Strategies for an Environment Friendly Low Energy Retrofitting of a Health Care Facility in the Hot Climate of UAE

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ABSTRACT
The existing building stock in the United Arab Emirates finds it more difficult to compete with the new more environmental friendly and energy efficient buildings and do not fit into the country’s vision of sustainability. Even if all new building have zero CO2 emissions, the older inefficient building stock will cause the CO2 emissions levels to remain unacceptably high which, means older building stock needs to adapt to environment friendly energy efficient measures. The current research focuses on the green retrofitting strategies of an existing building in the hot and arid climate of the UAE. The study examines the existing building envelope of Latifa hospital using the energy simulation software e-QUEST. Using the simulation model, the building behavior was predicted for the retrofitting strategies of thermal insulations, window to wall ratios, wind types, ventilation fans and types of HVAC system to achieve optimal retrofitting of the building.

INTRODUCTION
For the last forty years, the United Arab Emirates (UAE) has witnessed an unprecedented pace of urbanization and population growth due to rapid economic development. The rapid growth of UAE’s economy has been accompanied by a substantial increase in energy consumption. Partly, the significant increase in energy consumption is due to inefficient existing facilities (Elgendy, 2010a, 2010b). The UAE energy intensive construction approach coupled with its extreme hot climate, require heavy cooling and have appointed the UAE in the top 10 countries in terms of electricity usage per capita and the second highest in terms of CO2 emissions per capita (AlNaqbi et al, 2012a, 2012b, AlAwadhi, 2013). The single largest contribution to the electrical load comes from cooling which accounts for an average of 40% of total year around electrical load and up to 60% of the peak electrical load during the summer time (Al Awadhi, 2013). The majorities of UAE buildings stock was constructed long before the introduction to sustainability codes and standards and therefore is incompatible with current standards or the expectations of the users (Shady, 2010). Sustainable retrofit is not a new concept but is gaining recognition and importance owing to current concerns about intensive energy use in buildings leading to climate change (Backer, 2009).

Latifa Hospital (previously Al Wasl Hospital), a 367-bed specialized maternity and paediatric hospital, opened in 1986. The two-story hospital building is oriented east south-east (Figure1) and has a gross floor area of approximately 73,213 sq.m with the central plant area being around approximately 3,300 sq.m (Figures 2, 3).
Figure 1: Case study; Latifa Hospital: Massing and Orientation

The building has a reinforced concrete structural frame with foundations on piles and block work for the external envelope and internal partitions. The base structural bays are 7.20m x 7.20m for a 4.5 floor-to-floor height. Ceilings are set at 3 meters, except in wet areas where they are at a standard 2.70 meters. The external walls are made of a double block work with a 40 mm cavity filled with a pre-compressed isolation polystyrene board and a layer of bituminized fiber for dampproofing. The windows and doors are provided with sealed double glass with solar control coating to regulate the UV light and reduce heat gain while providing sufficient and uniform daylight. Double glazing windows are the common hospital window type, solar control reflective insulating glass type, and bronze color, 6 mm. with direct transmittance 21%, total solar transmittance 26%; shading coefficient 0.30% and U value 1.4 w/m2. K.

METHODOLOGY

In order to develop effective energy conservation guidelines, the nature and magnitude of the energy usage in the existing hospital was determined through direct collaboration with the hospital facility personnel.

Figure 2: Ground Floor Zones Layout
The study investigates the performance of the existing building envelope, the HVAC system and other energy efficiency measures then explores their optimization potential. The inputs for simulation program are collected through extensive review of design drawings.

**Figure 3:**  *First Floor Zones Layout*

All the collected data has been analyzed to determine the base case of the existing building electrical consumption and compared with the predictions of the simulations to validate the methodology. The existing building model was generated using e-QUEST software. The building was set at its actual orientation with all openings placed per their location and specificities. As a first step, the building was simulated “as is” to determine the base case. All required inputs of insulation level, type of window and glazing, shading, roof insulation, flooring construction materials, type of HVAC systems, building occupancy, operation schedules and loads were added to the program to calculate the annual energy consumption of the base case. Results obtained from the simulation (e-QUEST) software were compared with the actual energy consumption data achieved through bills and energy audit to validate the simulations results. Once the model was validated, the optimization was carried out to determine potential areas of energy savings pertinent to retrofitting.

**RESULTS AND DISCUSSION**

Various strategies for energy performance optimizations were tested through simulations. The energy performance simulations were performed through eQuest, in order to optimize the envelope for reduced heat gain through insulations, façade construction, envelop colour and glazings. The HVAC system was optimized for ventilation and infiltration, efficiency rating, better comfort settings and better HVAC scheduling. Thereafter based on the results and analysis, recommendations for retrofitting the building are outlined for façade construction and systems integration.
Wall Optimization

At first, the wall colour was studied for its impact on energy performance of the building to attain an optimum wall colour with reasonable energy performance assuming the darker colour as a reference and with no insulation applied. Walls colors were changed from dark abs.=0.9 to light abs.= 0.4 gradually and the electrical energy consumption was computed. The result shows that change in the walls color from dark to deer’ light (abs= 0.45) has reduced annual energy consumption by 0.13% (Figure 4). As a second measure, the effect of wall insulation was studied on the energy performance while changing the insulation gradually from R= 0 to R= 12. The increased insulation yielded a reduction in annual energy consumption of 0.33%. Finally the net effect of reduced colour absorptance and increased insulation was simulated which yielded an energy saving of 0.4%.

Figure 4: Simulation results of collective wall optimization through wall colour and added insulation for Latifa Hospital, Dubai using 2013 weather data.

Roof Optimization

The building roof was optimized following the same scheme described for wall optimization and the individual impact of color and insulation were studied at first while later the combined effect of reduced color absorptance and increased insulation were computed. Change in roof color from dark (abs.= 0.9) to deer light (abs.= 0.4) yielded a reduction in annual electrical energy consumption of 1.81% plotted (Figure 5). It was observed that the optimum reduction of 2.59% is achieved at R=9 while the drop in energy consumption at higher R-value is insignificant.

Figure 5: Simulation results applying roof insulation for Latifa Hospital, Dubai using 2013 weather data.
Envelop Optimization

It was observed that changing the whole envelop color from dark to deer’ light (abs = 0.4) yielded a reduction of 2.0% in annual energy consumption while increasing the envelop insulation from R=0 to R=9 resulted in a 3.41% decrease in annual energy consumption. Finally energy consumption for existing envelop insulation values (Wall Insulation R= 6 and Roof Insulation R=6) was simulated and compared with energy consumption of proposed insulation (wall insulation R=9 and roof insulation R=9) which achieved a further reduction of 1.93% compared to the existing insulation level which emphasized the need for retrofitting and replacing the wall and roof insulation. One very important observation writes the stronger impact of color yielding 2% decrease in annual energy consumption compared to the darker color, an option that carries minimal cost and would be an economically attractive option for retrofits and new designs.

**Figure 6:** Simulation results applying façade insulation for Latifa Hospital, Dubai using 2013 weather data.

Comparing the existing façade colour for retrofitting (wall abs=0.6 and roof abs.=0.4) to the proposed façade colour (wall abs.=0.4 and roof abs.=0.4) yields a reduction of 0.1% in annual energy consumption which indicates that the current façade colour is optimized and offers least opportunities for further energy savings.

**Figure 7:** Simulation results investigating façade colour for Latifa Hospital, Dubai using 2013 weather data.

Window Optimization

Proper placement of windows and optimized window to wall ratio achieves have a strong impact on energy consumption in the climatic context (Fathy, 1986). In order to optimize window to wall ratio
(WWR), it was increased from a minimal of 10% to relatively higher value of 45% and a discrete energy performance trend was observed in three different WWR regimes. In the first regime, increasing WWR from 10.5 to 20% has negligible increase in energy consumption primarily because the increase in heat gain is compensated by the decrease in area lighting load of the indoors. In the second regime increasing WWR from 20% -30% increased the energy consumption modestly which shows that the benefit of increased lighting loads are being outclassed by the increase in heat gain. In the third regime, increasing WWR beyond 30% yielded a sharp increase in energy consumption which indicated that at this stage only heat gain is the consequential for the increased WWR which emphasizes economic implications of increased WWR beyond a certain range. The simulated results agree with similar research which recommends WWR of 10-20% for better energy performance [Aboulnaga, 2006]. Comparing the optimum range of WWR of 20-30% computed through simulations with the existing building WWR of 17%, it is proposed that for retrofitting the glazings should be increased up to 25% to have better daylight for a healthier indoor climate critical for hospital buildings even at the cost of affordable extra energy consumption. At the second stage different window types were simulated and it was observed that replacing the existing double clear/tint glass type to double low-e a reduction of 0.7% in energy can be achieved which shows that while retrofitting, the window type needs to be re-considered.

![Figure 8: Simulation results with various WWR for Latifa Hospital, Dubai using 2013 weather data.](image)

**Optimizing HVAC**

Energy Efficiency Ratios (EER) of the HVAC was studied against energy consumption in the range of EER =10 to EER= 26 shown in figure 9.

![Figure 9: Simulation results for cooling system energy efficiency for Latifa Hospital, Dubai using 2013 weather data.](image)
The existing EER of the system being 17.5 was compared with a higher EER value of up to 26 and it is observed that energy consumption can be reduced by 5.92% while increasing the EER to 22. It is therefore emphasized that selecting a higher efficiency cooling system can save a huge amount of energy and the cooling system should be replaced with more efficient system while retrofitting.

**Optimizing Comfort Conditions**

A general observation made in UAE is a trend of setting thermostat to undesirably (and at times uncomfortably) low temperatures around 20-22 °C which has its implications on energy consumption and operation cost. Effective and comfortable cooling can still be achieved keeping the thermostat set point at a higher temperature and increasing a little more fan ventilation. An attempt was made to simulate the trend of the impact while changing the thermostat set-point from 22 °C to 24 °C in occupied areas and from 26 °C to 28°C in unoccupied areas being still in the comfort zone based on psychometrics of the place. The result shows a reduction of 0.27% in annual energy consumption which emphasized the importance of operating the cooling system at right comfort conditions without sacrificing comfort.

**Optimizing Fan Type**

Installing Variable Frequency Drives (VFDs) on the supply and return fans of the Air Handling Unit (AHU) can reduce energy consumption by 20% (Schneider Electric, 2006). In order to test this, the existing constant-volume air handling system with centrifugal fan type was replaced VFDs on the supply and return ducts of the AHUs. The results show a reduction of 20.23% in the annual energy consumption. Although the simulation result showed a substantial potential reduction in energy consumption, this type of fans cannot be used in the hospital environment as the variable VFD causes ventilation problem in low cooling load conditions and causes associated health hazard. It is therefore proposed to keep the same fan type.

**Integration of Solar Thermal Collectors**

The hospital has a 12,000 lit/day hot water consumption which demands a large amount of energy for water heating. Since UAE has vast solar energy potential, heating problem was solved by integrating solar thermal collector on the roof to provide hot water. The system consists of 18 collectors with aperture area of 1.87 m², water mass flow rate of 35 kg/hr and water tank capacity of 300 lit each. It is coupled with an auxiliary electrical heating system to constantly supply hot water at 63 °C.

![Figure 10 Solar Thermal Collector installed on the roof of Latifa Hospital, Dubai.](image)

In order to determine its performance, the solar thermal system is simulated in TRNSYS software using...
Dubai weather data to find out the ratio of solar thermal energy supplied to the auxiliary energy needed for the stable 63 °C supply water temperature. The solar thermal system attained a total yearly thermal energy production of 212,224 KWh which contributed 46% of the total energy consumption for hot water production in the hospital and therefore it is recommended that the share of solar thermal should further be increased to attain energy efficient and cost competitive hot water production.

**CONCLUSION**

This paper has explored energy saving opportunities while retrofitting an existing healthcare facility in Dubai, UAE through a simulation scheme. The simulations findings resulted in a number of recommendations for energy efficient and cost competitive retrofitting solutions in the climatic context while pointing out indicative impact of occupants’ behavior on energy consumption of cooling system.

The findings are in three different areas. First, for the façade construction, choosing a lighter color has huge impact reaching up to 2% energy savings with least cost incurred, adding wall and roof insulation yields up to 3.4% energy savings although they incur additional cost as well, proper window type can yield up to 0.7% of energy savings with minimal cost addition and the optimum WWR is a found between 20-25% for healthier indoors with little extra energy cost. Secondly for HVAC system operation and efficiency, keeping the cooling set points within acceptable comfort can achieve 0.27% energy savings with no extra cost and replacing the existing HVAC with a more efficient cooling system can achieve up to 5.9% energy savings with extra cost of system. Finally integration of 18 solar thermal collectors in the building as a means of renewable and environmental friendly source of energy contributed to 46% energy saving for hot water production economically competitive rates and therefore is recommended for a higher energy share.

**REFERENCES**


