Survey of the Existing Residential Buildings Stock in the UAE

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***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 identifying 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 introduce 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 that 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.

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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.

TABLE I: THERMAL INSULATION REQUIREMENTS IN THE UAE AT DIFFERENT TIMEFRAMES

Emirate	Timeframe	U-value (W/m^2 K)		
		Wall	Roof	Glazing (SHGC*)
Abu Dhabi	2003-2010	NA		
	2011**-	0.32	0.14	2.2 (0.4)
Dubai	2003-2010	0.57	0.44	3.28 (NA)
	2011-	0.57	0.3	2.1 (0.25)
Sharjah	2003-2010	0.57	0.44	3.18 (0.43) for w/w*** <40% 2.18 (0.43) for w/w >40%
	2011-	No change from the 2003 requirements		

* Solar Heat Gain Coefficient
** Requirements for 1 Pearl (mandatory) rating
*** Window/Wall ratio

The other item that can be read from Table I is the lack of any thermal insulation requirements in the other 4 emirates as well as in all federal projects irrespective of the emirate they are in. This coupled with the late introduction of the thermal insulation codes in Abu Dhabi, Dubai and Sharjah make it clear that a significant portion of the UAE's existing building stock has inadequate thermal insulation and could potentially benefit significantly from energy driven refurbishment work, but to do so we need to know the numbers and construction characteristics of these buildings in order to be to assess the scope and potential benefits of refurbishing this existing stock. This is where the second part of this work comes into play.

Collecting data about the existing buildings in the UAE proved to be very difficult. Ideally we wanted to collect information on the numbers, area and thermal insulation details of all residential buildings constructed in the UAE. Even though there were no thermal insulation requirements before 2003, different construction practices were used in the 1970s, 1980s and 1990s. The changes in wall material and construction layers

do impact the wall thermal insulation value and thus the energy consumption characters of the building. Details of the prevailing construction practices at different time frames will be collected later for the second phase of this study.

The team faced great difficulties and challenges in collecting the relevant residential data. All residential data in each of the seven emirates' municipalities were not available in a digital format in the period before 2000. Thus the research team had to rely on secondary data available through other establishments, e.g. bureau of statics (again there is a federal and multiple local bureaus of statistics each covering some aspects of the data and mainly after the year 2000). Only the MoPW had an electronic record of buildings constructed throughout the UAE. The team also went through some of the archives at municipalities to get some information about the typical residential housing being built at different times. Government red tape and other unforeseen circumstances significantly hampered this effort. In addition, the data available from the local municipalities were in different formats and with different levels of detail.

Table II shows the new private, i.e. non-MoPW, residential areas added in Dubai and Sharjah over time. There are no MoPW construction projects in Dubai but there are some in Sharjah, this will be detailed later after talking about MoPW construction. 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 m^2 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.

TABLE II: AREA OF NEW PRIVET RESIDENTIAL UNITS ADDED IN DUBAI AND SHARJAH

	New privet residential area added in (m^2)			
	Dubai		Sharjah	
Period	Villa	Buildings	Villa	Buildings
1980- 1989	779,438	1,987,383	62,550	28,400
1990- 1999	1,566,506	5,705,821	1,623,900	319,541
2000- 2002	2,924,036	3,687,755	324,450	236,049
Total Pre- 2003	5,269980	11,380,959	2,010,900	583,990
2003- 2011	14,228,703	30,839,414	12,472,285	7,834,573

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 III: NUMBER OF NEW RESIDENTIAL UNITS ADDED IN ABU DHABI

Period	Number of new units added during period
- 1975*	34647
1976-1985	63828
1986-1995	87838
1996-2001	65028
2002-2005	40004

* All building in Abu Dhabi utpo 1975

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 IV: NUMBER OF NEW RESIDENTIAL UNITS OF DIFFERENT SIZES ADDED IN ABU DHABI DURING THE MARCH QUARTER 2011 [14]

Building area (m^2)	Number of completed residential units
Less than 300	241
300-599	154
600-899	171
900-1200	174
More than 1200	2894

* All building in Abu Dhabi upto 1975

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 that fact that more UAE nationasl 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 m^2 in area then the average size grows steadily to reach 360 m^2 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 V: NUMBER OF NEW RESIDENTIAL UNITS ADDED BY THE MOPW IN DIFFERENT EMIRATES AND TIME FRAMES

	Period			
Emirate	1974-1979	1980-1989	1990- 1999	2000- 2009
Sharjah	539	777	876	103
Ras Al Khaimah	1369	530	0	400
Ajman	330	390	589	124
Umm Al-Quwain	385	56	511	27
Fujairah	1021	540	690	772
Total	3644	2343	2666	1426

TABLE VI: TOTAL NUMBER, TOTAL AREA AND AVERAGE AREA OF MOPW RESIDENTIAL UNITS ADDED IN RAS AL KHAIMAH AT DIFFERENT TIME FRAMES

Period	Total number of units	Total area of units (m^2)	Average area per unit (m^2)
1974-1979	1582	156654	99
1980-1989	369	49819	135
1990-1999	6014	1840451	306
2000-2012	759	273613	360

Based on the preceding data it is clear that the potential for refurbishment of existing buildings does exist in all emirates in the UAE although to different extents. To get an initial idea about the potential savings that could be achieved, energy simulation analysis was conducted for an existing building. The building chosen was one of the villas constructed by the MoPW in 1991. The building modeling and energy simulation were performed using the Integrated Environmental Solutions – Virtual Environment (IES-VE) version 6.4. IES is considered to be one of the top commercial energy modeling softwares and has been used in multiple research publications - see reference [15] for more detailed description of the software and some of the published research that used it.

Fig. 1 shows the computer model of the villa that is used in this simulation. The total floor area of the villa is 366 m^2. The energy simulation was conducted over a whole year and the focus was on the total cooling load per annum. The simulation was run for two thermal insulation configurations: the 'as built' configuration and one with the ESTIDAMA minimum thermal insulation requirements, i.e. 1 Pearl. 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.

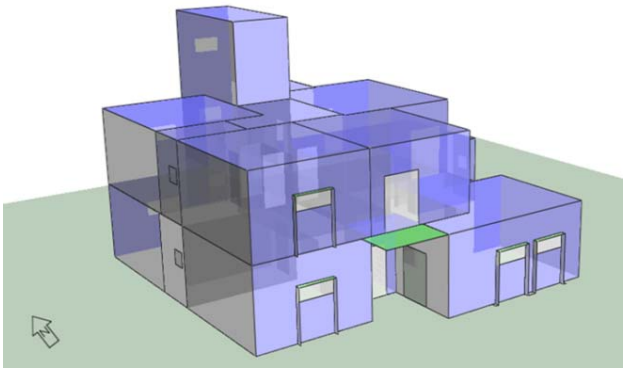

Fig. 1. Computer model of the villa used in the energy simulation.

TABLE VII: THE THERMAL INSULATION CHARACTERISTICS AND OVERALL ANNUAL COOLING LOAD OF THE TWO CONFIGURATIONS USED IN THE ENERGY SIMULATIONS TESTS

	As build configuration	ESTIDAMA 1 Pearl configuration
Wall U-value (W/m2 K)	2.97	0.32
Roof U-value (W/m2 K)	2.90	0.14
Glazing U-value (W/m2 K)	5.57	2.2
Total annual cooling load (MWh)	122.3	76.8

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.

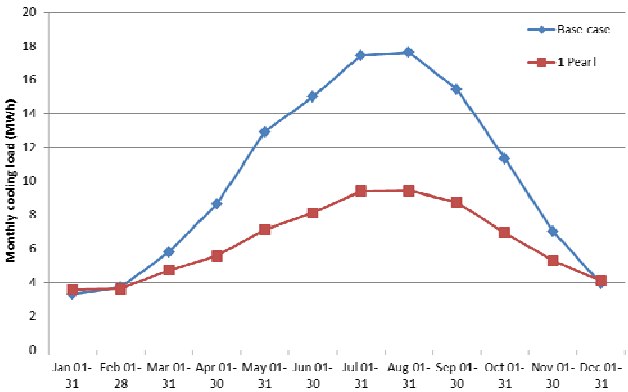

Fig. 2. Monthly cooling load of the two configuration used in the energy simulation study.

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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.

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