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Energy Consumption Behavior Analysis in the UAE Educational Buildings for Sustainable Economy: A Case Study of Ras Al Khaimah Schools

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ABSTRACT

Energy-saving in educational building has a significant contribution and a vital role in the economic and social development of nations. In this paper, the energy consumption of some educational buildings in the United Arab Emirates (UAE) are collected and analyzed. Four schools within the region of Ras Al Khaimah were selected to study their buildings' energy consumption behavior. Key energy, economic and environmental parameters were calculated and investigated such as the total annual energy consumption, energy consumption per person, energy consumption per area, energy consumption by category (AC, lighting, other devices, etc.), energy cost, and the amount of greenhouse gas (GHG) emissions. A detailed energy audit was applied to one of the selected schools in order to identify the major areas of energy usage within the school, and to suggest the appropriate measures for potential energy and cost savings. Results revealed that total annual energy consumption of the investigated schools is very high with a range of 3700-3900 MWh. Significantly, in these hot climatic regions, AC systems alone accounts for over 80% of the overall annual energy consumption, standing out as the predominant energy consumers particularly during the summer months. The annual energy consumption per unit area was also excessive with values ranging from 200 to 500 kWh/m^2. Total annual cost of energy was relatively substantial for all schools with values in the order of 1.2-1.5 million AED ($330,000-$400,000). The negative effects of the CO_2 emissions were estimated to be around 500-600 ton of CO_2/year per a single school.

Keywords: Energy Efficiency, Energy Audit, Sustainability, Energy Economics, CO_2 Emissions
JEL Classifications: C83, O13, Q41

1. INTRODUCTION

The United Arab Emirates (UAE) is one of the fastest-growing countries and has a fast increasing economy (Abu-Hijleh et al., 2017). As a result of this growth and country expansion, the electricity demand increases continuously reaching unprecedented levels. As per recent UAE's State of Energy Reports, it was shown that electricity peak demand has been nearly doubled over the last 10 years (Aldawoud et al., 2020). In the last 30 years, per capita electricity consumption was increased from 8.58 MWh to 16.39 MWh showing an increase by 91% (Ritchie and Roser, 2022). Numerous research activities in the UAE pointed out that the building sector is considered as the biggest energy consumer and one of the massive greenhouse gas (GHG) emissions contributors. Buildings account for 30% of the world energy consumption and up to 26% of the world energy-related emissions (IEA, n.d.).

The building sector is imposing massive energy and environmental consequences on the Gulf Cooperation Council (GCC) countries. Mainly driven by the building sector, the electric grid has a quick demand growth. In the KSA and UAE, buildings have significant electrical consumption by air conditioning (AC) systems, lighting, equipment, and other machines resulting in big consumption rates (Asif, 2016). Educational buildings are also one of the main building types that contribute to GHG since some of these facilities are old-built and conventionally constructed in the middle of 1900's. Therefore, as the education sector is a basic part of the society, it is essential to study the energy performance and carbon footprint of these buildings.

The UAE 2021 vision underlines the country's approach to the significance of offering the best education and embracing sustainable environmental infrastructure (Ahmed et al., 2021). There are more than 1,200 schools in the UAE with 639 public schools and 580 private schools (Ministry of Energy and Industry, n.d.). A median school in Dubai consumes about 134 kWh/m^2/year of energy (Emirates Green Building Council, n.d.). In hot weather of Abu Dhabi, HVAC is the biggest energy consumer in classroom buildings with more than 60% of the total energy usage (Al Amoodi and Azar, 2018).

As a result of high cooling demand in the region, this research aims to study and analyze the energy consumption of school buildings. Based on the this work outcomes, suggestions and recommendations will be made for a potential energy reduction, especially within the areas of largest energy consumption, in order to achieve the UAE's goal of transitioning to future sustainable buildings.

2. RELATED WORK

According to a recent comprehensive review study (Alettin et al., 2023), it was stated that there is still a lack of scientific research investigating the energy-saving magnitude and behavior amongst educational buildings. On the other hand, it was also revealed that there is a low level of students' awareness about the effective energy saving strategies and measures.

In recent years, several studies have been conducted to investigate the energy consumption in the school buildings. A study conducted in the Star International Primary School in Dubai showed that more than 80% of total electricity is consumed by AC systems, whereas lighting is responsible for about 5% of energy consumption. This excessive energy consumption is predictable in an area with such extreme hot-humid weather (Aldawoud et al., 2020). Having an ultimate hot-humid climate in the region resulted in an intensive dependance on AC systems to attain a comfortable environment in buildings. Thus, it is one of the main electricity consumption sources that is a common issue encountered in the UAE which influences the retrofitting process options. More than 80% of the total electricity is used to meet the cooling demand in the buildings (Ghulam et al., 2019). Al Amoodi and Azar (2018) studied three prototype building energy models representing archetype office, classroom, and dorm educational buildings in the UAE. As anticipated with the hot climate of Abu Dhabi, HVAC was the biggest energy consumer, compared to other equipment and lighting. The classroom building showed the highest energy saving potential, followed by the office and dorm buildings, respectively.

In hot arid climate like the UAE, different passive cooling measures can be recommended to be used for reducing the energy consumption. These strategies involve convenient window placement and daylight design, proper glazing for windows or skylights, suitable glass sized shading when heat gains are being prevented, usage of light or reflective-coloured materials for the building envelope and roof, suitable orientation decisions and proper landscaping design (Asimakopoulos, 1996). Aldawoud et al. (2020) assessed the effect of different retrofitting measures of AC system and building envelope components on the energy usage of educational building in UAE. The study indicated that the electricity usage can be declined by 29% when replacing the current AC equipment with more energy-efficient and suitably sized systems. Insulation of the building roof and exterior walls seemed to reduce the annual electricity consumption by 21.5%. Recent UAE-based research indicates that building direction and thermal insulation has the potential of 20% energy savings in the residential context. Proper glazing type and orientation in highly glazed office buildings reports up to 55% energy savings (Friess and Rakhshan, 2017). Based on (Abu-Hijleh and Jaheen, 2019), cooling load savings of 5.9%, 8.67%, 1.55%, 11% and 20% were accomplished when exploiting the new Dubai Green Buildings Regulations and Specification (GBRS) glazing, roof, floor, green roof specifications and the best three elements integration, respectively.

Globally, several studies showed applying energy efficiency measures and implementing renewable-energy-based systems lead to significant reductions not only in the total consumption and cost of energy but also in the GHG emissions. In their research, Dall'O' and Sarto (2020) emphasized the importance of the building envelope insulation and window changing in Italy. Since the consumption indicator weighted on the surfaces of 144 kWh/m^2/year at the beginning was declined to 75 kWh/m^2/year. In addition, a study conducted by Mora et al. (2018) on an Italian school building revealed that with combination of energy and seismic retrofit, there are about 53% of cost saving and around 96% of energy consumption reduction. Moreover, Italian school buildings were analyzed by Marrone et al. (2018) suggesting envelope insulations, energy service improvements such as heating and cooling, and renewable energy sources employment. The real energy requirements when the retrofits are applied represented 24% energy savings in 2012 and 20% in 2016. According to another global study in Germany (Reiss, 2019), school buildings' energy consumption can be lowered by approximately 80% if energy retrofitting of the building envelope are applied, with good quality thermal insulation materials, triple glazing and daylight redirecting techniques, and utilization of renewable energy. Furthermore, based on (De Santoli, 2014), lighting system and electric plug loads (such as computers, printers, etc.) are also other main energy consumers in school buildings in Rome since schools operates most of the time throughout the year.

On the other side, a study was carried out on a school sports area located in a hot semi-arid steppe climate (BSh) of Mexico (Valencia-Solares et al., 2023). Results showed that using an inorganic phase change material (PCM) and a low-concentration photovoltaic thermal (LCPV/T) hybrid collector led to 5.8% decline in the annual building electricity consumption. Additionally, the GHG emissions were reduced by up to 162 tonCO_2e/year for different applied scenarios. The main findings of a study conducted on school buildings in Serbia (Đukanović et al., 2022) revealed that, in terms of their energy efficiency, most of school buildings in the country are in a weak state. On the other hand, there was a great potential for building envelope enhancement, HVAC devices, and lighting systems, which can reduce the heating load by up to 80%. Cedillo et al. (2023) suggested procedures for minimizing GHG emissions of a school design in Mexico. Three different advanced mitigation cases were studied to cut the GHG emissions from commuting, energy consumption, collaborators and student movement, and material resources. Results showed a percentage of 63.5% cut in the GHG emissions.

A further study (Bohvalovs, 2023) presented a decline in primary energy consumption by 39% and GHG emissions by 34% in educational buildings. This decline was due to applying energy-efficient building systems, usage of renewable energy systems, and implementing sustainable practices into the school curriculum. A simulation study was applied on two multi-unit residential buildings in Toronto, Canada by Taileb and Sherzad (2023). The results showed that the use of triple low-E glazing lead to 38% and 34% reductions in the gas consumption over single- and double-glass windows, respectively. If window area is reduced by 20% (north/south sides), an additional 9% of energy saving is achieved.

3. METHODOLOGY

Three schools within Ras Al Khaimah region were selected to investigate the energy consumption behavior of their buildings. A more detailed analysis through an energy audit was applied to another fourth school to study the energy consumption behavior considering the different existing energy systems within the school building. The complete energy audit was conducted by firstly visiting the school and meeting the administrative staff and then listing all energy-dependent devices and equipment, along with their energy consumption rates and daily operating hours. Energy-related statistics available from school documents such as electricity bills and meters' readings based on the year of 2022 were also collected. Key parameters representing important energy, economic and environmental indicators were calculated and analyzed. Comparisons based on the energy, cost and environmental indicators were carried out between the investigated schools. The aim of this analysis is to identify the systems and devices that consume the largest energy, thus helping to take the right recommendations and decisions for energy retrofitting measures within the schools.

3.1. Mathematical Model

To properly analyze and judge the energy consumption behavior in the selected schools, different key parameters were calculated such as the total annual energy consumption, energy consumption per person, energy consumption per unit area, energy costs, and associated GHG emissions. These quantities are calculated as follows:

Total annual energy consumption for equipment *i* is calculated as

$$E_i = n_i \times P_i \times t_i \tag{1}$$

Where n_i is the number of items of equipment *i*, P_i is the rating power (kW) of the equipment *i*, and t_i refers to the time (hours) over which the equipment *i* operates in the year.

The total annual energy consumption of all equipment and devices in the school can be determined from

$$E_{tot} = \sum_{j=1}^{N} E_i \tag{2}$$

The total annual energy consumption per person is defined as

$$E_p = \frac{E_i}{N_p} \tag{3}$$

Where N_p is the total number of people in the school. The total annual energy consumption per unit area of the school is calculated as

$$E_A = \frac{E_i}{A} \tag{4}$$

Where *A* is the is total school area (m^2). The total annual cost of energy, C_{tot}, is estimated as

$$C_{tot} = E_{tot} \times TR \tag{5}$$

Where *TR* is the is the tariff rate (fils). 1 AED = 100 fils. The electricity supplier, Etihad Water and Electricity, adopts different tariff rates according to the monthly electricity consumption categorized in what are known as slabs. The tariff rate for the first 10,000 kWh is 23.0 fils whereas the remaining consumption is calculated using a tariff rate of 38.0 fils.

The amount of CO_2 emissions due to electricity generation vary depending on the energy source utilized (i.e. coal, natural gas, and petroleum) and the efficiency of the power generation plant. This is expressed in terms of CO_2 emission factors which is a function of the fuel/energy type. It is also known as carbon intensity, representing the amount of CO_2 emitted per unit of energy (e.g. kg of CO_2/kWh). The U.S. Energy Information Administration (EIA) periodically releases estimates of CO_2 emissions from electricity production. EIA considers electricity generation from renewable sources (i.e. biomass, hydro, solar, and wind) to be carbon neutral (EIA, n.d.). In this study, the annual amount of CO_2 emissions from each school is determined using Eq. 6, considering that the UAE carbon intensity is 160 kg of CO_2/MWh (Ritchie and Roser, 2020).

$$Em_{CO_2} = E_{tot} \times F_{CO_2} \tag{6}$$

3.2. Ras Al Khaimah Climate

Ras Al Khaimah is a costal Emirate located in the northernmost part of the UAE between the Latitude of 25-26N and Longitude of 55-60E. It has a subtropical desert climate with a classification of hot desert climates (BWh). The warmest month is July with 40.17°C and the coolest month is January with a range of 16.89°C (Weather and Climate, n.d.). It is categorized by its intense high temperature particularly among the summer months from June to September where the temperature can reach up to plus 40°C. In Ras al Khaimah, June has the most daily hours of sunshine with an average of 12.08 h of sunshine, with a total of 374.6 sunshine hours throughout the month. About 3877.74 h of sunshine are counted in Ras al-Khaimah throughout the year with an average of 127.43 h monthly (Climate Data, n.d.).

3.3. Case Studies

In order to investigate and assess the energy consumption behavior of their buildings, four different schools within Ras Al Khaimah region were chosen in this work. These schools include Al Rams Boys Cycle 2 School, Julphar Girls Cycle 3 School, Saeed Bin Jubair Cycle 3 School, and Mahra Bint Ahmed Cycle 1 School. The latter was selected to implement a detailed energy audit in order to explore the areas of major consumptions. This will, in turn, help to apply the appropriate measures for potential energy savings. Figure 1 shows the exterior view for the selected schools. Detailed information about the selected schools are listed in Table 1.

Figure 1: Exterior view of the four selected school buildings. (a) Al Rams Boys Cycle 2 School. (b) Julphar Girls Cycle 3 School. (c) Saeed Bin Jubair Cycle 3 School. (d) Mahra Bint Ahmed Cycle 1 School

4. RESULTS AND DISCUSSIONS

4.1. Al Rams Boys School - Cycle 2

Al Rams Boys Cycle 2 School was opened in 2007 over an area of 8,496.6 m^2 with a total capacity of 521 persons including students and staff (Figure 1a). Figure 2 presents the energy consumption by different categories of the school devices. It is clear that the highest energy consumer is the ducted split unit (4 Ton) AC systems with a percentage of 43.44% of the total energy consumption, followed by the AC package units with a percentage share of 28.22%. It is worth to mention that there are a total 67 installed units of the ducted split (4 Ton) AC system and a total of 9 installed AC package units with three different power ratings of 52.75 kW, 70 kW and 105.5 kW. The figure also demonstrates that the spilt AC (2 Ton) systems have a comparable energy consumption share of about 27.44% as a result of a total 85 installed units.

4.2. Julphar Girls School - Cycle 3

The second selected school is Julphar Girls Cycle 3 as illustrated in (Figure 1b). The school was established in 1991 with a total area of 7,518.7 m^2 and a population capacity of 608 persons. Figure 3 presents the energy consumption breakdown for Julphar girls cycle 3 school. The results indicate that the spilt AC (2 Ton) system is the dominant energy consuming devices with 90.44%. This can be attributed to the large number of such AC units. In the school, there are a total of 224 spilt AC (2 Ton) units distributed on different rooms. Approximately only 8% of the total energy consumption is due to the two installed AC package units each with 70 kW rating capacity.

4.3. Saeed Bin Jubair Boys School - Cycle 3

As depicted in (Figure 1c), Saeed Bin Jubair Boys Cycle 3 School building was built in 1995. It has an area of 6,727.7 m^2 and a total number of staff and students of 495. The energy consumption

Table 1: General information of the four selected schools

Item	Mahra Bint Ahmed Cycle 1	Al Rams Boys Cycle 2	Julphar Girls Cycle 3	Saeed Bin Jubair Cycle 3
Location	Julphar, Ras Al Khaimah	Al Rams, Ras Al Khaimah	Julphar, Ras Al Khaimah	Seih Al Qusidat, Ras Al Khaimah
School area (m^2)	14,377.5	8,496.6	7,518.7	6,727.7
Number of occupants				
Staff	44	32	45	44
Students	403	459	540	427
Workers	30	30	23	24
Visitors	10-15 (Approximately)			
Number of rooms				
Offices	25	9	10	13
Classrooms	31	33	20	22
Science labs	3	3	3	4
Technology classrooms	3	2	1	2
Activity rooms	6	3	1	1
Electricity rooms	5	9	1	4
Internet rooms	4	6	1	2
Pump rooms	4	1	1	1
Stores	13	18	2	6
Toilets	19	12	8	10

breakdown for Saeed Bin Jubair Boys Cycle 3 School is presented Figure 4. As demonstrated in the pie chart, it is noticeable that 89.49% of the total energy in the building is consumed by the spilt AC (2 Ton) systems, followed by the AC package units with 9.23% of the total consumption. The school contains of 194 spilt AC (2 Ton) units and 2 AC package units both with a power rating capacity of 70 kW.

4.4. Mahra Bint Ahmed School - Cycle 1

The fourth school is Mahra Bint Ahmed Cycle 1 as shown in (Figure 1d). The school was opened in 2014 with the greatest area of 14,377.5 m^2 and a capacity of 477 occupants. This school was chosen to conduct more detailed energy analysis in order to understand the energy consumption behavior. An energy audit was applied to the school by firstly listing all energy consuming equipment and devices along with their power rating and daily operation behavior, taking in consideration that the operating hours are estimated based on daily observations. This was followed by calculating the corresponding daily energy consumption quantities. Table 2 lists the main equipment and devices along with the energy related details.

Figure 5 illustrates the energy consumption breakdown for Mahra Bint Ahmed Cycle 1 School. As shown in the figure, more than half of the total daily energy in the school is consumed by the chillers. The three installed chillers, with 694 kW each, have the highest energy consumption within the school reaching about 56%. Fan Coil Units (74 units) are the second major consuming devices with a total share of approximately 22% of the total energy consumption. The lighting system is responsible for only 5.6% of the total consumption. The other equipment and devices consume very little energy which can be neglected. Results also demonstrated that the school total daily energy consumption is about 10,296 kWh.

Figure 2: Energy consumption breakdown for Al Rams boys cycle 2 school

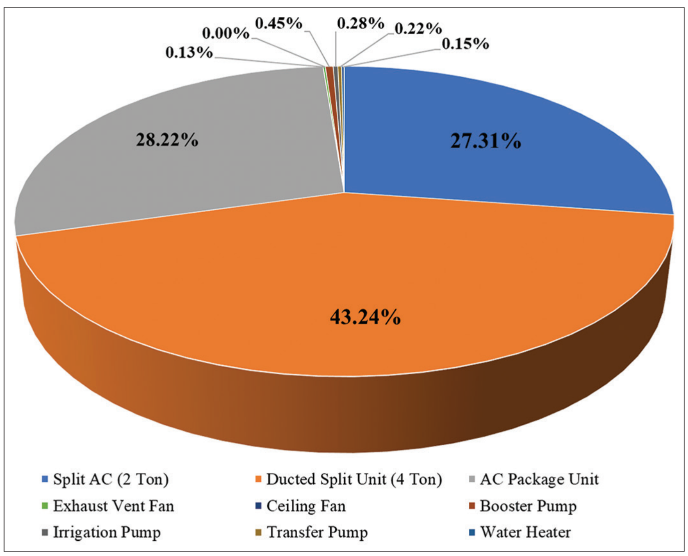

Figure 4: Energy consumption breakdown for Saeed Bin Jubair Boys Cycle 3 School

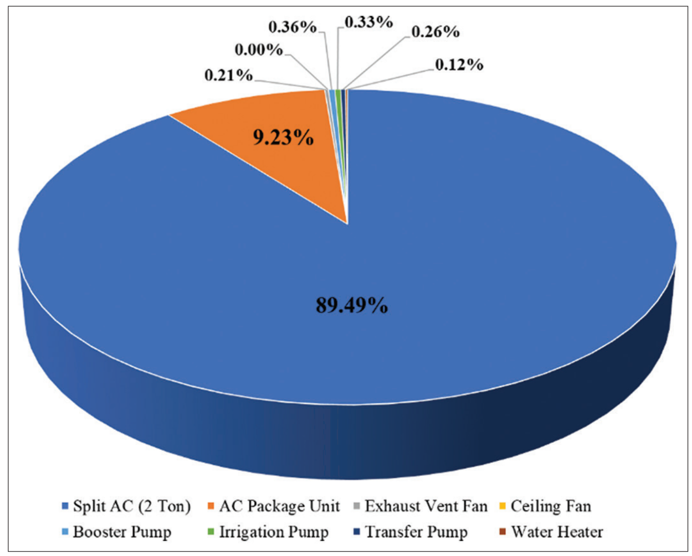

Figure 3: Energy consumption breakdown for Julphar girls cycle 3 school

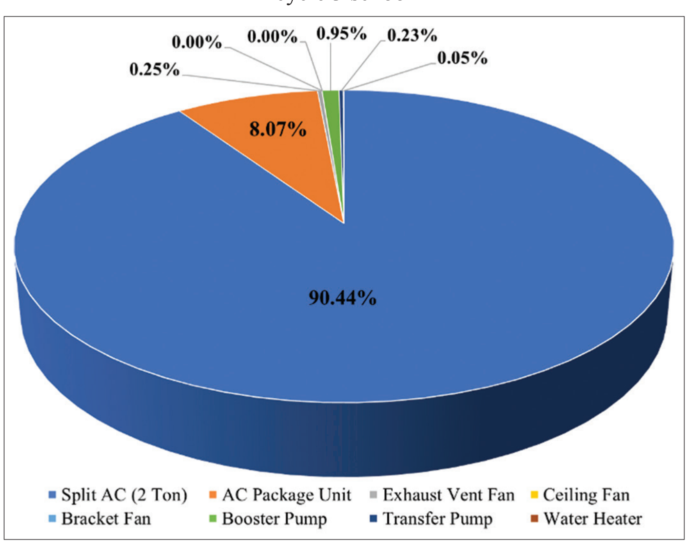

Figure 5: Energy consumption breakdown for Mahra Bint Ahmed Cycle 1 School

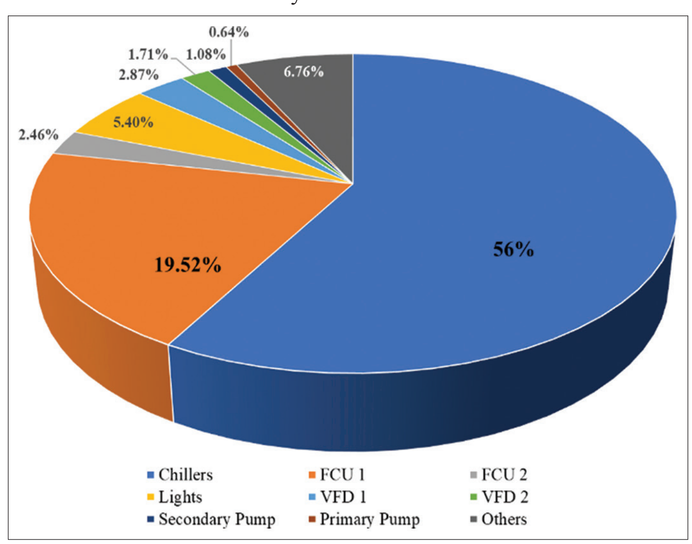

Table 2: List of energy consuming devices for Mahra Bint Ahmed cycle 1 school

Equipment/device	Number of units	Rating power (kW)	Operating hours per day (Hours)	Energy consumption per day (kWh)	Consumption percentage
Chillers	3	694	2	4,164	56
Fan coil unit (FCU)	68	10.55	2	1,435	19.52
	6	14.06	2	169	2.30
Lights (2 and 4 tubes in a fitting)	775	0.036	8	223	3.04
Lights (3 tubes in a fitting)	499	0.028	6	84	1.14
Lights (round LED lights)	144	0.018	8	21	0.28
Lights (flood lights)	24	0.4	4	38	0.52
Variable frequency drive	4	37	2	296	4.03
(VFD)	4	22	2	176	2.39
Secondary pump	3	18.5	2	111	1.51
Primary pump	3	11	2	66	0.90
Air handling unit (AHU)	1	11	2	22	0.30
	1	5.5	2	11	0.15
	1	2.2	2	4	0.06
Split AC	10	7	2	140	1.90
	1	5.27	8	42	0.57
Fresh air handling unit	2	5.5	2	22	0.30
(FAHU)	2	2.2	2	9	0.12
Booster pump	2	5.5	3	33	0.45
Transfer pump	2	4	3	24	0.33
Irrigation pump	2	3	2	12	0.16
Water heater	4	1.5	1	6	0.08
	21	1.2	1	25	0.34
Exhaust vent fan	2	1.5	1	3	0.04
	7	0.55	1	4	0.05
TASkalfa 5052ci Printer	1	0.733	2	1	0.02
	1	0.733	2	1	0.02
	1	0.05	2	0	0.00
	1	0.06	2	0	0.00
	1	0.0007	2	0	0.00
Taskalfa 356ci Printer	1	0.752	2	2	0.02
	1	0.0016	2	0	0.00
	1	0.11	2	0	0.00
Make up pump	2	0.55	3	3	0.04
Air curtain	2	0.47	2	2	0.03
	12	0.2	2	5	0.07
	6	0.1	2	1	0.02
EPSON EB-71OUI projector	34	0.423	6	86	1.17
hp COREi3 computer	38	0.12	6	27	0.37
SC-270E refrigerator	2	0.4114	24	20	0.27
TSB1CF 13 refrigerator	7	0.366	24	61	0.84

4.4.1. Average monthly energy consumption

Figure 6 shows the monthly variation of the electricity consumption for Mahra Bint Ahmed Cycle 1 during the whole year of 2022. As depicted in the figure, monthly electricity consumption exhibits significant fluctuations over the course of the year. The highest peak demand, reaching 307 MWh, occurs during the summer months, particularly in July and June, primarily driven by the extreme outdoor temperatures. At the beginning of the academic year, particularly in September and October, electricity consumption is notably high, ranging from 185 to 218 MWh. In the period from November to February, as the weather turns cooler in winter and early spring, energy consumption is relatively low and it decreases steadily, reaching a monthly minimum of 32 MWh in February. Subsequently, energy consumption begins to rise again in response to increasing outdoor temperatures. The high electricity consumption of the school can be mainly attributed to the poor envelope thermal properties and occupants' related manners.

Figure 6: Monthly energy consumption profile for Mahra Bint Ahmed Cycle 1 School

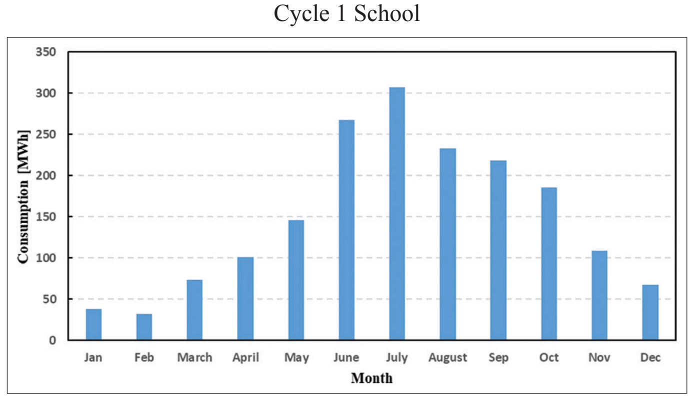

Table 3: Comparison between the four schools based on key energy parameters

General details				
Parameter	**Mahra Bint Ahmed School-Cycle 1**	**Al Rams Boys School-Cycle 2**	**Julphar Girls School-Cycle 3**	**Saeed Bin Jubair School-Cycle 3**
Total energy consumption per year (MWh/year)	3,706.80	3,921.65	3,745.01	3,277.63
Energy consumption per person (kWh/p/y)	7,771.08	7,527.16	6,159.56	6,621.48
Energy consumption per area (kWh/m^2/y)	257.8	461.6	498.1	487.2
Major energy consuming devices	Chillers: 56% FCUs: 21.98%	Ducted split: 43.24% AC package: 28.22%	Spilt AC: 90.44%	Spilt AC: 89.49%
Total annual energy cost (AED/year)	1,390,585.82	1,472,226.42	1,405,104.68	1,227,500.52
Annual GHG emissions (ton CO_2/year)	593.09	627.46	599.20	524.42

4.5. Comparing Energy Consumption Across the Four Schools

Table 3 summarizes the main key energy indicators for the four selected schools in order to compare their energy consumption behavior. The total annual energy consumption for all schools is considerably high ranging from approximately 3700-3900 MWh. The highest annual energy consumption per person is in Mahra Bint Ahmed Cycle 1 School with 7,771 kWh/p/y, whereas the lowest is in Julphar Girls Cycle 3 School with a value of 6,159 kWh/p/y. The energy consumption per unit area in all of the examined schools significantly surpasses the regional average for schools in Dubai, which stands at 134 kWh/m^2/year. In the case of the four schools under investigation, this metric varies between 250 and 500 kWh/m^2/year, with Mahra Bint Ahmed Cycle 1 School recording the lowest figure. Notably, in these hot climatic regions, air conditioning (AC) systems emerge as the primary energy consumers, representing a substantial portion of total annual energy consumption. Remarkably, during the summer months, the energy consumed by AC systems alone accounts for over 80% of the overall annual energy consumption.

Furthermore, the results reveal that the annual energy cost is notably high, exceeding 1.4 million AED/year (equivalent to $380,000). Additionally, the CO_2 emissions generated are substantial, reaching approximately 524-627 tons of CO_2 per MWh for a single school.

5. CONCLUSION

In this study, a comprehensive analysis of energy consumption in educational buildings located in the United Arab Emirates (UAE) was conducted, with a focus on four schools in the Ras Al Khaimah region. The investigation encompassed critical energy, economic, and environmental parameters, including total annual energy consumption, energy use per capita and per unit area, energy consumption by category (such as air conditioning, lighting, and other equipment), energy costs, and greenhouse gas emissions. A detailed energy audit was applied to one of the selected schools. The aim of this energy audit was to pinpoint primary areas of energy utilization within the school, evaluate the performance of existing systems, and propose energy-saving strategies.

The results of our analysis revealed striking patterns in energy consumption. The total annual energy consumption in the surveyed schools was notably high, ranging from 3700 to 3900 MWh. Moreover, the annual energy usage per unit area exceeded typical levels, with values ranging from 200 to 500 kWh per square meter. Cooling systems, as the predominant energy consumers, particularly air conditioning (AC) units, were identified as the largest contributors to energy consumption in all the schools. The total annual energy cost was also substantial across the schools, falling within the range of 1.2-1.5 million AED ($330,000-$400,000).

Furthermore, the analysis estimated the adverse environmental impact of CO_2 emissions, which ranged from 500 to 600 tons of CO_2 per school annually. These findings underscore the pressing need for energy-efficient measures in educational buildings to both reduce costs and mitigate environmental consequences.

6. RECOMMENDATIONS

The findings of this study underscore the pivotal role of air conditioning (AC) systems in the energy consumption of schools located in hot arid regions. AC systems are the predominant energy consumers, accounting for over 80% of the total energy consumption in school buildings. In light of these results, several energy-efficient measures are recommended for implementation in educational facilities across the UAE to curtail energy consumption and maximize cost savings. These strategies include:

1. Promoting energy-efficient behavior: First and foremost, there is a compelling need for structured initiatives aimed at fostering energy-saving behavior among school-age students and facility managers. These efforts can lead to heightened ecological awareness and provide crucial support for the implementation of national policies focused on energy conservation and efficiency.
2. Optimal AC system set point: It is advisable to maintain the AC system set point at 23°C or higher, aligning with the recommendation put forth by the RAK Municipality.
3. Enhanced building thermal insulation: The installation of effective thermal insulation for building walls and roofs, coupled with the use of appropriate shading devices, is strongly encouraged.
4. Window upgrades: Consider replacing existing windows with more efficient options, such as low-e double and triple glazing, as well as coatings with high reflection properties.
5. Efficient lighting solutions: Replace inefficient lighting systems with high-efficiency LED lamps, and incorporate motion sensors in corridors, storage areas, and halls to optimize lighting control.

Given the significant number of schools in the UAE, exceeding 1,200, the potential for savings in both energy and costs is substantial. When applying energy audits to diverse schools, the results are expected to be consistent, with larger institutions and those equipped with aging systems presenting even greater energy-saving opportunities. This study is poised to serve as a valuable benchmark, providing actionable recommendations for reducing energy consumption and mitigating associated environmental emissions in the educational sector.

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