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Measuring the discomfort of energy vulnerable elderly people. Recommendations for solutions

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Abstract. Energy poverty remains today one of the most important problems for a truly just urban energy transition. In addition, older people living alone are one of the main target groups of this problem. In this research, 525 households have been monitored of which 155 were potentially in fuel poverty in the city of Valencia, Spain. In the latter, the presence in the dwelling, temperature and humidity were monitored throughout the year. We reviewed the literature and compared different comfort standards with the data collected. None of the 155 dwellings meet the comfort requirements on a regular basis. That is, their inhabitants are too often at risk to their health because of low or high temperatures and humidity. A survey was conducted to find the causes of the vulnerability of these families and to quantify their importance. In addition to the expected causes: low income, high energy prices and poor housing quality, we found elements related to habits, low energy literacy, the digital divide and others. Our findings can inform policy development for an inclusive urban energy transition that does not leave behind older people living alone.

1. Introduction

The European Union (EU) is leading the way to the energy transition showcasing a paramount plan to reach an emissions reduction by 55% from 1990 levels by 2030 [1]. However, one topic that has only received limited attention to-date refers to the social justice implications resulting from this transformation [1]. In fact, there is a clear risk that climate policies could impose a financial burden on the poor through increased energy and food prices [2]. Hence, for Energy Transition to be successful it must avoid leaving energy poor behind [2].

The framing of energy poverty (or vulnerability), although a complex multi-dimensional concept, can be intuitively understood as a situation of impossibility to meet basic energy needs at an affordable cost. The causes are generally a sort of combination of low income, poor house insulation and high energy prices [2]. As a consequence, energy poverty correlates with important health issues, linked to extreme winter and/or summer temperatures and or humidity, mental health problems [3] and exacerbates social inequalities [4].

Energy poverty has only recently gained substantial attention by the European policy community. In Europe it was estimated that about 50 million individuals in 2018 experienced energy poverty [1].

Besides, there is currently a lack of clear agreement on indicators related to energy vulnerability. In fact, how to identify energy poverty and its consequences is still an object of debate [3]. This is due to the complexity of energy poverty, which involves several multi-dimensional aspects that are frequently not easily quantifiable, mostly related to cultural and/or social factors [3].

Research aims and objectives

For this research, we took advantage of a former H2020 European-funded project to make the lives of people living alone more active and fulfilling: ACTIVAGE (http://www.activageproject.eu/). Beneficiaries had to be low-income and signed an agreement to have their homes monitored to identify sedentary, health and other problems. In this way recommendations could be given in line with the project objectives. 525 households were selected and the potential to study other phenomena was then realized, such as energy poverty, its causes and consequences. Based on the reviewed literature, very few, if any, studies have analysed direct data from these vulnerable households. That is, they work with proxies such as energy expenditure, income, age of the dwelling, etc., but do not know the temperature and humidity (comfort) data of these dwellings [2]. This is due to the difficulty of monitoring dwellings, the need to protect people's privacy, and the sensitivity of the issue of low incomes and poor living conditions. Indeed, this lack of data prevents the identification of households in fuel poverty who spend as little as possible on energy, these families do not appear on the statistics.

Therefore, this research aims to obtain real direct data from energy vulnerable households, in this case, elderly people living alone. In this way, the understanding of energy poverty derived from traditional studies based on proxies can be completed. Thus, the objectives of the study are:

- To measure the consequences of fuel poverty in terms of exposure to unhealthy temperature and humidity conditions.
- To collect complementary information on the causes of fuel poverty
- To propose measures to alleviate and mitigate fuel poverty.

The study corresponds to dwellings in Valencia, a medium-sized city on the Mediterranean East coast of Spain. The results obtained here can be extrapolated to households and dwellings in many similar cities in the European Mediterranean.

2. Context and methodology

As introduced, this study used the data collected at the ACTIVAGE participants' homes in the City of Valencia to analyze their comfort situation at home and identify potential unhealthy environmental conditions. Additionally, surveys were also carried out among the participants more exposed to risk in order to assess their vulnerability: energy use and consumption, dwelling conditions, socioeconomic situation etc. The participants of the study met the following criteria:

- Age above 65 years-old
- Living alone or spending more than 4 hours a day alone at his/her home
- Having at least one relative (or other close contact) able to give him/her support with the project program.

Of the 525 households in the project, 155 were selected because they were exposed to unhealthy temperature and humidity both in summer and winter.

Stakeholders involved in the study

This project was achieved by a joint effort of different entities: i) the Cátedra de Transición Energética Urbana, responsible for the study coordination, the data analysis and the energy assessment; ii) The SME Mysphera, in charge of the management of IoT devices (installation, data collection and filtering); and iii) Social agencies (Atenzia, Iniciativa Social Integral per al Benestar and Gesmed), ensuring the contact with the participants and doing the surveys, etc.

Sensors' data collection

The critical parameters measured during the research project were temperature (T) and relative air humidity (RH). Exposure time to these conditions was also registered through movement detection's sensors able to detect the presence of the participant in each room. Sensors were located in two spaces of the house, living room and bedroom, and measurements were taken in timelapses where the person was more likely to be in that particular room (day and night, respectively):

- the living room, from 9 am to 10 pm
- the main bedroom, from 10 pm to 9 am

There were two measurement periods: one during summer months (from 15.06 to 30.09) and another during winter months (from 15.12 to 30.03 the following year).

2.1. Data Filtering to identify participants at risk

As introduced, a filtering was performed to the data collected by the sensors for all the project participants to identify the ones potentially at risk of unhealthy environmental conditions at home. To do this, the thresholds above which temperature and humidity are not safe had to be identified.

The literature examining the link between health and indoor temperature highlight the complexity of setting single temperature thresholds at which human health is not endangered. The impact of the same temperature on different people can be affected by both physiological (e.g., sex, age, level of activity, state of health) and non-physiological (e.g., geographical location, dwelling type) aspects [5]. To date, there are limited studies focused on the relationship between mortality or morbidity and indoor temperature, meanwhile there is high certainty of evidence for excess mortality and morbidity due to outdoor temperatures [5]. The medical scientific literature recommends a minimum indoor temperature of 21 °C for vulnerable population and 18 °C for non-vulnerable population [6]. In addition, Van Loenhout et al. demonstrated that for elderly, sleep disorders appeared at a temperature above 25 °C (problems reported by 40% residents), while a study in the United Kingdom reported that the quality of sleep is already affected when temperature exceed 24 °C and recommended a temperature not higher than 26 °C [5]. It can be concluded that health risks of low indoor temperatures in cold climates have been more studied than high indoor temperature in hot climates. Besides, there is still uncertainty about:

- the direct health consequences of high indoor temperatures;
- "safe" temperature thresholds for vulnerable groups;
- "safe" temperature thresholds broken down by climatic zone;
- the effects of time spent (occasional or extended periods) in adverse conditions on health.

Hence, a decision had to me be made, and the study partners, based on the different sources, guidelines and regulation [6], established the following risk conditions:

- in the summer period: T>27ºC and/or RH>70%
- in the winter period: T<18ºC and/or RH<30%

Participants who had suffered at least one of these conditions while in one of the measured rooms, for at least 45 minutes within an hour, were identified as potentially at risk.

2.2. Data output

For each day within the measurement periods, and for each room, the following parameters were obtained.

2.2.1. Total Presences (TP): total number of "presences" per day. A presence is defined as a one-hour time slot when the participant has been at least 75% of the time (45 minutes) in a selected room. In other words, a time slot between 45 minutes and 1 hour spent in a specific room. This parameter expresses the amount of time the participant has spent in the room on this specific day.

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2.2.2. Presences at Risk (PR): number of presences per day when risk conditions have been registered (risk conditions specified in Data Filtering section). This parameter expresses the amount of time the participant has spent in the room on that specific day under risk conditions.

2.2.3. Exposure time (%t): percentage of time spent at risk conditions in relation to the time spent in a specific room. This parameter expresses how much time the user has been exposed to risk conditions in a room. It gives an idea, although with some limitations, of the vulnerability severity.

$$\%t = PR/TP \tag{1}$$

However, this exposure time measure has its limitations since it does not reflect:

- the time spent in another room of the house (other than the living room/bedroom, such as the kitchen, or at other timeslots than the measured ones, e.g. living room at 7am)
- the time when the person is not at home

Both situations can result in false negatives (users would not be selected as a person at risk when they actually are) if these moments spent outside the monitored rooms are under risk conditions or if they decide to go out (outside or to another home) to avoid uncomfortable conditions at home.

Equally, the methodology can give some false positives cases (users would be selected as a person at risk when they actually are not) if they spend only a few hours/week in a monitored room but a very high percentage of this time is under risk conditions. The study has tried to avoid these cases by checking that the time spent at home (total presences within the measurement period) is significant enough.

2.2.4. Daily average air temperature (Tm): registered in the timeslots under risk conditions in a selected room within the specific time range (day or night) assigned to that room. This parameter expresses the average temperature level of users when identified in risk conditions (please note this is not the general daily average temperature level but only the one under risk conditions).

2.2.5. Daily average relative humidity (RHm): registered in the timeslots under risk conditions in a selected room within the specific time range (day or night) assigned to that room. This parameter expresses the average humidity level of users when identified in risk conditions (please note this is not the general daily average humidity level but only the one under risk conditions).

2.2.6. Daily maximum/minimum air temperature (Tmax/Tmin): registered in the timeslots under risk conditions in a selected room within the specific time range (day or night) assigned to that room. This parameter expresses the extreme temperature level of users when identified in risk conditions (please note this is not the general daily maximum/minimum temperature level but only the one under risk conditions). In the study, Tmax and Tmin are used as extreme temperatures for the summer and winter periods, respectively.

2.2.7. Daily average relative humidity (RHmax/RHmin): registered in the timeslots under risk conditions in a selected room within the specific time range (day or night) assigned to that room. This parameter expresses the extreme humidity conditions of users when identified in risk conditions (please note this is not the general daily maximum humidity level but only the one under risk conditions). In this study, only RHmax will be taken into consideration since only high humidity values have been identified as representing a risk in the place of study (above threshold level of 70%).

Figure 1 is an example of a weekly representation of the exposure time at risk conditions of a user in summertime period, in the living room. The X axis represents the weeks and the Y axis the number of "presences" (or timeslots of at least 45 minutes spent in that room). Total presences (TP) and presences at risk conditions (PR) for each week are shown in blue and red, respectively.

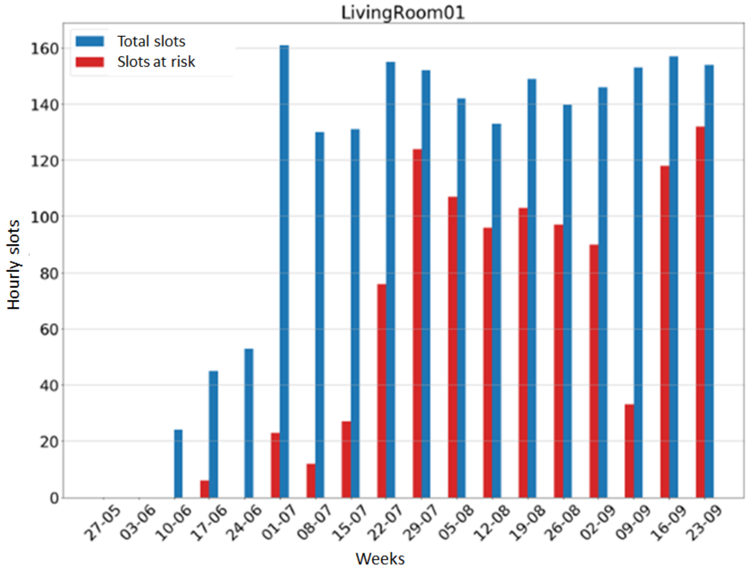

Figure 1. Example of the weekly exposure time at environmental (T, RH) risk conditions of a user, in summer and in the living room.

Survey on the causes of being exposed to risky temperatures and relative humidity.
To complete the study, a survey was conducted to identify the causes of people's exposure to health risk temperatures and humidity. For these, the agencies caring for these people, mostly within the social assistance program of Valencia City Council, chose those they knew who were most clearly classified as energy vulnerable. A visual inspection was made and a total of 70 families were interviewed who were selected on the basis of their conditions, and their willingness to participate voluntarily. Indeed, several families declined to participate because they rejected the idea of being called energy vulnerable or poor.

In the questionnaire there are questions on, the age of the dwelling and the age of the household appliances, heating and cooling systems, changes made to improve comfort in the home, income, etc. The questionnaire can be found in the annexes.

3. Discussion of Results

From the data we could estimate the distribution of extremes and average measures (both Tm and Tmax/Tmin; and both RHm and RHmax). We considered that both averages and extremes are important measures to depict the comfort conditions of the users, since, although averages show a general trend, they actually hide the real criticality.

3.1. Distributions

Starting by the distribution of extremes and average measures, figure 2 shows both Tm and Tmax/Tmin; and both RHm and RHmax. The shift of the Gaussian peak of the temperature distributions (minimum and average) in winter between the bedroom and the living room is associated with the temperature difference between day and night, and also shows the poor insulation of the homes. Indeed, in the City of Valencia, this is more pronounced in winter than in summer, and therefore in this season colder temperatures will be registered in the bedroom compared to the living room. Furthermore, it is observed that in winter the elderly went to the bedroom more than an hour earlier, on average, left the bedroom more than 2 hours earlier, on average, and fought the cold with blankets.

Following with the discussion on comfort, figure 3 shows the average temperature and the average of weekly temperature extremes for each family. As can be seen, the average temperatures are outside the comfort zone, and the average extreme temperatures are far outside the comfort zone. The latter measures the intensity of the risk.

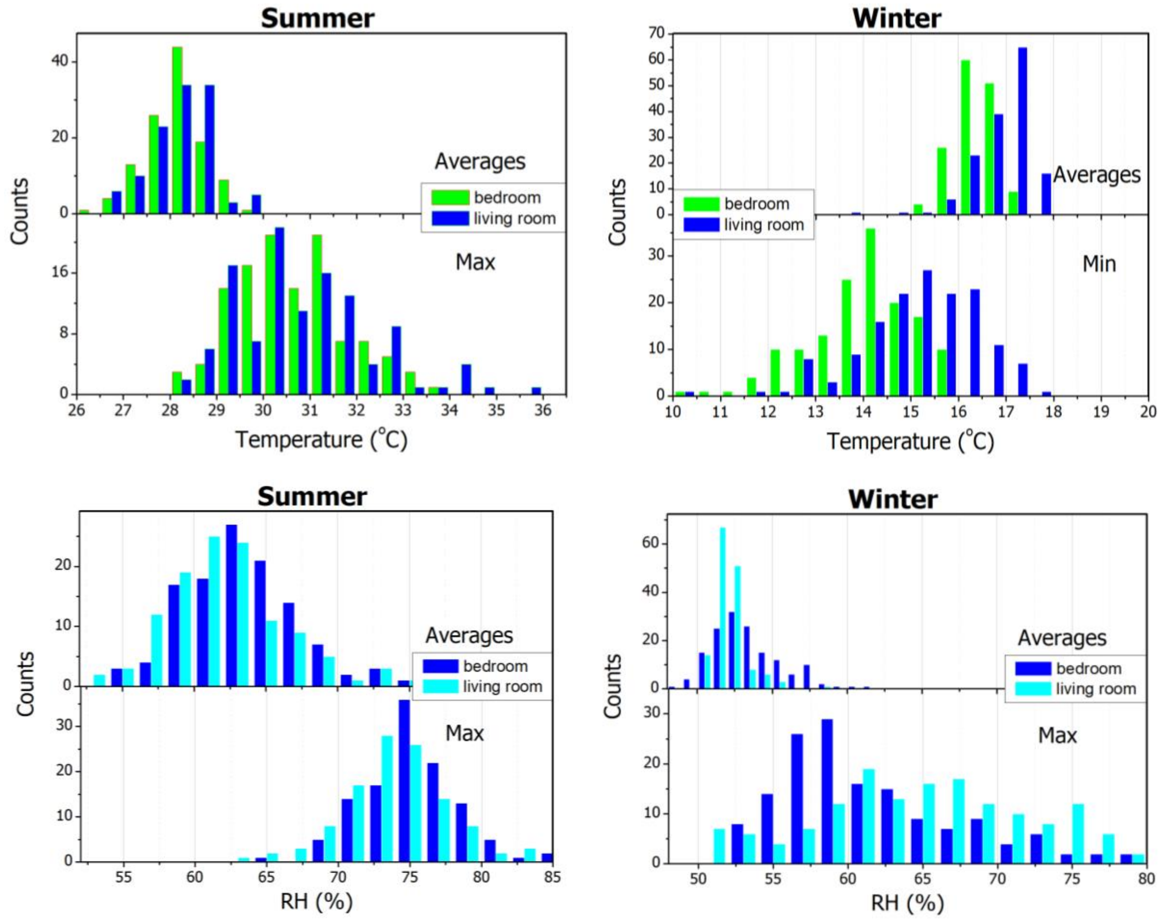

Figure 2. Distribution of extremes and average measures (both Tm and Tmax/Tmin; and both RHm and RHmax).

Figure 3 also shows the same calculation for average and extreme RH. In this case it can be seen that, while the averages usually fall in the comfort zone, the extreme values do not always do so in winter, and rarely in summer.

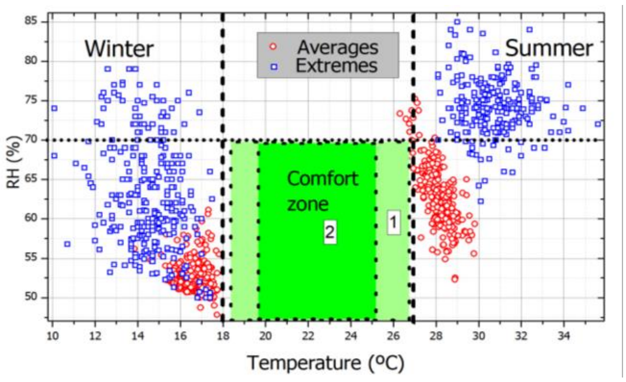

Figure 3: T-RH mapping showing average and extreme values (minimum and maximum Temperatures in winter and summer respectively, and maximum RH for both summer and winter) are reported.

These data are very valuable because they are among the few in the literature that show and quantify the consequences of fuel poverty in terms of exposure to temperatures and relative humidity of risk to health.

3.2. Surveys

Some of the key findings of the survey are discussed below.

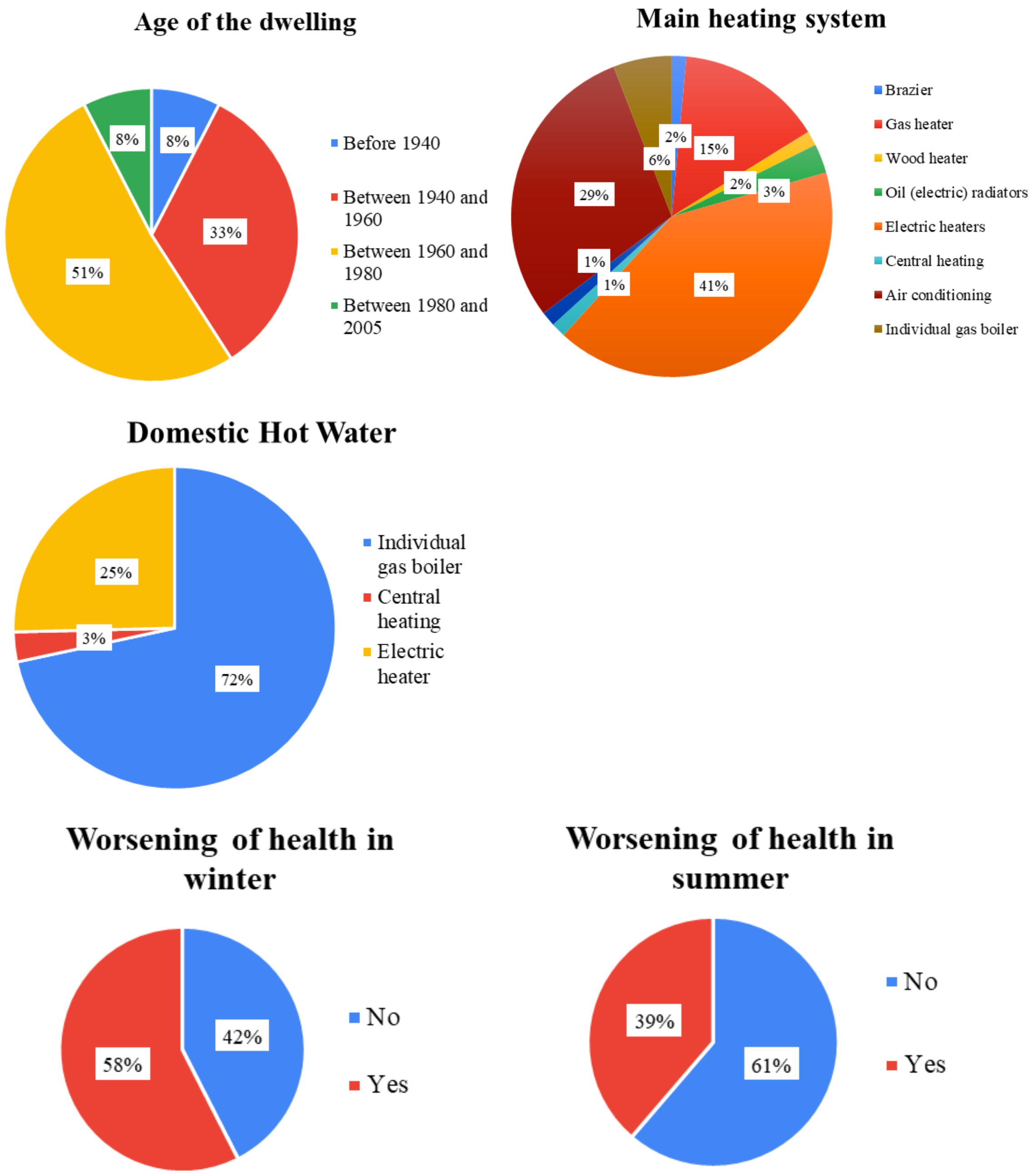

Figure 4: Several results from the survey about energy vulnerability causes

As figures 4 shows, the houses of the surveyed families are relatively old, and in those years, construction standards in Valencia were very poor. Moreover, due to the low income of the inhabitants, the houses have not been rehabilitated and still have old and inefficient energy installations, and several families use braziers, wood heaters and other high-risk heating systems as their main heating system. Only 29% of the families have air conditioning and the majority do not use it in summer in order to save energy. The rest have nothing to lower the temperature in summer, except fans, which are ineffective when the radiant temperature is high. As a consequence, approximately half of the interviewees declare that in the extreme seasons of the year their health worsens, a fact that was contrasted and corroborated by the social workers who care for them. This situation is worse in summer than in winter, but the situation in winter is worsened as a result of climate change. Another finding is that none of the households have, or conceived, shared air-conditioning or domestic hot water systems, let alone energy generation systems with renewable sources: solar, biomass, or underground energy, for example. But they would if it came from trusted people

Survey also found energy illiteracy in two ways: i) respondents are unaware of the existence of the term energy vulnerability and the support and subsidies they are entitled to; ii) respondents do not understand energy bills (gas/electricity), nor do they introduce energy efficiency habits such as correct management of insolation and ventilation, positioning of heaters, etc. Finally, they were not fully aware of the physical consequences of the exposure to long/intense periods of extreme temperatures and relative humidity.

4. Conclusions

The pursued energy transition will not be just if it does not solve energy poverty; but worse, it may fail, as the “yellow vest protests” showed, or the polluting and risky habits found in some of the survey’s respondents. This study allows to confirm and quantify the presumed consequences of energy vulnerability: undue exposure to extreme temperatures and humidity that pose a health risk. In fact, the intensity and duration of risk exposure in some cases has been surprising.

The causes of this vulnerability are the known ones: low incomes, poor energy quality of the dwellings and high energy price. To these, many older people add a low training in matters related to energy, its billing and its correct management.

Other conclusions of the study are that the risk to health is of the same magnitude in summer as in winter in cities such as Valencia, and it will become worse with the evolution of Climate Change. In addition, energy transition policies must improve the quality of housing, keep energy prices affordable, improve people's energy culture and, in the case of the elderly, overcome the digital divide. Finally, the development of electrical and thermal energy communities can alleviate the impact of investments for these families, while also helping to alleviate their condition of unwanted loneliness.

5. Acknowledgments

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6. Appendices

Annex 1: Questionnaire on the causes of suffering inadequate temperature and humidity conditions

1. Ownership status of the dwelling
- Tenant
- Owner

2. Age of the dwelling:
- After 2005
- Between 1980 and 2005
- Between 1960 and 1980
- Between 1940 and 1960
- Before 1940

3. ON HEATING/COOLING SYSTEMS
3.1. LIVING ROOM
- What type(s) of heating/cooling system(s) is/are being used for the space? Please select all that apply.
- Electric Radiators
- Air-conditioning Hot/Cold Central Heating
- Individual gas boiler
- Fans
- Wood burning cooker
- Gas cooker
- Fireplace
- Photovoltaic solar panels
- Other : ...

3.2. BEDROOM
- What type(s) of heating/cooling system(s) is/are being used for the space? Select all that apply.
- Electric radiators
- Air-conditioning Hot/Cold Central Heating
- Individual gas boiler
- Fans
- Wood burning cooker
- Gas cooker
- Fireplace
- Photovoltaic solar panels
- Other : ...

4. What type of system(s) is/are being used to obtain hot water (gas boiler, electric heaters...)? Please select all that apply.
- Central heating
- Individual gas boiler
- Electric boiler
- Solar thermal panels
- Other: ...

5. In addition, you observe in the house (please select all that apply):

6.2. Only during the summer and due to the heat: does the user suffer from:? Please select all that apply.
- Dizziness
- Diarrhoea
- Vomiting
- Choking sensation (frequent)
- Other: ...

7. Old electrical appliances and appliances. Please select all that apply.
- Very old refrigerator (pre-1980 model)
- Very old washing machine (model before 1980)
- Very old oven (model before 1980)
- Incandescent light bulbs (not energy saving)
- Other: ...

8. ON HOUSEHOLD INCOME
Do you think this person has problems paying electricity bills (interviewer's perception)?
- Yes (interviewer's perception)
- No (interviewer's perception)
- Don't know

What is your perception of the respondent's income?
- No income
- Very low (less than the income guarantee of social inclusion of the Com. Valenciana)
- Low income
- High or very high

9. ABOUT ENERGY CONSUMPTION
9.1. Electricity bills without personal data (with user code)
9.2. Gas bills without personal data (with user code)
9.3. In the last 12 months, due to financial difficulties, have you had delays in the payment of energy bills (electricity, gas, etc.)?
- Yes No
- Other: ...

9.4. Is there an inability to keep the house at an adequate temperature for financial reasons?
- Yes No
- Other: ...

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- Candles (and use them with some frequency)
- Old heating systems (braziers, chimney, burnt debris, etc.)
- Damp stains (including mould and mildew) on walls and ceilings
- Windows with deteriorated frames and/or broken glass.
- Blankets everywhere
- Easily identifiable cold draughts
- Plain windows (only one layer of glass)
- Unusual dress for indoor use (coat on in winter, underwear on in summer...)
- Other: ...

6. ON UNHEALTHINESS DUE TO INADEQUATE TEMPERATURE

6.1. Only during the winter and due to the cold: does the user suffer from:?
- Chilblains
- Breathing problems
- Joint or bone pain
- Other: ...

9.5. Has it ever happened to you that you had to leave home because of not having a comfortable temperature at home?
- Only some
- Often
- Not often
- Other: ...

9.6. Does the user receive a social energy voucher (electricity/gas)?
- Yes No
- Other: ...

9.7. Have you made any changes to improve the temperature in your home and/or reduce energy consumption?
- Use of an outdoor awning
- Change to LED or energy-saving light bulbs
- Insulating your home
- Purchase of more efficient appliances
- Change of electricity supplier
- Installation of solar panels
- Other: ...