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# Green Building Retrofitting in the UAE

Mariam Ibrahim[1], Eilin Rachid[1], Yousef Awera[1], and Salwa Beheiry [2]

[1] Civil Engineering Student, The American University of Sharjah, Sharjah, UAE.
[2] Associate Professor of Civil Engineering, The American University of Sharjah, Sharjah, UAE.
sbeheiry@aus.edu

**Abstract.** The UAE went through a huge building boom in the last twenty years, resulting in extensive useful infrastructure, yet not necessarily all was built with green design parameters in mind. As these buildings reach their retrofitting milestones, it is an opportunity for owner/developers to retrofit the necessary components for improved energy efficiency and reduced carbon footprints. Thus, this paper summarizes the rationale behind the basic elements identified in a study to develop a green retrofitting toolkit for commercial buildings in the United Arab Emirates. The study focused on refurbishing the passive systems, such as the building envelope (wall enclosures and roofs), and the active systems (lighting and HVAC systems). The methodology that was followed involved looking at the purpose of retrofitting a building for each criterion and examining the necessary issues to be considered, as well as providing the optimum solutions along with a performance matrix for the UAE climate in terms of energy and cost savings. Moreover, a Revit based model was used on a prototypical commercial building design to assess the energy efficiency and resultant cost savings. The study emphasized an all-inclusive retrofitting approach.

**Keywords:** Green Buildings, Retrofitting, UAE, Toolkit, Passive and Active Systems Design.

## 1 Introduction

Several innovative building technologies have been put into practice to reinforce the concept of sustainability in modern construction. These practices may include passive or active designs. Passive designs consist of dealing with the building envelope to help reduce energy consumption for the building as a whole. On the other hand, active designs deal with high efficiency ventilation systems that also contribute to energy savings. Countries such as the UAE can greatly benefit from implementing certain efficient design techniques since the cooling load is extremely high in the summer given the harsh summer weather. Buildings that use both techniques will have the most efficient energy performance.

This study focuses on retrofitting an existing building by looking at the passive and active design techniques together to create a holistic approach to building retrofitting. The focus of this paper is to tackle 3 main components of a building that are the building envelope components, lighting systems, and HVAC (heating, ventilating and air-conditioning) to save energy. This can be done by implementing the best techniques to

retrofit existing buildings in the UAE. It is essential to optimize the practical performance of each technique to obtain promising results, in which cost plays a role. Therefore, any client that uses this toolkit will vary his/her decisions based on the amount of money he/she is willing to pay, as well as examining the status of the energy performance of the building.

## 1.1 Background

The preliminary idea behind this project is to discover the possibility of revamping existing buildings, making them sustainable using passive and active design techniques. More focus will be placed on implementing this strategy in the UAE, where the climate is viewed as hot and humid. During the summer season, cooling systems are extensively used in buildings. Therefore, using efficient retrofitting techniques is a promising strategy to increase energy savings. The more general perspective of the project is to enforce energy-efficient strategies by enhancing air tightness measures, as well as the lighting and HVAC systems. This is because energy efficiency is the main component of green buildings. In practice, energy efficiency can be implemented using either active or passive systems. Active systems include improvements on HVAC and lighting, while passive systems tackle the building envelope components. It is the focus of this project to explore the considerations the main design techniques, and which types will be the most efficient in the UAE climate to allow for more energy-saving building systems. At the end of the project, our deliverables are to produce a toolkit that measures the performance of a retrofitted building. Furthermore, a physical model and a Revit model will be done to represent a retrofitted building.

## 1.2 Literature Review

### 1.2.1 Passive Buildings

With the rising level of energy consumption due to rapid industrialization and population growth, more fossil fuels are burned which essentially causes global warming. In a hot and humid climate such as the UAE, cooling is the major contributor in energy consumption specifically during summer peaks. It is mentioned that 75% of the electricity consumption in summer months in Abu-Dhabi is due to air conditioning [1]. For such high levels of energy consumption during harsh climate conditions, it is important to incorporate passive techniques that ensure the use of an appropriate building envelope and insulation measures. Since the weather plays a significant role in the performance of the building, accommodating for the humidity factor in the UAE is necessary for building design. Regarding the adverse effect of humidity on the building envelope, it is argued that the higher the humidity, the more is the decline of insulation benefits from the wall systems due to air infiltration [2]. In turn, this might affect the durability, which means that the building will not have a longer service life that will lead to costly maintenance results.

Green buildings, also called passive or low energy buildings, have less negative impact on the environment than traditional buildings due to natural lighting and aesthetic views when combined with green roofs. It is mentioned that green roofs with drought tolerant grasses, especially useful in the UAE, can a decrease in temperature by 15 degrees [3]. A green roof also helps in keeping the air clean and improving storm water management. In addition, using windows with low emission glazing helps in reducing the interior heat gain, lowering the need for high cooling loads.

The building envelope consists of the building components that surround the indoor spaces, while interacting with the outside environment [4]. This includes windows, doors, roofs, walls, cladding and façade systems. The main issue with building envelopes is their tendency to infiltrate air, increasing the heat gain, which may result in unfavorable indoor environments. The solution to this would be to focus on enhancing the air-tightness of the building by retrofitting its envelope using cost-effective measures. Another solution that is widely discussed regarding building energy efficiency in hot climates is the double facade [5].

The use of a double facade is justified to elevate the heating and cooling loads, as well as climate conditions found in the UAE such as humidity. In the UAE, solar avoidance would be the primary reason behind adding a double facade to escape the harsh summer sun. The best way to retrofit windows tailored for hot climates is to apply double glazed windows with low-e coatings [6]. In fact, a special coating will actually reduce the size of the air-conditioners needed and thereby reducing the cooling load of the building. In addition, a few added benefits come with better-insulated windows such as the reduced sound transfer and increased comfort of the occupants [6].

### 1.2.2 Active Buildings

Retrofitting active systems in a building involves elements such as lighting and HVAC. All building systems interact in a way that any improvements to a single system indirectly enhance the performance of the other. For example, the performance of the lighting system in a building is affected by the HVAC choices made [7]. Specifically, it was shown that lighting systems retrofits that save one watt in the lighting power would save about a third of a watt in the cooling load. Typically, lighting retrofits have a payback period of about 2 years [8]. LED lamps are shown to be more energy efficient when compared to fluorescent lamps. Therefore, considering a lighting retrofit that incorporates LED lamps would be important on a whole building scale. Besides changing the type of lamps to more efficient ones, the usage of a lighting control system is also an efficient method to upgrade a lighting system [8]. The main drawback of using control systems is the difficulty of estimating an exact payback period since it would mainly depend on the usage of the system by the occupants. Adding an automated occupancy-based control system which can increase energy savings by 20-93% [8]. Day lighting systems can also be used in a way that automatically switches off whenever daylight is sensed. According to the UAE Energy Efficiency Standard, 20% of the electricity is consumed by households globally for lighting purposes [9]. Also, there is a potential for using high energy efficient lamps such as Compact Fluorescent Lamps (CFLs), Light Emitting Diodes (LEDs) and Halogen bulbs [9]. The

UAE can save up to 668 million/year from overall saved electricity bills from households. For atypical medium-sized villa in Dubai, lighting retrofits that are more efficient can save up to AED 2,315/year.

In office buildings, lighting consumes about 20-45% of the total electrical demand. It is assured that using lighting control systems can reduce energy consumption up to 15% [10]. Similar to the positive effects of well-insulated windows, buildings with lighting systems that are appropriately designed to integrate enough daylight are shown to lead to increased occupants comfort and reduced headaches resulting from overly installed artificial lighting. When dealing with a harsh UAE summers, it is of great significance to focus on the most energy-intensive systems that are more relevant than others. Primarily, HVAC systems require the most energy in commercial buildings. As an example, researchers have explained that the use of Variable Air Volume (VAV) systems can lead to energy savings when compared to unitary systems [11]. Different studies were dedicated to explaining energy savings methods of an HVAC system. For example, air conditioners, central air conditioners, chillers and ducts can be more energy efficient when certain methodologies are followed. These will be elaborated on in more detail later in this report.

## 1.3 Statement of the Problem

Energy consumption should be considered when talking about the economy and the environment since it is an important feature. The energy consumption in the UAE has increased by huge amounts because of several factors, such as the rapid growth in the population and industrialization. Energy in the UAE is obtained from burning fossil fuels and this is known to be a high source of emitting the greenhouse gas carbon dioxide (CO2) [12]. These emissions have negative impact on the environment, human beings and animals; hence, they tend to speed up the climate change and global warming process, giving an unsuitable place for humans and animals to live in due to the health problems attributed with the emissions. The projected data for the UAE's $CO_2$ emissions from 2011 to 2050 has showed that it will increase to a high number from 188.77 Mtonnes to 390.05 Mtonnes [12].

However, this is a far-reaching problem that should be treated differently, and various solutions are available. In an attempt to decrease the carbon footprint, dealing with the building envelope by improving its insulation acts as a passive retrofitting technique. Furthermore, the problem can also be tackled by the concept of lighting and HVAC system retrofits as an active design technique. These elements can contribute in reducing the energy consumption of thermal heating and cooling loads during summer peak time, when the energy consumed on the usage of HVAC systems is the highest.

## 1.4 Significance of the Project

With regards to energy consumption, the UAE requires additional innovative design ideas for building systems that account for the general concept of sustainability. Currently, there exist ideas that have already been implemented in the UAE such as geothermal energy and solar energy used for building heating and cooling systems e.g.

Masdar City. More focus is placed on cooling systems since the country undergoes relatively violent summers. With the increasing amount of building construction, there is a growing need to increase energy savings as much as possible. The focus of this project is to bring the combination of active and passive design techniques idea forward to get a high-performance retrofitted building that is cost effective. It will benefit the engineering industry by providing an optimum solution that is tailored to the weather and existing building systems in the UAE. The aim is to offer an efficient solution that can be put into action in the hope of revamping existing buildings, making the building sustainable in nature. This project idea is unique since there is no combination of techniques that is specifically made to suit the climate of the UAE, which will have a strong impact in the building engineering industry. The objective of this study was to propose a green toolkit to retrofit existing buildings in the UAE for better energy efficiency.

# 2 Methodology and Approach

The methodology hinged on an extensive literature and products review for both passive and active buildings design criteria. In addition, certain building components were identified and analyzed to propose the standardized toolkit and assess the performance of the suggested retrofits based on cost and energy saving for these UAE based buildings. The suitability of the proposed retrofits for the UAE climate is also assessed. The following section summarizes the key elements included in the proposed toolkit with solutions.

# 3 The Basic Elements for a Green Retrofitting Toolkit

## 3.1 Building Envelope Air Tightness

The primary focus of improving the air-tightness of a building is to reduce heat gain through better insulation, namely preventing the entrance of hot air, dust, and moisture. Since these are specific problems in the UAE, it is vital that building envelope components should be retrofitted to provide better insulation, and hence elevated air-tightness measures. The building envelope consists of the parts of the building that are directly subjected to the outdoor environment, including windows, doors, roofs, walls, foundations etc. Windows and doors are very important components through which high-energy savings can be incurred if retrofitted appropriately.

At this point, it is essential to define the term ‘fenestration’. Fenestration means the arrangement, in terms of design and position, of structural openings in a building [4]. Fenestration affects building energy use in several ways including conductive heat transfer, solar heat gain, air leakage, and day lighting. Since day lighting does not fall under the aspect of air-tightness, it will be dedicated a whole section later in this report due to its significant energy contributions. Solar heat gain is the radiant solar heat that penetrates the building, usually through windows, that contributes to increased heat loads. Solar heat gain is defined by the Solar Heat Gain Coefficient (SHGC) meaning

"the fraction of solar energy that enters the window and becomes heat" [4]. Air leakage is the uncontrolled airflow throughout the building envelope. Any building envelope retrofit option that would minimize any of the above-mentioned energy mechanisms is considered worthwhile and efficient. Namely, adopting glazing systems that would reduce conductive heat transfer and solar heat gain would entail reduced cooling loads. Furthermore, components that prevent air infiltration through any possible openings are preferred.

### 3.2 Double-skin Façades

A double skin façade is one that includes constructing a second layer of façade over the existing one that is usually transparent [13]. It has been supported by several researchers that adopting a double-skin façade in a hot humid climate like the UAE is very energy efficient since it significantly reduces the solar heat gain parameter, while also keeping dust and humidity outside the building [3, 14]. This promotes the concept of enhanced air-tightness measures throughout the building envelope. However, the payback period is quite long due to its extensive planning and design making it an option that is more on the expensive side of the spectrum.

### 3.3 Green Roofs

Green roofs technology is on the rise all over the world for its great benefits to people and environment. Green roofs have been done widely in Europe for more than a decade, and now 20 percent of roofs on medium and large buildings in Tokyo are required to be green roofs [15]. Green roofs are vegetated roofs that have vegetation layer with waterproofing and sometimes drainage layer, which is considered to be optional. The five different layers of green roofs include a root barrier layer to prevent the root from penetrating the building; a protection mat layer to increase the safety from any penetrations; a drainage layer that allows heavy rain to runoff; a filter sheet to stop particles and dust from clogging the drainage layer; the last layer is the growing medium which can be soil or an engineered material that provide the necessary food for plants to grow [15]. Green roofs can be implemented by retrofitting or in new construction. Mainly, there are two types of green roofs: extensive and intensive. They differ in the layers and the lengths of the layers in addition to the maintenance. Intensive roofs allow for deeper substrates, while extensive roofs allow for thinner substrates [16]. Cutlip (2006) suggests that the use of extensive green roofs are more preferable because they do not require large-scale maintenance, unlike intensive green roofs, and they are thinner than intensive green roofs [17]. Extensive green roofs are known as "eco-roofs" and minimal weight load; whereas, the intensive green roofs have increased load/system weight [17].

### 3.4 Lighting Systems

It is important to look at the lighting system in a building because it can be considered a good contributor in saving energy. The electric lighting represents 15-60% of

electricity consumption in buildings [8]. Therefore, it is significant to retrofit the lighting system in the UAE since it can make a significant difference. Two aspects must be considered, efficiency and effectiveness. Efficiency looks at the performance of the equipment (lamps, control gears, etc.) and the improvement of the lighting design practice; while effectiveness looks at the lighting control systems and ways to improve it in order to avoid energy waste, and hence save energy [18]. The lighting system consists of three categories: the luminaires, the control system and the services. It is not necessary that retrofitting the lighting system would reduce energy only, it has several other advantages such as: improvement in lighting quality, occupant satisfaction and productivity, improved corporate image, energy security, etc. [8]. In order to retrofit a lighting system of a tall building it is important to select the most suitable light bulbs, control systems and services. The most common retrofitting strategy that has a high saving potential is the replacement of lamp, ballast and luminaire as well as the usage of an electric lighting control system that is known to reduce the energy consumption [8]. For the replacement of lamps, 3 standard lamps (Compact Fluorescent Lamps (CFLs), Light Emitting Diodes (LEDs) and Halogens) that are used in the UAE will be discussed later and compared to incandescent lamps [9]. As for the control systems, 4 main systems will be discussed including the manual control, scheduling, occupancy control, and day lighting.

### 3.5 HVAC Systems

The occupants' comfort in the surrounding environment of any building is of major importance which makes designing the most appropriate Heating Ventilation and Air Conditioning (HVAC) system crucial in providing the optimum temperature required by the occupant. However, the HVAC system is known to be one of the largest end-users of energy especially in hot harsh climates. Only in case the system is properly selected and designed, it can save energy up to 30% [11]. With proper operation of HVAC system, it is compelling to reach the highest energy consumption of the building [11]. The system tends to add and remove heat to maintain a certain temperature, as well as adds and removes air by keeping same temperature and aims at the improvement of the indoor air quality and thermal comfort [19]. The main concern in dealing with HVAC is occupants comfort which, according to an air conditioning clinic (Trane), can be categorized into temperature, humidity, air movement, fresh air, clean air, noise levels, lighting and furniture and work surface [20]. HVAC has 3 functional categories: the source component that is responsible in providing and removing heat/moisture, the distribution component that distributes the air to locations where conditioning is required and the delivery component that combines distribution system and occupied space [19].

## 4 Conclusions

This paper summarized the approach and the main elements that were identified in a study to develop a green retrofitting toolkit for commercial buildings in the UAE. In

addition to a thorough review of the relevant literature and available products, the study, highlighted in this paper, also used a Revit model to analyze a typical commercial building design in terms of energy efficiency and cost savings. The project focused on commercial buildings since they typically registered the highest energy consumption spikes as mentioned in a report of the American Council for an Energy Efficient Economy [21]. Making buildings more energy efficient is particularly relevant in harsh hot climates. Ultimately, the study identified the most UAE relevant measures and guidelines, and performance metrics were developed. Moreover, energy throughputs were modeled and cost savings analyzed. Future work can target more building types and explore different retrofitting elements and their feasibility.

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