Sustainable Framework for Upgrading Residential Buildings in United Arab Emirates

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***Abstract*—The Government of Abu Dhabi has lately started work to develop sustainability guidelines and regulatory tools. The program is called Estidama, which means 'sustainability' in Arabic, has been initiated by a group of government agencies and developers to align the leadership's vision in transforming Abu Dhabi to a sustainable Arab capital and to create guidelines and regulations to ensure sustainable design, operating and maintenance of all types of buildings and communities within the Emirates. At this time and since November 2010, the Estidama sustainable program has been specifically designed to apply to new residential and commercial buildings. Existing residential stock does not form part of the current appraisal and will need to be considered in the future. The old residential stock present 80% of the total residential units available in the market and extending the environmental standards to the old residential stock will certainly contribute in decreasing the gap between supply and demand while offering renovated to standard units. This paper highlights the status of the existing residential stock, old and new, in the UAE built environment. Though a various contextual characteristics, field observations, investigations and analysis, we propose series of solutions and tools for a long term plan to integrate effective sustainable retrofitting in architecture and interior design for the old residential stock, to compliment the national Abu Dhabi vision 2030.**

***Index Terms*—sustainability, housing, strategies, green materials, refurbishment**

I. Introduction

The built environment contributes to global warming through two main practices. First, buildings are responsible for relatively more than 40% of the materials consumption, and second, over one third of the total greenhouse gas emissions and other harmful atmospheric emissions in the world is caused by the building industry [1]. The United Arab Emirates (UAE) presented in this paper as a case study, is constituted of seven emirates with a surface area of 83,600 km2 situated in South west Asia, bordering Oman and Saudi Arabia between the Gulf of Oman and the Arabian Gulf, geographically lies between 22 ◦50'26" North latitude and between 51 ◦56'25" East longitude. The weather conditions are very hot and semi-arid during summer days becoming warm and humid at night. During winter, daytime conditions fall within the comfort zone, while the night times are cool and humid, Abu Dhabi is the capital of UAE.

The United Arab Emirates perceived rapid economic expenditure and extraordinary population growth rates in the past few decades. Such developments were accompanied with a significant increase in energy consumption; The 'Living Planet Report' [2] currently assigns the UAE the highest ecological footprint per person (11.9), mostly from carbon dioxide emissions. The water withdrawal rates (1,533 % of total resources) are also among the highest in the world. The building construction and operation practices are responsible for 4% of the CO2 production through direct emissions, 43% by electricity generation and 45% by manufacturing and construction. In fact, electricity consumption for cooling in buildings in the UAE has intensified ten times (from 5 to 50 Billion kWh) over the past two decades[6]. Undoubtedly, the design and operation of green buildings can help curtail these figures and achieve a more environmentally sustainable future for the UAE as a whole [3].

Measuring its alarming environmental problems, the government of Abu Dhabi has been volente to undertake quick steps to contain and reduce the environmental unbalance by introducing since November 2010 mandatory sustainability standards guidelines for new construction to support the leadership's vision to transform Abu Dhabi into a sustainable Arab Capital and to complements the country's vision for Plan 2030, one that outlines the future urban development of the city of Abu Dhabi. At this time, the Estidama Design Guidelines [4] have been specifically designed to apply to new residential and commercial buildings.

Abu Dhabi government measures the harmful effects of mass construction on the environment; the proposed Estidama program limits the damage caused by future constructions. In this paper, we highlight the problem of the residential market which experiencing a shortage in supply to meet the growing demands of the current population, specifically with regard to affordable housing.

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The old residential stock constructed before the start-up of Estidama program in 2010 presents 80% of the total housing units fails to meet a proper environmental criteria or energy inefficiency. The improvement of this old stock appears as a must to increase the supply of efficient units, reduce UAE footprint and meet Abu Dhabi vision 2030. Our proposals of strategies will go through the following:

- The analysis of regulations implemented by Abu Dhabi government to succeed a sustainable construction;
- Proposing complementary solutions to meet the growing demand for housing and reduce the gap between supply and demand while maintaining sustainable environment;
- Proposing strategies to encourage owners to invest in retrofitting of old buildings;
- Focus attention on the light and medium retrofitting as a fast tool to meet the housing demand in Abu Dhabi;
- Propose a better approach and materials selection for the retrofitted projects.

II. Abu Dhabi Residential Sector

Abu Dhabi residential stock reached approximately 256,000 units. In a recent study of Abu Dhabi's property market, only 750 new units were delivered to the market in 2015. At 3% of total housing stock, this represents the lowest level of new residential supply in five years, when average annual population growth has been around 5%. (Fig. 1).

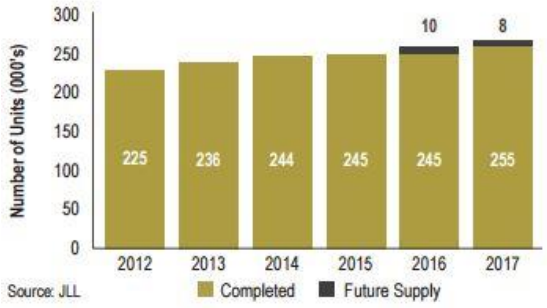

Figure 1. Abu Dhabi residential stock 2012-2017

In that sense, it is evident that the residential market is experiencing a shortage in supply to meet the growing demands of the current population, specifically with regard to affordable housing. This has led to significant increase in rents, rising up 7% year-on-year as the current shortage is estimated around 48,000 units. From 2010 to 2015, 50,000 units in different categories in accordance to the guidelines and standards have been provided to the market. However, prior to Estidama regulations, the residential stock still includes 205,000 units that were built in the last six decades, that should be examined to evaluate their status and efficiency in order to define if these units should be retrofitted to meet with current standards or just demolished. It is assumed that these buildings are highly CO2 generators based on international studies conducted in similar situation.

A. New Construction

In Estidama program, an initial listing of credits for each of the following environmental aspects to be contained within the proposed green building design assessment tool: Water, Energy Use, Indoor Environmental Quality, Ecology, Management, Transport, Pollution, Materials, Waste Management; and Land Use. Environmental aspects are not equally weighted within the scoring system of this assessment tool, 65% of the credits weight will be accredited by Estidama Program Committee to water and energy conservation for their importance within the current climate of Abu Dhabi. On completion of the assessment, a percentage score is awarded which provides an indication of the environmental performance of the building. Since 2010, all residential buildings have an official rating indicating their performance.

The Program Committee provides the possibility to those who are not interested in having high rating performance, to apply for a minimum of one pearl rating through a simplified submittal template where the consultants in charge of design and supervision of the project will apply the following:

- The exclusion of the use of Asbestos and Chromatid Copper.
- The use of a listed low debit of sanitary ware and mixers.
- A maximum U value of 0.57 W/m2.K for external walls, 0.31W/m2.K for external roofs, 2.2w/m2.K for fenestration and a solar heat gain of 0.4 SHGC for glazed fenestration.

In Q2 of 2015, UPC awarded a one pearl rating for 41 new buildings and 2 pearls for 22 buildings. Some 86% of Estidama rated projects fall within the one and two pearl rating.

In order to have some explanations about these limited steps towards sustainable developments, a questionnaire was distributed among a number of customers, designers and suppliers in the International Exhibition for Interior Design, in Abu Dhabi, to know the criteria of choosing the materials. The survey reveals that the sustainability criteria is not a priority as it arrive afterwards aesthetic, functional and economic factors (Fig. 2).

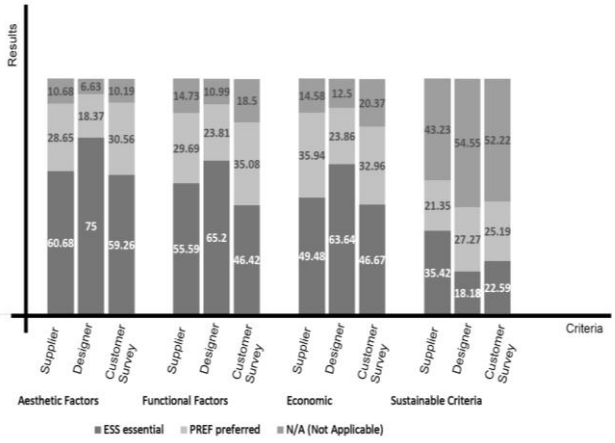

Figure 2. Influences criteria in the choice of materials (by authors)

B. Old Construction

We consider the 185, 000 residential units built in the last six decades, prior to Estidama regulations as an old stock that should be examined to meet with current standards and balancing the gap between supply and demand for high quality housing. For the evaluation process of this stock, We make reference to the world renowned engineering firm ARUP who has developed a classification model for appraisal of existing buildings based on 5 different categories, and accordingly the required level of intervention evaluating the required budget and times to retrofit each building, and finally creating a realistic statement map valid for implementation stages (Fig. 3).

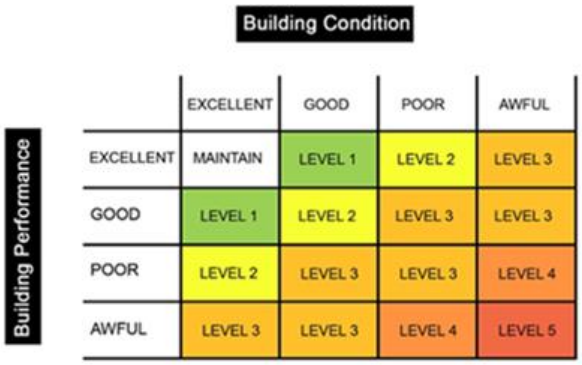

Figure 3. Retrofitting levels based on buildings status-(source ARUP).

Our preliminary studies mapped on Arup model estimate the following:

- Level 1. Tune-up and minor refurbishment: 1990's to 2010 residential buildings, including installation of smart control systems in the form of blinds, lighting fixtures, in addition to repainting interior spaces.
- Level 2. Intermediate refurbishment: 1980's – 1990's residential buildings, in addition to all level 1 works, revise layout to improve daylight exposure, install solar control devices, and install adaptable systems.
- Level 3. Major refurbishment: 1970's – 1980's residential buildings, replace major technical components and services.
- Level 4. Complete refurbishment: 1960's - 1970's residential buildings, retain only the substructure, superstructure and floor structure, then undertake structural and façade alterations, and consider relocation of cores and risers.
- Level 5. Demolish and rebuild: 1950's - 1960's residential buildings, in this level, carefulness must be given to evaluate the architectural value of these buildings before proceeding to any demolishing, Abu Dhabi possesses an interesting architectural heritage to conserve as it will always guide people find their way through the fascinating story of this city [5].

In all listed levels, attention must be given to Estidama requirements to control water consumption, and water leakage, to protect water supply, and to insure water efficient landscaping. For the energy use, attention must be given to the energy metering, internal and external lighting, hot water supply, lifts, cooling and air condition, energy efficient appliances, on site renewable energy generation.

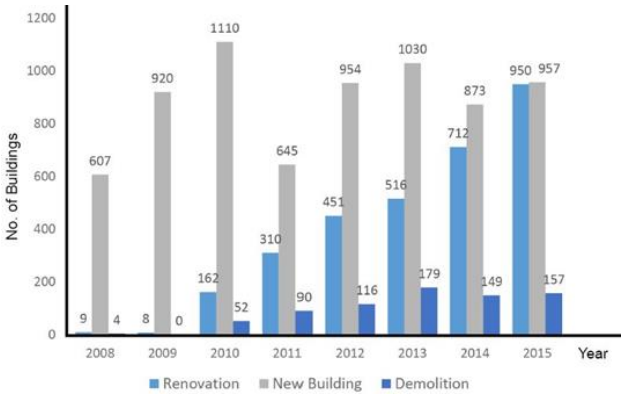

Figure. 4. Activities analysis in relation to residential sector (Department of municipal affairs–A.D.M)

The analysis of the different activities related to the residential sector (Fig. 4) indicates that the last five years there is a notable acceleration in the buildings renovation activity to reach the cadence of new construction permits, and this is due to the advantages that can offer a renovation comparing to a new building construction, mainly the exemption of required number of parking in the buildings and the application of a simplified environmental regulations. The demolition activity remain stable and minimized due to the complication of applying the new regulations including parking requirements in small plots.

III. Reflections

Estidama program proposed by Abu Dhabi government as a sustainable regulatory tool must adopt other survival strategies to retrofit the old existing buildings that do not fulfill current expectations in term of sustainability and to encourage new buildings constructions for a higher pearl rating. Proposing real initiatives are not about reproducing small-scale projects, but adopting a long term environmental map scaled up to serve the entire nation. The UK could be regarded as a very interesting model with a focused ambition to produce all new homes on a carbon-neutral basis by 2016 and non-domestic buildings by 2018, imposing a stronger time line with 60% to 80% reductions in carbon emissions from the UK economy by 2050 [6].

The improvement of the residential stock towards a real sustainable buildings must be subscribed in an ambitious long term action plan targeted a clear goals and operative tools, the weakness of developing the residential sector is not due to the regulations itself, but to the techniques and mechanism of their applications. From our analysis and observation, our recommendations could be presented as follow:

- Proposing an ambitious long term strategies that bring together different parties to the process,

including the owners, the tenants and the community in large.

- Providing well detailed analysis of the old buildings conditions will be necessary to identify the areas that need improvement and the level of retrofitting. This analysis should cover not only the characteristics of the old building stock but also building ownership, occupancy, and relevant aspects of the building sector. Actually, the Urban Planning Council does not possess statistics about buildings constructed before 2010.

Level 1 and 2 of retrofitting described above as minor and intermediate refurbishment could be an interesting starting point to improve performance in existing buildings especially for energy and water solution within a limited investment. According to Pippa and Nick [7], in these two levels, some initiatives can yield immediate substantial benefits:

- Replace existing lamps LED light to reduce consumption and internal heat.
- Modify AC set points to provide wider control band within acceptable comfort.
- Rebalance all plant to maximize efficiency.
- Implement a comprehensive preventive maintenance program to maximize equipment efficiency.
- Provide sub metering of electricity, water and gas highlighting areas of inefficiency and providing an economic incentive for reducing energy use.
- Provide water efficient appliances to reduce consumption.
- Replace interior finishing with new sustainable materials for flooring, ceiling and walls. According to Kang and Guerin [8], to achieve proper greening in soft materials, environmental, economic and social dimensions must be in balance with one another for sustainable outcomes in the long terms.

Many of these "quick win" initiatives are as much about management as they are about engineering and architecture. Level 3 and 4 consist of creating an inner double-glazed unit, double skin façade or creating atrium, these heavy works requires substantial capital investment financed over number of years.

- Educating Designers, Consultants and suppliers for the use of materials, Experts need training to learn how to properly implement deep renovations and to select materials, workers and contractors need to learn install materials and systems. According to the UK Building Research Establishment, nearly 70,000 new synthetic chemicals and materials were introduced in the 20th century, and less than 2% of them has been tested for their effect on human health, while 70% have not been tested at all [9]. Spiegel and Meadows [10] clarified 4 main steps to greening materials specifications. First, the designer should compile a list of environmental attributes for the materials that might be specified for a project. Similarly, designers should compile a list of attributes that should not be incorporated into the project. The next step is the evaluation of the available options in each category of material. The third step is to evaluate the specific materials and manufactures in each of the categories. The final step is writing the specifications using the information compiled in the previous step to include in the project manual. According to Patterson [11] the façade systems are often excluded from building energy retrofits. The reasons are cost and the potential for disruption to ongoing building operations. Each intervention in the façade will add to the embodied energy account of the building. It would seem logical to plan for this, to design the façade system to accommodate the inevitability of future retrofit requirements. Current design practices do not anticipate the need for retrofit façade systems can be better designed to accommodate retrofit and adaptive reuse.

The following guidelines for curtain wall systems in new buildings applications can improve the durability, adaptability, and future implementation of future curtain wall retrofits, potentially reducing life cycle cost:

- Establish a life cycle target for the curtain wall system matching with the building lifespan.
- Identify operable systems and components and assess their wear and durability based on projected usage.
- Anticipate the potential for future higher-performing materials and adaptive reuse requirements.
- Design framing systems and anchorage to be as durable as possible requiring minimal maintenance.
- Make panel materials easy to change-out from outside or inside the building.
- Spreading the mandatory environmental aspects of Estidama program to old and new buildings to target a higher level of pearl rating and improve the sustainable quality of buildings.
- Home owners and occupiers need to be made aware of the need for deep renovations and educated regarding the possibilities and requirements related to deep renovations, as well as of the significant financial benefits over time of investments in deep building renovation. These communications should link to other activities, such as financial support for renovations, legal requirements and certification of architects and construction companies.

- Stimulating financial instruments to support renovation plans, because the cost of deep

renovations can exceed the investment capacity of individual building owners, probably because the payback in the first years will not cover the cost of a renovation. Programs can help overcome this barrier in the form of loans, grants, subsidies, white certificate, third party financing, tax reduction. Some examples of successful implementations could be demonstrated in France with Green Loan for Social Housing; Germany with KWF Program Energy-Efficient Construction; Hungary with Grants for Renovation & Prefabricated Panel Residences [12]

IV. Conclusions

The government of Abu Dhabi should encourage renovation and retrofitting by focusing attention on longer-term issues and increasing the chances of success of innovations. The undertaken actions within a public policy programme, therefore, should relay to this general facilitating role:

- Helping to build new networks that bring firms, research institutes, public agents and users of technology together;
- Helping network members to reach common problem definitions, shared understandings of innovation challenges, shared visions of possible futures and shared expectations;
- Providing information, tools and approaches that network members can use to explore possible futures and to translate long-term visions into short-term action steps.
- Education policy: Building energy efficiency in general, and deep renovations in particular, are no major parts of the education of architects, building engineers or construction workers. For the longer term, these elements need to be included in school curricula, so that the next generation of workers in this sector is better trained in energy issues and building renovation techniques.
- Include financial mechanisms for investment in the deep renovation of the building stock, programmes to inform the public and building sector parties about new policies and requirements, and provide support to facilitate the design, commissioning, construction and supervision of renovation works.
- Providing logistical support to home owners. Planning, contracting, managing and checking whole-building renovations, which deep renovations typically are, requires professional or near-professional skills which most building owners do not possess and will not often need. The construction market is not yet organised around providing building owners with turn-key renovation solutions and logistical support is required to make deep renovations more accessible to building owners.

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