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AIR CONDITIONING IN SERBIAN LOW-RISE HOUSES

Abstract: This paper shows the survey in Serbia in city of Kragujevac devoted to air conditioning use in Serbian low rise-houses. The survey informs the existence of air conditioners in different rooms, houses with different locations, houses with different size, age, construction status, thermal insulation situation and and with residents having different income.

Keywords: Public opinion survey, Public action, Air conditioning.

1. INTRODUCTION

Since the global environmental crisis, energy and environmental concerns have increased in priority to study energy use in building construction and operation. It is important to understand position of people with different role in this process in different buildings and countries during entire building life cycle. This is done by using questionnaire surveys.

By questionnaire surveys, use of air conditioners in buildings is examined previously. Summers and Simmons [1] surveyed air conditioner use by Australians. Scott and Sheridan, [2] did a survey of public perception and response with use of air conditioners to heat warnings across four North American cities. Arsenault [3] did survey on use of air conditioners in southern states of USA. Lin and Deng [4] did a questionnaire survey on sleeping thermal environment and bedroom air conditioning in high-rise residences in Hong Kong. Bradley [5] did survey on disturbance caused by residential air conditioner noise. Mahlia, et al. [6] did

survey of use of room air conditioners in Malaysia regarding potential electricity savings when implementing energy labels. Yun et al. [7] surveyed a field survey of occupancy and air-conditioner use patterns in open plan offices. Seitz et al. [8] approached the consumers to find the most desired attributes of home air-conditioning systems.

This paper presents results of the examination of the home owners of low-rise residential houses in Serbia in city of Kragujevac on air conditioning used in their houses. The examination is done of the 165 home owners by a questionnaire survey. The survey investigates the existence of air conditioners in different rooms, houses with different locations, houses with different size, age, construction status. Then, the survey investigates existence air conditioners in houses with and without thermal insulation in house walls and in houses with residents having different income.

2. METHODS

This paper presents results of the 2011 survey in Serbia in city of Kragujevac on the air conditioning use in low energy houses. The general research approach is based on the structured questionnaire survey. The questionnaire is specially designed for this study. This is chosen because it allows a large number of subjects to be studied. The data collection technique is hand-delivered, self-administered survey. This method is chosen because it could efficiently reach a large sample, and allowed ease of response. The questionnaire is a more effective alternative to interviews because it enabled a greater proportion of the population to be reached within a limited time frame. Respondents are requested to base their responses on the home that they live in. A summary of the survey findings was available to respondents who are interested in the research to encourage participation.

Table 1. Total area of houses

Percentage of total number of houses			
<80 m ²	80-120 m ²	120-200 m ²	>200 m ²
19%	34%	36%	11%
Number of stories			
1	2	3	
38%	55%	7%	

Table 2. Age of house and net income in households

Age of house (a)		
<20 a	20-40 a	>40 a
31%	52%	17%
Net income in households (€)		
<6k	6-12k	>12k
42%	33%	21%

2.1 Participants

The hundred and sixty people responded to the survey. Each of respondents owns and lives in a house

located in the municipality of Kragujevac, Serbia. Number of residents is 660. Half of residents are male and half of them female. No control was kept over the demographic and socio-economic characteristics of participants, so consequently the sample constituted large families and people living on their own, and people in different professions and retired. The houses are almost evenly distributed between city core, suburb, and countryside. Total area of houses is given in Table 1. Almost half of houses have area less than 120 m² and rest greater than 120 m². Number of stories in the house is given in Table 1. The most houses have number of stories less than 3. Age of houses is given in Table 2. Most of houses are above 20 years old. Net income in households is given in Table 2. The most of residents have income below 12k €.

2.2 People presence in rooms

Figure 1 shows the survey results on how long different rooms are used. The investigated time spans are up to 5h and above 5h. The living rooms are used the highest amount of time while the all other rooms are used almost the same amount of time.

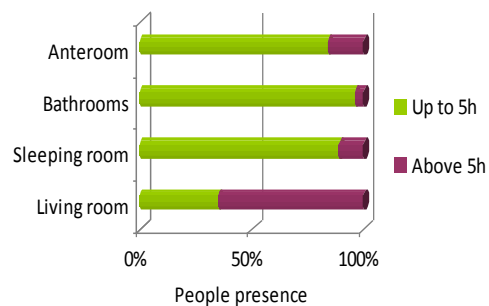


Figure 1. How long are different rooms used?

3. RESULTS & DISCUSSION

3.1 Existence of air conditioners in the house

Figure 2a shows the existence of air conditioners in the house. The existence of AC in the houses is an order of 30%. If the air conditioners are present in the house, the house can use either one AC or two AC or more. The highest use is of only one AC (25%).

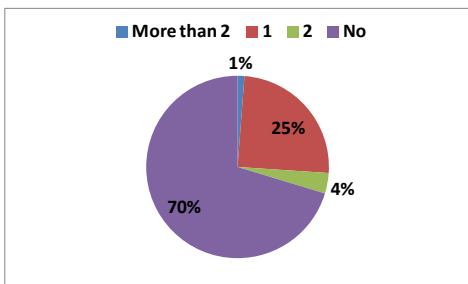


Figure 2a. Existence of air conditioners in the house

Figure 2b shows the existence of air conditioners in different rooms of the house. The highest existence of AC in the living rooms (60%).

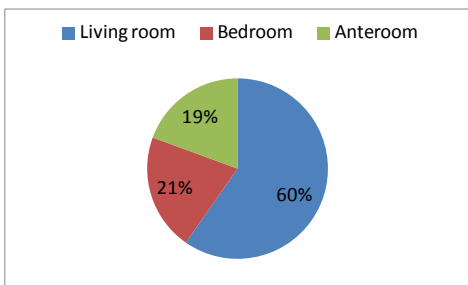


Figure 2b. Percentage of use of air conditioners in different rooms of the house

3.2 Types of used air conditioners

Figure 2a shows the results of survey on the type of air conditioners that are used in the house. Tenants use air conditioners of different power, however they use the air

conditioners of 12000 Btu/h the most often (66%).

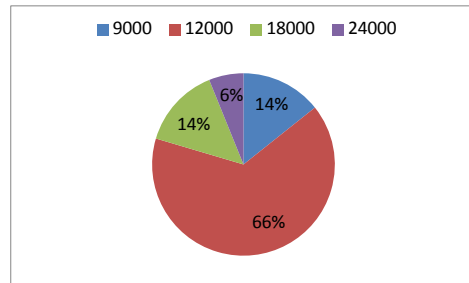


Figure 3a. Percentage of use of air conditioners

with different power expressed in Btu/h. Note that 9000Btu/h =2.64 kW; 12000 Btu/h = 3.52 kW; 18000 Btu/h =5.28 kW; 24000Btu/h =7.03 kW.

Figure 2b shows duty of air conditioners in the house that can be either only cooling or cooling and heating combined. The investigation shows that the duty of the air conditioners during year is the most often only cooling.

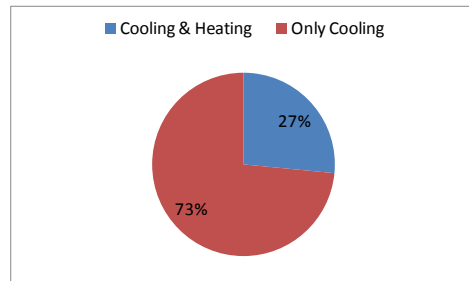


Figure 3b. Annual duty of air conditioners in the house

3.3 House location

Figure 4 shows existence of air conditioners used in the differently located houses. The investigated houses are in the city core, suburbs, and country side. The investigation shows that the number of houses that use the air conditioners is the highest the in the city core. In the city core, the air conditioners are used by around 50% of houses. The use of air conditioners

is the lowest in the country side. Then, the air conditioners are used by around 12 % of the houses.

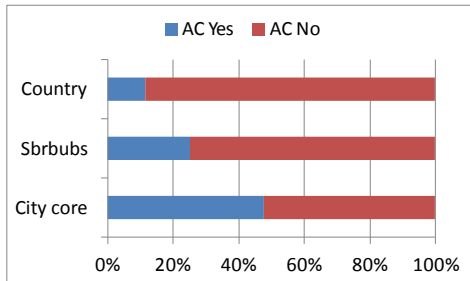


Figure 4. Existence of air conditioners in the house as a function of house location

3.4 Existence of air conditioners vs. house size

Figure 5 shows existence of air conditioners in the house as a function of its size. The investigated house sizes are “up to 80 m²”, 80-120 m², 120-200 m², and “above 200 m²”. Regarding this issue, it seems that the air conditioners are used more in the houses with size higher than 200 m².

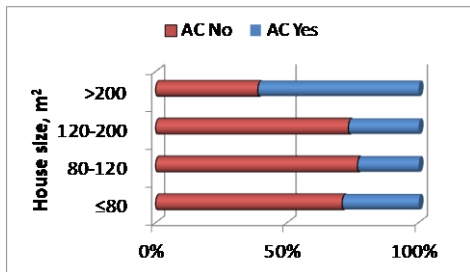


Figure 5. Existence of air conditioners in the house as a function of house size

3.5 Existence of air conditioners vs. house age

Figure 7 shows existence of air conditioners in the house as a function of house age. The investigated house ages are “up to 5 years”, 5-10 years, 10-20 years, 20-40 years, and “above 40 years”. Regarding this issue, it seems that the air

conditioners are used extensively in the houses with age that is up to 5 years.

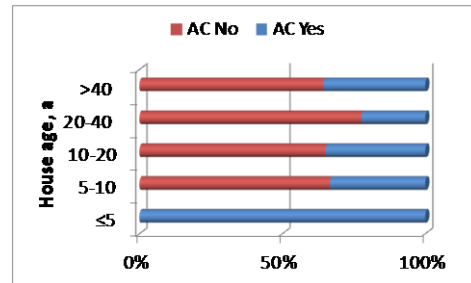


Figure 6. Existence of air conditioners used in the house as a function of house age.

3.6 Existence of air conditioners vs. net income

Figure 7 shows existence of air conditioner in houses as a function of the net income in the households. The studied net income ranges are <6k €/a, 6-12k €/a, and >12k €/a. The research shows that the highest application of the air conditioners is by the residents with the highest income (>12k€/a). Then, the air conditioners are used at 63% of houses. The application of the air conditioners is by other residents is that only 23% of residents have the air conditioner.

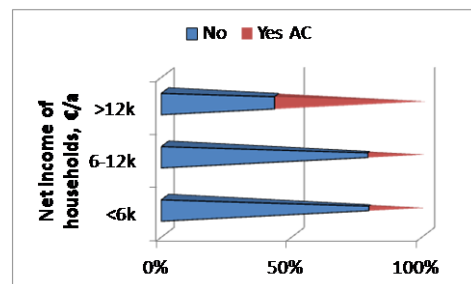


Figure 7. Existence of air conditioner as a function of the net income in the households

3.7 Existence of air conditioners vs. construction status

Figure 8 shows existences of air

conditioners used in the house as a function of its construction status. There are two options (1) the house is constructed as planned and the house is finished partially without putting mortar (and lives in such a house). Air conditioners are present in 34% of finished houses, while around 16% in unfinished houses.

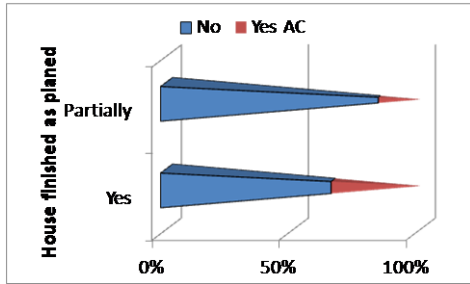


Figure 8. Existence of air conditioners used in the house as a function of construction status.

3.8 Air conditioner existence vs. thermal insulation existence

Figure 9 shows existences of air conditioners used in the house as a function of its thermal insulation. There are two options (1) the house is with thermal insulation and the house is without thermal insulation. The results show that air conditioners exist in 43% of the houses if they have the thermal insulation. When the houses are not thermally insulated the air conditioners exist in only 13% of the houses.

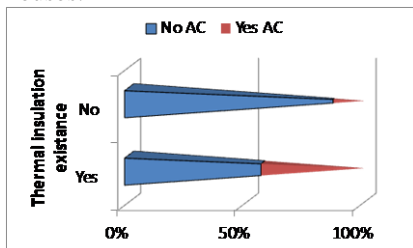


Figure 9: Air conditioners use in the house as a function of thermal insulation existence on a house

4. CONCLUSIONS

This paper presents results of the survey of the use of air conditioning in the Serbian houses in city of Kragujevac. The results may be valid for other Serbian cities and should be taken into account when designing any Serbian energy policy. The investigation found out that

- 1) The existence of AC in the houses is an order of 30%. If the air conditioners are present in the house, the highest use is of only one AC (25%).
- 2) The investigation shows that the air conditioners are the most often present in living rooms.
- 3) (3) The investigation shows that the number of houses with use of air conditioners is the highest in the city core, and the lowest in the country side.
- 4) Regarding the size of the house, it seems that the air conditioners are used more in the houses with size higher than 200 m².
- 5) Regarding house age, it seems that the air conditioners are used extensively in the houses with age that is up to 5 years.
- 6) The research shows that the highest application of the air conditioners is by the residents with the highest income (>12k€/a). The lowest application of the air conditioners is by the residents with the lowest income (<6k€/a).
- 7) The research shows that air conditioners are present more than double in finished houses, than that in unfinished houses.
- 8) The research shows that air conditioners 3 times mor in the houses with thermal insulation than that in the houses without thermal insulation.

REFERENCES:

- [1] Summers, M., & Simmons, R. (2009). *Keeping Cool Survey: Air Conditioner Use by Australians with MS*. Blackburn, Melbourne: MS Australia.
- [2] Scott, C., & Sheridan, S. C. (2007). A survey of public perception and response to heat warnings across four North American cities: an evaluation of municipal effectiveness. *International Journal of Biometeorol*, 52, 3-15.
- [3] Arsenault, R. (1984). The end of the long hot summer: the air conditioner and southern culture - The Journal of Southern History. *The Journal of Southern History*, 50(4).
- [4] Lin, Z., & Deng, S. (2006). A questionnaire survey on sleeping thermal environment and bedroom air conditioning in high-rise residences in Hong Kong, Energy and Environment of Residential Buildings in China. *Energy and Buildings*, 38(11), 1302-1307.
- [5] Bradley, J. S. (1993). Disturbance caused by residential air conditioner noise. *Journal of the Acoustical Society of America*, 93(4), 1978-1986.
- [6] Mahlia, T. M. I., Masjuki, H. H., & Choudhury, I. A. (2002). Potential electricity savings by implementing energy labels for room air conditioner in Malaysia. *Energy Conversion and Management*, 43(16), 2225-2233.
- [7] Yun, G. Y., Kong, H. J., & Kim, J. T. (2011). A Field Survey of Occupancy and Air-Conditioner Use Patterns in Open Plan Offices. *Indoor and Built Environment*, 20(1), 137-147.
- [8] Seitz, V., Razzouk, N., & Wells, D. M. (2010). The importance of brand equity on purchasing consumer durables: An analysis of home air-conditioning systems. *Journal of Consumer Marketing*, 27(3), 236-242.

Acknowledgment: This investigation is part of the project TR 33015 of Technological Development of the Republic of Serbia and the project III 42006 of Integral and Interdisciplinary investigations of the Republic of Serbia. We would like to thank to the Ministry of Education and Science of Republic of Serbia for the financial support during this investigation.