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ARTICLE (PEER REVIEWED)

# A Comparative Study of Energy Performance in Educational Buildings in the UAE

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## Abstract

Sustainability has gained popularity and importance around the globe due to the ever-increasing effects of climate change and global warming on Earth. As of the 21st century, human endeavour has caused an enormous amount of damage to the environmental ecological system. Among which, one of the major contributors to the increase in the environmental issues and CO2 emissions are the conventional sources of energy, especially in the built environment. Globally, the built environment accounts for 12 percent of the world's drinkable water, 40 percent of energy wastage and 35 percent of scarce natural resources, which in turn produces 40 percent of the total global carbon emission. Among which are educational buildings which tend to be a major contributor (as most of these facilities are old and conventionally built in the mid 1900's) Thus, with the education sector being an essential part of society, it becomes important to determine the energy performance and carbon footprint of these buildings. The United Arab Emirates (UAE) vision 2021 highlights the country's approach to the importance of providing the best education and adopting sustainable environmental infrastructure. Therefore, this study adopts a methodological approach based on semi-structured interviews and surveys, in order to compare the energy performance of three educational buildings within Higher Education establishments in the UAE as a case study. The study also evaluates the end user's awareness of the importance of sustainable practices in the buildings and their preference of these buildings. The findings of this study conclude that Net Zero Energy Buildings (NZEBs) are the most efficient buildings in terms of energy performance, carbon



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consumption and heat generated. Therefore, it is important that the integration of these types of buildings are considered in educational establishments.

## Introduction

Sustainability has gained popularity and importance around the globe due to the ever-increasing effects of climate change and global warming on Earth (Jordan, 2021). As of the 21st century human endeavour has caused an enormous amount of damage to the environmental ecological system. As per the latest report by NASA, 2020, the *Carbon Dioxide level* in the air is 415 parts per million which is the highest in 650,000 years; *Global Temperature* has risen up to 2.1 degrees Fahrenheit with 19 of the warmest years since 2000; *Arctic ice* decline of 13.1 percent per decade that shrank to the lowest extent on the record since 2012; *Ice Sheets* losing mass with 427 billion metric tons per year and Sea Levels increasing about 3.3 mm per year. The statistics depict the image of a falling Earth with its resources getting scarcer year by year, where the major contributor to the increase in the environmental issues and CO2 emissions are the conventional sources of energy, especially in the built environment.

Globally, the built environment accounts for 12 percent of the world's drinkable water; 40 percent of energy wastage and 35 percent of the scarce natural resources, which in turn produces 40 percent of the total global carbon emission (Gobain, 2020). Thus, this calls for the need to adopt green construction practices and effective management of natural resources as the need of the hour for mitigation of the reduction of energy consumption and CO2 emission in the built environment.

Parallel to this, literature reports on a significant growth and interest in achieving Zero Energy targets on an international level, for example in the United States of America in which the initiative is part of the Energy Independence and Security Act of 2007 (EISA) as well as the United Kingdom initiative of Energy Performance of Buildings 2010 (EPBD) with the recent UK parliament legislation in June 2019 committing the government to reduce the net emission by 100 percent relative to 1990 levels by 2050. Similarly, other nations such as Sweden, Scotland, France, Denmark, European Union (EU), Spain, Chile, Fiji and China also passed on the legislation to achieve their net zero target by 2050. Likewise, the Gulf Cooperation Council (GCC) also experiences huge energy and environmental challenges, with recent trends suggesting the realization by the GCC of adopting sustainability as the essential concept for the region. This is evident by the United Arab Emirates initiatives such as the 2021 National Agenda in 2014 to meet the long-term needs and improve the quality of resources as well as to expand the involvement of clean and green energy in the country. As part of this initiative the UAE planned to produce 27 percent of its electricity from sustainable sources by 2021 to secure the energy demands for the next generations (Mazumder, 2016). In addition, the UAE was one of the parties that agreed to the adoption of the Paris Agreement treaty on climate change at the Paris 21st Conference of Parties (COP21), which emphasizes the UAE vision to move forward with achieving its 2030 mission.

This said, and although there are a number of initiatives that have been proposed globally to achieve the net zero energy target in residential and commercial buildings, little has been reported on the utilisation of Zero Energy Buildings in the UAE in general and educational buildings in particular (Marszal, et al., 2011). Literature shows that the 'Education Sector' is a significant contributor to the nations' success while allowing societies to progress and flourish (Ahmed, Abu Alnaaj and Saboor, 2020). Therefore, it is important to consider the adoption of sustainable practices in educational buildings, in order to set a leading example for the adaptation of sustainable practices, which have a positive effect on the socio-economic and health of the occupants of buildings.

Therefore, given the growing interest of the UAE in global education, and the fact that the UAE is a growing hub for a number of national and international universities, this study, inspired by a number of studies such as (Agdas, et al., 2015 and Yeo, et al., 2019) is focused on examining the amount of energy consumption in a traditional educational building, and comparing it to a semi-traditional building as well as a Zero Energy building in terms of energy efficiency and the preference of the end users of these buildings.

## Energy Consumption and Sustainable buildings

Sustainability and sustainable development have become essential concepts for the survival of Earth. Sustainability is defined as living within an environment without causing any harm or damage to the environment for future generations (Mazumder, 2016). Furthermore, it is classified into three categories such as social, environmental, and economic sustainability to develop a balanced system (Roncz, 2011). This implies that to form a balanced ecosystem, the concept of sustainable development must be adopted into every field.

Moreover, sustainable development can be defined as any kind of development that occurs for the present generation in order to meet their demands and needs without compromising the needs of the future generations from their requirement (Abrahams, 2017). However, there are alarming statistics that show the impact of climate change causes around 12,000 extreme weather events since 1999 – 2018, which resulted in a loss of 4,95000 lives globally and losses of US$ 3.54 trillion as a direct result of these disasters (NASA, 2020). At the same time, studies show that there are key activities that have a significant impact on the ecosystem. These include activities reported by various sectors such as transportation, industrial and the agriculture sector which are a major contribution to climate change. Whilst the Energy Sector and Built Environment alone contribute to 40 percent of the total global carbon emission with a complex, direct and an ever-lasting impact on the ecosystem. In addition, around 90 percent of the total material and resources extracted from the environment reside in the built environment globally, at the time of writing (Bilgen, 2014).

Moreover, like other developed nations, the Gulf Cooperation Council (GCC), economic and political association of six countries of the Middle East such as Saudi Arabia, United Arab Emirates, Kuwait, Qatar, Bahrain, and Oman also experience huge energy and environmental challenges such as severe water scarcity, huge demand for energy and a high amount of CO2 emissions. Over the last few decades, the GCC has experienced a construction boom due to its huge and steady economic growth and modernization (Asif, 2016). However, the growth and construction boom has put the GCC among the highest in the world in terms of energy consumptions and CO2 emissions, with the average figure of per capita energy consumption for GCC being seven times higher than the global average as shown in Figure 1.

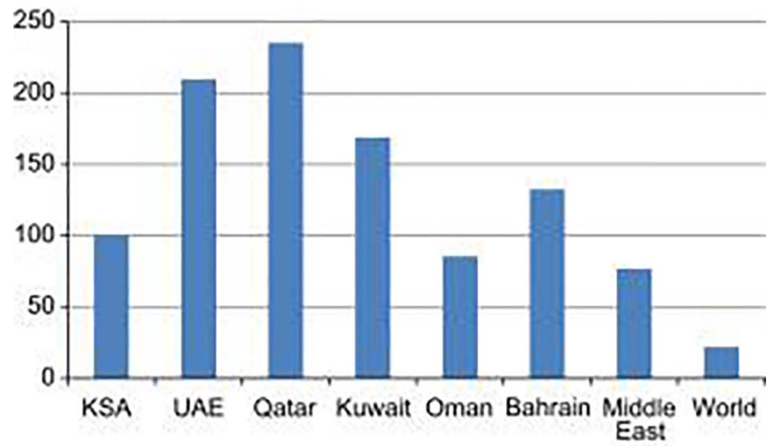


Figure 1. Annual per capita electricity consumption in MWh (Source: Asif, 2016)

As evident from the figure above, Qatar and the UAE are amongst the top six countries in the world in terms of metric tonnes of CO2 emission per person with Qatar accounting for 44 Annual per capita $CO_2$ emissions and the UAE accounting for 23 Annual per capita $CO_2$ emissions. According to Baldwin (2018), the Building Sector in the UAE is the major consumer of the total amount of energy generated which results in an increase in the number of environmental issues such as global warming, increase in temperature of the region and the amount of CO2 emissions. Whilst a report by the Dubai Carbon Centre of Excellence identified the Energy Sector of the UAE as the main reason for the increase of Green House Gases (GHG) as the electricity and water consumption level, which is considered much higher than other sectors, as shown in Figure 2 below (Mazumder, 2016).

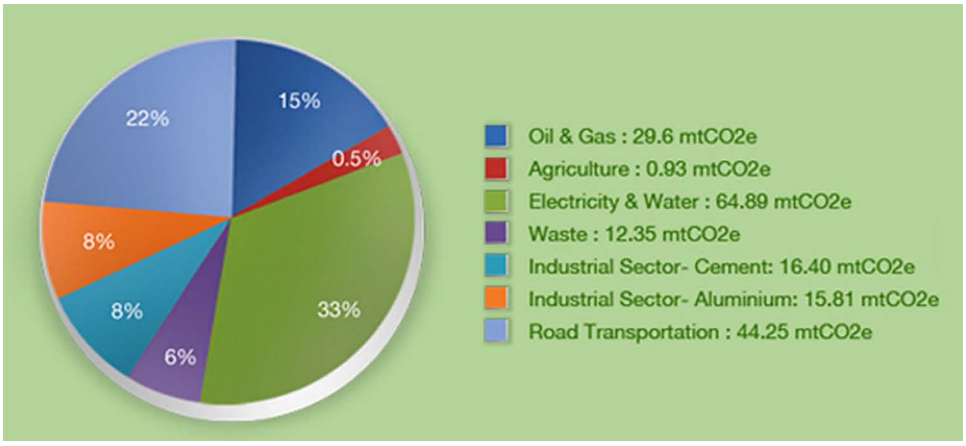


Figure 2. GHG Emission per Sector in UAE (Source: Mazumder, 2016)

This figure illustrates that the Building and Energy Sector in the UAE has a significant impact on the environment and climate change as well as being major contributors to the increase in temperature of the region. In addition, the massive increase in the population of the UAE has caused a huge increase in the energy demand, with a high concentration of GHG (Jayaraman, 2017).

Similarly, as reported by IPCC (2014), globally the GHG from buildings have more than doubled from 1970 to 2010 which account for one-third of the black carbon emission. In addition, most of GHG emissions are a result of the indirect CO2 emissions from the buildings such as electricity uses, heating and transportation. The report further highlights that the indirect emission of residential buildings has quintupled, and emissions of commercial buildings have also been quadrupled.

Though the Building Sector alone is the major contributor of CO2 emissions; however, as reported in the year 2010 the emission and the total global final energy use differs between the residential buildings that account for 24 percent or 24.3 PWh and 8 percent of the commercial buildings or 8.42 PWh from the total global final energy use as shown in Figure 3 below. This figure shows that in residential area cooking, space and water heating are the activities that result in higher energy consumption whereas for the commercial buildings it is the space heating and other activities dealing with IT equipment which are also supported by various studies (Nematchoua, et al., 2019; Khan et al., 2020). The same phenomena were witnessed in educational institutions where the electricity and vehicular emissions were key contributors to the total amount of carbon emissions (IPCC, 2014). It is also important to highlight that the cooling system of buildings represents 70% of the electricity load (Karlsson, Decker and Moussalli, 2015). Accordingly, there has been collaboration between the GCC and the EU to improve and enhance the energy consumed in Air

Conditioning systems. However, these plans need to be developed as these buildings are still consuming a huge amount of electricity.

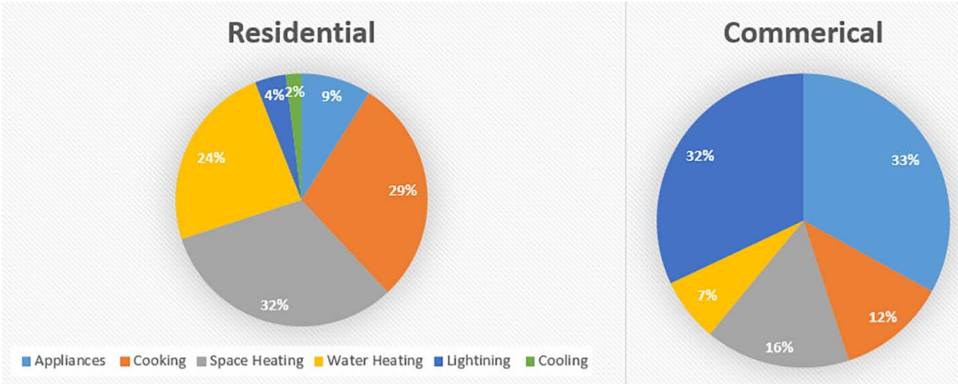


Figure 3. Energy Consumption Residential Vs Commercial Buildings (Adapted from IPCC 2014)

These statistics therefore make it essential to adopt the sustainability practices in the built environment sector as it has numerous benefits in terms of the economic, social and environmental aspects such as initial savings; maintenance and energy savings; improvement of quality of life with reduced health care costs; environmental benefits; productivity gain; decrease in the cost of future replacements and indirect gains such as improvement in the indoor quality of living.

Therefore, it can be concluded that sustainable or energy efficient buildings have major benefits in terms of economic, social, and environmental factors. However, to ensure the adoption of sustainable practices in the built environment, it is important to understand the different types of buildings based on their levels of energy performance.

## Types of Buildings

In order to integrate the energy efficient and sustainable practices in the built environment either during construction or renovation of buildings it is important to identify the types of buildings, given that the type greatly impacts on the energy performance and CO2 emission of the building. As such, buildings can be classified into; conventional buildings, sustainable buildings or Zero Energy Buildings (ZEBs) (Kamar, Abd Hamid and Azman, 2011; Kamali, Hewage and Sadiq, 2019). Conventional buildings are defined as buildings produced using traditional methods of construction . However, conventional ways of construction have been criticised for over a decade as they result in economic, environmental and social concerns with an increase in the amount of CO2 emission and carbon footprint (Kamali, Hewage and Sadiq, 2019). Thus, the adoption of sustainable, green or zero energy buildings has been frequently highlighted. These buildings have been defined by their adoption of advanced technologies and materials, which have allowed the Building Sector to reduce the burning of fossil fuels and generate energy from clean resources resulting in a positive impact on the environment and the decrease in GHG emissions, while leaning towards the development of more energy efficient buildings (Marszal, et al., 2011).

In addition, ZEBs are defined by the Department of Energy (Henderson , 2015) as "an energy efficient building where, on a source-energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy". This said, literature also reports on a number of terms used to define ZEB buildings such as; *Nearly, Net and Net Plus Energy Buildings*, however Fayyad and John (2017) emphasize on the importance of differentiating between these terms such as shown in Figure 4.

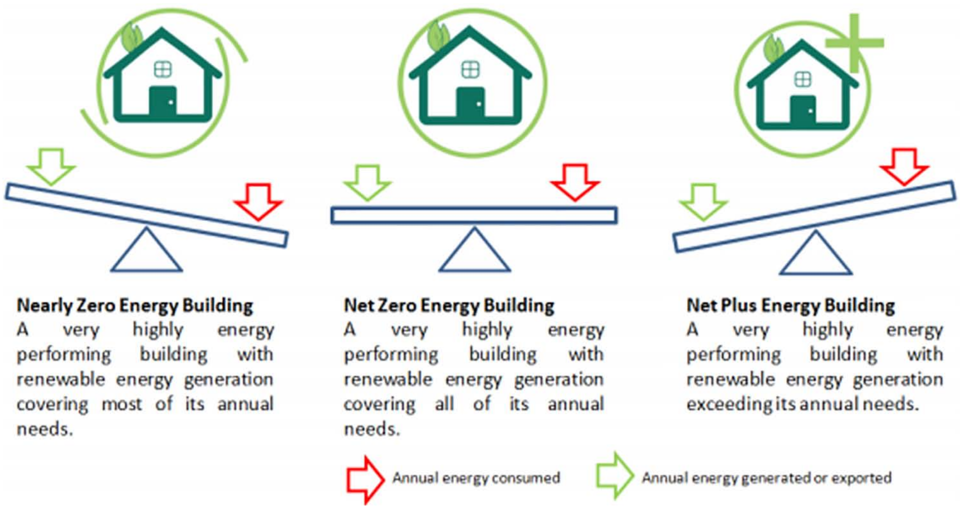


Figure 4. Different Definitions of Nearly, Net and Net Plus Energy Buildings (Source: Fayyad and John, 2017).

This study will therefore be guided by the classification of ZEBs in Figure 5 by adopting the following definitions.

*Nearly Zero Energy buildings* – Refers to buildings of high performance with a renewable energy generation source that covers most of its annual needs.

*Net Zero Energy Buildings* – Refers to buildings of high performance with a renewable energy generation source that covers all of its annual needs.

*Net Plus Energy building* – Refers to buildings of high performance with a renewable energy generation source exceeding its annual needs.

In addition, Agostino and Mazzarella (2018), define Net Zero Energy Buildings (NZEBs) or ZEBs by the amount of consumed energy which should almost be equal to the amount of energy generated from sustainable and renewable energy for any building. This means whatever is generated is nearly equal to the amount of energy consumed in a way that contributes to solving a large number of environmental issues. Moreover, this concept can be further explained through Figure 5 which further explains the concepts of ZEBs and NZEBs.

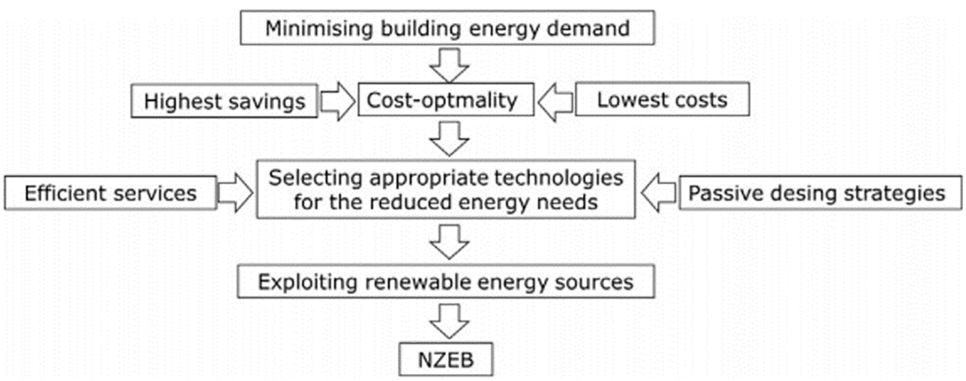


Figure 5. The Concept of ZEBs or NZEBs (Source: Agostino and Mazzarella, 2018)

According to Agostino and Mazzarella (2018) and as highlighted by Figure 6, the concept of ZEB is based on using sustainable and renewable energy sources such as solar, wind, and biomass to generate electricity for the entire building. Furthermore, the total amount of energy consumed shall be equal to the energy produced. This could be achieved by connecting ZEB to the electricity grid. For instance, if ZEB produces an excess amount of electricity, this will be transmitted through the grid lines and will be beneficial to other facilities. Similarly, ZEBs have the ability to import electricity from the grid if the energy generated is not enough (Brambilla, et al., 2018). By implementing such a concept, the reflection on the high-energy consumption, especially for the Buildings Sector and their impact on the environment will be minimized.

Moreover, the types of Zero Energy Buildings can be defined depending on the following attributes:

- *Location* - The first type depends on the actual location of the renewable energy source and to whether it is located within the site of the building, in which case the ZEB is called on-site ZEB. Conversely, the ZEB is called off-site, if the renewable energy source is located away from the building. In these types of buildings, additional electricity will be generated to be used for transmission purposes (Brambilla, et al., 2018).
- *Amount of Energy generated* - The second type of ZEBs depends on the total amount of energy generated and consumed. For example, if the annual energy consumed is higher than the energy generated, the building is called NZEB. Whilst the building is called Net plus Energy Building (NPEB) if the annual energy generated exceeds the actual demand (Fayyad and John, 2017).

Both types of ZEBs could be implemented based on the condition of the building as well as the location of the source. This will reflect the flexibility of implementing such a concept in different situations. However, for the purpose of this research, this study focuses on investigating the amount of 'energy generated' to define ZEBs.

## Energy Performance of Buildings

Energy performance is defined as the measure of "energy consumed, or estimated energy needed by the building to meet its standard's needs". The amount is reflected in multiple numeric indicators such as energy efficiency, energy consumption, CO2 emission and temperature in addition to taking into account criteria of buildings such as insulation, design and positioning in respect to climatic aspects, technical characteristics, exposure to solar rays, self-energy generation and indoor or outdoor climate that impact energy demand (Balaras, et al., 2007).

The importance of energy performance to ensure sustainable and zero energy buildings can be identified from a number of initiatives proposed such as the initiative by the USA as part of the Energy Independence and Security Act of 2007 (EISA) that aims to support the goal of net zero energy in new buildings. The initiative also specifies a target of zero energy for 50 percent of all the commercial buildings in the USA by 2040 and by 2050 for all buildings. Similarly, the United Kingdom adopted an initiative with the Energy Performance of Buildings 2010 (EPBD) which aimed to achieve a 'nearly zero energy building' target for all buildings by 2020. The UK parliament also passed legislation in June 2019 committing the government to reduce its net emission by 100 percent relative to 1990 levels by 2050 where 78 percent of UK total emissions was contributed to by the four highest emitting sectors such as transportation, energy, commercial and residential buildings (Shepheard, 2020). In addition to this, the recent initiatives by the UK government in 2020 such as the Ten Point Plan which calls for a green Industrial revolution is promising for a greener and better future that commits the government to build back better, support green jobs and accelerate towards a path of net zero (HM Government, 2020). Similarly, legislation has also been proposed in other nations such as Sweden, Scotland, France, Denmark, EU, Spain, Chile, Fiji and China to achieve their net zero targets by 2050.

Likewise, GCC countries have experienced a construction boom due to the huge and steady economic growth and modernization, as well as the realisation of the importance of sustainability concepts for the region, whilst the UAE and Qatar have the highest share of green buildings in the Middle East. Some of the significant examples of green buildings in the GCC include Masdar City; Abu Dhabi (UAE); King Abdullah University; Saudi Arabia (KSA) and Msheireb, Qatar. The KSA alone has invested 26 billion dollars in the Saudi green building initiatives (Asif, 2016). In addition, the UAE and KSA governments have set ambitious targets to achieve net zero energy. For example, where the UAE Energy strategy aims to achieve 50 percent of clean energy by 2020, KSA aims to generate 27GW of clean power by 2023 (Nagraj, 2020).

In addition, UAE past initiatives such as the 2021 National Agenda in 2014 to meet long-term needs and improve the quality of resources as well as expanding the involvement of clean and green energy in the country, depicts the region's commitment towards net zero energy. These initiatives aim for the UAE to produce 27 percent of its electricity from sustainable sources by 2021 to secure the needs of energy for the next generations (Mazumder, 2016). Also, the adoption of agreement of Paris 21$^{st}$ Conference of Parties (COP21) emphasizes the UAE's vision to move forward in achieving its 2030 mission.

However, despite the proposed initiatives to achieve net zero energy targets in buildings (especially residential and commercial), little attention has been given to educational buildings. The 'Education Sector' in particular is a significant contributor to the nation's success, allowing societies to progress and flourish. Therefore, it is important to consider the adoption of sustainable practices in educational buildings, given their positive effect on the socio-economic and health-environmental aspects of a building's occupants. This study will therefore focus on the energy performance of Higher Educational buildings as most of the top educational establishments have been-constructed in the early 60's till 80's such as Oxford University, Stanford university, Harvard university and university of Cambridge, which besides being ranked as the top universities of the world, they are also known for their remarkable architecture and history. Thus, it becomes important to adopt the sustainable practices in these establishments in order to reduce their carbon footprint but at the same time preserve their own history and architecture. In the UK alone, educational buildings are estimated to produce 9.245 million tonnes of CO2 per year which account for 1.32 percent of the UK's total emissions (Plan, 2006; Darby, et al., 2016). Furthermore, educational buildings cause direct and indirect emissions which is reported as 26 percent of the total CO2 emitted as a direct emission that includes electricity consumption, whereas 14 percent is the result of indirect emissions as a result of the commuting to and from educational buildings and other transport activities (Darby, et al., 2016). Similarly, the statistics show that the educational buildings contribute to a huge amount of CO2 emissions such as the Sam Wyly Hall University in the USA which produces up to 67,500 tonnes of CO2 emissions, whereas the educational institute in Argentina produces up to 34,000 µ person equivalent of CO2 emission in the year 2003 (Muthu, 2021). These statistics experience an exponential increase especially in hot climate regions such as the UAE where the Building Sector consumes about 80 percent of the total energy consumption.

Given that the UAE has been defined as a 'melting pot' of cultural diversity by Westley (2017) with a unique structure of its educational system that attracts students from all around the world, it will be the focus of this study to compare the energy performance amongst different types of educational buildings and determine the preference of the end users of these buildings.

To achieve this, the rest of this section intends to explore the approaches adopted to measure the energy performance of buildings which are defined in terms of energy efficiency, CO2 emissions and temperature (heat) generated by the buildings.

#### a. Calculating energy efficiency in buildings

The need for implementing a solution that increases energy efficiency is necessary as argued by Papadopoulou, et al. (2013) and RapidTable (2018). Thus, it is of significant importance to calculate the energy efficiency of buildings, whereby the energy efficiency could be calculated by dividing the energy consumed over the energy produced as shown in equation 1 (a) & (b) below:

$$\eta = \frac{Consumed\ Energy}{Produced\ Energy} \times 100 \tag{1a}$$

$$\eta = \frac{E_{out}}{E_{in}} \times 100 \tag{1b}$$

Where, $\eta$ is the efficiency in percentage (%)

$E_{in}$ is the energy produced from the generation plant in (kWh)

$E_{out}$ is the energy consumed from building users in (kWh)

As mentioned earlier, buildings consume a huge amount of energy, so controlling the energy efficiency is significant to secure the energy for upcoming generations and save the climate. By using this equation, the amount of energy consumed and saved will be known in order to help improve energy efficiency. The same equation could be used to calculate the efficiency of a building in a way to prove the fact that sustainable buildings are more efficient and generate less energy wastage and GHG i.e., CO2 emissions.

### b. CO2 emission

The combustion of fossil fuels results in the production of greenhouse gasses that comprises of Carbon Dioxide (CO2), Methane (CH4) , Nitrous Oxide (N2O) and other fluorinated gases. The GCC alone contributes to about 2.4 percent of the global greenhouse gasses emission (Solanki, Mallela and Zhou, 2013). However, since CO2 emissions cause an adverse impact on the environment in terms of climate change and global warming, it is therefore important to measure the CO2 emission generated from buildings as a measure of its energy performance. The measure of carbon gasses or greenhouse gasses i.e.. CO2 amount emitted from the building can be determined in terms of the electricity consumption of the building (EPA, 2021; OGL, 2020). The CO2 emission will be calculated in this study based on equation 2 stated below:

$$\begin{aligned} &CO_2\ Emission\ from\ the\ electricity\ consumption\ (ton\ CO_2) = \\ &Total\ electricity\ consumption\ from\ the\ building\ (kWh)\ * \\ &Grid\ emission\ factor\ (\frac{ton\ CO_2}{kWh}) \end{aligned} \tag{2}$$

The equation requires the electricity consumption units of all the building and the grid emission factor.

Furthermore, it was found from the literature that the GHG emission of buildings results in an increase in temperature generated by buildings that have a harmful impact on the environment (NOAA, 2021).

### c. Temperatures generated from buildings

According to Irimia and Gottschling (2016), the temperature emitted from buildings results in an increase of temperature in the environment. This can be done by finding the radiative forcing $\Delta F$ first (which is the change in the climate of the earth), as there is a difference in the incidence solar radiation and the absorption of this radiation by the earth which causes a defect in the concentration of the GHG. So, $\Delta F$ can be calculated by using the following equation:

$$\Delta F = \alpha\ ln\ ln\ \frac{CO_2}{CO_{2_0}} \tag{3}$$

Where: $\Delta f$ is the radiative forcing in W/m^2

$\alpha$ is the constant based on the radiative transfer and for CO2 calculations it is = 5.35

$CO_2$ is the CO2 emission that is produced in metric ton

$CO_{2_0}$ is the baseline value of CO2 in the atmosphere

This is followed by calculating the base temperature sensitivity $\Delta Ts$, that gives an indication about the fluctuations in temperature. In other words, if the temperature is negative this will cool the earth and if positive, it heats up the earth. The temperature will be calculated based on equation 4 according to Mills (2007):

$$\Delta Ts = \alpha_0 * \Delta F \tag{4}$$

Where: $\Delta Ts$ is the base temperature sensitivity in Kelvin (K)

$\alpha_0$ is the temperature sensitivity constant = 0.266 K/(W/m^2)

$\Delta F$ is the radiative forcing in W/m^2

From that, the temperature raised can be calculated in order to provide the change in climate of the world as a whole and in the country specifically; as such, improving the energy efficiency in the Building Sector will have a substantial positive enhancement on the environment and economic perspectives. From another environmental perspective applying this concept will contribute to the reduction of GHG emissions and solve a number of environmental issues. Similarly, from an economical perspective the contribution will be achieved by reducing the cost of maintenance and operation (Nulty, 2015).

Furthermore, energy consumption, sustainability, and sustainable development are related to each other as each practice pulls out the need for the next step. By logic, after harvesting the energy from different clean and sustainable sources, the necessity of managing the energy will arise. According to Golusin, Ivanovic and Vucenov (2012), the energy management concept is defined as professionally controlling, monitoring, and maintaining the produced and consumed energy in a very efficient way. This is helpful for measuring/calculating the electricity consumption for homes, organizations, and buildings, which will lead to creating different techniques to save energy. Besides, energy management emphasizes on the awareness, behaviour and perception of end users.

The rest of this paper will therefore discuss the methodological approach adopted by this study in order to observe the differences in the energy performance of different types of buildings within an educational establishment in the UAE, and in addition, evaluate the preferences of the end users in relation to these buildings.

## Methodological Approach

The study adopts a methodological approach to conducting experimental research in order to assess energy performance of buildings, which is important as it aids in monitoring the energy efficiency of buildings and motivates the end user to improve the performance of their buildings for a better quality of life. As such, this study will use the American University of Sharjah (AUS) as a case study since it is considered to be one of the top tier institutes in the UAE. This is an independent and non-profit educational institute which is based in Sharjah and is known for its multiple departments and centres that are involved in sustainability, sustainable development and smart city research. The institute has launched its own PhD program in Sustainable development for engineers and smart city, which shows the institute's dedication towards adopting sustainable practices and has taken serious steps towards transforming its campus into a sustainable campus. This study, therefore, targets three different types of buildings within the AUS campus to determine and compare their energy performance based on energy efficiency and CO2 emissions. The targeted buildings are *The Campus Service Centre, Engineering Building, and Business Administration Building*. These three buildings have been selected among the other buildings in AUS because they represent different sustainability levels, where the Campus Service Centre is classified as the Net Zero Energy Building, the School of Business Administration classified as the sustainable building and the Engineering building as the conventional building. In addition, it is within the intent of this study to determine the preference of the end users of these buildings. The following steps were therefore adopted to conduct this research.

- ***Step 1: Exploration of Current Practices*** **–** A set of semi-structured interviews were conducted in order to collect relevant data with regards to the energy performance of the buildings and to understand the current practices, methods and relationships used to determine factors such as CO2 emissions, energy efficiency, climate change and energy waste management. Key stakeholders from the Energy Sector of the UAE were therefore targeted with focus on the three entities:
    - ***The Sustainable Centre at AUS*****:** This centre was approached in order to identify the different types of buildings to be used for this study and to collect the relevant information that will assist in calculating the energy performance of these buildings. As such, information about the history and development of the buildings, the area and parameters of the buildings and annual energy consumption units for each month were obtained. In addition, information about preference of the end users and occupants of these buildings were sought.
    - ***Sharjah Electricity and Water Authority (SEWA):*** An electricity service provider was approached in order to obtain and verify the amount of energy consumed by the three buildings identified in this study, as well as the cost of electricity consumed. In addition, it was within the intention of this study to explore the current practices for calculating the energy efficiency of buildings which will be utilized in order to compare the energy performance of the selected buildings.
    - ***The Dubai Carbon:*** This organization was founded in 2011. It is located in Dubai and dedicated to monitoring and controlling the level of GHG concentration in Dubai. This organization offers consultancy and advisory services for reducing GHG as well as encouraging the use of solar and renewable sources. It is within the intention of this study to explore the existing practices for calculating the GHG emissions from the buildings which will be utilized in order to compare the energy performance of the selected buildings.

A representative from each entity was approached to collect the relevant data and information regarding the energy performance of the buildings. Each representative holds an essential decision-making position within the entity with 20 to 30 years of experience. However, due to ethical consideration the title and position of the interviewee will be referred only as a representative of the entity approached as shown in Table 1.

Table 1. Profile of Interviewees

| Position/ Title | Years of experience |
|---|---|
| Representative of the Sustainable Centre at AUS | 20 |
| Representative of Sharjah Electricity and Water Authority (SEWA) | 30 |
| Representative of The Dubai Carbon | 28 |

- ***Step 2: Energy Performance of Buildings*** **–** This study compares energy performance of targeted buildings i.e., *The Campus Service Centre, Engineering Building, and Business Administration Building* by considering the total energy consumption of the three targeted buildings over a period of six years i.e. (2013-2018). This step is conducted in three stages a discussed below.

- ***Energy Efficiency*** - To calculate the 'energy efficiency' and 'energy score' of the three buildings, the Energy Star Portfolio Manager tool was used. This tool provides information regarding the energy performance and energy usage of the building in terms of energy scores. Likewise, another method used was the Energy Use Intensity (EUI) method to measure the energy usage of the building. These methods assisted with determining the performance of the building which led to the effectiveness of the building.
- ***CO2 Emission*** - This stage entails calculating and comparing the CO2 emission from the targeted building in order to determine the impact of the buildings on the environment.
- ***Temperature*** – The temperature generated from each building is also calculated and compared in order to evaluate the adverse impact that the three buildings have on the environment.

- ***Step 3: Factors Affecting End User's Preferences*** – To confirm the findings of the experiments and the perception of representatives from the Sustainable centre, this study conducted an online survey targeting students who were the main occupants of these buildings in order to evaluate their preferences of the different types of buildings and the factors that influence their preferences.

The rest of this paper will discuss the results, analysis and main findings from the study.

## Results and Analysis

The methodological steps outlined in the previous section helped this study collect the relevant data regarding the energy performance of the buildings and to understand the current practices, methods adopted to determine factors such as CO2 emissions, energy efficiency, climate change, and energy waste management. The rest of this section will therefore discuss the results and analysis obtained from the study.

The interviews with the key stakeholders of the Sustainable Centre at the American University of Sharjah aided this study with;

a. Understanding the classification of the three selected buildings for this research as; the Net Zero Energy building, Sustainable (renovated) building, and finally the conventional building. Whereby, the Campus Service Centre building belongs to the first category which is the Net Zero Energy building on campus, followed by the School of Business Administration which is a Sustainable (renovated) building that incorporates sustainable features into its construction, whilst the Engineering building belongs to the conventional building.

The total area for each of the targeted buildings was provided by the centre as shown in Table 2. These areas of each type of building were also obtained to aid the study in comparing the energy consumption units of the selected buildings.

Table 2. Total Area of targeted building

| | Area | |
|---|---|---|
| | m^2 | ft^2 |
| EB | 9064 | 97564.08 |
| SBA | 13612 | 146518.34 |
| CSC | 3380 | 36382.02 |

These areas will assist this study with calculating the Energy Usage Intensity (EUI) which is explained later in this section.

b. The provision of the electricity consumption units for the three identified buildings between (2012–2018) to help draw comparisons of the energy consumption between the three buildings. However, the data for electricity consumption units for ***2012*** shows zero consumption in some of the months. Therefore, the year 2012 was eliminated from further analysis.

Based on the data provided by the Sustainable Centre at AUS, Figure 6 shows the electricity consumption for each building and the energy scores of the three identified buildings.

| | | Electricity Consumption (kWh) | | | | | |
|---|---|---|---|---|---|---|---|
| Month/Year | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Jan | 0 | 67,000 | 79,250 | 76,750 | 107,250 | 63,500 | 73,250 |
| Feb | 0 | 62,250 | 60,500 | 65,500 | 29,500 | 66,750 | 68,500 |
| March | 0 | 84,000 | 83,750 | 79,500 | 100,750 | 88,000 | 91,750 |
| Apr | 0 | 100,250 | 99,750 | 108,000 | 66,000 | 137,000 | 112,500 |
| May | 0 | 135,750 | 113,750 | 133,000 | 133,250 | 118,000 | 31,750 |
| Jun | 0 | 124,250 | 133,500 | 135,750 | 139,250 | 156,500 | 95,250 |
| Jul | 0 | 155,750 | 185,025 | 149,250 | 152,250 | 178,000 | 148,500 |
| Aug | 0 | 141,750 | 106,975 | 150,000 | 157,500 | 114,000 | 131,250 |
| Sep | 124,500 | 132,250 | 125,750 | 143,750 | 151,750 | 148,750 | 153,500 |
| Oct | 122,250 | 120,500 | 143,350 | 121,250 | 137,500 | 132,000 | 129,250 |
| Nov | 95,000 | 101,250 | 81,975 | 106,750 | 82,000 | 108,000 | 103,500 |
| Dec | 78,250 | 75,500 | 76,425 | 83,000 | 91,000 | 69,750 | 0 |
| Total | 420000 | 1300500 | 1,290,000 | 1352500 | 1,348,000 | 1380250 | 1139000 |
| Average | 105000 | 108375 | 107500 | 112708.33 | 112333.3 | 115020.8 | 103545.5 |

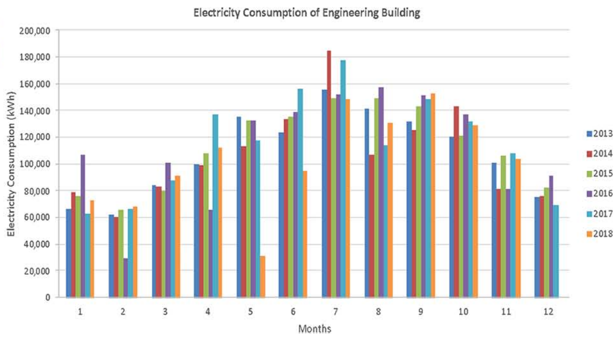


Figure 6(a). Electricity consumption of Engineering Building

| | | Electricity Consumption | | | | | |
|---|---|---|---|---|---|---|---|
| Month/Year | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Jan | | 70,500 | 84,250 | 74,750 | 124,000 | 62,250 | 74,000 |
| Feb | | 69,000 | 60,500 | 75,500 | 32,500 | 70,000 | 63,750 |
| March | | 80,250 | 79,750 | 78,500 | 101,500 | 80,250 | 79,500 |
| Apr | | 89,250 | 92,750 | 94,000 | 62,000 | 103,000 | 90,500 |
| May | | 108,500 | 100,250 | 100,750 | 109,500 | 89,750 | 111,000 |
| Jun | | 100,250 | 111,750 | 104,750 | 108,000 | 111,000 | 93,000 |
| Jul | | 112,250 | 152,250 | 107,250 | 108,500 | 126,250 | 101,750 |
| Aug | | 98,500 | 88,000 | 103,750 | 108,750 | 84,500 | 87,750 |
| Sep | 100,750 | 98,750 | 109,000 | 109,500 | 125,000 | 117,250 | 102,250 |
| Oct | 104,000 | 102,000 | 121,000 | 101,750 | 102,000 | 101,250 | 108,000 |
| Nov | 86,500 | 93,500 | 75,000 | 102,500 | 94,750 | 90,000 | 100,000 |
| Dec | 76,500 | 70,500 | 74,750 | 86,750 | 88,000 | 67,250 | 0 |
| Total | 367750 | 1093250 | 1149250 | 1139750 | 1164500 | 1102750 | 1011500 |
| Average | 91937.5 | 91104.17 | 95770.83 | 94979.17 | 97041.667 | 91895.83 | 91954.55 |

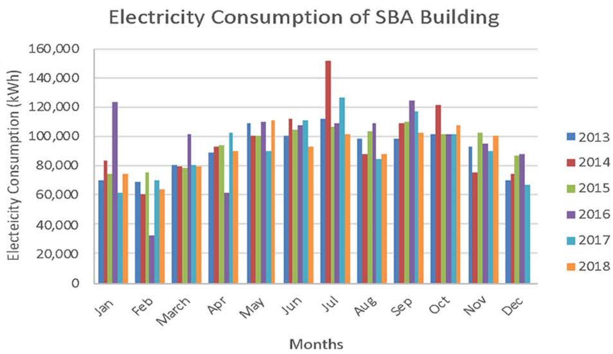


Figure 6(b). Electricity consumption of Business Administration Building

| | | Electricity Consumption | | | | | |
|---|---|---|---|---|---|---|---|
| Month/Year | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Jan | 0 | 0 | 51,000 | 41,500 | 69,500 | 38,500 | 46,500 |
| Feb | 0 | 159,500 | 36,000 | 43,000 | 14,500 | 38,000 | 33,500 |
| March | 0 | 46,000 | 42,500 | 39,000 | 51,000 | 42,500 | 43,000 |
| Apr | 0 | 49,500 | 41,500 | 46,000 | 29,000 | 49,000 | 42,000 |
| May | 0 | 59,000 | 43,500 | 44,500 | 46,500 | 38,500 | 50,000 |
| Jun | 0 | 50,500 | 45,000 | 43,000 | 46,500 | 46,000 | 42,500 |
| Jul | 0 | 52,000 | 57,000 | 46,000 | 47,000 | 54,000 | 48,000 |
| Aug | 0 | 53,000 | 36,500 | 45,500 | 53,500 | 37,500 | 41,500 |
| Sep | 0 | 52,500 | 44,000 | 45,000 | 49,000 | 46,500 | 48,000 |
| Oct | 0 | 53,000 | 50,500 | 40,500 | 42,000 | 46,000 | 49,500 |
| Nov | 0 | 53,500 | 36,000 | 46,000 | 44,500 | 46,000 | 44,000 |
| Dec | 0 | 40,500 | 39,000 | 46,500 | 48,500 | 39,000 | 0 |
| Total | 0 | 669,000 | 522,500 | 526,500 | 541,500 | 521,500 | 488,500 |
| Average | 0 | 55750 | 43541.67 | 43875 | 45125 | 43458.33 | 40708.33 |

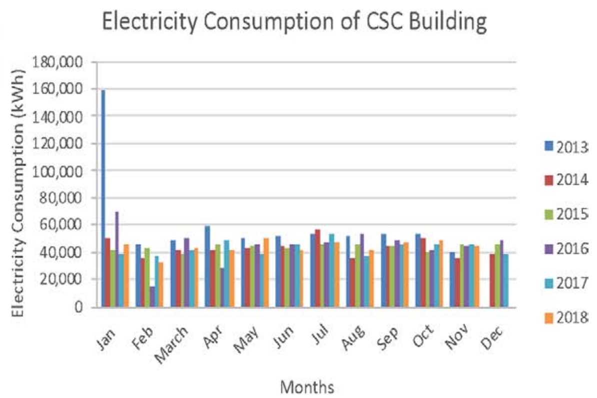


Figure 6(c). Electricity consumption of Campus Service Centre Building

It can be seen from these figures that the electricity consumption of the Engineering building (Figure 6a) is the highest, followed by the Business Administration building (Figure 6b), whilst the lowest consumption is the Campus Service Centre (Figure 6c). These results confirm that the energy consumption of each building aligns with their classification and type.

The interview results with the key stakeholders from the Sharjah Electricity and Water Authority (SEWA) showed that there are mainly two different methods that can be used to calculate energy efficiency in buildings, whereby these methods are aligned with the design and operation stages of buildings. The first method for the design stage adopts the Energy Modelling Tool to compare the proposed building energy consumption to the baseline building in order to simulate the energy performance of the building. Whereas the second method for the operation stage compares the energy bills to the project building's actual energy use in order to develop a building benchmark. This study focuses on the second method of operation stage and adopts the Energy Star Portfolio Manager and Energy Use Intensity (EUI) equations suggested by the interviewees to calculate the energy efficiency of the targeted buildings. As such, interviews guided the process of determining the efficiency of the buildings by using the *'Energy Star Portfolio Manager website'* that aids in measuring the energy performance of the building depending on their annual electricity consumption. Hence, the *Energy Star Portfolio Manager* helps track the energy use of any type of building.

Therefore, to determine the energy efficiency of the three identified buildings, the initial step was to create a profile on the '*Energy Star Portfolio Manager'* website, which required information regarding the type of buildings and the annual electricity consumption. The website then generates the values of energy score which is a measure of energy usage and its associated costs, that defines how efficient a building is. The energy score ranges from 0 to 100, where the highest number indicates more efficient building.

The energy score for the three categories of buildings were calculated for the period between (2013 – 2018). However, as indicated from Table 3 and Figure 7 the energy score for years 2013 and 2018 could not be calculated as it also has few months with zero consumption.

Table 3. Energy score of all Buildings

| | Energy Score (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Total | Average |
| SBA | 35 | 34 | 33 | 33 | 26 | 0 | 161 | 26.8333 |
| CSC | 84 | 81 | 83 | 81 | 82 | 0 | 411 | 68.5 |
| EB | 0 | 27 | 29 | 26 | 25 | 0 | 107 | 17.8333 |

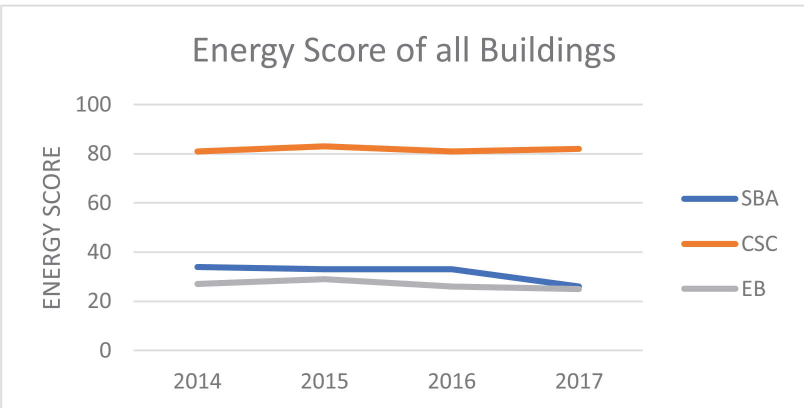


Figure 7. Energy score of all Buildings

This figure illustrates that the Campus Service Centre has the highest score implying it is more energy efficient followed by the Business Administrative Building, and lastly the Engineering building. These findings align with the classification of the identified buildings.

Another method proposed by the interviewees is to determine the ***Energy Usage Intensity (EUI)*** of the building from which the energy performance of the building can be evaluated. The EUI can be calculated by using equation 5 below:

$$EUI\left(\frac{kBTU}{ft^2}\right) = \frac{Total\ Energy\ Consumption\ of\ a\ Building\ for\ 12\ months\ (kBTU)}{Area\ of\ the\ Building\ (ft^2)} \quad (5)$$

The equation comprises of the total energy consumption of the building for 12 months to the area of the building in square feet. Table 4 below illustrates the Energy Usage Intensity of the three targeted buildings over a period of six years.

Table 4. Details of the three buildings

| Energy Score (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Total | Average |
| SBA | 45.48 | 45.12 | 47.3 | 47.14 | 48.27 | 39.83 | 273.14 | 45.5233 |
| CSC | 25.46 | 26.76 | 26.54 | 27.12 | 25.68 | 23.56 | 155.12 | 25.8533 |
| EB | 62.74 | 49 | 49.38 | 50.79 | 48.91 | 45.81 | 306.63 | 51.105 |

The calculated EUI value for all the buildings is illustrated in Figure 8, showing the lower the intensity, the more efficient the building is.

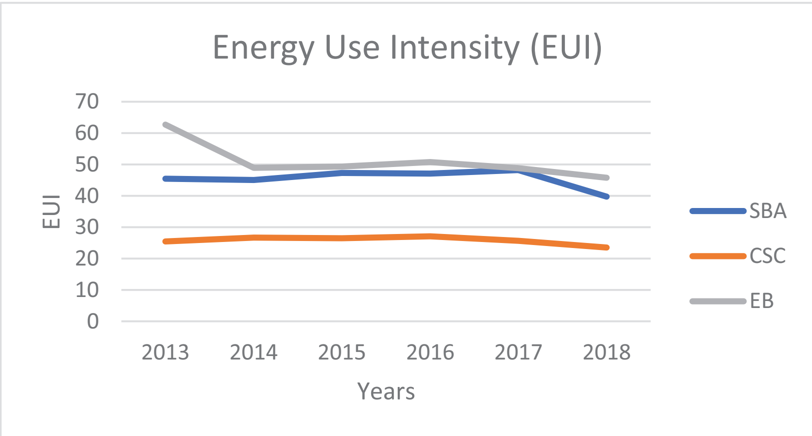


Figure 8. Energy Use Intensity of all Buildings

Hence, the results show that the Campus Service Centre building is the best in terms of the intensity of energy use (with an average of EUI of 25.85) than the Business Administration building (with an average of 45.53) and lastly is the Engineering building (with an average of 51.11). These results align with the first method of using Energy Star Portfolio Manager discussed earlier. The results also align with the findings from the literature whereby the Net Zero Energy buildings are marginally lower in terms of the EUI values than the ZEB buildings and the conventional type of buildings, indicating that the EUI value is a reflection of the energy efficiency of buildings.

***The Dubai Carbon:*** The results from the interviews with key stakeholders from Dubai Carbon confirmed that the carbon accounting or carbon emission could be calculated on different levels, such as country, city and building level. Therefore, any increase in the CO2 radiation of a building will definitely impact on the CO2 levels and the ecological footprint of the whole country. Furthermore, the interviewee stated that there are many activities that are carried out by the buildings' users that could emit CO2 but cannot be controlled, such as driving a car to reach the building. Therefore, this study only considers electricity consumption as a measure of energy consumption and a source of CO2 emission. Accordingly, this study will adopt the

| | | CO2 Emission (ton) | | | | | |
|---|---|---|---|---|---|---|---|
| Month/Year | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Jan | 0 | 43550 | 51512.5 | 49887.5 | 69712.5 | 41275 | 47612.5 |
| Feb | 0 | 40462.5 | 39325 | 42575 | 19175 | 43387.5 | 44525 |
| March | 0 | 54600 | 54437.5 | 51675 | 65487.5 | 57200 | 59637.5 |
| Apr | 0 | 65162.5 | 64837.5 | 70200 | 42900 | 89050 | 73125 |
| May | 0 | 88237.5 | 73937.5 | 86450 | 86612.5 | 76700 | 20637.5 |
| Jun | 0 | 80762.5 | 86775 | 88237.5 | 90512.5 | 101725 | 61912.5 |
| Jul | 0 | 101237.5 | 120266.3 | 97012.5 | 98962.5 | 115700 | 96525 |
| Aug | 0 | 92137.5 | 69533.75 | 97500 | 102375 | 74100 | 85312.5 |
| Sep | 80925 | 85962.5 | 81737.5 | 93437.5 | 98637.5 | 96687.5 | 99775 |
| Oct | 79462.5 | 78325 | 93177.5 | 78812.5 | 89375 | 85800 | 84012.5 |
| Nov | 61750 | 65812.5 | 53283.75 | 69387.5 | 53300 | 70200 | 67275 |
| Dec | 50862.5 | 49075 | 49676.25 | 53950 | 59150 | 45337.5 | 0 |
| Total | 273000 | 845325 | 838500 | 879125 | 876200 | 897162.5 | 740350 |
| Average | 68250 | 70443.75 | 69875 | 73260.4167 | 73016.67 | 74763.54 | 67304.55 |

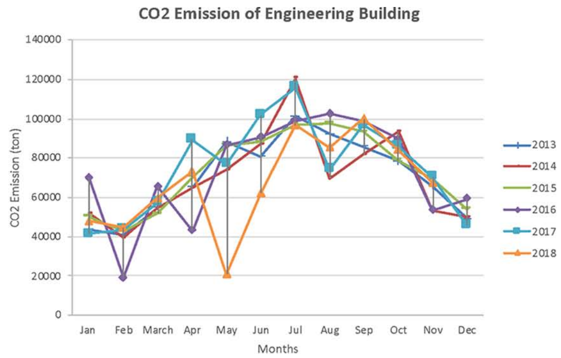


Figure 9(a). CO2 emission of Engineering Building

| | | CO2 Emission | | | | | |
|---|---|---|---|---|---|---|---|
| Month/Year | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Jan | 0 | 45825 | 54762.5 | 48587.5 | 80600 | 40462.5 | 48100 |
| Feb | 0 | 44850 | 39325 | 49075 | 21125 | 45500 | 41437.5 |
| March | 0 | 52162.5 | 51837.5 | 51025 | 65975 | 52162.5 | 51675 |
| Apr | 0 | 58012.5 | 60287.5 | 61100 | 40300 | 66950 | 58825 |
| May | 0 | 70525 | 65162.5 | 65487.5 | 71175 | 58337.5 | 72150 |
| Jun | 0 | 65162.5 | 72637.5 | 68087.5 | 70200 | 72150 | 60450 |
| Jul | 0 | 72962.5 | 98962.5 | 69712.5 | 70525 | 82062.5 | 66137.5 |
| Aug | 0 | 64025 | 57200 | 67437.5 | 70687.5 | 54925 | 57037.5 |
| Sep | 65487.5 | 64187.5 | 70850 | 71175 | 81250 | 76212.5 | 66462.5 |
| Oct | 67600 | 66300 | 78650 | 66137.5 | 66300 | 65812.5 | 70200 |
| Nov | 56225 | 60775 | 48750 | 66625 | 61587.5 | 58500 | 65000 |
| Dec | 49725 | 45825 | 48587.5 | 56387.5 | 57200 | 43712.5 | 0 |
| Total | 239037.5 | 710612.5 | 747012.5 | 740837.5 | 756925 | 716787.5 | 657475 |
| Average | 0 | 59217.71 | 62251.042 | 61736.46 | 63077.08333 | 59732.29 | 59770.45 |

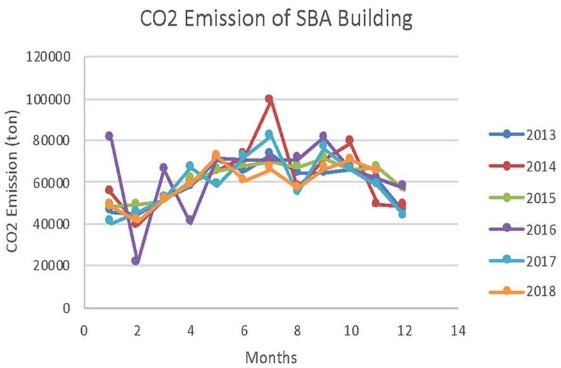


Figure 9(b). CO2 emission of Business Administration Building

| | | CO2 Emission | | | | | |
|---|---|---|---|---|---|---|---|
| Month/Year | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Jan | 0 | 0 | 33150 | 26975 | 45175 | 25025 | 30225 |
| Feb | 0 | 103675 | 23400 | 27950 | 9425 | 24700 | 21775 |
| March | 0 | 29900 | 27625 | 25350 | 33150 | 27625 | 27950 |
| Apr | 0 | 32175 | 26975 | 29900 | 18850 | 31850 | 27300 |
| May | 0 | 38350 | 28275 | 28925 | 30225 | 25025 | 32500 |
| Jun | 0 | 32825 | 29250 | 27950 | 30225 | 29900 | 27625 |
| Jul | 0 | 33800 | 37050 | 29900 | 30550 | 35100 | 31200 |
| Aug | 0 | 34450 | 23725 | 29575 | 34775 | 24375 | 26975 |
| Sep | 0 | 34125 | 28600 | 29250 | 31850 | 30225 | 31200 |
| Oct | 0 | 34450 | 32825 | 26325 | 27300 | 29900 | 32175 |
| Nov | 0 | 34775 | 23400 | 29900 | 28925 | 29900 | 28600 |
| Dec | 0 | 26325 | 25350 | 30225 | 31525 | 25350 | 0 |
| Total | 0 | 434850 | 339625 | 342225 | 351975 | 338975 | 317525 |
| Average | 0 | 36237.5 | 28302.08 | 28518.75 | 29331.25 | 28247.92 | 28865.91 |

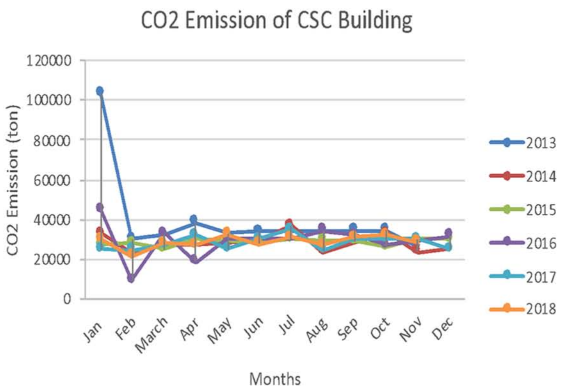


Figure 9(c). CO2 emission of CSC Building

CO2 emission equation cited from literature (see Section 4), which is aligned with the current practices as suggested by the representative of Dubai Carbon.

The equation requires the electricity consumption of the building and the grid emission factor as it is dependent on the grid used in the region i.e., for Sharjah, the grid emission factor is 0.65-ton CO2/kWh (as confirmed by the interviewees). Figure 9 shows the calculated CO2 emission of all the buildings.

The results show that CO2 emissions are the highest from the Engineering building with only twice a drop in the CO2 emission values for years 2013 and 2018, which as indicated before has had zero consumption for some months. This is followed by the Business Building; the least CO2 emissions being generated by the CSC building, which as evident from Figure 9(c) has a value lower than 40000 tonnes with a single spike in the year 2013.

Furthermore, to show the relationship between the CO2 emission and the electricity consumption, the CO2 emission of each building is plotted against the electricity consumption, as illustrated by Figure 10. Whereby it can be clearly seen that the increase in energy consumption increases the CO2 emissions and that they are directly proportional to each other; this can be seen from the Engineering building graph where the dots plotted on the gradient indicates the relation between the energy consumption and CO2 emission. The dots are dispersed over the gradient line whereas for the Business and CSC buildings the level of dispersion is less. As identified before, the CSC building is the most efficient building with low energy consumption and CO2 emission, followed by Business Administrative, and then the Engineering building.

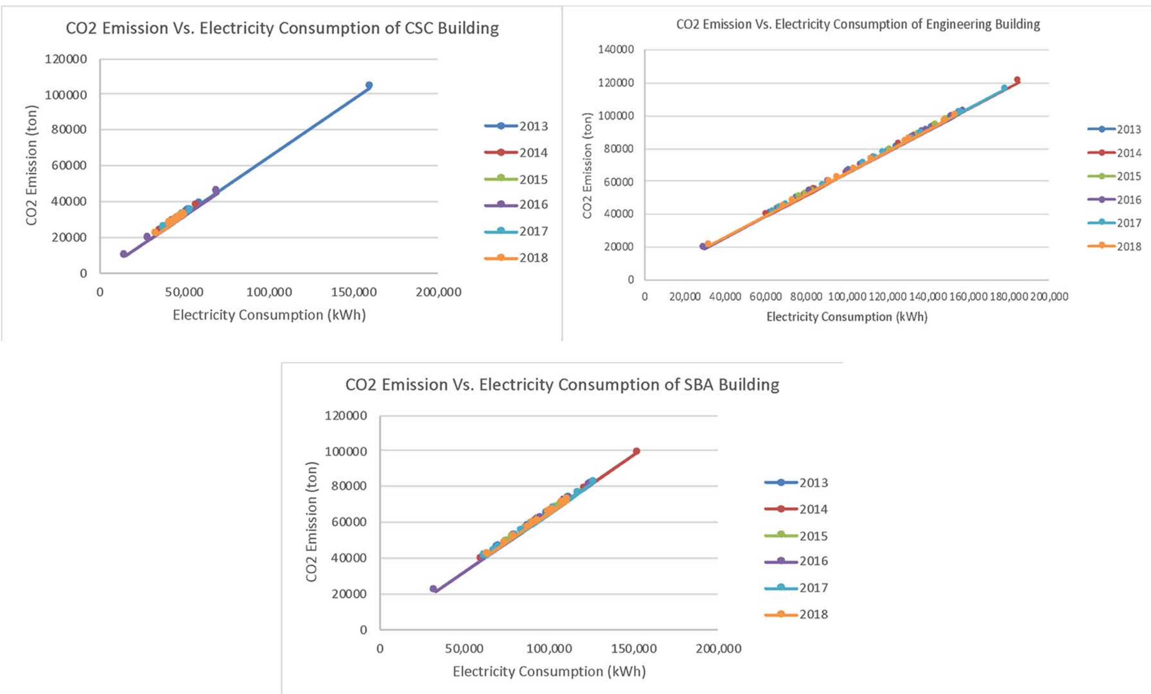


Figure 10. CO2 emission Vs. Electricity Consumption of all the Buildings

Moreover, CO2 emission also affects the environment by raising the temperature that results in global warming (as discussed in the Literature Review Section). In support of this, one of the Dubai Carbon interviewees stated;

> *"The emissions generated by one community may result in just a miniscule raise in temperature. It is the combined effect of emissions all around the globe that considerably results in temperature raise".*

Therefore, the temperature raised by the buildings due to $CO_2$ emission would have a significant impact on the environment. However, given that temperature cannot be calculated for each year individually (since the sample of this study is a building at AUS which is very small compared to whole country), it can still be calculated based on the previously calculated $CO_2$ emissions.

As such, the temperature is calculated cumulatively for all six years (2013 -2018); first the total $CO_2$ emission of all years were summed up for each building, then the equation from the literature review (see Section 4) was adopted to calculate the temperature of the buildings. As a result, the calculated values of $\Delta F$ and $\Delta Ts$ of each building are summarized in Table 5 and Figure 11 below which shows a positively proportional relationship between the $CO_2$ emission and the temperature. The findings of this stage align with the findings from the literature review.

Table 5. $\Delta F$ and $\Delta Ts$ of all three buildings

| Building/Factors | CO2 Emission (Metric tons) | Radiative Forcing (W/m^2) | Temperature (K) |
|---|---|---|---|
| EB | 4605472.1 | 9.742 | 2.59 |
| SBA | 4178015.2 | 8.891 | 2.36 |
| CSC | 3790232.7 | 5.083 | 1.35 |

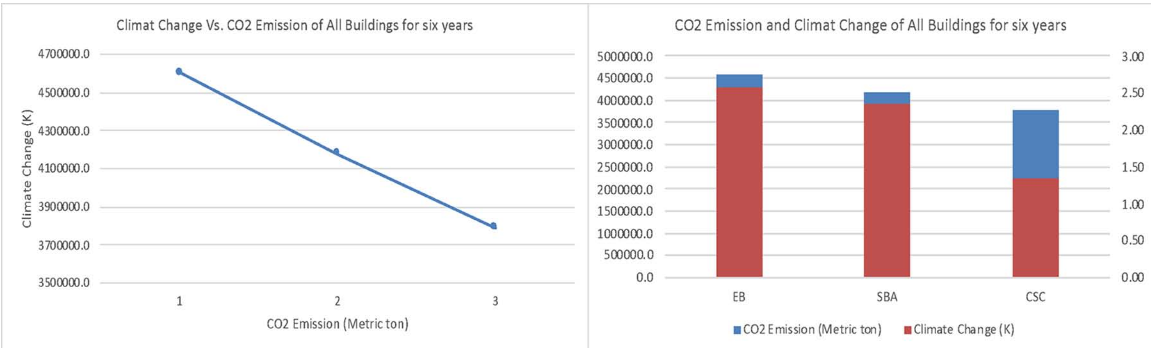


Figure 11. Climate Change Vs. CO2 Emission of all Buildings for Six Years

As can be seen from Figure 11 the higher the $CO_2$ emission of the building, the more will be the adverse impact of that building on Climate Change. It can be therefore concluded from the figure that the Engineering building has the highest $CO_2$ emission which leads to the highest temperature raised and affects the climate change followed by the Business Administration building, Sustainable building and lastly the Campus Service Centre - Net Zero Energy building which has the lowest temperature value. These results therefore highlight the importance of ZEBs and their reduced impact on the environment.

In summary, the results of this study have shown that the CSC Building (Net Zero Energy Building) has the best energy performance in terms of energy efficiency, $CO_2$ emission and Climate Change to other buildings. The experiment results align with the classification of the targeted building by the representative of the Sustainable Centre from AUS; where the Engineering building being the conventional building proves to be the least efficient building with high $CO_2$ emissions and Climate Change.

In addition, the results of this study and the PERCEPTIONS of the representatives from the Sustainable Centre, thus far indicate that there is an amount of energy that is wasted which means that none of the buildings are fully and effectively consuming the energy. Hence, the performance of buildings does not only depend on the type of building (whether it is energy efficient or not) but it also depends on the behaviours of the buildings' users.

Thus, ZEBs are capable of consuming all the electricity produced without any wasted energy, but this should go hand in hand with controlling and managing the end user practices through awareness plans.

Hence, the rest of this paper shares the results of a survey that targets students (as end users of these buildings) to evaluate their awareness and perceptions of the sustainability issues which play a role in the management of energy consumption within buildings, and to evaluate their preferences of the different types of buildings.

## FACTORS AFFECTING THE END USER'S PREFERENCES

This study argues that investing in Net-Zero or Zero Energy Buildings is not sufficient, and that the end users of buildings play an important role in all of this. In support of this, one of the key stakeholders at the AUS Sustainable Centre state that the performance of buildings does not only depend on the type of building (whether it is energy efficient or not) but it also depends on the behaviours of the buildings' users while stating: *"The user doesn't care about the electricity that is wasted as they are not paying for that and they require guidance to spread an awareness regarding the energy waste. Moreover, in each building there must be a community that is responsible for managing the energy waste of the building."*. Another interviewee from Dubai Carbon stated that "*Individuals need to be aware of the importance of sustainability, the government policies and agendas and to be educated on these aspects*".

Another employee emphasized the impact of the socio-economic factors on the usability of the buildings, stating that *"income, education, employment and community safety are important factors that play a role in the end users' behaviour"*.

This study has therefore conducted a short survey to evaluate building users' perceptions of the socio-economic factors.

Accordingly, a university-wise survey was distributed to a sample of 800 students who are known to be end users of the three identified buildings (Engineering, Business Administration and CSC) and 90 responses were returned. The survey aims to determine preference and factors that affect their preferences, awareness of the impact of sustainability on the environment, impact of environmental issues on their personal health and safety and awareness of the impact of buildings on the environment and Government Initiatives. The rest of this section shared the results of the survey;

### a. Preference and Factors that affect their preferences

Having compared the energy efficiency and performance of the three AUS buildings identified by this study; the participants were asked to select their most preferred building. Figure 12 shows that 43% of the participants preferred the Engineering Building (conventional building).

However, when asked about the factors that influence their choices of the preferred building, the results in Figure 13 indicate that 71% of the participants considered appearance and architecture as the most important factor that influence their choice followed by lighting system (43%), ease of access (43%). Surprisingly, a small percentage of the participants identified the ventilation system as a factor that influence their preference.

### b. Awareness of the impact of sustainability on the environment and the impact of environment issues on their personal health and safety

The students were asked to give a score of 1 (Low) and 5 (High) to the level of their awareness of the impact of sustainability on the environment and the extent to which environmental issues affect their personal health and safety as shown in Figure 14 below.

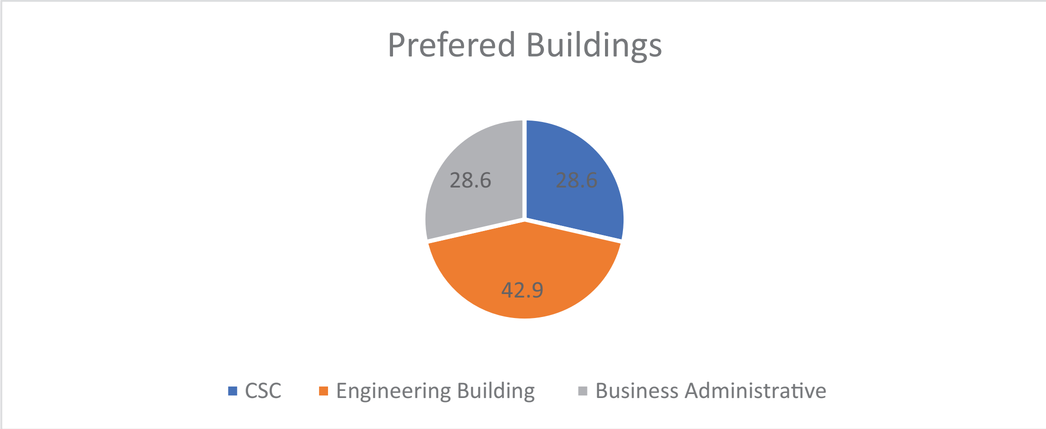


Figure 12. Preferred Buildings

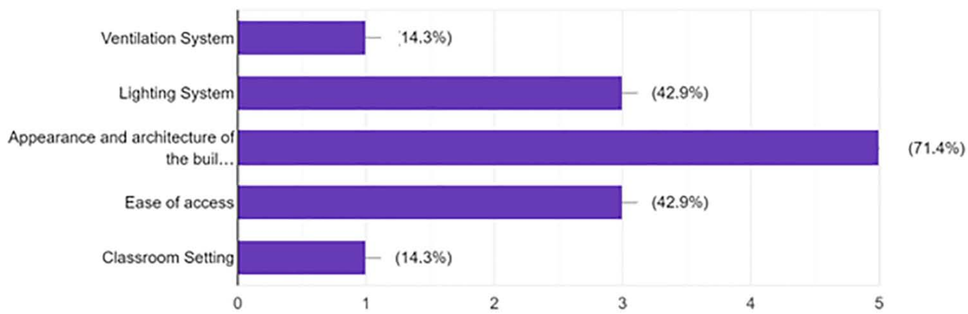


Figure 13. Factors of Socio-Cultural

The results revealed that around 70 percent of the participants were somehow aware or fully aware of the impact of sustainability on the environment. However, a smaller percentage of the participants (60%) were aware of the impact of environmental issues on their own personal health and safety. This indicates that the end users need to be educated on the health benefits of sustainable buildings and its positive impact on the environment.

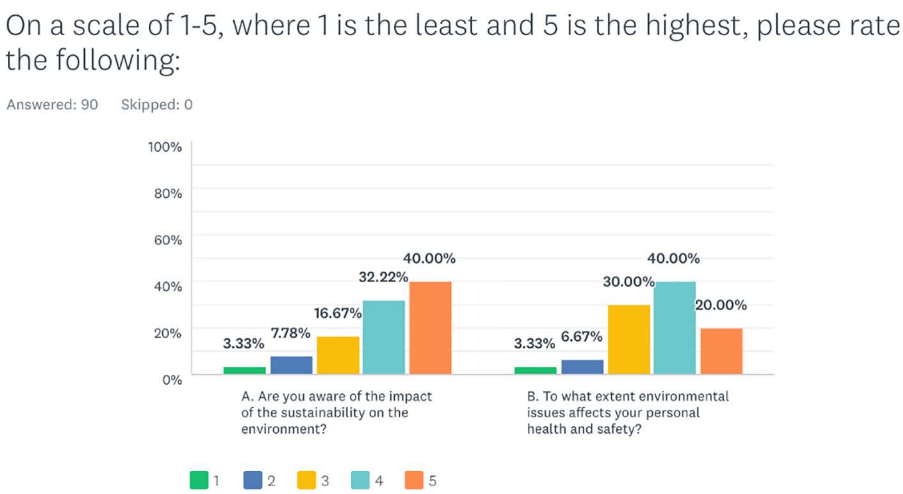


Figure 14. Awareness of the impact of the Sustainability

It can therefore be concluded that the majority of the students are not fully aware of the impact of sustainability on the environment and the impact of environmental issues on their personal health and safety.

**c. Awareness of the impact of buildings on the environment and Government Initiatives**

The participants were asked to rank the sources that have the most negative impact on the environment (1- High negative impact to 3 – Low Negative impact). Surprisingly, the results displayed in Table 6 revealed that the participants considered waste to have the most negative impact on the environment followed by transportation, then buildings.

Table 6. Biggest cause of environmental issues

| Cause/Rank | 1 | 2 | 3 |
|---|---|---|---|
| Transportation | 40.00% | 43.00% | 10.00% |
| Waste | 50.33% | 43.33% | 13.3% |
| Buildings | 16.67% | 6.67% | 76.6% |

This shows that most of the participants associate general waste with a negative impact on the environment without a clear definition of the form of waste. Whilst they also felt that transportation is a major source of negative impact on the environment, with limited responses reflecting their awareness of the negative impact that buildings have on the environment; whereby, around 77 percent of the participants gave a low rank to the impact of buildings on the environment. These results contradict the findings from literature which state that buildings are one of the major sources that have a negative impact on the environment.

Moreover, to determine the participants' awareness of the UAE's laws in relation to regulating building sustainability practices, 67% of the participants indicated that they were not aware of the building regulations laws. This supports the earlier findings in this section that the participants have limited knowledge about sustainability issues and practices that revolve around buildings as the major contributors to environmental issues.

Hence, it becomes significantly important to increase the end users' awareness of such laws and policies, in order to notify the consumers/users in the UAE about the impact of misusing the resources in buildings on the environment.

It can therefore be concluded that there exists a lack of awareness of end users and occupants of buildings regarding the impact of buildings on the environment, and that their preferred choices of buildings are pretty much associated with the appearance of the building rather than its sustainable components and impact on the environment. Therefore, there is a need for raising the awareness of sustainability issues in educational buildings in order to have a community of students and educators working together in harmony to adjust their perceptions and social behaviours as end users of these buildings.

## REFLECTION AND LIMITATION OF THE STUDY

This study achieved its ultimate goal of comparing the energy performance of three educational buildings within Higher Education establishments in the UAE, as a case study, in order to identify the most energy efficient building. This study, however, has a few limitations that are listed below:

- Some of the data for energy consumption of the three identified buildings were missing. Although this data did not have the great impact on the results, their presence may have increased the accuracy of the results obtained.
- While calculating the CO2 emission, the research was limited to considering the emission from the electricity consumption only. However, other causes of CO2 emission rather than electricity consumption could be considered for future work.
- The research was limited to cover only two aspects of sustainability which are environmental and social, however the future research could benefit from considering all the sustainability aspects in order to evaluate the energy performance of the ZEB buildings.
- The energy performance of the three identified buildings could be compared with buildings of large areas or more technologically advance educational buildings in order to identify the most viable type of buildings for educational establishments.

## Conclusion

Over the past few years, the GCC and United Arab Emirates in particular have realized the significance of sustainability as an essential concept for the region - which is evident from the UAE's initiatives which emphasized the UAE's vision to move forward with achieving its 2030 mission. However, although there are a number of initiatives being proposed globally to achieve the net zero energy target in residential and commercial buildings, little has been reported on the utilisation of ZEBs in the UAE in general and educational buildings in particular. Therefore, this study adopted a methodological approach to compare the energy performance of three educational buildings within a Higher Education establishment in the UAE as a case study in alignment with the growing interest of the UAE in global education, and the fact that the UAE is a growing hub for a number national and international universities. This study compared the Energy performance of three different types of buildings such as the Net Zero Energy Building, Sustainable (renovated) building and conventional building based on energy efficiency, CO2 emissions and temperature emitted from the buildings. The results indicated that the Net Zero Energy building (CSC building) has the better energy performance. However, the results also indicate that there is an amount of energy that is wasted which means that none of the buildings are fully and effectively consuming the energy. Hence, the performance of buildings does not only depend on the type of building (whether it is energy efficient or not) but it also depends on the behaviours of the buildings' users; which showed that there is a lack of awareness from the end users and occupants of the buildings regarding sustainability, its impact and initiatives by the UAE government. Thus, to ensure energy efficiency in buildings, the end-users and occupants' awareness of the benefits of ZEB or sustainability in buildings must be raised. For future studies, a robust method that compares the energy performance of buildings by the unit values i.e., energy consumption per GIFA could be adopted.

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