistically significantly associated with the most vulnerable households (98%), and with households where children under 18 live (86.7% vs. 76.7% in those where they do not). Dwellings with less than 60 m^2 are statistically significantly associated with using more electricity to heat water (33.8%). 52.1% of the sample did not change their hot water consumption habits during lockdown, although 43.6% increased it and 4.2% decreased it. Increasing it was statistically significantly related to being 35–54 years old (49.7% vs. 38.2% among those under 35, and 33.7% among those over 54); living with children (52.8% vs. 39.5% among those who did not live with children); and living in houses with less m^2 per household (57% in houses with less than 24 m^2 per household vs. 35.9% in houses with more than 50 m^2). On the other hand, living with people over 65 years of age was associated with a lower increase in hot water consumption (29.1% vs. 46.9% of people who did not live with older people). Increased expenditure on hot water during lockdown was not related to energy poverty.

Regarding heating, 65.8% had an individualised system (devices per room or dwelling), 31.5% had centralised-collective systems (shared in the building/district) and 2.7% claimed not to have it. Among those with individualised systems, 80.8% were powered by natural gas, and the rest by other sources. Among those with centralised systems, 65.5% ran on gas, 27.6% on diesel and the rest on other energy sources. During lockdown, 49.7% of the sample turned on the heating only as often as necessary, 21.4% never or hardly ever, and 28.9% quite often or continuously. Using it more frequently (quite a lot or continuously) was statistically significantly related to being female (34.4% vs. 16.7% in men); to being over 54 years old (34.6% vs. 16.3% in those under 35); and was close to statistical significance (*p*: 0.055) to living with people over 65 (33.3% vs. 27.9% in those not living with older people). The frequency of heating use was not statistically significantly associated with energy poverty.

Of the 10 energy saving measures in confinement that were asked about, 46.9% had not carried out any of them. The mean number of measures implemented was 1.4 (SD: 1.68; Range 0–7). A percentage of 26.2% had implemented three or more savings measures, and this percentage differed between those classified as energy-poor (40.2%) and those who were not (25.4%). The most frequently applied energy saving measures were: turning off unused lights (34.9%), adjusting/turning off heating (23.4%), making full use of the washing machine/dishwasher (29.7%) or unplugging unnecessary equipment (21.5%).

4.5. Thermal Comfort during Lockdown

The results of the questions related to thermal comfort are shown in Table 4, stratified by the energy poverty indicator (set at 10% or more of household income usually spent on energy bills).

Table 4. Relationship between aspects of thermal comfort during lockdown and energy poverty.

Variable	Total N (% Column)	No Energy Poverty (<10% Household Expenditure) N (% Col)	Energy Poverty (≥10% Household Expenditure) N (% Col)	*p* *
General	280 (100)	193 (68.9)	87 (31.1)	
Usual clothing				
Light/Very light	72 (25.8)	51 (26.6)	21 (24.1)	0.637
Normal	164 (58.8)	114 (59.4)	50 (57.5)	
Warm/Very warm	43 (15.4)	27 (14.1)	16 (18.4)	
Adaptation measures to thermal discomfort				
Changing clothes	163 (59.1)	111 (58.4)	52 (60.5)	0.819
Opening/closing windows	79 (28.6)	54 (28.4)	25 (29.1)	
Turning heating on/off	34 (12.3)	25 (13.2)	9 (10.1)	
Frequency of application of adaptation measures				
Daily	105 (38)	64 (33.9)	41 (47.1)	0.035
Weekly/occasionally	171 (62)	125 (66.1)	46 (52.9)	
Thermal sensation in the household				
Cold	72 (26.1)	42 (22.1)	30 (34.9)	0.025
Neutral/warm	204 (73.9)	148 (77.9)	56 (65.1)	
Thermal preferences in the household				
Warmer	87 (31.5)	52 (27.4)	35 (40.7)	0.027
No change/colder	189 (68.5)	138 (72.6)	51 (59.3)	

* *p* value for the chi-square test of the variable's relationship with energy poverty. A $p < 0.05$ implies a statistically significant relationship.

When the temperature in their home was not to their liking (perceived thermal dissatisfaction, in the language of ASHRAE Standard 55, [75]), 59.1% resorted to changing clothes as a priority adaptation measure, while 28.6% closed or opened windows, and 12.3% turned the heating on or off. The frequency with which these adaptation measures were used was daily for 38% of respondents, weekly for 27.3% and occasionally for 34.7%. Applying daily measures to compensate for thermal discomfort was statistically significantly associated with suffering from energy poverty (47.1% vs. 33.9%). Regarding perceived thermal sensation, 26.1% felt cold at home, 18.1% felt hot and 55.8% were in thermal comfort. Feeling cold at home was statistically significantly related to suffering from energy poverty (34.9% vs. 22.1%). Respecting thermal preferences, 31.5% would have liked it to be warmer in their home, 22.5% cooler and 46% were satisfied with the temperature of their home. Having a thermal preference for heat in the home in confinement showed a statistically significant relationship with energy poverty (40.7% vs. 27.4%).

5. Discussion

According to the results obtained in the study, households declaring themselves to be energy-poor (following the energy poverty indicator based on the ten percent rule index), are one third of the total sample, which is, despite the limitations of the index itself due to its simplicity [77], quite consistent with other studies that assess multidimensional indices for the same city of Madrid [78], which confirm this [31]. Although the energy poverty index shows a statistically significant relationship with the vulnerability index, cases continue to be observed for the least vulnerable quartiles, in a high percentage (26.5%). This shows that, apart from debates on methodologies for the description of energy poverty, it is clear that a very high investment of income is made in general terms to cover energy costs, which makes us reflect on the possible reasons why this occurs. As reported by this study, the energy-poor suffer more discomfort, and this in turn shows no relationship with the general characteristics of the dwelling, so it can be concluded that households, regardless of vulnerability quartile, that spend more than 10% of income on energy costs (therefore, whatever their income level), do so because they tend to suffer more discomfort. Consequently, this use of income is due to a question of quality of life, rather than being linked to the size or occupancy regime of the dwelling, or to the composition of the household. However, other aspects more related to the quality of housing in terms of design and maintenance should have been included in the study, such as year of construction, state of conservation, or perception of thermal insulation, among others, in order to be able to assess whether the quality of the dwelling in terms of indoor environmental quality and comfort potential could really offer more or less thermal well-being to households. In accordance with the long-term Strategy for Energy Rehabilitation in the Spanish Building Sector [36], more than half of the main dwellings were built before the entry into force of any specific energy and comfort regulations, and, in any case, almost all of them existed before the entry into force of the first version of the Technical Building Code [79]. This information was not addressed in the original questionnaire, because it was already very extensive, as it included many other issues related to the way of living the lockdown in general, linked to housing.

With regard to energy consumption during the period of confinement, it can be established that this is not directly linked to vulnerability or energy poverty. This implies that, as may seem reasonable, households have needed to consume more energy regardless of their situation, due to the 24/7 permanence of all household members. However, more specifically, there are certain increases in use and associated consumption whose distributions differ due to sociodemographic variables, household composition, or characteristics of the home. Among them, the greater use of certain household appliances by the female gender, associated with cleaning the home and preparing meals, stands out, which is related to the declaration of various sources, such as Eurofound [80] and gender studies during the COVID-19 pandemic, which point to a greater presence of women in the homes during this period for reasons of child or dependent care, and therefore, to their predisposition either to give up economic income or to the option of teleworking [14,81,82]. In turn, other electronic devices, such as computers and mobile ones, have been used differently depending on the employment situation, with employees and civil servants standing out. This is in line with the Eurofound survey on Life, Work and COVID-19, which states that this type of worker has seen a very significant increase in teleworking at home [14]. The increase in the use of equipment was also influenced by the age of the participants, being higher for middle-aged people, which can be explained by the fact that they have experienced a greater change of habits during lockdown, compared to their usual life, as well as being the age group with children present in the household. In relation to the thermal service of domestic hot water, the use increases for families with children, more vulnerable households, and smaller dwellings, while heating is generally used in a very controlled way (only when it is necessary), since it involves a comparatively much higher consumption of energy. The sample that has used it most consistently probably corresponds to those who have the service centralised, and it therefore has less of an impact on their bills. It is remarkable that natural gas is used mostly for these two thermal services, since natural gas prices in Spain range from one third to one half of the kWh of electricity [83]. Only smaller households use electricity for these services.

Where energy-poor households have shown more variability, compared to those that are not, was in behaviours related to energy saving and perceived comfort. In terms of energy saving, these energy-poor households were more likely to apply strategies leading to conscious and responsible energy consumption, although not as much as would have been desirable, since on average, they did not reach 1.5 strategies applied in lockdown, which is consistent with what is suggested by the third European Investment Bank Climate Survey [84], which states that, despite greater awareness of Energy and Climate issues, it is still difficult for them to make effective changes in their habits. Regarding comfort, the most energy-poor households reported higher levels of discomfort, as well as thermal preferences for more heat in the home. However, when it comes to coping with discomfort, there is little distinction between the energy-poor and non-energy-poor solutions, as the proportions depending on the solutions adopted are very even. It may rather be a question of acquired habits [25] or a culture of energy responsibility [84], with the majority opting for solutions that do not initially involve energy consumption, such as changing clothes or opening/closing windows. Nevertheless, the frequency with which these situations of adaptation do occur is directly linked to being energy-poor or not, as they resort to them more frequently in order to achieve the desired comfort.

Finally, one of the limitations in the use of the ten percent rule indicator to define households' energy poverty, was derived from the relativeness among home-income levels, and the differences found between countries [85], also related to differences in national energy prices [86]. Despite being an indicator based on energy expenditure, its application in national contexts complemented with other multidimensional indicators should be considered [87], as already shown in the recent literature.

6. Conclusions

Almost a third of the households participating in the study turned out to be habitually energy-poor, according to the 10% household income indicator established by Broadman, increasing during confinement, with the impact being greater among vulnerable households. Habitual energy poverty was also related to households over 65 years of age, and to those with a lower level of education. The rest of the sociodemographic and housing characteristics evaluated did not show a relationship.

Energy consumption increased during confinement, which seems obvious [1]. The increase in the use of some equipment was related to the female gender, employment situation and age. The sources of generation of thermal services were mainly natural gas and electricity, the former being the most used, except in the smallest homes, which used electricity. The use of heating and hot water was not related to energy poverty. Regarding energy saving strategies to mitigate these consumptions, almost half did not carry out any, but they were related to energy poverty. Perceived comfort was statistically related to suffering from energy poverty, as well as the thermal sensation of feeling cold, and wanting more heat as a thermal preference at home.

Although this study has the limitations inherent to the distribution of the online questionnaire among the potential sample of participants, it is of interest, given the lack of data reported by households, as well as the scarcity of studies of monitored consumption disaggregated by household, for this specific period, and gives an account of the reality lived in this period in which the house became the place of absolute centralization of all activity for three months, in the spring of 2020.

The declared data invite reflection on the real situation of the households, whether they are at risk due to vulnerability or not, and the role played by the different aspects valued: the configuration of the households, the characteristics of the dwellings, the patterns of energy consumption, as well as the sensation of thermal comfort, and the culture about responsibility and awareness in the use of energy in homes today. As further analysis, detailed considerations on the household configuration, also according to age ranges, and the underlying people situations, could be relevant to deepen in the socioeconomic impact of contexts such as this.

A situation similar to the one experienced in the spring of 2020 has led to higher household consumption, but also a greater exposure of the most vulnerable to uncomfortable environments, which was more difficult for them to address. This, in the long run, in addition to being able to give rise to situations of worsening vulnerability and broadening the spectrum to other households, suffering the so-called hidden energy poverty [88], directly affects the health and well-being of people [50,89], in its broadest sense, as already stated by the World Health Organization [90], so it is urgent to establish measures, not only to support and alleviate the situation of households in situations of vulnerability and at risk of energy poverty [35], taking into account the real needs of the population [91], but also measures of a preventive and contingency nature [92], since the future does not look very promising and it cannot be certain that, this type of situation, unusual for peers, will not be repeated [93,94], although it would be desirable not to have to resort to measures as extreme as that experienced during total confinement due to COVID-19.

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