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On the Effect of Global Warming and the UAE Built Environment

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1. Introduction

Climate changes have already been noted all over the world. The reasons for these changes are complex and there are disagreements in the scientific community about the causes. Some scientists believe that changes are part of natural variability while others point to human activity as the cause of increasing atmospheric concentrations of green house gases (GHGs) and the key driver of climate changes. Many scientific studies come to the conclusion that the expenditure of non-renewable energy has a direct impact on the climate, with potentially devastating results. This expenditure is said to be one of the main factors affecting the climate. It causes three major problems, namely air pollution, acid rain and greenhouse effects. The use of non-renewable energy has increased the carbon concentration in the atmosphere and has also increased the earth's temperature, which is known as ''Global Warming''. The Intergovernmental Panel of Climate Change [1] stated that there would be a steady increase in the ambient temperature during the end of the 21st century due to the large growth in carbon emissions. Much of this growth has come from energy generation, transport, industry and, above all, from building operation.
The energy generation represents the largest economic sector in the Gulf region. During the past few decades, the Gulf Council Corporation (GCC) countries, major oil producers, have witnessed an unprecedented economic and social transformation. Oil proceeds have been used to modernise infrastructure, create employment and improve social indicators. Due to the expenditure of oil, the GCC countries have fallen in the top countries of CO_2 emissions. On a global scale, all GCC countries fall in the top 25 countries of carbon dioxide emissions per capita, with UAE leading [2]. In addition, current reports on environmental policy in the GCC are very critical and have given them the image of being the worst environmental polluters worldwide, with UAE and Qatar at top. According to the Global Footprint Network [3], the UAE possesses the highest Ecological Footprint in the world. This issue in addition to the increase in energy demand have come to the agenda of the UAE government.

2. UAE agenda

Two important issues have become a hot topic in the UAE. Firstly, the current energy situation that shows a trend of growing demand. In one decade (1997-2007), the primary energy of this region increased by 55.8% with 15.3% change between 2007 and 2008. [4].

Secondly, the increase of CO_2 emissions. The statistics of the UAE show that the increase in CO_2 emissions is within the range of 33% and 35% between 1997 and 2006 [5]. The Environment Agency of Abu Dhabi stated that the UAE activities in pursuing developments, such as fossil fuel combustion, industrial processing, land-use change and waste management have caused the release of greenhouse gas (GHG) emissions into the atmosphere. Consequently, temperatures in the UAE regions could significantly increase. This increase will influence the economy, built environment and above all the micro-climate of the UAE.

2.1 Current and future climate

The United Arab Emirates (UAE) is a federation of seven Emirates located in the Gulf region (see Figure 1). It spans approximately 83,600 km² and can be divided into 3 major ecological areas: coastal areas, mountainous areas and desert areas. Over four-fifths of the UAE is classified as desert, especially in the western parts of the country. The general characteristics of the UAE's climate resemble those of arid and semi-arid zones. Figure 2 shows a brief analysis of climatic elements of the UAE provided by the Directorate of Meteorology of Abu Dhabi. The analysis shows two main seasons characterise the UAE's climate. Winter lasts from November through March, a period when temperatures seldom drop below 6 °C. Summers are very dry with temperatures rising to about 48 °C in coastal cities – with accompanying humidity levels reaching as high as 90%. In the southern arid regions such as Al-ain city, temperatures can reach to 50 °C. The UAE is blessed with a high solar radiation level. The highest monthly averages of total and direct radiation are 613 W/m² and 546 W/m² in May and October respectively, while the highest monthly average of diffuse radiation is 273 W/m² in July. Wind from a north-west direction throughout the year is the characteristic of the UAE. The wind speed average shows slight variation, being generally low from November to January with a monthly average of 3.5 m/s, while from February to October it is well above 4.2 m/s, reaching a monthly average of 4.6 m/s in May.

Hot arid regions, such as the UAE, are sensitive to climate changes and the effects they produce. The Environment Agency of Abu Dhabi and the Ministry of Energy [6] studied different scenarios of climate changes and stated that temperatures in the UAE regions could increase while precipitation levels could significantly decline by the end of the 21st century. This scenario was simulated and the output was generated at the regional level and then scaled to eight cities within the UAE including Abu Dhabi, Dubai, Sharjah, Al-Ain, Ras al-Khaymah, Khawr Fakkan, Umm al-Qaywayn, and Ajman. The result shows that the annual average temperatures in 2050 are projected to be between about 1.6 °C and 2.9 °C warmer than they were over the period 1961–1990 and between 2.3 °C and 5.9 °C warmer by 2100. It is clear that the climate of the UAE is tending to get warmer. This tendency is expected to impact the built environment, energy use in buildings and its associated CO_2 emissions.

2.2 Energy consumption and CO_2 emissions

The discovery of oil in 1958 in Abu Dhabi and 1966 in Dubai transformed the economy dramatically, enabling the country to move away from a subsistence economy toward a modern, industrial base. In some respects, however, it seems, the energy plans of the UAE is following the example of developed nations whose economic growth occurred through the use of technologies and expenditure of fossil fuels and electricity. The rapid and increasing economic expenditure with huge architectural projects and population growth rates and a

fairly low energy cost are increasing the UAE's energy consumption, making it one of the highest energy consumers per capita in the world [7]. Generally, energy in the UAE is consumed in five broad sectors defined by four end-uses, including residential, commercial, industrial and agriculture sectors. If electricity generation is included, the five sectors account for all energy consumption in the economy of the UAE.

On an international level, the consumption of energy for the building sector is a significant factor in the economy of many countries. Recent studies show such trends in different parts of the world. In the United States, for example, 41% of the total national energy production and nearly 70% of electricity production is used in buildings, as well as 28% in transportation, which is at least partly influenced by urban design [8]. In the United Kingdom, the building sector consumes about 50% of all the country's energy [9]. In Brazil, 48% of the national energy is consumed in buildings [10], while in China, building sector currently accounts for 23% of the country total energy use [11]. The same situation can be seen in the UAE. Figure 3 shows the energy consumption per sector in Al-Ain and Dubai [12-13]. Clearly, buildings, particularly those in the residential sector, have the largest impact on this growth, as 30% and 46% of the total energy in Al-ain and Dubai is consumed in this sector. Unlike many developed nations, however, the UAE always reacted to its growth in energy consumption by adding new generation capacity. Whereas, the developed countries are focusing on demand-side-policies to reduce the energy consumption as can be seen in Japan, which is considered as the most energy efficiency economy in the world due to innovative policy instruments such as the top runner approach [14].

As the fraction of the total energy increases, the production of CO_2 emitted becomes greater. Figure 4 shows the increase in CO_2 emissions relative to the use of energy. It is important to note that the production and consumption of energy are the dominant source of GHG emissions in the UAE. The UAE statistic data show that about 4% of the CO_2 production is caused by the direct emissions of buildings, 43% by electricity generation and 45% by manufacturing and construction [15]. The remaining is caused by other resources.

3. Global warming and the UAE buildings

The increasing emission of CO_2 and its contribution to global warming has become a growing concern for building industry and regulation bodies in the UAE. There are two reasons: firstly, CO_2 is the main by-product of the generation from fossil fuels of energy. As buildings are one of the largest consumers of energy then they are also the largest contributor to the increase in the atmospheric CO_2 and hence global warming and climate change. Secondly, building operation is likely to be especially affected by global warming. Clearly, by using none renewable fossil fuels, buildings contribute to the CO_2 emissions leading to warming the globe. In turns, global warming influences the energy consumption of buildings leading to increase the production of CO_2 emissions.

To evaluate the interaction between buildings and global warming, the following methodology was used. Statistically-based weather data files were generated in order to reflect the increases in air-temperatures. Each file represented a weather input of a sophisticated simulation program [16]. A typical residential building was used as a simulation model in order to represent the mainstream residential buildings in the UAE. The model was then validated using measurement data from field study and audit reports. Based on the output of simulation, a regression model was developed in order to estimate the CO_2 emission. This evaluation first estimated the variation in heating and cooling degree-days, as they were the

most straightforward indicators on building energy demands. It then predicted the variation on heating and cooling energy demands of the typical residential building to help illustrating the consequences at the national level. To estimate the CO_2 emissions, the electricity consumption was multiplied by the conversion factor of fuels in the UAE.
The first part of this section explores the contribution of UAE building sector to global warming. The second part studies the impact of global warming on UAE building design and operation in the UAE. The third part forecasts the future transformations in energy and CO_2 emissions of the UAE building sector.

3.1 UAE building sector and its contribution to global warming

The energy consumption of buildings and its associated CO_2 emissions are influenced by the interaction between three major factors including building design and materials, occupant behaviour and above all climate. To reach the energy efficiency target, sequential processes should be followed. These processes start with an optimum climatic design and end with an efficient operation of building system by the occupants. The optimum design positively impacts the building systems, particularly the HVAC and lighting systems. It may reduce the building loads and equipment size and consequently the cost and energy use. However, to obtain the maximum benefits of this design the occupants should operate the building systems in an efficient way because they can directly alter the system performance through controllers. For example, the energy consumption for heating and cooling depends on internal temperature and ventilation and these parameters are controlled by the occupants.
In the ground, however, there is no question that the majority of buildings in the UAE are designed, built and operated without attention being paid to the environmental and energy system. Today, under the umbrella of a worldwide international style of buildings, and in an attempt to embark on a new trend of modern architecture, huge glass façades facing the sun have appeared in cities such as Dubai, Abu Dhabi and Al-Ain. In energy terms, this strategy is generally applied to gain the most solar radiation possible in order to heat up buildings and utilise daylight and therefore, it is often used for cold climates. For hot climates, such as that of the UAE, using this strategy may lead to a different scenario with respect to cooling load. To apply this strategy in hot climates, the energy design should utilise the availability of useful daylight by striking a balance between light and heat gain. Nevertheless, this is not the case in the UAE. Huge projects have been constructed with enormous glazed façades facing the southeast and southwest without protection against overheating and sun glare in the summer [17]. Furthermore, some construction materials have low impact on CO_2 emissions that result from raw material acquisition, manufacture, transportation, installation, maintenance and recycling, but provide a moderate reduction in terms of operational energy, and vice versa. Others positively impact the embodied energy and environmental performance and can optimise the cooling and heating energy performance. Replacing or at least reducing the use of some construction material such as concrete, reinforcing steels, formwork, and gypsum board have a direct impact on CO_2 emissions. Some materials and construction systems can decrease the amount of CO_2 emissions by around 6.9% [18]. In most projects in the UAE, however, materials are evaluated and selected based on aesthetics and cost and not on their energy and environmental performance [19]. It is, therefore, not surprising that 70% of the yearly electric energy use is consumed by building systems. Figure 5 shows the energy end-uses of a typical residential building in the UAE, where the electricity consumed by the HVAC

system is the most significant, particularly for cooling energy. The growth in electricity consumption for cooling buildings in the UAE region has increased ten times (from 5 to 50 Billion kWh) over the past two decades [20].

A key function of building design is to modify the indoor environment to be more suitable for habitation than the outdoor. If the building fails to meet this objective due to one or more reasons, such as insufficient design and materials selection or variations in climate parameters that probably make it impossible for any certain level of comfortable indoor environment to be achieved through passive means. Then, it is necessary to rely upon mechanical means to achieve the comfort level. As a result, additional electricity will be used by the HVAC system to provide a comfortable internal temperature for human being. Most people feel comfortable at indoors temperature ranging from 22 °C to 24 °C along with a range of 40–60% relative humidity. For a residential building it would normally be designed with comfort temperature selected from range 20 °C to 24 °C. With a heating system one figure would be chosen, but with air-conditioning system two figures would be selected, the higher one for summer (cooling) conditions. These figures are taken to apply generally for cold climates such as North America and Europe, and for warm countries higher figures would often be used, and in the harsh climates of the UAE, where the average maximum air-temperature reaches above 50 °C, an internal temperature of 26 °C and 27 °C would be considered comfortable. A significant amount of electricity and between 26.8% and 33.6% savings in cost can be achieved by raising the set point temperature from 24 °C to 26 °C in similar climate [21]. Nevertheless, this is not the case in most cities in the UAE, as the point temperatures are often set below 24 °C. This attitude can be related to two main reasons, first, low electricity prices and second, the support of the government where the citizen pays 0.05 AED (1 AED = 0.27 USD) for each kilowatt-hours and in some cases the government pays for the consumption [22]. These two reasons have reduced the people immediate interest in electricity conservation.

Clearly, harsh climatic conditions, building design and occupant behaviour in the UAE are contributing negatively to the increase in energy consumption and its associated CO_2 emissions. As mentioned earlier that about 4% of the CO_2 production in the UAE is caused by the direct emissions of buildings, 43% by electricity generation and 45% by manufacturing and construction. Electricity use in building sector is within the range of 50% to 73% with an average of 60%. The net energy consumption of the UAE reached 52.6 Billion kWh and the total annual CO_2 emission got the level of 137.8 million metric tonnes [5]. These figures coupled with percentages in Figure 3 give a rough estimate of CO_2 emissions per sector in the UAE. Around 5.50 million metric tonnes is caused by the direct emissions of buildings, 35.5 million metric tonnes from electricity use by building sector and 62.0 million metric tonnes by material manufacturing and building construction.

To reduce the above figures, it is necessary to eliminate the reasons behind the CO_2 emissions. First, reduce the inefficient used of energy by educating people and providing a good energy management. Secondly, modify the impact of climate with minimum electricity use through climatic design. In this way it is possible to reduce the negative contribution of buildings to the global warming.

3.2 Impact of global warming on building design and operation

Changes in the external air-temperature will have significant consequences upon building thermal performance, particularly cooling and heating energy. The severity of the outside air-temperature related to cooling and heating energy consumption can be measured using

the so-called degree-days. Figure 6 shows the impact of air-temperature on the cooling and heating degree-days in the UAE. It is clear that there is a significant change, which positively influences the heating degree-days, but negatively influences the cooling degree-days. Cooling degree days can increase between 16% and 27% by 2050. This increase can reach between 22% and 42% by 2100. The growth in cooling degree-days implies that to reach a comfortable internal environment in the hot summer of the UAE, a dramatic change will occur in the amount of electricity used by air-conditioning systems. Table 1 illustrates the simulated impact of global warming on the cooling and heating demands. As can be seen, there is a brief drop in heating energy demand with different rates ranging from 9.5% to 37.1% due to the increase in air-temperature by 1.6 °C and 5.9 °C respectively. When this applies to the cooling and ventilation energy, a different scenario occurs. There is a sharp increase in the cooling energy which reaches a peak of 23.5% due to 5.9 °C increase. This increase represents a clear indication that global warming will lead to a negative impact on the total electricity demand, where changing from the current climate has reduced the heating energy demand at the expense of a rise in annual cooling energy demand, and therefore, additional total energy has been consumed. From the total energy increase; there has been in effect a further CO_2 increase, with electric cooling energy consumption.

3.3 Forecasting future transformations in energy consumption and CO_2 emissions of the UAE building sector

To forecast future transformations in the energy consumption and CO_2 emissions of the UAE residential sector, a simple regression model was constructed in the light of current building design and operation as well as the future weather conditions. The primary analysis of the constructed model is based on a weighted ordinary least squares regression. This type of regression is used to know the relationship between several independent or predictor variables and a dependent or criterion variable. In the current case, the cooling energy is the dependent and variables in the right side of the equation are the independents.

$$CE = C_0 + C_1\,Tao + C_2\;\; WWR + C_3\;\; U - v_{(w)} + C_4\;\; U - v_{(g)} + C_5\;\; SC_{(g)} \tag{2}$$

The result of regressing the simulated cooling energy (*CE*) as obtained from Table 1 onto the outside temperature (*Tao*) and building design parameters including U-value of the wall, $U\text{-}v^{(w)}$, window-to-wall ratio, WWR, U-value of the glazing, $U\text{-}v^{(g)}$, shading coefficient of the glazing, $SC^{(g)}$, as found in the representative residential building is shown in Table 2. The coefficient of determination, or R^2 of the CE, is 0.97 which would indicate a strong relationship between the CE variables and the outside temperature, U-value of the wall, WWR, U-value of the glazing and the SC of the glazing. The amount of CO_2 emissions (*E*) is subjected to the cooling energy, operational schedule (*Op_sch*) and the conversion factor of fuel (*Cf*). Therefore, a simple linear equation was developed and used to calculate the CO_2 emission reduction due to the examined weather and none weather dependants. The following equation was used.

$$C_{emission} = (CEI \times Op\_sch) \times Cf$$

With the current building design and operation in the UAE, the residential sector accounts for 2646 GWh, or almost 46% of the total regional consumption. The global warming is likely to increase the energy used for cooling buildings by 23.5% if the UAE warms by 5.9 °C leading to a growth in electricity consumption to almost (current consumption + 12.5%) 2977

GWh, and consequently the total CO_2 emissions will grow to almost 7.6 million metric tonnes. The net Emirati CO_2 emissions could increase at around 138.4 million metric tonnes over the next few decades.

When energy efficiency techniques are applied to the current building design and operation, different scenario is occurred. Table 3 illustrates cooling energy savings due to each efficiency technique under different scenarios. The energy breakdown of the representative building show that electricity used for space cooling is approximately 65% or 97.5 MWh. As illustrated, adding thermal insulation to the case building due to 1.6 °C increase reduces the cooling demand by 19.3%. Considering the large amount of cooling energy demand this figure is significant. The minimum reduction is 15.5% due to 5.9 °C increase. At the same time, replacing the glazing type from single glazing to double low-energy glazing produces a significant savings in cooling energy demand as can be seen in the fall of energy consumption which reaches 10.5% due to 5.9 °C increase. As a great amount of cooling energy can be saved by glazing type, an appropriate design of window area offers a considerable opportunity to control electricity used by the AC system. As seen, reducing the WWR reduces the cooling energy by 3.7% and 9.0% under current climate and 5.9 °C increase. These figures indicate that thermal insulation performs best, followed by glazing type and then window area in descending order.

As these techniques stop the heat flow from the outside and reduce the cooling load and energy consumption leading to decreasing the CO_2 emissions, authorities and energy code bodies in the UAE should develop such techniques and make the relevant part of the building design and regulations more stringent, and emphasise that the goal of saving energy is to reduce CO_2 emissions into the atmosphere. This can be done by using CO_2 emissions as one of the principal criteria by which the design of a building is judged. It can be implemented jointly with measures on specific envelope elements, system components and energy use patterns in order to ensure the dissemination of the most efficient building

4. The UAE strategy towards sustainability in the built environment

Indeed, the less a country depends on finite resources such as natural gas and oil, the stronger and more stable the economy will remain in the face of energy cost increases or reduced supplies. From an environmental point of view, the expenditure of non-renewable energy has a direct impact on the natural environment. Thereby, following the example of developed world without any consideration to the local environment may lead to critical economic and environmental consequences. To avoid such consequences, two major changes in patterns are proposed, first, effective measures to protect the depleted resources and second, valid policies to replace fossil fuels with non-fossil fuels.

4.1 Policies and legislations to reduce the energy demand

There has recently been a consensus to legislate for energy efficiency in the UAE. The government has realised the benefits of energy efficiency not from the point of view of the balance between energy supply and demand, but rather from a socio-economic and environmental standpoint. As the building sector is a major consumer of energy, the UAE government has concentrated on this sector and recognised the important role that efficiency codes play in reducing the amount of energy consumption, especially that of the HVAC systems. The thermal insulation code was first applied. The green building codes

were then introduced. The new building energy codes conform to the most demanding global standards and have been developed in tandem with the International Code Council (ICC), responsible for advising US regulators on their exacting regime. Therefore, the UAE building codes is considered as the first step towards developing consistent sustainable policies in the UAE and the region. The UAE government, also, launched the Estidama Program and the Pearls green building rating system which would become integrated into the building code and therefore enforceable, as well as the launch of the Emirates Green Buildings Council [23]. The rating system introduced by Estidama Program can be considered as an important step towards low carbon emission buildings. Rating the performance of buildings against itself and other buildings plays a key role in protecting the environment, reducing energy consumption and checking on energy efficiency. Its most significant contribution is that it provides a target for improvement.

A survey [24] concerns with the environmental sustainability in the UAE showed the residential buildings before the codes as poor energy and carbon emission performers, while a benchmarking study [25] categorised most educational buildings in Abu Dhabi Emirate as poor energy and environmental performers when compared to international benchmarks. Those studies indicated the inefficient building design and the poor energy management as the main reasons behind the high energy consumption and CO2 emissions of those buildings. An evaluation of the new building codes and their impact on energy and CO_2 emissions [22, 26] showed that using such codes can reduce the CO_2 emissions of buildings by 50%.

4.2 Initiatives to utilised renewable energy

Although the UAE has no consistent policy frameworks for sustainable technologies and renewable energies, it has planned economic development programmers dedicated to establishing new economic sectors focused on alternative energy and sustainable technologies. For instant, two promising projects are planned to be completed in the next few years: first, a $350 millions solar power plant and second, a $2 Billions hydrogen-fuelled power plant [22]. Such projects, in general, can contribute to the sustainable development including economic, environmental and technological well being. They will not only contribute towards employment generation, but also reduce significant amount of GHG emissions which would have taken place in ordinary power plant scenario with natural gas and fuel oil based generation. In the latter project, the CO_2 will be kept underground which represent one of the world first carbon capture and storage projects. Moreover, solar energy based power generation system will be a robust and clean technology involving the latest state of art renewable energy options to be used for the purpose of electricity generation.

Utilisation of clean and renewable energy has become a trend in the UAE, not only through the establishment of sustainable power stations, but also through the construction of low energy and free carbon emission built environment. There are some remarkable projects going on in the UAE. The most notable project among these is Masdar City. Although the concept is not new, Masdar City is planned to be a carbon-neutral, zero-waste city with the aim of being one of the world's most sustainable urban development powered by renewable energy [27]. This huge project incorporates various sustainability techniques and renewable energy technologies. It is planned to host two important institutions. First, the headquarter of the International Renewable Energy Agency (IRENA) which will be the first global agency based in the Middle East. Second, the Masdar Institute of Science and Technology which will offer MSc and PhD programmes in alternative energy and sustainable

technologies as well as give opportunities to do various research activities in sustainable design [28].

To this end, protecting the depleted resources and switching towards more efficient use of energy coupled with replacing fossil fuels with non-fossil fuels would have a number of benefits for the UAE:

- The UAE would be given a better reputation in the regional and international policy arena.
- The reduction in the use of fossil fuels will lead to an increase in the exported oil and natural gas.
- The UAE would gain another important benefit from none-fossil fuels such as solar and wind energy. Consequently, it will be prepared for the post-oil era.
- Reducing the use of fossil fuel and the use of renewable energy will limit the effect of global warning on the UAE and on other countries in the Gulf region.

5. Summary

As energy scarcity and global warming are threatening human sustainability, governments and organisations must spend much effort in reducing the energy consumption and CO_2 emissions. Buildings are one of the largest consumers of energy then they are also the largest contributor to the increase in the atmospheric CO_2 and hence global warming and climate change. At the same time, building operation is likely to be especially affected by global warming. A rise in the ambient air-temperature can lead to a significant increase in electricity consumption and its associated CO_2 emissions. Global warming is likely to increase the energy used for cooling residential buildings by 23.5% if the UAE warms by 5.9 °C. At the regional level, the energy consumption can be increased at around 5.4%. Consequently, the CO_2 emissions can increase to almost 7.6 million metric tonnes. The net Emirati CO_2 emissions could increase at around 138.4 million metric tonnes over the next few decades.

To cope with global warming and the increase of CO_2 emissions, two major changes in patterns are suggested in the UAE: first, effective measures to protect the depleted resources and second, valid policies to replace fossil fuels with non-fossil. The former can be seen in the new building energy regulations. Implementing these regulations can reduce the CO_2 emissions by 50%. The latter can be seen in establishing a new economic sector. This sector focuses on alternative energy and sustainable technologies through the installation of new power plants that use renewable resources in power generation. In addition, the construction of low energy and free carbon emission built environment such as Masdar City. Such a project can served as the foundation for an extension of activities in the field of low carbon emission buildings and renewable resources with the goal of reducing the impact of global warming on our life, economy and above all our built environment.

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Fig. 1. Locations of the UAE

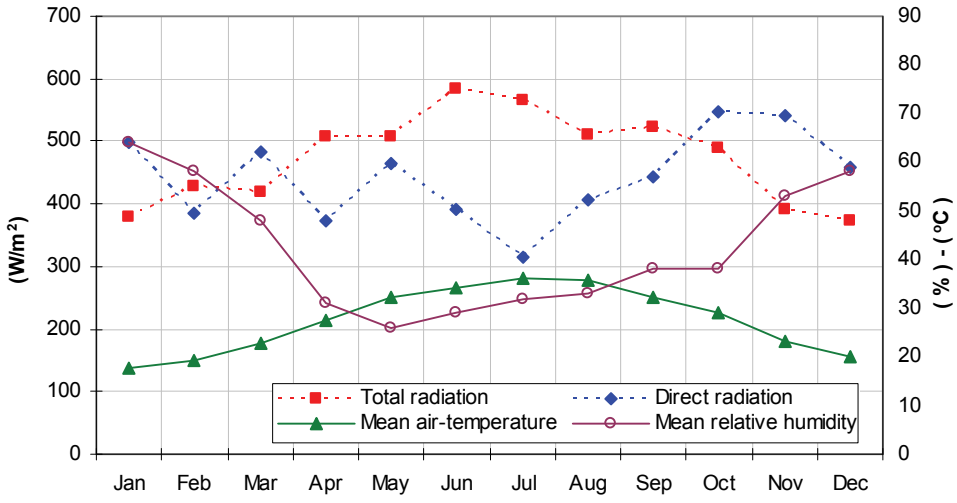

Fig. 2. Analysis of UAE climate

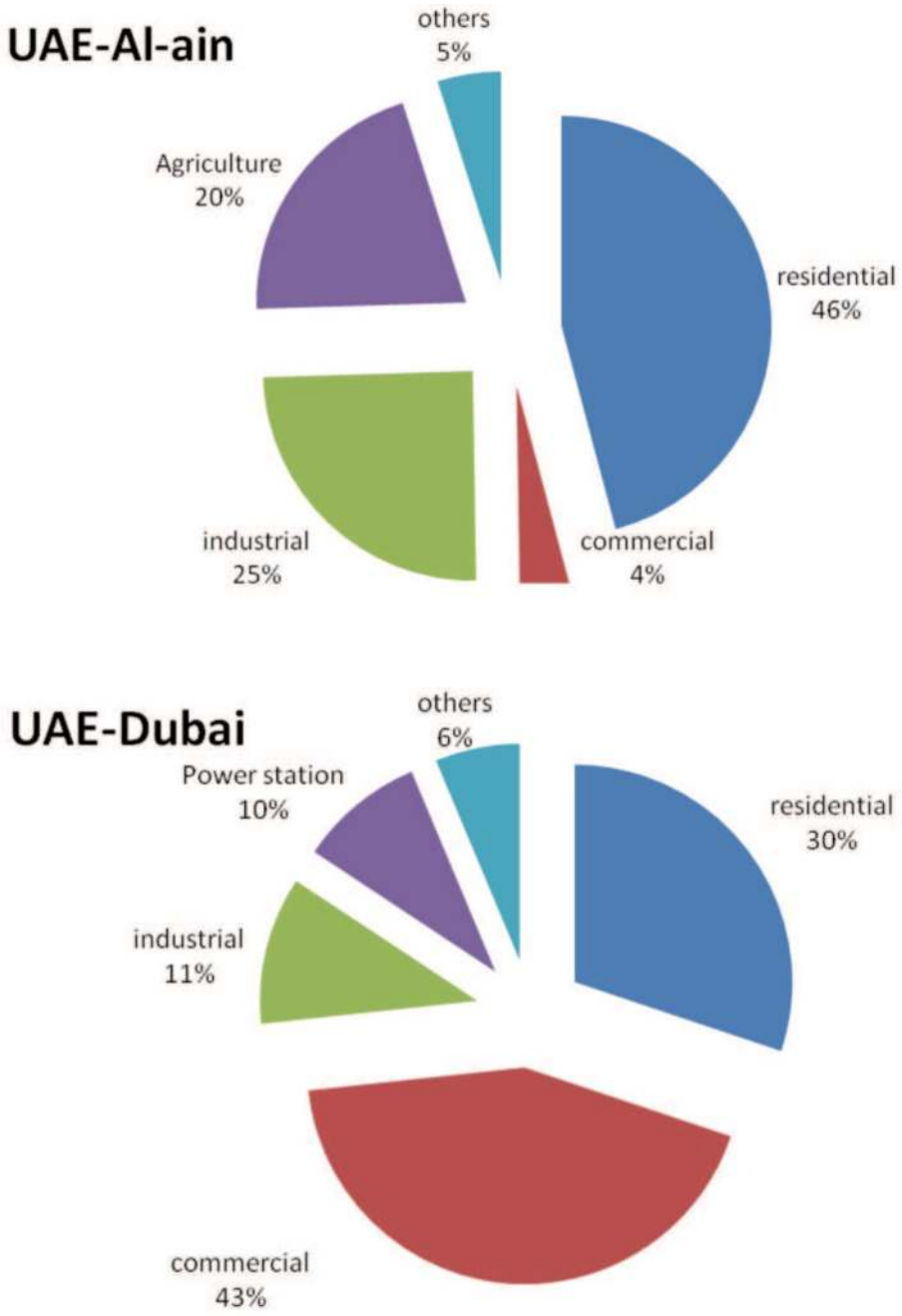

Fig. 3. Energy consumption per sector

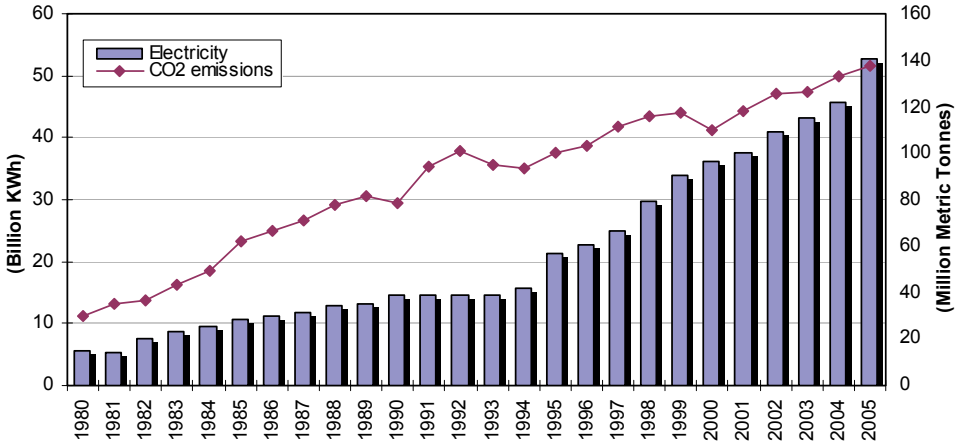

Fig. 4. Increase in CO_2 emissions relative to the use of energy

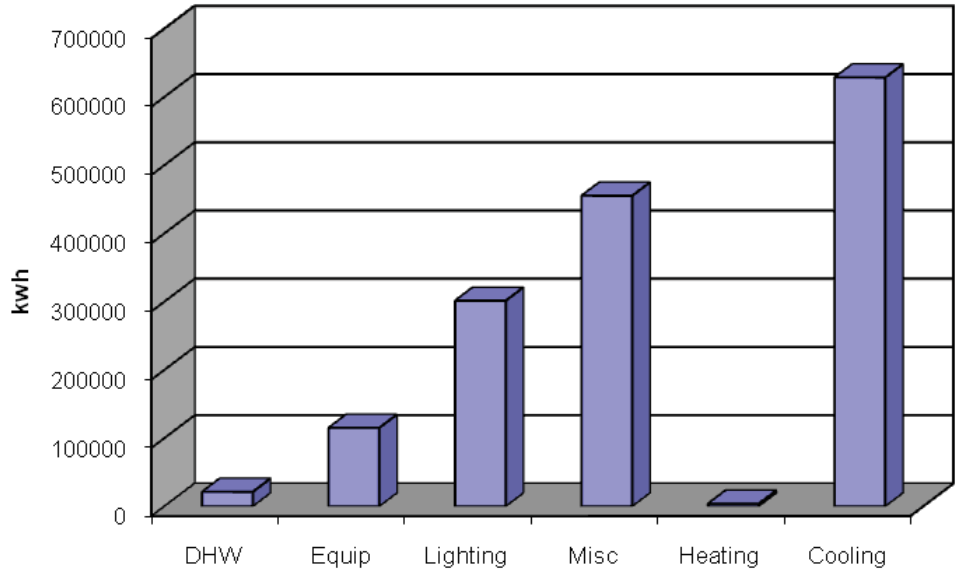

Fig. 5. Energy end-uses in the typical building

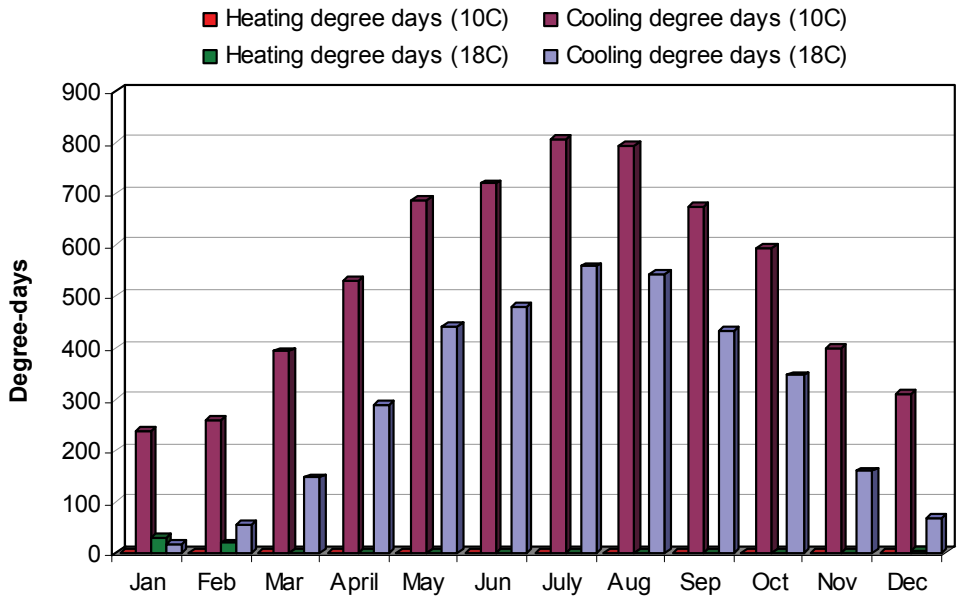

Fig. 6. Monthly heating and cooling degree days

	Heating (KWH)	Cooling (KWH)	Fans (KWH)	Electricity (KWH)	CO_2 emissions (Kg/m²/yr)
Baseline (consumption)	6369	73049	11886	122920	176
I.6 °C (%)	-9.5	7.3	3.9	4.1	183
2.9 °C (%)	-14.2	11.7	5.8	6.7	188
2.3 °C (%)	-17.4	16.7	6.8	9.5	193
5.9 °C (%)	-37.1	23.5	12.3	12.9	197

(-) reduction

Table 1. Increase in electricity and CO_2 emissions due to global warming

Cooling requirement (CR)						
	C_o	C_1	C_2	C_3	C_4	C_5
	-258	11.8	20.2	249	2.9	27.6
	7.4	0.2	0.7	8.6	0.5	4.9
R^2	0.97					
F	952					

Table 2. Regressing the energy cooling energy requirement

Climate	Baseline	1.6 °C	2.9 °C	2.3 °C	5.9 °C
Consumption (KWH)					
Cooling	75462	80434	83390	86811	96203
Electricity	126836	131393	134173	137397	145486
Reduction due to thermal insulation (%)					
Cooling	19.3	19.7	19.9	19.7	15.5
Electricity	15.5	15.9	16	15.9	13.1
Reduction due to glazing system (%)					
Cooling	5.4	5.4	5.5	5.5	10.5
Electricity	4.5	4.6	4.7	4.7	8.1
Reduction due to glazing area WWR (%)					
Cooling	3.7	3.8	3.9	3.9	9
Electricity	3.2	3.2	3.3	3.3	6.8
(-) increase in energy demand					

Table 3. Performance of design technologies under different scenarios

Global Warming

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This book is intended to introduce the reader to examples of the range of practical problems posed by "Global Warming". It includes 11 chapters split into 5 sections. Section 1 outlines the recent changes in the Indian Monsoon, the importance of greenhouse gases to life, and the relative importance of changes in solar radiation in causing the changes. Section 2 discusses the changes to natural hazards such as floods, retreating glaciers and potential sea level changes. Section 3 examines planning cities and transportation systems in the light of the changes, while section 4 looks at alternative energy sources. Section 5 estimates the changes to the carbon pool in the alpine meadows of the Qinghai-Tibet Plateau. The 11 authors come from 9 different countries, so the examples are taken from a truly international set of problems.

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