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Analysis of energy and Water Consumption in an Apartment Building

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Abstract: **This paper centers around building data related to the energy consumption and water consumption by analytical estimation which displays a breakdown of residential power vitality and water utilization information, identifying the elements of apartment buildings which are related to electricity and water use and demonstrate energy consumption forecast based on the proposed case study. In order to verify the patterns of electricity and water consumption in relation with apartment buildings, I will be collecting data from an apartment building. Weather history data, relative humidity and building information such as floor number, type of apartment units, and total area of each apartment unit will also be collected in order to analyze their impact on the consumption of energy and water in the apartment building. By conduction this analysis, the relationship between building information factors and energy consumption will be determined and can be essential for establishing a low energy consumption style apartment as well as establishing a real estate policy on housing pricing based on energy and water consumption. With the expense of energy and water consumption expanding (both financially and biologically), property holders need to discover approaches to check utilization and how the building factors affect consumption.**

Keywords: **energy consumption; water consumption; apartment building; building; information factors.**

1. INTRODUCTION

As of now, a great part of the world is centered around lessening power utilization; our expansion in utilization is neither financially nor earth maintainable. Also, there is a developing agreement that ecological and sparing maintainability are inseparably linked. As the expense of intensity rises, we should discover innovative arrangements that helps lessen and upgrade energy and water consumption. According to Ehrhardt-Martinez *et al.* in "*Advanced metering initiatives and residential feedback programs: a meta-review for household electricity-saving opportunities*", residential homes contribute about 34% to the total power consumption in the USA and their consumption is projected to increase to 39% by 2030. If household electricity consumption is compared between countries, it will be realized that there is a very significant gap based on countries and regions. In the US typical household power consumption is about11,700 kWh each year, in France it is 6,400 kWh, in the UK it is 4,600 kWh and in China around1,300 kWh. The global average electricity consumption for households with electricity was roughly 3,500 kWh in 2010.

There are a number of things that drive the differences in energy consumption between regions and countries, including physical house size, wealth, appliance standards, electricity prices and access to various alternatives when it comes to heating and cooling fuels and also cooking. The worldwide commitment from structures towards energy consumption, both private and business, has relentlessly expanded achieving figures somewhere in the range of 20% and 40% in created nations, and has surpassed the other significant segments: mechanical and transportation. Development in populace, expanding interest for building administrations and solace levels, together with the ascent in time spent inside structures, guarantee the upward pattern in energy request will proceed later on. Consequently, vitality proficiency in structures is today a prime target for vitality arrangement at provincial, national and global dimensions. Among building administrations, the development in HVAC frameworks vitality use is especially critical (half of building utilization and 20% of aggregate utilization in the USA). This paper investigations accessible data concerning vitality utilization in structures, and especially identified with HVAC frameworks. Numerous inquiries emerge: Is the essential data accessible?

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Which are the primary building types? What end uses ought to be considered in the breakdown?

The aim of this analysis is to find the relationship between building information factors and how they affect energy and water consumption in an apartment building. The paper also sheds light on the electric energy and water consumption patterns on a global scale and also the energy consumption in the geographical region where the survey for data collection is conducted.

2. LITERATURE REVIEW

Energy consumption generally refers to the total amount of energy or power which is used for a specific purpose during a set time duration. Electricity or electric energy is mostly measured in joules or watt hours W.H. which represents constant power over a period of time.

1 W·s = 1 J, 1 W·h = 3600 W·s = 3600 J.

From the diagram we can derive the main sources of electric power generation.

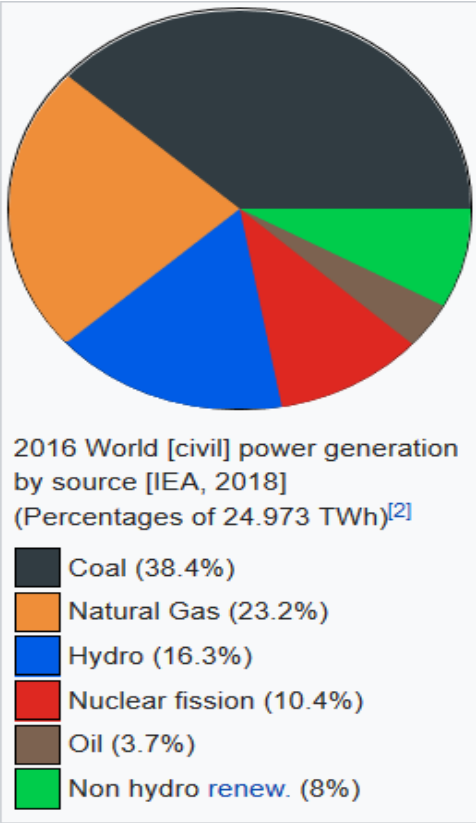

Fig 1: pie chart showing the major sources of electricity globally. Source: Electricity Generation By Wikipedia

The major sources of electricity worldwide as likely named in the diagram are coal, natural gas, hydroelectricity, nuclear fission, oil and renewable energy. Electric and electronic gadgets and appliances consume electricity to produce wanted output such as light, warmth, movement, and so forth. Amid activity, some piece of the energy— depending upon the electrical proficiency—is consumed in unintended yield, for example, waste heat. Since 1882, electricity has been generated in power stations. In 1883, the invention of the steam turbine which is used to drive the electric generator led to a significant increase in the world electricity consumption. According to Wikipedia “In 2008, the world total of electricity production was 20.279 petawatt-hours (PWh). Of which this number corresponds to a normal intensity of 2.31 TW consistently amid the year. The aggregate vitality which is expected to create this power is around a factor 2 to 3 higher on the grounds that a power plant's proficiency of producing power is generally 30– half. The created power is along these lines in the request of 5 TW. This is around 33% of the aggregate vitality utilization of 15 TW" The diagram below shows the world energy consumption by region from 1990 to 2017.

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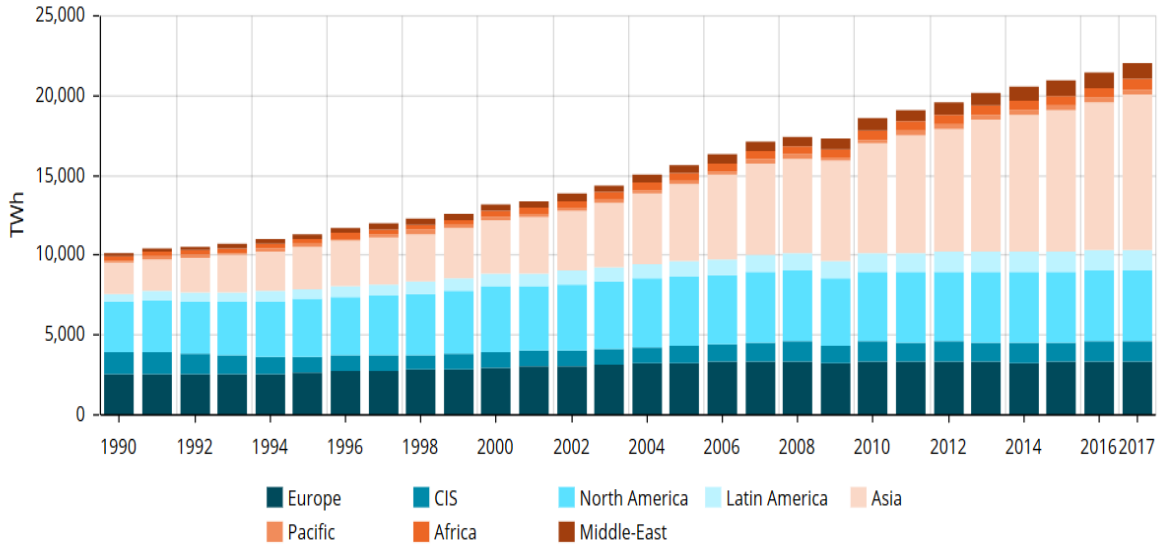

Fig 2: world energy consumption by region from 1990-2017. Source: Global Energy Statistical Yearbook 2018.

From the diagram above, it can be determined that there is a constantly increasing demand on electricity around the world which definitely leads to increasing energy consumption. The increase in energy consumption can also be directly linked to an increase in world population and advancement in technology. Water consumption can be defined as the freshwater which is taken from surface water sources or from the ground either temporarily or permanently and conveyed to the location of use. It can be noted that water used in hydroelectricity generation is not counted as water consumed because it is an in situ use. The distribution of water consumption geographically varies widely for instance, in arid regions, freshwater sources may be limited in comparison to the degree of demand and this demand can in most cases only be met by surpassing sustainable use when considering water quality. The phrase water footprint of an individual, business or a community is defined as the total volume or amount of water which is used in the production of goods and services which is then consumed by an individual or a community or the volume of water which is produced by a business. According to Wikipedia "The average global water footprint of an individual is 1,385 m^3 per year."

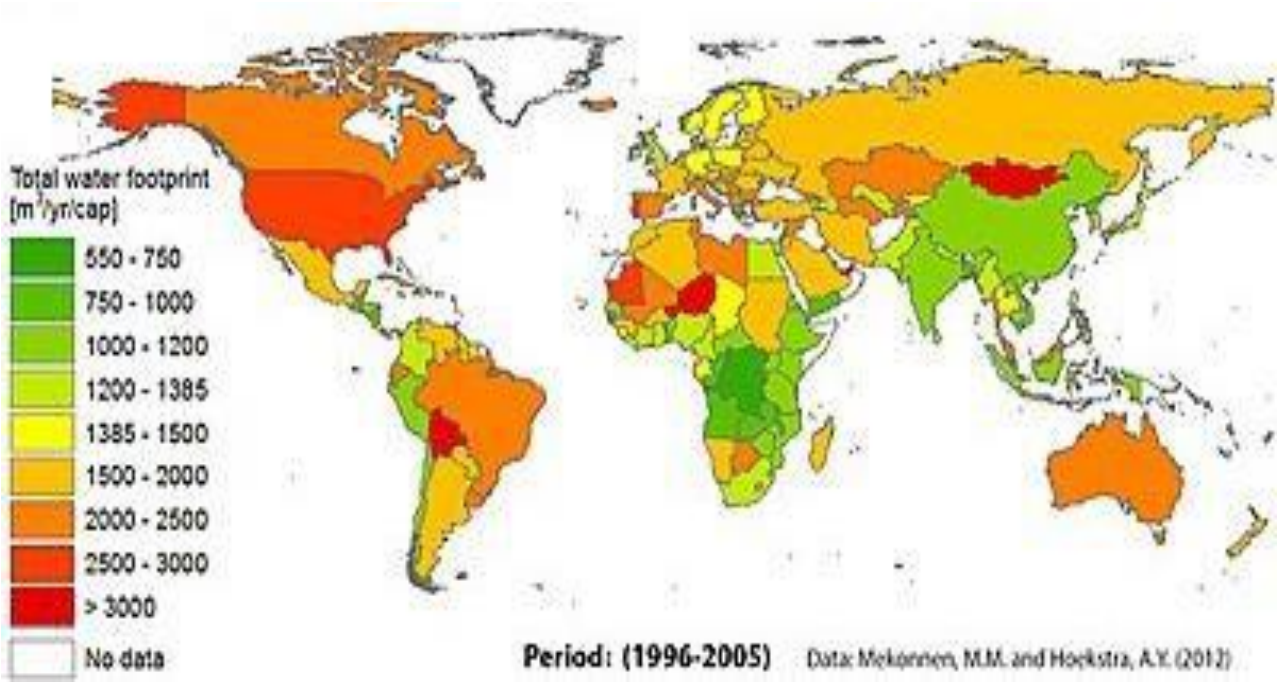

Fig 3: Global water footprint. Source: UN Water- Water Scarcity

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From the above image, it can be derived that there is a significant demand for freshwater all over the world and according to A third of the world's biggest groundwater systems are already in distress (**Richey et al., 2015**), 3.6 billion people worldwide (nearly half the global population) are already living in potential water-scarce areas at least one month per year and this could increase to 4.8–5.7 billion in 2050 (**UNESCO, 2018**).

An apartment building is a building which has one or more housing units on a single story and in most cases have a number of vertical floors. Among the various types of residential dwelling which are namely: single family house, multifamily house, condominium or apartment building, townhouse etc. apartment buildings tend to consume less energy. A survey was carried out in Finland by Jukka Heinonen and Seppo Junnila for their paper which is titled "Residential energy patterns and the overall housing energy requirements of urban and rural households in Finland". In their survey, they studied the energy consumption patterns in different residential building typologies over a time period and it was concluded that apartment buildings are one of the lowest in energy consumption.

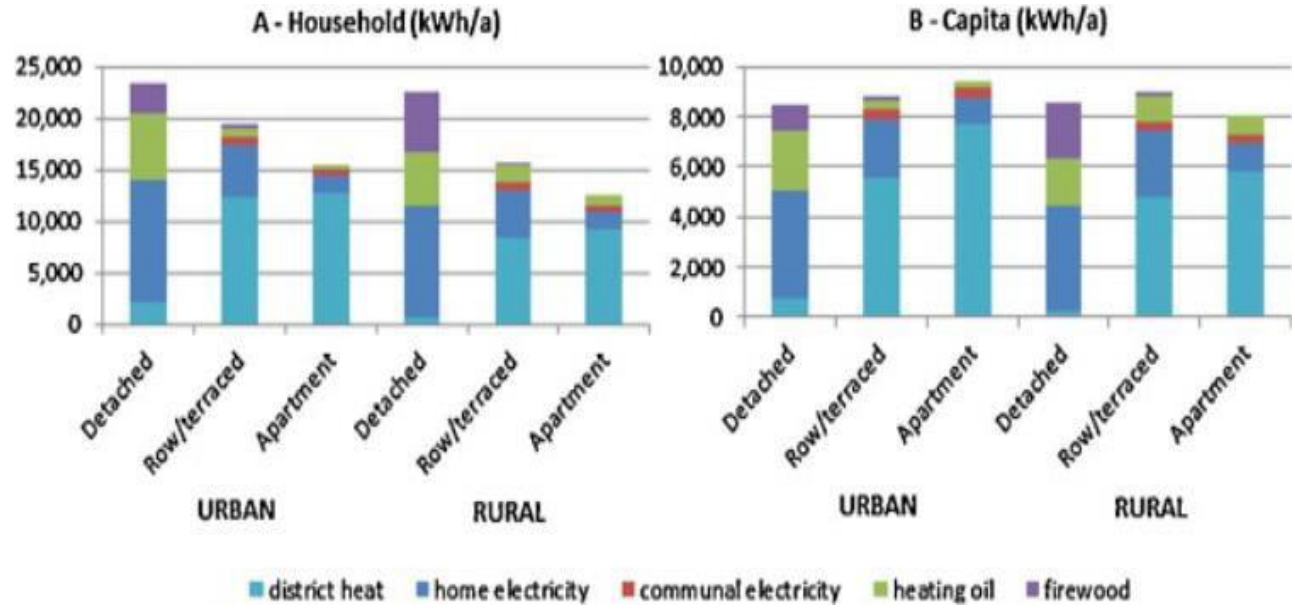

Fig 4: The average per household and per resident energy consumption in urban and rural areas and the three housing types in Finland.

Source: Residential energy consumption patterns and the overall housing energy requirements of urban and rural households in Finland

In the above figure, diagram A, it was determined that among detached, row or terraced and apartment buildings, the energy consumption of apartment buildings for households is comparatively lower than that of other building typologies both in the urban and rural context. Nonetheless the energy consumed by apartment buildings should not be determined solely based on the actual living spaces because communal spaces literarily generate a significant share of the overall energy used. furthermore, many required operations and maintenance activities are comparatively energy intensive which in turn also adds to the communal energy demand on apartment buildings. Contrary to energy consumption which puts into consideration the surface area of living spaces, types of living spaces, electrical appliances used, number of occupants and in a few cases, building location and maintenance in order to calculate and determine the amount of energy consumed, the use and consumption of water for domestic or household uses in most cases is solely determined on the number of occupants and their individual usage.

On an average, the water consumption of an apartment unit can be calculated based on number of occupants. A water consumption research project (WCRP) was carried out by the commission for regulation of utilities in Dublin (CRU) and a survey was conducted in order to determine how much water was consumed by households and its occupants. The survey was conducted in two phases and was also conducted based on residential building typologies in Dublin namely: apartments, detached, semidetached and terraced.

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	Phase 1		Phase 2	
	Sample size	litres/person	Sample size	litres/person
1 occupant	94	171	58	176
2 occupants	335	140	199	142
3 occupants	353	108	258	102
4 occupants	428	94	365	92
5 occupants	265	83	189	79
6 + occupants	111	84	75	81
Total	**1,586**		**1,144**	
Apartment	33	162	-	-
Detached	435	110	178	101
Semi-detached	748	106	498	103
Terraced	370	109	468	106
Total	**1,586**		**1,144**	

Fig 5: Table showing comparison of 2 phases of occupants and water consumption. source: Water Consumption Research Project. Dublin by CRU

The table above with the compiled data shows how many liters of water is used per person based on the number of occupants in a household. In both phases of the survey, it can be determined from the data collected that the more occupants in a household, the less water an individual consumes therefore households with more occupants spend less on an individual basis. Contrary to electric energy consumption, apartments tend to consume more water than other building typologies. Apartments were not included in the survey for the second phase of the survey.

3. METHODOLOGY

The analysis used in the paper is conducted in Famagusta north Cyprus on a residential apartment. In order to have background information of the cost and consumption of energy in north Cyprus, a detailed report is given below based on an energy consumption survey conducted in north Cyprus in 2009 by an ad hoc survey. According to the statistical service in a survey conducted in 2009, A typical household in Cyprus is estimated to have spent almost 1.500 euro on its energy demands. Based on the results of an ad hoc survey conducted by the Statistical Service in 2009, an average household in Cyprus is consumes an estimate amount for its total energy needs a quantity of 1.142kgoe (kilograms of oil equivalent) and to spend an amount of 1.374euro on energy consumption. According to the survey, published on Thursday 6th October 2011, energy consumption is categorized to end use categories namely: space heating - 44,8%, water heating - 5,7%, space cooling - 8,3%, cooking - 14,0% and finally lighting and electrical appliances - 27,2%. In particular, an average household consumes an annual amount of 6.288 KWh of electric energy, 44 liters of kerosene, 355 liters of heating oil, 125kg of liquefied petroleum gas, 244kg of biomass (for example: wood) and also 48kg of charcoal. almost all households (i.e. 98,4%) make use of some kind of equipment or system for heating part of their homes during the cold season of the year. Most households use portable heaters as the main space heating equipment (39,3%), while a notable amount of household is equipped with a central heating system (29,2%) and air conditioning split units (16,9%). The use of fireplaces (7,3%), Electricity Authority of Cyprus storage heaters (4,8%) and stoves or other equipment (0,9%) is less used.

A vast majority of households (68%) operate their main space heating equipment for a duration of 3 to 4 months each year, meanwhile a proportion of 46,2% use their heating equipment for a duration of 3 to 5 hours each day. The percentage of households that use air conditioning for space cooling during the hot period of year is also considerably

high in comparison with an amount of (80,8%). The yearly energy consumption of an average household for space cooling is 1.107 KWh of electric energy, while the average installed capacity of air conditioning units per household is of the order of 32.300Btu (or 9,47 KW). A large amount of the households (91,6%) make use of solar heaters installed for their water heating needs, while a significant proportion of 29,3% use their central heating system for water heating. The households' energy needs for cooking purposes proved to be particularly high. The yearly energy consumed in a typical household for cooking purposes comprises an average of 554 KWh of electricity, 67kg of liquefied petroleum gas, 11kg of wood and 48kg of charcoal. As regards electricity consumption for the operation of electrical appliances and lighting, it is estimated that a typical household consumes annually 3.603 KWh. On an average, appliances which are more intensely used weekly are television sets (46 hours), computers (31 hours) and washing machines for cloths (7 hours of weekly use).

3.1 Results and Discussion

The data used in this analysis was collected from an apartment built in 2001 in Famagusta north Cyprus, which underwent renovations in 2014. The apartment is located on Hasan Raif street, sakarya district of Famagusta. Elevation-wise, the apartment is 65m above sea level and the front of the house faces North West. The apartment has 5 floors and a basement floor which is a total of 6 floors. The main floor to ceiling height is (3.0 m) and the basement ceiling height is also (3.0 m) which gives a total building height of approximately 18m above the ground. The apartment building has 6 units of flats on each floor which comprises of 4 units of 1 bedroom apartments and 2 units of 2 bedroom apartments. The floor area of the 1-bedroom unit is approximately 40m2 while for the 2-bedroom unit, it's approximately 52m2. The total floor area of 1 floor is 280m2 including general circulation area.

To compile the data gotten from the survey questionnaire which is at the end of this paper, a software for data compilation was used. The software used is SPSS. Tables and graphs which are going to be discussed below were derived from the SPSS software.

The questionnaires were filled by 30 different occupants that reside in the apartment building and it was discovered that more than 80% of the respondents were students of the Eastern Mediterranean University because the apartment building is very close to the university, therefore a lot of its occupants turn out to be students. Table 1 below showing the average electricity and water consumption of each apartment unit and the cost on a monthly basis.

Table 1: Table showing apartment unit types and their energy and water consumption costs monthly.

Apartment unit no.	Unit type No. of bedrooms	Electricity cost/month. (TL)	Kilo watts	Water cost/month(TL)	Tons used
1	2	200	122.9	45	11.25
2	1	90	55.3	20	5
3	1	70	43	20	5
4	1	75	46.1	25	6.25
5	1	80	49.1	15	3.75
6	2	250	153.6	40	10
7	2	350	215.0	55	13.75
8	1	60	36.9	20	5
9	1	85	52.2	30	7.5
10	1	70	43	20	5
11	1	130	79.9	25	6.25
12	2	280	172.0	40	10
13	2	300	184.3	35	8.75
14	1	160	98.3	20	5
15	1	100	61.4	20	5
16	1	120	73.7	30	7.5
17	1	100	61.4	20	5
18	2	250	153.6	45	11.25

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19	2	200	122.9	50	12.5
20	1	95	58.4	25	6.25
21	1	130	79.9	20	5
22	1	95	58.4	25	6.25
23	1	180	110.6	20	5
24	2	450	276.4	40	10
25	2	400	245.7	55	13.75
26	1	90	55.3	15	3.75
27	1	110	67.6	20	5
28	1	75	46.1	30	7.5
29	1	90	55.3	25	6.25
30	2	300	184.3	50	12.5

From the analysis conducted on the apartment, 1 bedroom units spend between 60tl and 180tl on electricity which is 36.9kw – 110.6kw, while 2 bedroom units spend between 200tl and 450tl on electricity which is between 122.9kw – 276.4kw. the water consumption of 1 bedroom units on an average is 3.75 – 7.5 tons which costs between 15tl – 30tl, while the water consumption for 2 bedroom units on an average is 8.75 – 13.75 tons which costs between 35tl – 55tl. From this analysis, it can be concluded that 1 bedroom units consume approximately 73.75kw of electricity and 5.63 tons of water while 2 bedroom units consume 199.65kw of electricity and 11.25 tons of water.

Table 2: The average amount of time spent daily by occupants of an apartment unit.

average time spent in the unit by occupants					
Time spent		Frequenc y	Percent	Valid Percent	Cumulative Percent
Valid	0-6hours	2	6.7	6.7	6.7
	6-12hours	18	60.0	60.0	66.7
	12-18hours	8	26.7	26.7	93.3
	18-24hours	2	6.7	6.7	100.0
	Total	30	100.0	100.0	

From the above table, it is derived that the amount of time spent by the majority of occupants in the unit is between 6 – 12 hours on a daily basis by 60% of the occupants while the least number or percentage of occupants 6.7% spent between 18 – 24 hours in their apartment unit. The result of this table can be attributed to the fact that most occupants of the apartment are students of the university, therefore they spend a lot of time outside their residence for educational purposed and spent less time in their apartment units. The result of this Table 2 will affect the amount of money spent by occupants on energy and water which is explained below.

Table 3: The percentage of units with child occupants

are there child occupants in your unit					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	3	10.0	10.0	10.0
	no	27	90.0	90.0	100.0
	Total	30	100.0	100.0	

The above Table 3 shows how many units have child occupants. According to the data compiled, it is derived that only 10% of the units have child occupants while 90% of the unit do not have child occupants.

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Table 4: It shows occupation of respondents.

occupation of respondents.					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	service	4	13.3	13.3	13.3
	business	4	13.3	13.3	26.7
	student	22	73.3	73.3	100.0
	Total	30	100.0	100.0	

The above table shows the occupation of respondents residing in the apartment building. From the above table, it is derived that 73.3% of the apartment occupants are students while a total of only 8% involve in business or provide services as a form of occupation. The results of this Table 4 is influenced by the fact that the apartment is located close to a university therefore most of it occupants are students of the university.

Table 5: It shows the number of occupants per unit.

how many occupants reside in your unit					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 occupant	20	66.7	66.7	66.7
	2 occupants	7	23.3	23.3	90.0
	3 occupants	3	10.0	10.0	100.0
	Total	30	100.0	100.0	

The Table 5 above shows the number of occupants that reside in each unit. The results derived from the above table shows that 66.7% of the units have just one occupant, 23.7% of the units have two occupants while just 10% of the units have three occupants. The number of occupants is directly proportional to the number of bedrooms available in each unit. The apartment comprises of 1 bedroom and two bedroom units and the number of occupants will in turn play a role in the amount spent on electric energy and water consumption in their individual units.

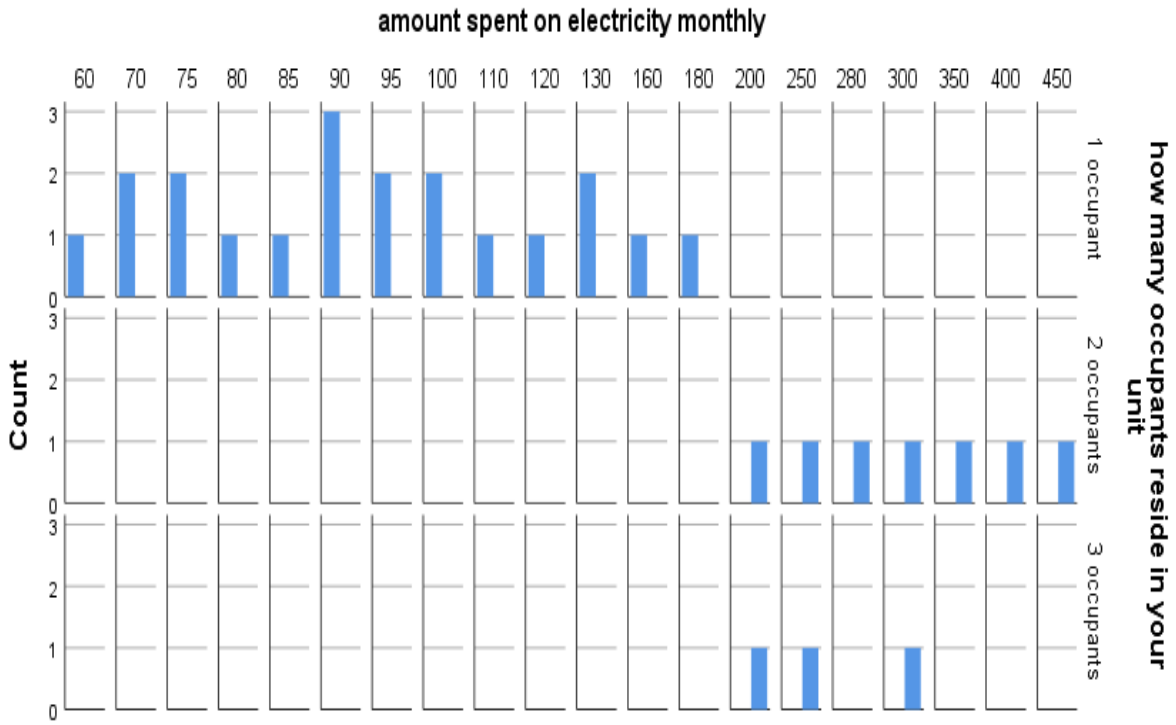

Fig 6: Graph showing the amount spent on electricity monthly in relation to the number of occupants residing in each unit.

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From the above graph, it can be derived that on a monthly basis, the amount spent on electricity for all the occupants in the apartment ranges between 60 Turkish lira(TL) and 450 Turkish lira(TL). For apartment units with a single occupant, the least amount spent is 60TL while the highest amount spent is 180TL. For units with two occupants, the least amount spent is 180TL while the highest amount spent is about 450TL which is the highest amount on the chart. For units with three occupants, the least amount spent is about 200TL while the highest amount spent is about 350TL. The amount spent for units with three occupants is lower than the highest amount spent by the units with two occupants. By assumption, this can be attributed to the point that the apartment units with three occupants have child occupants present and adults in their units are more conscious of the electricity bills. In summary for this chart, units with more occupants spend more on electricity bills while units with less occupants spend less on electricity bills. It is also good to note that units with child occupants tend to spend a little less than units without child occupants.

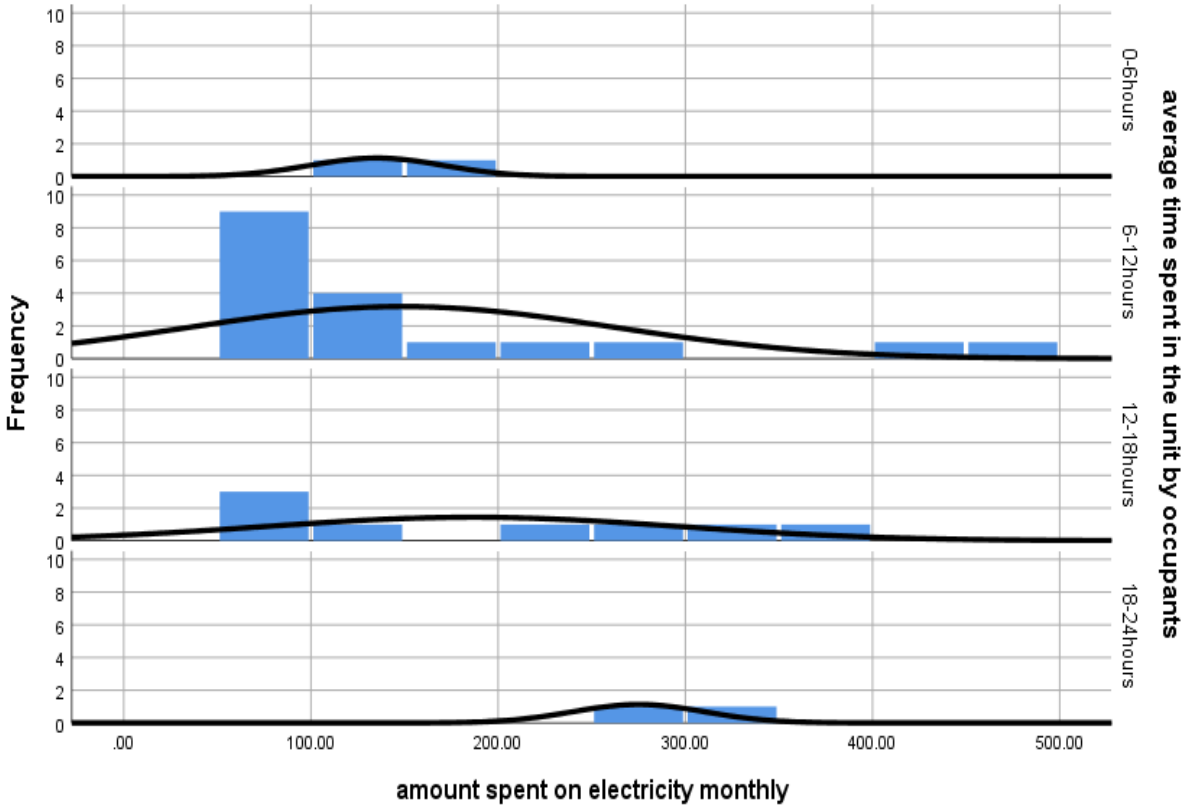

Fig 7: Graphs showing the amount spent on electricity in relation to the average number of hours spent in the units by its occupants.

The graph above shows four different chats which represent time ranges spent in the apartment units by its occupants and the amount the spend on electricity consumption. From the very first graph at the top for 0 – 6 hours, it is derived that occupants spent between 100TL – 200TL on electricity bills. In the second graph of 6 – 12 hours where most of the occupants fall, it is determined that occupants spend within a range of 60TL – 500TL on electricity but with the curve of this particular graph, it is determined that the majority spent between 60TL – 250TL. The third graph which is a range between 12 – 18 hours shows a spending range of 60TL –400TL. From the curve of this particular chart, it is determined that the majority fall between 100TL – 300TL. The fourth and final chart for this sections shows the range of occupants that spend between 18 – 24 hours in their unit on a daily basis and their electricity expenses fall between 250TL and 350TL monthly. From the results of the chat, occupants within the ranges of 6 and 12 hours which is the majority tend to spend the highest on electricity. It can be assumed that occupants that spend more time their apartment units tend to be more cautious of energy consumption unlike occupants which spend less to average time in their apartment units.

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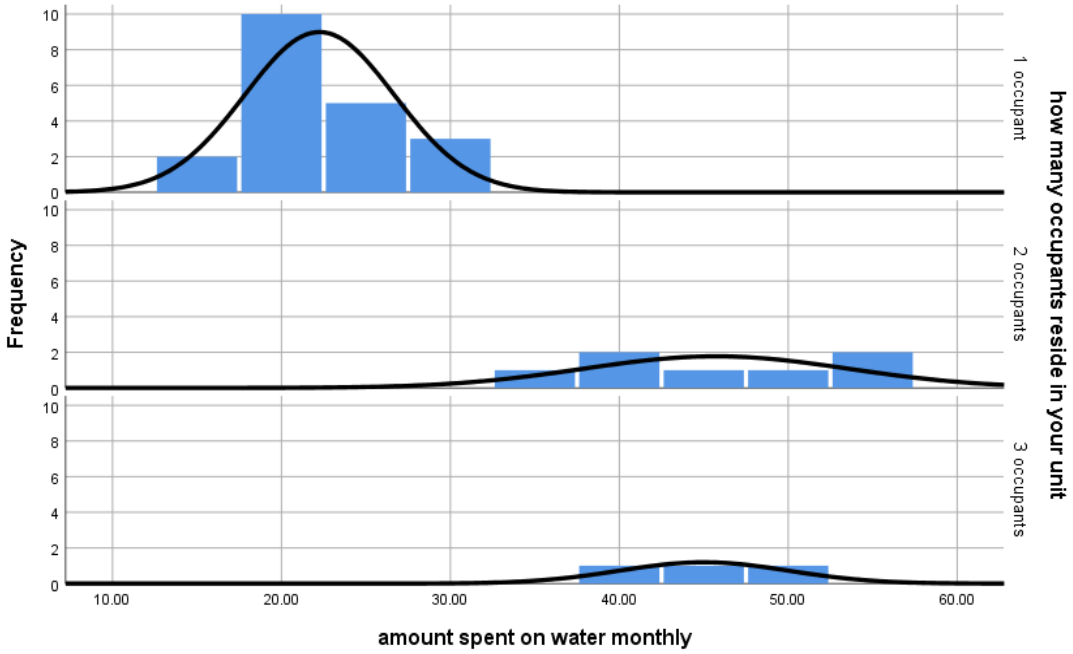

Fig 8: Graphs showing the amount spent on water consumption in relation to the number of occupants in the apartment units.

In the graphs above, the amount spent on water is related to the number of occupants residing each unit. For the first graph which shows the units with single occupants, it is derived that their expenditure on water consumption is between 12TL and 35TL. The curve of this chart shows that the highest amount spent on water is about 25TL for units with one occupant. The second graph which shows the expenditure of units with two occupants shows that these units spend between 30TL and 60TL on water and the curve shows that the highest expenditure is about45TL. The graph of the units with three occupants which is the least in frequency shows that occupants spend between 35TL and 55TL on water bills and the curve also shows that the highest point of expenditure is about 45TL. From the above graph, it can be determined that the units with the least occupants spend less on water consumption while the units with more occupants spend more o water consumption. The units with 3 occupants have child occupants and it can be assumed that units with child occupants tend to spend a little lower than units without child occupants.

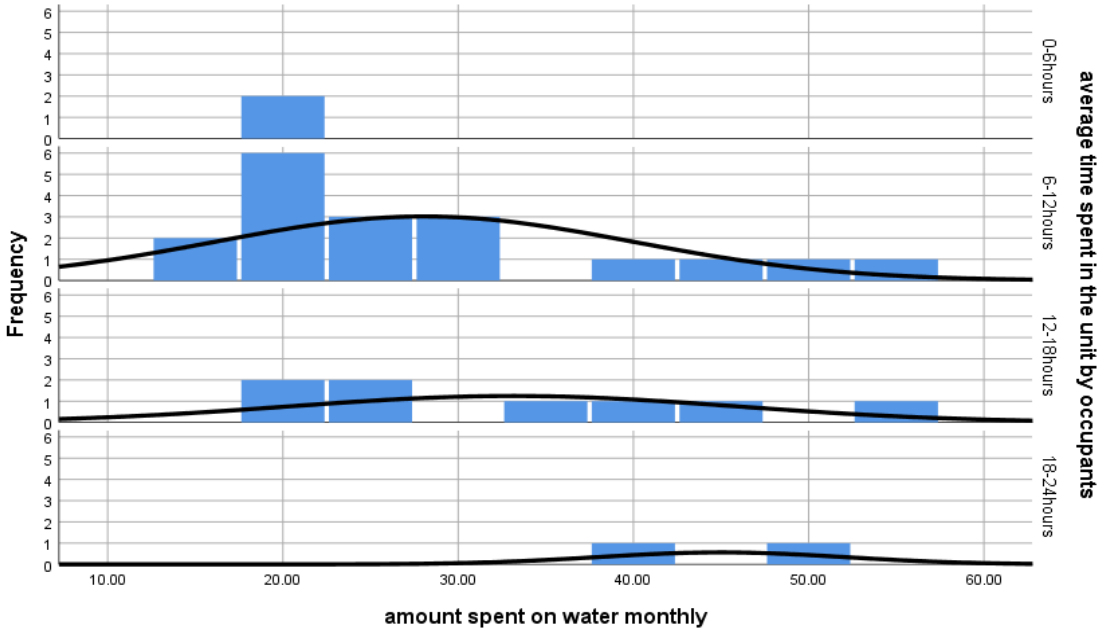

Fig 9: Graphs showing the amount spent on water monthly in relation to the number of hours spent in the apartment units by its occupants on a daily basis.

The graph above shows the amount of money spent on water consumption and its relation to the average number of hours spent in the apartment units by its occupants. The first chart of residents that spend between 0 – 6 hours in their units' shows that their expenditure is between 15TL and 25TL. The second graph of residents that spend between 6 – 12 hours in their unit shows their expenditure on water to be between 15TL and 55TL. The amount with the highest number of people is about 20 TL. The third chart of residents that spend between 12 – 18 hours in their residence spend between 15 TL and 55tl on electricity while the highest number of people for this range spend about 35TL on water consumption. The fourth graph shows residents that spend between 18 -24 hours in their units on a daily basis. This fourth graph shows that these occupants spend between 35TL and 55TL on water consumption. This set of graphs summarizes the fact that occupants who spend between 0 – 6 hours in their units spend less on water than those who spend more time. The occupants who spend between 18 – 24 hours in their units tend to spend a little lower than occupants who spend between 6 and 18 hours in their apartment units. It can be assumed that the occupants who spend more than 18 hours in their units are more cautious of consumption that those who spend between 6 – 18 hours in their apartment units.

4. CONCLUSION

The information and results derived from the questionnaire survey conducted explained the different occupant's behaviors in relation with their environment which takes the presence of the university into consideration as it influences the types of occupants that reside in the apartment. The environment also played a role in determining the rate of child occupants in the apartment and how it influences the consumption of both water and electric energy. The survey carried out also shows the occupants behavior in terms of how many hours they spend in their apartment units and how it influences the rate of water consumption, the results on this behavior shows that occupants who spend more time in their units spend more on electricity and water consumption, but it should also be noted that units with child occupants tend to be more cautious in both electricity and water consumption. The questionnaire survey also included the occupant's behavior in relation to the number of bedrooms in each unit and the number of occupants in each unit. The apartment units consisted of between one to three occupants. The units with one occupant generally spent less on both electric energy and water consumption while the units with two or more occupants generally spent more on water and energy bills. It is important to note that units with occupants that spent more than 18 hours on a daily basis in their units spend a little lower that occupants that spend between 12 – 18 hours in their units.

In conclusion, energy and water consumption irrespective of any average data collected still depends solely on the occupants of a household and their individual lifestyle. Various reasons are linked with an increased level of basic comfort and level of amenities and with the widespread usage of new types of loads brought about by advancement in technology.

In order to increase the understanding of the energy consumption in households, factors like the different types of equipment including the consumers' behavior and comfort levels should be put into consideration. Advances and diversion loads are key supporters of the power request. In fundamentally a wide range of burdens there is extensive variety of execution levels in the models accessible in the market. Accessible innovation, related with capable purchaser conduct, can decrease wasteful consumption of electric energy. In terms of water consumption, a critical pattern in various nations is the utilization of water evaluating as an apparatus to decrease water use during water shortage. Be that as it may, we should remember that the value flexibility for consumable water is, when all is said in done, low or even zero. Nonetheless, water estimating alone can't be the instrument that guarantees practical water utilize. This is just a single of the instruments accessible to water administrators, controllers and lawmakers to achieve the objective of manageable water utilize. Maybe the most imperative device, and one regularly neglected, is the conduct of consumers, and their attention to the genuine estimation of the water assets they utilize. Indeed, even in areas with water shortage we still need to put resources into changing this client conduct. Nonetheless and irrespective of location, there is always a similar pattern in which electricity energy and water is consumed globally. In the diagrams stated above in fig.1 and fig.2, the data used to determine the results gotten are on a global scale and this shows similarity in the pattern of energy consumed on a global scale. From the general analysis on a global scale, it can be determined that the rate of energy and water consumption is constantly on a rise as demand for energy and water for domestic use continues to rise with the years. The data collected from the case study shows how building factors such as surface area of a housing unit can be directly proportional to the energy consumed in the housing unit.

Finally, this paper tried to establish a relationship between the energy and water consumed in a housing unit and the number of household occupants to the total surface area occupied. A little emphasis is also laid upon how time and advancement in technology together with consumer behavior can also influence the rate at which energy and water is consumed in apartment buildings.

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