Title:

Do unemployment benefits and economic aids to pay electricity bills remove the energy poverty risk of Spanish family units during lockdown? A study of COVID-19-induced lockdown

Abstract

The COVID-19 pandemic has triggered serious economic crises in many countries. In Spain, millions of individuals have been ordered to remain at home and many are unemployed. The increased use of electrical appliances and low incomes make energy poverty highly likely. This study thus analyses the effectiveness of unemployment benefits and social measures to help Spanish family units pay their electricity bill during the COVID-19-induced lockdown in Spain (March-May 2020) and during a hypothetical lockdown in winter and summer. The results showed that the unemployment aids can contribute to alleviating energy poverty, especially if the unemployed individual worked in a poorly-paying job or for just a few hours. However, the social measures were found insufficient to avoid energy poverty. The application of a variable discount percentage in the electricity bill based on income and the month of the year would reduce energy poverty risk during further incidences of lockdown.

Keywords: energy poverty, COVID-19, pandemic, lockdown, unemployment benefits, electrical social bonus.

1. Introduction

The COVID-19 pandemic has changed today's society (Chakraborty and Maity, 2020). The pandemic and resultant lockdown have resulted in significant negative changes in countries' industrial (Nicola et al., 2020), educational (Alsafi et al., 2020) and energy activities (Hosseini, 2020). In Europe, one of the countries most affected by the COVID-19 pandemic is Spain. In March 2020, the Spanish government published a standard in which all sectors not considered essential were stopped, and citizens were ordered to be confined to their dwellings (Saez et al., 2020).

Consequently, many job positions disappeared under an economy that already had a high number of unemployed individuals due to an imminent economic recession (Dallari and Ribba, 2020). In quantified data, 959,996 individuals have been involved in a temporary labour force adjustment plan (The Government of Spain, 2020). These individuals are added to the 3 million who were already unemployed in the country (Spanish Institute of Statistics, 2020). Under these circumstances, many family units (FUs) have been forced to remain at home without the chance to search for new jobs. Their primary sources of income have been unemployment benefits, putting them at risk of falling into energy poverty.

Energy poverty occurs when FUs find it difficult to pay the energy expenses incurred from the use of electrical equipment and systems—heating, ventilation, air conditioning (HVAC)—in their homes (Bouzarovski and Petrova, 2015; Legendre and Ricci, 2015). Energy poverty was a problem before the COVID-19 pandemic with an estimated 124 million residents in the European Union (EU) living in energy poverty before the lockdown. In 2016, 5.1 million individuals in Spain could not maintain thermal comfort conditions in their homes, corresponding to 22% of Spanish households (Tirado Herrero et al., 2016; 2012). As a result, many FUs adopted measures to reduce their energy consumption (Liddell and Guiney, 2015; Middlemiss and Gillard, 2015; Thomson and Snell, 2013). These include reducing the hours of use of HVAC systems (Shortt and Rugkåsa, 2007).

In addition to the social component of the energy poverty problem, studies have stressed the importance of mitigating energy poverty to mitigate climate change, because of the relationship between reducing energy poverty by reducing the energy consumption of FUs and thus reducing greenhouse gas emissions (Dubois et al., 2019; Ürge-Vorsatz and Tirado Herrero, 2012). However, building renovation as an energy-saving strategy is not necessarily effective in alleviating energy poverty. This can be attributed to the possible rebound effects, such as a nudge of the set-point temperatures of HVAC systems, that can be generated (Seebauer, 2018). FUs in energy poverty usually have low incomes, and the renovation of buildings is an ineffective measure because of insufficient financing and the time required for implementation (Vilches et al., 2017). Social measures are the most effective for reducing the number of energy vulnerability cases (Meyer et al., 2018).

In Spain, the social measure for helping FUs pay their electricity bills is the electrical social bonus (The Government of Spain, 2017). This economic aid provides 25% to 40% savings off the electricity bill, based on the income and size of the FU. The effectiveness of this social measure during the lockdown periods when individuals received unemployment benefits and stayed indoors the whole time has not been studied. For this reason, this research analyses the effectiveness of unemployment benefits and the electrical social bonus in Spain in mitigating energy poverty during the lockdown. Several case studies that focused on the lockdown period in Spain (March-May 2020) were analysed, alongside a hypothetical scenario of a lockdown in winter and summer to assess the effect during months when the cooling and heating energy demand are highest. The results of this research are useful for creating social measures that alleviate or eradicate the energy poverty of FUs in times when there is a lockdown coupled with high unemployment rate.

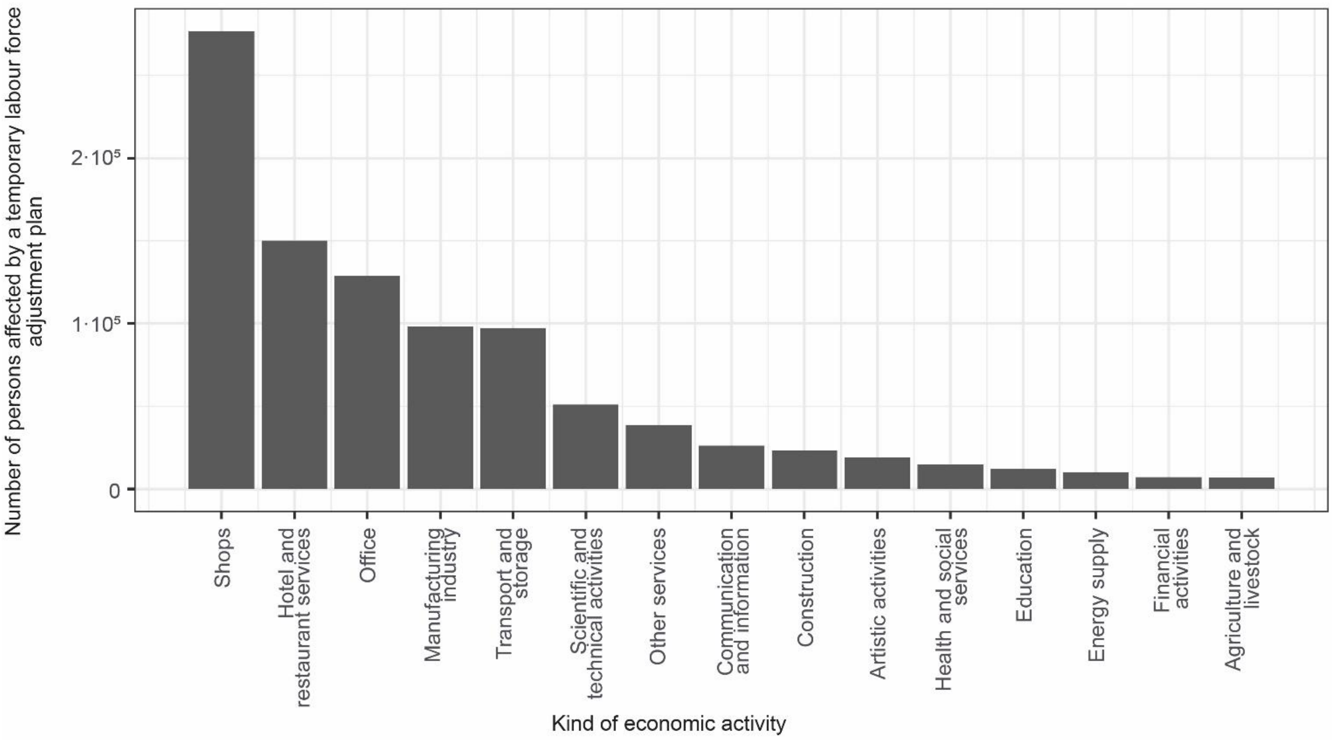
2. Social framework of the economic situation of FUs during the COVID-19 lockdown and economic aids

2.1. Job loss due to the COVID-19 pandemic

Similar to other pandemics (Ceylan et al., 2020), the COVID-19 pandemic has resulted in a serious economic crisis. Many companies have closed down in response to the pandemic and the social distancing and lockdown measures put in place by governments. The lockdown significantly affected the Spanish economy which had been weak for years (Hiscott et al., 2020). The government allowed companies to make temporary labour force adjustment plans that guarantee their workers unemployment benefits during the closure of the company. The incomes received by workers are therefore the same as those received by individuals whose contracts have expired.

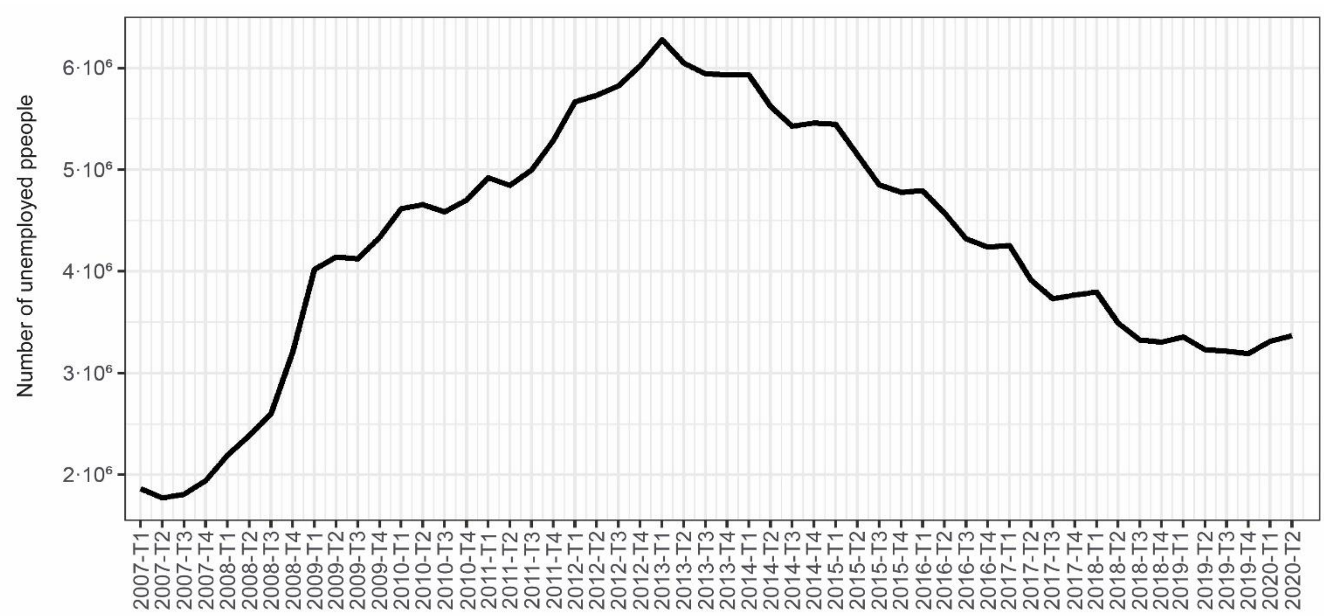
Figure 1 shows the estimated number of workers whose companies temporarily closed down per type of activity (The Government of Spain, 2020). A total of 959,996 individuals were involved in a temporary labour force adjustment plan. The effect of which has differed according to the type of activity, with shops and the hospitality industry being the most affected. As these sectors are characterised by low wages, the possible savings level of workers would be low.

Figure 1. Estimated number of workers affected by labour force adjustment during COVID-19 pandemic.



The temporary closure of companies has added to the progressive increase in unemployment in Spain due to the economic deceleration of recent years. Since the Lehman Brothers' economic crisis, Spain has suffered a progressive increase in unemployment until 2013 (Aguilar-Palacio et al., 2015), when a slow work-recovery process started. However, the most recent data show that there is a progressive economic deceleration (del Río and Gordo, 2019). The data of unemployed individuals from the first quarter of 2020 indicate that 3,313,000 individuals (the workers affected by labour force adjustment plans are not included) were unemployed (Figure 2), representing 14.41% of the Spanish population that can work (i.e. the population aged between 16 and 65 years) (Spanish Institute of Statistics, 2020). In previous years, the first quarter numbers usually decrease in subsequent quarters due to the jobs created by the great inflow of tourists. In 2020, however, the number increased to 3,368,000 individuals due to the pandemic-induced total lockdown and closure of many businesses.

Figure 2. Evolution of quarterly data of unemployed individuals from 2007 (before the economic crisis in 2008 because of the Lehman Brothers crisis) to the second quarter of 2020.



2.2. Unemployment benefits in Spain

Economic aids for unemployed individuals in Spain can be divided into two: (i) unemployment benefits unemployed individuals receive based on what they were paid while working; and (ii) unemployment assistances (also known as subsidies) provided to unemployed individuals without a contributive benefit because their income is insufficient or they have exhausted this benefit and still have not found a job (The Government of Spain, 1985).

The income received by the worker depends on the type of economic aid (unemployment benefit or subsidy), what has been paid, and the size of the FU. According to the combination of unemployed individuals, their incomes are determined according to the value established by the Public Income Indicator of Multiple Effects (IPREM in Spanish) by the government that year. The incomes established by the unemployment benefits therefore vary each year.

Table 1 shows the minimum and maximum values that an unemployed individual can receive according to the various possible combinations in 2020. This income will be a value oscillating between the minimum and maximum value of each combination. As for the subsidy, the monthly income is €430.27 if the unemployed individual had a full-time job or €215.13 in the case of a part-time job, and these values are fixed for all cases.

Table 1. Monthly maximum and minimum values that an unemployed individual can receive in 2020.

Type of benefit	Type of job	Size of FU	Minimum value [€]	Maximum value [€]
Unemployment benefit	Full-time job	Childless	501.98	1,098.00
		1 child	671.40	1,254.86
		With 2 children	671.40	1,411.83
	Part-time job	Childless	248.50	< 1,098.00
		With children	334.87	< 1,254.86
Subsidy	Full-time job	-	430.27	430.27
	Part-time job	-	215.13	215.13

2.3. Electrical social bonus and voluntary price for the small consumer

The income scarcity for an FU could imply that meeting everyday expenses, such as the electricity bill, would require a substantial effort. Due to this, there is an aid programme—electrical social bonus—for managing electricity bills for low-income FUs (The Government of Spain, 2017). To benefit from the electrical social bonus, certain income- and familial-related requirements have to be fulfilled and an application has to be made to government-approved energy companies. The electrical social bonus gives the recipient a discount on the amount of the energy term and the power term. The discount is 25% if the FU is a vulnerable consumer and 40% if the FU is a severely vulnerable consumer. For example, if the energy term in an electricity bill is €20 and the power term is €17, the 25% discount is €9.25, and the 40% discount is €14.80. To determine the vulnerability of an FU, the annual income of the previous year is analysed (e.g., to benefit from the social bonus in any month of the year 2020, the annual incomes of 2019 are analysed). The limit values of annual incomes vary each year according to the variations established in the IPREM. Table 2 presents the annual limit values for 2020 according to the type of FU, which establishes whether an FU is a vulnerable consumer or a severely vulnerable consumer.

Table 2. Limit values of annual incomes to be considered a vulnerable or severely vulnerable consumer and to benefit from the electrical social bonus in 2020.

Size of the FU	Limit of annual incomes of the FU [€]	
	Vulnerable consumer	Severely vulnerable consumer
With no child in the FU	€11,279	€5,640
With 1 child in the FU	€15,039	€7,520
With 2 children in the FU	€18,799	€9,400
Large family	Without limit	€15,039

The contract that FUs should establish with these energy companies should be with a power equal to or lower than 10 kW and with the Voluntary Price for the Small Consumer (PVPC in Spanish). PVPC is the price of the energy term regulated by the Spanish government since 2014, and this price varies according to the hour of the day (The Government of Spain, 2014). Prices are available on the internet for the next day; thus, users can adopt the use of electrical household appliances with higher energy consumption (e.g., washing machines) in the hours with the lowest price.

3. Methodology

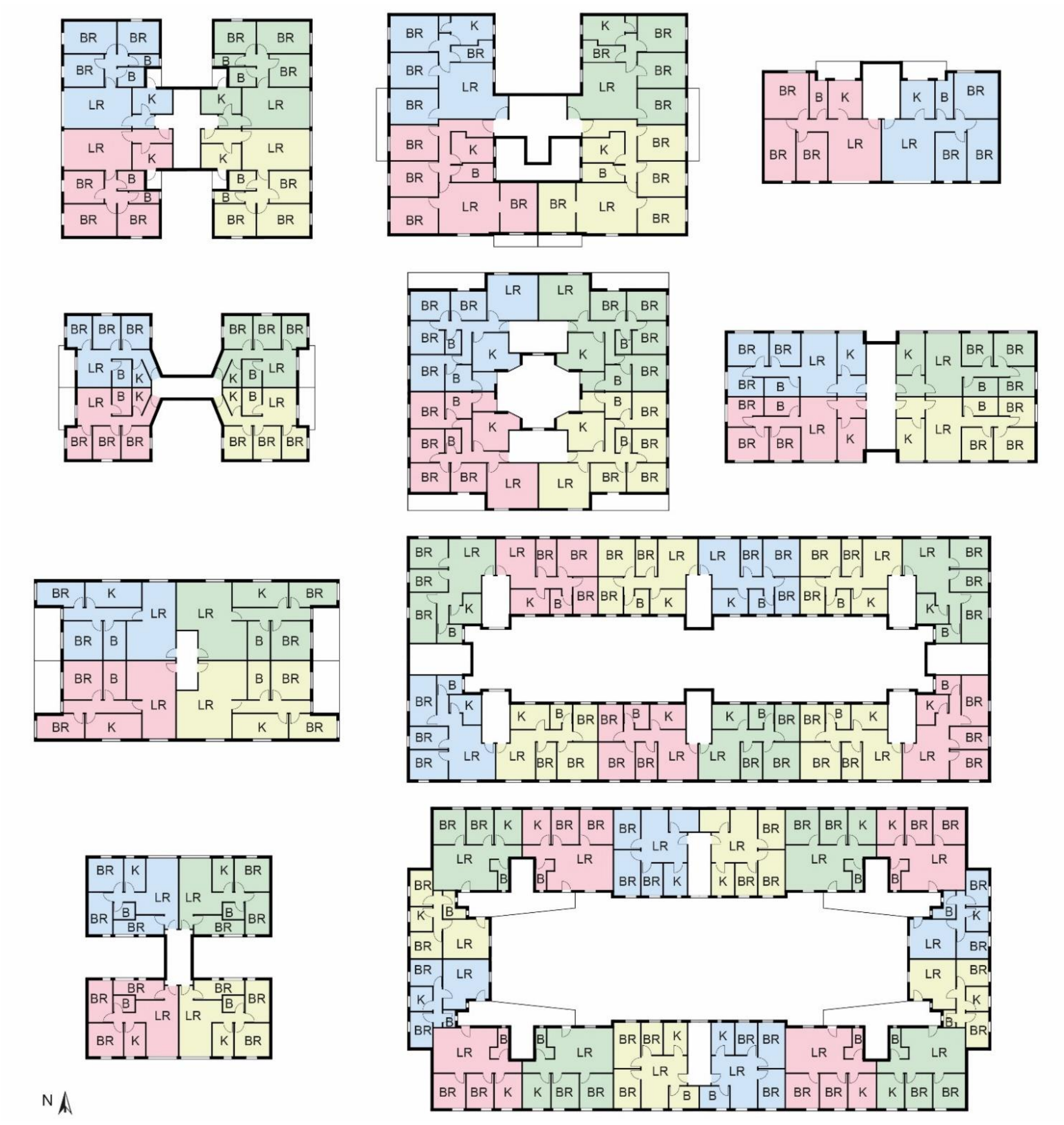
3.1. Energy simulation

This research aimed to analyse the energy poverty risk of unemployed FUs during the COVID-19 pandemic, new outbreaks, and the possibility of financing through aids to pay electricity bills. To assess the energy poverty risk of Spanish FUs, an exhaustive energy simulation process was conducted with EnergyPlus to determine the energy consumption of Spanish households. For this purpose, 10 typologies of case studies between 2 and 16 dwellings per floor were modelled (see Figure 3). The structures of the buildings correspond to actual cases and constitute the most common structures of buildings in the Spanish building stock (Domínguez-Amarillo et al., 2016; Oteiza San José, 2018). The analysis was conducted on the third floor of the buildings. Regarding the thermal properties of the envelope, two building envelope possibilities were analysed: (i) envelopes corresponding to buildings built before the first regulation on energy efficiency in Spain in 1979 (i.e. before the NBE-CT-79 standard) and: (ii) after the NBE-CT-79 standard (The Government of Spain, 1979). Table 3 shows the values of the thermal properties established for the envelope designs analysed. These values were established after cataloguing studies on the thermal properties of the envelope of Spanish building stock (Kurtz et al., 2015). The thermal properties for the roof or the floor in contact with the ground were not defined because the study focused on the intermediate floor of the studied buildings.

Table 3. Limit thermal transmittance values of the two envelope designs considered for the study

Envelope design	Thermal transmittance of the façade [$W/(m^2K)$]	Thermal transmittance of the window [$W/(m^2K)$]
1	1.10	5.70
2	0.79	1.80

Figure 3. Case studies considered in the research.



Regarding the use profile of the equipment, the residential profile defined in the Spanish Building Technical Code was used as a basis to establish the maximum values of occupancy load (2.15 W/m²), electrical appliance households (4.40 W/m²), and lighting equipment (4.40 W/m²). However, the schedule of the occupancy and the use of equipment was adapted. Figure 4 represents the percentage distribution of the load in the 24 hours of any day. The occupancy of the dwelling is 100% during the day during the lockdown, whereas the use of lighting equipment and systems varied according to the hour of the day. A profile for weekdays and weekends is not distinguished because the activities were the same during the lockdown. As for the use of HVAC systems, the possibility of using them the whole day was considered to ensure acceptable thermal comfort conditions and not to contribute to the possible emergence of diseases because of unacceptable thermal conditions in indoor spaces. Thus, this study did not consider other types of energy poverty, such as families with abnormally low energy expenditure. Nevertheless, and because of the possible high influence of HVAC systems on energy consumption, various operational patterns of HVAC systems were analysed. Table 4 presents the six operational approaches with their respective heating and cooling setpoint temperatures. These approaches are from the effective use of an HVAC system (AP-01) to a use implying high energy consumption (AP-06). Regarding the type and characteristics of the HVAC system, a heat pump with a coefficient of performance of 2.1 and an energy efficiency ratio of 2.0 was considered.

Figure 4. Load profiles of occupancy, lighting, and equipment considered for the case studies.

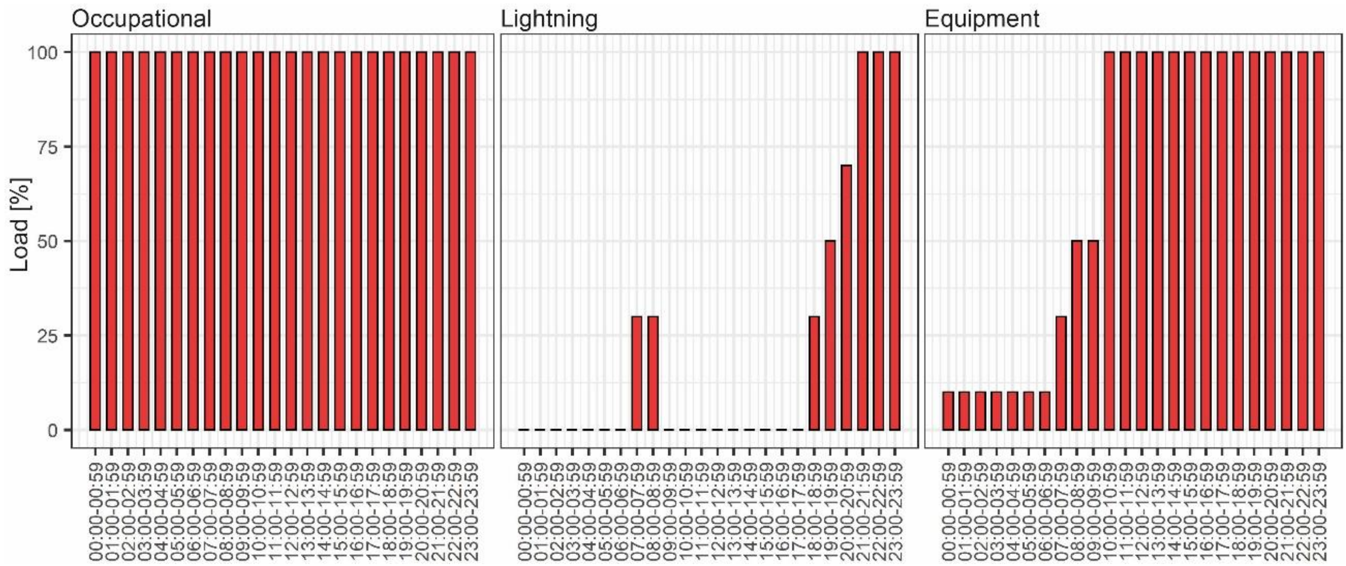


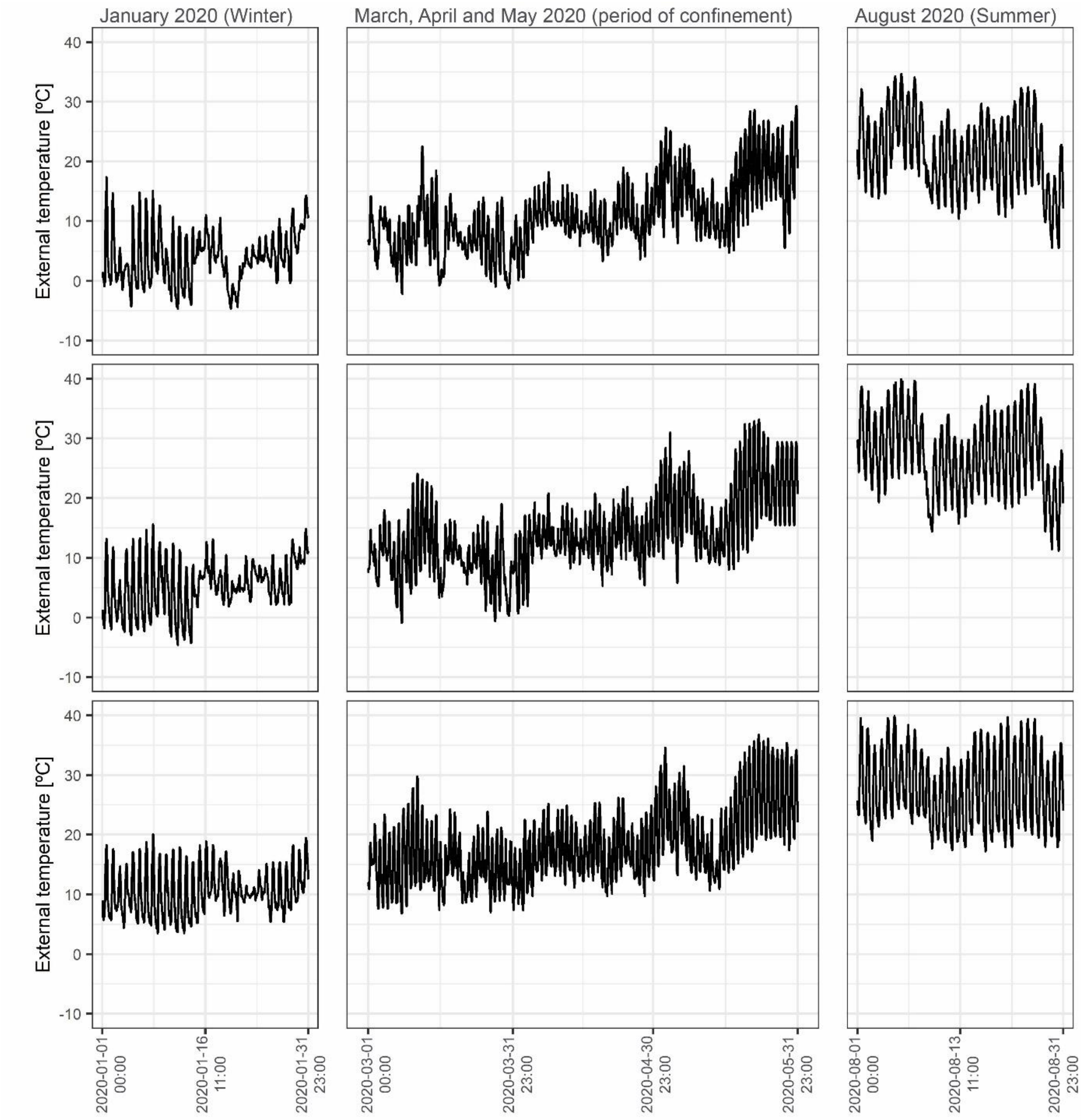
Table 4. Approaches considered for the operational patterns of the HVAC systems.

Approach	Heating setpoint temperature [ºC]	Cooling setpoint temperature [ºC]
AP-01	17	28
AP-02	18	27
AP-03	19	26
AP-04	20	25
AP-05	21	24
AP-06	22	23

Regarding the location and the climate data analysed, the case studies analysed were taken from the 52 Spanish province capitals (Figure 5). To have energy simulation data similar to the actual performance conditions of buildings during the Covid-19 pandemic, hourly data of the temperature, relative humidity, and wind speed were obtained during the lockdown in Spain (i.e. in March, April, and May of 2020) for the 52 cities. These hourly temperature data were used to generate the EnergyPlus Weather (EPW) files that were used in the simulation process. Because the study also aimed to assess the effect of lockdown in severe winter and summer months under an energy poverty risk, hourly data of the 52 cities in January 2020 and in August 2020 were also compiled. Thus, the energy simulations of the case studies in the 52 cities were performed in three periods using actual meteorological data (Figure 6).

Figure 5. Provinces in Spain.

Figure 6. Example of the climate data compiled in the three analysis periods of the study (COVID-19 lockdown period, winter, and summer).



3.2. Types of incomes and aids of the FUs

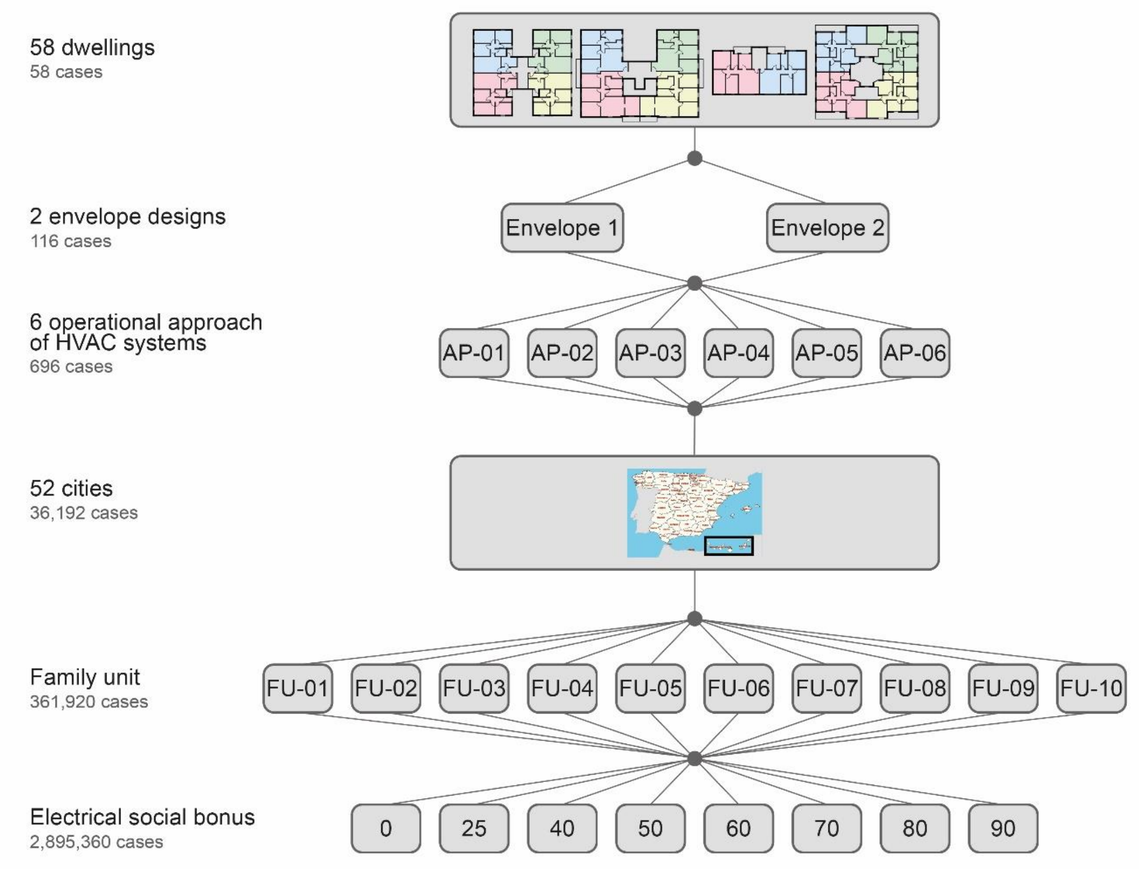
The establishment of the monthly income levels of the FUs is essential to analyse the energy poverty risk. Various FU typologies were considered according to the monthly incomes obtained by the unemployment benefits. For this reason, the income values per unemployment benefits included in Table 1 were used to establish 10 FU typologies. Table 5 presents the monthly incomes related to each FU. The characteristics of each FU are as follows: (i) FU-01 corresponds to an FU receiving a monthly income subsidy because of the loss of a part-time job; (ii) FU-02 corresponds to an FU receiving unemployment benefits because of the loss of a part-time job and with children in the FU; (iii) FU-03 corresponds to receiving the subsidy because of the loss of a full-time job; (iv) FU-04 corresponds to the minimum value of the unemployment benefit that can be received because of the loss of a full-time job and without children in the FU; (v) FU-05 corresponds to the minimum value of the unemployment benefit that can be received because of the loss of a full-time job and with children in the FU; (vi) FU-06 corresponds to the maximum value of the unemployment benefit that can be received because of the loss of a full-time job and without children in the FU; (vii) FU-07 corresponds to the maximum value of the unemployment benefit that can be received because of the loss of a full-time job and with one child in the FU; (viii) FU-08 corresponds to the maximum value of the unemployment benefit that can be received because of the loss of a full-time job and with two children in the FU; and (ix) FU-09 and FU-10 correspond to possible combinations in which two members of the FU receive unemployment benefits.

Table 5. Monthly incomes related to each FU.

FU	Monthly incomes [€]
FU-01	215.13
FU-02	334.87
FU-03	430.27
FU-04	501.98
FU-05	671.40
FU-06	1,098.00
FU-07	1,254.86
FU-08	1,411.83
FU-09	1,600.00
FU-10	1,800.00

Various hypotheses of economic aids to pay the electricity bill were considered alongside the electrical social bonus. For this purpose, the risk presented by the FU of either not receiving a discount or with the discounts given by the state (of 25% and 40%) was analysed. Moreover, the possibility of new discount percentages in the social bonus (50%, 60%, 70%, 80%, and 90%) was studied. In this manner, the need to increase the discount percentage in the electrical social bonus to mitigate the energy poverty in FUs with low economic resources was assessed. The number of cases analysed in the research was 2,895,360 cases. Figure 7 summarises the process of obtaining the cases analysed: the aspects that relate to the energy simulation, the FU cases, and the discounts of the electrical social bonus. A total of 36,192 cases were determined per FU, and the total combination of FU and discount was 2,895,360 cases.

Figure 7. Flow of the simulation and determination process of the cases of the research.



3.3. Determination of the energy poverty situation

The high share of energy expenditure in income (2M) indicator used by the European Energy Poverty Observatory (EPOV) and the National Strategy against Energy Poverty (2019-2024) of the Government of Spain was used to analyse the energy poverty level (The Government of Spain, 2019). This indicator assumes that families that have a relationship between energy expenditure and their income greater than the national median are in energy poverty. Sánchez-Guevara Sánchez et al. (2020) showed that the threshold value for this indicator is 10%, coinciding with the value established by Boardman (1991). Thus, for this study, this threshold value of 10% was considered for 2M. The energy poverty ratio (EPR) was determined according to Eq. (1). If the value obtained by Eq. (1) is higher than 10%, the family is in energy poverty (E1. (2)). This assessment is carried out monthly, so a result will be obtained for each month analysed (i.e., the months of lockdown and the month of winter and summer) (Bienvenido-Huertas, 2020). It should be noted that, although the national median of energy expenditure during the lockdown months is possibly higher than the national median under normal conditions, it is appropriate to use the threshold of the country's median energy expenditure under normal conditions. Thus, using the new threshold value for energy expenditure in lockdown episodes (which will be higher than in normal conditions) will mean that many families will not be considered as being in energy poverty, even though their energy expenditure is high (ie, they would be false negatives). Therefore, the use of the median value of energy expenditure under normal conditions allows a more adequate perspective of the energy poverty risk of families.

$$EPR = \frac{\text{Monthly energy expense}}{\text{Monthly household income}} \cdot 100 \quad [\%] \tag{1}$$

$$Case\ in\ energy\ poverty \quad \text{if} \quad EPR \geq 2M\ (10\%) \tag{2}$$

Household energy consumption was obtained through the energy simulations indicated in subsection 3.1. The household contract type was defined to determine monthly energy expenses. In this case and given that it is a contract that is related to the application for an electrical social bonus, it was assumed that FUs have contracted the price of the PVPC without hourly discrimination and with a power of 4.6 kW. The following concepts are included in the PVPC bill to determine the calculation of the energy cost of the dwellings (Eq. (3)): (i) energy term (ET), (ii) power term (PT), (iii) discount of the electrical social bonus (ESB); (iv) electricity tax (ElT), (v) rent of the digital electricity meter (EMR), and (vi) value-added tax (VAT).

$$\text{Monthly energy expense} = (1 + VAT) \cdot (ET + PT - ESB + ElT + EMR) \tag{3}$$

The energy term is the associated expense for each kWh consumed in the home (Eq. (4)). The energy term was obtained from the sum of the cost of electricity production and grid access. The cost of the energy term varies throughout the day. Figure 8 shows the hourly price values of energy terms in the periods analysed. The power term is an expense that is paid for having the contracted power available (in the case of this study, 4.6 kW). The power term was obtained through two concepts: the grid access (€ 0.104229/(kWday)) and the marketing margin (€0.010959/(kWday)). The number of days included in the invoice made it possible to determine the exact amount of the power term (Eq. (5)). With the power term and the energy term, it was possible to determine the discount on the electrical social bonus. To do this, the discount percentage was applied to the sum of the expenditure on the energy term and the power term (Eq. (6)). If the electrical social bonus is not used, the discount percentage is 0%.

$$ET = Energy\ consumption \cdot Price\ of\ energy\ term \tag{4}$$

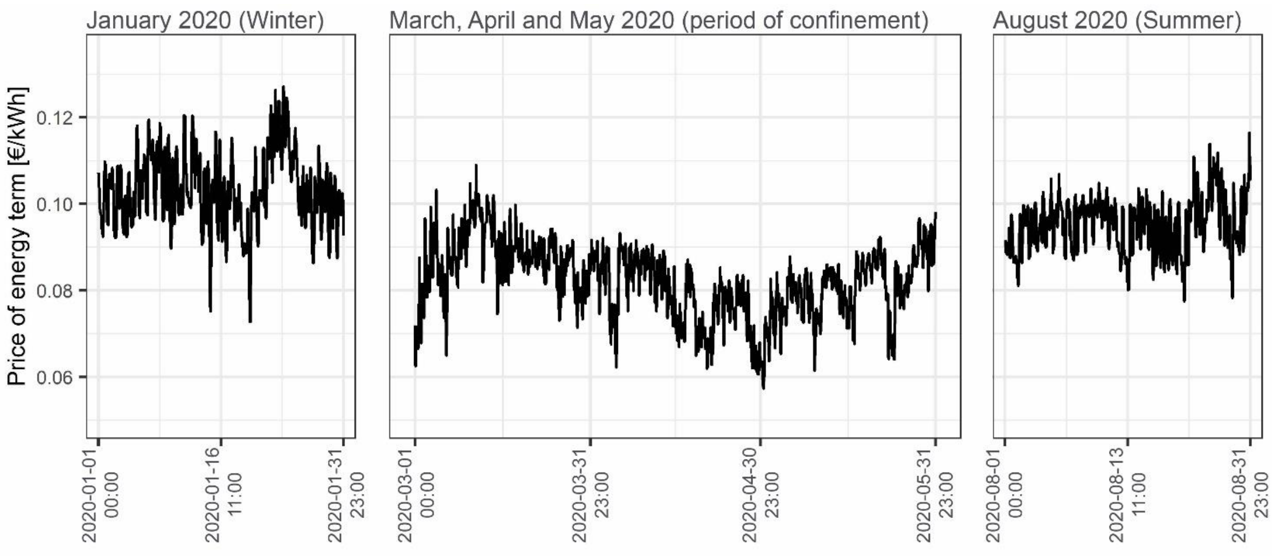
$$PT = 4.6 \cdot Number\ of\ days \cdot 0.115188 \tag{5}$$

$$ESB = Discount\ percentage\ \cdot (ET + PT) \tag{6}$$

In addition, other items on the invoice are taxes. The first of these is the tax on electricity, which is obtained by applying the percentage of the tax on electricity (5.1127%) to the sum of the amounts of the energy term, the power term and the discount on the electricity social bonus (Eq. (7)). The last is value-added tax (VAT), which is obtained by applying 21% to the sum of all the concepts described in the invoice together with the rental of meters (EMR). In this study, the rental of meters is priced at € 1.11/month.

$$ElT = 0.051127 \cdot (ET + PT - ESB) \tag{7}$$

Figure 8. Data of the price of the energy term of the PVPC in the three periods (COVID-19 lockdown period, winter, and summer).



4. Results and discussion

The results are shown and discussed in the following subsections. The results obtained from the energy poverty risk assessment for the pandemic-induced lockdown period in Spain (March-May of 2020) were analysed. This was done alongside an analysis of the possible energy poverty in a confinement scenario during the most severe winter and summer months (in the case of this study, the winter months till January 2020, and the summer months till August 2020).

4.1. Effect of the lockdown because of the Covid-19 pandemic

Apart from the health implications, the lockdown put Spanish families in a difficult situation as their income fell and coincided with the months with certain heating demands in dwellings. The possible energy expenditure of the FUs tended to progressively decrease as the lockdown progressed (Figure 9). Additionally, the energy expense had a downward tendency from March to May because of the progressive increase in the external temperature of Spanish cities because the lockdown coincided with spring. Thus, although the duration of stay in the dwellings was the same in the three months, May presented a significantly lower energy expenditure. Likewise, the operational pattern of the users of each FU could significantly influence energy expenses.

The analysis of the quartiles of the distributions demonstrated an average increase of 7.42%, 8.87%, and 9.18% in the values of the first (Q1), second (Q2), and third quartile (Q3) in March. In April, there were similar values for the increase in the energy expense (6.96% in Q1, 8.94% in Q2, and 9.92% in Q3), and in May, the influence of the operational pattern of users was lower due to the energy demand reduction in the dwellings (the values increased by 0.59% in Q1, 0.93% in Q, and 0.52% in Q3). Thus, a user's behaviour could vary the impact of the energy expenditure in the months of lockdown. For example, behaviours using highly effective setpoint temperatures in HVAC systems could reduce the energy expense, particularly the existing outliers in the energy expense distributions. The values of distributions were also similar, and the analysis of the energy poverty risk focused on the impact of the level of the unemployed FUs' incomes in the months of lockdown.

Figure 10 shows the distributions of the EPR in the various cases of FU without the electrical social bonus. The red line represents the 10% threshold for Spain. Thus, FUs with a EPR value greater than 10% are in the energy poverty risk group. The energy poverty risk of unemployed FUs during the months of lockdown was high. In March, there were combinations in which all the FUs considered were at energy poverty risk. As for high FU incomes due to the combination of unemployment benefits of two members, cases of energy poverty could be reached. However, the number of these cases in the distributions were low in comparison to the numbers obtained from FU-01, FU-02, FU-03, FU-04, and FU-05, in which almost all cases were at energy poverty risk in March. These income values correspond to the unemployment benefit received by the FUs where one member had a part-time job or received the subsidy. These incomes can be related to the FUs that are economically vulnerable even with a job. Thus, it is very difficult for these FUs to have enough savings to manage the high energy expense incurred during the lockdown period. Additionally, the high value of EPR found in these FUs is notable, as the energy expense sometimes exceeded the incomes received by the FUs (i.e. values of EPR greater than 100% were obtained). This situation is therefore untenable, putting these FUs in energy poverty. Similar results were obtained in April and May, although the reduction in the energy consumption by heating systems decreased the values of EPR obtained in the distributions and the number of cases at energy poverty risk. In May, when HVAC system energy consumption was low, the combined consumption of equipment and lighting with thermal conditioning generated unacceptable EPR values for FUs with low incomes. However, FU-04 and FU-05 were not in energy poverty risk, whereas the FUs with incomes higher than those of FU-05 had no energy poverty situation.

The mitigation of energy poverty in May was low, particularly for the FUs with lower incomes. The electrical social bonus is therefore essential to mitigate energy poverty. Figure 11 presents the distributions of EPR obtained for various discount hypotheses of the social bonus. The social bonuses—25% and 40%--are determined based on the level of incomes of an FU in the previous year (for further information, see Section 2). By contrast, in this research, the discounts considered are between 50% and 90%. The economic aids reducing the expense of the electricity bill directly influence the energy poverty risk of FUs. In this regard, the existing discounts of 25% and 40% achieved percentage reductions in the number of cases in energy poverty, although their effectiveness varies according to the incomes of the FUs (Figure 12).

The FUs with high unemployment incomes (i.e. greater than FU-06) were characterised by obtaining a significant reduction in the energy poverty risk in March with the social bonus: (i) FU-06 went from 73.65% of cases with energy poverty risk without the electrical social bonus to 47.93 and 24.46% of cases with the discounts of 25% and 40%, respectively; (ii) FU-07 went from 61.27% of cases with energy poverty risk to 31.28% and 11.96% with discounts of 25% and 40%, respectively; (iii) FU-08 went from 47.82% of cases in energy poverty to 18.56% and 5.47% with the discounts of 25% and 40%, respectively; and (iv) FU-09 and FU-10 went from percentage values at energy poverty risk of 32.9% and 19.91% to values lower than 8% and 2% with the discounts of the electrical social bonus of 25% and 40%, respectively. However, these percentage reductions did not remove 100% of the cases of energy poverty in these FUs with higher incomes.

In FUs with lower incomes, the electrical social bonus did not remove their energy poverty risk. The application of the electrical social bonus did not significantly affect the decrease in the energy poverty risk in March for FU-01, FU-02, FU-03, and FU-04, whereas in FU-05, there were 79.77% of cases at energy poverty risk with the discount at 40%. This means that the FUs receiving the discounts from unemployment benefits because of a part-time job or subsidy are energy vulnerable even with the electrical social bonus. This same result was found in the other months, although the decrease in heating energy consumption showed that the application of the electrical social bonus was more effective. In May, FU-04 and FU-05 went from a percentage of cases at energy poverty risk of 87.24% and 28.61% without receiving the electrical social bonus to percentage values between 27.62% and 0% with discounts of 25% and 40%. However, although energy consumption was high in May, FU-01, FU-02, and FU-03 were characterised by a high number of cases at energy poverty risk, even with a discount of 40%.

Thus, greater discounts should be applied in the electrical social bonus to reduce FUs' energy poverty risk. By analysing the results of the additional discounts studied (between 50% and 90%), the application of a 50% discount virtually removed the energy poverty risk of FUs with monthly incomes equal to or greater than those of FU-06 (i.e. higher than €1098), whereas greater discounts should be applied to FUs receiving lower unemployment benefits.

In this regard, the application of an 80% discount removed cases of energy poverty in March for FU-05, and the application of 90% removed the cases of energy poverty in March for FU-03 and FU-04. However, even the application of a 90% discount would not remove the cases of energy poverty for FU-01 and FU-02. Thus, these FUs should receive 100% discounts on the price of the electricity bill to prevent them from entering energy poverty.

In May, when incomes were lower than in March, the discount can be lower: A discount of 60%, 70%, and 80% removed FU-04, FU-03, and FU-02, respectively from energy poverty risks, and a discount of 100% was required in FU-01 to remove the energy poverty risk of FUs. Therefore, there is variability between the discount percentages that should be applied to the electricity bills of the FUs according to the month of the year, or more particularly, according to the energy demand due to HVAC system use. The specific determination of the variable and more detailed discount percentages according to both the income levels of the FU and the month of the year would reduce the energy poverty risk of FUs without implying a high expense for public funds due to the variation that can be applied to the discount from the electrical social bonus, reducing the energy poverty of the FUs in combined episodes of lockdown and unemployment, such as during the pandemic. To obtain these discounts, more flexible requirements should be established for FUs to benefit from the social bonus. The current requirement is based on the annual incomes received by FUs during the previous year (e.g., in the case of the year 2020, the annual incomes of 2019 would be assessed). This implies that many FUs under unemployment situations would not benefit from the social bonus by their annual incomes could vary from the limits established by the social bonus to lower incomes, due to the unemployment situation in the new year. Modifications should therefore be established in the state regulations such that social services would have greater flexibility when determining the FUs that can benefit from the electrical social bonus.

Figure 9. Distribution of the energy expense of FUs in the months of lockdown, according to the operational patterns of the HVAC systems considered.

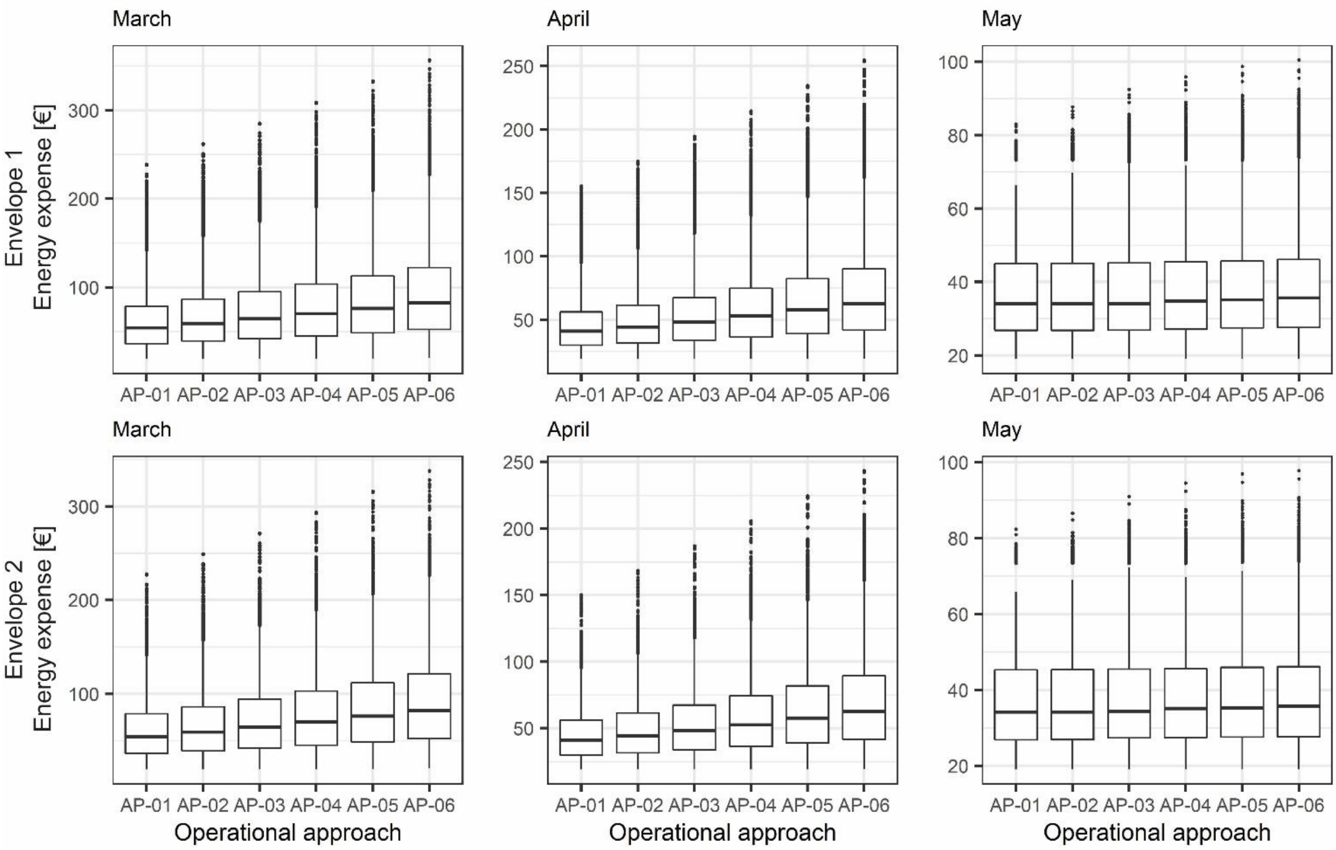


Figure 10. Variation of the distribution of results of the energy poverty ratio in the months of lockdown, according to the FU incomes considered and obtained with the unemployment benefits and without the economic aid of the electrical social bonus. The red line represents the 10% threshold for Spain.

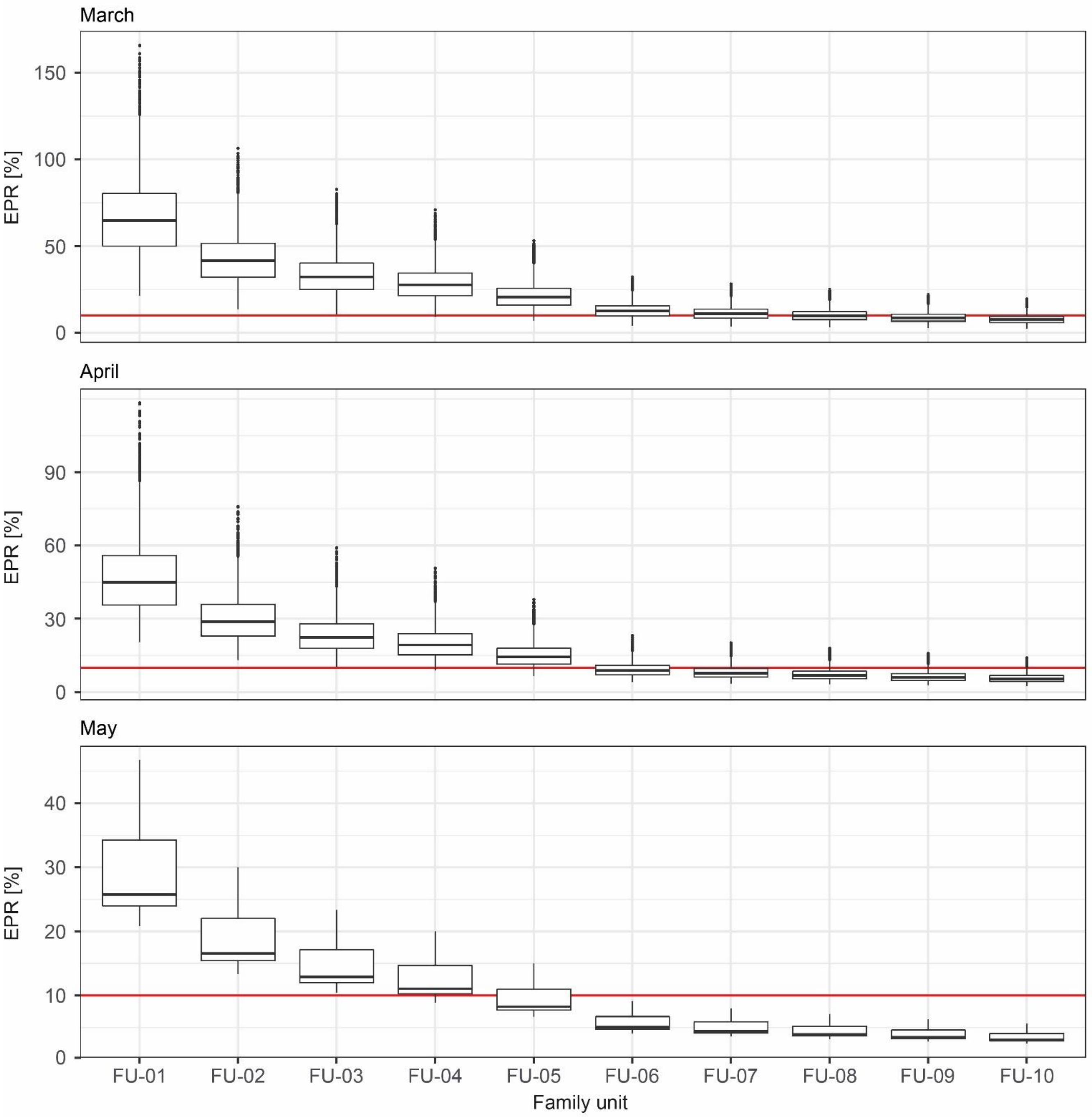


Figure 11. Variation of the distribution of results of the energy poverty ratio in the months of lockdown, according to the FU incomes considered and obtained with the unemployment benefits and the discount obtained with the electrical social bonus (the two existing discounts and the new discounts considered in this research). The red line represents the 10% threshold for Spain.

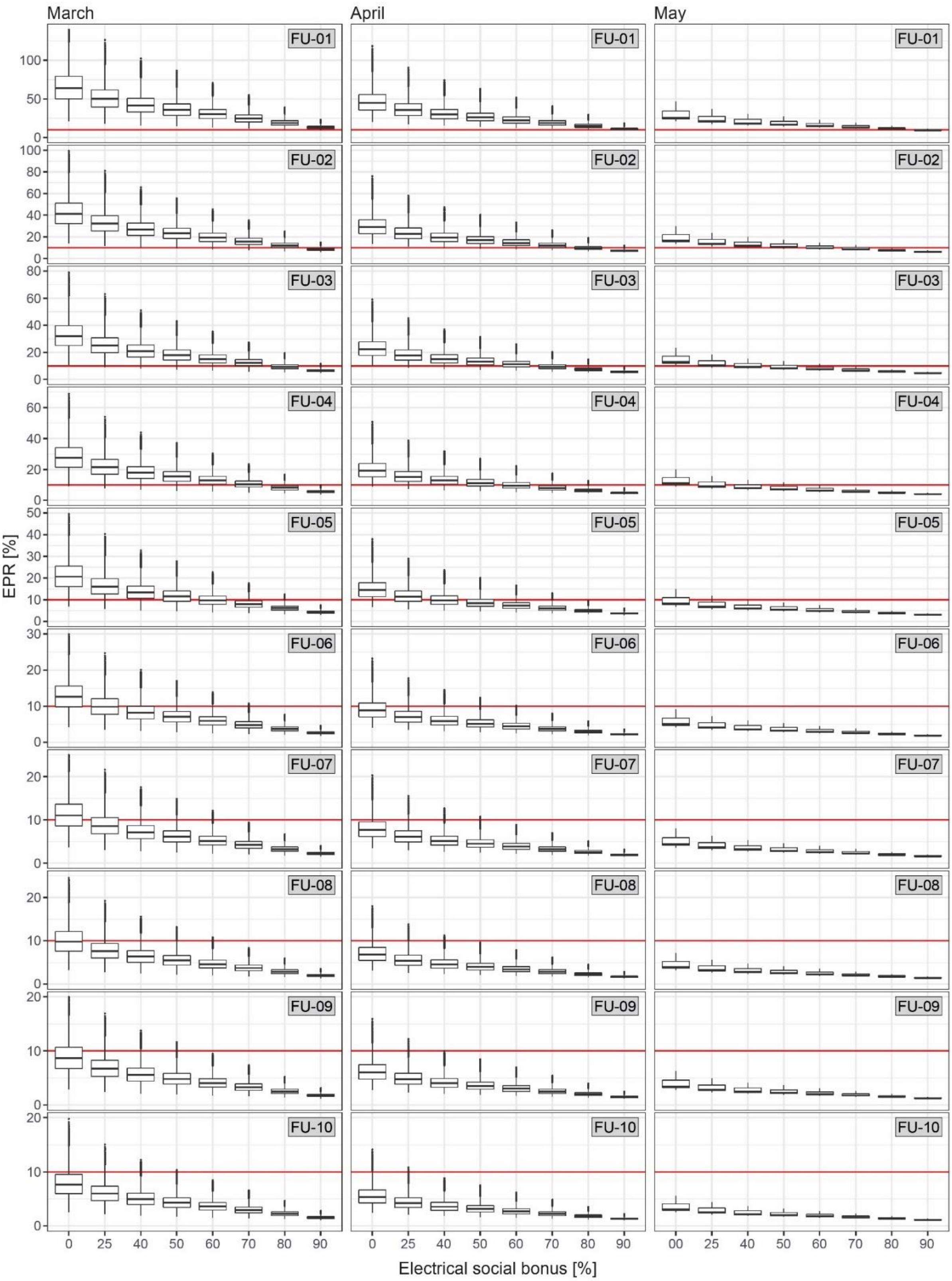
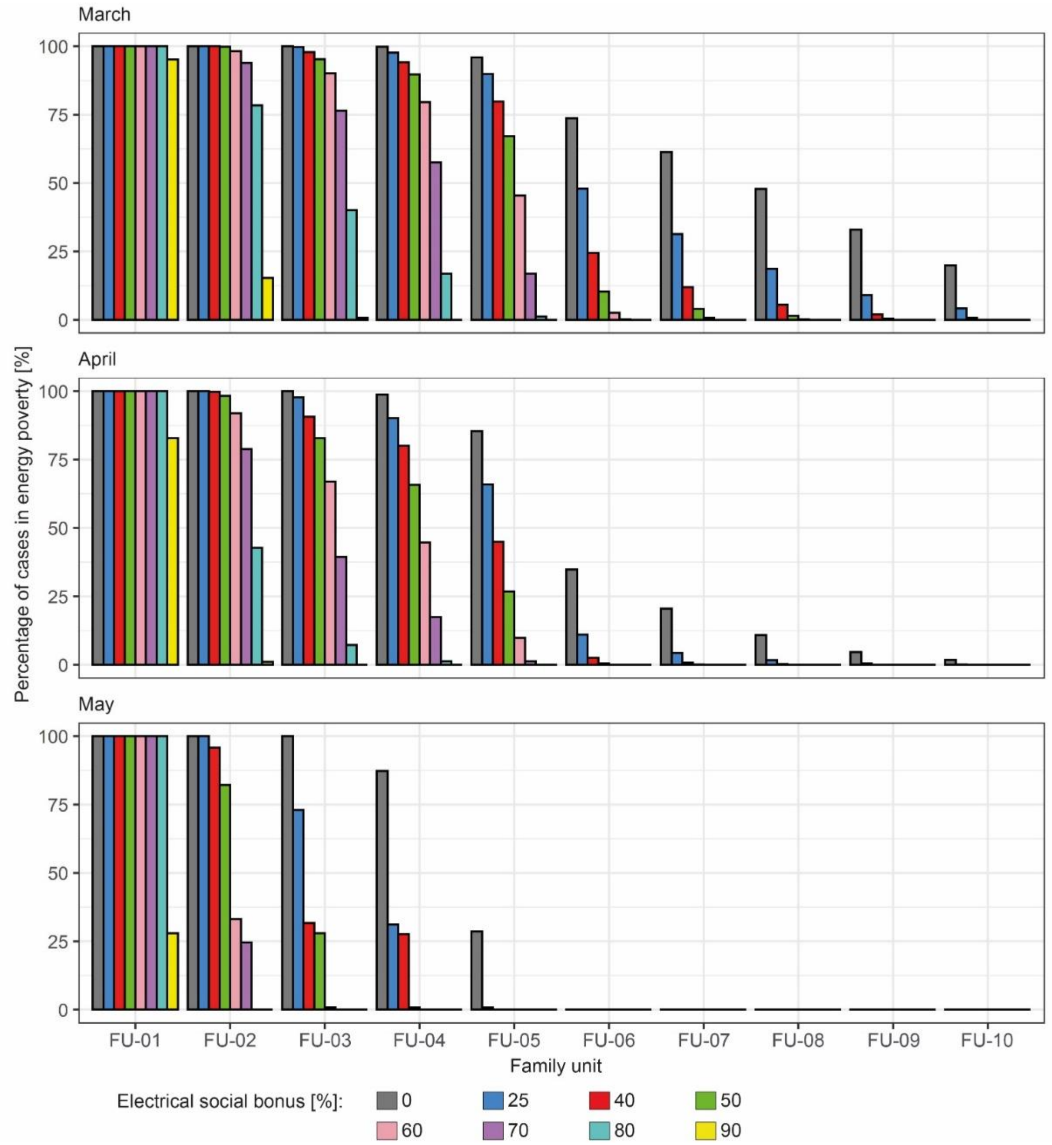


Figure 12. Variation of the percentage of cases at energy poverty risk in the months of lockdown, according to the FU incomes considered and obtained with the unemployment benefits and the discount obtained with the electrical social bonus (the two existing discounts and the new discounts considered in this research).

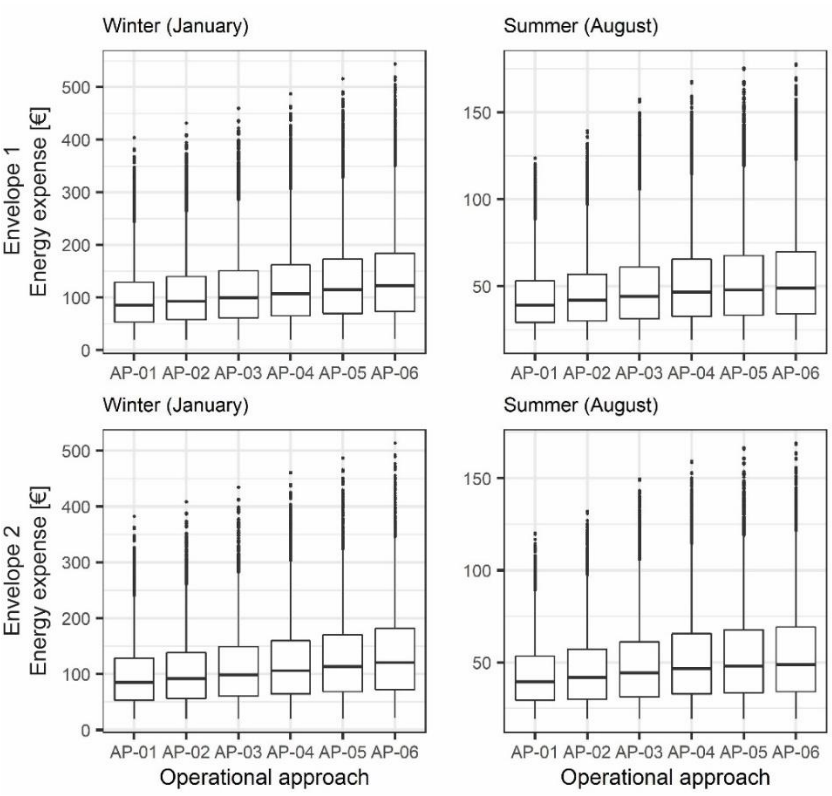


4.2. The effect of lockdown in severe summer and winter months on the energy poverty of the FU

The previous results only analysed the effect of the months of lockdown due to the pandemic on the energy poverty of unemployed FU. However, the possible scenario from the combination of lockdown, unemployment, and energy poverty should be analysed in the months with greater heating and cooling energy demand. This analysis should be conducted in such a manner that the energy poverty risk can be assessed in outbreak scenarios of the COVID-19 pandemic (Lopez and Rodo, 2020), and other types of pandemics in the months when HVAC systems demand greater energy.

For this purpose, the case studies were analysed using climate data recorded in the Spanish capitals in January 2020 and August 2020 because these months are the coldest and hottest months in winter and summer, respectively. First, the energy expense of FUs was analysed according to the operational patterns considered for the case studies. Figure 13 shows the distributions of the energy expense obtained in winter and summer, according to the operational pattern. Similar to the influence found in the months of lockdown, these operational patterns significantly influenced the values of the distributions, with average variations between 6.69 and 7.40% in the quartiles of the distributions obtained in winter, and between 3.19 and 5.61% in the quartiles of the distributions obtained in summer. The modifications of the operational patterns again showed a greater effect on the outliers of the distributions. In the most extreme cases, users could adopt more effective HVAC system use patterns to reduce the energy expenditure of their FU without affecting the thermal comfort in indoor spaces. In addition, the effect of the winter conditions on the energy expenditure was greater than that in summer, with a difference between €23 and €114 in the quartile values. This difference was due to the possibility of the thermal conditioning of indoor spaces with natural ventilation in summer, which would reduce the number of hours of HVAC system use and thus the energy consumption of dwellings.

Figure 13. Distribution of the energy expense of FUs in a lockdown in the summer and winter months, according to the operational patterns of the HVAC systems considered.



Regarding the energy poverty risk in the winter month (Figure 14), there were values of EPR greater than those found in March during the lockdown. In this regard, the values of EPR presented increases of up to 84% compared with those obtained in March, implying that in some cases, such as FU-01, the energy expense was almost twice the incomes of the FUs. Likewise, the energy poverty risk in winter increased in FUs with higher incomes. Thus, lockdown in a winter month with a greater heating energy demand than in March could lead to great energy poverty for unemployed FUs. In this regard, the summer month presented a high risk, with values similar to those found in April during lockdown. The use of the cooling system of dwellings could imply a greater energy consumption than the use of the heating system due to the lower performance considered for the equipment. However, the possibility of acclimatising the indoor space through natural ventilation reduced the use of these systems. Although there were cases of energy poverty until FU-09, the cases of energy poverty were very low from FU-06. This aspect implied that FUs receiving unemployment benefits greater than €1098 (corresponding to the maximum unemployment benefit for full-time jobs) were ensured a low risk of energy poverty. Nevertheless, the high values of EPR in the winter and summer months forced the establishment of economic aids through the electrical social bonus to mitigate cases of energy poverty (Figures 15 and 16). As expected, similar to the summer month, the application of discount strategies such as those observed in April achieved the same percentage reductions in cases of energy poverty according to the type of incomes of an FU. In this regard, the application of a social bonus of 25% reduced the cases of energy poverty in FUs with incomes equal to or greater than those of FU-07, and the 40% discount removed cases of energy poverty in FU-06. However, for FUs with lower incomes, the official discounts of 25% and 40% were insufficient. Thus, greater discounts should be applied. In this regard, the application of a social bonus of 70% removed cases of energy poverty in FU-05, and 80% removed cases of energy poverty in FU-04. For FUs receiving the subsidy or unemployment benefits because they have part-time jobs, a discount of 90% should be applied, except in the case of FU-01, where a 100% discount on the electricity bill is required. Nevertheless, in the winter month analysed, the discount from the electrical social bonus should be greater than the results obtained both in the summer month and in the months of lockdown. In March, the application of the 25% and 40% discount removed cases of energy poverty in the FUs with high incomes (FU-09 and FU-10), but the winter month did not completely remove the energy poverty risk. Thus, a 50 % discount is required. Furthermore, FU-01, FU-02, FU-03, and FU-04 required 100% discounts to completely remove the risk of energy poverty. These results show the substantial energy poverty risk that the Spanish FUs receiving unemployment benefits face if confined in the months with the most severe weather. Because these monthly unemployment benefits cannot ensure that FUs are not in unemployment situations, the discounts received through the electrical social bonus should be adapted on a monthly basis and to the FU's incomes. Additionally, because the energy poverty risk was low for incomes higher than those of FU-06 (i.e. €1,098), the possibility of adding the monthly incomes of unemployed FUs to this limit value during severe lockdown episodes should be assessed. The combination of increases in monthly incomes due to the unemployment of these FUs or the modification of the electrical social bonus would reduce the energy poverty risk of the most vulnerable households and guarantee that these households have sufficient economic resources to manage their other expenses, such as food or medicine. In addition, guaranteeing acceptable economic conditions for FUs such that they avoid energy poverty can have a positive impact on other aspects, such as improved childcare for children (David Gómez-Quintero et al., 2020) and an increase in the birth rate (Puig-Barrachina et al., 2020). Second-most viewed title

Figure 14. Variation of the distribution of results of the energy poverty ratio in the scenario of lockdown in the summer and winter months, according to the incomes considered of the FU obtained with the unemployment benefits and without the economic aid of the electrical social bonus. The red line represents the 10% threshold for Spain.

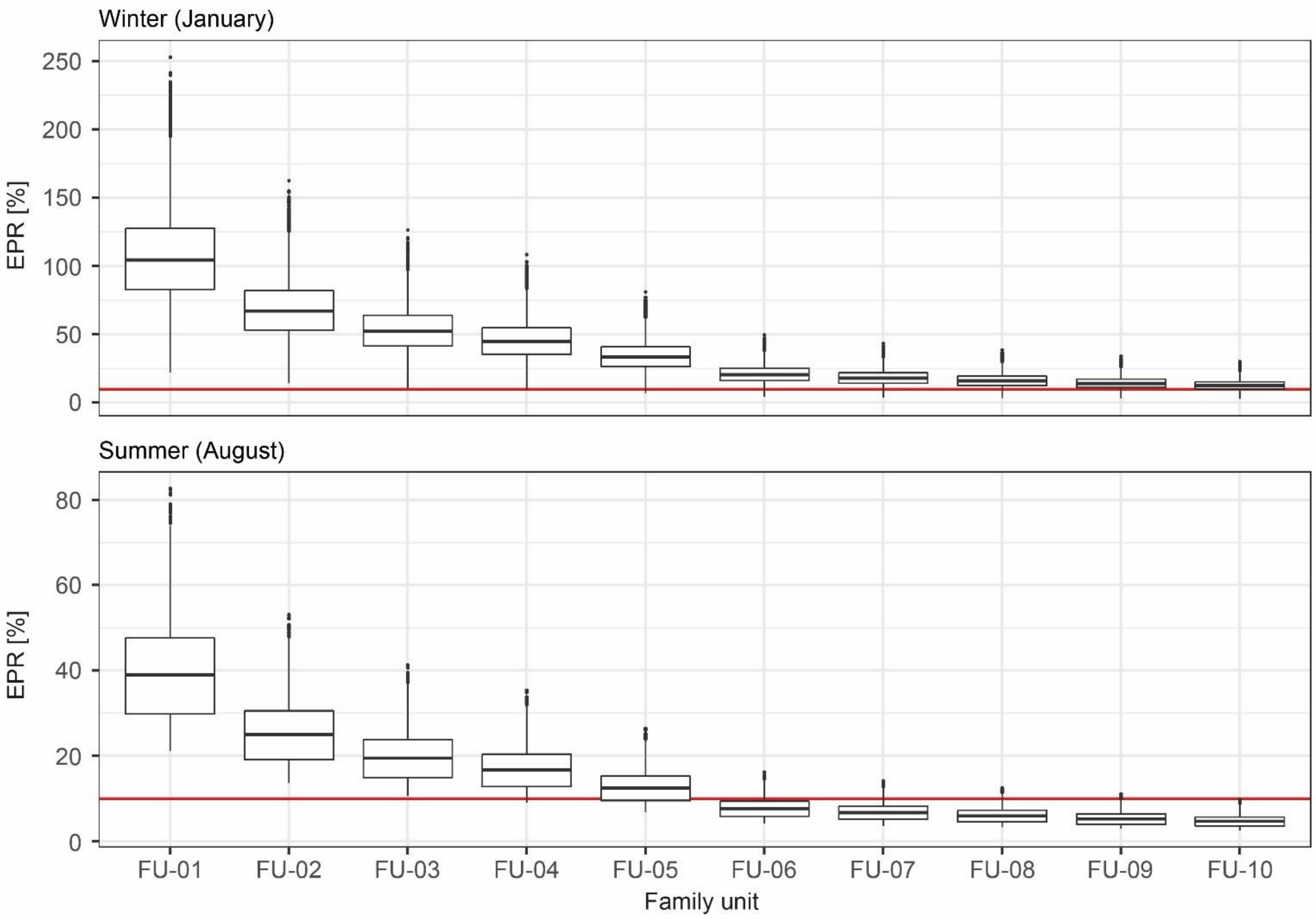


Figure 15. Variation of the distribution of results of the energy poverty ratio in the scenario of a lockdown in the summer and winter months, according to the incomes considered of the FU obtained with the unemployment benefits and the discount obtained with the electrical social bonus (the two existing discounts and the new discounts considered in this research). The red line represents the 10% threshold for Spain.

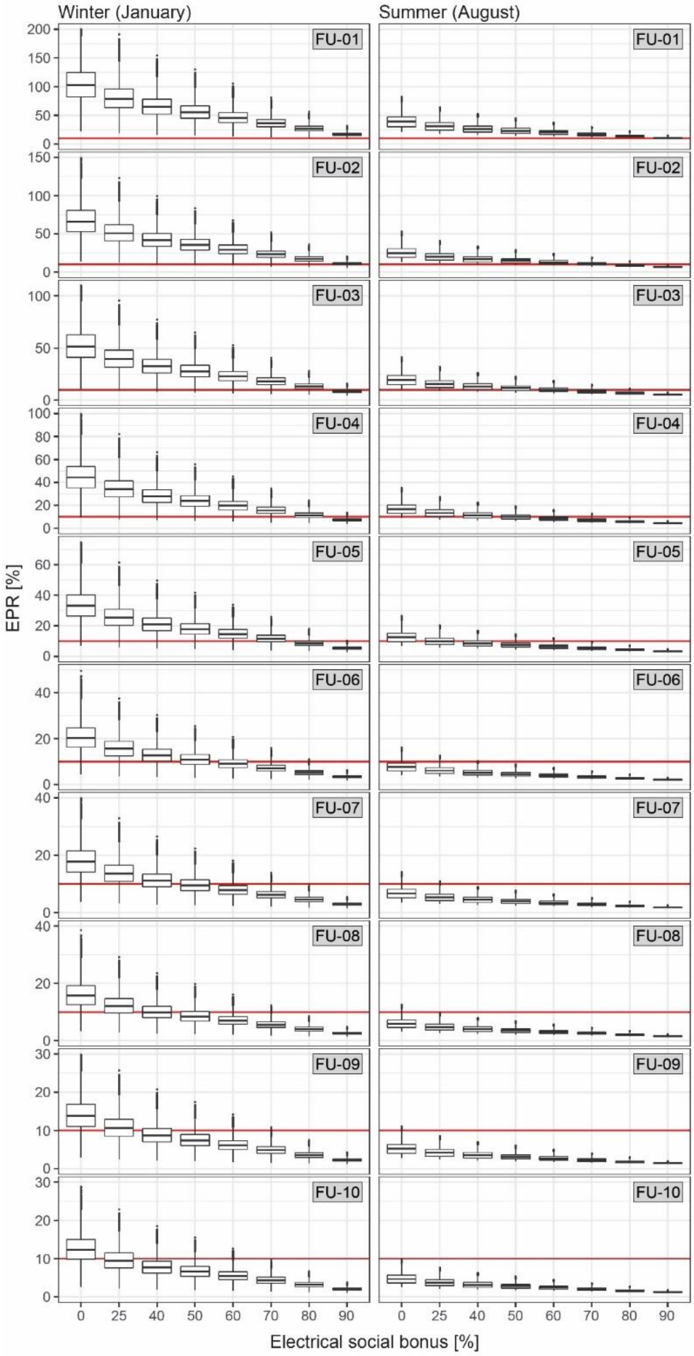
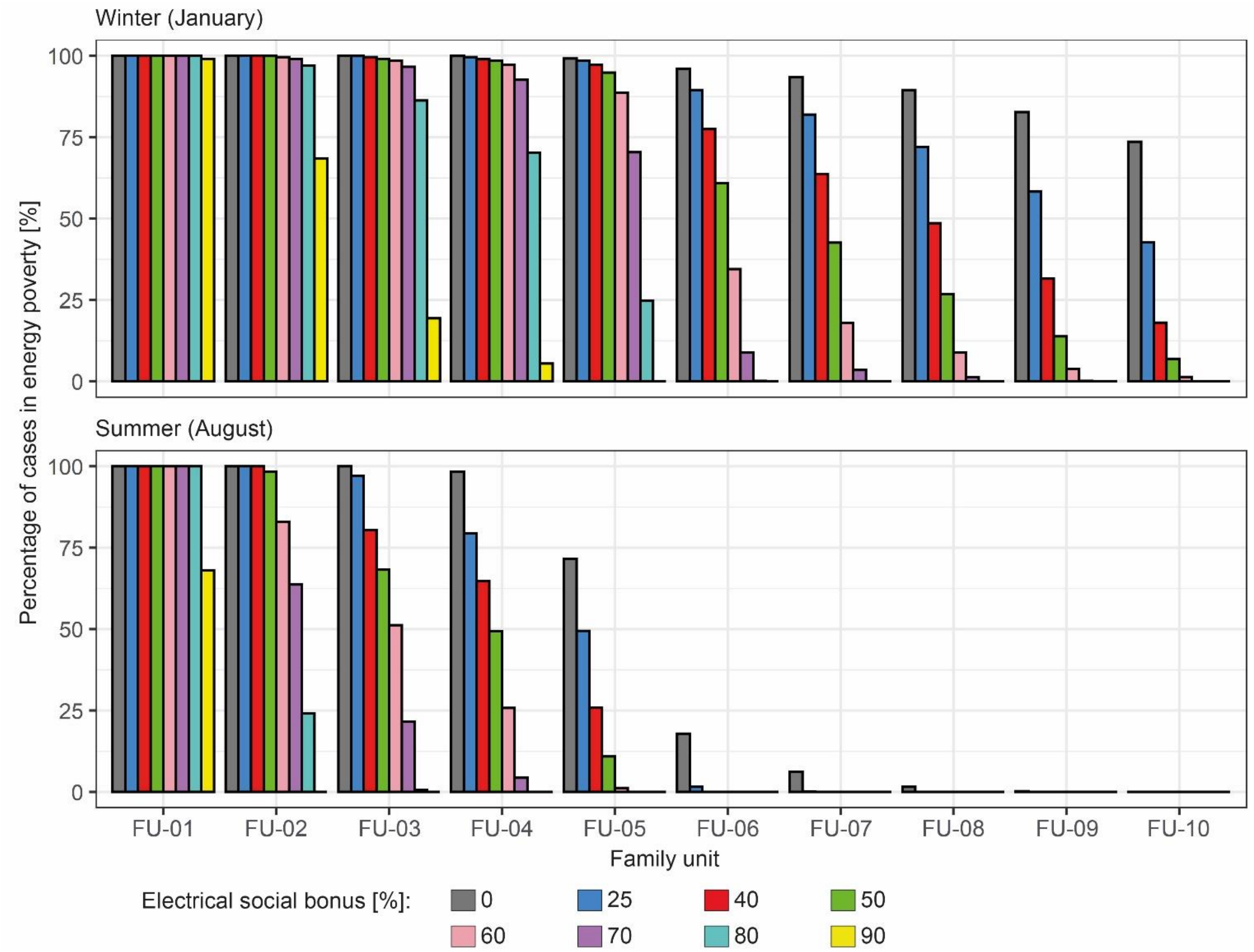


Figure 16. Variation of the percentage of cases at energy poverty risk in the scenario of a lockdown in the summer and winter months, according to the incomes considered of the FU obtained with the unemployment benefits and the discount obtained with the electrical social bonus (the two existing discounts and the new discounts considered in this research).



5. Conclusions and policy implications

The COVID-19 pandemic has changed the economic situation and the lockdown guidelines of many FU. In Spain, the economic effect of the pandemic is among the greatest in the European Union. Due to this situation, the monthly income of many FUs is the unemployment benefits they receive from the Spanish government. Their options to find jobs have been limited by the lockdown, and they have had to spend more time in their homes, thus generating greater energy consumption. This research analysed the energy poverty risk of confined unemployed families.

The results showed that the income from the existing unemployment benefits in Spain does not guarantee the prevention of energy poverty. In general, the monthly incomes from these benefits result in a very high risk of energy poverty. Only FUs with monthly incomes from unemployment benefits greater than the minimum guaranteed interprofessional wage regulated by the Spanish government (in 2020, this wage had a monthly income value of €950) had a lower number of cases of energy poverty. Thus, an increase in unemployment benefits, such as the subsidy, to values of the minimum guaranteed interprofessional wages would reduce the energy poverty risk in these FUs. This increase in the amounts from the unemployment benefits should apply particularly pandemic-induced lockdown periods coincide with unemployment, difficulty in finding a job, increased time in dwellings, and increased energy consumption and expense.

Likewise, increases greater than those in the existing electrical social bonus should be established such that FUs can manage the energy expense. The results of this research suggest the possibility of establishing a variable discount according to the incomes of FUs and the month. In certain cases, the low level of family incomes from unemployment benefits should be balanced by an electrical social bonus that pays FUs' total electricity bill. Additionally, increasing the flexibility of the requirements is necessary for more FUs to benefit from the social bonus. Today, the social bonus is based on the annual incomes of the previous year. However, the economic situation of FUs can substantially vary by year, such as the COVID-19 pandemic has demonstrated. An individual analysis based on the current incomes of FUs conducted by social services would imply that a large number of FUs would benefit from this type of economic aid and thus decrease energy poverty.

Furthermore, the substantial probability of many cases of energy poverty during months-long lockdown at a time of great climate severity. The lockdown period for the pandemic coincided with the spring months when the heating and cooling energy demand is not very high. However, the results showed that unemployment aids and the discount on the electricity bill are insufficient to manage a lockdown period in the winter and summer months and thus facilitates energy poverty.

However, official bodies are not solely responsible for decreasing cases of energy poverty, because users could decrease them by adopting acceptable behaviours when using equipment that consumes energy. In this regard, modification of the operational patterns of the HVAC systems by using effective setpoint temperatures reduced the monthly energy expense of the case studies and particularly influenced those cases that recorded the greatest values of monthly energy expense. Thus, the design of information and online training programs on the use of HVAC systems for unemployed families can reduce the energy poverty risk without affecting thermal comfort. The training of users would fall within the measures considered by the National Strategy against Energy Poverty (2019-2024) to reduce the energy poverty risk. Training measures (use of HVAC systems) and social measures (electrical social bonus) can be considered valid in the short term. In the medium term, it is essential to improve the energy efficiency of buildings to ensure that during future confinements, users reside in energy-efficient buildings. For this, it is essential to finance measures for the energy improvement of buildings (improvement of the thermal performance of the envelope or improvement of HVAC systems). In this sense, the Government of Spain has designed several financing programs in recent years, such as the Program for the Energy Rehabilitation of Buildings (PAREER-CRECE and PAREER II) and the Program for the Energy Rehabilitation of Buildings (PREE). However, the energy retrofitting rate is still slow and low, so it is also necessary to increase energy renewal awareness in society.

Likewise, the episodes of lockdown and the economic crisis may make it difficult to achieve the objectives established in the National Strategy against Energy Poverty (2019-2024). According to these objectives, by 2025 the values of the different energy poverty indicators obtained in 2017 (including 2M) should be reduced by between 25% and 50%. If the lockdown episodes occur without the modification of the characteristics of the electrical social bonus and a change in the consumption behaviour of the users in the use of HVAC systems, it will be difficult to alleviate or eradicate energy poverty.

Finally, the international aspect of the results should be emphasised. The COVID-19 pandemic has demonstrated that today's society is a global ONE in which the changes produced in a region can affect other regions. Likewise, the impact of the pandemic on the economic activity of countries has followed a similar pattern: the stoppage of activities and the disappearance of employment. The results of this study are applicable to those countries that implement programmes for unemployment aid or discounts on electricity. In addition, the results of energy consumption and energy poverty could be extrapolated to other countries close to Spain (e.g., Portugal and Italy) and with similar economic living standards. Despite this, further research lines should be addressed by other research works. On the one hand, the variation that the discount from the electrical social bonus be based on the incomes of the household and the month of the year should be addressed through a more detailed analysis by studying the variability presented in recent years. On the other hand, the impact of the pandemic on FUs with small businesses and how incomes and energy poverty risk have decreased.

Nomenclature

2M: high share of energy expenditure in the income

AP: approach for the operational patterns of the HVAC systems

ElT: electricity tax

EMR: rent of the digital electricity meter

EPOV: European Energy Poverty Observatory

EPR: energy poverty ratio

EPW: EnergyPlus Weather

ESB: discount of the electrical social bonus

ET: energy term

FU: family unit

HVAC: heating, ventilation and air conditioning

NBE-CT-79: first standard for energy efficiency in buildings (Spain)

PT: power term

PVPC: Voluntary Price for the Small Consumer (Spain)

Q1: first quartile

Q2: second quartile

Q3: third quartile

VAT: value-added tax

References

Aguilar-Palacio, I., Carrera-Lasfuentes, P., Rabanaque, M.J., 2015. Youth unemployment and economic recession in Spain: influence on health and lifestyles in young people (16–24 years old). Int. J. Public Health 60, 427–435.

https://doi.org/10.1007/s00038-015-0668-9

Alsafi, Z., Abbas, A.R., Hassan, A., Ali, M.A., 2020. The coronavirus (COVID-19) pandemic: Adaptations in medical education. Int. J. Surg. 78, 64–65. https://doi.org/10.1016/j.ijsu.2020.03.083

Bienvenido-Huertas, D., 2020. Analysis of the impact of the use profile of HVAC systems established by the spanish standard to assess residential building energy performance. Sustain. 12. https://doi.org/10.3390/su12177153

Boardman, B., 1991. Fuel Poverty: From Cold Homes to Affordable Warmth. John Wiley & Sons Ltd, London, UK.

Bouzarovski, S., Petrova, S., 2015. A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary. Energy Res. Soc. Sci. 10, 31–40. https://doi.org/10.1016/j.erss.2015.06.007

Ceylan, R.F., Ozkan, B., Mulazimogullari, E., 2020. Historical evidence for economic effects of COVID-19. Eur. J. Heal. Econ. https://doi.org/10.1007/s10198-020-01206-8

Chakraborty, I., Maity, P., 2020. COVID-19 outbreak: Migration, effects on society, global environment and prevention. Sci. Total Environ. 728, 138882. https://doi.org/10.1016/j.scitotenv.2020.138882

Dallari, P., Ribba, A., 2020. The dynamic effects of monetary policy and government spending shocks on unemployment in the peripheral Euro area countries. Econ. Model. 85, 218–232. https://doi.org/10.1016/j.econmod.2019.05.018

David Gómez-Quintero, J., García Martínez, J., Maldonado, L., 2020. Socioeconomic vulnerability and housing insecurity: A critical factor in child care in Spain. Child. Youth Serv. Rev. 114, 105021. https://doi.org/10.1016/j.childyouth.2020.105021

del Río, P., Gordo, E., 2019. World economic outlook for 2019.

Domínguez-Amarillo, S., Sendra, J.J., Oteiza, I., 2016. La envolvente térmica de la vivienda social. El caso de Sevilla, 1939 a 1979. Editorial CSIC: Madrid.

Dubois, G., Sovacool, B., Aall, C., Nilsson, M., Barbier, C., Herrmann, A., Bruyère, S., Andersson, C., Skold, B., Nadaud, F., Dorner, F., Moberg, K.R., Ceron, J.P., Fischer, H., Amelung, D., Baltruszewicz, M., Fischer, J., Benevise, F., Louis, V.R., Sauerborn, R., 2019. It starts at home? Climate policies targeting household consumption and behavioral decisions are key to low-carbon futures. Energy Res. Soc. Sci. 52, 144–158. https://doi.org/10.1016/j.erss.2019.02.001

Hiscott, J., Alexandridi, M., Muscolini, M., Tassone, E., Palermo, E., Soultsioti, M., Zevini, A., 2020. The global impact of the coronavirus pandemic. Cytokine Growth Factor Rev. 1–9. https://doi.org/10.1016/j.cytogfr.2020.05.010

Hosseini, S.E., 2020. An outlook on the global development of renewable and sustainable energy at the time of COVID-19. Energy Res. Soc. Sci. 68, 101633. https://doi.org/10.1016/j.erss.2020.101633

Kurtz, F., Monzón, M., López-Mesa, B., 2015. Energy and acoustics related obsolescence of social housing of Spain's post-war in less favoured urban areas. The case of Zaragoza. Inf. la Construcción 67, m021. https://doi.org/10.3989/ic.14.062

Legendre, B., Ricci, O., 2015. Measuring fuel poverty in France: Which households are the most fuel vulnerable? Energy Econ. 49, 620–628. https://doi.org/10.1016/j.eneco.2015.01.022

Liddell, C., Guiney, C., 2015. Living in a cold and damp home: frameworks for understanding impacts on mental well-being. Public Health 129, 191–199.

Lopez, L., Rodo, X., 2020. The end of the social confinement in Spain and the COVID-19 re-emergence risk. medRxiv 1–7. https://doi.org/10.1101/2020.04.14.20064766

Meyer, S., Laurence, H., Bart, D., Lucie, M., Kevin, M., 2018. Capturing the multifaceted nature of energy poverty: Lessons from Belgium. Energy Res. Soc. Sci. 40, 273–283. https://doi.org/10.1016/j.erss.2018.01.017

Middlemiss, L., Gillard, R., 2015. Fuel poverty from the bottom-up: Characterising household energy vulnerability through the lived experience of the fuel poor. Energy Res. Soc. Sci. 6, 146–154.

Nicola, M., Alsafi, Z., Sohrabi, C., Kerwan, A., Al-Jabir, A., Iosifidis, C., Agha, M., Agha, R., 2020. The Socio-Economic Implications of the Coronavirus and COVID-19 Pandemic: A Review. Int. J. Surg. 78, 185–193. https://doi.org/10.1016/j.ijsu.2020.04.018

Oteiza San José, I., 2018. La envolvente energética de la vivienda social: el caso de Madrid en el periodo 1939-1979. CSIC, Consejo Superior de Investigaciones Cient{\'\i}ficas.

Puig-Barrachina, V., Rodríguez-Sanz, M., Domínguez-Berjón, M.F., Martín, U., Luque, M.Á., Ruiz, M., Perez, G., 2020. Decline in fertility induced by economic recession in Spain. Gac. Sanit. 34, 238–244. https://doi.org/10.1016/j.gaceta.2019.05.011

Saez, M., Tobias, A., Varga, D., Barceló, M.A., 2020. Effectiveness of the measures to flatten the epidemic curve of COVID-19. The case of Spain. Sci. Total Environ. 727, 138761.

https://doi.org/10.1016/j.scitotenv.2020.138761

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

Seebauer, S., 2018. The psychology of rebound effects: Explaining energy efficiency rebound behaviours with electric vehicles and building insulation in Austria. Energy Res. Soc. Sci. 46, 311–320. https://doi.org/10.1016/j.erss.2018.08.006

Shortt, N., Rugkåsa, J., 2007. “The walls were so damp and cold” fuel poverty and ill health in Northern Ireland: Results from a housing intervention. Heal. Place 13, 99–110. https://doi.org/10.1016/j.healthplace.2005.10.004

Spanish Institute of Statistics, 2020. Labor force survey [WWW Document]. URL https://www.ine.es/dynt3/inebase/index.htm?padre=979&capsel=979

The Government of Spain, 2020. Employment regulation statistics advance. January 2020 - August 2020 [WWW Document]. URL http://www.mites.gob.es/estadisticas/Reg/reg20ene_ago/reg_08_2020.pdf

The Government of Spain, 2019. National Strategy against energy poverty 2019-2024 (Spain).

The Government of Spain, 2017. Royal Decree 897/2017. Approving the electrical social bonus.

The Government of Spain, 2014. Royal Decree 216/2014, of 28 March, sets out the methodology for the calculation of the Voluntary Price for the Small Consumer.

The Government of Spain, 1985. Royal Decree 625/1985. Unemployment Protection.

The Government of Spain, 1979. Royal Decree 2429/79. Approving the Basic Building Norm NBE-CT-79, about the Thermal Conditions in Buildings, Normas básicas de la edificación.

Thomson, H., Snell, C., 2013. Quantifying the prevalence of fuel poverty across the European Union. Energy Policy 52, 563–572. https://doi.org/10.1016/j.enpol.2012.10.009

Tirado Herrero, S., Jiménez Meneses, L., López Fernández, J.L., Perero Van Hove, E., Irigoyen Hidalgo, V.M., Savary, P., 2016. Poverty, vulnerability and energy inequality. New approaches to analysis, 1ª. ed. Madrid.

Tirado Herrero, S., López Fernández, J.L., Martín Gracía, P., 2012. Energy poverty in Spain. Employment generation potential derived from housing rehabilitation, 1ª. ed. Madrid.

Ürge-Vorsatz, D., Tirado Herrero, S., 2012. Building synergies between climate change mitigation and energy poverty alleviation. Energy Policy 49, 83–90. https://doi.org/10.1016/j.enpol.2011.11.093

Vilches, A., Barrios Padura, Á., Molina Huelva, M., 2017. Retrofitting of homes for people in fuel poverty: Approach based on household thermal comfort. Energy Policy 100, 283–291. https://doi.org/10.1016/j.enpol.2016.10.016