Exploring the Energy Consumption Dimensions of a Residential Building in Tripoli, Libya

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***Abstract*— A huge numbers of recently-built residential buildings in Libya provide a poor quality indoor environment which requires a large amount of energy to provide not only comfortable indoor environment but run the air conditioning. Also, the use of energy in buildings is becoming a major contributor to both air pollution and climate change. Improving the energy efficiency, reducing the energy consumption, securing thermal comfort in residential buildings through the application of bioclimatic design principles is a very critical factor. A domestic building in Libya was studied with a view of reducing its energy consumption. The study included detailed monitoring which was followed by a computer simulation with a wider range of intervention strategies. The use of appropriate orientation, materials and building configuration which would offer suitable solutions to the energy and environmental problems in hot arid countries are recommended.**

Keywords*— *Architectural design, climatic change, Energy in building, Libya, Residential buildings

I. INTRODUCTION

A huge number of recently-built residential buildings in Libya provide a poor quality indoor environment which requires a large amount of energy to provide not only comfortable indoor environment but run the air conditioning [1]. Also, the use of energy in buildings is becoming a major contributor to both air pollution and climate change. Reference [2] reports that the contribution of buildings alone towards the global energy consumption, is in the range of between 20% and 40% in developed countries which made the built environment a major contributor than industrial and transportation sectors. Improving the energy efficiency, reducing the energy consumption, securing thermal comfort in residential buildings through the application of bioclimatic design principles is a very critical factor which needs consideration.

Also the energy use for air conditioning in hot climates regions such as Libya is one of the significant contributors to fossil fuel depletion and carbon emissions [1][6][7]. In particular, air conditioning in residential buildings constitutes a substantial proportion of building energy use due to the long occupancy hours. Reference [3.p201] report that, urban areas particularly in developing economies without high climatic quality use more energy for air conditioning and lighting in summer periods. Typically, the cooling environment provided at any particular time does not precisely match the cooling load at that time as the air condition units do not have a continuously variable output. Moreover, the occupancy patterns are not continuous and the on and off witching of the air condition units whenever the room is occupy or vacated, allows the heat gains to build up over a period. In this paper, the temperatures and energy consumption in a multi-occupancy building in Libya were monitored over an extended period of 45 days to characterize the energy consumption patterns in relation to the climate and occupancy. Besides, the issue of discomfort and inconvenience arising out other urban activities, high temperatures, wind tunnel effects, erroneously and insufficient designed of residential buildings is very common [4].

Available statistics on the electricity consumption among some European cities ranges from 60 GWh to 26,452 GWh per annum [3]. Moreover, the average electricity consumption calculated on the basis of available data for cities with more than 1,000,000 inhabitants is around 4500 GWh per annum [3]. The above according to [2] has also raised concerns over supply difficulties, exhaustion of energy resources and heavy environmental impacts on residence and the building fabrics particularly in developing economies such as Libya. The city of Tripoli lies on the far north of the continent of Africa overlooking the Mediterranean Sea. The ordinates of the city are latitude 32º 47” N and longitude 13º 04” E respectively. Tripoli is classified as a hot dry climate, which usually is found on latitudes between 20°C and 35°C.

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The main shelter issue is overheating with mean summer temperatures around 25ºC but can reach a maximum of 45ºC. The energy consumption pattern in the residential sector in Libya is approximately 36% of the total energy consumption and almost half of this is used for cooling buildings as shown in Figure 1 below.

The electricity generation in Libya according to [5] has increased by 50% between 2000 and 2010 as shown in Figure 2 below. Although Libya is an oil producing country, there is an energy crisis due to; extensive use of conventional energy sources which leads to their depletion and the increase in individual annual consumption of electrical energy.

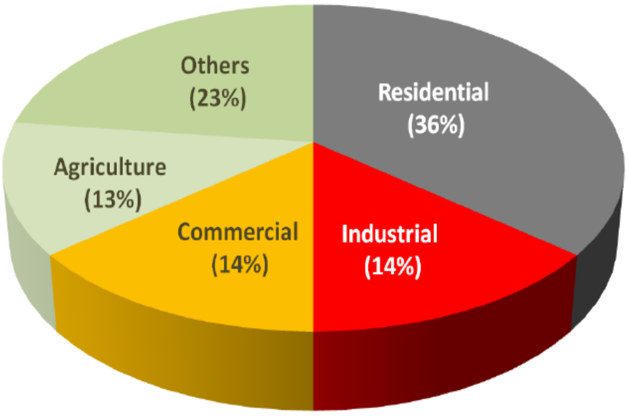

Figure: 1. Electricity consumption per sector in Libya [5].

Most of the energy consumption deficiency in the country is from the over reliance on conventional energy source than non-renewable sources and the inefficiency of electricity generation.

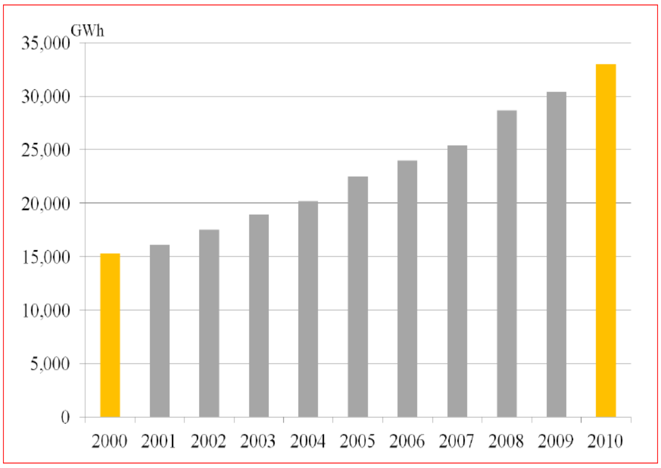

Figure: 2. the electricity generation in Libya, (2000-2010) [5].

A domestic building in Libya was studied with a view of reducing its energy consumption.

II. THE EXPERIMENTAL WORK

A field study including electricity consumption measurements was carried out and results from the study were gathered and analyzed. The case study residential building has a rectangular plan and was built in 1999. The building has two storeys with a total height of 8m. The ceiling height is 3.5 m. The ground floor is 1m above street level and the roof has a sill of one meter figure 3 shows the four facades. The building structure was constructed with concrete, all both internal and external walls are blocks with dimension of 20cm thick, 20cm height, and 40cm wide, covered from outside with 1-2cm mortar. Moreover, the roof was built of reinforced concrete with 45cm thickness in the middle of the building and 25cm from the edge of the roof. The floor area is approximately 700 m^2 for the first floor; this includes two flats, each of which has two bedrooms, two living rooms, two bathrooms, and a kitchen. The second floor is also divided into two flats, each of these having three bedrooms, two living rooms, a kitchen and three bathrooms see plans in figure 4. It is occupied as a multifamily residence.

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Figure: 3. the building four facades

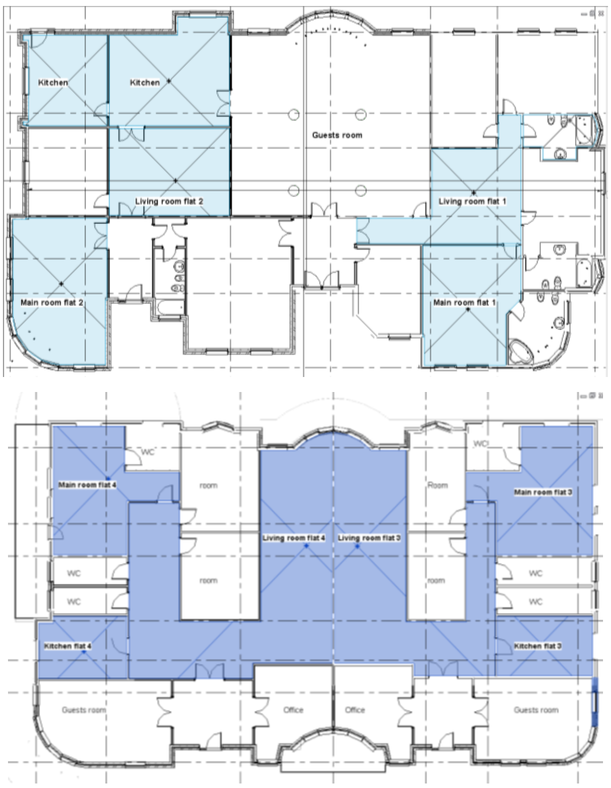

Figure: 4. Ground and first floor plan.

The building was monitored continuously for 45 days, and the results clearly showed that there were two peak days; in between these days there is a sharp drop in temperature, otherwise the average temperature range is between 27°C-33°C. Three typical days were selected for detailed study, the first being the peak day (21/07/2013), the second day having a low temperature (09/07/2013) and the last day is a mid-temperature day (08/08/2013). The outside air temperatures for the 45 days are shown in figure 5 whilst those of the chosen three days are shown in figure 6 below.

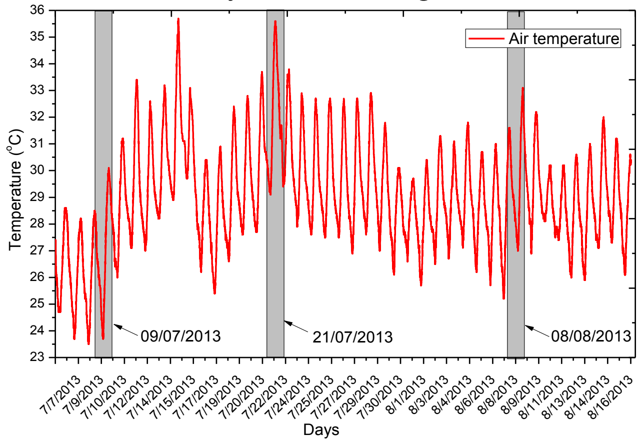

Figure: 5. the studied outdoor air temperature for the 45 days [6].

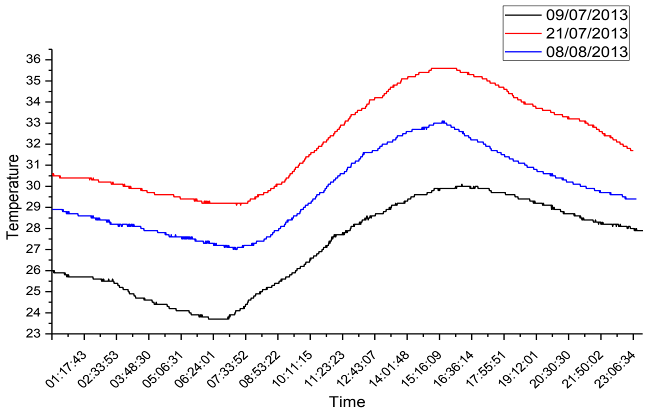

Figure: 6. Outdoor air temperatures for the selected three days [6].

III. THE ENERGY CONSUMPTION IN FLAT 1 AND 2

The electricity readings for flat one and two were taken together because there is only one meter for both of them. The relationship between air temperature and energy consumption figure 7 shows that electricity consumption can reach up to 350kW, which is extremely high for two flats (approx. 0.5kW/m^2).

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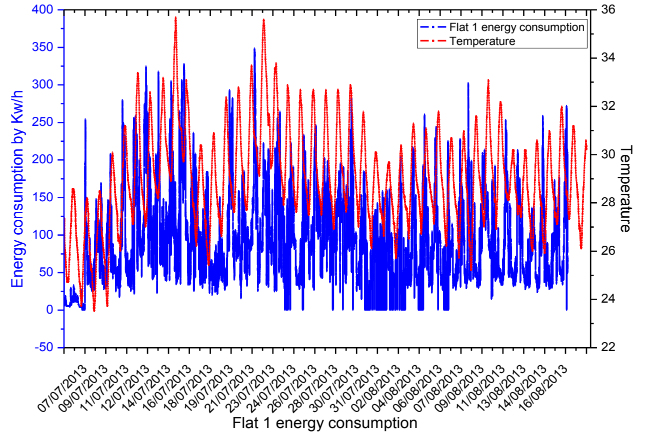

Figure: 7. the relationship between air temperature and energy consumption for flat 1 and 2.

For more details figure 8 shows the energy consumption on 9th of July and it is clear that energy is increasing when the temperature is increasing until it reaches a maximum value and then starts to decrease when the temperature starts to decrease, making it clear that there is strong relationship between the temperature and the energy use.

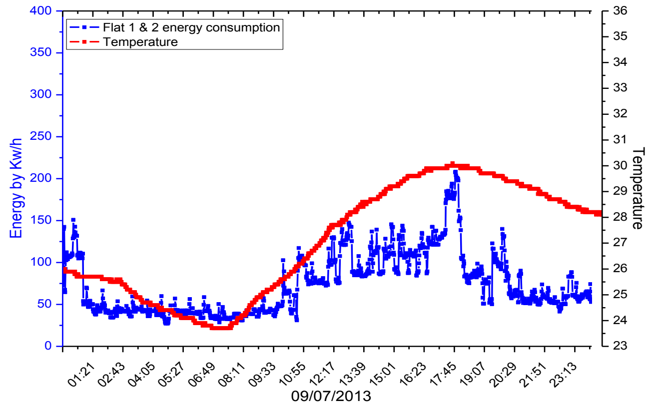

Figure 8 the relationship between energy use and outdoor temperature for 9th of July in flat 1 & 2.

Figure 9 confirms the relationship and clarifies that on the 21st of July, which was the hottest day, the energy use was stable around 100kW until midday after which it starts to increase to reach 350kW at which time temperatures were above 35ºC.

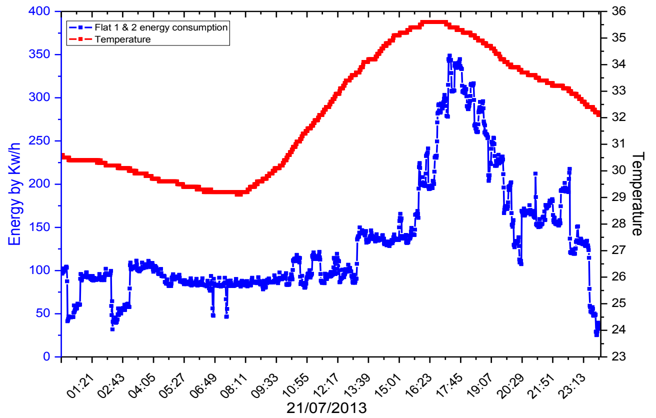

Figure: 9. the relationship between energy use and temperature for the 21st of July in flat 1 & 2.

The last day on the study for flat 1 and 2 was on the 8th of august, 2013. The situation was different until midday when the energy use was increasing while the temperature increased but there was a drop after midday due to non-occupation in both flats by the occupants for the rest of the day and energy use fell as shown in figure 10.

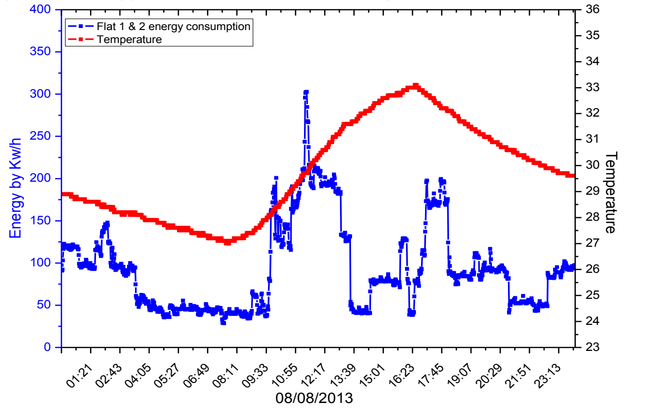

Figure: 10. The relationship between energy use and temperature for the 8th of august in flat 1 & 2.

IV. ENERGY CONSUMPTION FOR FLAT THREE

The overall picture in this flat show that the energy use was ranging between 20kW to 130kW and those of 26th of July and 7th of August were different from the other days, which are shown in figure 11.

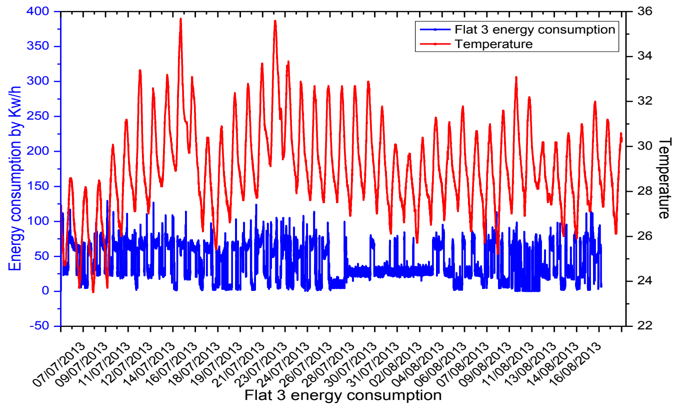

Figure: 11. The relationship between air temperature and energy consumption for the whole study for flat 3.

On the 9th of July, in the first hours of 06:00am in the morning the energy consumption was around 75kW when the temperature was 26ºC. However, the energy dropped to around 30kW whilst the temperature also dropped to 24ºC, at 08:00am. The temperature also starts to rise followed by the energy, and continues until 15:00hrs when the energy consumption fell by more than 50% due to the non-occupation of the flat by occupant and returned around 22:00hrs when the energy consumption rose up again as shown in figure 12.

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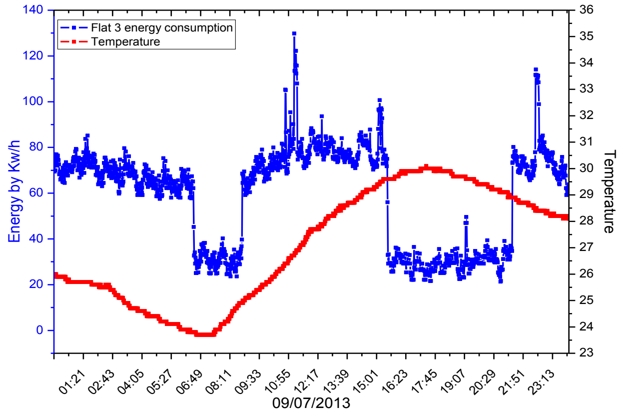


Figure: 12. The relationship between the energy use and temperature for the 9th of July in flat 3.

The same situation applies on the 21st of July and it is clear that energy use starts to increase with temperature but at around 14:00 the flat became unoccupied and the energy use dropped to around 20kW figure 13.

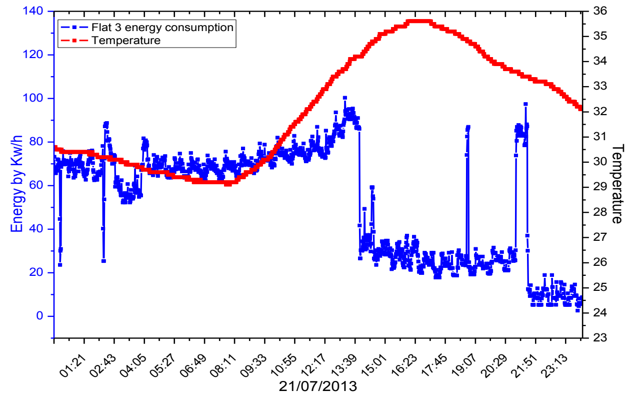


Figure: 14. The relationship between energy use and temperature for the 21st of July in flat 3.

The same situation applies on the 8th of august; in general for flat 3 is known that it became unoccupied from 15:00 till midnight figure 15.

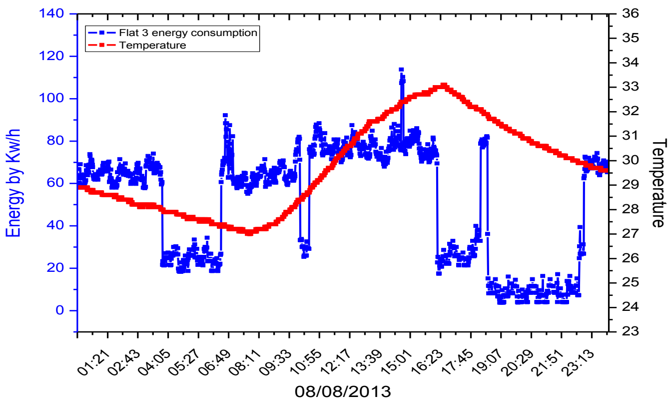


Figure: 15. The relationship between energy use and temperature for the 8th of august in flat 3

V. ENERGY CONSUMPTION FOR FLAT FOUR

The last energy consumption is for flat four, but this flat is different from the other flats because of non-use of air conditioner. Figure 16 shows that no matter what the temperature outside the energy consumption does not change.

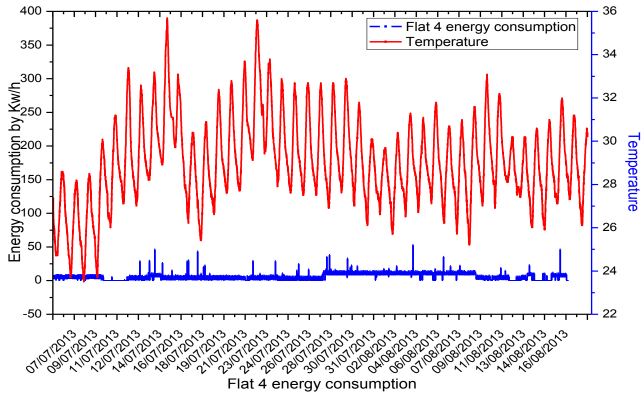
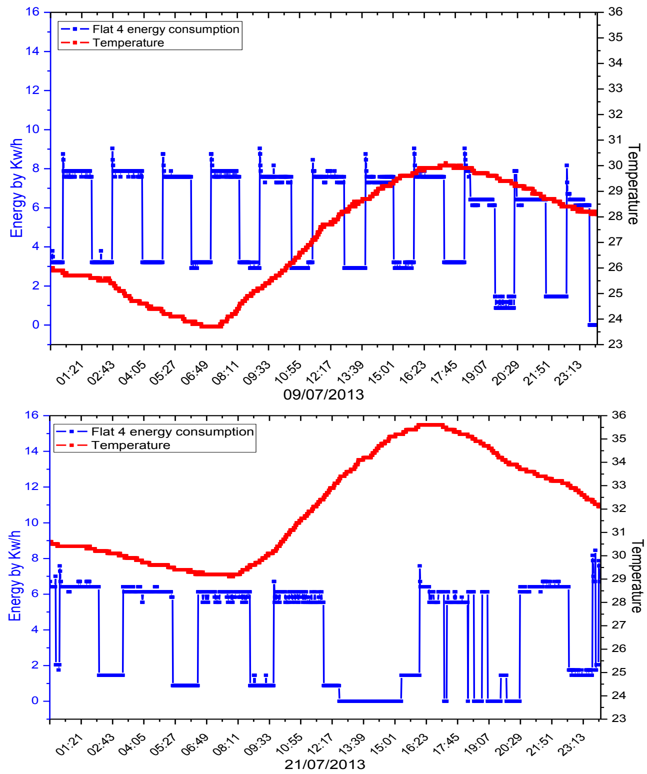


Figure: 16. The relationship between air temperature and energy consumption for the 45 days in flat 4

To illustrate this more figure 17 shows the three days the 9th, 21st of July and the 8th of August. The difference in energy use between the maximum and minimum is only 7kW. Furthermore, on the 9th of July the average use was 6Kw/h, on the 21st of July it was 5kW, and on the 8th of August 12kW.



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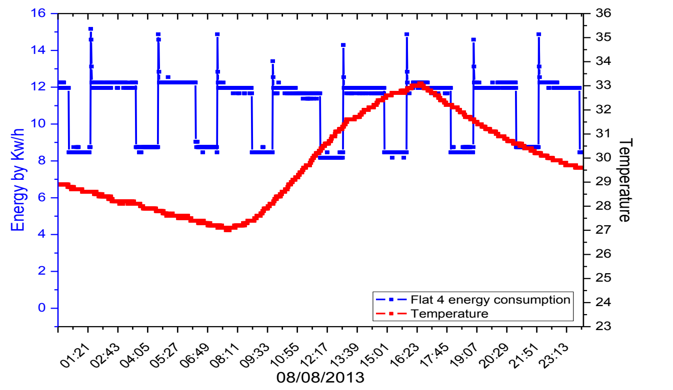
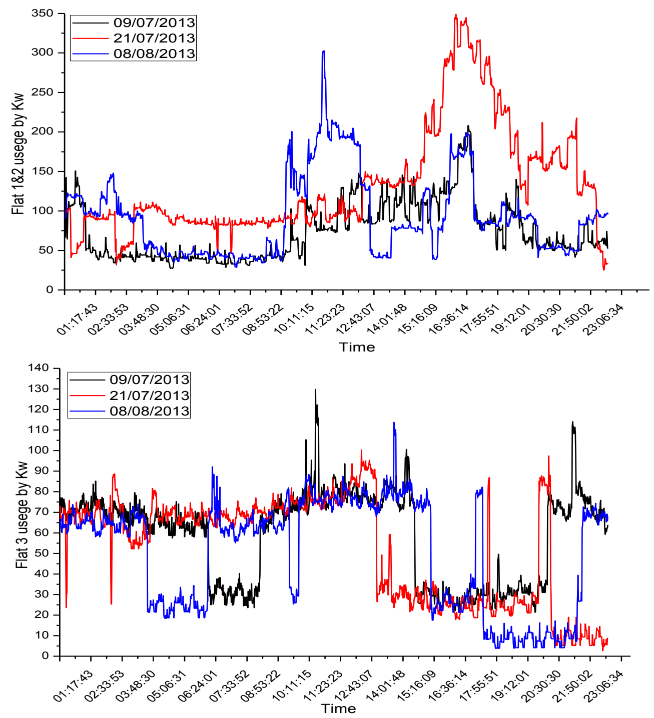


Figure: 17. The relation between energy consumption and temperature for the 9th, 21st of July and the 8th of August, 2013

In general flats 1 and 2 were stable until 09:00, after which the consumption starts to increase and can reach more than double the usage due to the temperature increasing outside which requires the air conditioning to be run. There are 8 conditioners in flat one and 7 in flat two, furthermore, each air conditioning unit consumes 6359W/h, and the consumption can reach up to 200kW as can be seen in figure 18. Most of the air-conditioner usage is in flat three late at night and it continues running until almost 14:00, presumably because of the huge heat transfer from the roof and the east surface. In flat four there is less consumption because of the lack of air-conditioning, and it can be noted that there is a significant difference between the consumption in flat 1 & 2 and 3 and between flat 4.



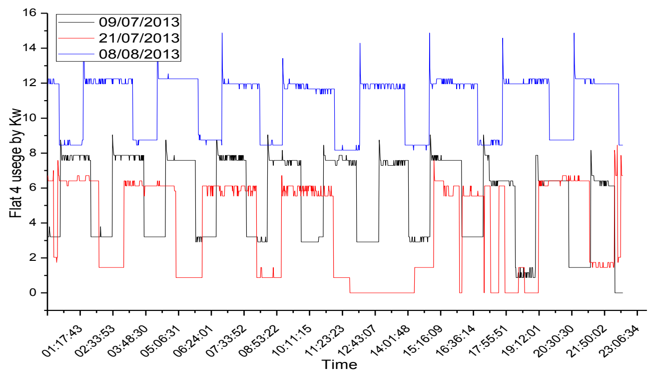


Figure: 18. Electricity consumptions for all the flats for the 9th, 21th of July and the 8th of August, 2013

VI. CONCLUSION

There is a very strong correlation between electricity consumption and temperature; all indicators indicate that the higher temperatures increased electricity consumption increased, although it is not clear how well the cooling availability is matched to the load. This can lead to difficulties in modelling the performance of the building as it is generally assumed in such models that the cooling output will increase incrementally to meet the load exactly. In practice the situation is more complex than this, as this work shows. Because of the intermittent occupation patterns, the relationship between cooling load and air conditioning energy is difficult to define mathematically. Furthermore, the cooling supplied by the a/c units at any particular time usually does not precisely match the load at that time.

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