THERMAL BEHAVIOR OF LOW-INCOME HOUSES IN THE MEDITERRANEAN REGION, DURING SUMMER

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ABSTRACT

Creating conditions that are suitable for occupants' thermal comfort is essential for providing an appropriate indoor environment. Many studies report an association between indoor temperatures and thermal environment in residential buildings, as urban residents typically spend most of their time indoors. This paper presents the results of a survey, which records the differences in indoor temperatures for summer, among low-income dwellings in Cyprus and examines their analysis and comparative studies with outdoor ambient weather.

Indoor temperature monitoring has been carried out in ten (10) low-income houses in the city of Limassol, followed by a questionnaire based on economic aspects survey amongst the residents of the houses, in order to evaluate the thermal comfort of the indoor environment of low-income households during the summer season.

The temperature monitoring has been carried out using data loggers and the measurements were performed for the period between June and August of 2014. The relationship between indoor temperatures of the dwellings and outdoor ambient weather conditions is also examined. Furthermore, a questionnaire was contacted amongst the occupants of the houses, in order to develop an understanding of their economic circumstances and their perception of their comfort conditions. From the analysis of the results it was found that during the summer season, there is overheating in the low-income households leading to the thermal discomfort of the residents.

Keywords: Indoor temperatures; Thermal environment; Outdoor weather; Low-income households;

1. Introduction

For fulfilling the thermal comfort conditions, to protect human health and to improve quality of life, appropriate indoor temperature of buildings is an essential requirement. A percentage of 16.4% of the world population lives below the poverty line, residing in houses with poor indoor environmental conditions [2]. Year after year, the population in Cyprus is increasing (865,900 people in 2012) during the same period the average annual income of the Cypriot citizen is being reduced. The monetary poverty risk threshold in Cyprus is the annual amount of €9.524 per person and €20.001 for households with two adults and two dependent children under 14 years [1].

Official statistics in Europe show that the percentage of population living in low-income homes, in different European countries, is ranging from 10 to 25% [3]. Very high internal temperatures during the summer have serious impact on the quality of the indoor environment and significant impact on households' prosperity, leading to a seasonal increase in mortality [3,7]. The average internal temperature of 29 °C during summer is proposed to be within the limits of the comfort zone in Cyprus [4,5,6]. Moreover, a large portion of the low-income population cannot finance their energy needs for housing and they live in thermal conditions, which are outside the comfort limits. These conditions force them to spend a much higher proportion of their income in order to obtain for covering thermal comfort in their houses [7].

Summertime temperatures in low-income housing are of increasing concern for at least three reasons. First, very high indoor temperatures can be life threatening. Second, whilst elevated temperatures can be overcome with air conditioning, this would simply increase electricity use and would be for Cyprus a new source of greenhouse gas emissions. Third, high temperatures are likely to occur more often as global temperatures rise [8]. It is therefore imperative to investigate indoor summertime temperatures in low-income Cypriot homes, and the effect of thermal comfort and occupant behaviour on these temperatures. This paper is based on a survey that assesses thermal behavior. The results are subsequently compared with outdoor ambient temperatures.

2. Methodology

Ten low-income households were selected for daily monitoring in Limassol. The most important criterion taken into account for their selection was the annual income which falls into the monetary poverty hazard limit of Cyprus. A miniature temperature sensor (Key Tag KTL-108) was placed in each house, which was adjusted to measure the internal temperature at intervals of one hour. All sensors were placed in a well-ventilated and protected from any temperature alternations area in the house, which is used by all members of the household, mainly the living room. Also, all sensors were properly calibrated, with their accuracy being better than 0,5 K. Temperature measurements were taken between June and August 2014 and the analysis was performed using the software package MATLAB. For the entire period of the study, the daily outdoor, ambient temperature data of the external environment were obtained by Cyprus Meteorological Service. All information about the main characteristics, the comfort conditions and the financial household sectors were collected using a questionnaire similar to that used in the LARES study. The questionnaires are answered during meetings with the tenants.

3. Case studies and results

Limassol is the second largest city of Cyprus and the southernmost of Europe. The population amounts to 241,900 inhabitants [1]. Limassol has an intense Mediterranean climate with hot dry summers and quite mild winters. Spring and autumn are effectively short intervals, characterized by good weather. It has clear skies and sunshine all year round. The following analysis focuses on the data collected during the summer months June, July and August.

3.1. Characteristics of the dwellings included in the study

The dwellings which were studied are characterized by significant social, economic and environmental difficulties. The main characteristics of the households surveyed in accordance with the questionnaires are given. The average number of persons per household was close to three people, whereas for the whole of Cyprus is slightly lower (2.79). Furthermore, the average age of people surveyed was 31 years old. As expected, the percentage of employed people was very low (4.17%), compared to 64.8% of the average in Cyprus, while 58.3% were unemployed and non-active people (average in Cyprus 59.5%). Also, 8.3% were retired versus 25.8% which is the national average. The average annual household income was €7750,4 while per capita gross domestic product (GDP) for 2013 was about €16.400 in constant prices of 2005 [9]. Nearly 8% of respondents have higher education against 96% of the national average, while 16.67% of respondents have primary education. Most of the participants have secondary education (75%).

The dwellings survey provides a data set about thermal and construction characteristics of the households. The average surface of the dwellings was 86,3 m^2, while the corresponding average in the country is close to 141 m^2. The average age construction of the dwellings is 25 years (1989), while the official statistics of the country give that 17.9% of homes were built before 1971. A percentage of 20% of the dwellings are apartments and 80% detached houses or cottages. In average, almost 25% of the population in Cyprus lives in apartments and 75% in detached houses, semi-detached houses or cottages. As far as ownership is concerned, 30% of the dwellings are rented and 70% are privately owned, compared to 22% and 78%, respectively, which is the national average. Regarding the thermal quality of the envelope, none of the houses is insulated, while the national average is 7.5%. Also, 50% of the selected dwellings are double glazed but there is no percentage of homes with both insulation and double glazed windows.

Concerning the cooling of the households, 80% have an air conditioning unit. Average values on the island record that 80.8% of households have air conditioning units.

3.2 Levels of Indoor and Outdoor Temperature

The indoor and outdoor temperatures of the ten dwellings for June to August 2014 were recorded and their variation are illustrated in the figures 1 to 5. The average indoor temperatures of the ten dwellings range between 29-30°C, while the maximum internal temperatures vary between 33-35 °C. The maximum outdoor temperature value for June 2014 was 36.1°C, for July was 33.5°C and for August was 35.4°C. August was the period with the highest temperatures for the whole summer months. For all of the houses, the internal temperature was high or very high and certainly well beyond the comfort zone.

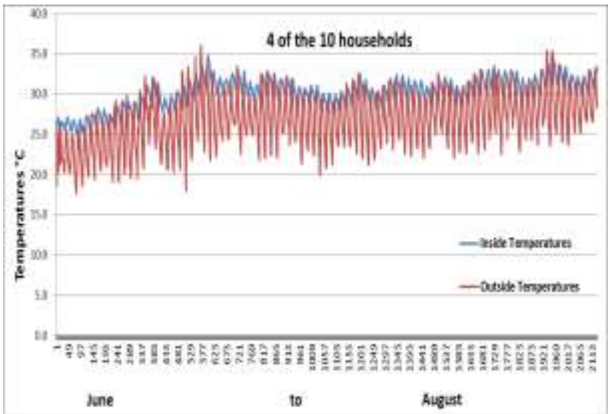

Figure 1: Indoor and Outdoor Temperatures for four households with a surface area of 120 and 70 m^2.

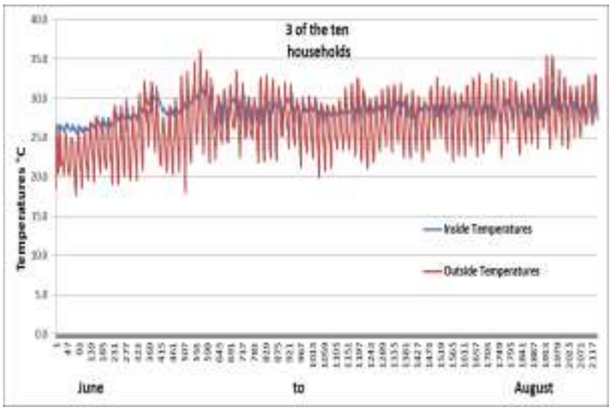

Figure 2: Indoor and Outdoor Temperatures for three households with a surface area of 60 m^2.

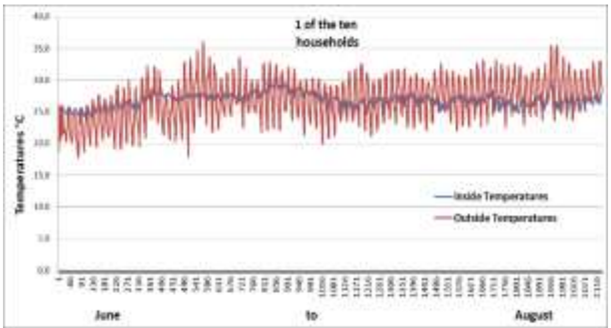

Figure 3: Indoor and Outdoor Temperatures for a household with a surface area of 60 m^2.

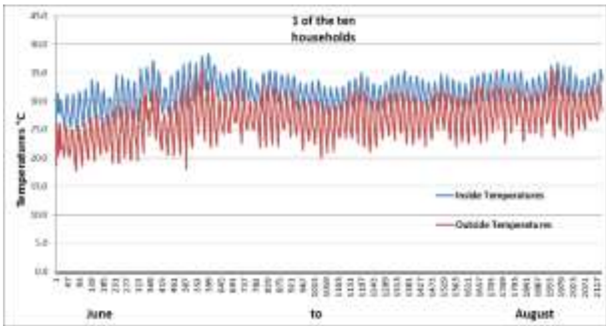

Figure 4: Indoor and Outdoor Temperatures for a household with a surface area

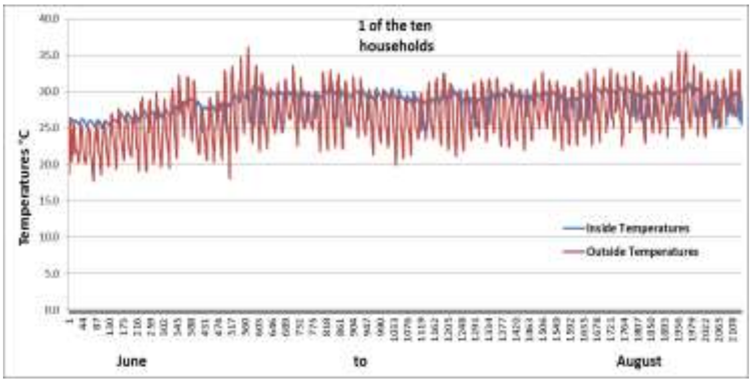

Figure 5: Indoor and Outdoor Temperatures for a household with a surface area of 90 m^2.

Four houses have average internal temperatures at 29-33°C during the summer months. This means that the temperatures are above the maximum comfort level of 29°C. Two of the dwellings have a surface area of 120 m^2 and the other two of 70 m^2. These four households have also from 33 to 35°C for 240-500 hours continuously in the period of the summer. The temperatures of these dwellings vary according to the maximum temperatures of the external environment (see Figure 1). Three houses, with a surface area of 60 m^2, have average internal temperatures at 27-29°C, which vary in-between temperatures of the external environment. The dwellings during the summer months usually have temperatures within the comfort zone (29°C) (see Figure 2). The lowest daily average temperatures recorded only in a 60 m^2 house, which had all of its temperatures below the maximum level of comfort zone for summer in Cyprus. As you can see in Figure 3, when the outdoor temperature was at 35°C, the indoor temperatures were at 25-27°C. In general, indoors' house temperatures range at much lower temperatures than those of ambient weather. On the other hand, Figure 4 indicates the highest temperatures of all the houses under study, within a 90 m^2 household which displayed temperature values until 38 degrees. Almost all the temperatures go well beyond the maximum comfort level for the summer (29°C) and particularly for more than 500 consecutive hours. Figure 5 shows that the indoor temperatures of a 90 m^2 house under study, varying to the standard of the ambient temperatures throughout the summer. With the increase of the ambient temperature, the internal temperature increases too.

3.3. Data Analysis

From the plotted data, some of the dwellings seemed to show some evidence of using cooling systems during the monitoring period. It is observed that the dwellings with larger surface area have higher income and higher temperature values in the summer, than those with smaller surface area, which have also lower income. The household that has the lowest temperatures from all is a new built 60 m^2 apartment, which consists of three residents (a mother with her children) and receives a low income of about €8000 a year. The residents reported that they have used the air-conditioning a lot, which it means that they have consumed much more electricity. Residents consider good quality of their home. The temperatures shown in Figure 1 are recorded for houses built before 1980 and consist of older age residents, and each household receive about €10000 a year. They all have higher temperatures in their house than the previous dwelling. They did not use cooling system. In these households there is evidence of serious mold and humidity problems and residents have identified problems with mice and snakes. The occupants characterize the quality of their home very poor. The dwellings shown in Figure 2 were built on 1990 and 2000; are all families with small children and receives about €4000-6000 annually. They used the air-conditioning rarely and when it was much needed. Residents consider good quality of their home. The dwelling shown in Figure 4, is a 120 m^2 house, built before 1980 and is inhabited by five people, including children. They have an annual income of about €9500 and they never used a cooling system at the period of the study. The indoor temperatures were much higher than the outdoors. The quality of the house is in very poor condition; it is very old and has not been made any renovations. The rapid temperature rises due to solar gains and internal heat gains from appliances etc; the latter being most obvious in living rooms in the evenings. The dwelling shown in Figure 5 was built in 1976, consists of four inhabitants, including two minors, and has an annual income of around €13500. This household sometimes use the air-conditioning because they report in the questionnaire that the house cannot hold a constant temperature, resulting in differences in their thermal preferences.

4. Conclusions

The study was performed in order to examine the differences in internal temperatures among ten low and very low-income dwellings, during the summer of 2014 in Limassol, Cyprus. Also, it examines their analysis and compares them with outdoor ambient weather. Data were collected from the households in order to study their living conditions, mainly related to their income and the characteristics of each building.

Monitoring has shown that the internal temperatures of most of the houses are higher than the marginal comfort and health levels for the summer. The maximum internal temperatures of the ten dwellings in summer were ranging between 33 and 35°C. During summer some of the dwellings were recorded as being high or very high, and above the comfort limit zone of 29°C. Most of the indoor temperatures have a high correlation with the weather measurements due to the lack of thermal insulation. It seems that the internal temperature levels are determined mainly by the quality of the building's envelope. The fore mentioned situation affects the thermal preferences, the socioeconomic status, and the health conditions of the home's occupants. Even though the households with higher income have significantly greater ability to buy and consume energy, some of the dwellings with lower income use the air-conditioning more and spend more for cooling, as others with the same number of residents and higher income use it less. This cannot be directly linked to personal exposures due to differences in time-activity patterns within the home, and the outdoors, and individual clothing preferences. Also, houses with larger surface area had higher temperatures in the house than those with smaller area.

The study provides a deep understanding of the complex functioning of the low-income dwellings and the parameters that affect their thermal performance. However, further studies are needed to correlate the thermal comfort of the low-income households, with their energy consumption as well as with their construction characteristics. In this study, all the households are not insulated and rather leaky thus they can heat rapidly when external temperatures rise. However, this is just one study in one locality and further work to shed more light on these matters is encouraged.

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