The Sustainable Development of Local Housing Units in UAE

التطور المستدام للوحدات السكنية المحلية في دولة الإمارات العربية المتحدة

By

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Abstract

WWF (2010) ranked United Arab Emirates (UAE) as the country with the world's largest Ecological Footprint per capita in 2007, by means of that if the earth's population consumed and emitted carbons as much as UAE residents do, more than “4.5 earths” would be required to sustain it. Accordingly, UAE has classed as one of the most energy consumers globally due to its massive economic development and abnormal population growth. Despite the fact that the urban development has formed the cornerstone of the Dubai economic growth; it has failed in creating sustainable urban environment.

The immediate need for conservation and sufficient control of building development in UAE has led to initiate several foundations to ensure a sustainable development future of the country. Abu Dhabi Urban Planning Council has produced the Pearl Rating System for Estidama while Dubai Municipality has set up the first edition of Green Buildings Regulations and Specifications.

This study investigates the sustainable development of local housing units in Dubai from historical ages until the expected status after applying the Green Regulations on 2014 and compares the results with that of Estidama System of Abu Dhabi.

Different computer simulation has been conducted using (IES-VE) to evaluate the energy consumption and thermal performance. It was found that the traditional unit has the minimum value of energy consumption among all other units. With the beginning of using cooling systems in 1970’s, the total energy consumption has lifted up about four times than the total

energy of traditional unit. Remarkable reductions below 1970's – 1990's levels has recorded in future cases of Dubai (49% - 63%) and Estidama cases of Abu Dhabi (57% - 71%) due to new policy instruments, energy efficiency direction and thermal performance development. Simple payback analyses has been conducted and verified that the future green practices and sustainable developments have the ability to re-create environmentally friendly buildings that present green and comfort balance within an affordable price where the total construction cost of Dubai and Abu Dhabi green buildings has ranged between 0.46% to 2.04% above the levels of total construction cost of the year 2000 – 2010 levels. And the payback period has ranged between 1.3 to 3.6 years for the re-traditional design and 5.4 to 7 years in post-modern design.

Acknowledgments

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Chapter 1: Introduction

1.1 Introduction of Dubai Foundation

Pacione (2005) stated that similar to many other modern cities; Dubai is running to set up its foundation within the global economy and it is in front of the challenge of presenting sufficient infrastructure in a perspective of express urban development where property expansion forms a cornerstone of Dubai's development approach. Since the early 1800s, Dubai played an important role as a distribution centre of trade. It was the chief port where goods from India were re-exported to Persia and neighboring countries. Records of Dubai (2000) documented that Dubai was a transmit spot of business route from Iraq to Oman, and between India, East Africa and the Northern Gulf. This ultimately led to setting up the city as an international point of commerce where many traditions and cultures assorted.

1.2 Dubai History and Building Development

Handal (1983) recorded that the year 1833 represents the establishment of Dubai and its political appearance in the region by Sheikh Maktoum bin Buti bin Suhail Al Falasi. Lorimer (1986) stated that in 1841, many residents moved to Bar Deira as a result of epidemic fever spread in Bur Dubai. History of Dubai (2007) contained that in 1861 some people started to move from Bur Dubai to Al Shindagha which formed a nucleus of new construction and expansion of the city. Michael (2005) recorded that Dubai's historical architecture exposes a mixture of cultures and nationalities and at the same time Arabic in style, it is additionally inspired by Asian and European methods. Kay and Zandi (1991) recorded that the historical vernacular approach of architecture in Dubai is the outcome of a combination of three principal factors: the climate (hot and humid), the religion and traditions of people, and the locally available building materials.

Heard (1982) stated that the most of population reside in extended families in Al Arish houses (made of palm fronds). Residential accommodations were built in groups for grounds of collective security and privacy. The domestic divisions of each enclave were linked by narrow walkways planned for pedestrians and local animals used for goods' carrying and drinking water from four public wells. Kay and Zandi (1991) and History of Dubai (2007) documented that in 1893 a major fire broke out in Bar Deira and burned all the houses, which resulted in a new stage of growth. The wealthier people started building their houses from coral stone and gypsum, while the other residents still exist in huts Al Arish houses as shown in Figure 1.1 and Figure 1.2.

Figure 1.1: Al Arish houses beside coral stone houses. Source: History of Dubai (2007)

Figure 1.2: Al Arish houses made of palm fronds Source: the architecture of UAE (2006)

Kay and Zandi (1991) and History of Dubai (2007) stated that the year 1896 represents the building of Sheikh Maktoum bin Hasher house in Al Shindagha which is one of the most important marks of architectural heritage overlooking the creek as shown in Figure 1.3 and Figure 1.4. It has a special historical value for being the seat of government and president housing until 1958 during the reign of Sheikh Rashid bin Said. The house dimensions of 48 X 54 m (Figure 1.4) varying between one floor and two floors (Figure 1.5). It is currently known as the house of Sheikh Saeed Al Maktoum.

Figure 1.3: house of Sheikh Saeed Al Maktoum. Source: Dubai History (2007)

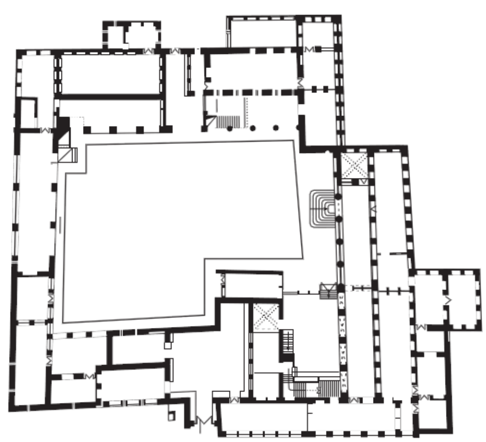


Figure 1.4: ground floor plan of Sheikh Saeed house. Source: Architecture of UAE (2006)

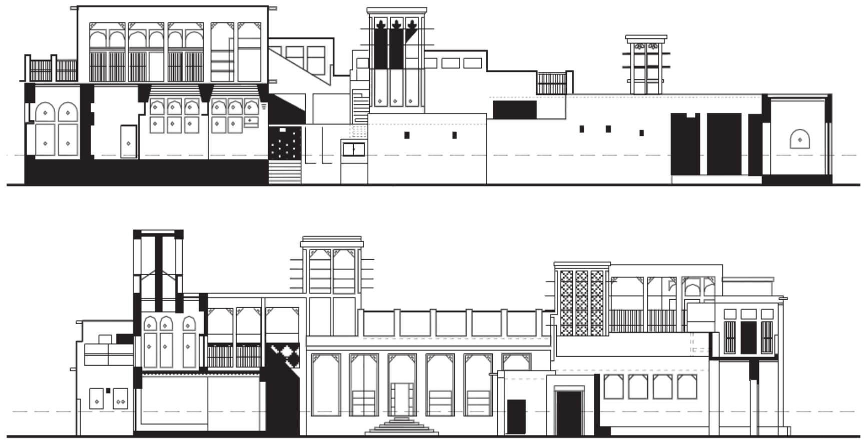


Figure 1.5: sections through courtyard of Sheikh Saeed house. Source: Architecture of UAE (2006)

1.3 Dubai History and Urban Development

Heard (1982) recorded that at the late 1800s and early 1900s, Dubai population was around 10,000 and concentrated in three residential areas: Bar Deira, consisting of 1600 dwellings and 350 souqe shops, with Arabs, Persians and Baluchis creating the greater part of the population. Al Shindagha, a former habitation of the ruling family, where there was 250 residences but without souqes and just Arab inhabitants. Bar Dubai, the nominal of the settlement quarters with 200 dwellings and 50 souqe shops, and occupied by Persian and Indian merchants. Figure 1.6 shows the map of old Dubai. History of Dubai (2007) contains that Sheikh Rashid bin Saeed Al Maktoum was born in 1912 and he is the eldest son of Sheikh Saeed Al Maktoum and the founder of modern Dubai until his death in 1990. Michael (2005) and Handal (1983) acknowledged that the year 1930 represents the the economic recession of natural pearls market in the gulf region and particularly in Dubai caused by Japan pearl manufacturing and exporting. History of Dubai (2007) recorded that in 1940 a large fire broke out in Bur Dubai and burned nearly 400 of Al Arish houses which gradually led to import the cement from India in 1948 to start using it in building construction. Codrai (1990) stated that the year 1950 symbolize the first attempts for oil exploration in Jebel Ali.

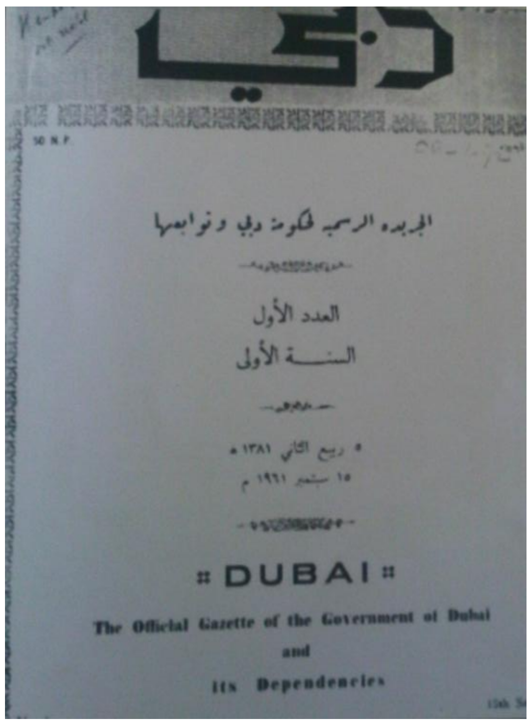
Figure 1.6: Map of old Dubai. Source: History of Dubai (2007)

1.4 <u>Discovery of Oil and Urban Development</u>

With the discovery of oil in 1950, Dubai witnessed an unprecedented population explosion. History of Dubai (2007) recorded that 1956 signify the use of reinforced concrete for the first time in Bar Deira. Hamza (1986) recorded that in 1958 Sheikh Rashid bin Saeed bin Maktoum Al Maktoum took the reins of government. He was the founder of modern Dubai where he set up the development of infrastructure and future plans of economic, urban, and architecture renaissance of the city. In 1959 the first urban planning project of the city has been created by Sir Jon Harris from UK.

1.5 <u>The First commencement of Governmental Commands on Building Development</u>

History of Dubai (2007) documented that in 1960 a declaration by the Council of Dubai Municipality providing the regulation of building codes to preserve the urban layout and keep pace with the evolution of modern construction in the world due to the significant increase of population and serious need of new buildings for accommodation and new businesses. Figure 1.7 shows the first governmental publication in 1961.



دبي

50 N.P.

الجريده الرسميه لحكومة دبي وتوابعها

العدد الأول

السنـــة الأولى

٥ ربيع الثاني ١٣٨١ هـ

١٥ سبتمبر ١٩٦١ م

:: DUBAI ::

The Official Gazette of the Government of Dubai

and

Its Dependencies

Figure 1.7: The first governmental publication in 1961. Source: History of Dubai (2007)

It is important to mention that the regulations that time prevented the design of the courtyards in new houses and buildings. The prominence was on accommodating more people in less space, and Dubai's skyline commenced to grow, as the western scheme of apartment buildings began to come into view at the side of the traditional houses.

1.6 The Foundation of Modern Dubai

In 1963 the Clock Tower which is the first monument in the city and Al Maktoum Bridge which is the first link between Bar Diera and Bar Dubai has been constructed from reinforced concrete as shown in Figure 1.8 and Figure 1.9.

Figure 1.8: The Clock Tower of Dubai. Source: History of Dubai (2007)

Figure 1.9: Al Maktoum Bridge. Source: History of Dubai (2007)

Renovation projects were commenced all over the city, while community gardens were produced in numerous areas. 1971 represent the first establishment of UAE where the rulers signed the interim constitution in Al Deyafa palace in Dubai as shown in Figure 1.10.

Figure 1.10: first establishment of UAE in Al Deyafa palace in Dubai. Source: History of Dubai (2007)

1.7 The Economic Revolution and Building Regulations

After 1990s the economic revolution had place in Dubai and led to significant increase on population and construction booming. The new materials and technologies became more available and facilitated more adventurous designs. In 2000; the second edition of Dubai rules and regulations has been updated to be more compatible with the city growth requirements combined with the first edition of thermal insulation specifications as shown in Figure 1.11 and Figure 1.12.

Figure 1.11: The first edition of Thermal Insulation Specifications (left side) and the second edition of Dubai Rules and Regulations (right side). Source: Dubai Municipality

1.8 Quality of Life and Ecological Footprint

This rapid development of economic growth in Dubai and UAE in general has resulted in an increasing rate of consumption of natural resources such as energy, food, fiber and timber, which in turn has helped improve the quality of life of the country's population. WWF (2010) ranked UAE as the country with the world's largest Ecological Footprint per capita in 2007, which is four times higher than the average humanity's Footprint. The report recorded that each person in the UAE requires an average of 10.68 global hectares (gha) to sustain current rates of consumption and carbon emissions. This means that if the earth's population consumed and emitted carbons as much as UAE residents do, more than "4.5 earths" would be required to sustain it.

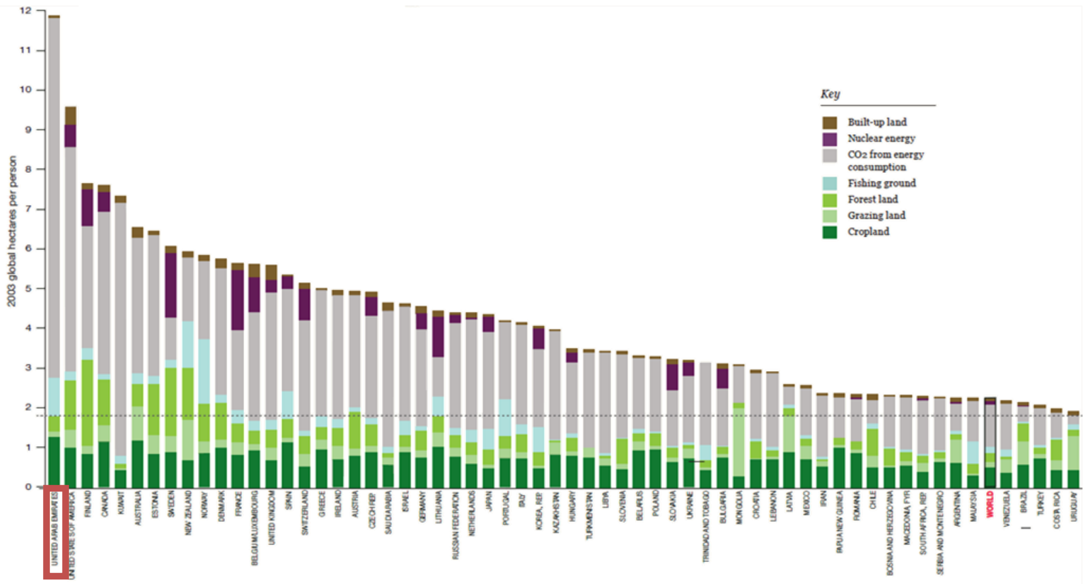


Figure 1.12: UAE is the world's largest Ecological Footprint per capita in 2007. Source: (http://uae.panda.org)

1.9 <u>The Economic Crises and Environmental Problems Recognition</u>

Bassens et. al. (2010) incorporated that the international financial booming for urban development and building industry in Dubai has failed to produce a sustainable urban environment but the meltdown has created a new starting point for preplanning the future of the city in a sustainable way. The case of urban development of the city was a reproduction of international urban and building developments which has a significant role for the express grow of the city specially with the leading role of the ruling Al Maktoum family. One of the most flourishing urban economies is the International Financial Centers (IFCs) like those in Hong Kong and Singapore; and the formation of the global cities like London and New York. The vision of Al Maktoum was to create a world class city and global flows hub of capitals, knowledge, and people through commerce, international services and facilities, and architecture. At that time the sustainability was not a concern or an interest of the urban and economic development of Dubai resulting in environmental drop ecologically through artificial islands, socially through employment of low income workers, and economically in view of the fact that Dubai by some means failed to drive in the international runs of capital, knowledge, and people into its rapid developing urbanity. The recent economic crisis, in spite of all its negatives, guides the city of Dubai to think again about the future plans of its urban development and consider the sustainability in its strategies.

1.10 Green Buildings Revolution

With the beginning of economic crises in 2008 UAE has witnessed the global environmental problem resulted from its rapid development without a conscious consideration of the natural resources and has taken a serious and innovative approach towards understanding and managing its Ecological Footprint through establishing different foundations and Initiatives like Masdar and Estidama of Abu Dhabi. Abu Dhabi Urban Planning Council has initiated the Pearl Rating System for Estidama (Figure 1.14) with clear vision of sustainable development of Abu Dhabi 2030 and ideal relationship among governance and community development.

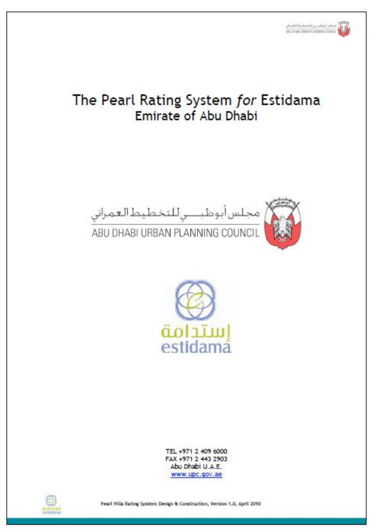


Figure 1.13: The Pearl Rating System for Estidama. Source: (http://estidama.org/)

Dubai Municipality (2010) recorded that within the implementation of the decision of the UAE Vice President, Prime Minister and Ruler of Dubai His Highness Sheikh Mohammed bin Rashid Al Maktoum, and in line with Dubai Strategic Plan 2015, and the directives for applying green building specifications on all buildings in Dubai as per the best environmentally friendly standards to keep Dubai a healthy city that follows the highest standards of sustainable development. The Green Buildings Regulations and Specifications have been published and it is expected to be mandatory for every new building permit in Dubai with the beginning of 2014.

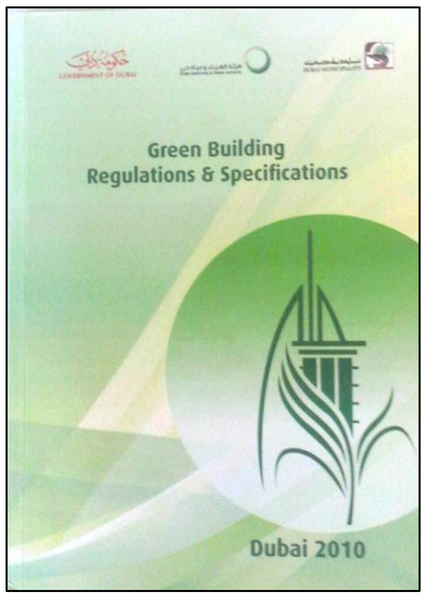


Figure 1.14: Green Buildings Regulations and Specifications of Dubai. Source: Dubai Municipality.

Chapter 2: Literature Review

2.1 <u>Introduction of Sustainable Development through Energy Consumption and Thermal Performance</u>

The following literature review discuses the sustainable development methods and techniques of effective thermal performance and energy consumption among historical buildings and vernacular architecture when the climate was dominating the people behaviors, building forms and architectural appearance in order to reach adequate level of comfort; and through building development progression overtime after employing energy tools and methods. The presented studies show different means of passive and active techniques that aim to reduce the energy consumption with maximum thermal comfort possible. The role of governmental policies and their integration with voluntary instruments has been reviewed and followed by international cases of successful sustainable developments.

2.2 <u>Thermal Comfort and Vernacular Architecture</u>

Raof (1988) described the daily thermal routine of people exists in desert climate as Yazd in Iran living in traditional mud houses with wind catchers and internal courtyards where climate was controlling the people behaviors from day to night and from summer to winter. People were choosing the room based on its climate so they were moving from room to room in order to get the best thermal comfort during the day. This kind of movement created a behavioral adjustment that has been a basic adaptive approach formed by the people of such hot desert area. In summer and starting from sleeping on the roof, people were moves to the internal courtyard looking for some shade and relative cool in the morning hours. During the hottest hours of the day, they were migrate to the basement until evening time where they came out to the courtyard and cool it slightly by throwing water on the hot surfaces which will keep cooling as night draws near. Another kind of movement occurs in winter where people move horizontally from the shaded north side to the south side rooms looking to the courtyard to be warmed by the sun. The effect of this every day transfer is that by recording climate in one or two spaces, one does not cover the diurnal scale in climate experienced by the house occupants. It has been needed to follow the residents throughout the residence, climatically, in order to record and understand the characteristics of the occupied summer climate in the houses of Yazd.

2.2.1 Wind Towers

In vernacular buildings in hot desert climate the wind catchers (Barjeel) were functioning like the present modern air conditioning systems. It doesn't have a standard design or dimensions but they creatively designed to fit the local climate conditions. In north east Iran wind catchers are small cowl ventilators on the top of domes (Figure 2.1) while in the tremendously hot climates as the Gulf region, Barjeels are exceptionally large and attached to ventilated parapet and wall to increase the air flow through the house and move as much air as possible across the living areas as shown in Figure 2.2. The traditional heavy mass structure and the wind catchers are the only practical approach for cooling in Gulf houses.

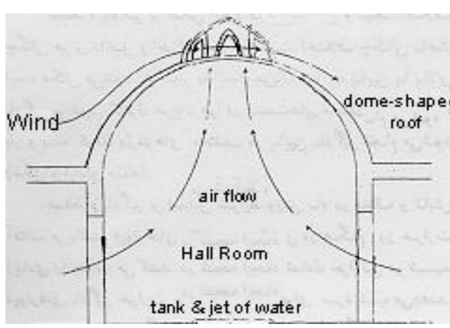


Figure 2.1: Small cowl ventilators on the top of domes in north east Iran.

Source: (cais-soas.com)

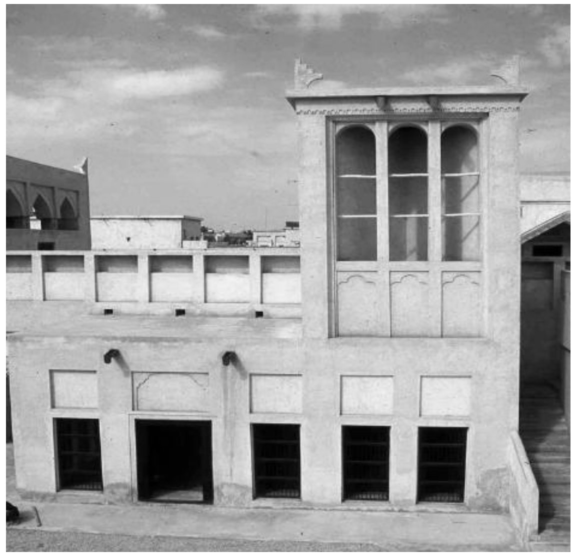


Figure 2.2: Gulf Barjeel in Bahrain Source: Raof (1988)

In the awfully hot interiors of Iraq, the wind catchers are connected by thin ducts to the cellars rooms occupied on hot afternoons in order to supply small ventilation as the air inflowing the rooms from the roof might be at temperatures of 40s C. In cooler desert metropolis of Cairo, wind catchers applied as huge roof ventilators passing air down throughout the high living halls in combination with cupolas at the apex of domes above the halls (Figure 2.3).

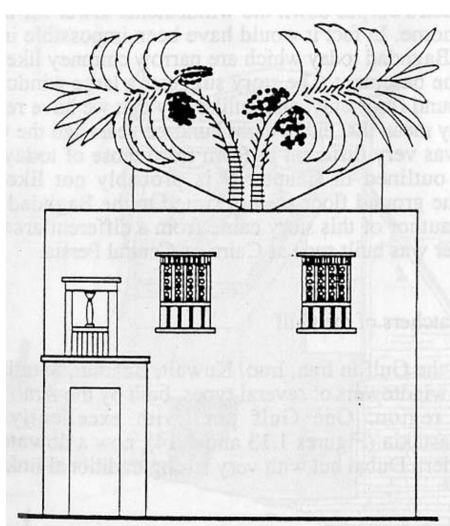


Figure 2.3: Huge roof ventilators in Cairo. Source: Raof (1988)

Traditional wind catchers are used in four ways: To supply fundamental ventilation as in Baghdad; to allow convective cooling for indoor temperatures of 25-35°C; to provide evaporative cooling at temperatures above 35°C; and to cool the building mass down by either coupling the internal air temperatures to those of the night sky or with the earth in basements and underground tunnels and streams. By basically looking at the type of local original wind catchers, with respect to the rooms served, an impression of what the local climate is in a region could be observed from the form and size of the wind catchers.

2.2.2 Courtyards

The courtyards also, are essential in hot climate regions when building forms and environmental performance comes together. Ratti et al. (2003) declared that no complete answer could be obtained for the question of ‘‘which urban forms make the best use of land?’’ stated by Martin and March’s approach where there are countless considerations that have an effect on building form even with a single direction where a significant amount of variable are closely to be conflicts.

In Ratti et al. (2003) paper - building form and environmental performance- stated that even though there is no single solution or optimum geometry of building form to make the best use of land in term of climatic contexts where there are infinite patterns of diverse climatic perspectives, urban geometries, climate variables and design objectives; there are principal urban forms that are related to particular climate types, like the courtyards and the hot climates where courtyards meets a lot of terms in hot zones like alleviating solar overload by creating a shaded spaces combined with natural cooling strategies and protection from dust or sand. Ratti et al. (2003) adding that climate considered as the fundamental determinant of architectural and urban form where in such harsh desert climate, even streets designed to be narrow and suitably oriented to prevent the hot winds. Ratti et al. (2003) have been simulated three types of building forms in term of different environmental variables. The main analysis principle is that they took the same built volume of the three types and reshape it in different forms as shown in Figure 2.4.

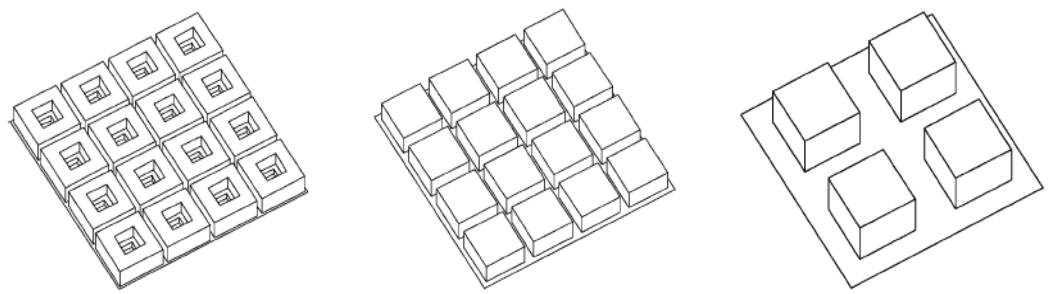


Figure 2.4: Axonometric representation on a 67.5m x 67.5 m site of the traditional Arabic courtyard (left: three floor courtyard) and of two pavilion structures. (Middle: micro-pavilion, three floors; right: pavilion, six floors). Source: Ratti et al. (2003)

The results of surface to volume ratio propose that a courtyard doesn’t operate in proper way thermally because it is exposed to heat gain during summer and heat loss during winter. Nevertheless, when the possible heat loss and heat gain throughout cold and warm periods is analyzed, correspondingly, within the complication of hot arid climate, outcomes begin to suggest reasonable conclusions. In hot arid climates night, temperatures are notably lower than day temperatures. Summer diurnal temperature changes between 15 and 19 C° (for Morocco - Marrakech during summer). The winter months contain a diurnal swing of around 3 C° and are reasonably warm and sunny. As a result, the critical months are the hot months, and extenuating the temperature extremes of this period is a necessity. The creative resolution of the courtyard house form in hot arid climate is to make use of great thermal mass to store heat by the extensive surface area throughout the day with the purpose of advantage from it through the cooler nights. By maximizing the surface to volume ratio, the courtyard operates as heat sink and consequently, limit severe temperature stress, and reradiates this heat insides and to the night sky. Therefore, the bigger surface to volume ratio of courtyards combined with its thermal mass is an advantage in the thermal performance of the building.

The results of high shadow density and daylight distribution showed that courtyards has benefited from narrow streets that create shade to people and to the horizontal surface of the streets from solar radiation. Also, the white and light colors of external parts of courtyards increase the reflected light amount in the city. Low values for sky view factor were recorded and it seems to be an advantage in hot arid climates as comfort is based extensively on temperature and radiative exchange, and low sky view factors assure a grow in direct shading and a drop in reflected radiation particularly during day hours as people are outdoors in courtyards and streets and comfort is essential.

Ratti et al. (2003) recorded that the case study confirmed that the courtyard pattern demonstrated better reaction all through the intended environmental variables (surface to volume ratio, shadow density, daylight distribution, sky view factor) than the pavilion styles in the particular environment of hot arid climates. The researchers' answer for ''what building forms make the best use of land?'' is that if 'best' is accounted for environmental context without giving up floor space for a specified plot, therefore the resolve for hot arid climates is the courtyard form. The mixture of large surface area and great thermal mass, daylight by means of the courtyard and shallow plan outline, and tight areas for shade and enhanced thermal comfort, create a framework where low energy strategies throughout the restraint of air conditioning loads are achievable. A principal feature of this is that courtyards are able to create a microclimate in the shape of an in-between environment that will be extra quite, clean and private.

2.3 Lessons to learn from Vernacular Architecture

Santamouris (2007) described vernacular architecture as an expression that is used to call local buildings which have grown in the fullness of time in one locality matching the local climate, culture and economy. There is a lot to gain knowledge from the vernacular architecture when designing the passive low energy buildings leading the 21st century design prototypes which will be gradually more designed. Simultaneously vernacular design approach cannot be easily applied in modern buildings without taking into consideration the consequences on design of such local context. What might confirm the major inspiration on the appearance of the new vernacular; is the speedily increasing price of oil and gas. Buildings that rely on central control and regular oil and gas power-driven systems will no longer be capable to provide sufficient comfort at a reasonable price for the most of the world's population. The improvement of new healthy and comfortable prototypes of exceptionally sustainable buildings is a crucial foundation in the development of future buildings.

Zhai and Previtali (2010) recorded that the rising world environment and energy crisis require an extensive transformation of building design attitudes, methods, knowledge, and construction and management procedures. Vernacular architecture is accustomed to express buildings constructed by people whose design determinations are inspired by traditional practice in their culture. Vernacular architecture differs broadly with the world's substantial range of climate, topography and culture. It includes essential unrecorded data concerning how to optimize the energy efficiency of buildings at minimal cost by means of local materials. Over time, vernacular houses have developed to act in response to confronts of climate, materials and cultural prospects in a particular location. Vernacular traditions have been gathered throughout an extensive time of experiments, miscalculation, and the creativity of local builders who have particular experience concerning their location. So that, there is importance in recognizing and using characteristics observed from vernacular architecture to modern buildings.

2.4 Vernacular and Modern Architecture in comparison

Zhai and Previtali (2010) were mainly concerned in the energy saving features of vernacular architecture. Their project creates a scheme for classifying different vernacular zones (Figure 2.5); a method by which energy performance of vernacular dwellings can be analyzed comparative to typical houses designed using the International Energy Conservation Code (IECC), and a way to recognize best constructions by vernacular architecture methods. The scheme was to look into a number of symbolic vernacular houses gathered at 22 locations in 11 most important climate zones, with an attempt to classify vernacular tendencies, technology efficiency, and shed light ahead vernacular architecture methods at possibility of being disappeared by the building industry. This project concentrate on a formation of vernacular architecture derived from climate, cultural and continent, with a purpose of setting up a controllable number of vernacular regions that can be investigated over a limited period of time.

Figure 2.5: symbolic vernacular architecture most important climate zones.
Source: Zhai and Previtali (2010)

The concept is to apply energy saving vernacular methods to modern buildings and preserve vernacular architecture patterns. Fifty nine styles of symbolic vernacular houses were recognized and chosen with a minimum of two samples in every climate zone (Table 2.1). After classifying and summarizing the principal features of vernacular architecture, an additional analysis of energy applications of these characteristics has been conducted to total building energy consumption.

Table 2.1: vernacular regions per climate zones. Source: Zhai and Previtali (2010)

Climate zone	Number of vernacular regions
Continental subarctic (CS)	10
Tundra ice cap (TIC)	6
Desert (D)	13
High altitude (HA)	11
Humid mid latitude (HML)	8
Mediterranean (M)	11
Semi desert (SD)	15
Tropical Savanna (TS)	13
West coast marine (WCM)	9
Wet equatorial (WE)	11
Humid subtropical (HS)	7
Total	**114**

The energy efficiencies of the dwellings with vernacular characteristics were compared opposed to those build up based on to the International Energy Conservation Code (IECC). Since this research carried out a significant investigation and computer energy modeling for a group of symbolic vernacular architectural methods and characteristics for several climatic regions; the simulation outcome of computer energy models propose that building codes (IECC) can offer effective directions for designing an energy efficient dwelling. These codes are improved on the strength of several earlier experiences and scientific investigations. For now, making an allowance for particular building practices observed from vernacular architecture as a methodology to improve building energy performance is a valuable attempt. For example, the simulation reveals that using vernacular materials, such as, earth walls and thatch roofs, will enhance the efficiency of houses.

In a world that is considering the fast distribution of mass produced houses and buildings designed by architects sometimes thousands of miles away from the building site, there is a risk that vernacular practices that assist describe the culture of people and a place will be forgotten. The challenge to protect these precious strategies and methods will be to envelope these technologies a way that vernacular architecture turn out to be generally acknowledged to modern designers and builders.

2.5 Sustainability in Context of Energy and Thermal Performance

Dili et al. (2011) stated that the major function of a building is to present a comfortable environment, and ruins neither the health nor performance of its users. A high-quality indoor environment is essential to the succeed building not only for the reason that it will make its users comfortable, but also because it will determine its energy consumption and therefore affect its sustainability in context of energy.

2.5.1 Passive Techniques and Energy Consumption

The task of passive means in minimizing the necessity for excessive energy solutions has become significant within present energy economic crises. Passive and natural cooling method for buildings can enhance the quality of indoor environment, present thermal comfort, and minimize energy spending in buildings. As a consequence, the investigations of natural and passive techniques for managing indoor environment have gained progressive concentration in recently. The energy reductions by means of passive and traditional means in dwellings for the intention of preserving thermal comfort in comparison with modern practices are proved in a lot of explorations. Furthermore, the tendency concerning further effective architectural designs is recessing confronts to the engineers to offer healthy low energy design solutions.

This research shows the passive methods of Kerala in India traditional architecture by evaluating different thermal comfort parameters in comparison with that of modern building. Dili et al. (2011) have carried out a research on the passive environment methods of traditional architecture of Kerala which located in the southwest coast of India, has a warm humid climate. The high sum of moisture in the atmosphere for most of the year produces thermal discomfort as there is not as much of evaporation resulting in sweating. Long exposure to these conditions can generate unpleasant consequences together with massive loss of effectiveness. A qualitative analysis about the passive ideas implemented in traditional dwellings. A quantitative study conducted throughout the year to assess thermal comfort and an investigation derived from questionnaire survey amongst the inhabitants of traditional and modern dwellings on the particular answers of thermal comfort have been recorded. Nevertheless, it is necessary to have a relative analysis of traditional dwelling in comparison with modern dwelling to prove the efficiency of passive methods. Dili et al. (2011) stated that a field examine was consequently performed in a chosen traditional and a modern residential dwelling through the majority of summer period. It was found that the diurnal difference of indoor air temperature is lower in traditional dwelling compared to the modern dwelling. Time lag between indoor and outdoor temperature in traditional dwelling is small while that in modern dwelling is about three hours. This demonstrates the high thermal insulation and temperature control of the traditional building. Mean radiant temperature of traditional dwelling is particularly lower than that of modern residence. This is because of the attendance of cold air deposition and attendance of cooler surfaces in the interiors of traditional dwelling. This, low mean radiant temperature adds a lot to the indoor thermal comfort. While air flow in traditional dwelling is managed and permanent, that in modern dwelling is few and occasional. The features of air flow in traditional dwelling preserve the air temperature at a lower level while supplying evaporative cooling to the inhabitants. It can be obtained that the traditional architecture of Kerala has an efficient passive and natural control methods that is reliable for delivering a comfortable thermal indoors in summer.

2.5.2 Integration of Passive and Active Techniques

Ochoa and Capeluto (2007) have simulated a sample office building in the city of Haifa in Palestine which have a Mediterranean climate (warm summers and mild winters). The simulations have been conducted in term of energy performance and visual comfort within three main approaches. The first approach is the outcome of integrating active systems only, the second is by passive means only and the third approach is the combination of both approaches. The first group of alternatives contains active features only using reflective radiation/glare control blinds working automatically at a fixed angle, stepped lighting controls, low emissivity glass, and artificial night ventilation motivated by electric fan.

The second group of alternatives includes passive design strategies only using fixed shading, stepped lighting controls, low emissivity glass, and natural night ventilation provided by passive methods. Regardless of the excessive relative humidity levels of Haifa, there are substantial temperature swings between day and night. Vernacular architectural buildings are built with great thermal mass. The design process applied for the second approach incorporates a significant modifies to south orientation and additional light shelves to grant an optimized passive module.

The third group of alternatives introduces the active systems together with implementation of intelligent passive design strategies with taking the benefit of orientation and the energy code system in Haifa with the intention of achieving the maximum energy efficiency grades that the code can award to an office project. Three types of light shelves were used, and the active systems determined by performance in heating, cooling, electricity for fans and lighting.

The results of applying active systems only seemed to be not reliable for constant reduction within all conditions where its range between 8% and 40%. Passive design methods achieved from 20% to 60% energy reduction, but some of these means may not be appropriate to all situations (based on south orientations only). Nevertheless, mixing active means and accurate passive design techniques creates consistent reductions between 50 and 55% generally when compared to regular conditions. An efficient intelligent building, as observed from the outcome, cannot be simply a group of smart active systems. It requires being a creation of a design procedure that integrates intelligence in all its phases, counting the early decisions, at the same time as taking benefit of technological advances.

2.6 Sustainable Energy Development

West (2001) stated that with the current greenhouse emissions and energy decrease movement and according to ecological and environmental sustainable development, the importance of integrating sustainable energy developments is now rewarding a huge concentration of building designers all over the world. The difficulties related to utilization of energy like costs, materials, greenhouse gas emissions, and renewable and non renewable reductions have motivated the consciousness and readiness for technologies that upgrade the sustainability of building development.

2.6.1 Minimizing energy Loads and Operation Cost

West (2001) project is concerned with developing the design and functionality of curtain walls in a way that it help reducing the reliance on artificial lighting and minimizing the heat loads and operation cost for both lighting and cooling through solar control and by means of forwarding the reflected sunlight inside the building through the curtain walls. Two methods of solar hood design (horizontal and vertical light pipe technology) have been tested and it was found that vertical light pipe technology with north reflectors reached a 40% enhancement in excess of the vertical light pipe technology without reflectors and it show that borrowed light does not produce heat load as same as direct incident radiation and it can effectively reduce the need of artificial lighting and additionally, it is flexible and manageable to be integrated and distributed throughout the building. Such a method has gained a significant attention around the world especially in hot climates where solar gain is tremendously strong and heat gains and loads affects the human comfort and productivity extensively (Figure 2.6).

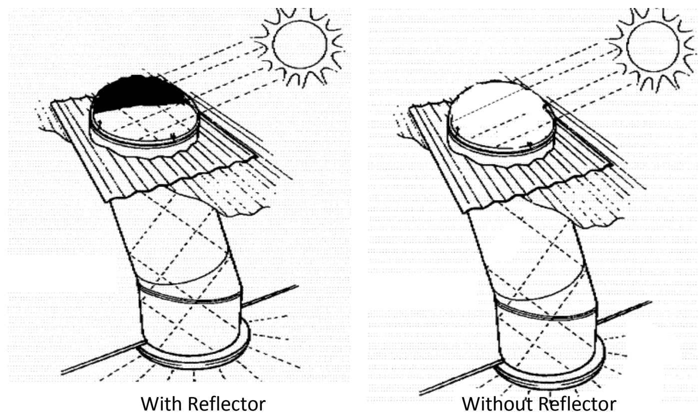


Figure 2.6: Vertical light pipe technology. Source: West (2001)

In term of ventilation, West (2001) described the stack effect as one of thermal laws where building can be rinsed out of hot air by stirring up a convection cycle and replacing hot internal air with cooler external air if available. It can be supported by wind ventilators when there is no wind or air movement and some of new building designs show thermal stacks with the support of wind driven turbines such as The Science Precinct Building at the University of New South Wales (Figure 2.7).

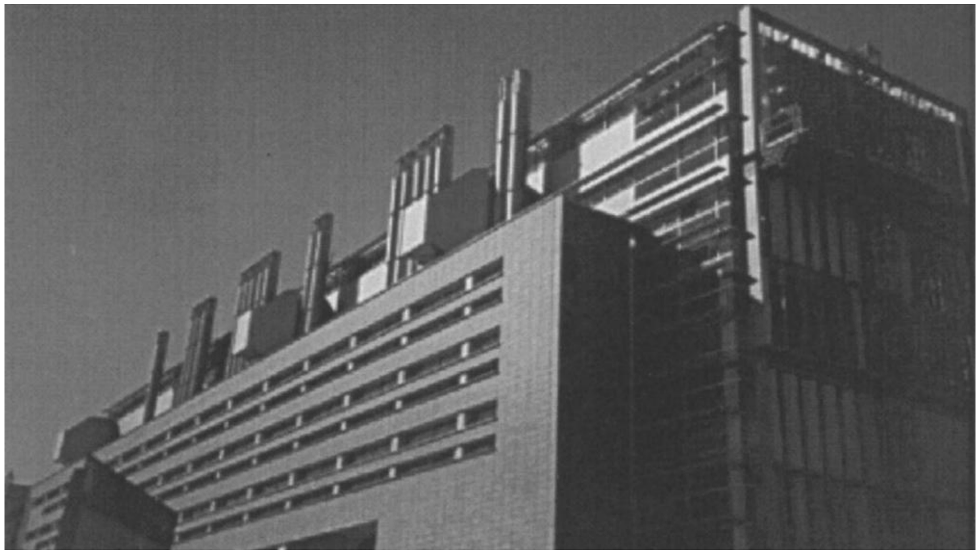


Figure 2.7: The Science Precinct Building at the University of New South Wales.
Source: West (2001)

West (2001) stated that flourishing integration of daylighting and ventilation technologies rely on cautious design and logical and scientific evaluation. According to West (2001) assessment, building integrates improved energy saving features combining daylighting and ventilation technologies could contain the following features (Figure 2.8): A north oriented facade can allows the sunlight to access the refracting panels on every floor without shading the panel beneath, at the same time as presenting adequate shading to shelter the recessed openings from direct sunlight in summer.

An arrangement of photovoltaic panels and particular wave length reflecting or refracting panels that delivers refracted or reflected daylight above an insulated ceiling and reflects it into the office space. In order to minimize the heat flow to the office space and operates consistently from the glazing to the air shafts; the floating ceiling is insulated.

By insulating and opening the floating ceiling to the air shaft, hot air is drawn off to the core generating a thermal chimney and emptying the heat from every floor. The thermal chimney is formed by creating air passages at the side of the elevators shafts which run by utilizing the stack effect where cooler denser air is drawn to the building from the open ground. To support the stack, wind turbines could be implemented on top of the air stacks.

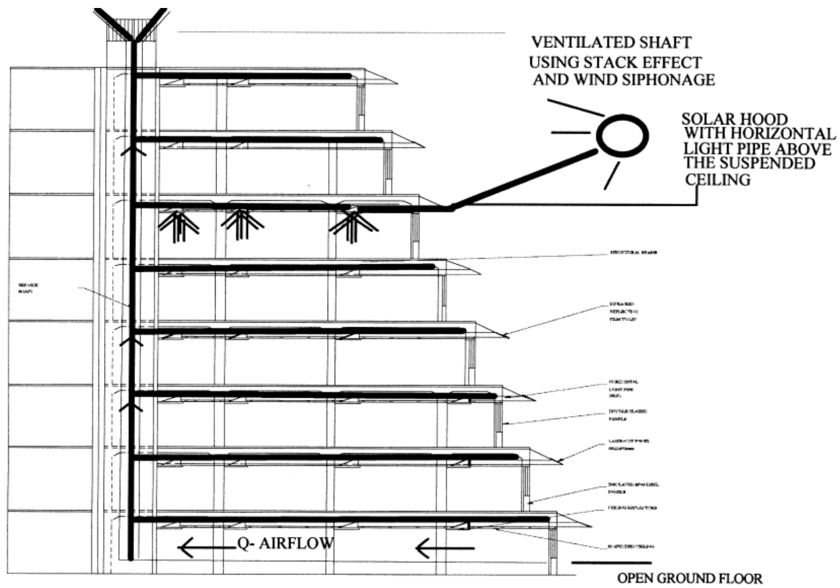


Figure 2.8: integrating energy saving features and daylighting and ventilation technologies. Source: West (2001)

The results of daylighting and ventilation design confederations of West (2001) have created a better understanding of the advantages that could possibly achieved by making use of enhanced designs and sustainable development of buildings industry where daylighting and ventilation are essential climate control modules that must be measured to enhance the sustainability conditions of the building and reduce energy consumption.

2.6.2 Building Design and Energy Consumption

Perez and Capeluto (2009) recorded that in relation to estimations of the US Department of Energy, 25% of energy operating expenses in schools can be avoided by improved design of the building and by means of using energy efficient technologies together with enhancement in operation and maintenance. The main concept of the project is to present particular design principles for classrooms that most energy conserving by simulating all building characteristics to verify their effect on thermal comfort and on total energy consumption required for heating, cooling, ventilating, and lighting during the occupied period of the year (1st of September to 30th of June). The analyzed classroom and its features were derived from an initial research of general design principles of classrooms in Palestine and obtainable references, specifications and standards.

The base-case classroom employed in this project is derived from conventional construction methods, standards, and materials. Before implementing the proposals, a sensitivity analysis has been done to assess their implication on the achieved results. The classroom size is 50 m2 (7 m X 7.14 m), with a height of 2.80 m. The preliminary design variables are: infiltration 0.75 air changes per hour (ach); heavy thermal mass in walls and roof; the outside wall is totally exposed to sun and has a medium white color (0.65); and the roof is clear (0.8) and has 30% of its area shaded by systems fitted on it. The regular opening area is 6 m2 (6 m length and 1 m height) with a single 6 mm clear glazing and internal shutters that offers a shading coefficient (SC) of 0.45. The lighting control system is on/off, with three control zones.

The simulations were conducted initially for sensitivity analysis to find out the diverse values on energy consumption of each variable by changing one and holding all the others constant. The insulation and night ventilation were evaluated to verify the suitable insulation values of walls and roof. These values were tested with several fundamental night ventilation rates.

In relation to the outcome, it is proposed that external walls should have thermal conductivity of 0.87 W/m2 _C, and roof should have of 0.52 W/m2 _C, together with 30 ach mechanical night ventilation. The infiltration was assessed by determining the air tightness of a classroom that relies on the kind, quality, and materials of openings and doors. It was found that doors and windows shouldn't allow for more than .75 to 1.0 ach within closing time. Various wall and roof sections were checked in term of the location of the insulation in the external walls and in the roof from being internal to the thermal mass or being external to the thermal mass. It was verified that no need for any limitations in term of locating the insulation layer of the external wall.

Color and exposure of the roof and walls were evaluated to show the variation of external wall's color and exposure to sun radiation and it was determined that light color roofs with 70 to 100% exposure to direct radiation demonstrate considerable decrease in the energy consumption. As the openings have an important effect on energy consumption and classroom performance, comprehensive assessment were carried out for various characteristics. It was proposed that windows in north south directions should have 12% of classroom floor area while 10% for windows in east west directions. Extreme shading can unfavorably affect the energy needed for enlightening the classroom. Results demonstrate that northern windows do not need shading at all. Different glazing types were assessed to find out the recommended glazing for windows. It was found that low emissivity glazing can reduce cooling loads and enhance daylighting. Lighting control system was evaluated within three types of lighting control features. Automated feature that turns on and off the lights in each different zone in the classroom resulted in energy savings. Perez and Capeluto (2009) stated that great operation design of a school classroom in the hot humid climate might decrease the yearly energy consumption for heating, cooling, ventilation and lighting from 180 to 80 kWh/m2. This indicates a drop of over 50% of the energy consumption as put side by side to conventional classroom in Palestine. The cooling scheme is the foremost energy consumer that has remarkable energy reduction ability. However, even in the enhanced classroom cooling energy is much higher than the energy used in all the other systems due to the climate that is hot and humid with high latent and sensible heat.

A decrease in utilizing the artificial lighting plays a role in lessening the heat loads and consequently energy lessening for cooling. The use of mechanical ventilation system in the enhanced classroom does spend some energy but it trims down the energy utilized for cooling and general reduction in energy consumption. These results highlight that applying these design suggestions in schools in the hot and humid climates will not only achieve a substantial minimization in the energy consumption, but will also provide more enjoyable and comfortable space for the children.

2.7 Regulatory and Voluntary Policy Instruments

Lee and Yik (2004) stated that in modern cities, Buildings are the major energy consumers however their expenditure could be reduced by enhancing the performance to minimize the greenhouse gas emissions and hold up the diminution of nonrenewable resources. Lee and Yik (2004) have discussed the regulatory and voluntary policy instruments correlated to building energy efficiency and they found that the implementation of policy mix concerning both regulatory and voluntary instruments are more preferable and effective. They reported that optimistic alterations to the social, economic and environmental gains in societies can be achieved through employing regulatory instruments. The strongest regulatory instruments are those that enforce restrictions, such as on energy consumption or a forbid on import, export, manufacturing and making use of particular materials such as CFC compounds.

Other regulatory methods is commanding tax over energy consume or fines for extreme expend, energy tax would assist reducing energy waste and GHG emissions by raising the cost of energy to consumers where consumer should pay an amount of tax relative to the amount of energy consumed.

Supporting voluntary methods is also one policy means. Eco-labeling systems have been used to advance improved environmental efficiency of products. such systems would encourage building owners and developers to object buildings with advanced environmental performance if it will expose improved building performance that attract future buyers and tenants of their properties. Lee and Yik (2004) proposed particular classifications that allows for more methodical study of the numerous schemes employed for improving building energy efficiency:

- Building energy codes that are regulatory necessities.

- Incentive methods, together with several methods that grant financial support or allowance that can offset the costs.

- Eco-labeling systems, counting those that take on a single threshold rating of different levels of standards.

Lee and Yik (2004) reported that more determined objectives would require to be accomplished by means of mixing regulatory and voluntary instruments. The association employs of compulsory building energy codes and voluntary systems should be a good methodology, as they can reveal the improvement costs for the assessment method; can decrease the institutional costs by permitting the regulatory tool to apply a extra willingly suitable compliance level; and can minimize the costs of completion if positive voluntary evaluation results can be regarded as verification of fulfillment with regulations.

2.8 Successful Sustainable Development Experience

Melchert (2007) recorded that since buildings industry indicates consuming of water, energy, raw material and usage of land; it is thus responsible for a huge division of environmental degradation in the world where in organization for economic development and co-operation countries around half the total carbon dioxide output is produced which can be significantly affected through designers, engineers, urban planners, and policymakers. The poor coordination between building and urban planning and the ineffective management of lands have resulted in building a sick environment in the developing world. These concerns regarding building sustainability have crashed the energy domain and sustainable building policy fields extensively and it is became a necessity to rise up and enhance the research programs together with new legislation and policy instruments.

Melchert (2007) have described the Dutch sustainable building policy recording that until the 19^{th} century the Dutch planning regulatory have eliminated the open sewers and provisioned the clean water with clear instructions regarding noise and damp reduction, enhanced natural light, ventilation, and heating in the buildings. Through the 20^{th} century and mainly in mid 1980s, the Netherlands has spent huge efforts to manage the negative building impacts on the environment and has attained an ideal approach broadly.

Melchert (2007) reporting that the first development period of the Dutch sustainable building policy was in the 1970s with disconnectivity from the existing networks of infrastructure where the first significant matters of building energy and environmental impacts in the Netherlands took place in 1973 when the Organization of Petroleum Exporting Countries (OPEC) enforced an oil restriction against Western nations, minimizing oil exports to a number of countries and forbid it totally to the United States and the Netherlands. In the early 1980s energy efficiency developed to be basic matter of the building business where number of new programs was carried out in residential, offices and other commercial and industrial buildings. In mid 1980s, a new period started with policies motivated to upgrade the environmental effectiveness of buildings in perspective of comparatively deep connections to networks where National Environmental Policy Plan which was issued in 1989 and the National Environmental Policy Plan Plus in 1990.

Melchert (2007) acknowledged that an innovative stage in the instituting the systems of sustainable building in the Netherlands therefore started to come out as the sustainable expansion moved toward the forefront setting up the concept of energy efficiency, quality, and closed loops for materials as major policy outlines.

Melchert (2007) noted down that the most outstanding case that showed how a sustainable building ought to be like was the Ecolonia residential district (Figure 2.9), presenting several environmental methods that time like solar boilers, heat buffers, sandlime brick, cellulose insulation, broken concrete granulate, high efficiency glazing, and low solvent paint. Even though environmentally appeared, the houses do not separated from the conventional image of architecture, and offer nothing exceptionally unusual in terms of design of the façade and themes of 1970s time. Similarly, society started to believe more simply the concept of living in a more sustainable means, playing a role to justifying the environmental problems in the world. Ecolonia, which had been launched by Queen Beatrix, turned out to be a sustainable building symbol in the Netherlands within the following years. The government was considerably careful in improving the policy instruments of sustainable buildings as effectively as probable, converting the application of sustainable policies into the authority of every municipality.

Figure 2.9: Ecolonia residential district. Source: Melchert (2007)

Melchert (2007) declared that a realization of strong collaboration that ought to be improved among construction industry and government came out because of the policy statement of environmental tasks in the construction industry in order to guarantee the application of sustainable instruments.

From this point, the sustainable building practices started to grow and cover all building industries and projects in order to create green resolution in construction developments. The Dutch government began to work on the equivalence of a preparation structure, and in 1996 it initiated the national sustainable building packages representing approaches projected to be implemented by the Dutch building industry in a voluntary means, and signing a new statement in the sustainable building policy in the Netherlands. The Dutch energy and environmental agency set up an energy performance standard determining the amount of energy that a building is permitted to utilize. This policy standard symbolizes an innovation in the Dutch sustainable policy and forcing several types of buildings to meet a required performance that reduces over the years. In 1995 the energy performance standard was set at 1000 MJ/m2/year, while in 2001 it was set at 850MJ/m2/year, and it is expected to be 600MJ/ m2/year in future.

Another policy instituted for existing buildings which long term agreement program is commanding the existing buildings to minimize their energy utilization 25% based on 1995 levels for duration of 10 years. An additional policy instrument produced by the government is an energy performance advisory which determines the energy spending of existing buildings by measures of a scan, to which commendations for upgrading might to be added. At the present time, the energy performance standard is associated in the building cod and managed in the building permit granting processes.

Melchert (2007) stated that one of the cases that preeminent demonstrates the present sustainable renovation of the Dutch sustainable building experience is the ABN AMRO international headquarters in Amsterdam (Figure 2.10). ABN AMRO international headquarters was graded by the American Institute of Architects (AIA) as one of the ten best global green developments in 2001. This building forms a foremost channel scheme for sustainable development. With a total floor area of 90,000 m2 to contain 3000 employees, it's not easy to afford a healthy and comfortable internal environment and at the same time preserve a great amount of energy saving. An additional confront is to articulate the uniqueness and integrity of one of the world's principal banks, that is to reveal, of an international powerful, professional, reliable, dynamic and experienced financial foundation.

Figure 2.10: Dutch sustainable building experience - the ABN AMRO international headquarters. Source: Melchert (2007)

Melchert (2007) illustrated that at the first phase of the project, the bank and the department of physical planning in Amsterdam authorized an agreement determining a number of manners of collaboration. This contract involves a best possible incorporation of the building with the neighboring environment ensuing in the integration of a public plaza in front of the building. Another agreement was as well initiated with authorities of public transportation, providing only 750 car parking for 3000 employees to support the make use of public transportation. In response, the municipality had dedicated to develop the public transportation routes.

The bank supports the use of bicycles and affords suitable amenities on the location of bicycle parking. In terms of environmental technologies, the building presents a scheme of ventilated glazing that remove the old air from the offices through a cavity in the middle of the external and internal glass panels in order to minimize the cooling energy. The suns radiation is decreased throughout these cavities with sun blinds in-between. In wintry weather, the condition is upturned and there are no heating mechanisms needed along the façade since the great thermal insulation avoids from heat losses. Furthermore, the building has a technique of climate ceiling that activates the cooling and divisions of the heating methods of the building. These are perforated aluminum panes with split linking channels for temperate and cooled water, which are in sequence s delivered to the offices as needed. The cooling is derived from the coldness of a basement aquifer and attached to night ventilation in summer. In term of heating, the compound attempts to employ waste heat to heat the basement parking, which automatically assists the rest of the building being hot. The building is associated to the district heating system that in sequence provides the fundamental requirements. Further demands are produced through a boilers scheme.

Finally, in terms of environmental management, the building integrates an energy scheme to meet the terms of the Dutch energy policy. This comprises a comprehensive observation technique recording rhythms of energy, electricity and gas consumption every 15 min in order to discover defects immediately. Moreover, the energy management system controls the consumption of energy through behavioral operations and when the offices are closed or empty from employees. According to these attempts, the building saves about 1–2 million Euros for every year owing to the minimization in energy utilization.

Melchert (2007) demonstrated that integrating the concept that combining environmental policy methods together with sustainable tools and effective resource supervision can direct to substantial environmental developments without being far from modernity and modern schemes or conflicting with the economic benefits of the building business. With the intention of performing such a representation effectively, it is essential that a meaning of association and loyalty relating the investors and government to be formed to start through conversation encouragement and elevating the grade of environmental consciousness of every related stakeholder; certifying and defining clearly the collaboration schemes of sustainable building attempts by formal documents; lastly, by efficient mixture of limitations and facilitating policies of legal, economic and voluntary instruments.

Chapter 3: Research Plan

3.1 Introduction to Research Phases

The intention of the study is to evaluate the sustainable development of local housing units in UAE within its rapid economic growth from its: Historical housing before 1970s crossing the discovery of oil, population explosion, and first appearance of governmental requirements during 1970's-1990's., The economic revolution and first edition of building regulations after 1990s, the second edition of buildings regulations in 2000 until economic crises., The expected results of new practices of Dubai Green Buildings Regulations and Specifications after 2014; and afterward the effectiveness of Estidama rating system of Abu Dhabi as a mix policy of regulatory and voluntary instrument.

3.2 Motivations

Over the last 30 years, the UAE and Dubai specifically has faced an expeditious expand in infrastructure and urbanization. This rapid development has come out with huge increase in residences, offices, factories and overall building businesses.

The rapid development and urbanization has significant effects on sustainable development of building industry in UAE especially for the local housing units which has faced sudden change, radical transform and fundamental renovate of total housing architecture and technologies.

Investigating on the sustainable development of local housing units in UAE has come out from several motivations. One of the most important reasons to explore is that the hot and humid climate of UAE which is a primary ground of changing building form and technology in order to achieve maximum and stable thermal comfort level without thinking about the impacts of this change. Another motivation is that the waving and unstable development of building technologies due to rapid increase of urbanization and economic expansion which led to escalate the energy consumption extensively and abnormally and as a result rising global environmental problems that necessitates an immediate interventions and revolutionary solutions

3.3 Aims

- To identify a clear vision of sustainable development of local housing units in UAE.

- To create an expound reference of housing development features of the country.

- To enhance the green buildings industry in UAE and encourage owners and investors to invest on sustainable projects.

- To verify that sustainable practices are capable to provide more comfortable homes with better thermal performance and lesser energy consumption which enhances the quality of life and turns down the Ecological Footprint.

- To create a reference guide of sustainable development history, practices, policies, expenses and experience for architects, consultants, contractors and investors and other concerned professionals.

3.4 Objectives

- Create a timeline of building development that shows the waving of sustainable progression overtime.

- Evaluate the local housing units of the created timeline in term of sustainable development scope of energy consumption and thermal performance.

- Evaluate the sustainable progression and built environment and find out the perfect balance of (green and comfort) for future development of the country.

- Set up a cost effective analysis of implementing green buildings practices in Dubai and Abu Dhabi in comparison with current state expenses.

3.5 Justification

Since the UAE is in immediate need for radical change to improve its sustainable future, and since there is no clear layout of its expected results within its green revolution, and given that the green revolution is totally new and up to date experience for UAE people, investors, consultants, contractors and other concerned professionals, and in view of the fact that UAE lacks of research and studies in this field; it was found that investigating on sustainable development of local housing units in UAE is essential and indispensable at present time with the purpose of living through a successful sustainable development experience worldwide.

3.6 Research Plan

The research will comprise theoretical and technical assessment of sustainable building development in UAE focusing on local housing units and villas throughout:

- Analyze the impacts of different evaluation parameters of sustainable development on each period specified in the timeline.

- Analyze and estimate the energy consumption, and the thermal performance of each period specified in the timeline.

- Compare the buildings of each timeline period to each other and evaluate the building and sustainable statement of each period.

- Predict the future outcome of the planned practices of Green Buildings Regulations and Specifications on sustainable development of local housing units in Dubai and afterward compare it to Estidama Rating System of Abu Dhabi.

Chapter 4: Methodology

4.1 Method Selection and Justification

Going back to the papers conducted in the literature review, it was found that the methodologies used are varying from paper to paper and from topic to another conducting different methods and approach to achieve particular results such as observation method, computer simulation, qualitative and quantitative analysis, survey, field observation, lab experiment, qualitative evaluation and an extensive literature review and case studies with the consideration of that all papers were concerned with sustainable development, thermal comfort, and energy conservation matters. The following discussion about pros and cons of the above mentioned methods is conducted in order to select the appropriate research method for this study.

4.1.1 Field Observation and Survey Method

Observation method allows gathering direct, actual and wide range data with large variety of interaction and operation behaviors between people and surrounding environment. It describes the behaviors as it happens in the natural environment. It helps understanding the general context of the environment and how people deal with it. The observation method is used so as to record the general behavior of particular building or people using that building or even the surrounding environment of it within certain conditions with the purpose of analyzing the recorded data in order to understand and perceive the motivations and the grounds of such performance and routines. The observation method can present exact data regarding actions and reactions of people, buildings and environment. It can help in understanding the situation and context of the observed object. It could be good method in recognizing unexpected results and it could be applied in natural environment. It is effective in primary phases of a research. On the other hand, observation method does not allocate solid grounds regarding cause and effect. observation method is expensive and time consuming since it is hard to control or repeat particular situations and could disturb the results if any actions are missed or passed without recording thus the observation method require qualified and well trained observers.

When the descriptive and observational method is not enough or too general to gather the required information then a survey method could be conducted in order to collect the exact data needed in the research area to be analyzed. Survey method is inexpensive, effective in describing features of large areas of projects or people, results can statistically organized and analyzed with flexibility of different variables. It is worth to mention that surveying method is subjected to be strong on reliability and weak on validity since it is based on accuracy of people’s answers and responds.

In the paper of Dili et al. (2011) they have used field observation method combined with qualitative and quantitative analysis and survey method. The paper introduces the passive environment control of traditional residential buildings in Kerala in India by investigating different thermal comfort factors in comparison with that of contemporary architecture. In order to detail the passive means implemented in vernacular architecture; a qualitative analysis has been conducted. And with the intention of assessing the thermal comfort; a quantitative exploration has been performed throughout the year. A questionnaire survey with the inhabitants of modern and traditional houses have been carried in order to report the thermal comfort conditions in each type of building. A field study was consequently performed in a chosen vernacular and contemporary dwellings in the period of the most unlikable summer season. After that a comparative analysis between vernacular and contemporary houses carried out in order to validate the efficiency of passive control systems.

4.1.2 Lab Experiment Method

Lab experiments are known to be easier in controlling and repeating different environmental variables as needed which enhances its reliability and flexibility. Lab experiment method allows setting variety of control variables and testing actual material properties of three dimensional scaled model within artificial environment that has same as natural settings which can be repeated, isolated and assembled. However, lab experiments contribute some disadvantages regarding ecologically validity since it is conducting in artificial environment as well as it is costly in term of material cost, physical model cost, and lab preparation, tools and equipments cost. It is important to state that the validity of lab experiment is derived from the correctness of the controlled variables while the field experiments have the benefit that results are performed in natural settings rather than in an artificial lab atmosphere and it provides real time outcome. On the other hand, field experiments are exposed to the chance of corruption since its conditions cannot be repeated or controlled with more concentration and assurance as that of experiments conducted in the lab. Furthermore, field experiments are time, efforts, and money consuming compared to lab experiments.

West (2001) have used lab experiment test method with the support of the Construction Management program at University of Technology in Sydney (UTS) which has constructed a light inlet test building to be a symbol of the curtain wall configuration that is similar to that of multi storey buildings. A variety of techniques have been assessed in order to transport mirrored light on top of the floating ceiling and afterward circulate this light all over the building. The Construction Management program and Mechanical Engineering program at UTS have additionally formed a test rig to evaluate wind driven ventilators which resulted in calculating the natural ventilation rates.

4.1.3 Computer Simulation Method

Computer simulation method was found to be a valid method in the area of energy performance and sustainable built environment since it does not require a real materials or human resources and it offers an actual results of the selected design before put it into practice in the real environment which helps avoiding errors and mistakes without consuming a lot of time and money for testing out. This methodology provides wide scale testing with wide range of combinations, computations, variations, and variables in a shorter period of time and with the minimum possible cost. The environmental parameters in the computer simulation method are able to be more controlled and separately operated, modified and repeated. It is important to clarify that the accuracy and logically results of computer simulations depends on the level of correctness and the scale of details of the input data. Another thing to be considered when choosing the computer simulation method is the reliability and validity of the software and its flexibility to use.

In Ratti et al.(2003) paper a computer simulation method and comparative analysis have been conducted to find out which urban form make the best use of land in hot climates. Ratti et al. (2003) have built three computerized models for different urban forms with the same built up volume. The computer simulations were performed using Matlab image processing toolbox which assessed finding out the energy consumption within several variables, solar radiation and exposure, wind and effect of form on pollutant movement. After that they applied mathematical method to obtain accurate expectations concerning their conclusion. Similar to Ratti et al. (2003) paper, Zhai and Previtali (2010) paper was conducted computer simulation also as the main method for their investigation. This investigation brought up a method to classify different vernacular zones and assess energy efficiency of early historical dwellings in addition to categorizing most favorable buildings employing vernacular practices. The paper performed a substantial computer energy modeling using Building energy simulation and optimization tool (BEopt) for a quantity of symbolic early vernacular architectural features experimented for diverse climatic zones. The vernacular assessment themes were evaluated in contradiction of those built based on the International Energy Conservation Code and those produced by the optimization software.

Another time in the direction of computer simulation, Ochoa and Capeluto (2007) investigation has utilized computerized energy modeling methods as well where a base case model of office space was created with three different varsities of environmental technologies in order to assess the energy efficiency and visual comfort. The first division was the outcome of the integration of active technologies only, the second division was directed through intelligent passive design strategies, and the third division was the mixture of both approaches. Ochoa and Capeluto (2007) reported that the computer simulation using EnergyPlus software has helped in reducing the time required for such investigation in other evaluating methods as well as determining the significant points that needs a detailed analysis, and evaluate the simulated technologies in term of electricity used for lights and fans, heating, and cooling.

Perez and Capeluto (2009) paper had conducted comprehensive computer simulation methods using three computer softwares: the dynamic simulation model ENERGY was used for energy efficiency evaluation, SHADING software was used for hourly geometric insulation coefficient (GIC) of the windows, and ‘RADIANCE software was used to calculate the daylight scattering in the classroom for every window size, location, and geometry. The main concept of the simulation method was to modify the specified values separately to discover the value that reduces energy spending and at the same time as maintaining thermal and visual comfort of the space. After that, a comparative analysis were conducted to find out which variables have best effect on the energy utilization and thermal comfort and how their total influence relies on the arrangement of application of every development.

4.1.4 Literature Review and Case Studies Method

Literature review method can offer great volume of strong and inexpensive information. It forms a solid foundation of future work that based on better understanding and empirical basis for efficiency. Literature review and case studies research methodology can offer well knowledge of complicated issues or subjects through elder investigations. It could be a good exploratory and investigative method to generate new findings; and constructive method to solve some problems; or even confirmatory method to evaluate particular findings and observed records. However, case studies cannot be controlled as lab experiments and computer simulations. Case studies accuracy is based on similar findings and outcomes thus it is usually not enough to relay on one case. Most case studies investigations employ several cases to prove particular finding.

Roaf (1988) paper has used the case study and observation method to describe the living routines of people exist in hot climates as those of Yazd in Iran. She has evaluated their level of thermal comfort based on weather data characteristics of Yazd together with the recording of the people movement during day and night, and summer and winter. After that she conducted a comparative analysis between different design configurations of wind towers in several types of hot climates to show how building form and people behavior changes from region to region in order to achieve certain thermal comfort level.

Lee and Yik (2004) paper illustrates a qualitative evaluation and an extensive literature review concerning regulatory and voluntary policy instruments regarding building energy performance and efficiency. And Melchert (2007) paper investigates the establishment of environmental policy instruments in the Dutch building division and the ability of the present example to be applied in developing countries. Primary, it evaluates the conversion of sustainable customs in the Netherlands from the 1970s until present time, investigating how these were initially rooted in a discussion of de modernization which tried to develop the environmental implementation of buildings by approaches of self sufficient tools, while these days they implement a structure of ecological modernization with integration schemes looking to enhance the environmental efficiency of buildings by more effective tools.

The paper afterward demonstrates how the present Dutch sustainable building foundation has in that way directed to reach a practical and broadly acknowledged motivation that can work to adjust the ecological reformation of building industry in developing countries.

4.2 Method Selection Conclusion

Different methods have been used to assess the sustainable development, energy consumption and thermal performance overtime. Most papers have relied on more than one method to attain reliable outcomes while other papers have employed classical methods of literature reviews and observations in order to explain and clarify particular conditions. It was found that the advantages and disadvantages of the discussed methods is based on particular aspects such as time consuming, money spending, instruments availability, output accuracy, controllable variables and environment, changeable factors, validity and reliability.

4.3 Selected Method

Based on the above discussion about different research methodologies used in this research area, it was found that computer simulation method is the most appropriate method to handle the objectives of the research field due to its ability of saving time and money, using plenty of materials properties, presenting annual climate data, providing wide range of changeable parameters and giving valid dependable and reliable results.

Other supportive methods have been selected beside the main method of computer simulation which are database survey and field observation method in order to gather particular specifications since the study is conducted on different properties and characteristics of building development over long timeline period and each period has its identifiable specifications.

4.4 Selected Computer Simulation Software

Crawley et al, (2008) have performed a comparative study of most important building energy programs including: BLAST, BSim, DeST, DOE-2.1E, ECOTECT, Ener-Win, Energy Express, Energy-10, EnergyPlus, eQUEST, ESP-r, IDA ICE, IES/VES, HAP, HEED, PowerDomus, SUNREL, Tas, TRACE and TRNSYS. The paper has compared the above programs in term of: General Modeling Features, Zone Loads, Building Envelope and Daylighting, Infiltration, Ventilation and Multizone Airflow, Renewable Energy Systems, Electrical Systems and Equipment, HVAC Systems, HVAC Equipment, Environmental Emissions, Economic Evaluation, Climate Data Availability, Results Reporting, Validation, and User Interface, Links to Other Programs, and Availability. The following tables illustrate the general modeling features and thermal performance estimations of each software.

Table 4.1: Zone loads and general modeling features of major building simulation softwares. Crawley et al, (2008)

	BLAST	BSim	DeST	DOE-2.1E	ECOTECT	Ener-Win	Energy Express	Energy-10	EnergyPlus	eQUEST	ESP-r	IDA ICE	IES VE	HAP	HEED	PowerDomus	SUNREL	Tas	TRACE	TRNSYS
Interior surface convection																				
• Dependent on temperature	X	X					P		X		X	X	X		X	X	X	X		X
• Dependent on air flow	X						X		P		X		X		X			X		E
• Dependent on surface heat coefficient from CFD									E		E		X							
• User-defined coefficients (constants, equations or correlations)		X	X	X	X				X		E	R	X		X	X	X	X		X
Internal thermal mass	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Automatic design day calculations for sizing																				
• Dry bulb temperature	X	X	X	X	X	X	X	X	X	X		X	X	X	X	P		X	X	
• Dew point temperature or relative humidity			X	X		X	X		X	X		X	X	X				X	X	
• User-specified minimum and maximum			X	X		X	X		X	X		X	X	X	X			X	X	
• User-specified steady-state, steady-periodic or fully dynamic design conditions			X									X	X	X				X	X	X

X feature or capability available and in common use; P feature or capability partially implemented; O optional feature or capability; R optional feature or capability for research use; E feature or capability requires domain expertise; I feature or capability with difficult to obtain input.

Table 4.2: Building envelope, daylighting, solar radiation and thermal performance estimations. Crawley et al, (2008)

	BLAST	BSim	DeST	DOE-2.1E	ECOTECT	Ener-Win	Energy Express	Energy-10	EnergyPlus	eQUEST	ESP-r	IDA ICE	IES VE〉	HAP	HEED	PowerDomus	SUNREL	Tas	TRACE	TRNSYS
Outside surface convection algorithm																				
• BLAST/TARP	X								X										X	
• DOE-2				X					X	X									X	
• MoWiTT									X		X								X	
• ASHRAE simple	X					X		X	X				X		X			X	X	
• Ito, Kimura, and Oka correlation											X	X								
• User-selectable			X						X		X	X	X			X		X	X	X
Inside radiation view factors		X	X						X		X	X	X				P	X		
Radiation-to-air component separate from detailed convection (exterior)		X	X						X	X	X	X	X				X	X	P	X
Solar gain and daylighting calculations account for inter-reflections from external building components and other buildings		P			X				X		X		X			P				X

X feature or capability available and in common use; P feature or capability partially implemented; O optional feature or capability; R optional feature or capability for research use; E feature or capability requires domain expertise; I feature or capability with difficult to obtain input.

From the previous comparisons of Table 3.1 and Table 3.2 it was found that the software of Integrated Environmental Solutions-Virtual Environment (IES-VE) is the best software to be selected in the area of the sustainable development of local housing units in UAE mostly owing to its reliability, validity and flexibility to use. It can carry out energy performance snaps to evaluate the results of the conducted design; it can measure different passive and active technologies; it can estimate the effects of daylight and solar radiation; it can analyze the building loads and results of conservation schemes; and it can evaluate the compatibility with a series of international regulations and voluntary policy instruments. IES offers an extensive series of diverse analysis choices and potentials intended to provide response immediately and professionally at the appropriate point with comprehensive simulations at hourly or less as required. Crawley et al, (2008) reported that IES-VE contains:

- Model IT- geometry creation and editing.
- Apache Calc- loads- analysis.
- Apache Sim- thermal.

- Macro flo- natural ventilations.
- Apache HVAC- component- based HVAC.
- Sun cast- Shading visualization and analysis.
- Micro flo- 3D computational fluid dynamics.
- Flucs pro/ radiance- lighting design.
- DEFT- model optimization.
- Life cycle- life- cycle energy and cost analysis.
- Simulex- building evacuation.

4.5 Selected Software Validation

The IES-VE software has been validated and certified from several international institutions such as the Department of Communities and Local Government (CLG), Energy Balance Evaluation (EBE) and American Institute of Architecture (AIA). The official website of IES-VE incorporate more details about its validity (www.iesve.com). Additionally, the computerized model has been reviewed by IES technical team and other software professionals throughout different project phases. It is worth to mention that international case studies have been simulated and evaluated in term of energy consumption and thermal performance by IES-VE software such as the Grand Mosque of Abu Dhabi (Figure 3.1) which has been simulated in term of HVAC design and optimization, thermal comfort analysis, occupant evacuation and smoke extract performance, dynamic thermal, solar shading, bulk air flow, CFD and evacuation simulation.

Figure 4.1: IES-VE model (left side) and simulations (right side) of Grand Mosque of Abu Dhabi. Source: (www.iesve.com)

Other international cases that have been simulated by IES-VE software like: Heathrow Airport Terminal 5 Concourse in London (Figure 3.2), Royal Bank of Scotland World HQ in Edinburgh (Figure 3.3), Royal London Hospital (Figure 3.4) and Worcester College of Oxford University in London (Figure 3.5).

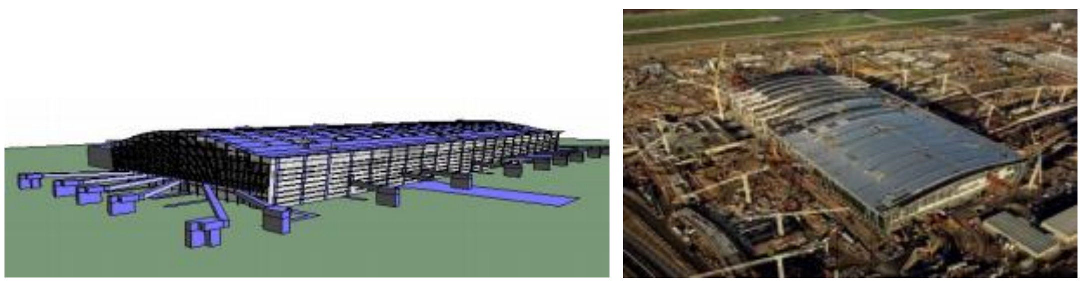


Figure 4.2: IES-VE model (left side) and constructions (right side) of Heathrow Airport Terminal 5 Concourse in London. Source: (www.iesve.com)

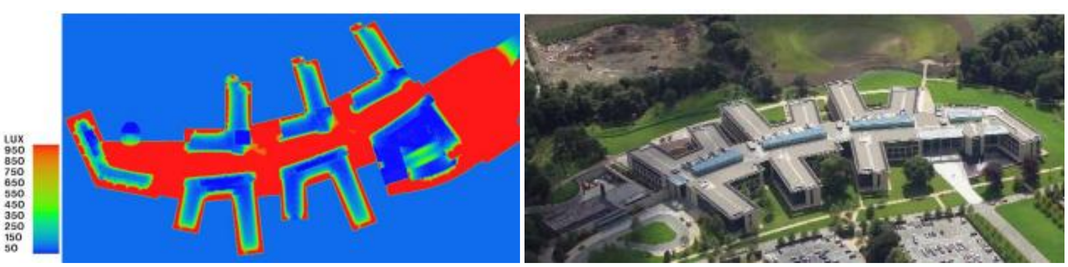


Figure 4.3: IES-VE simulation (left side) and building (right side) Royal Bank of Scotland World HQ in Edinburgh. Source: (www.iesve.com)

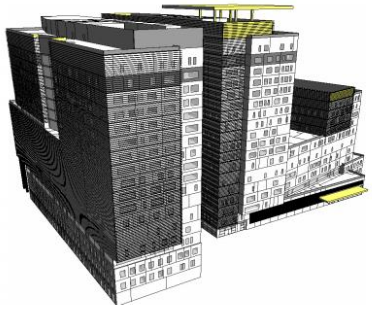
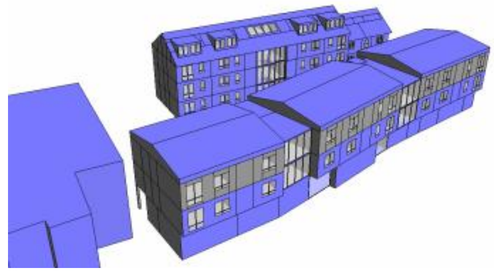
 

Figure 4.4: IES-VE model of Royal London Hospital (left side). Source: (www.iesve.com).

Figure 4.5: IES-VE model of Worcester College of Oxford University in London (right side). Source: (www.iesve.com)

4.6 Analysis Procedure

- Set up a Building impacts analysis of local housing units within timeline periods in term of energy consumption and thermal performance.

- Set up an energy cost analysis of sustainable development timeline based on current market values and compare the cost difference among the current state, Dubai future after applying green buildings regulations and Estidama rating system of Abu Dhabi.

- Set up a material cost analysis of the changed or modified materials between current statement, future statement after applying Dubai green regulations and subsequently the statement of Abu Dhabi Estidama rating system.

- Conduct a simple payback analyses of recent sustainable development timeline based on energy cost analysis and modified material cost analysis.

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Chapter 5: Housing Units Selection

5.1 Introduction of Housing Units Selection

A detailed historical review has been conducted in order to create the periods of sustainable development timeline based on historical data and breaking times that have a significant change in architectural and sustainable appearance of the city as discussed earlier in the introduction section. The local housing units have been selected after creating the sustainable development timeline.

5.2 Sustainable Development Timeline

It was found that the local housing units have faced remarkable changes from living in traditional houses before 1970's to start living in houses with new forms, materials and technologies since new concrete materials has arrived and new electricity consuming cooling systems became available. After 1990's the local housing units has faced new architectural appearance due to increased population and arriving new international styles of architecture as well as the first edition of rules and regulations that has organized and controlled the building forms.

After the year 2000 the second edition of rules and regulations has been established in order to be more compatible with life style requirements. At the same time the first edition of thermal specifications has been instituted which has a fundamental effect on overall building industry since that time until current statement.

In the year 2010 the first edition of Dubai green buildings regulations and specifications has produced with the intention of make it a mandatory policy instrument in 2014 while Abu Dhabi has established the new Pearl Rating

System for Estidama which is a mix policy of regulatory and voluntary instrument. Table 4.1 demonstrate the remarkable periods of building development in Dubai and Abu Dhabi which will be the reference guide of selecting typical housing unit of each period in the created timeline of sustainable development.

Table 5.1: Sustainable Development Timeline of Local Housing Units in UAE

Before 1970's	1970's – 1990's	1990's - 2000	2000 - 2010	After 2014 Dubai Green Regulations	Abu Dhabi Estidama Rating System
Historical buildings	**Oil, population explosion, and first appearance of governmental commands (forbidding the integration of internal courtyards)**	**Economic revolution and first edition of building rules and regulations**	**Second edition of building rules and regulations and first edition of thermal insulation specifications**	**Green Building Revolution**	**Green Building Revolution**

5.3 Selection and Evaluation Parameters

The selection and evaluation parameters of local housing units have been determined in term of major impacts on energy consumption and thermal performance of buildings and sustainable development in UAE (Table 4.2). The factors were obtained from literature review, Dubai building rules and regulations, and Estidama Rating System of Abu Dhabi.

Table 5.2: Selection and evaluation parameters of local housing units in UAE.

1	**Social Factors**	**Persons/ m2**
2	**Building Concept**	**Building features.**
		Building mass.
		Opening size.
		Building height
3	**Building Material**	**Structural type**
		Building envelope and Thermal mass
4	**Building Technology**	**Lighting**
		Shading
		Glazing type
5	**Building Impact**	**Energy consumption**
		Thermal performance

5.4 Selected Units

A symposium about the conservation of historical buildings in Dubai have been performed from 21st to 23rd of February 2011 sponsored by the Heritage Architecture Department in Dubai Municipality and chaired by the head of the department Eng. Rashad Bokhash (www.dubaihistoric.ae).

The symposium has offered great information about the history of traditional buildings in Dubai and its transformation during ages especially after 1970's.

In order to select the typical case housing units of each period in the timeline, a field observation and database survey using Dubai Municipality records, archives and permits system has been conducted on 100 villas for each period between 1970's and 2010 with the purpose of selecting the typical cases of each period and determining the basic characteristics of design features, material properties and technologies.

5.4.1 Historical Unit

The traditional house of Dar Al Nadwa in Al Bastakiya historical district as shown in Figure 4.1 was chosen to be simulated and analyzed since it is symbolizes the typical traditional house of that era and considered as one of the most important historical buildings in Dubai.

Figure 5.1: The traditional house of Dar Al Nadwa in Al Bastakiya historical district.
Source: (www.dubaihistoric.ae)

5.4.2 1970's – 1990's Unit

It was found that the arcade design element was the dominant feature of the houses built in early 1970's until late 1980's since 86% of houses at that time contain this feature. Figure 4.2 and Figure 4.3 illustrate the arcade feature design that has been obtained from Dubai Municipality archives system and Figure 4.4 shows the arcade feature design that has been recorded by field observation method.

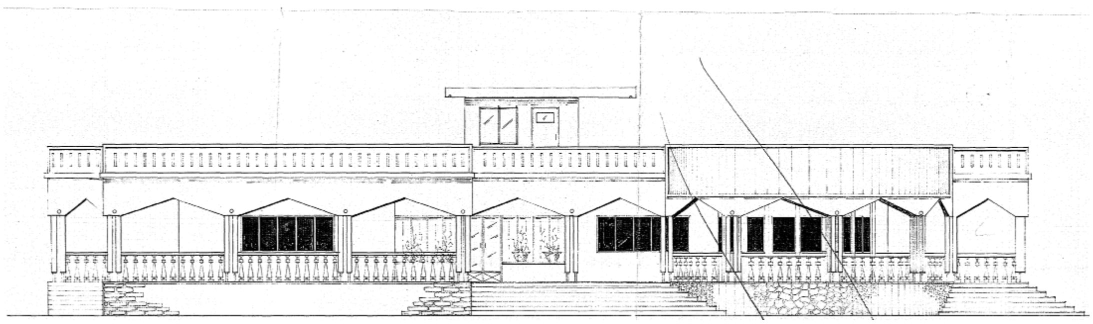

Figure 5.2: Arcade design element for ground floor house of 1970's- 1990's period.

Source: Dubai Municipality

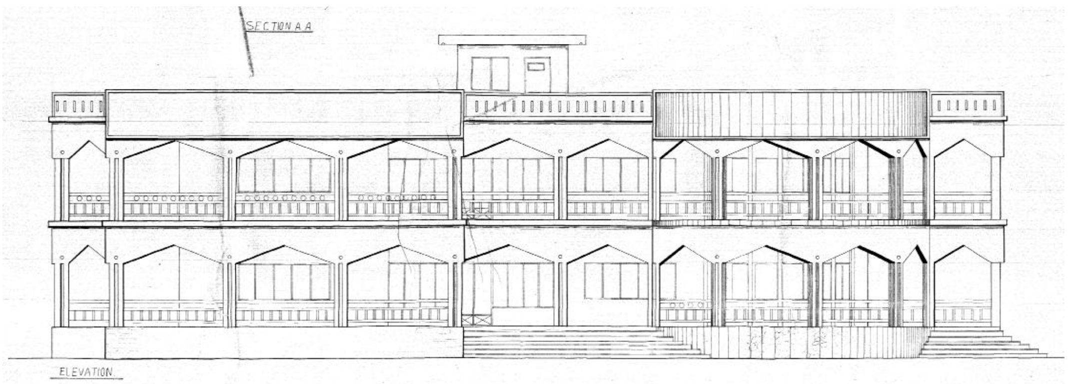

Figure 5.3: Arcade design element for two floors house of 1970's- 1990's period.

Source: Dubai Municipality

Figure 5.4: Different houses shows arcade design element of 1970's- 1990's period

5.4.3 <u>1990's – 2000's Unit</u>

After the beginning of 1990's, a 72% of houses found to have the pitched roof design combined with outer brickwork finishing.

5.4.4 <u>2000's – 2010's Units</u>

After the year 2000 the design forms started to expand, thus two cases were selected to be simulated in this period as it was found that 38% of the houses are post-modern designed (Figure 4.5), 41% are re-traditional designed (Figure 4.6), and 19% comprise other forms and designs.

Figure 5.5: post-modern designed housing units of 2000 – 2010 (left side). Source: (http://dubaipropertiesgroup.ae)

Figure 5.6: re-traditional designed housing units of 2000 – 2010 (right side). Source: (http://dubaipropertiesgroup.ae)

5.5.5 <u>2010's – 2014's Units</u>

The future cases are enclose the same design of the current period 2000 – 2010 (Figure 4.5) and (Figure 4.6) but with particular modification on its construction materials, sustainable technologies and specifications that based on green building regulations and specifications which will be mandatory policies after 2014.

Table 5.3 demonstrates the general specifications of each local housing unit based on selection and evaluation parameters.

Table 5.3: general specifications of each local housing unit based on selection and evaluation parameters

Sustainable Development Timeline	Building Features	Persons / m2	U-Value (W/m²·K)	Building Description	Structural type.	Building mass	Building envelope.	Openings size and distribution	Glazing type	Shading	Cooling	Lighting	Set back
Before 1970	traditional	0.06	1.6	barjeel wind tower & internal courtyard surrounded with shaded corridors.	coral stone, mud, straw, palm timber	.6 m thick walls	mud	no or very small windows to outside & large windows overlooking to the internal courtyard 1x 2.5 m	no glazing - onlu wooden shutters	tree inside the courtyard - shaded corridors around the courtyard	natural ventilation only	natural light, tungsten lamps and lantern	no set back limits - very narrow sikkas
1970-1990	arcade façade	0.03	2.7	square shape with partial projections and arcades surrounding the outer façade of the house.	heavyweight concrete block - gypsum plastering	.23 m thick walls without insulation layer	gypsum plastering	medium size external windows only 1x1 m	single layer of Clear float glass panel 6mm	concrete projections above external windows - covered arcade around the house	HVAC window unite only	natural light, & tungsten lamps	no setback limits - narrow sikkas - narrow streets
1990-2000 (First Edition Regulations)	brickwork façade and pitched roof	0.02	1.9	pitched roof design with brick blocks covering the outer façade of the house	medium concrete block - brick work - gypsum plastering	.315 m thick walls without insulation layer	brick work	external windows only - 10 % of room area	double layer of clear float glass panels 6mm with air cavity 12 mm in between	pitched roof projection	natural ventilation - window unite only	natural light - florescent lighting	1.5 m setback - wide sikkas and streets
2000-2010 (Second Edition Regulations with Thermal Insulation Specifications)	re-traditional	0.02	1.7	barjeel (decorative only) with terrace in front elevation shaded by wooden pergola.	lightweight concrete block - gypsum plastering - glass-fiber insulating	.22 thick walls with insulation layer. Max. U-value= 0.57 W/m²·K	gypsum plastering	external windows only - 10 % of room area	double layer of Pilkington k glassand clear float glasswith air cavity in between and maximum U-value of 3.28 W/m²·K	wooden pergola covers the terrace - timber blinds and louvers	natural ventilation - HVAC split unit	natural light - florescent lighting	3 m minimum setback wide sikkas and streets
	post-modern			simple plain design, flat roofs with excessive use of glass and sensible use of decorative features.			gypsum plastering - glass cladding	external windows only - floor to ceiling and clearstory windows.		some shading elements and shaded terrace			
After 2014 (Dubai Green Regulations)	re-traditional	0.02	1.5	barjeel (decorative only) with terrace in front elevation shaded by wooden pergola.	lightweight concrete block - gypsum plastering - glass-fiber insulating	.22 thick walls with insulation layer. Max. U-value= 0.57 W/m²·K	gypsum plastering	50% of total glazed area of the building must have a north orientation	double layer of Pilkington k glass with air cavity in between and maximum U-value of 2.1 W/m²·K	wooden pergola covers the terrace - timber blinds and louvers in east west sides	natural ventilation - HVAC split unit	natural light - florescent lighting	3 m minimum setback wide sikkas and streets
	post-modern			simple plain design, flat roofs with excessive use of glass and sensible use of decorative features.			gypsum plastering - glass cladding			shaded terrace and vertical louvers in east west sides		natural light - florescent lighting	
Abu Dhabi Estidama (Pearl Rating System)	re-traditionalism	0.02	1.1	barjeel (decorative only) with terrace in front elevation shaded by wooden pergola.	lightweight concrete block - gypsum plastering - glass-fiber insulating	.3 thick walls with insulation layer. U-value= 0.29 W/m²·K	gypsum plastering	15% of room area with 25% increase in openable window areas	double layer of Pilkington k glass with air cavity in between and maximum U-value of 1.9 W/m²·K	wooden pergola covers the terrace - timber blinds and louvers in east west sides	natural ventilation - HVAC split unit	natural light - florescent lighting	3 m minimum setback wide sikkas and streets
	post-modern			simple plain design, flat roofs with excessive use of glass and sensible use of decorative features.			gypsum plastering - glass cladding			shaded terrace and vertical louvers in east west sides		natural light - florescent lighting	

Chapter 6: Simulation Models

6.1 Computer Simulation Models

After selecting the proto type housing units for each timeline period the computer simulation models will be created in order to conduct the simulations and analyze them. The creation of simulation models is divided into the following steps:

- Create a climatic model for Dubai based on weather data file.
- Create symbolic models for local housing units in each timeline period.
- Create a range of variables and different values based on evaluation and selection parameters in order to test the created models in term of different configurations of sustainable development.
- Conduct the simulation of the computerized models and analyze the results.

6.2 Weather Data Profile

The weather data file was conducted from Dubai International Airport and it includes detailed annual information. The simulation data comprises all records needed to run the simulations properly including latitude, longitude, altitude, time zone, ground reflectance, wind exposure, heating and cooling loads as illustrated in Table 6.1.

Table 6.1: Weather Data Profile. Source (Dubai International Airport)

Location & Site Data	
• Location	Dubai/Int'l Airport
Region	UAE
Latitude	25.25 N
Longitude	55.33 E
Altitude	5.0m
Time zone **Hours ahead of GMT**	4.0 hours
• Site Data	
Ground reflectance	0.2
Terrain type	Suburbs
Wind exposure **(ASHRAE Heating Loads)**	Normal
Weather Simulation Data	
ApacheSim File	DubaiIWEC.fwt
• Design Weather Data Source & Statistics	
Source of Design Weather	ASHRAE design weather database
ASHRAE weather location	Dubai/Int'l Airport, UAE
Monthly percentile for Heating Loads design weather	99.60%
Monthly percentile for Cooling Loads design weather	0.40%
• Heating Loads Weather Data	
Outdoor Winter Design Temperature	12.3°C
• Cooling Loads Weather Data	
Max. Outside Dry-Bulb	44.2°C
Max. Outside Wet-Bulb	24.2°C

6.3 Local Housing Units Description

It is important to state that the materials used in all cases are obtained from the records of Dubai Municipality, default material specifications of IES-VE software, Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05) and ASHRAE Handbook - Fundamentals (I-P Edition).

Another thing to be mentioned is that the total built up areas of all cases are determined on the basis of the total built up area of the traditional house in order to simulate all cases with the same conditions and conduct a comparable analysis between each other properly. Furthermore, all cases are simulated based on north orientation since it is the best orientation that determined and verified by Dubai green buildings regulations and specifications.

The following section demonstrates the general description of each case unit.

6.3.1 Historical Unit

The traditional house of Dar Al Nadwa is 20m x 20m with total built up area of 500 m^2 including two floors, each floor is 4m high and above the roof are two wind towers (Barjeels) one of them located in the main façade of the house starting after the ground floor directly and reaching around 8 meters height. The second Barjeel is located in the west side façade starting after the first floor and reaching 4 meters height. The house is mainly formed of internal courtyard that includes a central tree used for shading needs and surrounded by shaded corridors. All rooms are opened to the internal courtyard with very few and small windows directed to the external sides for privacy and religious reasons except the front rooms which served for guests use and men gathering area (Majlis). It is worth to mention that there was no or very small set back between the houses creating narrow and shaded routs for pedestrian.

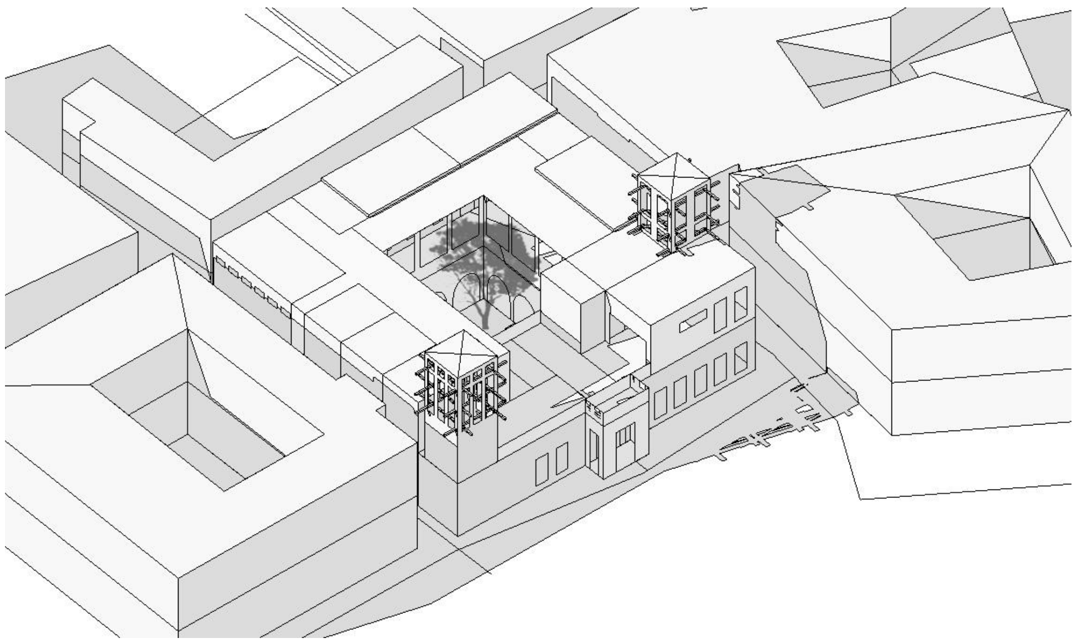

Figure 6.1: Traditional Unit of IES-VE model

In Dar Al Nadwa house (Figure 6.1), the ground floor is made of four simple layers including the sand layer of the ground which covered with mix of gravels and clay and then enclosed by carpets made of palm leafs (Haseer) with a total U-value of 0.195 W/m²K. The walls are made mainly of coral stone, gypsum and mud with a total thickness of 60 cm and a U-value of 0.299 W/m²K. The internal floor and the external roof were made of traditional timber imported from India called Chandal timber and covered by palm leaf carpet (Haseer) and then roofed by gypsum and clay with a total U-value of 0.273 W/m²K. The windows were covered and framed by local timber only without glass panels and the doors are made of local timber also. Table 6.2 is shows the general specifications of construction materials of the traditional unit.

Table 6.2: general specifications of construction materials of the traditional model

	Material Description	U-value ASHRAE (W/m²·K)
Roof	Chandal, Palm Leaf Carpet, Gypsum, Clay	0.273
Internal floor	Chandal, Palm Leaf Carpet, Gypsum, Clay	0. 268
Wall	Mud; Gypsum; Coralston	0.299
Ground Floor	Palm Leaf Carpet; Clay; Gravel; Sand	1.564
Door	Local Wood	2.296
Glazing	Wooden shutters only	5.602
Total U-value		1.62

6.3.2 1970's – 1990's Unit

The general design features and materials of houses built in early 1970's until late 1980's were collected from the building permit archives in Dubai Municipality together with site visits observation and information recorded from the conservation of historical buildings symposium.

The design features of this era was totally changed compared to the features of traditional houses due to the new materials and construction technologies arrived the city and the government restrictions that prevents the concept of internal courtyards which led to a new appearance of housing architecture. It is important to mention that there were no rules and regulations arranging the building industry and regulating its specifications as well as there was no building permitting procedures or even inspections until the early 1990's. A prototype case of a typical house of that period has been modeled with a total built up area of 500 m² (Figure 6.2). It is L shape with partial projections and arcades surrounding the outer façade of the house.

Figure 6.2: 1970's – 1990's Unit of IES-VE model

The ground floor is consist of synthetic carpet, cast concrete as the main structure material and covered by tiles with a total U-value 1.564 W/m²K. The walls are 20cm thick made of concrete blocks covered by gypsum plastering from internal and external sides without any insulation material and with a total U-value of 2.725 W/m²K. The floor consists of dens cast concrete and covered by synthetic carpet with a total U-value 2.117 W/m²K. The roof is made of cast concrete covered with bitumen layer and stone chippings with a total U-value of 2.821 W/m²K. The doors are made of 20% moist pine timber with a U-value of 2.161 W/m²K. The windows are made of clear float glass with a total shading coefficient 1.046 and total U-value 5.121 W/m²K. Table 6.3 is shows the general specifications of construction materials of 1970's – 1990's Unit.

Table 6.3: general specifications of construction materials of 1970's – 1990's model

	Description	U-value ASHRAE (W/m²·K)	Total shading coefficient (glazed only)
Roof	Chipping-Asphalt-Concrete	2.821	
Internal floor	Carpet-Concrete	2.117	
Wall	Gypsum-Concrete-Gypsum	2.725	
Ground Floor	Tiles-Concrete-Carpet	1.564	
Door	wooden door	2.161	
Glazing	Clear Float	5.121	1.046
total		2.743	

6.3.3 <u>1990's – 2000's Unit</u>

In the beginning of 1990's the design approach of single housing unites started to change and transform since Dubai started to catch an international attention together with the economic revolution which attracted people and businesses to enlarge and expand the building industry all over the city. The western design of the houses started to appear with new materials and building technologies together with the first addition of building rules and regulations in order to control the huge transformation and economic revolution of the city from being local town to be international city like New York, London and Hong Kong. In spite of this, the first edition of building policy does not include any instrument managing the thermal insulation of the building materials until issuing the thermal insulation systems for buildings in 2001. The prototype case specifications of early 1990 are until 2000 is collected from the building permit archives in Dubai Municipality together with site visits observation. The house is and the outer façade is covered by brick blocks and then the house is enclosed by pitched roof with 25% slope and 1 m projection creating shading for the underneath floors (Figure 6.3)

Figure 6.3: 1990's – 2000's Unit of IES-VE model

The ground floor is consist of synthetic carpet, cast concrete as the main structure material and covered by tiles with a total U-value 1.564 W/m²K. The external walls are 30cm thick made of medium concrete blocks covered by brick work in outer leaf and gypsum plastering from inner leaf with total U-value of 1.381 W/m²K. The internal partitions are 13cm thick made of medium concrete blocks also and covered by gypsum plastering from both sides with total U-value 1.993 W/m²K. The floor is made of dens cast concrete and covered by synthetic carpet with a total U-value 2.117 W/m²K. The pitched roof is 25% slope with .9m cavity and brick work outer leaf cover with a total U-value 0.146 W/m²K. The doors are made of 20% moist pine timber with a U-value of 2.161 W/m²K. the windows are consist of double layers of clear float glass panels with 6mm thick including air cavity of 12mm in between with a total shading coefficient 0.825 and total U-value 4.686 W/m²K. Table 6.4 shows the general specifications of the house materials together with its U-values and total shading coefficient.

Table 6.4: general specifications of construction materials of 1990's – 2000's model

	Description	U-value ASHRAE (W/m²·K)	Total shading coefficient (glazed only)
Roof	Pitched roof Brick-Cavity	0.146	
Internal floor	Carpet-Concrete	2.117	
External Wall	Brick-Concrete-Gypsum	1.381	
Internal Partition	Gypsum-Concrete-Gypsum	1.993	
Ground Floor	Tiles-Concrete-Carpet	1.564	
Door	wooden door	2.161	
Glazing	double glazing	3.679	0.825
		1.863	

6.3.4 2000's – 2010's Units

In 2000; the second edition of Dubai rules and regulations has been updated and followed by the thermal insulation systems for buildings in 2001. These policy instruments have been modernized in order to be more compatible with the city growth provisions since new designs, material, technologies and owners and investors requirements has enlarged with the city growth.

Different type of local housing unites started to arise beside the arcade and the pitched roof designs varies between post modern concepts with clearstory themes and full glass façades (Figure 6.5) and between re-traditionalism modern that employs the traditional design features like wind towers as decorative figures only (Figure 6.4).

Two types of modern approach houses have been modeled with properties and specifications that follow the building rules and regulations of Dubai Municipality in section of private villas and local housing units. The policies that have affected the design and the building construction technologies of the houses are includes 3 m setback from the edges of the plot, maximum of 15m of the total house height counting G+1 with roof service only, providing natural light and ventilation with a minimum of 10% of total room area for glazing with a maximum U-value of 3.28 W/m²K. The external walls shouldn't exceed a U-value of 0.57 W/m²K and the roof maximum U-value is 0.44 W/m²K. Moreover, all construction materials should follow ASHRAE guide and approved from Dubai Central Laboratory (DCL).

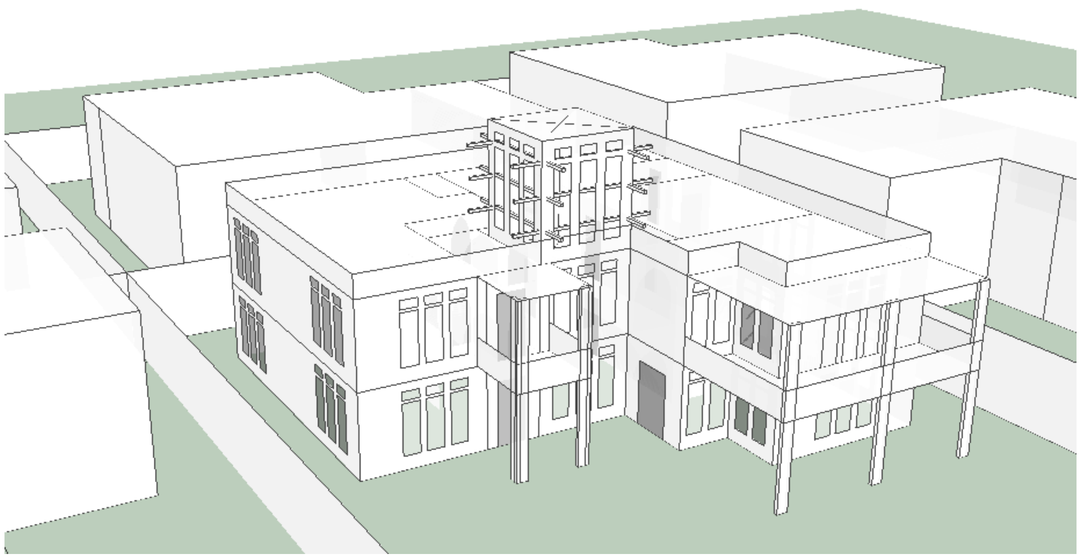

Figure 6.4: 2000's – 2010's re-traditional unit of IES-VE model

Figure 6.4 shows the IES-VE model of traditional design house which is 500 m² total built up area with two stories height each floor is 3 meters high and a Barjeel (decorative only) above the roof and terrace in front elevation shaded by wooden pergola.

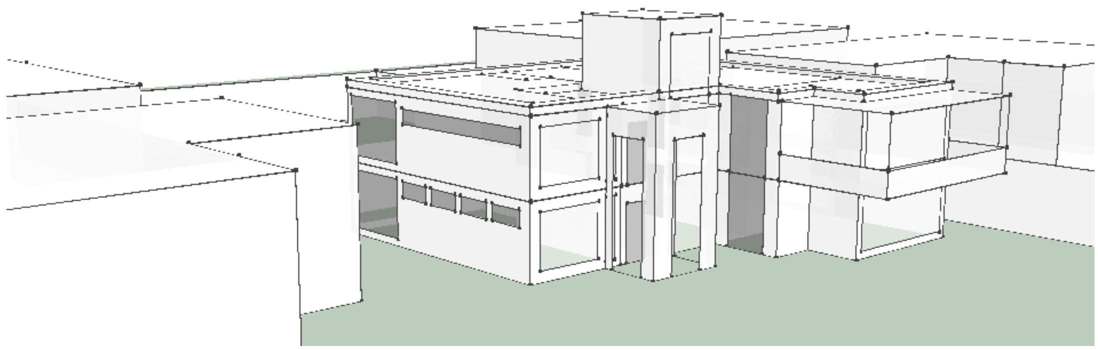

Figure 6.5: 2000's – 2010's post-modern unit of IES-VE model

Figure 6.5 shows the IES-VE model of modern type which is simple plain design with flat roofs including excessive use of glass and minimal use of decorative features. It is 500 m² total built up areas with two stories height each floor is 3 meters high with stair room in the roof.

In both cases (the modern and the traditional) new houses have used the same material properties where the ground floor is consist of synthetic carpet, cast concrete as the main structure material and covered by finishing tiles with a total U-value 1.564 W/m²K. The external walls are 22cm thick made of light weight concrete blocks with an insulation layer of glass-fiber (ASHRAE) and covered by gypsum plastering from both sides with a total U-value of 0.572 W/m²K. The internal partitions are 13cm thick made of brickwork and covered by lightweight plaster from both sides with total U-value 1.767 W/m²K. The floor is made of dens cast concrete and covered by synthetic carpet with a total U-value 2.117 W/m²K. The roof is consist of two layers of aerated concrete slab with insulating material in between and covered by gypsum plastering from the inner side and by gravels and concrete tiles from the outer side with a total U-value of 0.441 W/m²K. The doors are made of 20% moist pine timber with a U-value of 2.161 W/m²K. the windows are consist of double layers of Pilkington k glass which is low emissivity coated glass with 6 mm thick and clear float glass 6mm thick including an air cavity of 12 mm in between with a total shading coefficient 0.402 and total U-value 3.28 W/m²K. The following table shows the general specifications of the house materials together with its U-values and total shading coefficient. The following table shows the general specifications of the house materials together with its U-values and total shading coefficient.

Table 6.5: general specifications of construction materials of 2000's – 2010's model

	Description	U-value ASHRAE (W/m²·K)	Total shading coefficient (glazed only)
Roof	Tiles-Sand-Concrete-Insulation-Concrete-Gypsum	0.441	
Internal floor	Carpeted reinforced-concrete ceiling	2.117	
External Wall	Gypsum-Insulation-Concrete-Gypsum	0.572	
Internal Partition	Plaster-Brick-Plaster	1.767	
Ground Floor	Tiles-Concrete	1.564	
Door	wooden door	2.161	
External Glazing	low-e double glazing (6mm+6mm)	3.28	0.402
		1.700	

6.3.5 <u>2010's – 2014's Units</u>

It is expected to experience a new revolution of sustainable development in 2014 since the green regulations and specifications established by Dubai Municipality will be mandatory for all types of buildings in Dubai.

Furthermore, the Pearl rating system (Figure 6.6) for Estidama initiated by Abu Dhabi Urban Planning Council has recorded further improvements owing to the combination of regulatory and voluntary policy instruments, recommendations and incentives.

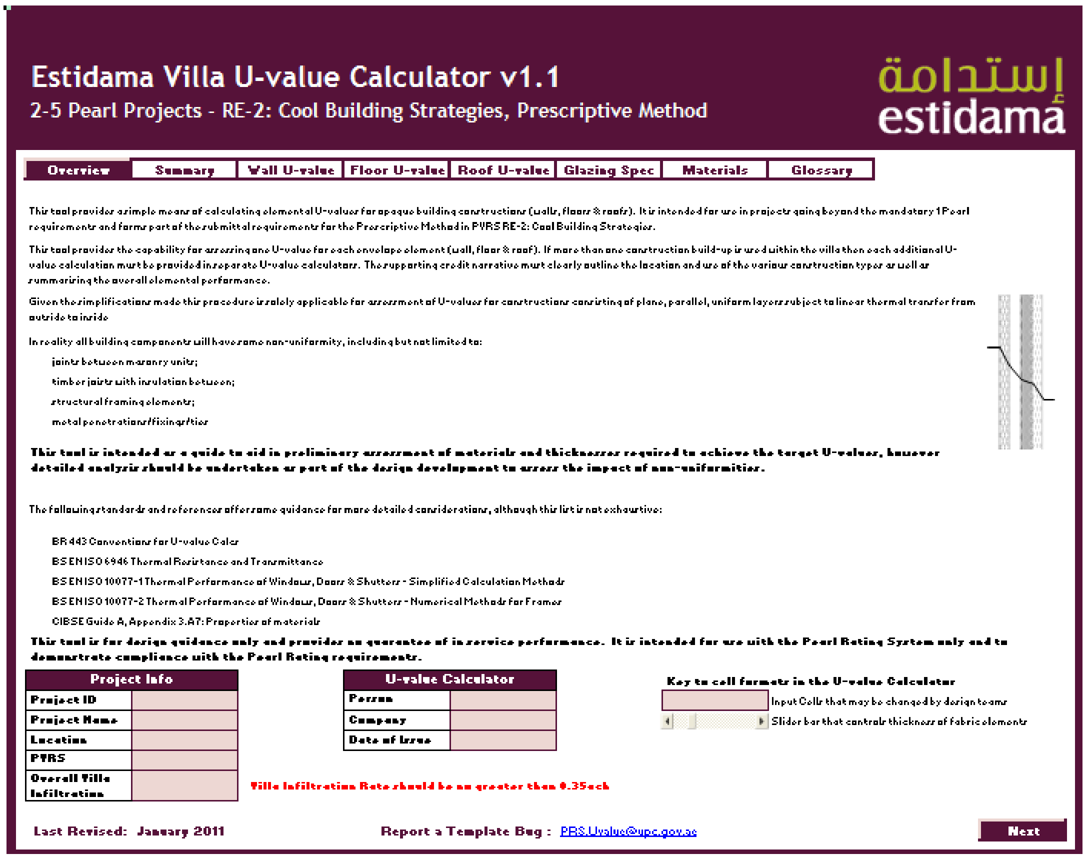

Figure 6.6: Pearl Rating System for Estidama. Source: (www.estidama.com)

The above modern cases were modified to meet the future expectations of private villas and local housing units in Dubai and then customized to meet Abu Dhabi Estidama recommendations that are related to the research area in order to evaluate the level of sustainable development of local housing units.

In Dubai Green Regulations and specifications the roof U-value has been changed from 0.44 W/m²K to maximum of 0.30 W/m²K while in Estidama it is recommended to be 0.12 W/m²K. In term of external walls, the U-value in Dubai future regulations has not changed 0.57 W/m²K while in Abu Dhabi Estidama rating system it is recommended to be 0.29 W/m²K. The glazing U-value in Dubai regulations has changed from 3.28 W/m²K to 2.1 W/m²K in green specifications while in Abu Dhabi Estidama the U-value of glazing is 1.9 W/m²K. The shading coefficient (SC) has not changed in Dubai regulations 0.4 while in Abu Dhabi Estidama is 0.3. Additional issue regarding glazing orientation has established by Dubai green regulations and specifications which imposing at least 50% of total glazed area of the building must have a north orientation. South and west glazed areas must be treated environmentally with shading elements and methods since it is not possible to re-orient the buildings due to the general planning directives. The following table demonstrates the general building specifications of each timeline period.

6.4 Computer Simulation Procedure

Various computer simulation will be conducted since the investigation is applied on eleven computerized models and will be measured in term of energy consumption and thermal performance which will be inspected by heat gain assessment due to its major impacts on cooling loads and internal temperature with the intention of investigating the compatibility of building materials and new building construction methods with UAE climate and environment, and compare the results with the compatibility of the traditional house and future houses with its sustainable properties and harmony with nature.

The thermal performance simulation will be conducted in order to examine the building passivity and sustainability in UAE environment as a hot climate region and assess its thermal performance in comparison with the sustainable practices of traditional houses. Each unit will be simulated twice based on principle features of each period in order to check if these features were added for general architectural appearance only or it have an environmental benefits that helps minimizing the energy consumption and enhancing the thermal performance of the building at each period of time.

The energy consumption analysis will be obtained from three simulation runs including total lights energy, cooling load energy, and fans and pumps energy. A thermal performance analysis will be conducted in order to investigate the grounds of energy consumption levels in local housing units in UAE, each housing unit will be analyzed in term of thermal performance conducting heat gain analysis for both lighting and cooling loads as shown in Figure 6.7 since heat gain assessment illustrates the amount of heat introduced into the housing unit from different heat sources which creates temperature difference between exterior and interior spaces and has substantial impacts on cooling loads.

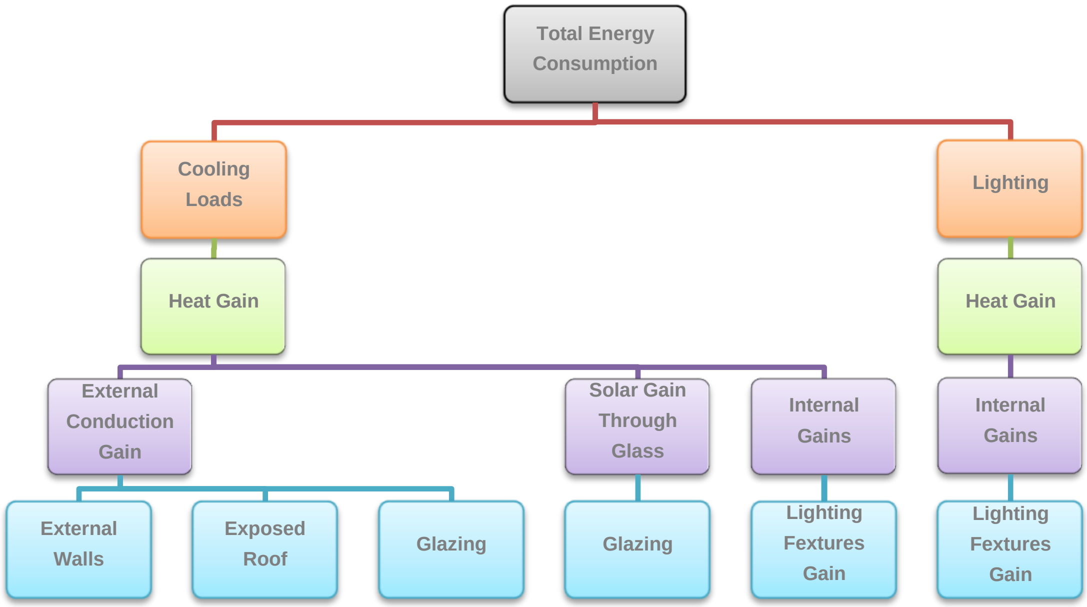

Figure 6.7: Systematic analysis of total energy consumption of local housing units in Dubai.

Heat gain assessment will be obtained from four main simulation runs as shown in Figure 6.7 witch demonstrates the systematic analysis of total energy consumption of local housing units in Dubai. The heat gain assessment counts:

- External conduction gains through external walls, external glazing, external doors, ground floor and exposed roof.
- Internal conduction gains through internal partitions, internal doors, internal floor and ceiling.
- Internal gains through people, lighting and other equipments.
- Solar gains through glass.

Chapter 7: Results and Discussion

7.1 Total Energy Consumption

The energy consumption analysis has obtained from three simulation runs including total lights energy, cooling load energy, and fans and pumps energy.

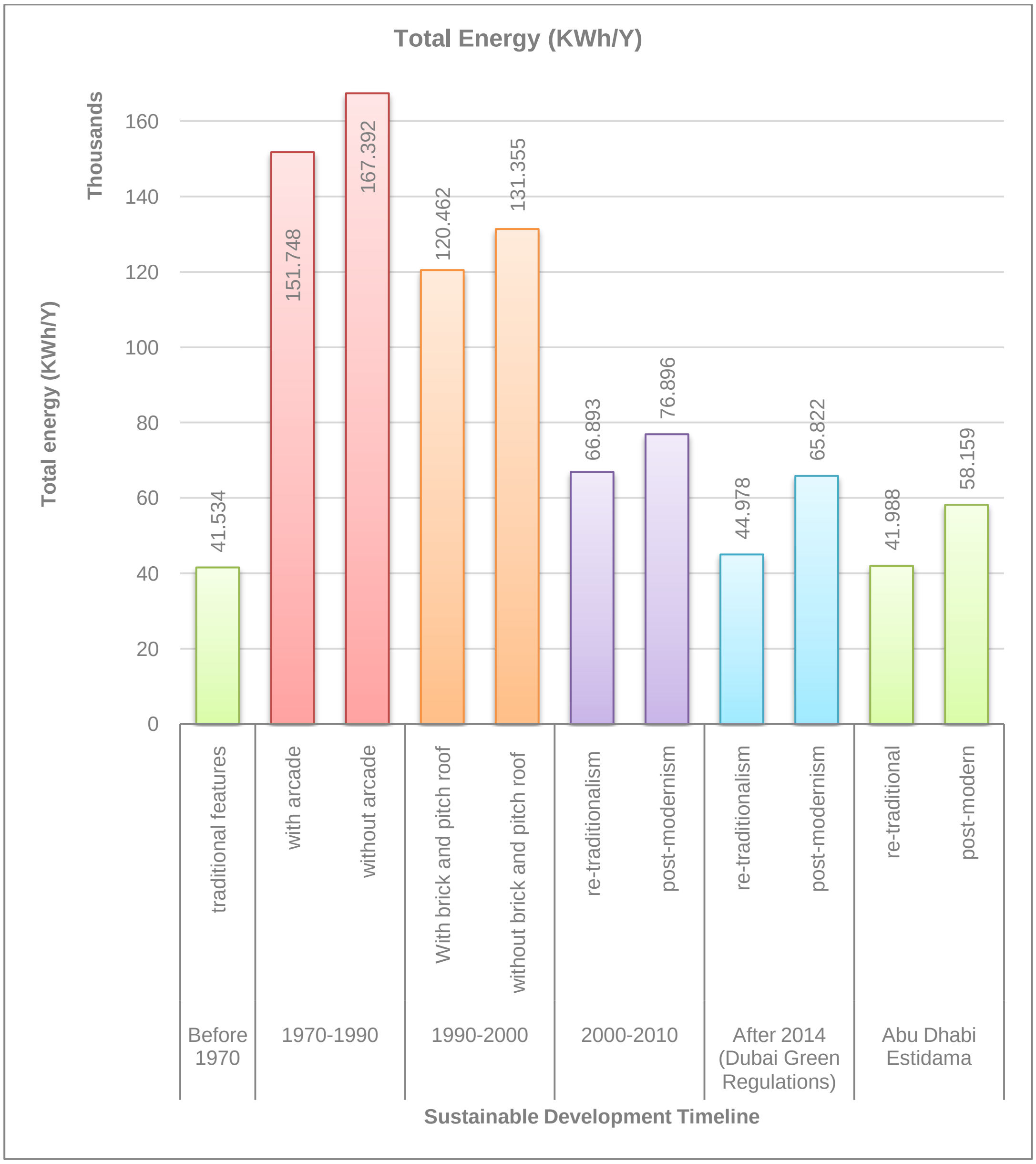

Figure 7.1: Total Energy Consumption (KWh/Y)

Figure 7.1 illustrates the total energy consumption among all types of local housing units in Dubai. It was found that the lighting and cooling loads have the largest influence on energy consumption from traditional unites (lighting only) headed for future units; thus the lighting and cooling outcomes will be analyzed in detail as shown in Figure 7.2 and Figure 7.3.

7.1.1 Lighting Energy Consumption

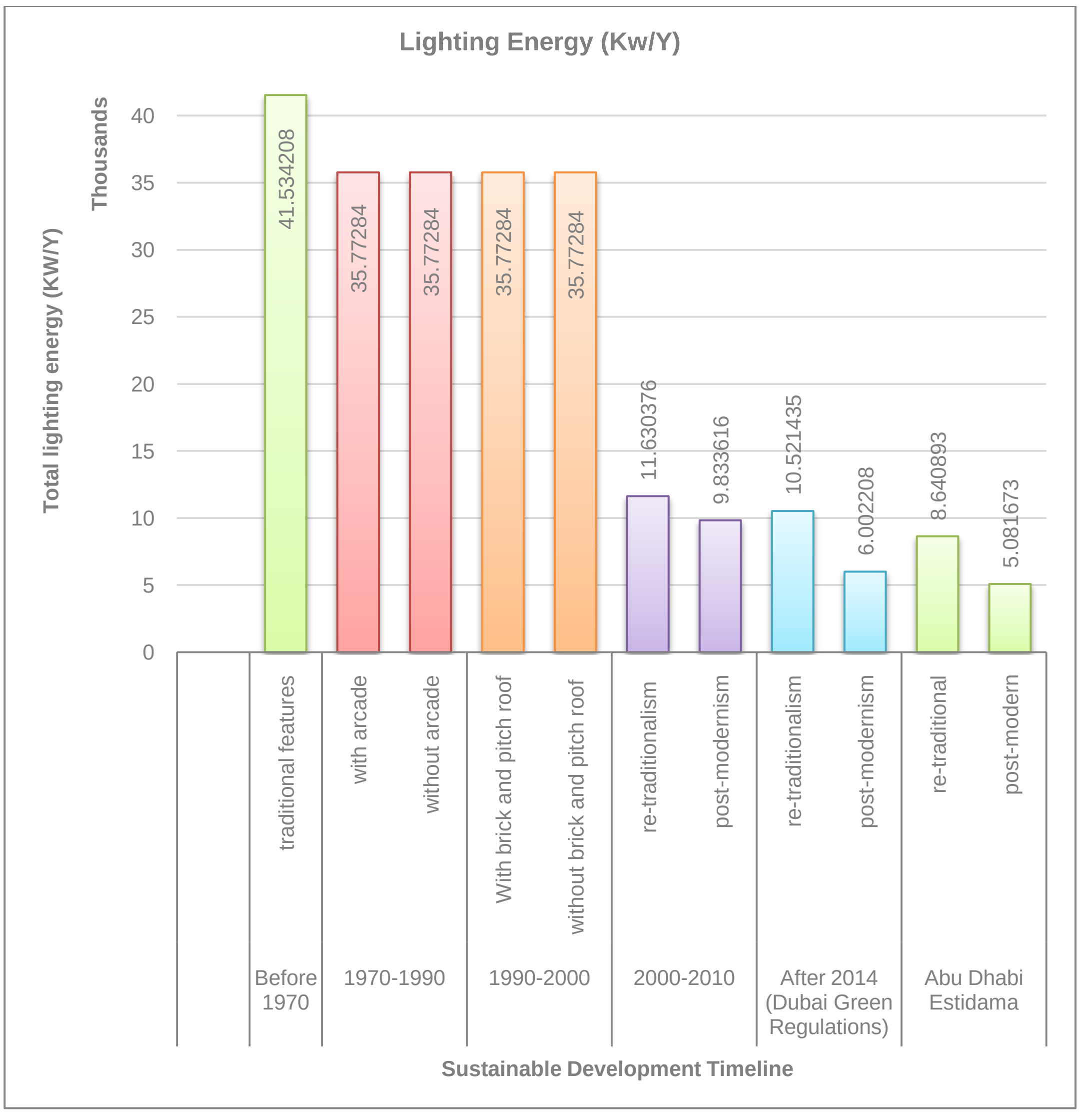

Figure 7.2: Lighting Energy Consumption (KWh/Y)

From the previous results of energy consumption, it is clear that the traditional house has the minimum value of energy consumption among all other units. The only energy consumer of this type of buildings was the lighting units of tungsten lamps which consume (41,534 KWh per Year) and dominate the highest rate of lighting energy consumption in comparison with all types of housing units as shown in Figure 7.1 and Figure 7.2.

Another reason makes the traditional unite utmost lighting consumption is that the running time of lighting fixtures since most windows are opened to the internal courtyard that surrounded by shaded corridors from all sides and enclosing big tree in the middle for shading proposes; accordingly small windows together with shaded corridors and shaded courtyard enhance the natural shading and passive cooling levels and elevate the demand for lighting inside the house spaces which make it the highest consumer in term of lighting energy.

In spite of this, the traditional house is found to enclose the minimum rate of total energy consumption compared to other timeline cases since no energy is used for cooling or any other electrical activities as shown in Figure 7.1 and Figure 7.3.

7.1.2 Cooling Energy Consumption

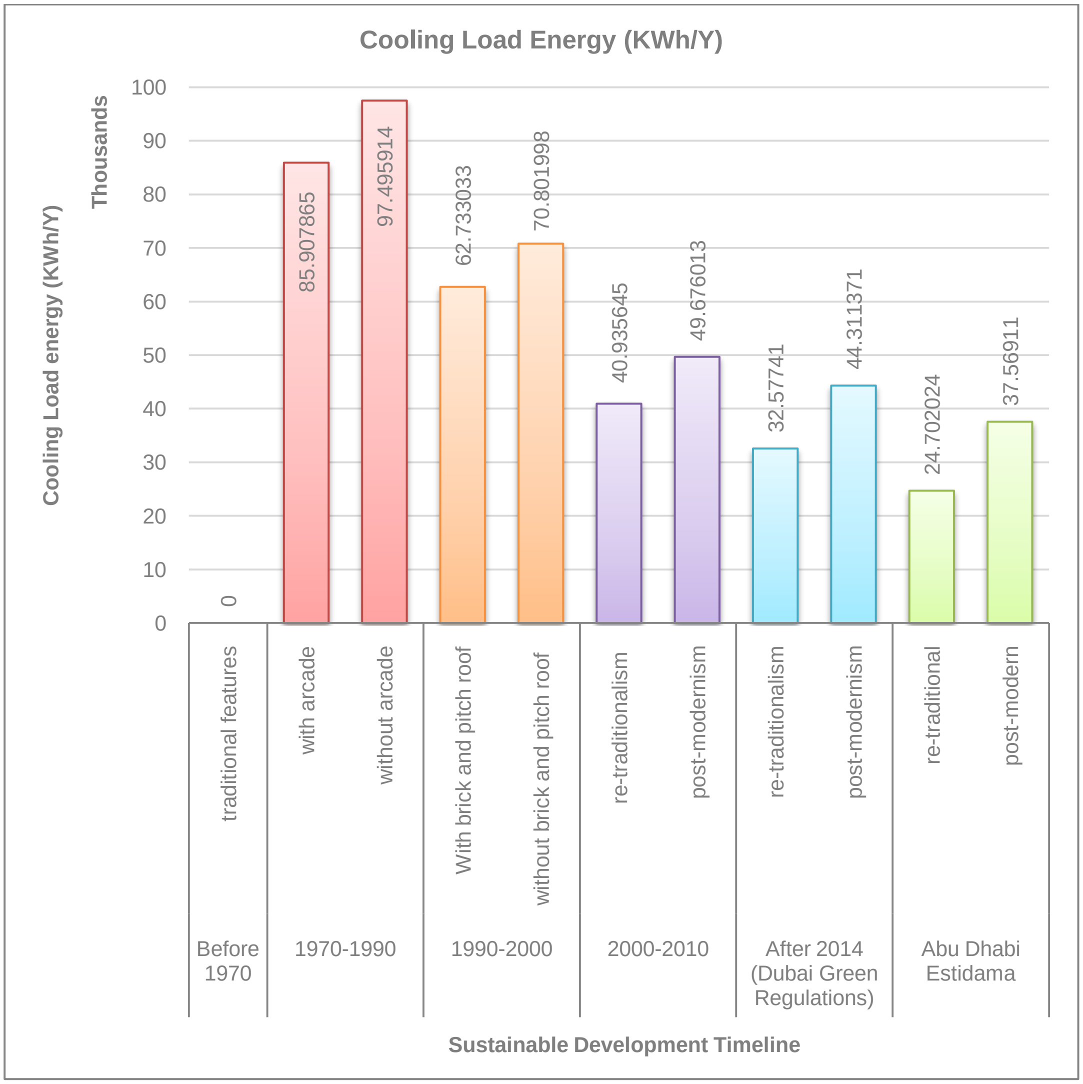

Figure 7.3: Cooling energy consumption (KWh/Y)

With the beginning of using air conditioning window units in 1970's, the total energy consumption has lifted up extremely about four times than the total energy of traditional unit as shown in Figure 7.1 and was found to consume 60% of total energy demands of the building (85,907 KWh/Y).

The arcade integration has helped a little in reducing the energy consumption but comparing to other cases in timeline, the 1970's case showed the most energy consumer among all cases. The case of 1990's – 2000 showed a 22% decrease in cooling consumption compared to 1970's case and that's mostly due to thermal characteristics of building materials used since the air conditioning system (window unit) wasn't changed at that period of time until the beginning of 2000 when the new rules and regulations has controlled the cooling systems and its efficiency together with complete building processes and construction management which led to decrease the cooling energy between 43% and 53% below 1970's levels according to building design (re-traditional or post-modern).

A further reduction has obtained in future cases of Dubai (49% - 63%) and Estidama cases of Abu Dhabi (57% - 71%) below 1970's – 1990's levels due to new policy instruments, energy efficiency direction and thermal performance development.

7.2 Thermal Performance

Beside the development of lighting and cooling technologies that contributed in minimizing the total energy consumption overtime, a thermal performance analysis has been conducted in order to investigate the grounds of energy consumption levels in local housing units in Dubai, each housing unit has analyzed in term of thermal performance conducting heat gain analysis for both lighting and cooling loads as shown in Figure 6.7 since heat gain assessment illustrates the amount of heat introduced into the housing unit from different heat sources which creates temperature difference between exterior and interior spaces and has substantial impacts on cooling loads.

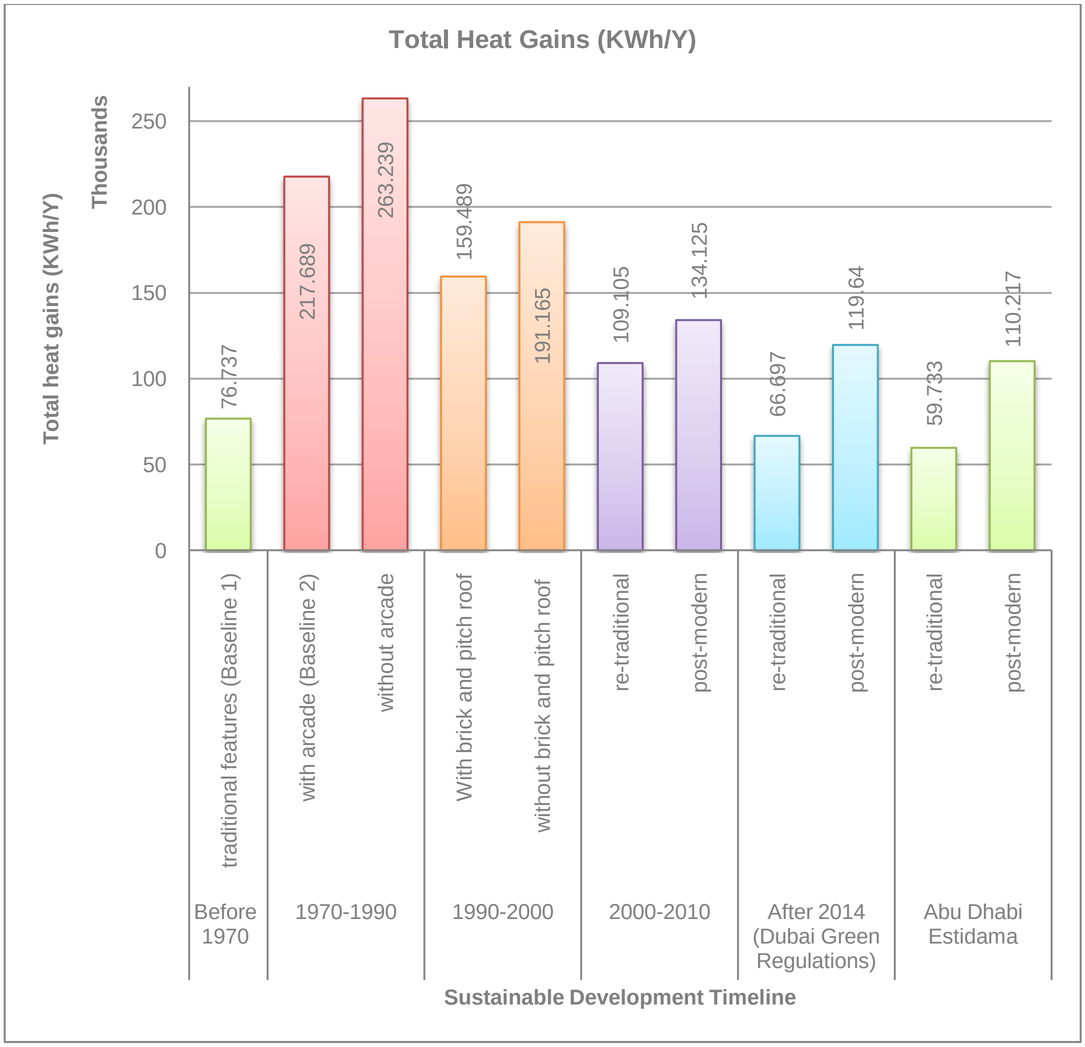

Figure 7.4: Total heat gains (KWh/Y)

Due to passive methods used in the traditional house with the aim of providing maximum thermal comfort possible since no active means or any cooling systems were available; a passive solutions such as wind towers, internal courtyard with shaded corridors and tree in the middle for shading purposes, massive thick internal and external walls that made of light and cold materials of mud and coral stone were the major grounds of preventing the heat gain flows into the internal parts of the house and place it within the most effective thermal performance as shown in Figure 7.4 except that of internal gain through lighting which will be discussed later in this chapter.

Figure 7.4 illustrates that in 1970’s, the total gain has bound 182% above total heat gain level in traditional building due to new construction materials and new active technologies utilized at that period of time. After 1990’s a 26% reduction from the level of 1970’s has achieved but still it is about double value above the total heat gain level of the traditional unit.

After the beginning of using thermal insulation materials in 2001 a 50% reduction has achieved compared to 1970’s levels and it is expected to be reduced to 69% after 2014 with an extra reduction of 14% compared to total heat gain level in traditional unit. Abu Dhabi Estidama unites have reached 22.5% reduction from the level of traditional unit and 73% from the level of 1970’s unit.

From heat gain simulation, it was found that three main breakdowns have affected the energy consumption of the tested units. These breakdowns are:

- External conduction gain through external walls, exposed roof and glazing.

- Solar gain through glass.

- Internal gain through lights.

Figure 6.7 shows the systematic analysis of total energy consumption of local housing units in Dubai.

7.2.1 Thermal Comfort in Traditional Unit

The traditional house showed interesting results related to passive techniques used to fulfill the thermal comfort needs since no cooling systems were employed except that of innovative passive control of natural ventilation through wind towers, internal courtyard, shaded corridors and small openings and windows distributed throughout the house spaces.

A double simulation runs for single room that integrates a wind tower has been conducted in the hottest month of the year (July) with the purpose of testing the internal temperature and wind tower efficiency.

The first run was performed with closed and ineffective wind tower while the second run was performed with open effective wind tower. The first run showed 10 C° degrees difference between dry bulb temperature and indoor temperature and that’s most probably due to cold and light materials used together with great thickness of the walls which is 60cm.

A further reduction of 5 C° degrees in internal temperature has achieved when the wind tower has activated which present a total of 15 C° degrees difference as shown in Figure 7.5 which proves the efficiency of wind tower in such hot climate of Dubai.

Even though wind tower has showed a substantial passive cooling control in hottest months; the thermal comfort cannot achieved easily at certain point when dry bulb temperature reaches extreme levels beyond 40 C° degrees.

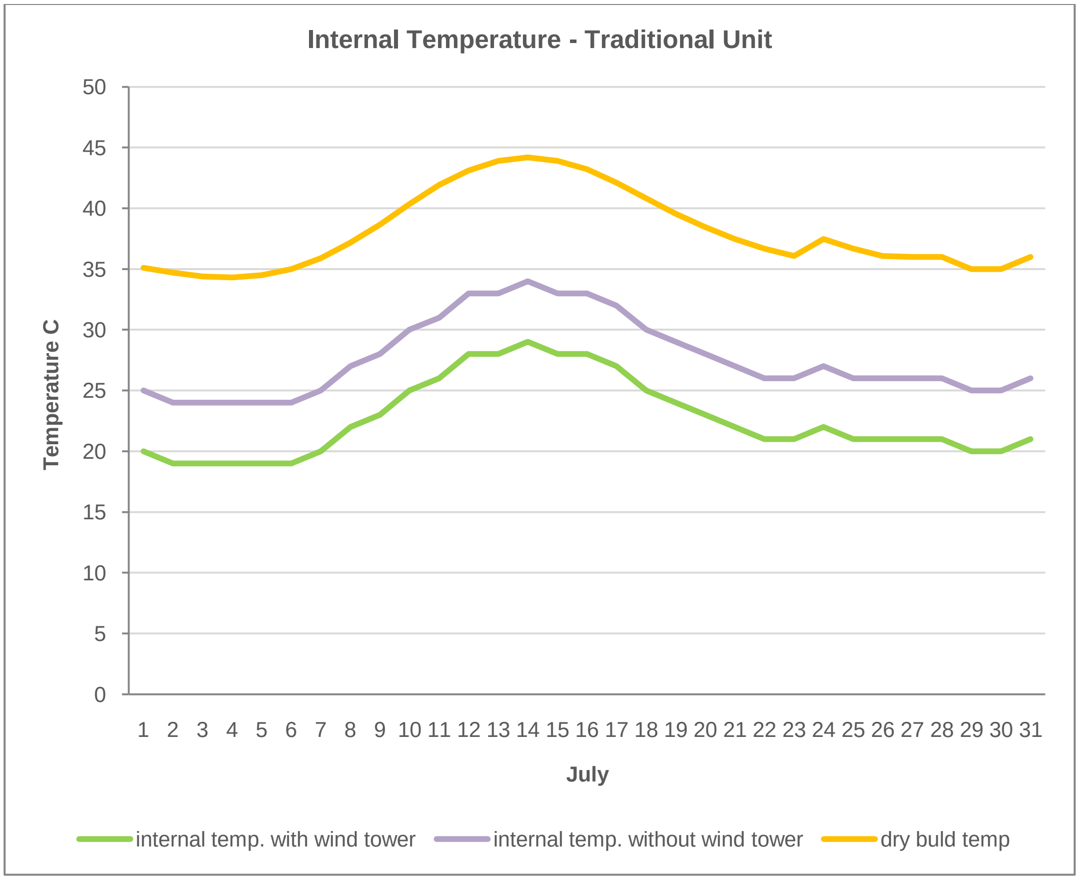

Figure 7.5: Internal temperature of traditional unit

7.2.2 <u>External Conduction Gain – External Walls</u>

Starting with heat gain assessment, firstly; external conduction gains were analyzed through external walls, exposed roof and glazing. Figure 7.6 presents the external conduction gain through external walls among timeline houses.

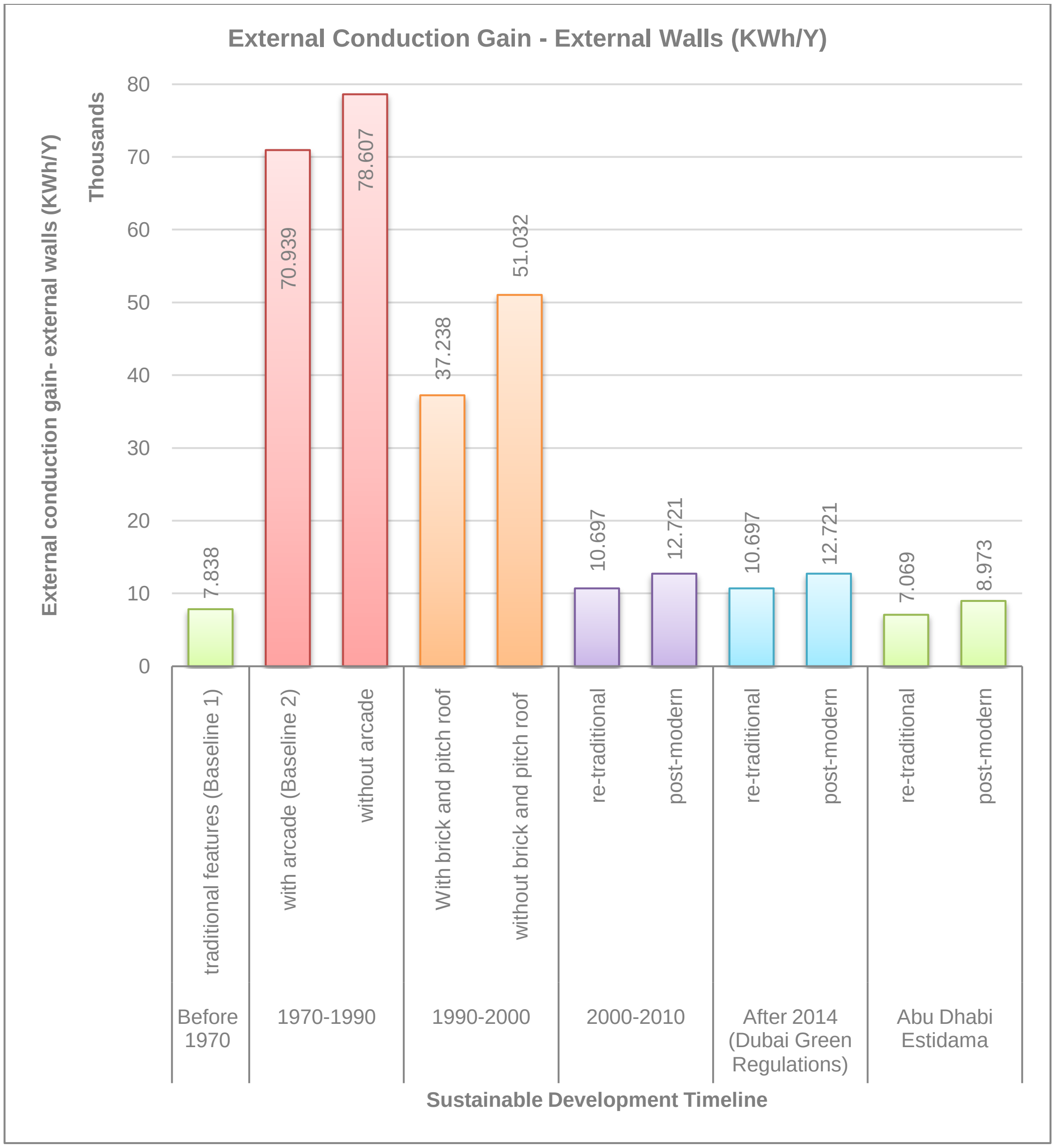

Figure 7.6: External Conduction Gain - External Walls (KWh/Y)

From the previous results, it was found that the conduction gain of external walls of the traditional unit (7,838 KWh/Y) is producing the minimum values compared to the other tested units in Dubai since re-traditional unit generates (10,697 KWh/Y) and post-modern unit generates (12,721 KWh/Y) while Abu Dhabi Estidama units have showed further reductions in external conduction gain through walls since it imposed a minimum U-value of external walls that does not exceed 0.290 W/m²K while Dubai green regulations did not impose any modification on external walls U-value which is 0.57 W/m²K.

The traditional unit has reached such performance mostly because of external walls' light cold materials with its great thickness of 60cm which significantly helped in preventing the heat gain passes through external walls with a total U-value of 0.299 W/m²K. The slight amount of openings in external walls sides has played an important role in minimizing the external conduction gain also.

Abu Dhabi Estidama units have reached this performance mostly owing to new directions of sustainable technologies combined with new green buildings policies and new thermal insulation materials.

A remarkable finding regarding the recommended U-value for external walls in Estidama units was found to be similar to that of traditional units which prove the compatibility of traditional materials with the surrounding environment.

It is clear that the conduction gain of external walls in post-modern unit is larger than that of re-traditional unit. That's mostly owing to the percentage of glass area integrated to post-modern design.

A breaking out results of 1970's-1990's unit has achieved where the conduction gain of external walls is around ten times more than that of external walls of traditional unit (70,939 KWh/Y). The arcade element has helped to reduce the external conduction gain of the walls but due to the vast change of utilizing new concrete materials with slight thicknesses and without any insulation material has most probably led to the obtained outcome.

The unit of 1990’s-2000 presents a better performance than that of arcade element and that is also because of new medium weight blocks used in building construction combined with outer finishing brickwork which created a total external walls thickness of 30cm and enhance the ability of preventing heat gain passes through external walls (37,238 KWh/Y). The outer brickwork has played a role in minimizing the total conduction gain of external walls compared to 1970’s-1990’s unit but still the value is extreme compared to the traditional unit.

In 2000-2010 units the conduction gain of external walls started to come close to the traditional unit value mostly due to the beginning of using thermal insulation materials in building construction after it became a mandatory policy instrument in 2001.

A slight difference of external walls’ conduction gain between re-traditional unit and post-modern unit is mostly owing to the use of some decorative and shading elements in re-traditional design and the total solid area of the external façade.

7.2.3 External Conduction Gain – Exposed Roof

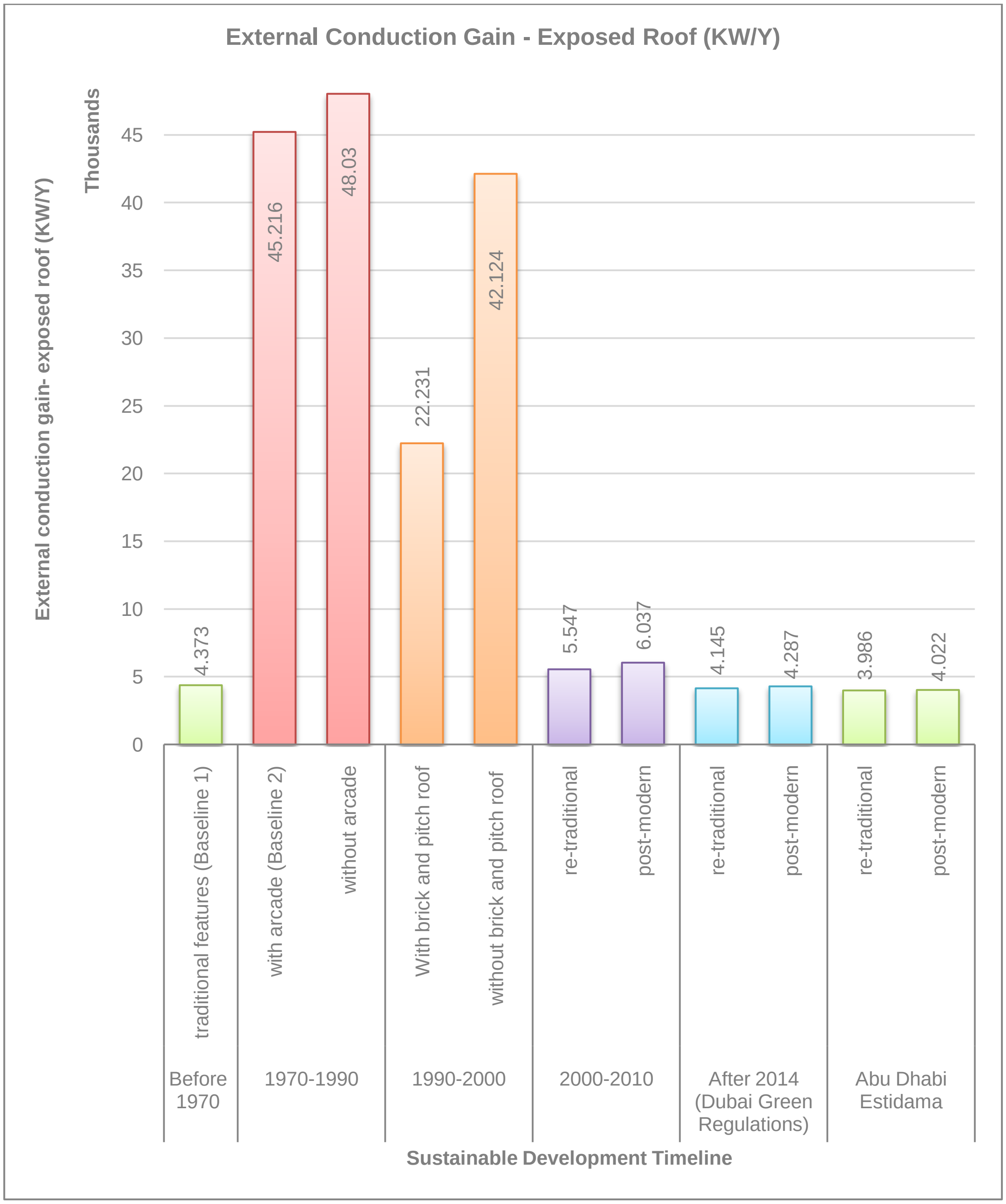

Figure 7.7: External Conduction Gain – Exposed Roof (KWh/Y)

Figure 7.7 illustrate a significant outcomes regarding the roof of 1990's – 2000 unit which has discovered after conducting two simulations one of them including the pitched roof element and the other one without the pitched roof integration in order to check if this element is thermally efficient or it is for architectural appearance of that period only.

The pitched roof element has helped extensively to prevent a significant amount of heat gain passes through it (22,231 KWh/Y) compared to that case without pitched roof element (42,124 KWh/Y) and that's most likely due to double roof idea since the pitched roof performed as outer roof layer followed by 90 cm cavity which is the main reason of the achieved performance and then enclosed by inner ceiling layer which turned out to be as internal floor.

The 1970's – 1990's unit illustrate a substantial value of conduction gain passes through its exposed roof (45,216 KWh/Y) since no thermal concerns were applied in building construction at that time.

After 2000 a significant drop in conduction gain through exposed roof has realized due to new rules and regulations regarding thermal insulation integration in all types of buildings in Dubai which led to new phase of sustainable development of the building industry in the city. A slight difference in conduction gain of exposed roof occurred between re-traditional unit (5,547 KWh/Y) and post-modern unit (6,037 KWh/Y) most likely occurred as a consequence of parapet height since it is higher in re-traditional unit than post-modern unit which provides more shading for roof area.

In future expectations of Dubai green regulations and specifications the roof conduction gain is minimized a little more but does not elevated to a level that could make it a substantial improvement like that of 2001 since the U-value of exposed roof has changed from 0.44 W/m²K to 0.3 W/m²K while in Abu Dhabi Estidama a further reduction has achieved since the U-value of exposed roof became 0.12 W/m²K.

7.2.4 External Conduction Gain – Glazing

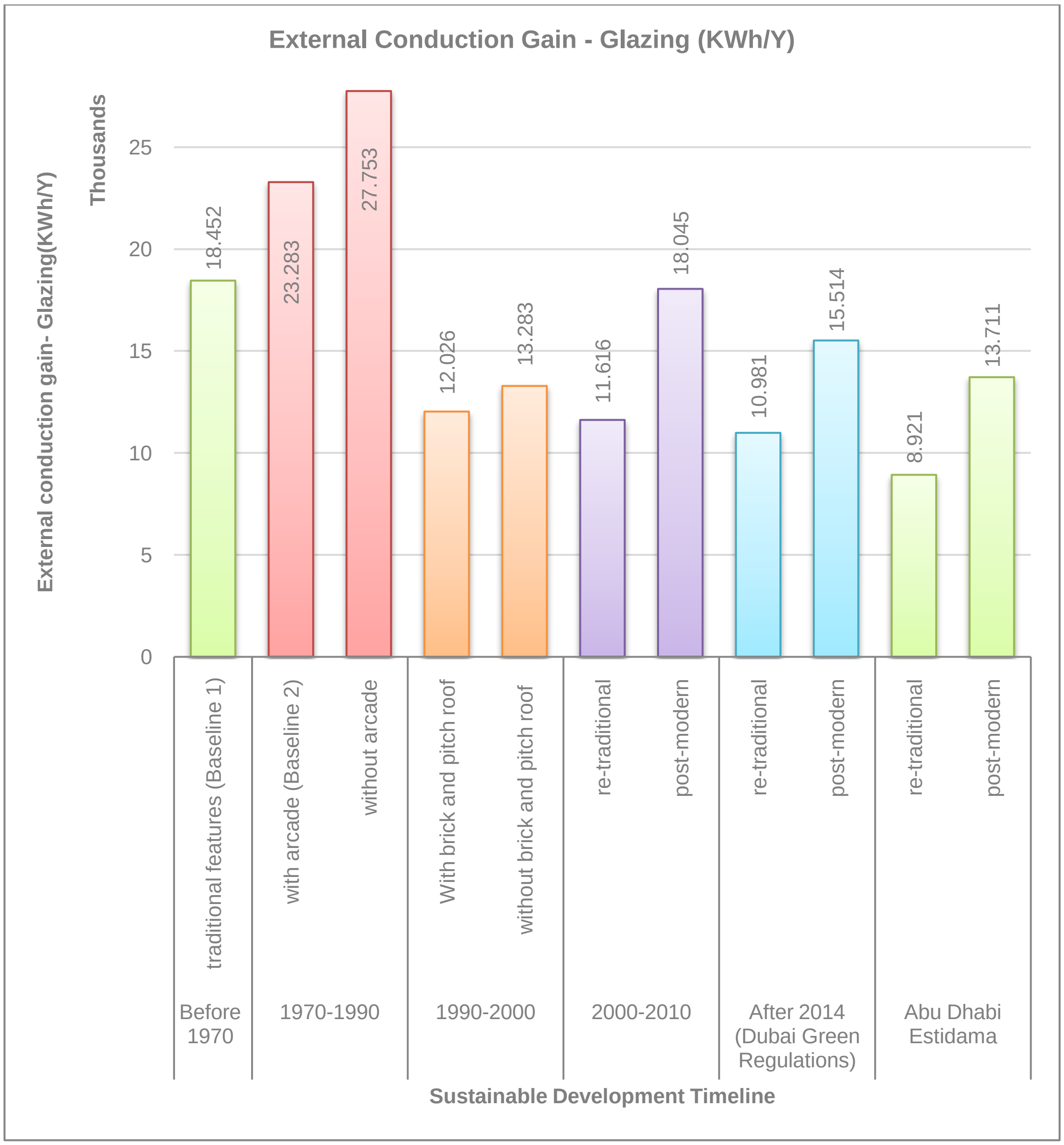

Figure 7.8: External Conduction Gain – Glazing (KWh/Y)

The heat gain through glazing has two divisions; conduction gain and solar gain. The conduction gain of a glazed area depends on the material used combined with its emittancety, thickness and ability to passes the heat gain through it.

In the traditional unit there was no glazing used in windows but instead, wooden frame and shutters were built-in for opening and closing as required since no glazing materials were available that time thus the conduction gain presented in Figure 7.8 illustrates the external conduction gain of wooden frame and shutters that enclosing high rate of external conduction gains and that's due to un-partitioned windows that prevent external heat inflowing the indoor spaces.

As shown in Figure 7.8, With the beginning of using glass windows in 1970's, the external conduction gain of glazing was in utmost level among all tested units (23,283 KWh/Y) and these results are accordingly due to the employment of single glazing of clear float glass with 6mm thickness and U-value of 5.69 W/m²K.

In 1990's double glazing windows started to be employed in building construction methods since new building technologies and materials began flowing. Double layers of clear float glass panels are consequently the grounds of that minimization in external conduction gain of glazing in 1990's – 2000 unit (12,026 KWh/Y).

A sizeable decrease has achieved after 2000 since low-emittence glazing with a maximum U-value of 3.28 became a mandatory specification after initiating the thermal insulation regulations. A slight difference between re-traditional unit (9,616 KWh/Y) and post-modern unit (11,045 KWh/Y) occurred due to area of glazing in each design since re-traditional unit comprise less glazing areas than the post-modern unit.

Future units' shows further reductions in external conduction gain of glazing since U-value has regulated to be decreased from 3.28 W/m²K to 2.1 W/m²K. Abu Dhabi Estidama units illustrates a little more reduction since the glazing U-value shouldn't exceed 1.9 W/m²K.

7.2.5 Solar Heat Gain – Glazing

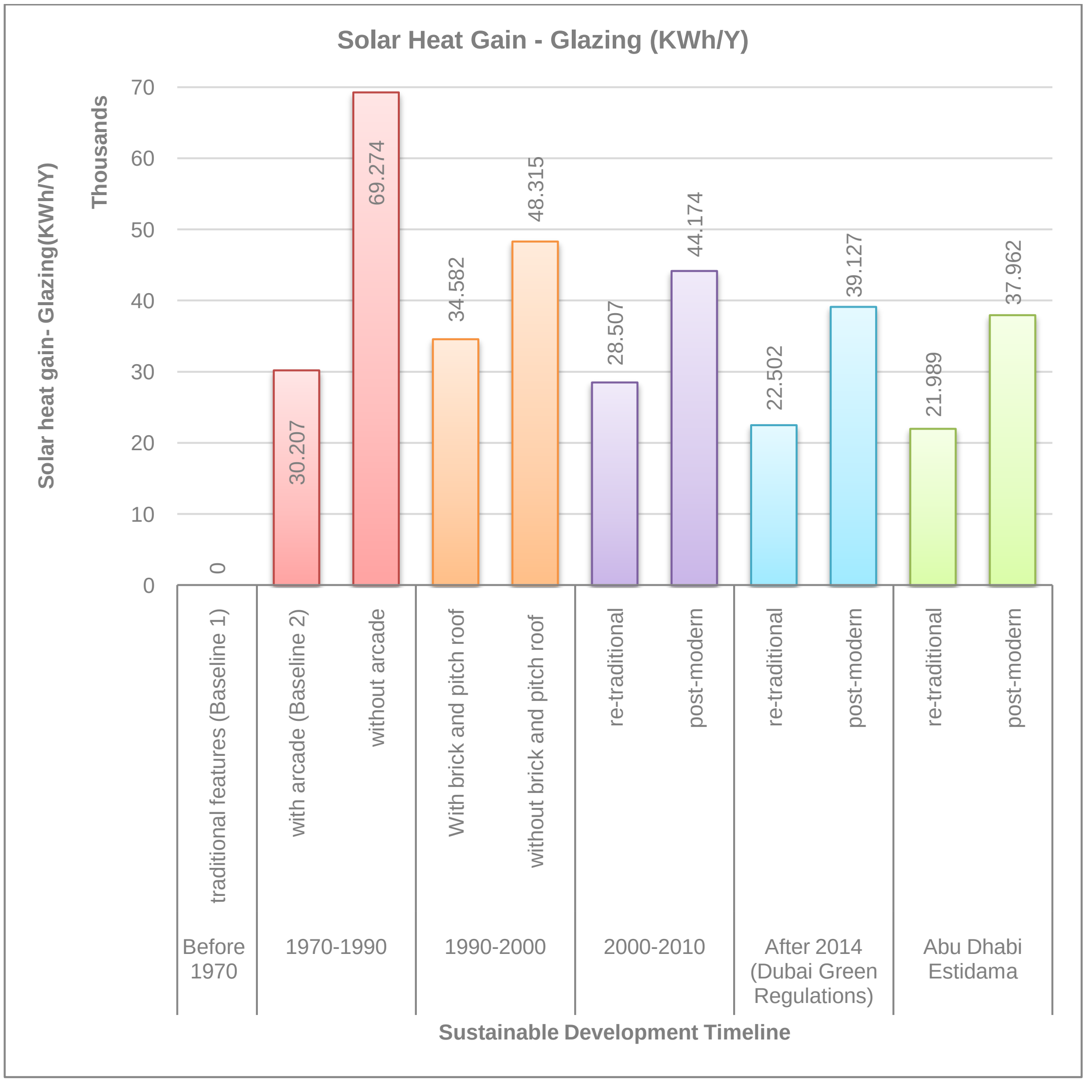

Figure 7.9: Solar Heat Gain – Glazing (KWh/Y)

The second division of heat gain through glazing is the solar heat gain which occurs when solar radiation flows into internal spaces through glazing areas. The traditional unit does not include this kind of gain since there is no glazing used in this type of buildings.

In 1970’s - 1990’s unit a remarkable outcome of solar gain through glass has recorded (Figure 7.9) since the unit with arcade façade has played a significant role in minimizing the solar radiation flows into the internal parts of the house (30,207 KWh/Y) while without arcade integration the solar gain through glass reached (69,274 KWh/Y).

The solar gain through glass started to minimize with the beginning of double glazing use in 1990’s, but the thermal performance of 1970’s unit have reached higher level due to arcade integration which acted as double skin façade and provided shading for windows in comparison with 1970’s unit.

After 2000, the ability of glazing to transmit solar heat has minimized and controlled by the establishment of Dubai rules and regulations which specified a maximum solar heat gain coefficient (SHGC) of 0.4.

In future unites a slight reduction has achieved due to the light transmittance control with minimum value of 0.25. An extra reduction in Abu Dhabi Estidama unites has achieved since the solar heat gain coefficient (SHGC) is set to be 0.3.

7.2.6 Internal Gains – Lighting

Figure 7.10 illustrate remarkable findings of internal gains through lighting units since lighting gains have substantial impacts on total energy consumption (for both lighting and cooling loads).

Inversely to the conducted simulations, the traditional house has recorded the highest value of internal gains through lightings among all timeline cases and that's due to inefficient type of lightings used at that time since tungsten lamps were generating heat gains up to (41,534 KWh/Y) which presents the total energy consumption of traditional house before 1970's.

Another reason makes the traditional house in the top of light gain producers is the operating time of tungsten lamps due to high overall shading level of the internal spaces of house which extends the working time of lighting units and thus extend the heat gain through them.

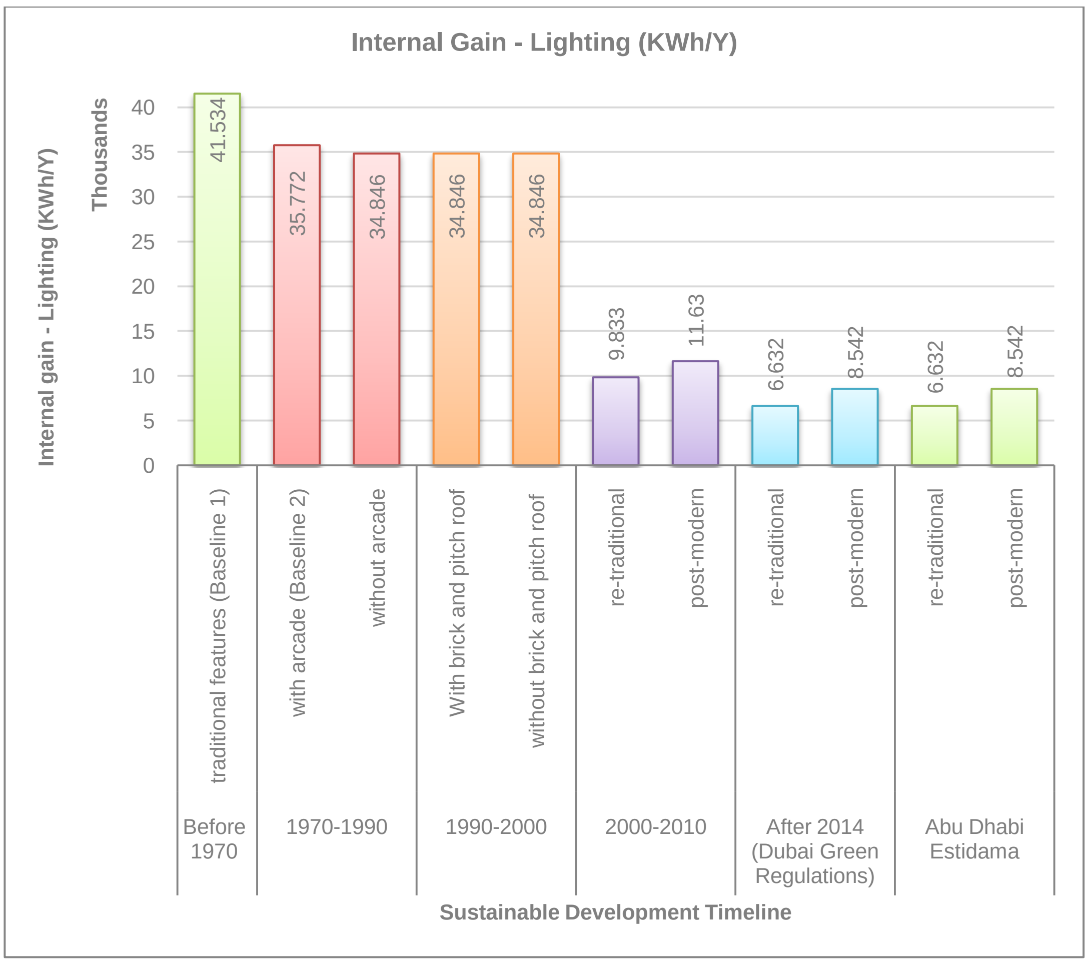

Figure 7.10: Internal Gain – Lighting (KWh/Y)

In 1970's – 1990's unit the heat gain through tungsten lamps has minimized 14% compared to traditional house levels due to less operation time of the lighting fixtures.

In 1990's – 2000 unit, a 16.2% reduction has recorded also due to the same reason of minimizing the working time of tungsten lamps since the demand of lighting in 1970's house was higher due to the outer façade of arcade integration which maximize the shading level in indoor spaces.

After 2000, a massive drop in heat gain through lights has occurred due to the utilizing of new florescent lightings in this era. This drop has reached a reduction between 72% and 76% of historical gain level in relation to the house design (re-traditional or post-modern).

Further reductions have recorded in future units in Dubai and in Abu Dhabi Estidama units (79% - 84%) from the level of light gain in historical house. The following section shows how these reductions affected the total cost of energy bill in Dubai.

7.3 Total Energy Cost

The energy cost analysis has derived from the current price of electricity according to Dubai Electricity and Water Authority (DEWA) as the actual price of electricity that cost the government is equal to AED 0.25/KW.

From the conducted results of total energy cost per year of local housing units in Dubai (Figure 7.11), it is clear that the rate of minimization of total energy cost is compatible with the improvement of sustainable conditions of the buildings.

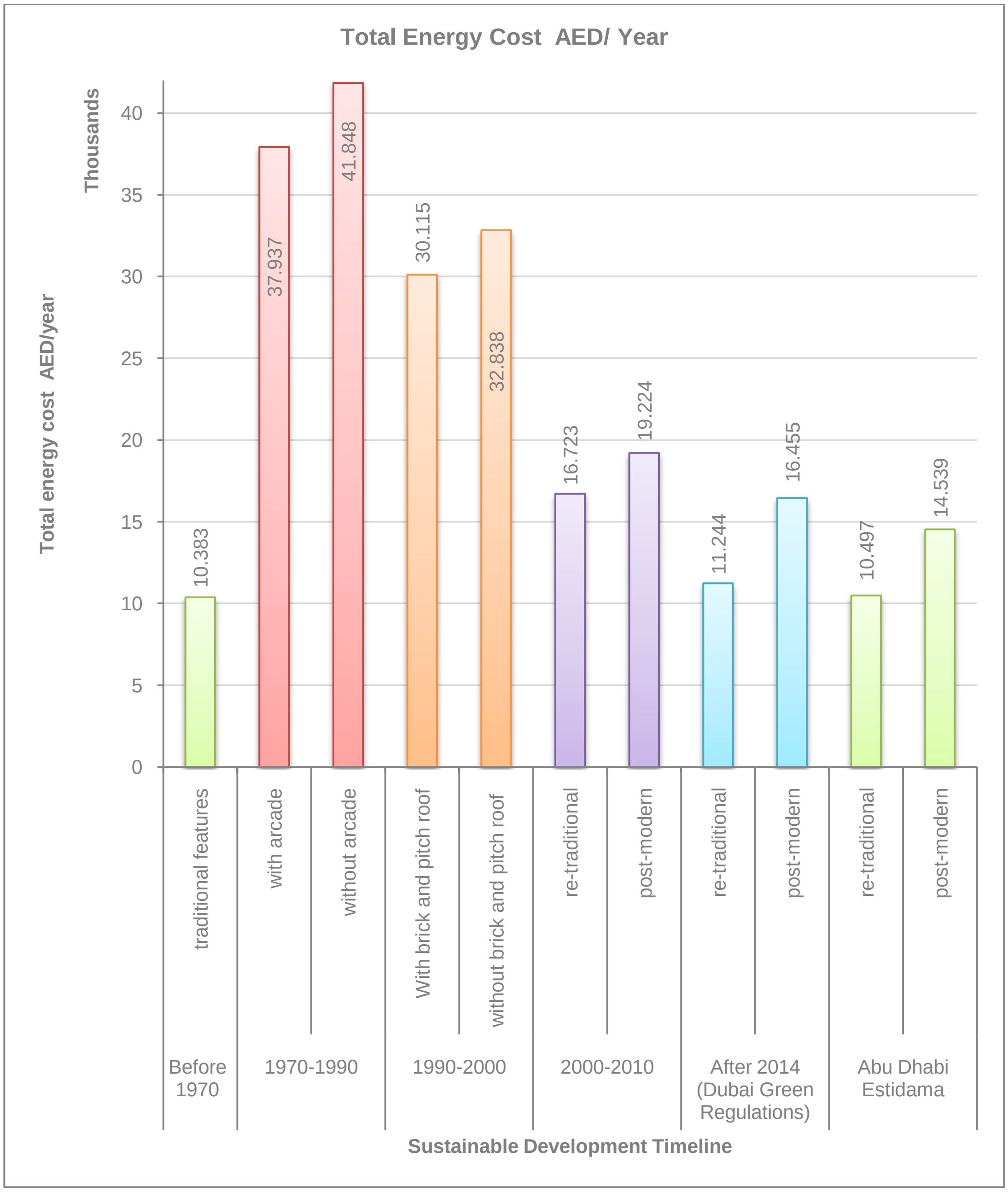

Figure 7.11: Total Energy Cost – AED/Y

A reduction of 57% to 70% of total energy cost in Dubai green buildings has achieved comparing the energy cost in 1970's. And further reduction has achieved of 62% to 73% by Estidama units of Abu Dhabi also in comparison with 1970's level.

Another significant result has recorded is that the total energy cost of re-traditional design of Abu Dhabi Estidama unit which enclosing lighting and cooling energy is almost equal to the total energy cost of traditional building that involve lighting energy only which verify that the ability of future green practices and sustainable developments to re-create environmentally friendly buildings that present green and comfort balance within affordable price of energy.

7.4 Modified Material Cost

A material cost analysis that contains the price of materials which has been changed or modified for green provisions proposes has been performed between current statement, future statement after applying Dubai green regulations and subsequently the statement of Abu Dhabi Estidama rating system in order to evaluate the effectiveness of energy cost in relation to construction material cost of local housing units and its sustainable development. Figure 7.12 demonstrates the total changing cost of modified materials of thermal insulations and glazing.

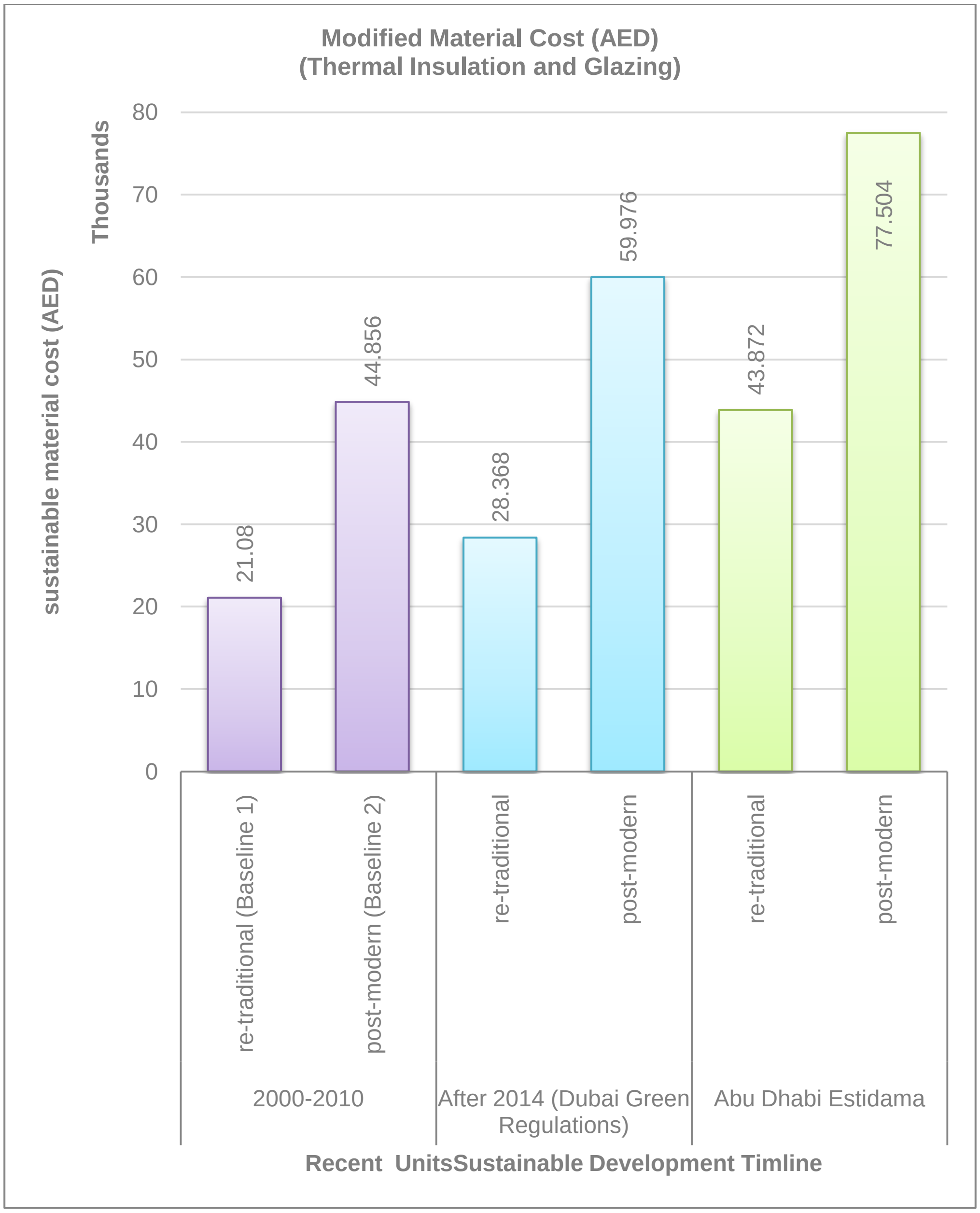

Figure 7.12: Modified Material Cost (AED) – (Thermal Insulation and Glazing)

From the previous investigations it was found that the thermal insulation of external walls, exposed roof and glazing type has the foremost impact on total cost of local housing units in the last three periods of sustainable development timeline which enclose the units of 2000-2010, units after 2014 of Dubai green regulations and units of Abu Dhabi Estidama system since the other building construction materials of these recent periods hasn't changed in local housing industry and accordingly only the materials that has been changed or modified are calculated with the intention of conducting a sensible analysis regarding the additional cost of sustainable local housing units.

According to the previous information and as shown if Figure 7.12 the total cost of double glazing and thermal insulation material of exposed roof and external walls is increasing with the improvement of sustainable development timeline.

Based on recent market prices and certified suppliers and manufacturers of double glazing and thermal insulation materials in Dubai, it was found that the cost of double glazing with a U-value of 3.28 is in the range of AED 300/m², double glazing with a U-value of 2.1 is in the range of AED 400/m², double glazing with a U-value of 1.9 is in the range of AED 440/m². And the cost of thermal insulation is in the range of AED 1.40/ m² with a thickness of 1cm. Figure 7.13 shows the details of thermal insulation cost and glazing cost in different timeline periods.

The total exposed roof area together with the solid and glazed areas of external façade has been calculated for each unit in order to set up the total cost of the modified materials of every housing unit in recent sustainable development timeline.

It is important to mention that the extra cost ratio is conducted for the material cost only without distribute it on total building construction cost which will be discussed later in this chapter.

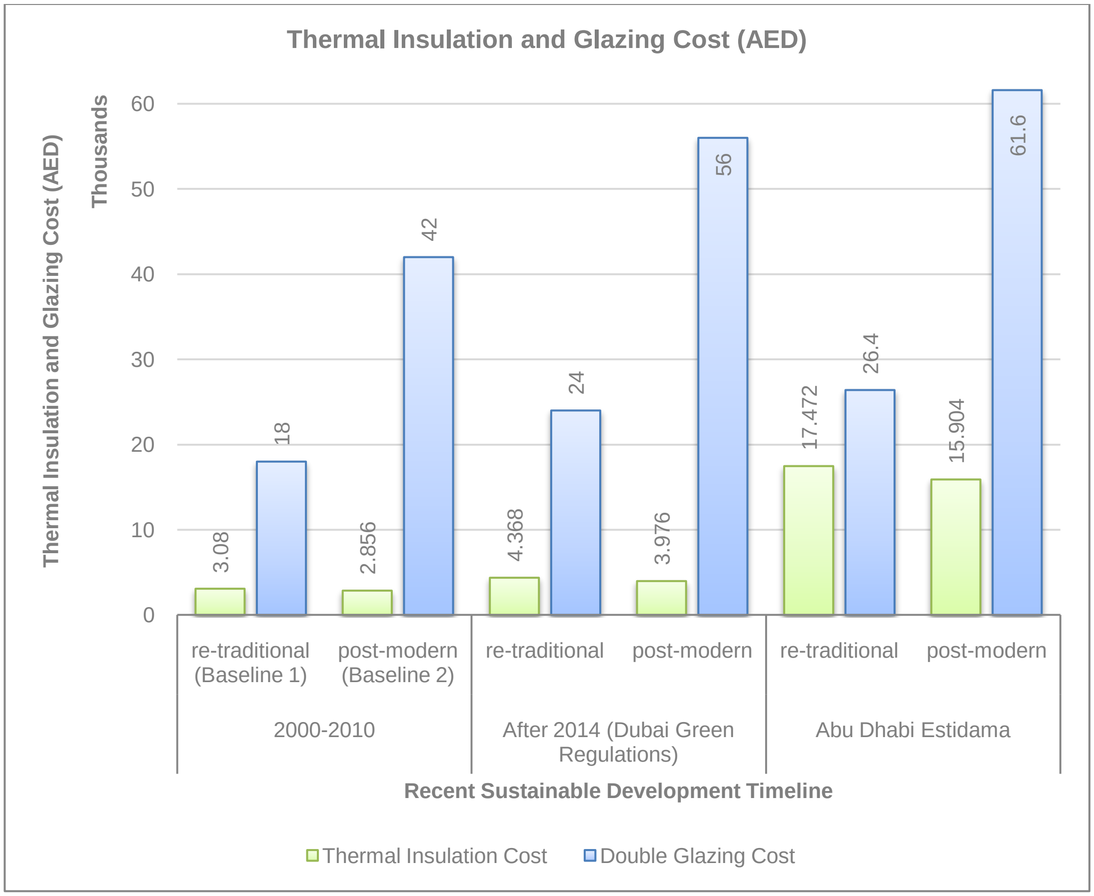

Figure 7.13: Modified Material Cost (AED) – (Thermal Insulation and Glazing)

It is clear that the cost of materials is increasing with improved material specifications but a significant finding of that even though the cost of thermal insulation is increasing but its increasement is not parallel with glazing cost increasing which is considered to be notably expansive in comparison with thermal insulation cost as shown in Figure 7.13.

Based on U-Value calculator of Abu Dhabi Estidama (Figure:6.6) and the software of integrated environmental solutions (IES-VE), it was found that the thickness of thermal insulation needs to be increased in order to reduce its U-value as per Dubai green regulations and Estidama rating system which leads to extend its cost as shown in Figure 7.13.

In re-traditional unit of Dubai Green Regulations an increase of 33% of total material cost was recorded in comparison with the same type in the period of 2000 - 2010 while it is almost the double price in Estidama unit in comparison with the same type of 2000 – 2010.

In post-modern unit of Dubai Green Regulations it was found that an increase of 33% also was recorded in comparison with 2000 – 2010 levels while in Abu Dhabi Estidama an increase of 71% was found in comparison with the post-modern type of 2000 – 2010.

7.5 Energy and Modified Material Cost and Cost Difference

The difference in modified material cost and total energy cost of green buildings of Dubai and Abu Dhabi in relation with the current state period of 2000 - 2010 has been conducted with the purpose of applying a payback period analysis. Figure 7.14 presents the cost and cost difference between total energy consumption and modified material properties within recent units of timeline periods.

It was found that the total energy cost in re-traditional type of Dubai Green regulations is decreased AED 5,497 per year in comparison with the same type in 2000-2010 levels while in re-traditional type of Abu Dhabi Estidama the total energy cost is decreased AED 6,226 per year in comparison with the same type of 2000 - 2010.

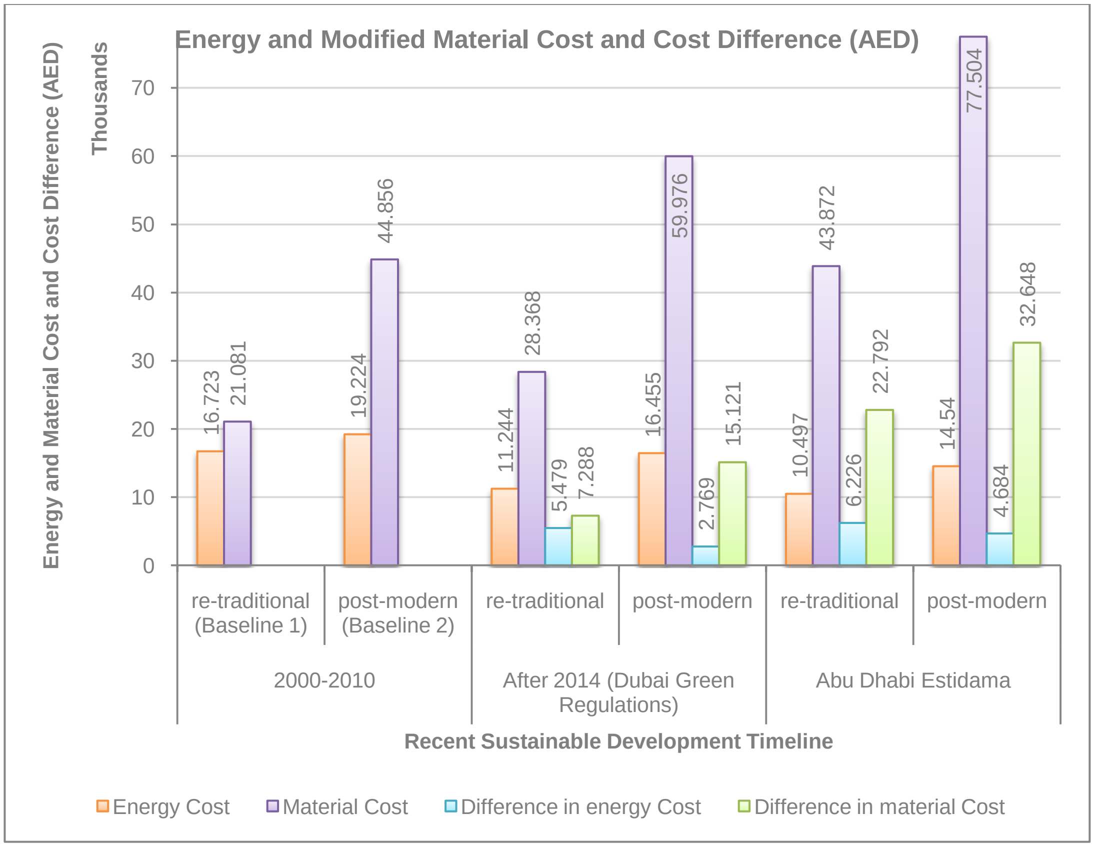

Figure 7.14: Energy and Material Cost and Cost Difference (AED) – (Thermal Insulation and Glazing)

Figure 7.14 shows a decrease of AED 2,769 per year that has achieved in post-modern type of Dubai Green regulations while a reduction of AED 4,684 per year has recorded in post-modern type of Abu Dhabi Estidama in comparison with the same type of 2000 - 2010.

In the subject of modified materials cost, it was found that an increase of AED 7,288 in re-traditional type of Dubai green regulations while an increase of AED 22,792 was recorded in the same type of Abu Dhabi Estidama in comparison with that of 2000 – 2010.

And an increase of AED 15,121 was recorded of post-modern type of Dubai Green regulations while an increase of AED 32,648 in the post-modern type of Abu Dhabi Estidama with comparison with the same type in current state of 2000 – 2010.

7.6 Total Construction Cost

Based on recent market prices and licensed consultants and contractors in Dubai Municipality it was found that the total construction cost for local housing units that comprise re-traditional design (less glazed areas) is in the range of AED 3100/m², and the total construction cost of local housing units that comprise post-modern design (wide glazed areas) is in the range of AED 3200/m².,

The total construction cost of local housing units of recent sustainable development timeline has been created based on the obtained informations of total construction cost of local housing units in the recent market and based on the obtained data of difference in modified material cost of green buildings of Dubai and Abu Dhabi as illustrated in Figure 7.14.

Figure 7.15 shows that the total construction cost of re-traditional unit of Dubai future has increased 0.46% compared to the level of the same design of current statement and the total construction cost of post-modern unit of Dubai future has increased 0.94% compared to the same type of current statement.

Abu Dhabi Estidama units has shown a little more increasement than Dubai future units where the total construction cost of re-traditional unit has increased 1.46% compared to the same type of 2000’s-2010’s levels while the post-modern design has increased 2.04% compared to the same design of 2000’s-2010’s levels.

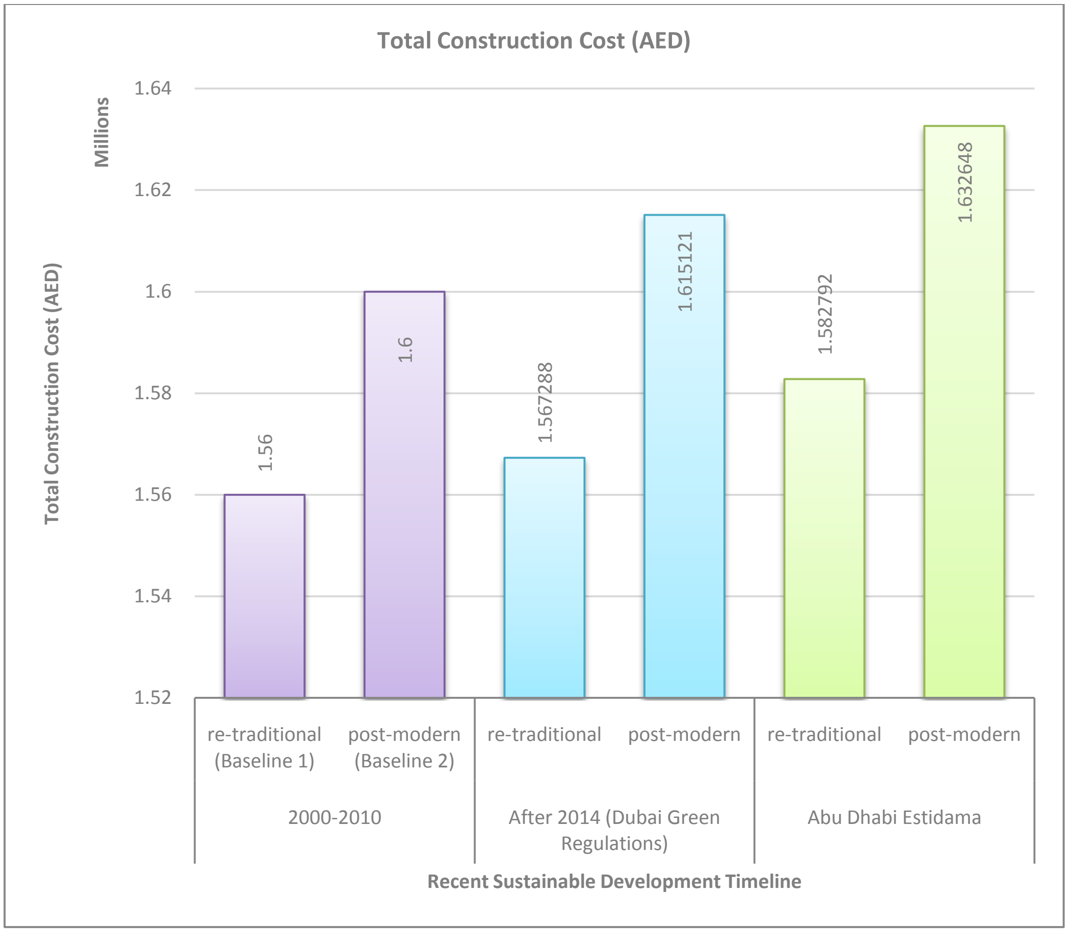

Figure 7.15: Total Construction Cost (AED)

7.7 <u>Payback Period Analysis</u>

Based on the previous discussion and obtained information, the difference of total construction cost then is divided on the difference of total energy cost of each type in the recent sustainable development timeline in order to get the payback period results and analyze them as shown in Figure 7.16.

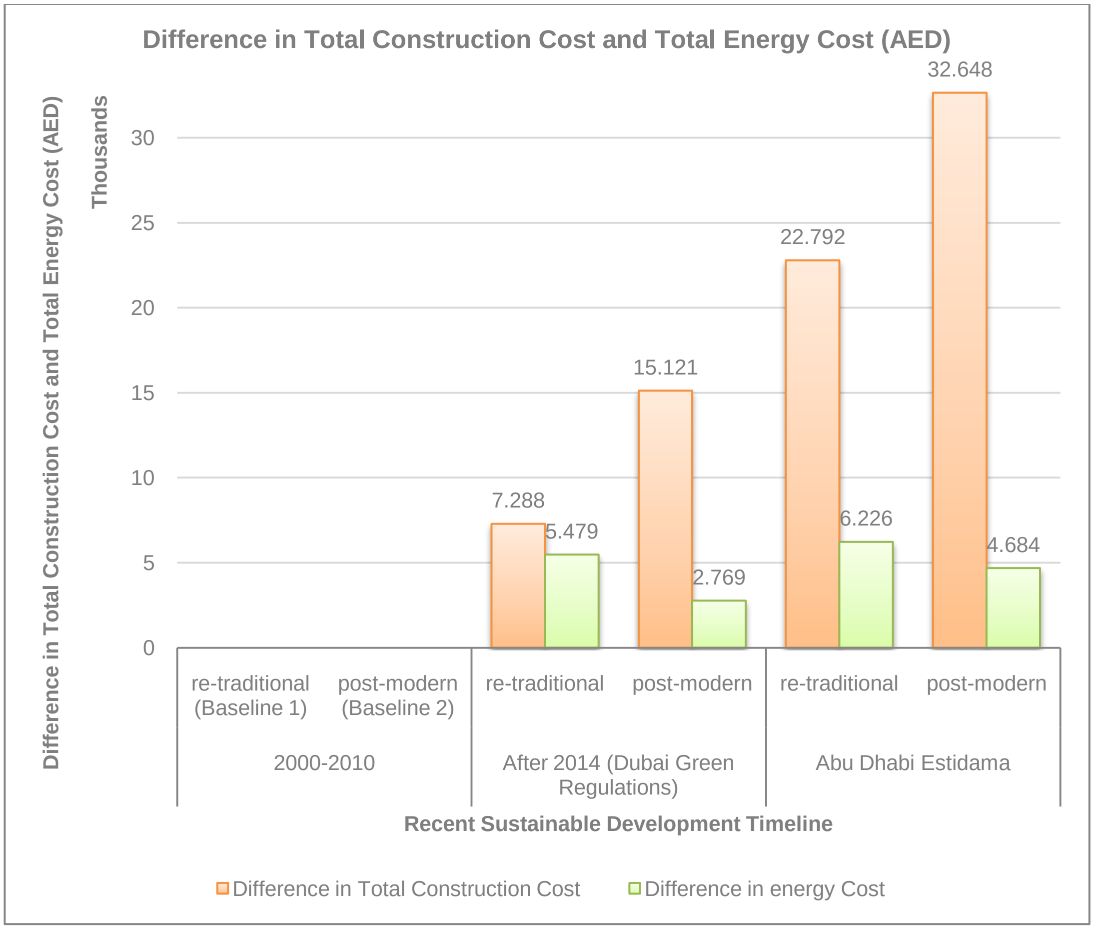

Figure 7.16: Difference in Total Construction Cost and Total Energy Cost (AED)

It was found that the payback period of each unit in the recent sustainable development timeline is based on two reasons; the first reason is the design of the local housing unit (re-traditional or post-modern), the second reason is the level of sustainable instruments used in each type.

Figure 7.17 shows that in re-traditional unit of Dubai green regulations 1.3 years are required to recover the total additional cost of total construction based on the minimized energy cost per year while a payback period of the same type in Abu Dhabi Estidama was found to be 3.6 years to recover the additional cost paid for modified materials.

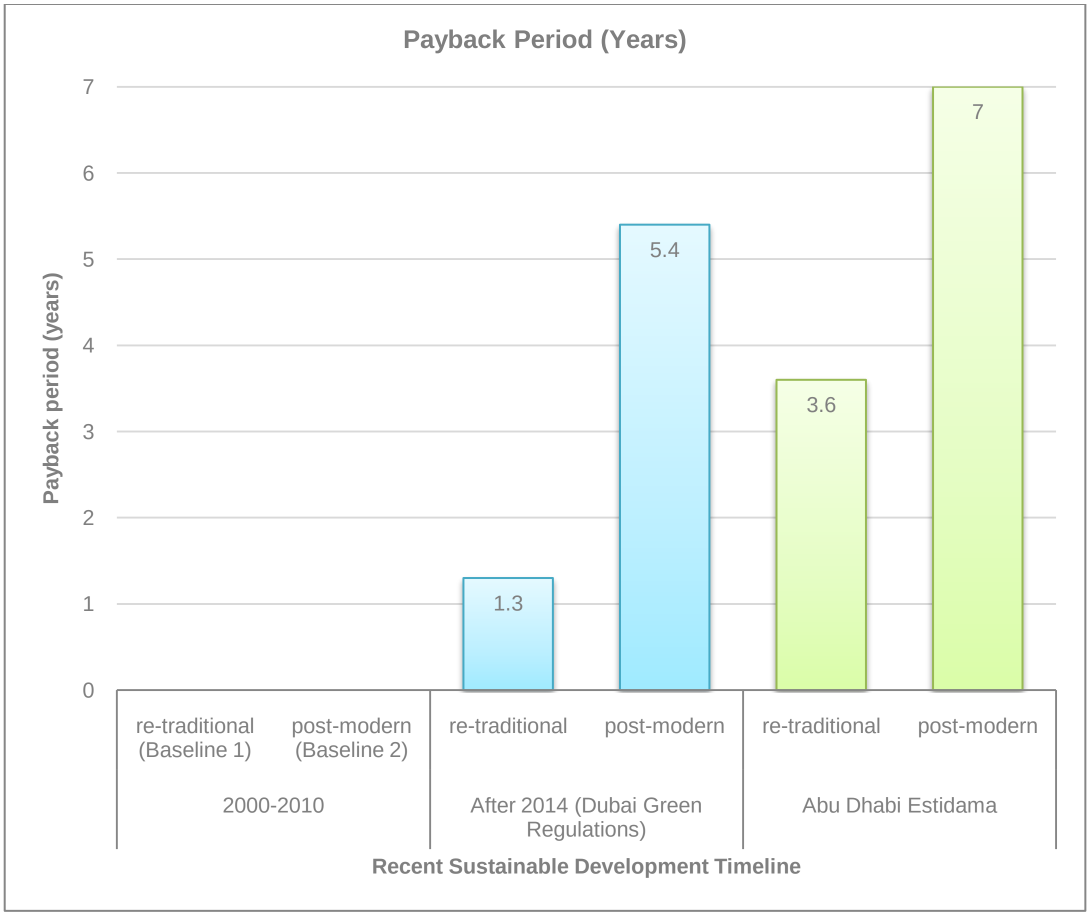

Figure 7.17: Payback Period (Years)

Figure 7.17 shows that in post-modern design of Dubai Green regulations the payback period was be 5.4 years while in the same type of Abu Dhabi Estidama the payback period was recorded to be 7 years in order to recover the additional cost of total construction.

From the previous discussion about the payback period it was found that the re-traditional design in all periods of sustainable development timeline is more cost effective than that of post-modern design and that’s mostly due to the excessive use of glass façades which is more costly and expensive than that of re-traditional design which requires less glass and more solids.

Chapter 8: Conclusions and Recommendation

8.1 Conclusions

Based on literature review, the computer simulation has found to be the most appropriate method to achieve the objectives of the research of sustainable development of local housing units in Dubai. The software of Integrated Environmental Solutions (IES-VE) was found the best software to be used in this research area due to its reliability, validity and flexibility to use.

Before conducting the computer simulation, a database survey using Dubai Municipality archives and permit system has been conducted in order to collect the required information for local housing units' specifications and building material properties.

After conducting the computer simulations, it was found that the traditional house has the minimum value of energy consumption among all other units. The only energy consumer of this type of buildings was the lighting units of tungsten lamps.
With the beginning of using air conditioning window units in 1970's, the total energy consumption has lifted up extremely about four times than the total energy of traditional unit.

Remarkable reductions has obtained in future cases of Dubai (49% - 63%) and Estidama cases of Abu Dhabi (57% - 71%) below 1970's – 1990's levels due to new policy instruments, energy efficiency direction and thermal performance development.

Another significant result has recorded is that the total energy cost of re-traditional design of Abu Dhabi Estidama unit which enclosing lighting and cooling energy is almost equal to the total energy cost of traditional building that involve lighting energy only which verify that the ability of future green practices and sustainable developments to re-create environmentally friendly buildings that present green and comfort balance within affordable price of energy.

Finally, it was found that the payback period of each unit in the recent sustainable development timeline is based on two reasons; the first reason is the design of the local housing unit (re-traditional or post-modern), the second reason is the level of sustainable instruments used in each type (Dubai Green Regulations or Abu Dhabi Estidama System). For example the payback period of re-traditional design of Dubai green regulations was 1.3 years with an extra construction cost of 0.46% above current levels while in Abu Dhabi Estidama unit of the same design the payback period reached 3.6 years with an additional construction cost of 1.46% but it is worth to mention that the unit that follows Estidama system is more sufficient and sustainable in term of energy consumption, thermal performance and sustainable development.

Based on that the re-traditional design was found to be more cost effective than post-modern design but in both cases the payback period range in all cases was found to be compatible with the city growth and improvement in term of sustainable development since it enhances the overall thermal performance of the houses which makes it more comfortable and reduces its total energy consumption which will lead to reduce the CO_2 emissions, operating costs, cooling loads and consequently ensure more sustainable future with minimized ecological footprint .

8.2 Recommendations for future studies

Throughout the conducted study of sustainable development of local housing units in UAE it was found that some investigations and studies needed to be conducted in future in the following areas:

- The effect of setbacks and surrounding neighbors on heat gain and thermal performance.
- The natural daylight and direct sunlight estimations on visual comfort and energy consumption.
- The mix use of HVAC systems and natural ventilation through operable windows and their impacts on energy performance and Indoor Air Quality.
- The impacts of integrating green roof strategies on thermal performance, energy consumption, water consumption and total cost.
- The integration of intelligent buildings systems, modern technologies, and new construction materials and their impacts on overall building performance, cost and conservations.

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Apendex A: Input Data Details – weather data model, rooms specifications, constructions material specifications, electrical lighting specifications.

Weather Model Data

Weather model data				
	Temperature		Humidity	Solar Radiation
	Dry bulb T Min	Dry bulb T Max	Wet bulb T at Max dry bulb	Linke Turbidity Factor
	(°C)	(°C)	(°C)	
Jan	19.1	27.9	17.2	2.3
Feb	21.9	30.5	18.1	2.35
Mar	26.1	35.1	18.7	2.56
Apr	28.5	39.1	20	2.86
May	30.5	42.1	21.4	3.07
Jun	31.7	42.9	23.1	3.23
Jul	34.3	44.2	24	3.31
Aug	34.3	44.1	24.2	3.15
Sep	30.8	41.2	22.9	2.84
Oct	27.7	38.2	21.5	2.64
Nov	23.7	33.8	19.6	2.43
Dec	20.8	30	18.9	2.37

Rooms Specifications

Room Settings 2000 – 2010		
Room ID	Floor Area (m^2)	Volume (m^3)
ROOM0000	65.7	197.1
ROOM0001	4.1	12.2
ROOM0002	17.5	52.6
ROOM0003	14.2	42.7
ROOM0004	16.6	49.8
ROOM0005	34.6	103.7
ROOM0007	8	24
ROOM0008	20.7	62
ROOM0009	14	41.9
ROOM0010	37	110.9
ROOM0011	65.7	197.1
ROOM0012	4.1	12.2

ROOM0013	17.5	52.6
ROOM0014	14.2	42.7
ROOM0015	16.6	49.8
ROOM0016	34.6	103.7
ROOM0017	8	24
ROOM0018	20.7	62
ROOM0020	37	110.9
ROOM0032	14	41.9
	464.8	1393.8

Associated Construction Material

Electric Lighting Templates 2000 - 2010			
Luminance Level	500 cd/m²	Luminaire:	DULCET: CROMPTON DULCET WITH OPAL DIFFUSER (source: unknown file)
Limiting Glare Index	19	Lamp:	1203: 1200mm Polylux T8 lamp
Working Surface Height	0.850 m	Lamp Colour:	WW: 3450.0 lm, lmf=3
Mounting Height	2.7 m		
Luminaire Maintenance Factor (LMF)	0.9		
Room Surface Maintenance Factor (RSMF)	0.9		
Lamp-Lumen Maintenance Factor (LLMF)	5000		
Replacement period			
Lamp Survival Factor (LSF)	1		

Construction Materials Details

2000 - 2010							
Floor							
Material ID (outside to inside)	Category	Thickness (m)	Conductivity W/(m·K)	Density (kg/m³)	Specific heat capacity (J/(kg·K))	Resistance (m²K/W)	Vapour resistance
SLATE TILES	Tiles	0.1	2	2700	753	0	0
Sand	Sands, Stones, & Soils	0.015	0.35	2080	840		
CAST CONCRETE	Concretes	0.2	1.13	2000	1000	0	0
Total construction thickness (m)	0.315						
R-value (m²K/W)	0.2698						
U-Value (W/m²K)	2.084						
Building Regulations - thermal bridging coefficient (W/m²K)	0.208						
Outside surface							
Emissivity	0.9						
Resistance (m2K/W)	0.04						
Solar absorptance	0.7						
Inside surface							
Emissivity	0.9						
Resistance (m2K/W)	0.17						
Solar absorptance	0.55						
Roof							
Material ID (outside to inside)	Category	Thickness (m)	Conductivity W/(m·K)	Density (kg/m³)	Specific heat capacity (J/(kg·K))	Resistance (m²K/W)	Vapour resistance
CONCRETE TILES	Tiles	0.015	1.1	2100	837	0	0
SAND	Sands, Stones, & Soils	0.015	0.35	2080	840	0	0
AERATED-CONCRETE SLAB	Concretes	0.07	0.16	500	840		

GLASS-FIBRE SLAB	Insulating material	0.075	0.035	25	1000		
AERATED-CONCRETE SLAB	Concretes	0.07	0.16	500	840		
GYPSUM PLASTERING	Plaster	0.01	0.16	801	837	0	0
Total construction thickness (m)	0.335						
R-value (m²K/W)	3.6369						
U-Value (W/m²K)	0.2648						
Building Regulations - thermal bridging coefficient (W/m²K)	0.026						
Outside surface							
Emissivity	0.9						
Resistance (m2K/W)	0.04						
Solar absorptance	0.5						
Inside surface							
Emissivity	0.9						
Resistance (m2K/W)	0.1						
Solar absorptance	0.55						
External walls							
Material ID (outside to inside)	Category	Thickness (m)	Conductivity W/(m·K)	Density (kg/m³)	Specific heat capacity (J/(kg·K))	Resistance (m²K/W)	Vapour resistance
GYPSUM PLASTERING	Plaster	0.015	0.42	1200	837	0	0
GLASS-FIBER - ORGANIC BONDED (ASHRAE)	Insulating material	0.05	0.036	100	1000		
CONCRETE BLOCK (LIGHTWEIGHT)	Concretes	0.2	0.19	600	1000	0	0
GYPSUM PLASTERING	Plaster	0.015	0.42	1200	837	0	0
Total construction thickness (m)	0.28						
R-value (m²K/W)	2.5129						
U-Value (W/m²K)	0.3727						
Building Regulations - thermal bridging coefficient	0.037						

(W/m2 K)							
Outside surface							
Emissivity	0.9						
Resistance (m2K/W)	0.04						
Solar absorptance	0.7						
Inside surface							
Emissivity	0.9						
Resistance (m2K/W)	0.13						
Solar absorptance	0.55						
Internal partitions							
Material ID (outside to inside)	Category	Thickness (m)	Conductivity W/(m·K)	Density (kg/m³)	Specific heat capacity (J/(kg·K))	Resistance (m²K/W)	Vapour resistance
PLASTER (LIGHTWEIGHT)	Plaster	0.013	0.16	600	1000	0	0
BRICKWORK (INNER LEAF)	Brick & Block work	0.105	0.62	1700	800	0	0
PLASTER (LIGHTWEIGHT)	Plaster	0.013	0.16	600	1000	0	0
Total construction thickness (m)	0.131						
R-value (m²K/W)	0.3319						
U-Value (W/m²K)	1.6896						
Building Regulations - thermal bridging coefficient (W/m2 K)	0.169						
Outside surface							
Emissivity	0.9						
Resistance (m2K/W)	0.13						
Solar absorptance	0.55						
Inside surface							
Emissivity	0.9						
Resistance (m2K/W)	0.13						
Solar absorptance	0.55						
Doors							

Material ID (outside to inside)	Category	Thickness (m)	Conductivity W/(m·K)	Density (kg/m³)	Specific heat capacity (J/(kg·K))	Resistance (m²K/W)	Vapour resistance
PINE (20% MOIST)	Timber	0.04	0.14	419	2720	0	0
Total construction thickness (m)	0.04						
R-value (m²K/W)	0.2857						
U-Value (W/m²K)	2.1944						
Building Regulations - thermal bridging coefficient (W/m2 K)	0.219						
Outside surface							
Emissivity	0.9						
Resistance (m2K/W)	0.04						
Solar absorptance	0.7						
Inside surface							
Emissivity	0.9						
Resistance (m2K/W)	0.13						
Solar absorptance	0.55						

External glazing								
Material ID (outside to inside)	Thickness (m)	Conductivity W/(m·K)	Outside reflectance	Inside reflectance	Transmittance	Refractive indesx	Convection coeffecient (W/m²K)	Resistance (m²K/W)
PILKINGTON K 6MM	0.006	1.06	0.09	0.09	0.69	1.526		
Cavity (Air)	0.012						2.08	0.3247
CLEAR FLOAT 6MM	0.006	1.06	0.07	0.07	0.78	1.526		
Total construction thickness (m)	0.024							
Frame material	Percentage		Absorbtance		Resistance (m²K/W)			U-value (W/m²K)
Metal	10%		0.7		0.3332			1.9873
U-value (glass only) (W/m²K)	1.9762							
U-value (with frame) (W/m²K)	1.9773							

Building Regulations - thermal bridging coefficient (W/m²K)	0.274
Outside surface	
Emissivity	0.9
Resistance (m²K/W)	0.04
Inside surface	
Emissivity	0.9
Resistance (m²K/W)	0.13

Appendix B: Simulation Model Results – 2000-2010 units

Thermal performance and energy consumption

2000's 2010 Re-traditional Unit Simulations – Thermal performance

External conduction Gain							
		Conduction gain - external walls (kW)	Conduction gain - external glazing (kW)	Conduction gain - external doors (kW)	Conduction gain - ground floor (kW)	Conduction gain - roof (kW)	External conduction gain (kW)
		20 rooms	20 rooms	20 rooms	20 rooms	20 rooms	20 rooms
Date	Time	2000-2010.clg	2000-2010.clg	2000-2010.clg	2000-2010.clg	2000-2010.clg	2000-2010.clg
January	0:30	0.6662	-0.7281	-0.0881	0.6879	0.3289	0.8667
	1:30	0.5894	-0.7928	-0.1021	0.6487	0.2637	0.607
	2:30	0.5356	-0.8511	-0.1136	0.5801	0.2141	0.365
	3:30	0.4832	-0.8957	-0.1233	0.487	0.1657	0.1169
	4:30	0.4294	-0.9195	-0.1308	0.3734	0.1175	-0.13
	5:30	0.373	-0.909	-0.1351	0.243	0.0693	-0.3587
	6:30	0.4705	-0.8397	-0.1299	0.2537	0.1114	-0.134
	7:30	0.2175	-0.6767	-0.1246	-0.008	-0.0697	-0.6615
	8:30	-0.2662	-0.3212	-0.0892	-0.7113	-0.3483	-1.7361
	9:30	-0.5047	0.096	-0.0006	-1.8026	-0.411	-2.6229
	10:30	-0.4565	0.484	0.1176	-1.99	-0.3869	-2.2318
	11:30	-0.3475	0.8188	0.216	-1.9954	-0.3458	-1.6539
	12:30	-0.3468	1.0456	0.2532	-2.3075	-0.3375	-1.693
	13:30	-0.448	1.1608	0.2662	-2.4087	-0.3472	-1.7768
	14:30	-0.5672	1.1326	0.3051	-2.5717	-0.3359	-2.0371
	15:30	-0.3212	0.9497	0.3452	-2.125	-0.2365	-1.3878
	16:30	-0.2363	0.5957	0.3494	-1.1028	-0.1598	-0.5538
	17:30	0.4973	0.2525	0.274	-0.1351	0.1913	1.0801
	18:30	0.5466	0.0353	0.1348	0.0861	0.2477	1.0505
	19:30	0.5369	-0.143	0.0496	0.2013	0.2737	0.9185
	20:30	0.5517	-0.3083	0.0028	0.322	0.2966	0.8648
	21:30	0.5619	-0.4526	-0.0295	0.4271	0.3046	0.8115
	22:30	0.5605	-0.5756	-0.055	0.5034	0.2971	0.7303
	23:30	0.5465	-0.6706	-0.0758	0.5436	0.2763	0.6199
February	0:30	1.0209	-0.3193	-0.0229	1.9971	0.5666	3.2423
	1:30	0.9413	-0.3826	-0.0366	1.9599	0.4941	2.976

	2:30	0.8844	-0.4398	-0.0479	1.894	0.4372	2.7278
	3:30	0.8289	-0.4835	-0.0575	1.8041	0.3819	2.4739
	4:30	0.7721	-0.5068	-0.0649	1.694	0.3273	2.2218
	5:30	0.7129	-0.4963	-0.0691	1.5674	0.2733	1.9882
	6:30	0.8077	-0.4277	-0.0639	1.5821	0.3102	2.2084
	7:30	0.3999	-0.2424	-0.0615	1.2965	0.0724	1.465
	8:30	0.0182	0.1576	-0.0203	0.4964	-0.2018	0.4501
	9:30	-0.1256	0.5862	0.0931	-0.4907	-0.226	-0.1631
	10:30	-0.1197	0.9876	0.217	-0.5266	-0.1996	0.3586
	11:30	-0.0031	1.3359	0.3117	-0.4621	-0.156	1.0263
	12:30	0.0114	1.5697	0.3396	-0.7226	-0.1373	1.0608
	13:30	-0.0652	1.6869	0.3438	-0.8065	-0.1486	1.0104
	14:30	-0.1714	1.6558	0.3865	-0.976	-0.1465	0.7483
	15:30	0.0125	1.4664	0.4344	-0.6645	-0.0625	1.1862
	16:30	-0.0257	1.1109	0.4309	0.0103	-0.0189	1.5077
	17:30	0.7821	0.6934	0.3733	1.0527	0.4105	3.312
	18:30	0.9151	0.4302	0.2257	1.3958	0.5056	3.4723
	19:30	0.8959	0.255	0.1223	1.5106	0.5281	3.3119
	20:30	0.9097	0.0928	0.0695	1.6301	0.5517	3.2537
	21:30	0.9203	-0.049	0.0356	1.7344	0.5586	3.1999
	22:30	0.9186	-0.1699	0.0098	1.8106	0.5473	3.1165
	23:30	0.9032	-0.2631	-0.0108	1.8514	0.5209	3.0016
March	0:30	1.5608	0.2998	0.0777	4.1789	0.9016	7.0187
	1:30	1.4785	0.2328	0.0632	4.1418	0.8208	6.7371
	2:30	1.4183	0.1725	0.0513	4.0744	0.7552	6.4717
	3:30	1.359	0.1264	0.0413	3.9816	0.6914	6.1997
	4:30	1.2981	0.1018	0.0334	3.8676	0.6286	5.9296
	5:30	1.2345	0.113	0.029	3.7361	0.5669	5.6795
	6:30	1.2372	0.2101	0.034	3.7016	0.5597	5.7425
	7:30	0.7692	0.4745	0.0488	3.2569	0.2465	4.7959
	8:30	0.4656	0.9211	0.1198	2.1963	0.0419	3.7447
	9:30	0.3671	1.3659	0.2415	1.5177	0.0469	3.539
	10:30	0.442	1.7856	0.3676	1.6462	0.0876	4.3291
	11:30	0.5423	2.1489	0.4502	1.8708	0.144	5.1562
	12:30	0.5632	2.392	0.4722	1.7466	0.1616	5.3356
	13:30	0.4875	2.5111	0.4824	1.5947	0.1425	5.2182
	14:30	0.4125	2.471	0.529	1.2994	0.1446	4.8565
	15:30	0.5419	2.2646	0.5656	1.5459	0.2305	5.1485
	16:30	0.5024	1.8889	0.5354	2.0593	0.2577	5.2437
	17:30	1.1919	1.4394	0.471	3.055	0.6951	6.8524

	18:30	1.4347	1.1113	0.3436	3.5037	0.8508	7.2441
	19:30	1.4407	0.907	0.2368	3.6653	0.8829	7.1327
	20:30	1.4516	0.7357	0.1774	3.793	0.905	7.0626
	21:30	1.4627	0.586	0.1403	3.9047	0.9106	7.0043
	22:30	1.4613	0.4584	0.1127	3.9867	0.8957	6.9148
	23:30	1.4451	0.36	0.0907	4.0313	0.8634	6.7904
April	0:30	1.96	0.6925	0.1437	5.8017	1.1731	9.7709
	1:30	1.8772	0.6124	0.1266	5.7626	1.0852	9.464
	2:30	1.8151	0.5402	0.1125	5.6871	1.0115	9.1665
	3:30	1.7527	0.4852	0.1006	5.5813	0.939	8.8587
	4:30	1.6875	0.4556	0.0913	5.4501	0.8673	8.5518
	5:30	1.6184	0.4685	0.086	5.298	0.7965	8.2674
	6:30	1.453	0.6347	0.0902	5.1559	0.7002	8.034
	7:30	1.0303	1.0069	0.1331	4.5062	0.3539	7.0304
	8:30	0.8155	1.471	0.2321	3.2568	0.2678	6.0433
	9:30	0.7802	1.9451	0.3619	2.8876	0.2833	6.2581
	10:30	0.8703	2.4	0.4767	3.2694	0.328	7.3444
	11:30	0.9705	2.7983	0.5448	3.5841	0.3851	8.2827
	12:30	0.9786	3.0717	0.5673	3.5506	0.3915	8.5597
	13:30	0.9023	3.2092	0.5931	3.291	0.3669	8.3626
	14:30	0.8407	3.171	0.6441	2.8997	0.376	7.9314
	15:30	0.9425	2.9519	0.6564	3.018	0.4694	8.0382
	16:30	0.937	2.5521	0.5962	3.5358	0.4875	8.1086
	17:30	1.4924	2.0833	0.5301	4.4799	0.8975	9.4832
	18:30	1.7473	1.684	0.4214	4.9589	1.1074	9.919
	19:30	1.8241	1.419	0.3253	5.191	1.163	9.9223
	20:30	1.8366	1.2148	0.2604	5.3508	1.1855	9.8482
	21:30	1.8531	1.0365	0.2181	5.4897	1.1923	9.7897
	22:30	1.8564	0.8845	0.1858	5.592	1.1765	9.6952
	23:30	1.8432	0.7673	0.1599	5.6492	1.1406	9.5602
May	0:30	2.2878	1.0235	0.1981	7.0544	1.3712	11.9351
	1:30	2.2039	0.9349	0.1795	7.0149	1.28	11.6132
	2:30	2.1397	0.8552	0.164	6.9352	1.2023	11.2963
	3:30	2.0744	0.7944	0.1508	6.8218	1.1253	10.9666
	4:30	2.0056	0.7616	0.1405	6.6804	1.0488	10.6369
	5:30	1.9006	0.7881	0.1345	6.4935	0.9584	10.2751
	6:30	1.6396	1.0053	0.1469	6.2994	0.8148	9.906
	7:30	1.1956	1.4175	0.212	5.5607	0.5028	8.8885
	8:30	1.168	1.8849	0.3263	4.4702	0.4535	8.3028
	9:30	1.1337	2.3695	0.4506	4.1168	0.4687	8.5394

	10:30	1.2207	2.8436	0.5497	4.524	0.5134	9.6514
	11:30	1.3187	3.2634	0.6095	4.8966	0.5666	10.6549
	12:30	1.3148	3.5579	0.6351	4.8645	0.5664	10.9387
	13:30	1.2313	3.7125	0.6685	4.5371	0.5422	10.6916
	14:30	1.1693	3.6825	0.718	4.1225	0.5547	10.247
	15:30	1.2512	3.469	0.7169	4.1854	0.6463	10.2688
	16:30	1.1943	3.0747	0.6422	4.7879	0.635	10.3341
	17:30	1.6546	2.6003	0.5617	5.5814	1.007	11.405
	18:30	2.0578	2.1372	0.4797	6.0855	1.2968	12.057
	19:30	2.1565	1.8266	0.3932	6.376	1.3674	12.1197
	20:30	2.1615	1.6015	0.3256	6.558	1.3868	12.0335
	21:30	2.1784	1.4048	0.2801	6.7154	1.3939	11.9727
	22:30	2.1834	1.2371	0.2449	6.8318	1.3781	11.8753
	23:30	2.1712	1.1078	0.2164	6.8979	1.3411	11.7344
June	0:30	2.4434	1.2233	0.228	7.5303	1.4662	12.8913
	1:30	2.3582	1.1375	0.2099	7.4919	1.3746	12.5721
	2:30	2.2928	1.0603	0.1949	7.4146	1.2965	12.2591
	3:30	2.2263	1.0014	0.1821	7.305	1.2191	11.9339
	4:30	2.1566	0.9697	0.1721	7.1684	1.1424	11.6091
	5:30	2.0373	1.0024	0.1663	6.9763	1.0451	11.2273
	6:30	1.7548	1.2275	0.1814	6.7639	0.8962	10.8238
	7:30	1.3207	1.6292	0.2511	6.0147	0.5992	9.8149
	8:30	1.315	2.0851	0.3658	5.0468	0.5529	9.3656
	9:30	1.3031	2.5582	0.4852	4.6635	0.5692	9.5792
	10:30	1.3862	3.0155	0.5775	5.0571	0.6119	10.6482
	11:30	1.4835	3.426	0.6346	5.4388	0.6647	11.6477
	12:30	1.4878	3.7155	0.6618	5.4352	0.6685	11.9688
	13:30	1.4148	3.8695	0.6912	5.141	0.6491	11.7656
	14:30	1.3483	3.8503	0.7352	4.7309	0.6576	11.3222
	15:30	1.3996	3.6556	0.7314	4.6902	0.739	11.2157
	16:30	1.3013	3.2737	0.6591	5.2139	0.7126	11.1607
	17:30	1.7126	2.8145	0.5767	6.0385	1.0441	12.1864
	18:30	2.2299	2.3248	0.5135	6.5705	1.3907	13.0294
	19:30	2.3262	2.0011	0.4237	6.8744	1.4668	13.0922
	20:30	2.3234	1.7831	0.3537	7.0481	1.4825	12.9907
	21:30	2.3377	1.5924	0.308	7.1991	1.4891	12.9264
	22:30	2.3414	1.4299	0.2734	7.3109	1.4734	12.829
	23:30	2.328	1.3045	0.2456	7.3745	1.4364	12.689
July	0:30	2.6527	1.6053	0.2859	8.4441	1.58	14.568
	1:30	2.5677	1.5294	0.2697	8.4083	1.4893	14.2643

	2:30	2.5032	1.461	0.2563	8.3386	1.4127	13.9717
	3:30	2.4384	1.4088	0.2449	8.2405	1.3374	13.67
	4:30	2.3711	1.3809	0.2361	8.1186	1.2631	13.3698
	5:30	2.2855	1.4002	0.231	7.9645	1.1831	13.0644
	6:30	2.0662	1.5964	0.2401	7.8064	1.0598	12.769
	7:30	1.6134	1.9905	0.3016	7.1605	0.739	11.805
	8:30	1.5249	2.4351	0.4124	6.1489	0.6767	11.198
	9:30	1.5084	2.8898	0.5325	5.6729	0.6936	11.2971
	10:30	1.5929	3.325	0.6283	6.0532	0.7369	12.3362
	11:30	1.7026	3.7107	0.6868	6.4756	0.7958	13.3715
	12:30	1.7223	3.9748	0.7111	6.5218	0.8068	13.7368
	13:30	1.6585	4.1137	0.7332	6.2617	0.7895	13.5566
	14:30	1.5887	4.0827	0.7741	5.8434	0.7927	13.0816
	15:30	1.6331	3.8878	0.7743	5.7511	0.8693	12.9157
	16:30	1.5484	3.5152	0.7035	6.2529	0.8385	12.8586
	17:30	1.9398	3.0708	0.6216	7.0524	1.1684	13.853
	18:30	2.4505	2.5962	0.5549	7.5761	1.5088	14.6864
	19:30	2.5471	2.2937	0.4665	7.8607	1.5842	14.7521
	20:30	2.5404	2.1003	0.3993	8.0095	1.598	14.6475
	21:30	2.5515	1.9311	0.3572	8.1399	1.6034	14.5831
	22:30	2.5528	1.7868	0.3259	8.2366	1.587	14.4889
	23:30	2.5379	1.6755	0.3011	8.2911	1.5497	14.3554
August	0:30	2.6113	1.608	0.2859	8.425	1.5511	14.4812
	1:30	2.5276	1.5328	0.2698	8.3885	1.4625	14.1813
	2:30	2.4649	1.465	0.2566	8.3185	1.3884	13.8933
	3:30	2.4022	1.4134	0.2453	8.2204	1.3155	13.5968
	4:30	2.337	1.3857	0.2366	8.099	1.2437	13.302
	5:30	2.2684	1.3979	0.2316	7.9583	1.173	13.0292
	6:30	2.1414	1.5653	0.2381	7.837	1.0858	12.8676
	7:30	1.656	1.9465	0.2866	7.203	0.741	11.8331
	8:30	1.4875	2.4016	0.3862	6.0612	0.6534	10.9898
	9:30	1.4443	2.868	0.5104	5.623	0.6673	11.113
	10:30	1.5334	3.3126	0.6194	5.997	0.7123	12.1747
	11:30	1.6418	3.6994	0.6856	6.3869	0.7722	13.1858
	12:30	1.6599	3.9617	0.709	6.4043	0.7829	13.5177
	13:30	1.591	4.0939	0.7311	6.1506	0.7617	13.3283
	14:30	1.5273	4.0535	0.7767	5.7472	0.7668	12.8716
	15:30	1.6019	3.8377	0.7846	5.7443	0.852	12.8205
	16:30	1.5601	3.4467	0.7201	6.2384	0.8406	12.8059
	17:30	2.0141	2.9904	0.6426	7.0859	1.2208	13.9539

	18:30	2.4016	2.5625	0.5494	7.6003	1.4827	14.5966
	19:30	2.4979	2.2896	0.4615	7.8534	1.547	14.6494
	20:30	2.4975	2.098	0.397	7.9991	1.5654	14.557
	21:30	2.5093	1.9304	0.356	8.1266	1.5714	14.4937
	22:30	2.5103	1.7875	0.3253	8.2207	1.5554	14.3992
	23:30	2.4956	1.6773	0.3008	8.2734	1.5191	14.2664
September	0:30	2.1993	1.0769	0.2027	6.8803	1.2823	11.6415
	1:30	2.1171	0.9975	0.1859	6.8415	1.1987	11.3406
	2:30	2.0561	0.926	0.1719	6.767	1.1298	11.0508
	3:30	1.9951	0.8714	0.1601	6.6626	1.0622	10.7515
	4:30	1.9316	0.8421	0.1509	6.5335	0.9951	10.4533
	5:30	1.8644	0.8547	0.1457	6.3839	0.9288	10.1775
	6:30	1.7779	1.0045	0.1503	6.2745	0.8573	10.0645
	7:30	1.2711	1.3646	0.183	5.6162	0.504	8.9389
	8:30	1.0628	1.8339	0.2775	4.405	0.4124	7.9915
	9:30	1.0216	2.3062	0.4076	4.0711	0.4253	8.2318
	10:30	1.111	2.7563	0.5249	4.3891	0.4667	9.248
	11:30	1.1952	3.1473	0.594	4.5364	0.5178	9.9907
	12:30	1.1881	3.4127	0.6149	4.4215	0.5189	10.1561
	13:30	1.1025	3.5357	0.644	4.1911	0.4936	9.967
	14:30	1.0479	3.4843	0.6981	3.8507	0.5114	9.5924
	15:30	1.2117	3.2531	0.7175	4.2134	0.6182	10.014
	16:30	1.2445	2.841	0.6664	4.8458	0.6803	10.2779
	17:30	1.8543	2.3604	0.5956	5.7078	1.105	11.6231
	18:30	2.0398	2.0247	0.4697	6.0983	1.2279	11.8604
	19:30	2.0557	1.7965	0.3722	6.2754	1.2639	11.7637
	20:30	2.078	1.594	0.3148	6.4347	1.2898	11.7114
	21:30	2.0949	1.4174	0.2753	6.5718	1.296	11.6554
	22:30	2.0969	1.2669	0.2441	6.6724	1.2804	11.5606
	23:30	2.0827	1.1508	0.2186	6.7284	1.2464	11.427
October	0:30	1.7945	0.6019	0.1272	5.3928	0.9984	8.9148
	1:30	1.7143	0.5223	0.1104	5.3524	0.9229	8.6222
	2:30	1.6559	0.4506	0.0964	5.276	0.8622	8.3412
	3:30	1.5978	0.3958	0.0846	5.1697	0.8027	8.0505
	4:30	1.5373	0.3663	0.0754	5.0383	0.7432	7.7605
	5:30	1.4731	0.3788	0.0701	4.8864	0.6839	7.4923
	6:30	1.4136	0.5051	0.0735	4.8002	0.6442	7.4364
	7:30	0.9175	0.8193	0.0957	4.2326	0.316	6.3811
	8:30	0.6858	1.2785	0.1798	3.0877	0.1909	5.4229
	9:30	0.629	1.7372	0.3041	2.658	0.1995	5.5278

	10:30	0.7213	2.1745	0.4276	2.7899	0.231	6.3444
	11:30	0.7757	2.5491	0.495	2.678	0.2663	6.764
	12:30	0.7437	2.8036	0.5107	2.5185	0.2588	6.8354
	13:30	0.6217	2.9127	0.5454	2.3106	0.2349	6.6252
	14:30	0.614	2.8512	0.6041	2.2314	0.2714	6.5721
	15:30	0.8546	2.617	0.6366	2.7673	0.4003	7.2758
	16:30	0.949	2.202	0.6016	3.5554	0.5228	7.8307
	17:30	1.5915	1.8051	0.5058	4.3669	0.8708	9.14
	18:30	1.6442	1.5426	0.3723	4.6275	0.9342	9.1209
	19:30	1.6519	1.3231	0.2875	4.7888	0.9668	9.018
	20:30	1.6754	1.1202	0.2365	4.9492	0.9914	8.9727
	21:30	1.6904	0.9432	0.199	5.0865	0.9971	8.9163
	22:30	1.691	0.7924	0.1684	5.1868	0.9841	8.8227
	23:30	1.6767	0.6761	0.1431	5.242	0.9554	8.6934
November	0:30	1.2527	-0.0125	0.0285	3.3036	0.6504	5.2226
	1:30	1.1758	-0.0884	0.0124	3.2639	0.5834	4.9471
	2:30	1.1212	-0.1567	-0.0009	3.1897	0.5315	4.6848
	3:30	1.0673	-0.2089	-0.0122	3.0867	0.4805	4.4134
	4:30	1.0112	-0.237	-0.021	2.9599	0.4293	4.1423
	5:30	0.9516	-0.2252	-0.026	2.8133	0.3777	3.8914
	6:30	1.0069	-0.1368	-0.0209	2.7854	0.3951	4.0296
	7:30	0.58	0.1032	-0.011	2.4098	0.1189	3.2008
	8:30	0.1928	0.5393	0.0469	1.4513	-0.0848	2.1454
	9:30	0.1271	0.9738	0.1611	0.6677	-0.091	1.8387
	10:30	0.1977	1.3849	0.284	0.6906	-0.0593	2.4979
	11:30	0.2395	1.7369	0.3596	0.46	-0.0354	2.7607
	12:30	0.2033	1.9772	0.384	0.2448	-0.0425	2.7669
	13:30	0.0686	2.0825	0.4165	0.0771	-0.0585	2.5863
	14:30	0.0777	2.0271	0.4672	0.102	-0.0201	2.6539
	15:30	0.3514	1.8069	0.5082	0.7783	0.1297	3.5744
	16:30	0.6083	1.4066	0.486	1.7522	0.281	4.5341
	17:30	1.0739	1.0986	0.3667	2.3827	0.5192	5.4411
	18:30	1.0883	0.8829	0.2448	2.5655	0.5633	5.3448
	19:30	1.1047	0.6736	0.1753	2.7207	0.5985	5.2729
	20:30	1.1292	0.4804	0.1306	2.8743	0.6228	5.2373
	21:30	1.1439	0.3119	0.0961	3.0057	0.6302	5.1878
	22:30	1.145	0.1683	0.0673	3.1014	0.6215	5.1035
	23:30	1.1324	0.0574	0.0434	3.1538	0.5994	4.9864
December	0:30	0.8575	-0.4548	-0.0444	1.6343	0.4225	2.4151
	1:30	0.7818	-0.523	-0.059	1.5947	0.3596	2.1541

	2:30	0.7291	-0.5846	-0.0711	1.5242	0.312	1.9096
	3:30	0.6777	-0.6317	-0.0813	1.4278	0.2655	1.6581
	4:30	0.6246	-0.657	-0.0892	1.31	0.2189	1.4073
	5:30	0.5686	-0.6461	-0.0937	1.1744	0.172	1.1752
	6:30	0.6662	-0.5744	-0.0885	1.1793	0.2151	1.3977
	7:30	0.3922	-0.3945	-0.0835	0.8943	0.0228	0.8313
	8:30	-0.1043	-0.0138	-0.0455	0.1038	-0.2493	-0.3092
	9:30	-0.2904	0.4029	0.0543	-0.8914	-0.2946	-1.0191
	10:30	-0.2237	0.7905	0.1725	-1.0272	-0.2644	-0.5522
	11:30	-0.151	1.1232	0.2609	-1.2411	-0.2347	-0.2426
	12:30	-0.1752	1.3477	0.2942	-1.5269	-0.2364	-0.2967
	13:30	-0.3009	1.4545	0.3165	-1.6248	-0.2458	-0.4004
	14:30	-0.3497	1.4125	0.358	-1.6508	-0.2198	-0.4499
	15:30	-0.0506	1.2136	0.3956	-0.9749	-0.087	0.4967
	16:30	0.1766	0.8409	0.3893	0.1246	0.0363	1.5678
	17:30	0.6956	0.5489	0.2814	0.8231	0.2895	2.6385
	18:30	0.712	0.3514	0.1591	0.9875	0.3316	2.5416
	19:30	0.7186	0.1629	0.0906	1.1171	0.3629	2.452
	20:30	0.7381	-0.0114	0.0483	1.2487	0.386	2.4097
	21:30	0.75	-0.1635	0.0165	1.3622	0.394	2.3592
	22:30	0.7496	-0.2932	-0.0096	1.4446	0.3872	2.2786
	23:30	0.7366	-0.3932	-0.0313	1.4885	0.368	2.1685
total gains		10697.7	11616	2421.34	33679	5547.7	63962.259
	Internal conduction Gain						
		Conduction gain - internal walls (kW) 20 rooms	Conduction gain - internal glazing (kW) 20 rooms	Conduction gain - internal doors (kW) 20 rooms	Conduction gain - floor (kW) 20 rooms	Conduction gain - ceiling (kW) 20 rooms	Internal conduction gain (kW) 20 rooms
Date	Time	2000-2010.clg	2000-2010.clg	2000-2010.clg	2000-2010.clg	2000-2010.clg	2000-2010.clg
January	0:30	0.4206	0	0.0114	0.1874	0.3071	0.9266
	1:30	0.3778	0	0.0066	0.1699	0.2768	0.831
	2:30	0.3533	0	0.0045	0.1565	0.2521	0.7664
	3:30	0.3333	0	0.0036	0.1442	0.2335	0.7146
	4:30	0.3161	0	0.0033	0.1325	0.2194	0.6714
	5:30	0.2996	0	0.0031	0.1207	0.2077	0.6311
	6:30	0.5459	0	0.0141	0.1966	0.3435	1.1
	7:30	0.1684	0	-0.0095	0.0105	0.2562	0.4256
	8:30	-0.4445	0	-0.0264	-0.6001	0.0148	-1.0562
	9:30	-0.5228	0	-0.0121	-0.8873	-0.2388	-1.661

	10:30	-0.5884	0	-0.0068	-0.7673	-0.2446	-1.6071
	11:30	-0.4974	0	-0.0009	-0.566	-0.1106	-1.1748
	12:30	-0.4193	0	-0.0019	-0.4931	-0.047	-0.9613
	13:30	-0.4213	0	-0.0036	-0.571	-0.0981	-1.094
	14:30	-0.4732	0	-0.0053	-0.6969	-0.1966	-1.372
	15:30	-0.4799	0	-0.0003	-0.6149	-0.0717	-1.1668
	16:30	-0.7264	0	-0.015	-0.3003	-0.0166	-1.0583
	17:30	0.2366	0	0.0148	0.1593	0.3768	0.7875
	18:30	0.3428	0	0.0111	0.2113	0.4328	0.998
	19:30	0.3004	0	0.0047	0.1848	0.3757	0.8655
	20:30	0.2608	0	0.002	0.1609	0.3176	0.7413
	21:30	0.2282	0	0.001	0.1415	0.267	0.6377
	22:30	0.2041	0	0.0008	0.1265	0.2262	0.5577
	23:30	0.1874	0	0.0009	0.1148	0.1947	0.4978
February	0:30	0.4233	0	0.0115	0.2529	0.2639	0.9516
	1:30	0.381	0	0.0067	0.2349	0.2309	0.8535
	2:30	0.357	0	0.0046	0.2213	0.2038	0.7866
	3:30	0.3372	0	0.0037	0.2089	0.1831	0.7329
	4:30	0.3201	0	0.0034	0.1972	0.1672	0.6878
	5:30	0.3036	0	0.0032	0.1853	0.1538	0.6458
	6:30	0.5499	0	0.0141	0.2613	0.288	1.1133
	7:30	0.135	0	-0.0072	-0.0289	0.1852	0.2841
	8:30	-0.5156	0	-0.0261	-0.6986	-0.0801	-1.3203
	9:30	-0.5551	0	-0.014	-0.8821	-0.2773	-1.7285
	10:30	-0.5686	0	-0.0091	-0.7238	-0.2426	-1.544
	11:30	-0.478	0	-0.0012	-0.4828	-0.1137	-1.0757
	12:30	-0.3884	0	-0.001	-0.3762	-0.0523	-0.8179
	13:30	-0.3696	0	-0.0027	-0.4683	-0.101	-0.9416
	14:30	-0.3899	0	-0.004	-0.6537	-0.2043	-1.252
	15:30	-0.3788	0	0.0001	-0.675	-0.0989	-1.1526
	16:30	-0.7827	0	-0.0179	-0.4571	-0.0874	-1.3451
	17:30	0.0912	0	0.0119	0.168	0.3019	0.5729
	18:30	0.3424	0	0.013	0.286	0.4126	1.054
	19:30	0.3014	0	0.0056	0.258	0.3531	0.9181
	20:30	0.262	0	0.0024	0.2317	0.2899	0.786
	21:30	0.2295	0	0.0012	0.2102	0.2345	0.6755
	22:30	0.2057	0	0.0009	0.1937	0.1896	0.5899
	23:30	0.1895	0	0.001	0.181	0.1545	0.526
March	0:30	0.4384	0	0.0117	0.3638	0.1789	0.9928
	1:30	0.3957	0	0.0069	0.3456	0.1439	0.8921

	2:30	0.3717	0	0.0047	0.3318	0.1153	0.8235
	3:30	0.3519	0	0.0039	0.3192	0.0934	0.7685
	4:30	0.3349	0	0.0036	0.3074	0.0765	0.7224
	5:30	0.3183	0	0.0034	0.2955	0.0622	0.6793
	6:30	0.4823	0	0.0099	0.3251	0.1725	0.9897
	7:30	-0.1101	0	-0.0214	-0.1867	0.0102	-0.308
	8:30	-0.6395	0	-0.0207	-0.7799	-0.2938	-1.7339
	9:30	-0.6702	0	-0.0078	-0.7714	-0.4015	-1.8509
	10:30	-0.5106	0	-0.0058	-0.5611	-0.2902	-1.3677
	11:30	-0.3557	0	0.0007	-0.2643	-0.133	-0.7523
	12:30	-0.2727	0	0.0008	-0.1639	-0.0809	-0.5167
	13:30	-0.2755	0	-0.0022	-0.2992	-0.1495	-0.7264
	14:30	-0.328	0	-0.0045	-0.5268	-0.2598	-1.1192
	15:30	-0.2876	0	-0.0012	-0.616	-0.1748	-1.0796
	16:30	-0.7794	0	-0.0156	-0.5338	-0.2028	-1.5316
	17:30	-0.0827	0	0.0085	0.1783	0.1657	0.2698
	18:30	0.3312	0	0.0122	0.3851	0.325	1.0536
	19:30	0.3279	0	0.0065	0.3753	0.2866	0.9964
	20:30	0.2845	0	0.0028	0.3472	0.219	0.8535
	21:30	0.249	0	0.0014	0.324	0.1591	0.7335
	22:30	0.223	0	0.0011	0.3061	0.1103	0.6405
	23:30	0.2054	0	0.0011	0.2925	0.072	0.571
April	0:30	0.428	0	0.0118	0.4348	0.1009	0.9755
	1:30	0.3899	0	0.007	0.4183	0.068	0.8831
	2:30	0.3706	0	0.005	0.406	0.0419	0.8235
	3:30	0.3554	0	0.0042	0.3949	0.0228	0.7773
	4:30	0.3425	0	0.0039	0.3841	0.0085	0.739
	5:30	0.3291	0	0.0037	0.3727	-0.0034	0.7022
	6:30	0.2826	0	-0.0058	0.2673	0.0551	0.5993
	7:30	-0.2888	0	-0.0143	-0.4626	-0.1319	-0.8976
	8:30	-0.5596	0	-0.0103	-0.7916	-0.4173	-1.7789
	9:30	-0.6231	0	-0.0095	-0.6178	-0.4498	-1.7002
	10:30	-0.4387	0	-0.003	-0.3205	-0.2768	-1.039
	11:30	-0.2326	0	0.002	-0.0162	-0.1139	-0.3607
	12:30	-0.1642	0	0.0015	0.0358	-0.0789	-0.2058
	13:30	-0.2032	0	-0.0024	-0.1479	-0.1681	-0.5215
	14:30	-0.2759	0	-0.0053	-0.4056	-0.2831	-0.9699
	15:30	-0.2295	0	-0.0027	-0.5369	-0.2295	-0.9986
	16:30	-0.615	0	-0.0161	-0.5967	-0.2417	-1.4695
	17:30	-0.2559	0	0.0047	0.1286	0.085	-0.0376

	18:30	0.2122	0	0.0102	0.4173	0.2235	0.8632
	19:30	0.2982	0	0.0081	0.4368	0.2084	0.9514
	20:30	0.2585	0	0.0035	0.4108	0.1398	0.8126
	21:30	0.2266	0	0.0016	0.3895	0.0792	0.697
	22:30	0.2044	0	0.0011	0.3735	0.0303	0.6094
	23:30	0.1907	0	0.0012	0.3617	-0.0072	0.5464
May	0:30	0.4308	0	0.0119	0.4918	0.0426	0.9772
	1:30	0.3939	0	0.0071	0.4762	0.0107	0.888
	2:30	0.3761	0	0.0051	0.4649	-0.014	0.8322
	3:30	0.3627	0	0.0044	0.4545	-0.0316	0.7899
	4:30	0.3514	0	0.0041	0.4442	-0.0444	0.7554
	5:30	0.3023	0	0.0014	0.4144	-0.0667	0.6513
	6:30	0.2081	0	-0.0039	0.1942	-0.0271	0.3713
	7:30	-0.3297	0	-0.0153	-0.5127	-0.2559	-1.1135
	8:30	-0.5405	0	-0.0099	-0.6699	-0.446	-1.6663
	9:30	-0.5684	0	-0.0081	-0.4748	-0.4639	-1.5152
	10:30	-0.3668	0	-0.0014	-0.163	-0.2883	-0.8194
	11:30	-0.1501	0	0.0033	0.1241	-0.128	-0.1506
	12:30	-0.1017	0	0.002	0.1497	-0.1042	-0.0542
	13:30	-0.1666	0	-0.0025	-0.0462	-0.2018	-0.417
	14:30	-0.2504	0	-0.0057	-0.3105	-0.3201	-0.8868
	15:30	-0.2309	0	-0.0038	-0.457	-0.2914	-0.9831
	16:30	-0.6172	0	-0.0193	-0.6032	-0.3074	-1.5472
	17:30	-0.4438	0	-0.001	0.0185	-0.0303	-0.4566
	18:30	0.1462	0	0.0117	0.4316	0.1394	0.7288
	19:30	0.304	0	0.0106	0.4871	0.1511	0.9528
	20:30	0.2628	0	0.0046	0.4633	0.0822	0.8128
	21:30	0.2298	0	0.0021	0.4434	0.0208	0.6961
	22:30	0.2069	0	0.0013	0.4286	-0.0285	0.6083
	23:30	0.1931	0	0.0013	0.4178	-0.066	0.5461
June	0:30	0.4388	0	0.012	0.5169	0.0285	0.9962
	1:30	0.4005	0	0.0072	0.5007	-0.0048	0.9035
	2:30	0.3814	0	0.0052	0.4888	-0.0309	0.8445
	3:30	0.3667	0	0.0044	0.4779	-0.0498	0.7992
	4:30	0.3542	0	0.0041	0.4674	-0.0637	0.762
	5:30	0.2835	0	0	0.4287	-0.0929	0.6194
	6:30	0.1459	0	-0.0087	0.1942	-0.0678	0.2636
	7:30	-0.3668	0	-0.0165	-0.4801	-0.3015	-1.1649
	8:30	-0.5249	0	-0.0069	-0.6239	-0.4585	-1.6143
	9:30	-0.5424	0	-0.0059	-0.4334	-0.4779	-1.4595

	10:30	-0.3445	0	-0.0001	-0.131	-0.3068	-0.7824
	11:30	-0.1313	0	0.0039	0.1517	-0.1494	-0.1251
	12:30	-0.0779	0	0.0025	0.1898	-0.1184	-0.0041
	13:30	-0.1389	0	-0.0019	0.0168	-0.2066	-0.3306
	14:30	-0.2305	0	-0.0056	-0.2453	-0.3269	-0.8084
	15:30	-0.2482	0	-0.0054	-0.4111	-0.3332	-0.9979
	16:30	-0.6568	0	-0.0221	-0.5889	-0.3809	-1.6487
	17:30	-0.5083	0	-0.005	-0.112	-0.0984	-0.7237
	18:30	0.1439	0	0.0147	0.4313	0.1107	0.7006
	19:30	0.3185	0	0.0129	0.5174	0.1428	0.9915
	20:30	0.2767	0	0.0056	0.4925	0.0735	0.8484
	21:30	0.2423	0	0.0026	0.4715	0.0108	0.7272
	22:30	0.2178	0	0.0016	0.4555	-0.0399	0.6349
	23:30	0.2024	0	0.0014	0.4437	-0.0788	0.5688
July	0:30	0.4389	0	0.0119	0.5625	-0.0159	0.9974
	1:30	0.3988	0	0.0071	0.5455	-0.0505	0.9009
	2:30	0.3776	0	0.0051	0.533	-0.0784	0.8372
	3:30	0.3607	0	0.0043	0.5217	-0.0994	0.7872
	4:30	0.3461	0	0.0039	0.5109	-0.1154	0.7455
	5:30	0.3134	0	0.0026	0.4902	-0.1356	0.6706
	6:30	0.2266	0	-0.0046	0.3261	-0.092	0.4562
	7:30	-0.3251	0	-0.0177	-0.3689	-0.3045	-1.0162
	8:30	-0.5174	0	-0.0088	-0.5975	-0.5041	-1.6278
	9:30	-0.5797	0	-0.008	-0.4229	-0.557	-1.5676
	10:30	-0.3966	0	-0.0018	-0.1284	-0.3947	-0.9214
	11:30	-0.1721	0	0.0031	0.1734	-0.2279	-0.2234
	12:30	-0.097	0	0.0025	0.2373	-0.1805	-0.0376
	13:30	-0.1454	0	-0.0015	0.083	-0.2574	-0.3213
	14:30	-0.2329	0	-0.0053	-0.181	-0.3775	-0.7967
	15:30	-0.2474	0	-0.005	-0.3512	-0.3935	-0.997
	16:30	-0.6464	0	-0.0213	-0.5376	-0.4387	-1.644
	17:30	-0.5061	0	-0.0043	-0.064	-0.158	-0.7325
	18:30	0.137	0	0.0141	0.481	0.0578	0.69
	19:30	0.3209	0	0.0126	0.5676	0.0963	0.9975
	20:30	0.2794	0	0.0055	0.5417	0.0288	0.8554
	21:30	0.245	0	0.0026	0.5196	-0.033	0.7342
	22:30	0.22	0	0.0016	0.5027	-0.0833	0.6409
	23:30	0.2038	0	0.0014	0.49	-0.1224	0.5729
August	0:30	0.4315	0	0.0118	0.5605	-0.0222	0.9816
	1:30	0.392	0	0.007	0.5436	-0.0561	0.8866

	2:30	0.3711	0	0.0049	0.5312	-0.0833	0.8239
	3:30	0.3544	0	0.0041	0.5199	-0.1039	0.7746
	4:30	0.34	0	0.0038	0.5091	-0.1195	0.7334
	5:30	0.3255	0	0.0036	0.4978	-0.1327	0.6942
	6:30	0.3283	0	0.0027	0.4012	-0.0646	0.6676
	7:30	-0.2764	0	-0.0176	-0.2964	-0.2684	-0.8588
	8:30	-0.5399	0	-0.0123	-0.6281	-0.5298	-1.71
	9:30	-0.6146	0	-0.0108	-0.4689	-0.5822	-1.6765
	10:30	-0.4409	0	-0.0035	-0.1741	-0.419	-1.0375
	11:30	-0.2216	0	0.002	0.1348	-0.2498	-0.3345
	12:30	-0.144	0	0.0018	0.2008	-0.203	-0.1443
	13:30	-0.1835	0	-0.002	0.0357	-0.2831	-0.4328
	14:30	-0.2581	0	-0.0053	-0.2263	-0.3979	-0.8876
	15:30	-0.2351	0	-0.0035	-0.3747	-0.3789	-0.9922
	16:30	-0.6013	0	-0.0178	-0.5205	-0.4061	-1.5457
	17:30	-0.3961	0	0.0015	0.1413	-0.1135	-0.3669
	18:30	0.1569	0	0.0106	0.519	0.0655	0.7519
	19:30	0.3069	0	0.01	0.5637	0.083	0.9637
	20:30	0.2667	0	0.0043	0.5381	0.0166	0.8257
	21:30	0.234	0	0.002	0.5165	-0.0432	0.7093
	22:30	0.2106	0	0.0013	0.5	-0.0919	0.62
	23:30	0.1956	0	0.0013	0.4878	-0.1297	0.5549
September	0:30	0.4161	0	0.0116	0.4837	0.0356	0.947
	1:30	0.3786	0	0.0069	0.4675	0.0042	0.8572
	2:30	0.3596	0	0.0048	0.4556	-0.0206	0.7994
	3:30	0.3447	0	0.0041	0.4445	-0.0388	0.7545
	4:30	0.3319	0	0.0038	0.4339	-0.0523	0.7173
	5:30	0.3188	0	0.0036	0.4226	-0.0635	0.6815
	6:30	0.3473	0	0.0024	0.346	0.0191	0.7148
	7:30	-0.2899	0	-0.0188	-0.3655	-0.185	-0.8593
	8:30	-0.606	0	-0.0117	-0.6974	-0.4726	-1.7876
	9:30	-0.6396	0	-0.0111	-0.5617	-0.5027	-1.7151
	10:30	-0.4327	0	-0.0043	-0.3013	-0.3327	-1.071
	11:30	-0.2747	0	0.0011	-0.0229	-0.1943	-0.4908
	12:30	-0.222	0	0.0005	0.007	-0.1786	-0.3932
	13:30	-0.2451	0	-0.0029	-0.1891	-0.271	-0.7082
	14:30	-0.3131	0	-0.0049	-0.4099	-0.3738	-1.1017
	15:30	-0.2282	0	-0.0007	-0.4791	-0.2515	-0.9595
	16:30	-0.6426	0	-0.0133	-0.3245	-0.2343	-1.2147
	17:30	0.0045	0	0.0087	0.3514	0.0809	0.4455

	18:30	0.2969	0	0.0103	0.4983	0.1835	0.989
	19:30	0.2786	0	0.005	0.4806	0.1296	0.8939
	20:30	0.2405	0	0.0021	0.4555	0.0635	0.7615
	21:30	0.2105	0	0.001	0.4356	0.0062	0.6534
	22:30	0.1902	0	0.0008	0.4209	-0.0395	0.5723
	23:30	0.1779	0	0.001	0.41	-0.0746	0.5143
October	0:30	0.4155	0	0.0115	0.4098	0.088	0.9249
	1:30	0.3769	0	0.0068	0.3941	0.0589	0.8367
	2:30	0.357	0	0.0047	0.3824	0.036	0.7801
	3:30	0.3413	0	0.004	0.3715	0.0196	0.7363
	4:30	0.328	0	0.0037	0.3608	0.0077	0.7002
	5:30	0.3145	0	0.0035	0.3495	-0.0021	0.6653
	6:30	0.3966	0	0.0049	0.3277	0.0954	0.8247
	7:30	-0.2697	0	-0.0214	-0.2537	-0.0959	-0.6406
	8:30	-0.5854	0	-0.0144	-0.6856	-0.3846	-1.67
	9:30	-0.5351	0	-0.0102	-0.6335	-0.4277	-1.6065
	10:30	-0.4485	0	-0.0032	-0.4131	-0.3039	-1.1687
	11:30	-0.3588	0	0.0004	-0.1944	-0.1909	-0.7437
	12:30	-0.3191	0	-0.001	-0.198	-0.1853	-0.7034
	13:30	-0.3442	0	-0.0039	-0.3858	-0.2829	-1.0168
	14:30	-0.3738	0	-0.0046	-0.5352	-0.3322	-1.2458
	15:30	-0.3532	0	0.0017	-0.4525	-0.1489	-0.9529
	16:30	-0.5924	0	-0.0111	-0.0458	-0.1009	-0.7503
	17:30	0.2186	0	0.0121	0.384	0.2002	0.8149
	18:30	0.3259	0	0.0089	0.4244	0.2291	0.9882
	19:30	0.282	0	0.0037	0.3984	0.1647	0.8488
	20:30	0.2432	0	0.0015	0.3758	0.1025	0.723
	21:30	0.2128	0	0.0008	0.3582	0.0494	0.6211
	22:30	0.1917	0	0.0007	0.3451	0.0073	0.5448
	23:30	0.1784	0	0.0009	0.3354	-0.0247	0.49
November	0:30	0.3992	0	0.0113	0.3035	0.1611	0.8752
	1:30	0.361	0	0.0066	0.2884	0.1348	0.7907
	2:30	0.3411	0	0.0045	0.277	0.1141	0.7367
	3:30	0.3254	0	0.0037	0.2664	0.0994	0.695
	4:30	0.3121	0	0.0034	0.256	0.089	0.6606
	5:30	0.2987	0	0.0033	0.245	0.0805	0.6275
	6:30	0.4946	0	0.0117	0.2971	0.2083	1.0117
	7:30	-0.1039	0	-0.0213	-0.0984	0.068	-0.1555
	8:30	-0.5663	0	-0.0274	-0.6734	-0.2356	-1.5026
	9:30	-0.4905	0	-0.0049	-0.7311	-0.3353	-1.5619

	10:30	-0.5006	0	-0.0006	-0.5383	-0.2584	-1.2979
	11:30	-0.4211	0	-0.0001	-0.3713	-0.1595	-0.9521
	12:30	-0.3785	0	-0.0017	-0.3731	-0.15	-0.9034
	13:30	-0.3976	0	-0.0042	-0.5134	-0.2428	-1.158
	14:30	-0.4247	0	-0.0023	-0.5992	-0.2629	-1.2891
	15:30	-0.462	0	0.0009	-0.3667	-0.0694	-0.8972
	16:30	-0.3667	0	-0.0066	0.0441	0.0267	-0.3025
	17:30	0.2798	0	0.0117	0.3034	0.2809	0.8758
	18:30	0.2971	0	0.0067	0.3069	0.2708	0.8815
	19:30	0.2564	0	0.0026	0.2833	0.2121	0.7545
	20:30	0.2207	0	0.001	0.2634	0.1566	0.6417
	21:30	0.1929	0	0.0005	0.2481	0.1096	0.551
	22:30	0.1736	0	0.0005	0.2367	0.0726	0.4834
	23:30	0.1615	0	0.0007	0.2283	0.0449	0.4354
December	0:30	0.407	0	0.0113	0.2263	0.2425	0.8871
	1:30	0.366	0	0.0065	0.21	0.2151	0.7976
	2:30	0.3433	0	0.0044	0.1977	0.1931	0.7385
	3:30	0.325	0	0.0036	0.1862	0.177	0.6918
	4:30	0.3094	0	0.0033	0.1752	0.1651	0.6529
	5:30	0.2941	0	0.0031	0.1639	0.1553	0.6164
	6:30	0.5415	0	0.0141	0.24	0.2927	1.0882
	7:30	0.1354	0	-0.0087	0.025	0.1967	0.3484
	8:30	-0.5072	0	-0.0288	-0.5835	-0.0801	-1.1995
	9:30	-0.5198	0	-0.0108	-0.804	-0.2895	-1.624
	10:30	-0.5639	0	-0.0044	-0.6587	-0.2699	-1.4969
	11:30	-0.4736	0	-0.0015	-0.4946	-0.1539	-1.1237
	12:30	-0.4294	0	-0.0028	-0.4663	-0.1243	-1.0228
	13:30	-0.4347	0	-0.0044	-0.5608	-0.1973	-1.1972
	14:30	-0.4998	0	-0.0049	-0.6415	-0.2451	-1.3914
	15:30	-0.5106	0	-0.0015	-0.4503	-0.0657	-1.0282
	16:30	-0.4609	0	-0.0068	-0.0695	0.041	-0.4962
	17:30	0.2849	0	0.0138	0.227	0.3427	0.8683
	18:30	0.3166	0	0.0081	0.2366	0.3481	0.9095
	19:30	0.2751	0	0.0033	0.2122	0.2922	0.7829
	20:30	0.2378	0	0.0014	0.1912	0.2381	0.6685
	21:30	0.2079	0	0.0007	0.1745	0.1918	0.5749
	22:30	0.1863	0	0.0006	0.1619	0.155	0.5038
	23:30	0.1718	0	0.0007	0.1521	0.127	0.4517
		0.768	0	0.015	364.25	-364.89	0.159
Internal gain					solar gain through glass		

Date	Time	People gain (kW) 20 rooms 2000-2010.clg	Lighting gain (kW) 20 rooms 2000-2010.clg	Internal gain (kW) 20 rooms 2000-2010.clg	Date	Time	Solar gain (kW) 20 rooms 2000-2010.clg
January	0:30	0.5794	1.4419	2.0213	January	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0
	5:30	0.5794	1.4419	2.0213		5:30	0
	6:30	0.5794	0.5632	1.1426		6:30	0
	7:30	0.5794	0.5632	1.1426		7:30	1.2552
	8:30	0.5794	0.5632	1.1426		8:30	5.4721
	9:30	0.5794	0.5632	1.1426		9:30	8.5339
	10:30	0.5794	0.5632	1.1426		10:30	8.9477
	11:30	0.5794	0.5632	1.1426		11:30	8.1955
	12:30	0.5794	0.5632	1.1426		12:30	8.2961
	13:30	0.5794	0.5632	1.1426		13:30	9.1119
	14:30	0.5794	0.5632	1.1426		14:30	10.5016
	15:30	0.5794	0.5632	1.1426		15:30	10.0039
	16:30	0.5794	2.2529	2.8323		16:30	6.3806
	17:30	0.5794	2.2529	2.8323		17:30	1.1107
	18:30	0.5794	2.2529	2.8323		18:30	0
	19:30	0.5794	2.2529	2.8323		19:30	0
	20:30	0.5794	2.2529	2.8323		20:30	0
	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
February	0:30	0.5794	1.4419	2.0213	February	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0
	5:30	0.5794	1.4419	2.0213		5:30	0
	6:30	0.5794	0.5632	1.1426		6:30	0
	7:30	0.5794	0.5632	1.1426		7:30	1.8438
	8:30	0.5794	0.5632	1.1426		8:30	6.3718
	9:30	0.5794	0.5632	1.1426		9:30	8.8035
	10:30	0.5794	0.5632	1.1426		10:30	8.812
	11:30	0.5794	0.5632	1.1426		11:30	7.88
	12:30	0.5794	0.5632	1.1426		12:30	7.7353

	13:30	0.5794	0.5632	1.1426		13:30	8.4292
	14:30	0.5794	0.5632	1.1426		14:30	9.8275
	15:30	0.5794	0.5632	1.1426		15:30	9.7556
	16:30	0.5794	2.2529	2.8323		16:30	7.325
	17:30	0.5794	2.2529	2.8323		17:30	1.9313
	18:30	0.5794	2.2529	2.8323		18:30	0.0073
	19:30	0.5794	2.2529	2.8323		19:30	0
	20:30	0.5794	2.2529	2.8323		20:30	0
	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
March	0:30	0.5794	1.4419	2.0213	March	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0
	5:30	0.5794	1.4419	2.0213		5:30	0
	6:30	0.5794	0.5632	1.1426		6:30	0.4463
	7:30	0.5794	0.5632	1.1426		7:30	3.5626
	8:30	0.5794	0.5632	1.1426		8:30	8.0728
	9:30	0.5794	0.5632	1.1426		9:30	9.5777
	10:30	0.5794	0.5632	1.1426		10:30	8.7537
	11:30	0.5794	0.5632	1.1426		11:30	7.2598
	12:30	0.5794	0.5632	1.1426		12:30	6.849
	13:30	0.5794	0.5632	1.1426		13:30	7.6763
	14:30	0.5794	0.5632	1.1426		14:30	9.275
	15:30	0.5794	0.5632	1.1426		15:30	9.4443
	16:30	0.5794	2.2529	2.8323		16:30	7.688
	17:30	0.5794	2.2529	2.8323		17:30	2.8955
	18:30	0.5794	2.2529	2.8323		18:30	0.279
	19:30	0.5794	2.2529	2.8323		19:30	0
	20:30	0.5794	2.2529	2.8323		20:30	0
	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
April	0:30	0.5794	1.4419	2.0213	April	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0

	5:30	0.5794	1.4419	2.0213		5:30	0
	6:30	0.5794	0.5632	1.1426		6:30	1.5098
	7:30	0.5794	0.5632	1.1426		7:30	5.5334
	8:30	0.5794	0.5632	1.1426		8:30	9.0476
	9:30	0.5794	0.5632	1.1426		9:30	9.6453
	10:30	0.5794	0.5632	1.1426		10:30	8.0283
	11:30	0.5794	0.5632	1.1426		11:30	6.1325
	12:30	0.5794	0.5632	1.1426		12:30	5.6351
	13:30	0.5794	0.5632	1.1426		13:30	6.6751
	14:30	0.5794	0.5632	1.1426		14:30	8.4008
	15:30	0.5794	0.5632	1.1426		15:30	8.8367
	16:30	0.5794	2.2529	2.8323		16:30	7.1951
	17:30	0.5794	2.2529	2.8323		17:30	3.3307
	18:30	0.5794	2.2529	2.8323		18:30	0.6844
	19:30	0.5794	2.2529	2.8323		19:30	0
	20:30	0.5794	2.2529	2.8323		20:30	0
	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
May	0:30	0.5794	1.4419	2.0213	May	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0
	5:30	0.5794	1.4419	2.0213		5:30	0.1958
	6:30	0.5794	0.5632	1.1426		6:30	2.2834
	7:30	0.5794	0.5632	1.1426		7:30	6.5234
	8:30	0.5794	0.5632	1.1426		8:30	8.9492
	9:30	0.5794	0.5632	1.1426		9:30	9.2597
	10:30	0.5794	0.5632	1.1426		10:30	7.4371
	11:30	0.5794	0.5632	1.1426		11:30	5.378
	12:30	0.5794	0.5632	1.1426		12:30	4.9278
	13:30	0.5794	0.5632	1.1426		13:30	6.0835
	14:30	0.5794	0.5632	1.1426		14:30	7.8516
	15:30	0.5794	0.5632	1.1426		15:30	8.5019
	16:30	0.5794	2.2529	2.8323		16:30	7.1283
	17:30	0.5794	2.2529	2.8323		17:30	4.3039
	18:30	0.5794	2.2529	2.8323		18:30	1.0831
	19:30	0.5794	2.2529	2.8323		19:30	0
	20:30	0.5794	2.2529	2.8323		20:30	0

	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
June	0:30	0.5794	1.4419	2.0213	June	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0
	5:30	0.5794	1.4419	2.0213		5:30	0.2879
	6:30	0.5794	0.5632	1.1426		6:30	2.5965
	7:30	0.5794	0.5632	1.1426		7:30	6.78
	8:30	0.5794	0.5632	1.1426		8:30	8.8898
	9:30	0.5794	0.5632	1.1426		9:30	9.1534
	10:30	0.5794	0.5632	1.1426		10:30	7.366
	11:30	0.5794	0.5632	1.1426		11:30	5.3151
	12:30	0.5794	0.5632	1.1426		12:30	4.7613
	13:30	0.5794	0.5632	1.1426		13:30	5.7743
	14:30	0.5794	0.5632	1.1426		14:30	7.5295
	15:30	0.5794	0.5632	1.1426		15:30	8.4835
	16:30	0.5794	2.2529	2.8323		16:30	7.461
	17:30	0.5794	2.2529	2.8323		17:30	5.0573
	18:30	0.5794	2.2529	2.8323		18:30	1.2983
	19:30	0.5794	2.2529	2.8323		19:30	0
	20:30	0.5794	2.2529	2.8323		20:30	0
	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
July	0:30	0.5794	1.4419	2.0213	July	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0
	5:30	0.5794	1.4419	2.0213		5:30	0.0971
	6:30	0.5794	0.5632	1.1426		6:30	1.9471
	7:30	0.5794	0.5632	1.1426		7:30	6.0699
	8:30	0.5794	0.5632	1.1426		8:30	8.6484
	9:30	0.5794	0.5632	1.1426		9:30	9.2499
	10:30	0.5794	0.5632	1.1426		10:30	7.6152
	11:30	0.5794	0.5632	1.1426		11:30	5.5116
	12:30	0.5794	0.5632	1.1426		12:30	4.7907

	13:30	0.5794	0.5632	1.1426		13:30	5.6766
	14:30	0.5794	0.5632	1.1426		14:30	7.4361
	15:30	0.5794	0.5632	1.1426		15:30	8.4584
	16:30	0.5794	2.2529	2.8323		16:30	7.4274
	17:30	0.5794	2.2529	2.8323		17:30	5.066
	18:30	0.5794	2.2529	2.8323		18:30	1.3295
	19:30	0.5794	2.2529	2.8323		19:30	0.0006
	20:30	0.5794	2.2529	2.8323		20:30	0
	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
August	0:30	0.5794	1.4419	2.0213	August	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0
	5:30	0.5794	1.4419	2.0213		5:30	0
	6:30	0.5794	0.5632	1.1426		6:30	1.3023
	7:30	0.5794	0.5632	1.1426		7:30	5.4086
	8:30	0.5794	0.5632	1.1426		8:30	8.694
	9:30	0.5794	0.5632	1.1426		9:30	9.4371
	10:30	0.5794	0.5632	1.1426		10:30	7.8774
	11:30	0.5794	0.5632	1.1426		11:30	5.8564
	12:30	0.5794	0.5632	1.1426		12:30	5.2027
	13:30	0.5794	0.5632	1.1426		13:30	6.1468
	14:30	0.5794	0.5632	1.1426		14:30	7.8677
	15:30	0.5794	0.5632	1.1426		15:30	8.5839
	16:30	0.5794	2.2529	2.8323		16:30	7.2545
	17:30	0.5794	2.2529	2.8323		17:30	4.1637
	18:30	0.5794	2.2529	2.8323		18:30	1.036
	19:30	0.5794	2.2529	2.8323		19:30	0
	20:30	0.5794	2.2529	2.8323		20:30	0
	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
September	0:30	0.5794	1.4419	2.0213	September	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0

	5:30	0.5794	1.4419	2.0213		5:30	0
	6:30	0.5794	0.5632	1.1426		6:30	1.1127
	7:30	0.5794	0.5632	1.1426		7:30	5.3345
	8:30	0.5794	0.5632	1.1426		8:30	8.9075
	9:30	0.5794	0.5632	1.1426		9:30	9.5159
	10:30	0.5794	0.5632	1.1426		10:30	8.0357
	11:30	0.5794	0.5632	1.1426		11:30	6.5517
	12:30	0.5794	0.5632	1.1426		12:30	6.3691
	13:30	0.5794	0.5632	1.1426		13:30	7.473
	14:30	0.5794	0.5632	1.1426		14:30	9.0855
	15:30	0.5794	0.5632	1.1426		15:30	8.9019
	16:30	0.5794	2.2529	2.8323		16:30	6.5266
	17:30	0.5794	2.2529	2.8323		17:30	2.0957
	18:30	0.5794	2.2529	2.8323		18:30	0.1436
	19:30	0.5794	2.2529	2.8323		19:30	0
	20:30	0.5794	2.2529	2.8323		20:30	0
	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
October	0:30	0.5794	1.4419	2.0213	October	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0
	5:30	0.5794	1.4419	2.0213		5:30	0
	6:30	0.5794	0.5632	1.1426		6:30	0.8353
	7:30	0.5794	0.5632	1.1426		7:30	4.5983
	8:30	0.5794	0.5632	1.1426		8:30	8.3687
	9:30	0.5794	0.5632	1.1426		9:30	9.1306
	10:30	0.5794	0.5632	1.1426		10:30	8.2135
	11:30	0.5794	0.5632	1.1426		11:30	7.4206
	12:30	0.5794	0.5632	1.1426		12:30	7.5986
	13:30	0.5794	0.5632	1.1426		13:30	8.8467
	14:30	0.5794	0.5632	1.1426		14:30	9.9139
	15:30	0.5794	0.5632	1.1426		15:30	9.0851
	16:30	0.5794	2.2529	2.8323		16:30	5.51
	17:30	0.5794	2.2529	2.8323		17:30	0.9773
	18:30	0.5794	2.2529	2.8323		18:30	0
	19:30	0.5794	2.2529	2.8323		19:30	0
	20:30	0.5794	2.2529	2.8323		20:30	0

	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
November	0:30	0.5794	1.4419	2.0213	November	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0
	5:30	0.5794	1.4419	2.0213		5:30	0
	6:30	0.5794	0.5632	1.1426		6:30	0.2361
	7:30	0.5794	0.5632	1.1426		7:30	2.863
	8:30	0.5794	0.5632	1.1426		8:30	7.1985
	9:30	0.5794	0.5632	1.1426		9:30	8.6704
	10:30	0.5794	0.5632	1.1426		10:30	8.2412
	11:30	0.5794	0.5632	1.1426		11:30	7.8361
	12:30	0.5794	0.5632	1.1426		12:30	8.1833
	13:30	0.5794	0.5632	1.1426		13:30	9.3543
	14:30	0.5794	0.5632	1.1426		14:30	10.1584
	15:30	0.5794	0.5632	1.1426		15:30	8.8565
	16:30	0.5794	2.2529	2.8323		16:30	4.04
	17:30	0.5794	2.2529	2.8323		17:30	0.4317
	18:30	0.5794	2.2529	2.8323		18:30	0
	19:30	0.5794	2.2529	2.8323		19:30	0
	20:30	0.5794	2.2529	2.8323		20:30	0
	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
December	0:30	0.5794	1.4419	2.0213	December	0:30	0
	1:30	0.5794	1.4419	2.0213		1:30	0
	2:30	0.5794	1.4419	2.0213		2:30	0
	3:30	0.5794	1.4419	2.0213		3:30	0
	4:30	0.5794	1.4419	2.0213		4:30	0
	5:30	0.5794	1.4419	2.0213		5:30	0
	6:30	0.5794	0.5632	1.1426		6:30	0
	7:30	0.5794	0.5632	1.1426		7:30	1.4182
	8:30	0.5794	0.5632	1.1426		8:30	5.8903
	9:30	0.5794	0.5632	1.1426		9:30	8.4784
	10:30	0.5794	0.5632	1.1426		10:30	8.6183
	11:30	0.5794	0.5632	1.1426		11:30	8.2189
	12:30	0.5794	0.5632	1.1426		12:30	8.5789

	13:30	0.5794	0.5632	1.1426		13:30	9.5403
	14:30	0.5794	0.5632	1.1426		14:30	10.5778
	15:30	0.5794	0.5632	1.1426		15:30	9.3702
	16:30	0.5794	2.2529	2.8323		16:30	4.5924
	17:30	0.5794	2.2529	2.8323		17:30	0.5495
	18:30	0.5794	2.2529	2.8323		18:30	0
	19:30	0.5794	2.2529	2.8323		19:30	0
	20:30	0.5794	2.2529	2.8323		20:30	0
	21:30	0.5794	2.2529	2.8323		21:30	0
	22:30	0.5794	2.2529	2.8323		22:30	0
	23:30	0.5794	2.2529	2.8323		23:30	0
		5006.02	11630	16636.4			28507.116

Energy Consumption

energy consumption									external weather data			
		Total lights energy (kW)	Ap Sys heat rej fans/pumps energy (kW)	Chillers energy (kW)	Total energy (kW)						Dry-bulb temperature (°C)	Global radiation (W/m²)
		2000-2010.clg	2000-2010.clg	2000-2010.clg	2000-2010.clg						1970-1990 house no shading.clg	1970-1990 house no shading.clg
Date	Time					total consumption	actual coast AED	supported coast AED	Date	Time		
January	0:30	1.4419	0.4858	1.3879	3.3156				January	1:00	20.24	0
	1:30	1.4419	0.4496	1.2846	3.1761					2:00	19.8	0
	2:30	1.4419	0.4139	1.1826	3.0383					3:00	19.45	0
	3:30	1.4419	0.3779	1.0796	2.8993					4:00	19.19	0
	4:30	1.4419	0.3424	0.9783	2.7626					5:00	19.1	0
	5:30	1.4419	0.3093	0.8837	2.6349					6:00	19.28	0
	6:30	0.5632	0.1983	0.5667	1.3282					7:00	19.72	0
	7:30	0.5632	0.2213	0.6324	1.417					8:00	20.51	148.9
	8:30	0.5632	0.4458	1.2737	2.2827					9:00	21.65	381.36
	9:30	0.5632	0.6569	1.8767	3.0968					10:00	22.97	569.1
	10:30	0.5632	0.7744	2.2125	3.5501					11:00	24.47	700.46
	11:30	0.5632	0.8128	2.3224	3.6984					12:00	25.88	767.12
	12:30	0.5632	0.8533	2.4381	3.8546					13:00	26.93	764.76
	13:30	0.5632	0.9352	2.6719	4.1702					14:00	27.64	693.53
	14:30	0.5632	1.049	2.9971	4.6094					15:00	27.9	558.05

	15:30	0.5632	1.0982	3.1378	4.7992					16:00	27.64	366.87
	16:30	2.2529	1.1417	3.2619	6.6565					17:00	27.02	132.02
	17:30	2.2529	0.8836	2.5246	5.6611					18:00	26.05	0
	18:30	2.2529	0.7492	2.1407	5.1428					19:00	24.91	0
	19:30	2.2529	0.7042	2.012	4.9691					20:00	23.76	0
	20:30	2.2529	0.6723	1.9209	4.8461					21:00	22.8	0
	21:30	2.2529	0.6446	1.8417	4.7392					22:00	21.92	0
	22:30	2.2529	0.6173	1.7638	4.634					23:00	21.21	0
	23:30	2.2529	0.5898	1.6851	4.5278	2754.3	688.58	192.8		#####	20.68	0
February	0:30	1.4419	0.797	2.2772	4.516				February	1:00	23.02	0
	1:30	1.4419	0.7597	2.1705	4.372					2:00	22.59	0
	2:30	1.4419	0.7228	2.0653	4.23					3:00	22.24	0
	3:30	1.4419	0.6858	1.9594	4.087					4:00	21.99	0
	4:30	1.4419	0.6494	1.8555	3.9468					5:00	21.9	0
	5:30	1.4419	0.6155	1.7585	3.8158					6:00	22.07	0
	6:30	0.5632	0.5037	1.4392	2.5061					7:00	22.5	0
	7:30	0.5632	0.5549	1.5854	2.7035					8:00	23.28	210.42
	8:30	0.5632	0.8116	2.3188	3.6936					9:00	24.39	452.95
	9:30	0.5632	1.002	2.8628	4.428					10:00	25.68	650.65
	10:30	0.5632	1.1008	3.1452	4.8092					11:00	27.15	791.41
	11:30	0.5632	1.1323	3.2353	4.9309					12:00	28.52	866.18
	12:30	0.5632	1.1562	3.3035	5.023					13:00	29.55	870.08
	13:30	0.5632	1.2278	3.508	5.299					14:00	30.24	802.83
	14:30	0.5632	1.3383	3.8238	5.7253					15:00	30.5	668.86
	15:30	0.5632	1.4017	4.0048	5.9696					16:00	30.24	476.79
	16:30	2.2529	1.4946	4.2703	8.0178					17:00	29.64	238.45
	17:30	2.2529	1.2519	3.577	7.0818					18:00	28.69	1.22
	18:30	2.2529	1.0714	3.0612	6.3855					19:00	27.58	0
	19:30	2.2529	1.0213	2.9179	6.1921					20:00	26.46	0
	20:30	2.2529	0.9878	2.8223	6.063					21:00	25.51	0
	21:30	2.2529	0.9591	2.7402	5.9522					22:00	24.65	0
	22:30	2.2529	0.9308	2.6596	5.8433					23:00	23.96	0
	23:30	2.2529	0.9022	2.5777	5.7327	3639.7	909.93	254.78		#####	23.45	0
March	0:30	1.4419	1.2919	3.6911	6.4248				March	1:00	27.27	0
	1:30	1.4419	1.2522	3.5778	6.2719					2:00	26.82	0
	2:30	1.4419	1.213	3.4656	6.1204					3:00	26.46	0
	3:30	1.4419	1.1734	3.3525	5.9678					4:00	26.19	0
	4:30	1.4419	1.1346	3.2416	5.8181					5:00	26.1	0
	5:30	1.4419	1.0983	3.1381	5.6782					6:00	26.28	0
	6:30	0.5632	1.0036	2.8674	4.4342					7:00	26.73	58.519

	7:30	0.5632	1.1326	3.236	4.9319					8:00	27.54	326.21
	8:30	0.5632	1.4056	4.0159	5.9847					9:00	28.71	566.35
	9:30	0.5632	1.5664	4.4755	6.6051					10:00	30.06	760.72
	10:30	0.5632	1.6309	4.6597	6.8538					11:00	31.59	897.09
	11:30	0.5632	1.6293	4.6552	6.8478					12:00	33.03	966.57
	12:30	0.5632	1.6346	4.6704	6.8683					13:00	34.11	964.57
	13:30	0.5632	1.7035	4.8672	7.134					14:00	34.83	891.21
	14:30	0.5632	1.8164	5.1896	7.5692					15:00	35.1	751.36
	15:30	0.5632	1.8844	5.384	7.8316					16:00	34.83	554.11
	16:30	2.2529	2.0024	5.7211	9.9764					17:00	34.2	311.84
	17:30	2.2529	1.7968	5.1337	9.1834					18:00	33.21	44.655
	18:30	2.2529	1.5956	4.5589	8.4074					19:00	32.04	0
	19:30	2.2529	1.5267	4.3621	8.1417					20:00	30.87	0
	20:30	2.2529	1.4903	4.258	8.0013					21:00	29.88	0
	21:30	2.2529	1.4598	4.1708	7.8835					22:00	28.98	0
	22:30	2.2529	1.4298	4.0851	7.7677					23:00	28.26	0
	23:30	2.2529	1.3992	3.9976	7.6497	5050.6	1262.6	353.54		#####	27.72	0
April	0:30	1.4419	1.6464	4.704	7.7923				April	1:00	29.88	0
	1:30	1.4419	1.6046	4.5844	7.6309					2:00	29.35	0
	2:30	1.4419	1.5623	4.4637	7.4679					3:00	28.92	0
	3:30	1.4419	1.5192	4.3406	7.3017					4:00	28.61	0
	4:30	1.4419	1.4766	4.219	7.1375					5:00	28.5	0
	5:30	1.4419	1.4368	4.105	6.9836					6:00	28.71	0
	6:30	0.5632	1.3876	3.9647	5.9156					7:00	29.24	192.58
	7:30	0.5632	1.6013	4.5752	6.7398					8:00	30.2	448.2
	8:30	0.5632	1.8241	5.2118	7.5991					9:00	31.57	672.15
	9:30	0.5632	1.9473	5.5636	8.0741					10:00	33.16	850.44
	10:30	0.5632	1.9704	5.6297	8.1633					11:00	34.97	971.59
	11:30	0.5632	1.9395	5.5413	8.044					12:00	36.66	1027.6
	12:30	0.5632	1.9356	5.5302	8.029					13:00	37.93	1014.8
	13:30	0.5632	2.0078	5.7367	8.3078					14:00	38.78	934.03
	14:30	0.5632	2.1209	6.0598	8.7439					15:00	39.1	790.61
	15:30	0.5632	2.1907	6.2592	9.0132					16:00	38.78	593.94
	16:30	2.2529	2.3179	6.6226	11.193					17:00	38.04	356.5
	17:30	2.2529	2.1543	6.1551	10.562					18:00	36.87	94.695
	18:30	2.2529	1.9703	5.6294	9.8526					19:00	35.5	0
	19:30	2.2529	1.8825	5.3786	9.5141					20:00	34.12	0
	20:30	2.2529	1.8461	5.2746	9.3736					21:00	32.95	0
	21:30	2.2529	1.8161	5.1889	9.258					22:00	31.89	0
	22:30	2.2529	1.7862	5.1034	9.1424					23:00	31.04	0

	23:30	2.2529	1.755	5.0143	9.0223	6025.9	1506.5	421.81		#####	30.41	0
May	0:30	1.4419	1.9272	5.5063	8.8753				May	1:00	32.01	0
	1:30	1.4419	1.8838	5.3822	8.7079					2:00	31.43	0
	2:30	1.4419	1.8395	5.2557	8.5371					3:00	30.96	0
	3:30	1.4419	1.7941	5.126	8.362					4:00	30.62	0
	4:30	1.4419	1.7491	4.9973	8.1883					5:00	30.5	0
	5:30	1.4419	1.7158	4.9022	8.0598					6:00	30.73	26.805
	6:30	0.5632	1.701	4.8599	7.1241					7:00	31.31	268.96
	7:30	0.5632	1.9426	5.5503	8.0561					8:00	32.36	507.41
	8:30	0.5632	2.1189	6.0541	8.7363					9:00	33.86	715.31
	9:30	0.5632	2.217	6.3343	9.1145					10:00	35.6	879.57
	10:30	0.5632	2.2214	6.3467	9.1313					11:00	37.58	989.54
	11:30	0.5632	2.1765	6.2186	8.9583					12:00	39.43	1038
	12:30	0.5632	2.1719	6.2054	8.9405					13:00	40.82	1021.6
	13:30	0.5632	2.2465	6.4187	9.2284					14:00	41.75	941.61
	14:30	0.5632	2.3606	6.7447	9.6686					15:00	42.1	803.22
	15:30	0.5632	2.4384	6.967	9.9687					16:00	41.75	615.52
	16:30	2.2529	2.5877	7.3933	12.234					17:00	40.94	390.51
	17:30	2.2529	2.4751	7.0716	11.8					18:00	39.66	142.91
	18:30	2.2529	2.2818	6.5194	11.054					19:00	38.16	0
	19:30	2.2529	2.1676	6.193	10.614					20:00	36.65	0
	20:30	2.2529	2.1294	6.084	10.466					21:00	35.37	0
	21:30	2.2529	2.099	5.9971	10.349					22:00	34.21	0
	22:30	2.2529	2.0686	5.9104	10.232					23:00	33.28	0
	23:30	2.2529	2.0368	5.8195	10.109	6795.4	1698.9	475.68		#####	32.59	0
June	0:30	1.4419	2.0536	5.8674	9.3628				June	1:00	33.16	0
	1:30	1.4419	2.0101	5.7431	9.1951					2:00	32.6	0
	2:30	1.4419	1.9659	5.6168	9.0246					3:00	32.15	0
	3:30	1.4419	1.9207	5.4877	8.8503					4:00	31.81	0
	4:30	1.4419	1.8759	5.3599	8.6777					5:00	31.7	0
	5:30	1.4419	1.847	5.2771	8.5659					6:00	31.92	40.999
	6:30	0.5632	1.8466	5.2759	7.6857					7:00	32.48	276.48
	7:30	0.5632	2.0893	5.9694	8.6219					8:00	33.49	506.43
	8:30	0.5632	2.2558	6.445	9.264					9:00	34.95	708.04
	9:30	0.5632	2.3452	6.7007	9.6092					10:00	36.63	868.59
	10:30	0.5632	2.3462	6.7034	9.6128					11:00	38.53	977.7
	11:30	0.5632	2.3004	6.5725	9.4362					12:00	40.32	1028.2
	12:30	0.5632	2.2904	6.5439	9.3974					13:00	41.67	1016.7
	13:30	0.5632	2.3569	6.7339	9.654					14:00	42.56	943.93
	14:30	0.5632	2.4684	7.0526	10.084					15:00	42.9	814.8

	15:30	0.5632	2.5569	7.3053	10.425					16:00	42.56	637.73
	16:30	2.2529	2.7248	7.785	12.763					17:00	41.78	424.07
	17:30	2.2529	2.6393	7.5408	12.433					18:00	40.55	187.46
	18:30	2.2529	2.4322	6.9491	11.634					19:00	39.09	0.023
	19:30	2.2529	2.2986	6.5675	11.119					20:00	37.64	0
	20:30	2.2529	2.2581	6.4517	10.963					21:00	36.4	0
	21:30	2.2529	2.2266	6.3618	10.841					22:00	35.28	0
	22:30	2.2529	2.1957	6.2734	10.722					23:00	34.39	0
	23:30	2.2529	2.1635	6.1814	10.598	7156.2	1789	500.93		#####	33.72	0
July	0:30	1.4419	2.2711	6.4888	10.202				July	1:00	35.59	0
	1:30	1.4419	2.2291	6.3689	10.04					2:00	35.09	0
	2:30	1.4419	2.187	6.2485	9.8773					3:00	34.7	0
	3:30	1.4419	2.1442	6.1262	9.7123					4:00	34.4	0
	4:30	1.4419	2.102	6.0058	9.5497					5:00	34.3	0
	5:30	1.4419	2.067	5.9058	9.4147					6:00	34.5	14.239
	6:30	0.5632	2.0395	5.8272	8.43					7:00	34.99	242.99
	7:30	0.5632	2.2745	6.4986	9.3363					8:00	35.88	478.17
	8:30	0.5632	2.4602	7.0292	10.053					9:00	37.17	685.8
	9:30	0.5632	2.5664	7.3326	10.462					10:00	38.66	852.83
	10:30	0.5632	2.5793	7.3693	10.512					11:00	40.34	968.49
	11:30	0.5632	2.5366	7.2474	10.347					12:00	41.92	1025.2
	12:30	0.5632	2.519	7.1972	10.28					13:00	43.11	1019.2
	13:30	0.5632	2.5776	7.3645	10.505					14:00	43.9	950.86
	14:30	0.5632	2.6859	7.674	10.923					15:00	44.2	824.73
	15:30	0.5632	2.7741	7.9259	11.263					16:00	43.9	649.07
	16:30	2.2529	2.9411	8.4032	13.597					17:00	43.21	435.14
	17:30	2.2529	2.8553	8.158	13.266					18:00	42.12	196.49
	18:30	2.2529	2.6496	7.5704	12.473					19:00	40.83	0.137
	19:30	2.2529	2.5146	7.1847	11.952					20:00	39.55	0
	20:30	2.2529	2.4738	7.0679	11.795					21:00	38.46	0
	21:30	2.2529	2.4423	6.9779	11.673					22:00	37.47	0
	22:30	2.2529	2.4116	6.8904	11.555					23:00	36.68	0
	23:30	2.2529	2.38	6.8001	11.433	7759.5	1939.9	543.17		#####	36.08	0
August	0:30	1.4419	2.2578	6.4508	10.151				August	1:00	35.57	0
	1:30	1.4419	2.2165	6.3328	9.9912					2:00	35.08	0
	2:30	1.4419	2.1751	6.2145	9.8314					3:00	34.69	0
	3:30	1.4419	2.1331	6.0944	9.6694					4:00	34.4	0
	4:30	1.4419	2.0917	5.9762	9.5097					5:00	34.3	0
	5:30	1.4419	2.053	5.8656	9.3605					6:00	34.5	0.001
	6:30	0.5632	1.9962	5.7034	8.2629					7:00	34.99	198.13

	7:30	0.5632	2.2128	6.3222	9.0982					8:00	35.87	446.31
	8:30	0.5632	2.4285	6.9384	9.9301					9:00	37.14	664.99
	9:30	0.5632	2.5527	7.2934	10.409					10:00	38.61	840.34
	10:30	0.5632	2.5772	7.3635	10.504					11:00	40.28	961.12
	11:30	0.5632	2.5427	7.2649	10.371					12:00	41.85	1019.4
	12:30	0.5632	2.5302	7.2292	10.323					13:00	43.02	1011.4
	13:30	0.5632	2.5945	7.4129	10.571					14:00	43.81	937.51
	14:30	0.5632	2.7029	7.7226	10.989					15:00	44.1	802.72
	15:30	0.5632	2.7787	7.9391	11.281					16:00	43.81	615.81
	16:30	2.2529	2.9246	8.356	13.534					17:00	43.12	388.66
	17:30	2.2529	2.7989	7.997	13.049					18:00	42.04	136.28
	18:30	2.2529	2.6078	7.451	12.312					19:00	40.77	0
	19:30	2.2529	2.4969	7.1339	11.884					20:00	39.49	0
	20:30	2.2529	2.4582	7.0234	11.734					21:00	38.42	0
	21:30	2.2529	2.4275	6.9356	11.616					22:00	37.44	0
	22:30	2.2529	2.3973	6.8494	11.5					23:00	36.65	0
	23:30	2.2529	2.3662	6.7604	11.38	7717.7	1929.4	540.24		#####	36.06	0
September	0:30	1.4419	1.8852	5.3863	8.7133				September	1:00	32.15	0
	1:30	1.4419	1.8445	5.2699	8.5562					2:00	31.63	0
	2:30	1.4419	1.8034	5.1526	8.3979					3:00	31.22	0
	3:30	1.4419	1.7616	5.0332	8.2367					4:00	30.9	0
	4:30	1.4419	1.7203	4.9152	8.0774					5:00	30.8	0
	5:30	1.4419	1.6817	4.8048	7.9283					6:00	31.01	0
	6:30	0.5632	1.6144	4.6126	6.7903					7:00	31.53	160.46
	7:30	0.5632	1.8279	5.2226	7.6138					8:00	32.46	418.73
	8:30	0.5632	2.0574	5.8783	8.4989					9:00	33.82	643.17
	9:30	0.5632	2.1844	6.2412	8.9888					10:00	35.38	819.62
	10:30	0.5632	2.2139	6.3255	9.1026					11:00	37.14	936.82
	11:30	0.5632	2.1982	6.2806	9.0421					12:00	38.81	987.1
	12:30	0.5632	2.2134	6.324	9.1006					13:00	40.06	967.14
	13:30	0.5632	2.2951	6.5575	9.4158					14:00	40.89	878.24
	14:30	0.5632	2.4079	6.8798	9.851					15:00	41.2	726.28
	15:30	0.5632	2.4604	7.0298	10.053					16:00	40.89	521.07
	16:30	2.2529	2.5456	7.273	12.072					17:00	40.16	275.44
	17:30	2.2529	2.3342	6.6692	11.256					18:00	39.02	18.8
	18:30	2.2529	2.168	6.1943	10.615					19:00	37.66	0
	19:30	2.2529	2.1137	6.0392	10.406					20:00	36.31	0
	20:30	2.2529	2.081	5.9456	10.28					21:00	35.17	0
	21:30	2.2529	2.0523	5.8637	10.169					22:00	34.13	0
	22:30	2.2529	2.0232	5.7804	10.057					23:00	33.3	0

	23:30	2.2529	1.9928	5.6938	9.9395	6694.8	1673.7	468.64		#####	32.67	0
October	0:30	1.4419	1.5289	4.3682	7.3389				October	1:00	29.07	0
	1:30	1.4419	1.4894	4.2555	7.1867					2:00	28.54	0
	2:30	1.4419	1.4497	4.1419	7.0334					3:00	28.12	0
	3:30	1.4419	1.4091	4.0261	6.8771					4:00	27.81	0
	4:30	1.4419	1.369	3.9115	6.7224					5:00	27.7	0
	5:30	1.4419	1.3315	3.8043	6.5776					6:00	27.91	0
	6:30	0.5632	1.2521	3.5774	5.3927					7:00	28.44	105.47
	7:30	0.5632	1.4293	4.0836	6.0761					8:00	29.38	362.67
	8:30	0.5632	1.6698	4.7709	7.004					9:00	30.75	583.67
	9:30	0.5632	1.798	5.1371	7.4983					10:00	32.32	753.88
	10:30	0.5632	1.8477	5.2792	7.6902					11:00	34.1	862.53
	11:30	0.5632	1.8597	5.3133	7.7362					12:00	35.78	902.55
	12:30	0.5632	1.9021	5.4345	7.8998					13:00	37.05	871.3
	13:30	0.5632	2	5.7143	8.2775					14:00	37.89	770.85
	14:30	0.5632	2.1052	6.0149	8.6834					15:00	38.2	607.74
	15:30	0.5632	2.1301	6.0859	8.7792					16:00	37.89	392.36
	16:30	2.2529	2.1566	6.1617	10.571					17:00	37.15	138.3
	17:30	2.2529	1.915	5.4715	9.6395					18:00	35.99	0
	18:30	2.2529	1.7941	5.1261	9.1731					19:00	34.63	0
	19:30	2.2529	1.752	5.0056	9.0105					20:00	33.26	0
	20:30	2.2529	1.721	4.9171	8.891					21:00	32.11	0
	21:30	2.2529	1.693	4.8373	8.7832					22:00	31.06	0
	22:30	2.2529	1.6647	4.7562	8.6738					23:00	30.22	0
	23:30	2.2529	1.6353	4.6724	8.5606	5702.3	1425.6	399.16		#####	29.59	0
November	0:30	1.4419	1.0438	2.9823	5.468				November	1:00	25.01	0
	1:30	1.4419	1.007	2.8772	5.3261					2:00	24.51	0
	2:30	1.4419	0.9701	2.7716	5.1835					3:00	24.1	0
	3:30	1.4419	0.9323	2.6637	5.0378					4:00	23.8	0
	4:30	1.4419	0.8949	2.5567	4.8935					5:00	23.7	0
	5:30	1.4419	0.8598	2.4566	4.7583					6:00	23.9	0
	6:30	0.5632	0.7572	2.1634	3.4838					7:00	24.41	24.022
	7:30	0.5632	0.855	2.4428	3.8609					8:00	25.32	268.01
	8:30	0.5632	1.1149	3.1855	4.8637					9:00	26.63	485.03
	9:30	0.5632	1.2659	3.6167	5.4458					10:00	28.14	652
	10:30	0.5632	1.3359	3.8169	5.716					11:00	29.86	758.62
	11:30	0.5632	1.3674	3.9069	5.8376					12:00	31.48	798.06
	12:30	0.5632	1.4246	4.0702	6.058					13:00	32.69	767.73
	13:30	0.5632	1.5239	4.3541	6.4412					14:00	33.5	669.63
	14:30	0.5632	1.6234	4.6383	6.825					15:00	33.8	510.06

	15:30	0.5632	1.6269	4.6482	6.8384					16:00	33.5	298.92
	16:30	2.2529	1.5958	4.5594	8.408					17:00	32.79	52.966
	17:30	2.2529	1.3725	3.9213	7.5467					18:00	31.68	0
	18:30	2.2529	1.2908	3.688	7.2317					19:00	30.37	0
	19:30	2.2529	1.2542	3.5836	7.0907					20:00	29.05	0
	20:30	2.2529	1.2262	3.5035	6.9826					21:00	27.94	0
	21:30	2.2529	1.2006	3.4304	6.8839					22:00	26.93	0
	22:30	2.2529	1.1746	3.356	6.7835					23:00	26.12	0
	23:30	2.2529	1.1477	3.2792	6.6798	4309.3	1077.3	301.65		#####	25.52	0
December	0:30	1.4419	0.6814	1.9468	4.0701				December	1:00	22	0
	1:30	1.4419	0.6459	1.8453	3.933					2:00	21.54	0
	2:30	1.4419	0.6105	1.7444	3.7968					3:00	21.17	0
	3:30	1.4419	0.5747	1.642	3.6586					4:00	20.89	0
	4:30	1.4419	0.5393	1.5409	3.5221					5:00	20.8	0
	5:30	1.4419	0.5063	1.4464	3.3945					6:00	20.98	0
	6:30	0.5632	0.3954	1.1296	2.0882					7:00	21.44	0
	7:30	0.5632	0.426	1.217	2.2062					8:00	22.27	178.86
	8:30	0.5632	0.6664	1.904	3.1337					9:00	23.47	400.09
	9:30	0.5632	0.8624	2.464	3.8896					10:00	24.85	574.22
	10:30	0.5632	0.9636	2.7533	4.2802					11:00	26.41	690.54
	11:30	0.5632	1.0054	2.8725	4.4411					12:00	27.88	741.66
	12:30	0.5632	1.0631	3.0376	4.6639					13:00	28.99	724.28
	13:30	0.5632	1.1557	3.3021	5.0211					14:00	29.72	639.53
	14:30	0.5632	1.2621	3.6061	5.4314					15:00	30	492.85
	15:30	0.5632	1.2778	3.651	5.492					16:00	29.72	293.36
	16:30	2.2529	1.2578	3.5938	7.1046					17:00	29.08	56.767
	17:30	2.2529	1.0233	2.9238	6.2					18:00	28.07	0
	18:30	2.2529	0.931	2.6601	5.844					19:00	26.87	0
	19:30	2.2529	0.8923	2.5493	5.6945					20:00	25.68	0
	20:30	2.2529	0.8631	2.4661	5.5822					21:00	24.66	0
	21:30	2.2529	0.8371	2.3916	5.4816					22:00	23.74	0
	22:30	2.2529	0.811	2.3173	5.3812					23:00	23.01	0
	23:30	2.2529	0.7845	2.2415	5.2789	3287.7	821.92	230.14		#####	22.46	0
total consumption		11630.4	14327	40936	66894	66894	16723	4682.5				

Internal Temperature without AC

Date	Time	2000-2010 no AC.clg	outside tempreture	Date	Time	2000-2010 no AC.clg	outside tempreture
January	0:30	24.54	20.24	July	0:30	39.21	35.59
	1:30	24.5	19.8		1:30	39.2	35.09
	2:30	24.49	19.45		2:30	39.2	34.7
	3:30	24.47	19.19		3:30	39.2	34.4
	4:30	24.45	19.1		4:30	39.19	34.3
	5:30	24.42	19.28		5:30	39.18	34.5
	6:30	24.3	19.72		6:30	39.08	34.99
	7:30	24.23	20.51		7:30	39.05	35.88
	8:30	24.21	21.65		8:30	39.07	37.17
	9:30	24.22	22.97		9:30	39.11	38.66
	10:30	24.24	24.47		10:30	39.17	40.34
	11:30	24.27	25.88		11:30	39.23	41.92
	12:30	24.31	26.93		12:30	39.3	43.11
	13:30	24.33	27.64		13:30	39.36	43.9
	14:30	24.35	27.9		14:30	39.41	44.2
	15:30	24.36	27.64		15:30	39.44	43.9
	16:30	24.54	27.02		16:30	39.65	43.21
	17:30	24.63	26.05		17:30	39.76	42.12
	18:30	24.67	24.91		18:30	39.79	40.83
	19:30	24.7	23.76		19:30	39.83	39.55
	20:30	24.74	22.8		20:30	39.88	38.46
	21:30	24.77	21.92		21:30	39.92	37.47
	22:30	24.8	21.21		22:30	39.96	36.68
	23:30	24.82	20.68		23:30	40	36.08
February	0:30	27.06	23.02	August	0:30	39.16	35.57
	1:30	27.03	22.59		1:30	39.14	35.08
	2:30	27.02	22.24		2:30	39.14	34.69
	3:30	27.01	21.99		3:30	39.14	34.4
	4:30	26.99	21.9		4:30	39.13	34.3
	5:30	26.96	22.07		5:30	39.12	34.5
	6:30	26.85	22.5		6:30	39.02	34.99
	7:30	26.78	23.28		7:30	38.99	35.87
	8:30	26.77	24.39		8:30	39.01	37.14
	9:30	26.79	25.68		9:30	39.06	38.61
	10:30	26.82	27.15		10:30	39.11	40.28

	11:30	26.86	28.52		11:30	39.18	41.85
	12:30	26.9	29.55		12:30	39.24	43.02
	13:30	26.93	30.24		13:30	39.3	43.81
	14:30	26.96	30.5		14:30	39.35	44.1
	15:30	26.97	30.24		15:30	39.38	43.81
	16:30	27.16	29.64		16:30	39.59	43.12
	17:30	27.24	28.69		17:30	39.69	42.04
	18:30	27.27	27.58		18:30	39.73	40.77
	19:30	27.31	26.46		19:30	39.77	39.49
	20:30	27.35	25.51		20:30	39.81	38.42
	21:30	27.38	24.65		21:30	39.86	37.44
	22:30	27.41	23.96		22:30	39.9	36.65
	23:30	27.43	23.45		23:30	39.94	36.06
March	0:30	31.08	27.27	September	0:30	36.09	32.15
	1:30	31.05	26.82		1:30	36.07	31.63
	2:30	31.04	26.46		2:30	36.07	31.22
	3:30	31.03	26.19		3:30	36.06	30.9
	4:30	31.02	26.1		4:30	36.05	30.8
	5:30	31	26.28		5:30	36.03	31.01
	6:30	30.89	26.73		6:30	35.92	31.53
	7:30	30.83	27.54		7:30	35.89	32.46
	8:30	30.84	28.71		8:30	35.9	33.82
	9:30	30.86	30.06		9:30	35.94	35.38
	10:30	30.9	31.59		10:30	35.99	37.14
	11:30	30.95	33.03		11:30	36.05	38.81
	12:30	31	34.11		12:30	36.11	40.06
	13:30	31.05	34.83		13:30	36.16	40.89
	14:30	31.08	35.1		14:30	36.2	41.2
	15:30	31.1	34.83		15:30	36.23	40.89
	16:30	31.29	34.2		16:30	36.43	40.16
	17:30	31.38	33.21		17:30	36.52	39.02
	18:30	31.41	32.04		18:30	36.56	37.66
	19:30	31.45	30.87		19:30	36.61	36.31
	20:30	31.49	29.88		20:30	36.65	35.17
	21:30	31.52	28.98		21:30	36.7	34.13
	22:30	31.56	28.26		22:30	36.74	33.3
	23:30	31.59	27.72		23:30	36.77	32.67
April	0:30	33.99	29.88	October	0:30	33.18	29.07
	1:30	33.97	29.35		1:30	33.15	28.54
	2:30	33.96	28.92		2:30	33.15	28.12

	3:30	33.95	28.61		3:30	33.14	27.81
	4:30	33.93	28.5		4:30	33.12	27.7
	5:30	33.91	28.71		5:30	33.1	27.91
	6:30	33.8	29.24		6:30	32.99	28.44
	7:30	33.76	30.2		7:30	32.94	29.38
	8:30	33.77	31.57		8:30	32.95	30.75
	9:30	33.8	33.16		9:30	32.98	32.32
	10:30	33.85	34.97		10:30	33.02	34.1
	11:30	33.9	36.66		11:30	33.07	35.78
	12:30	33.96	37.93		12:30	33.12	37.05
	13:30	34.01	38.78		13:30	33.16	37.89
	14:30	34.05	39.1		14:30	33.2	38.2
	15:30	34.08	38.78		15:30	33.22	37.89
	16:30	34.28	38.04		16:30	33.41	37.15
	17:30	34.38	36.87		17:30	33.5	35.99
	18:30	34.41	35.5		18:30	33.55	34.63
	19:30	34.45	34.12		19:30	33.6	33.26
	20:30	34.49	32.95		20:30	33.64	32.11
	21:30	34.53	31.89		21:30	33.69	31.06
	22:30	34.57	31.04		22:30	33.72	30.22
	23:30	34.6	30.41		23:30	33.75	29.59
May	0:30	36.29	32.01	November	0:30	29.25	25.01
	1:30	36.27	31.43		1:30	29.23	24.51
	2:30	36.27	30.96		2:30	29.22	24.1
	3:30	36.26	30.62		3:30	29.2	23.8
	4:30	36.24	30.5		4:30	29.18	23.7
	5:30	36.22	30.73		5:30	29.16	23.9
	6:30	36.11	31.31		6:30	29.04	24.41
	7:30	36.08	32.36		7:30	28.98	25.32
	8:30	36.09	33.86		8:30	28.98	26.63
	9:30	36.13	35.6		9:30	29	28.14
	10:30	36.18	37.58		10:30	29.03	29.86
	11:30	36.24	39.43		11:30	29.07	31.48
	12:30	36.3	40.82		12:30	29.11	32.69
	13:30	36.36	41.75		13:30	29.15	33.5
	14:30	36.4	42.1		14:30	29.17	33.8
	15:30	36.44	41.75		15:30	29.18	33.5
	16:30	36.64	40.94		16:30	29.37	32.79
	17:30	36.74	39.66		17:30	29.46	31.68
	18:30	36.78	38.16		18:30	29.51	30.37

	19:30	36.82	36.65		19:30	29.56	29.05	
	20:30	36.87	35.37		20:30	29.6	27.94	
	21:30	36.91	34.21		21:30	29.64	26.93	
	22:30	36.95	33.28		22:30	29.67	26.12	
	23:30	36.98	32.59		23:30	29.7	25.52	
June	0:30	37.33	33.16	December	0:30	26.25	22	
	1:30	37.31	32.6		1:30	26.22	21.54	
	2:30	37.31	32.15		2:30	26.21	21.17	
	3:30	37.3	31.81		3:30	26.19	20.89	
	4:30	37.28	31.7		4:30	26.17	20.8	
	5:30	37.27	31.92		5:30	26.15	20.98	
	6:30	37.16	32.48		6:30	26.03	21.44	
	7:30	37.13	33.49		7:30	25.96	22.27	
	8:30	37.15	34.95		8:30	25.95	23.47	
	9:30	37.18	36.63		9:30	25.96	24.85	
	10:30	37.23	38.53		10:30	25.98	26.41	
	11:30	37.29	40.32		11:30	26.02	27.88	
	12:30	37.36	41.67		12:30	26.05	28.99	
	13:30	37.42	42.56		13:30	26.08	29.72	
	14:30	37.47	42.9		14:30	26.1	30	
	15:30	37.5	42.56		15:30	26.11	29.72	
	16:30	37.71	41.78		16:30	26.29	29.08	
	17:30	37.82	40.55		17:30	26.38	28.07	
	18:30	37.85	39.09		18:30	26.43	26.87	
	19:30	37.89	37.64		19:30	26.47	25.68	
	20:30	37.93	36.4		20:30	26.5	24.66	
	21:30	37.98	35.28		21:30	26.54	23.74	
	22:30	38.02	34.39		22:30	26.57	23.01	
	23:30	38.05	33.72		23:30	26.59	22.46	
						31.784236	30.655972	1.1282639

Main Simulation Table

Period	Building Features	Simulation code	material table	Heat Gain					Energy Consumtion						Internal tempreture (if no AC)		
				External conduction Gain KW/Y	Internal conduction Gain kW/Y	Internal gain kW/Y	solar gain through glass kW/Y	total gains kW/Y	Total lights energy kW/Y	Ap Sys heat rej fans/pumps energy	Ap Sys chillers energy kW/Y	Total energy kW/Y	ACTUAL ENERGY COAST AED/YEAR	SUPPORTED ENERGY COAST AED/YEA	inside avarageE Air temperature (°C)	outside avarage Dry-bulb temperature (°C)	diffrences in tempreture (outside/i
Traditional House Before 1970's	with tengusten ligths	S-T	Table 1	39224.73	-317.17	51703.49	0	76737.27	41534.21	5200.527	14858.61	61593.28	15398.32	4311.53	24.97809	31.80986	-6.83177
1970's-1990's	with arcade	S-S1	Table 2	144765.4	-65.406	42781.61	30207.78	217689.4	35772.84	30067.74	85907.87	151748.3	37937.06	10622.38	36.31868	31.80986	4.508819
	without arcade	S-S1	Table3	151248.5	-65.469	42781.61	69274.8	263239.4	35772.84	34123.57	97495.91	167392.2	41848.04	11717.45			
1990's-2000	With brick and pitch roof	S-N1	Table 4	82125.71	0.75	42780.74	34582.71	159489.9	35772.84	21956.53	62733.03	120462.3	30115.57	8432.358	34.17851	31.80986	2.368646
	without brick and pitch roof	S-N2	Table 5	100068.3	0.759	42780.74	48315.81	191165.6	35772.84	24780.68	70802	131355.4	32838.84	9194.875			
2000-2010	re-traditionalism	S-T1	Table 6	63962.26	0.159	16636.39	28507.12	109105.9	11630.38	14327.48	40935.65	66893.52	16723.38	4682.546	32.87372	31.80986	1.063854
	post-modernism	S-T2	Table 7	74955.01	0.192	14995.15	44174.72	134125.1	9833.616	17386.61	49676.01	76896.39	19224.1	5382.748	33.12691	31.80986	1.317049
Future House After 2014	re-traditionalism	S-F1	Table 8	28566.05	-31.764	9660.384	28502.92	66697.59	11630.38	8645.697	24702.02	44978.12	11244.53	3148.469	27.56438	31.80986	-4.24549
	post-modernism	S-F2	Table 9	69260.61	0.159	11252.74	39127.3	119640.8	6002.208	15508.98	44311.37	65822.78	16455.7	4607.595	32.15563	31.80986	0.345764