Survey of the Existing Residential Buildings Stock in the UAE

Athari AlNaqbi, Wafa AlAwadhi, Abeer Manneh, Ayoub Kazim, and Bassam Abu-Hijleh

Abstract—This paper presents the results of a survey study that aims to establish a representative database of the existing residential building stock in the United Arab Emirates (UAE) starting in 1974 until 2012. The main goal is to identify the approximate numbers built as well as applicable thermal energy insulation building regulations applicable at each period. It was found that buildings constructed pre-2003 did not have to adhere to any such regulations in both the emirates of Dubai and Sharjah. In Abu Dhabi, thermal insulation requirements were only introduced in 2011. At the time of writing this paper, there are no thermal insulation requirements in the other four emirates or the federal institutions. Energy modeling on a 1991 villa was done using the IES-VE energy modeling software. The results showed a 37.2% reduction in the total annual cooling load between the villa as built and if it had been upgraded to ESTIDAMA 1 Pearl thermal insulation requirements. This study clearly shows that there is great potential for reducing the energy consumption of existing buildings in the UAE.

Index Terms—Existing building stock, energy efficiency, UAE.

I. INTRODUCTION

There is an increasing determination in the UAE to reduce CO2 emissions as part of the global effort to reduce greenhouse gases and mitigate the effects of global warming. The focus until now has been on regulations for new buildings. As a young country, compulsory building regulations relating to energy savings and conservation were only introduced in the past decade (2003 in Dubai and 2007 in Abu Dhabi). This means that even if all new buildings were to adhere to significantly high energy conservation standards, the UAE would still have a large stock of buildings, some just completed, which have excessive cooling loads and thus are not environmentally friendly. This can be seen from the data that shows the UAE has one of the highest electricity consumptions per capita in the world. This reflects negatively on the CO2 emissions as the UAE has the 2nd highest CO2 emissions per capita in the world. If the UAE is to significantly reduce its CO2 footprint, the energy inefficiencies in the existing building stock needs to be addressed.

This paper presents the results of a survey study that aims to establish a representative database of the existing building stock in the UAE identifying the approximate numbers built as well as building technologies and material used. Computer simulation is used to estimate the energy consumption of several existing buildings. The buildings are chosen in such a way that they are representative of the wide range of existing building stock in the UAE. The results show the high energy consumption in such buildings.

II. LITERATURE REVIEW

Although the Copenhagen conference has failed to reach a binding agreement on CO2 emission reductions, all participants have indicated that they have devised their own plans and targets for these reductions. The gravity of the problem is such that a binding agreement will surely follow soon. As of February 18 2010, 101 countries have, or are likely to engage with the accord, representing 81.2% of the global emissions [1]. The accord lays out the required reduction in CO2 emissions by the year 2020. The proposed solutions are not universal. Each country will have to look at its own sources of CO2 emissions and possible remedies depending on its climatic conditions, potential energy resources available and level of human and industrial development.

The built environment is responsible for approximately 40% of the total primary energy consumption [2]. Although most of the new regulations focus on new buildings to be constructed, these new buildings add around 0.5-2% to the total building stock, depending on the type and the regional economic conditions [3, 4]. There is a growing realization that this is not enough. Even if all new buildings have zero CO2 emissions, the older inefficient building stock will cause the CO2 emission levels to remain unacceptably high. The only practical way of reducing CO2 emissions in the short to medium term is by refurbishing the existing building stock [5]. The maturity of the technical knowledge of refurbishment practices, coupled with their relatively low costs, makes refurbishment a better choice for reducing CO2 emissions than using renewable energy resources to supply the high demand of inefficient buildings. It is easier to reduce the demand than to provide more renewable supplies of energy.

There have been many studies conducted, in different countries, on the potential and needs for refurbishment of existing buildings [4], [6-9]. The studies looked at the environmental, social and economic aspects of the refurbishment process. In all cases, the results strongly favored the refurbishment of older buildings. The extent of the refurbishment process is strongly dependent on the age of the building, original building technology and materials as
well as the local climatic conditions and environmental regulations.

As a young country, the UAE has been late in implementing energy conservation regulations for buildings. It was not until 2003, that Dubai Municipality started enforcing Decree 66 which included energy saving requirements, mainly insulation and glazing. In Abu Dhabi, the Urban Planning Council (UPC) was established in 2007 and became responsible for preparing and enforcing building regulation including energy saving requirements. This means that the majority of the buildings in the UAE were constructed with little or no consideration to energy savings. This is especially true for buildings constructed by developers to be sold to end users. Thus initial cost savings were the dominate concern rather than long term energy operating costs savings. This means that the vast majority of these inefficient buildings will still be operational in 2020, the target year for the Copenhagen accord. Without proper refurbishment of these buildings, the drain on energy used in the building will remain high and would require significant investment in renewable energy resources if the UAE is to achieve the required CO2 emissions reduction goals set for 2020.

The poor energy saving construction approach used along with the harsh weather conditions in the UAE have resulted in the UAE being ranked in the top 10 countries in terms of electricity and heat usage per capita and the 2nd highest in terms of CO2 emissions per capita [10]. The high growth in electricity demand (25, 50 and 76 terrawatt hr/year in 1995, 2003 and 2007, respectively [10]), is also an indication that new buildings are not incorporating energy savings measures. The highest electrical load comes from HVAC equipment which accounts for an average of 40% of the total year around electrical load and up to 60% of the peak electrical load during the summer time [11].

A recent study showed that applying the new 2011 Abu Dhabi ESTIDAMA PEARL rating system can result in significant energy reductions [12]. The PEARL rating system has five levels starting with the mandatory level of 1 pearl and goes up to 5 pearls. In this study a recently built villa that adhered to the 2003 Dubai Municipality (DM) insulation code, which is not as stringent as the ESTIDAMA system, was analyzed to estimate the energy savings potential if it was built according to the ESTIDAMA system. The results showed energy savings results of 10% and 26% compared to the as built design if the villa was designed to the ESTIDAMA 1 pearl and 2 pearls standards, respectively. If this is the level of savings that could be achieved on a newly built villa then the potential savings for older buildings is expected to be much higher.

The first step in assessing the potential energy savings in the existing building stock in the UAE to try and quantify the numbers and thermal construction of these buildings, involves collecting the relevant data across the UAE. This is not an easy task as the UAE is a federation of seven emirates, each responsible for its own building regulations. On top of that there is the federal building regulation which applies to federal buildings anywhere within the UAE. Thus, for a complete picture, data needs to be collected from eight different institutions each with a different data storage/archiving system, if any. Thus the study focuses on the emirates with highest concentration of population/buildings i.e. Abu Dhabi, Dubai, Sharjah, Ajman, and Ras Al Khaimah as well as the federal buildings. Less than 10% of the UAE population lives in the two emirates not included in the study, Fujairah and Umm Al-Quwain [13], with some of this data being included in the federal data that lists residential buildings by the Ministry of Public Works (MoPW). MoPW is responsible for building public housing for UAE nationals in the Northern Emirates (Sharjah, Ajman, Ras Al Khaimah, Fujairah and Umm Al-Quwain). The MoPW does not build public housing in Abu Dhabi and Dubai as this task is taken over by the local governments in these two emirates.

III. RESULTS AND DISCUSSION

The objectives of this research are two folds; first to identify the thermal insulation codes applicable across the UAE at different time frames; the second is to estimate the number/area of existing buildings constructed in different time frames, and thus the thermal insulation regulation applicable at the time. Once this data is available, estimates of energy saving in the existing buildings can be performed using the energy modeling of representative buildings. This part has not been done yet and hopefully will be presented in future publications once completed.

Identifying the different applicable thermal insulation regulations was the easy part; partly because, if they exist, they need to be properly documented. Secondly, and sadly, it was found that there has been a lack of such regulations for a long time. Theearliest such regulations appeared in 2003. Additionally, the 1985 Abu Dhabi building regulations mentioned the use of thermal insulation but did not specify any values that needed to be adhered to. Even until now, only Abu Dhabi, Dubai and Sharjah have such regulations. The rest of the emirates as well as the federal government do not have comprehensive thermal insulation requirements; although some encourage the use of thermal insulation features without specifying minimum values. Three thermal insulation guideline timeframes have been identified: pre-2003 (no insulation regulations anywhere within the UAE), 2003-2011 and post 2011. Table I shows the required U values for the last two timeframes for the emirates that did have such regulations.

The data in Table I convey a strong massage; all buildings in the UAE before 2003 did not have to satisfy any thermal insulation requirements, however, some had voluntarily installed varying levels of thermal insulation but this tended to be the exception rather than the rule. The good news is that most of the buildings constructed during the building boom in Dubai and Sharjah had to comply with a decent level of thermal insulation. The 2011 regulation introduced in Abu Dhabi was a significant achievement as it pushed the thermal insulation requirements well beyond those of Dubai and Sharjah. This was at a time when Dubai slightly improved its requirements and Sharjah continued to use the requirements introduced in 2003.
The “Buildings” data includes all pure and mixed use residential buildings of all heights: i.e. low rise, medium rise and high rise. The results in Table II show that 27% of the villas and residential buildings in Dubai were constructed pre-2003, this means they did not have to comply with any insulation regulations. The situation in Sharjah is much better where 14% of the villas and 7% of the residential buildings were constructed pre-2003, that is before the introduction of thermal insulation regulations. This translates to 12.8% of all residential construction (villas and buildings) in Sharjah being constructed pre-2003. These numbers indicate that the potential for existing buildings thermal refurbishment is much higher in Dubai that it is in Sharjah.

As for Ajman, only the total private built up area was available (2,697,195 m² in 2010). For Ras Al Khaimah, no private built up area data was available as all relevant documentation was lost due to a fire shortly before the start of this work.

In Abu Dhabi, the Abu Dhabi bureau of statistics had compiled information regarding the number of housing units added every 10 years; however, no information was available regarding the area. Table III shows the number of private (non-MoPW) residential homes/buildings added in Abu Dhabi during different intervals, up to 2005. This information was received directly from the Statistics Centre-Abu Dhabi (SCAD) in response to an e-mail request. Note that all of these numbers are pre-2011 which means the buildings were constructed without any thermal insulation regulation. This is in stark contrast to the cases of Dubai and Sharjah shown in Table II earlier.

Table II. Area of new private residential units added in Dubai and Sharjah

<table>
<thead>
<tr>
<th>Period</th>
<th>Villa Buildings</th>
<th>Villa Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-1999</td>
<td>1,566,506</td>
<td>5,705,821</td>
</tr>
<tr>
<td>2000-2002</td>
<td>2,924,036</td>
<td>3,687,755</td>
</tr>
<tr>
<td>Total Pre-2003</td>
<td>5,269,980</td>
<td>11,380,959</td>
</tr>
</tbody>
</table>

- 1975*
- 1976-1985: 63828
- 1986-1995: 87838
- 1996-2001: 65028
- 2002-2005: 40004
- All building in Abu Dhabi up to 1975

Table III. Number of new residential units added in Abu Dhabi

<table>
<thead>
<tr>
<th>Period</th>
<th>Number of new units added during period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975-1979</td>
<td>34647</td>
</tr>
<tr>
<td>1976-1985</td>
<td>63828</td>
</tr>
<tr>
<td>1986-1995</td>
<td>87838</td>
</tr>
<tr>
<td>1996-2001</td>
<td>65028</td>
</tr>
<tr>
<td>2002-2005</td>
<td>40004</td>
</tr>
</tbody>
</table>

Focusing only on the number of new homes/buildings in each period shown in Table III could be misleading. Starting in 2000, more high-rise residential buildings were being built compared to the low and medium rise buildings of earlier eras. In addition, more of the units constructed were of large area. Table IV shows the number of residential units completed in the Jan - March quarter of 2011 in Abu Dhabi [14]. Table IV shows that the largest units comprised more than 79% of the units constructed during this period. This shows the need to get at least an estimate of the average size of the residential units being built in different time frames.
Table V shows the number of residential buildings constructed by the MoPW at different time frames in the five emirates in which it builds in. The data in table V shows a drop in the number of public housing units being built every decade. This is due in part to the fact that more UAE nationals are becoming wealthier and are choosing to build their own customized houses rather than rely on the MoPW pre-designed units. At the same time, the units being built by the MoPW are becoming larger in size. Table VI shows the number and total area of units built by the MoPW in Ras Al Khaimah in different time frames. We can see that the earlier units averaged just under 100 m² in area then the average size grows steadily to reach 360 m² in the 2000-2012 period. This was the most detailed data that we could get during this study. We need to remind ourselves that to date (September 2012) there is no thermal insulation regulation for MoPW buildings which means that there is great potential for energy savings in all these buildings constructed until the current date.

Table VII shows the U values for the two configurations as well as the total annual cooling load for both configurations. The results show a 37.2% reduction in the annual cooling load which means significant reduction in the electricity bill of the villa. The effect of the improved thermal insulation in the case of 1 Pearl, is most significant in the summer months, as seen in Fig. 2 which shows the monthly cooling load for both configurations. This initial test gives an indication of the potential savings that could result from refurbishing existing buildings. A more accurate estimate of the energy savings across the UAE can be achieved once the data of the existing buildings has been defined. At which point several buildings of different configurations and time frames will be simulated in order to come up with a national estimate of the potential energy savings form refurbishing existing buildings in the UAE.

IV. CONCLUSIONS

A survey of the existing buildings in the UAE has been conducted. This paper reports whatever data that could be collected toward this goal. The applicable thermal insulation guidelines at different timeframes are also reported. The task has been greatly hampered by lack of consistency between the different local regulations within the seven emirates and even federal regulations within the UAE. The data collected...
shows that around 27% and 12.8% of the residential housing (villas & buildings) were built without having to adhere to any thermal insulation regulation in Dubai and Sharjah, respectively. All the data available for Abu Dhabi were pre-2011, the year in which the 1st thermal insulation regulations were introduced in Abu Dhabi. As for the other four emirates as well as the federal institutions, no thermal insulation regulations exist as of yet. An initial energy modeling of an existing villa was conducted using the IES-VE energy modeling software. The effect of upgrading the existing design to the ESTIDAMA 1 Pearl requirements was also conducted. The results show a 37.2% reduction in the total annual cooling load of the villa studied. This gives a strong indication that thermal insulation refurbishment of existing buildings could result in significant energy savings.

Fig. 2. Monthly cooling load of the two configuration used in the energy simulation study.

REFERENCES


Athari AlNaqbi received her BSc in Civil Engineering from UAE University in 2000 and is currently an MSc candidate in the Sustainable Design of the Built Environment at the British University in Dubai.

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in the number of business partners at both DKV and DIAC. Under his guidance, Dubai Knowledge Village has channelled its focus on Human Resource Management, Consultation, Training and Personal Development programmes, as well as in positioning itself as a prominent events and conference centre for the region.

Dr. Kazim has over 20 years of experience gained from working in TECOM, Dubai Municipality and UAE University in Al Ain. He has an in-depth understanding of technical, administrative and academic work environments. This experience has led to his success in the education sector, in line with the vision of Dubai becoming a knowledge-based economy. In addition to his work with both DKV and DIAC, he is actively involved in research studies and has published numerous articles and technical papers on renewable energy, hydrogen energy, fuel cells, energy policy and economics.

Bassam Abu-Hijleh hold a BSc, an MSc and a PhD in Mechanical Engineering, all from The Ohio State University. He has more than 20 years of post-PhD career include industrial, educational, research and administrative experiences. He held several positions including Professor of Mechanical Engineering at Jordan University of Science & Technology (Jordan), Visiting Research Professor at Swinburne University (Australia) and Senior Research Fellow at RMIT University (Australia). He has published more than 50 journal articles, in internationally renowned and refereed journals, and more than 30 international conference papers. He is also a reviewer for several well renowned international conferences and journals.

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