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Potential of upgrading federal buildings in the United Arab Emirates to reduce energy demand

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Abstract

The efforts of the United Arab Emirates' (UAE) government regarding sustainable developments are remarkable. However, the challenge relies within the existing buildings. Lately, many strategies and initiatives have been launched to manage energy demand, as well as energy supply. In this paper, a federal building in the UAE is chosen as a case study to assess the potential of upgrading its energy efficiency performance. Passive and active strategies are implemented in order to reduce the energy demand from grid electricity. This building is chosen to represent a broader message of the country's vision towards sustainability both locally and globally.

VE IES simulation software is used to assess the impact of each strategy from both categories (passive and active) on reducing energy consumption. Different scenarios are applied to highlight the optimal strategy for each category. The optimal retrofit approach is defined and assessed to reach the maximum reduction from grid electricity. The results reveal that implementing passive measures, such as shading elements and upgrading walls and windows' thermal insulation, provide18.5 % saving of cooling energy consumption and 14.5% in total grid electricity consumption. Moreover, active measures, such as enhancing COP of cooling system and varying the cooling set-point, increase savings in electricity up to 65%. To form a complete image of a holistic retrofit, the results of a previous study conducted on the same building regarding the lighting system retrofit is considered in this study as well.

Keywords: Existing Buildings; Energy Retrofit Measures; Energy Simulation; Energy Demand Reduction; UAE

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1. Introduction

In the last few decades, changes in the climate have been globally recognized as a hot topic that needed to be seriously addressed. The causes for these changes are varied and many theories highlight different key triggers for these changes. Eventually, the carbon footprint has been considered as a measurement tool to estimate the green house gases (GHG) levels [1]. Governments and policymakers worldwide were required to consider mitigating global warming and to provide initiatives to reduce GHG emissions. The built environment is responsible for 40% of global energy consumption, 25% of global water, 40% of global resources, in total producing around 1/3 of global GHG emission. This in turn makes the building sector the largest contributor to GHG emissions [2].

1.1. Energy profile in the UAE

In the last three decades, the UAE has witnessed an active development in the building construction sector. Unfortunately, the country was labeled as the highest ecological footprint worldwide. In 2006, the UAE's per capita footprint was found to be 11.68 global hectares compared to the average ecological footprint per person worldwide being 2.6 hectares [3]. As a result, the country adopted the Ecological Footprint Initiative (EFI) in 2007. Moreover, in the year 2010, the UAE's government decided to join the Copenhagen Accord and has shown commitment to reduce CO_2 [4]. Lately, the Ministry of Environment and Water announced that the UAE ecological footprint in 2014 was dropped to 7.75 hectares [5]; a reduction of 33.6% in only 8 years.

A research conducted of the UAE explained that tackling the built environment with serious regulations regarding energy consumption, as well as replacing fossil fuels with clean energy sources, could reduce the emission of CO_2 by 50% [6]. Therefore, government organizations developed standards and codes that regulate the newly constructed buildings, such as the 2010 Abu Dhabi's Estidama with its 1-5 Pearls rating system and the 2011 Dubai Green Buildings Regulations. However, the majority of these efforts have focused on new buildings, whilst the existing buildings were neglected. It is evident that considering retrofit for the existing buildings is a practical and effective way to reduce the CO_2 emission, as shown through Etihad super ESCO's accomplished work on refurbishing some projects. For instance, the executed project for lighting retrofit at DEWA power station in Jabel Ali and Al-Awir confirmed a saving of 75% compared to the previous consumption and a reduction of 6,286 tons of CO_2 [7]. Statistics in 2011 showed that governmental buildings (offices and facilities) in Abu Dhabi alone consumed around 21% of the total energy, followed by commercial buildings with 30%. The residential sector showed the highest consumption with 33%. Moreover, Figure 1 shows the percentage of the consumed electricity in the UAE of each building sector according to 2013 statistics.

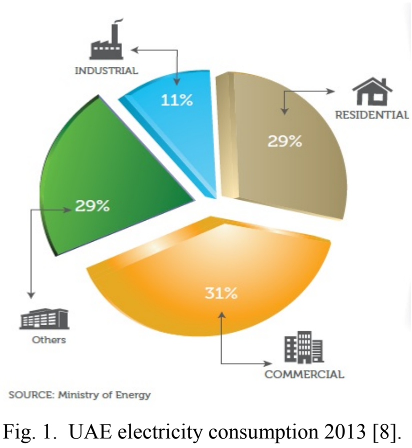

Fig. 1. UAE electricity consumption 2013 [8].

This paper will assess the potentials of upgrading a federal building in the UAE in order to reduce its electricity demand through implementing different passive and active measures. By retrofitting such buildings, a broader message of the country's vision towards sustainability will be delivered across the nation, which will increase the public's awareness towards the importance of energy efficiency and its potentials. Globally, presenting the federal buildings in the UAE as sustainable buildings will prove the country's serious efforts to positively contribute to mitigating the GHGs. It is important that the government leads by example and lays the ground work to make low energy buildings (LEBs) accessible to other building sectors which will allow the retrofit movement to progress.

1.2. Retrofitting the existing buildings

Manneh stated [9] that there are many factors that affect choosing one measure over other measures, such as applicability, feasibility, and outcome. Moreover, although upgrading HVAC system could be a costly, it offers big savings in energy consumption, especially in commercial buildings. On the other hand, enhancing the building envelope's thermal performance through implementing passive measures could be more feasible despite having less energy savings. Many case studies provided great examples that follow simple low investment conservation measures with good operational and maintenance practices in existing buildings which will provide great amounts of energy savings [7] & [10].

1.3. Passive measures

According to Gong, Akashi & Sumiyoshi [11], passive measures showed great influence in minimizing the amount of total energy consumption to achieve the occupants' thermal comfort when implemented in different climatic zones in China. Passive measures are considered among the most effective and viable strategies to save energy and money. These measures include shading elements, wall insulation, roof insulation, glazing materials and the windows to wall ratio. Moreover, it was found that the total energy consumption could be reduced by 23.6% if passive cooling measures are implemented [12].

Shading devices have proven to be an effective strategy in saving energy in areas with a hot summer. For example, the savings in energy due to implementing shading devices ranges between 8% for the coldest areas in Italy and 20% for the warmest [13]. However, the rate of the heat transfer is dependent on the U-values of the different elements that make up the building envelop. Reducing these values will lead to saving energy for cooling or heating purposes. A study was conducted with different scenarios of implementing thermal insulations for walls and roofs in a residential building in Saudi Arabia. It was found that insulating external walls and roofs could provide a higher energy saving compared to other passive elements such as external shading and efficient glazing [14].

Regarding glazing's thermal properties, by analyzing the correlation between the windows' proprieties and the rate of energy savings, the windows' retrofit measure has been standardized [15]. The authors of this study explained that by changing the windows' U-value in poorly insulated homes, the cooling or heating demands decrease by 7.9-16.7%, regardless of the windows' size. However, in better insulated houses with large windows, the percentage in energy saving increased to 18.4-29.7% by using a lower SHGC. They concluded that for the retrofitted windows, the U-value and the SHGC need to be adjusted to consider the thermal performance, in addition to the window-wall ratio, to obtain the maximum energy efficiency [15].

1.4. Active retrofit measures

Active retrofit measures deal with the building's electrical and mechanical systems which provide lighting, domestic hot water, heating, cooling and ventilation. Improvements could include upgrading the HVAC elements such as: chillers' performance sequencing, heat recovery, programmable thermostats and volume speed drive on air handling units. However, in order to insure achieving the maximum benefits of implementing different schemes of active measures, upgrading the building envelope's thermal performance should be applied as an initial step and evaluated at the same time along with the energy efficiency measures of the HVAC systems [16]. The scope of this paper will focus on a few active measures which are: varying the cooling set point and the air conditioning's coefficient of performance (COP).

The impact on saving energy by varying the thermostat cooling and heating set-points was investigated in a typical medium-sized office building [17]. Benefits in saving energy are expected by increasing the cooling set point in hot regions and decreasing the heating set-point in cold regions. It was stated that increasing the cooling set-point by 1°C will reduce the cooling load by 7.3% and the total energy consumption will be decreased by 3.4% [18]. Moreover, this measure is the easiest with no cost and without compromising thermal comfort [19].

The efficiency of air conditioning systems varies with the different operating conditions. However, chillers consume up to 35% of HVAC energy [20]. The cooling efficiency of the chiller is identified by its Coefficient of Performance (COP) or Energy Efficiency Ratio (EER). The higher the COP/EER the more efficient the system is. In commercial and office buildings, upgrading the HVAC system could provide more impact compared to some other elements, especially if the building is internal load dominant. [20] & [21]. The change from SEER 10 (COP 2.9) to SEER 13 (COP 3.8) represents around 30% improvement in energy efficiency [22]. Since 2006, the federal government in the U.S. has required a minimum SEER rating of SEER-13 for all new air conditioning units [23].

2. Methodology

Computer modelling using IES VE software is an efficient method to conduct this study. IES VE software has been validated against some standards such as USGBC, ASHRAE 140 and BEST [24]. Two sets of building simulations are conducted; the first set represents the current as built configuration. Whereas the second one assesses the proposed measures both passive and active and their impact on reducing the building energy demand, The obtained results of the different applied scenarios are studied through a quantitative analysis.

3. The Case Study

The Ministry of Infrastructure Development (MOID) building at the Emirate Ras Al Khaimah (RAK) was been chosen as a case study for multiple reasons. Although the government of the UAE shows serious efforts towards green buildings and sustainability, the few recent studies conducted in the UAE tented to focus on retrofitting residential and commercial buildings [9, 25, and 26]. Also, the chosen building "MOID RAK" was chosen in a previous study for retrofitting the electrical system [27]. It is worth mentioning that the UAE in general moves with a slow pace in retrofitting existing buildings due to some barriers and challenges [28]. Keeping this in mind, it is essential to perform a holistic retrofit study on all federal buildings in order for them to become a model for other buildings to follow.

3.1. Geographical and climatic conditions

Ras Al Khaimah is the fourth largest emirate of the UAE and covers an area of 1684 sq Km, which is equal to 3.16% of the total area of the UAE (Figure 2a). The climate is hot arid desert climate, with high temperatures and low levels of rainfall. In general, the climate features two major seasons with slight variations, a hot summer and a mild winter. Summer usually begins in late April with average high temperatures around 30°C, while July sees a drastic increase with temperatures normally beyond 40°C. Furthermore, humidity is very high during the summer months. During winter, the highest temperatures fluctuate between 19°C and 28°C and drops to its lowest during the nights of January and February.

3.2. Building characteristics

The chosen building as a case study (Figure 2b) was built in 2010, in accordance to the MOPW Green Building Guidelines (2009). It shows very good application of thermal insulation and new technologies for building systems as shown in Table 1. However, the electricity consumption for the year 2015 was 568.4 MWh, which translates to 252.5 kWh/m^2/year, which is considered relatively high comparing to the best practice in the UAE that shows its most energy efficient buildings consuming 110-160 kWh/m^2/year [29].

3.3. Implemented passive measures

The baseline building lacks any consideration for any kind of shading elements, except the horizontal overhang shading for the main entrance which is orientated northwest. The main concern is to focus on the elevations which are exposed to solar gain. For that, only southeast and southwest windows are implemented with shading strategies.

a b

Fig. 2. Location map (a), The case study front view (b)

Different scenarios with different shading element designs are assessed such as: vertical fins, cantilever and egg-crate (2x2 meters) as shown in Figure 3.

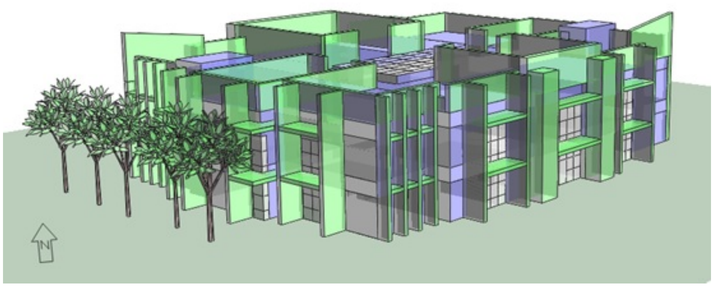

Fig. 3. Egg-crate shading elements (IIES VE, ModellIT).

Building codes worldwide have been designed in a way to reduce the building's impact on the environment, with a chance of making them more efficient over time. For example, some energy codes for commercial buildings in the United States, such as standard 90.1.2013 and IECC 2015, offer extra savings by 7.6% comparing to standards 90.1.2010 and IECC 2012 [30]. As an initial step, Estidama building regulations with its Pearls configuration (1 Pearl & 2 Pearls) will be applied [31], as well as Passivhaus regulations which is a low energy standard with EUI≤15 [32]. The design values for these systems are summarized in Table 1.

Table 1. Building codes thermal proprieties values.

Design component	MOPW Green Code	1 Pearl target values	2 Pearls target value	Passivhaus limiting values
Walls (U-values)	0.47 W/m^2k	0.320 W/m^2k	0.290 W/m^2k	$\leq$ 0.15 W/m^2k
Floor	1.38 W/m^2k	0.150 $W/m^2/k$	0.140 $W/m^2/k$	$\leq$ 0.15 W/m^2k
Roof	0.21 W/m^2k	0.140 W/m^2k	0.120 W/m^2k	$\leq$ 0.15 W/m^2k
Glazing	2.1 W/m^2k	2.200 $W/m^2/k$	1.900 $W/m^2/k$	$\leq$ 0.8 W/m^2k

Infiltration	0.350 ach	0.350 ach	0.200 ach	≤ 0.042 ach
Glazing SHGS	0.35	0.40	0.30	0.50

3.4. Implemented active measures

The biggest portion of the buildings' total energy consumption goes for cooling purposes. Increasing the cooling set-point is the easiest retrofit measure with no cost and with minimal effect on thermal comfort. Although the working hours for MOID-RAK are from 7 AM- 4 PM, the cooling system is usually left on continuously. Also, after interviewing some of the people in charge, it was found that employees have an easy access to the cooling set-point thermostat and can change it according to their preferences. The building's cooling system set-point is supposed to be set 23°C ± 1°C. However, in reality, the system was working at a cooling set-point temperature of 21°C for the nine summer months in the year 2015. During the winter months of 2015, the set-point was usually set for 24°C.

In this research, increasing the cooling set point to 24°C during working hours and shutting off the system during non-working hours will be the first scenario. Moreover, this strategy will increase the cooling set point up to 25°C in some selected zones, without compromising the occupants' thermal comfort. By analyzing the building's orientation, it is noticed that the office zones are mainly facing northeast and northwest, which is considered a good orientation with less solar heat gain as compared to the other zones that are facing southeast and southwest and have a higher chance of solar heat gain. Also, some zones which are used for short periods of time (transit zones) can handle higher cooling set points, regardless of their orientation, such as washrooms and service rooms.

Moreover, the system's COP for MOID-RAK is 2.88. Two scenarios will be proposed to enhance the energy efficiency performance of the cooling's system: one scenario in which the COP will be upgraded from 2.88 to the US Federal minimum COP 3.8, while the other scenario will consider a COP value based on the average of the most recent efficient systems. For that, (COP 5.3) has been chosen.

3.5. Optimal retrofit proposal

This proposal consists of the optimal passive scenario and the optimal active scenario combined in a single simulation. This approach considers the UAE's local region requirements, in addition to the amount of saving in electricity. At the end, in order to get a complete image of a holistic approach, the results of a previous study for the same building which assessed the lighting retrofit impact on reducing electricity will be considered.

4. Results and Discussion

4.1 Passive measures' impact on reducing grid electricity

Regarding shading elements, it is found that egg-crate shading design provides the best saving in HVAC energy system by1.6%; whereas, the horizontal cantilever offered 1.2% saving in system energy however, the vertical shading contributed with the least saving by 0.99% as shown in Figure 4.

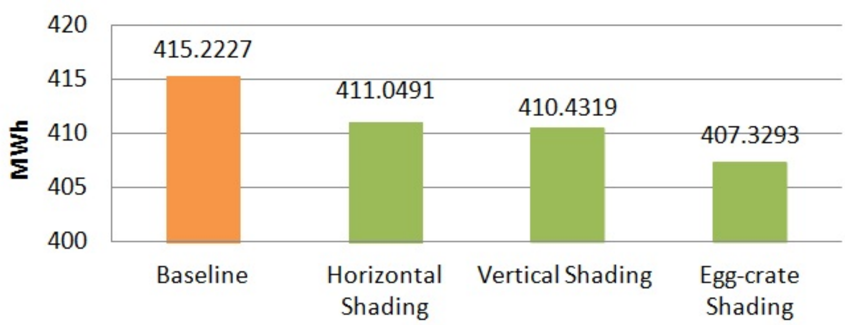

Fig. 4. The impact of different shading approaches on system energy.

Moreover, on the subject of upgrading the existing building code to be more efficient, it is noted that by applying 1 Pearl values, the total cooling system energy was dropped from 415.22 MWh to 408.69, which is equivalent to 1.4%. However, 2 Pearl values offer more saving where the system's energy was reduced from 415.22 MWh to 382.75 MWh, which is equal to 7.8 % saving.

However, in case of Passivhaus regulations it is noted that during the winter months (December-February) the system consumed more energy than 1 Pearl and 2 Pearls. This happened because of the type of glazing used in this Passivhaus standard (triple glazing with SC=0.5). In winter, when the sun is low, more solar radiation is penetrated and trapped; eventually adding up to the internal heat gain. However, aside from the winter months, Passivhaus standard has shown more reduction in the system's energy. The annual consumption for the cooling system dropped to 376.23 MWh with a 9.4% reduction. Using Passivhaus standards are expected to provide more reduction in energy with smaller glazing SC. Therefore, in order to reduce the solar radiation, Passivhaus values are used with a glazing SC=0.2. It was found that this change was very effective due to the building's glazing area, which is around 485 m2 of the total external walls (1300 m^2), 35% of which is facing south. The reduction in this scenario reached 16.2%.

It is important to mention that multi-layered glazing does not provide the same energy efficiency in all climates [33]. Since Passivhaus standards, with its triple glazing, is more appropriate for cold climates, another assessment will examine using Passivhaus values for opaque building elements; however, glazing will be replaced with double glazing (DG) windows with SC=0.2. The obtained results were impressive. It was found that DG with a low SC could provide better solar protection than triple glazing with a high SC. Also, such glazing combined with the opaque Passivhaus standard was able to reduce the system's energy by 15.3%. Figure 5 shows the different building codes scenarios.

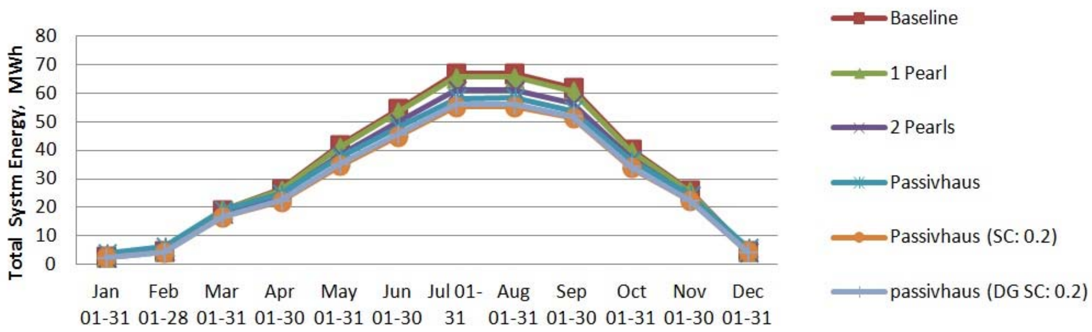

Fig. 5. The impact of different building codes with different scenarios on reducing the cooling system energy.

Ultimately, combining the optimal shading strategy (egg-crate) with the optimal building code for the local region (Passivhaus values for opaque elements & DG with SC=0.2) offers saving up to 18.5% in system energy and 14.5% in total electricity consumption.

4.2. Active measures impact

Increasing the cooling set point for the whole building up to 24°C, in addition to shutting off the AC after working hours, resulted in a significant saving in the cooling system energy by 64%. However, increasing the cooling set points to 24°C and 25°C for zones that are oriented southeast/southwest and northeast/northwest respectively, as well as, shutting off the AC during none working hours, increases the saving in cooling system energy up to 65.55%.

Regarding the COP upgrade, it provides great saving in cooling system energy as well. It is found that upgrading COP 2.88 to 3.8 and 5.3 saves 24.1% and 45.4% in the cooling system energy respectively . Eventually, the optimal active approach which considers the best scenario of each measure in this category was able to reduce the cooling energy demand by 80.4% and the electricity by 63.2%, see Figure 6.

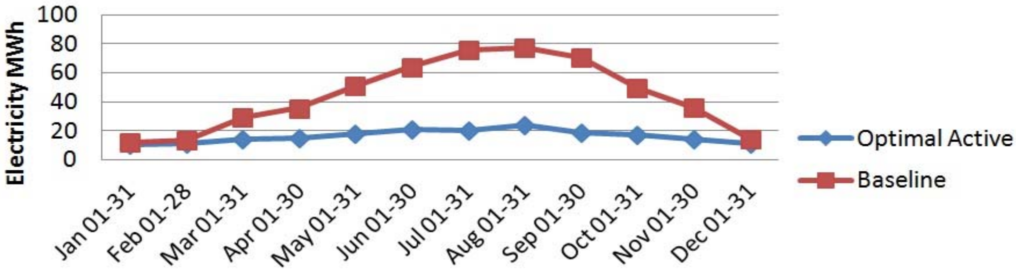

Fig. 6. The impact of both active measures (increasing cooling set point and upgrading the COP) on electricity demand.

4.3 Optimal retrofit impact

The obtained result in combining the passive optimal scenario and the active optimal scenario provides a major reduction in the total system energy from 415.22 MWh to 69.23 MWh, which is equivalent to 83%. The reduction in total energy has reached 65% and the total electricity reduction reached 65.3% as shown in Figure 7. Ultimately, the 34.6% energy demand has to be offset with PVs solar energy which is not part of this research's scope of work.

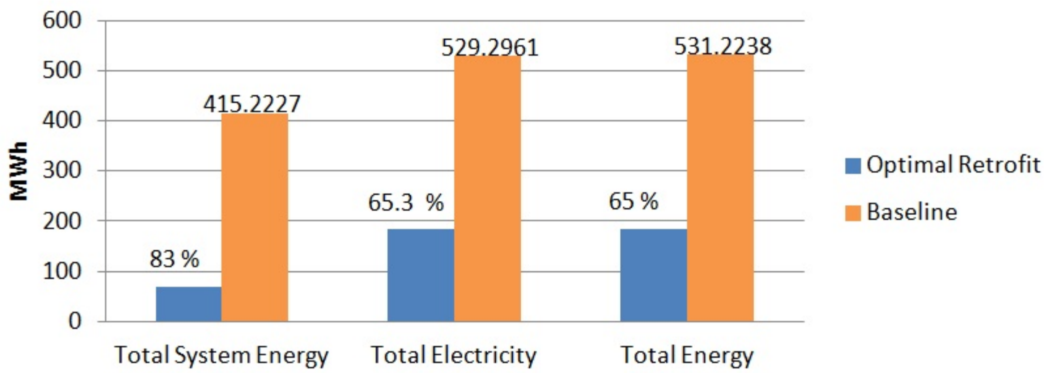

Fig. 7. Building energy consumption due to optimal retrofit approach.

A holistic retrofit approach is recommended when considering renewable energy such as PVs as an energy supply. For that, the results of a previous work [27], which focused on retrofitting the lighting system for the same building, is used in this research to help provide a holistic image. The result of 25% saving in lighting electricity consumption is deducted in this project to find out the total reduction in electricity consumption before introducing the photovoltaic system. The total electricity demand after the holistic retrofit is 169.9 MWh.

5. Conclusion

Both passive and active measures have played an important role in reducing electricity consumption. However, in newly constructed federal buildings, that take into good consideration the construction materials' thermal proprieties, the optimal passive scenario reduced electricity by 14.5%. Despite this, the building is an office building with a high internal gain; therefore, active measures proved to be more effective in reducing electricity consumption. The optimal active scenario reduced electricity consumption up to 63.2%.

The obtained results does not contradict with the fact that being in such a hot climate region requires consideration towards protecting the glazing from solar radiation as a priority; especially in a building with large windows such as the base case [15].

The optimal retrofit scenario that combines passive and active measures offered 65% savings in electricity consumption. Eventually, a holistic retrofit approach for a federal building in the UAE has the potential to reduce the energy demand from annual consumption of 568.4 MWh (year 2015) to 169.9 MWh which is equivalent to 70% reduction in electricity demand.

Acknowledgment

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References

[1] T. Wiedmann, Editorial: Carbon footprint and input-output analysis: An introduction; *Economic System Research*, (2009), 21 (3), 175–186.
[2] UNEP, Why Buildings?,United Nation Environment Programme and Sustainable Building and Climate Initiative, (2015), available at: www.unep.org/sbci/AboutSBCI/Background.asp, accessed on 3 October 2015,
[3] http:/business.heroesoftheuae.ae/en/section/the-problem retrieved on 10/1/ 2015
[4] Ministry of Foreign Affairs, United Nations Framework Convention on Climatic Change, (2010), available at: http://unfccc.int/files/meetings/cop_15/copenhagen_accord/application/pdf/uaecphaccord.pdf, accessed on 1 May 2016,
[5] https://www.wam.ae/en/news/emirates/1395279019133.html, retrieved on 4/5/ 2016
[6] H. RADHI, 'On the Effect of Global Warming and the UAE Built Environment, Global Warming', *Stuart Arthur Harris (Ed)* , (2010)
[7] http://www.etihadesco.ae/pressreleases/75-measured-and-verified-electricity-savings-at-dewa-power-stations/ , retrieved on 31/5/ 2016
[8] M. Saches, Ministry of Energy, UAE, "STATE OF ENERGY REPORT UAE 2015", 2016,
[9] A. Manneh, Assessing energy saving potential in existing buildings in Abu Dhabi through passive retrofitting strategies: Case study- office buildings, *M.Sc. Thesis. British University in Dubai*. 2013
[10] http://emiratesgbc.org/wp-content/uploads/2014/08/case_study_dubai_chamber_leed.pdf retrieved on 10/1/ 2015
[11] X. Gong, , Y. Akashi , & D. Sumiyoshi, Optimization of passive design measures for residential buildings in different Chinese areas, *Building and Environment,* (2012), 58, 46-57
[12] H.M. Taleb, 'Using passive cooling strategies to improve thermal performance and reduce energy consumption of residential buildings in U.A.E. Buildings', *Frontiers of Architectural Research*, (2014), 3(2), 154-165
[13] L, Bellia , F. De. Falco, & F. Minichiello, Effects of solar shading devices on energy requirements of standalone office buildings for Italian climates, *Applied thermal Engineering*, (2013), 54, 190-201.
[14] H. Taleb**,** and S. Sharples, Developing sustainable residential buildings in Saudi Arabia: A case study, *Applied Energy,* (2011), 88, 383–391
[15] B.Lip Ahn, J.Hun Kim, C. Yong Jang, S.Bok Leigh & H. Jeong, Window retrofit strategy for energy saving in existing residences with different thermal characteristics and window sizes. *Building services Engineering Research*

& Technology, The Charted Institution of Building services Engineering, (2015), DOI: 10.1177/0143624415595904
[16] Z. Wang, Y. Ding, G. Geng & N. Zhu, Analysis of energy efficiency retrofit schemes for heating ventilating and air-conditioning systems in buildings based on the modified bin methods. *Energy Conversion and Management*, (2014), 77, 233-242
[17] T. Hoyt, E. Arens, & H. Zhang, Extending air temperature setpoints: Simulated energy savings and design considerations for new and retrofit buildings. *Building and Environment*. (2014), 88, 89-96
[18] T. Itani, N. Ghaddar, & K. Ghali, Strategies for reducing energy consumption in existing office buildings, *International Journal of Sustainable Energy*, (2013) 32:4, 259-275, DOI: 10.1080/14786451.2011.622765
[19] O.J.Kwong, , , N.M. Adam and B.B Sahari, Thermal comfort assessment and potential for energy efficiency enhancement in modern tropical buildings: A review, *Energy and Buildings,* (2014), 68, 547-557.
[20] http://industry.gov.au/Energy/EnergyEfficiency/Documents/09_2013/hvac-fs-chiller-efficiency.pdf retrieved on 22/6/2016
[20] Y. Liu, and W. Guo, Effects of energy conservation and emission reduction on energy efficiency retrofit for existing residence: A case from China. *Energy and Buildings*, (2013), 61, 61-72.
[21] M. Levine , W. Feng , J. Ke, T. Hong & N. Zhou, A Retrofit Tool for Improving Energy Efficiency of Commercial Buildings. *ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY*, (2014)
[22] http://www.eesi.org/papers/view/fact-sheet-air-conditioner-efficiency-standards- , retrieved on 15/6/ 2016
[23] http://allclimate.net/2014/11/26/seer-stand/retrieved on 17/6/ 2016
[24] https://www.iesve.com/software/software-validation, retrieved on 10/7/ 2016
[25] W. AlAwadi , A. AlNaqabi , A. Manneh , K. Ayoub & B. A.K. Abu-Hijleh, Energy Saving Potential Due to Refurbishment of Federal Public Housing in the UAE. *Engineering,* (2013),5, 132-136.
[26] A. Manneh, , A. AlNaqabi, , W. AlAwadi, , K. Ayoub, & B. Abu-Hijleh, Economic Assessment of Refurbishment of Federal Public Housing in the UAE. *World Sustainable Building 14 Conference.* Barcelona, Spain, 28-30/10/ 2014.
[27] W. Al Awadhi, Reducing the energy consumption in the federal buildings in UAE using lighting and control system, *M.Sc. Thesis. British University in Dubai*, (2014)
[28] E. Al Khateeb and H. Altan, Retrofitting the Existing Buildings in the United Arab Emirates, Barriers, opportunities and Recommendations", *Conference Proceeding Zero Energy Mass Custom Home (ZEMCH*), Leece, Italy, 22-25/9/ 2015
[29] http://www.khaleejtimes.com/nation/abu-dhabi/80-energy-consumed-by-buildings, retrieved on 21/4/2016
[30] http://cxegroup.com/wp-content/uploads/2015/11/Energy-Code-Analysis-by-CxE-150728.pdf, retrieved on 4/5/2016
[31] http://estidama.upc.gov.ae/pearl-rating-system-v10/pearl-building-rating-system.aspx , retrieved on 4/6/ 2016
[32] http://www.passivhaus.org.uk/standard, retrieved on 4/6/ 2016
[33] N. Mingotti, T. Chenvidyakarn, and A.W. Woods, 'Combined impacts of climate and wall insulation on the energy benefit on an extra layer of glazing in the facade', *Energy and Buildings*, (2013), 58, 237-249.