

Potential of Energy and Water Savings by Implementation of Estidama Pearl Villa Rating System in Abu Dhabi, UAE

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ABSTRACT: The aim of this project is to analyze the energy and water consumption reduction by implementing Estidama Pearl Villa Rating System (PVRs) to residential buildings in Abu Dhabi. To evaluate the potential of energy savings, eQUEST software was used to compare the energy performance of a Pearl-2 rated villa and a conventional villa. For water consumption assessment, the Estidama Villa Water Calculator was used. The energy simulation and water analysis of the chosen villas showed that the Pearl-2 rated villa has a potential of electricity reduction by 25.4% and water consumption reduction by 54.3% compared to the conventional villa.

KEYWORDS: Estidama, Pearl Villa Rating System, eQUEST, U-value, Energy Efficiency, Sustainability, Energy Simulation

I. INTRODUCTION

With the rapid development and population growth in UAE, sustainability has become increasingly important in the last five years. Estidama (meaning “sustainability” in Arabic) is one of the first organic sustainability frameworks in the Middle East. Introduced by Abu Dhabi Urban Planning Council in 2009, Estidama seeks to ensure that all new development in Abu Dhabi is undertaken in a sustainable manner [10]. There are three rating systems under Estidama: the Pearl Community Rating System, the Pearl Building Rating System and the Pearl Villa Rating System [10]. Together, these rating systems encourage water, energy and waste minimisation, local material use, and aim to improve supply chains for sustainable and recycled materials and products [1]. The Government of Abu Dhabi has encouraged this initiative by requiring that all government buildings have a minimum of a two pearl rating. All other new buildings must meet a minimum of a one pearl rating. With Estidama, Abu Dhabi is making a positive contribution to the global need for sustainable development by focussing on four pre-defined pillars; economic, social, culture and environment [2].

Energy simulation tools are increasingly used for analysis of energy performance of buildings and the thermal comfort of their occupants. eQUEST is an easy to use building energy analysis tool, which calculates hour-by-hour building energy consumption over an entire year (8760 hours) using hourly weather data for the location under consideration. eQUEST provides results by combining a building creation wizard, an energy efficiency-measure wizard and a graphical results display module with an enhanced DOE-2.2 derived building energy simulation program. [11] The building creation wizard walks a user through the process of creating a building model. Within eQUEST, DOE-2.2 performs an hourly simulation of the building based on inputs that describe its construction, occupancy patterns, equipment load, plug loads and lighting loads, as well as heating and cooling systems. eQUEST allows users to create multiple simulations and view the alternative results in side-by-side graphics.

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Paper is organized as follows. Section II describes related work. Section III describes the methodology which explains the eQUEST software and the input data required for the analysis. Section IV describes the Energy Efficiency Analysis using eQUEST and Section V deals with Water Analysis using Estidama Villa Water Calculator. Section VI presents the final energy and water analysis results with graphs. Finally, Section VII presents conclusion.

II. RELATED WORK

1. Ming- TsunKeet *al.* stated that illumination density has the greatest impact on energy consumption. They examined the Energy-Saving Performance Contract (ESPC) of an office building by applying IPMVP (Energy Performance Measurement and Verification Protocol) Option D in combination with the energy analysis model established for the building by eQUEST simulation software to calibrate energy consumption simulation results using actual electricity billing data. It was found that when lighting power density was increased or decreased by 50%, overall energy consumption decreased by 30.78% or increased by 31.19%, respectively. [18]
2. Jincheng Xinget *al.* explored the Energy Retrofit Measures (ERMs) using eQUEST software, with the example of an existing four-star hotel in Tianjin, China. The study investigated predictive accuracy for the major factors in the energy consumption of hotel buildings. The results indicate that the schedules of internal loads have the most significant impact on the accuracy of the model for hotel buildings, followed by occupancy rate and coefficient of performance (COP) of the chillers. [26]
3. Sameer Assaf and MutasimNour analysed the energy and water reduction by implementing Estidama pearl regulations and compared it using Business-as-Usual for three sample buildings- villa, multi-storey residential and office building. For energy assessment eQUEST software was used and for water assessment Estidama and LEED calculation tools were used. The results of energy simulation and water analysis of the chosen buildings showed a potential of electricity reduction between 31% and 38% and potential of water reduction between 22% and 36% depending on building type and other parameters. [20]
4. Hanan M Taleb analysed the thermal performance and reduction in energy consumption by residential buildings in UAE by the implementation of eight passive cooling strategies. Energy simulation software – namely IES – was used to assess the performance of the building. Solar shading performance was assessed using Sun Cast Analysis. Energy reduction was achieved due to both the harnessing of natural ventilation and the minimising of heat gain in line with applying good shading devices alongside the use of double glazing. Additionally, green roofing proved its potential by acting as effective roof insulation. The study revealed several significant findings including that the total annual energy consumption of a residential building in Dubai may be reduced by up to 23.6% when a building uses passive cooling strategies. [13]
5. Wilhelm Alexander Friesset *al.* investigated the impact of thermal bridging effect on the building's envelope by using a mid-plane insulated prefabricated block to attain the maximum wall U value ($0.57 \text{ W/m}^2 \text{ K}$), prescribed in the building legislation (2001 and 2003). The building's energy consumption was analysed by modelling (hourly simulation using DesignBuilder/EnergyPlus) the energy performance of a series of typically applied insulation strategies, both for buildings in the initial design stage, and in retrofit mode. Simulation results showed energy savings of up to 30%. [25]
6. HananTaleb stated that Green Roofing in a building has many advantages including absorbing rainwater, providing thermal insulation, enhancing the ecology, creating a peaceful retreat for people and animals, improving air quality and helping to offset the air temperature and heat island effect. With the aid of energy simulation software, namely DesignBuilder, as well as manual recording and calculations, the energy savings after applying the green roofing to residential buildings in Dubai were detected. Based on this real experiment that took place over a one year period, recommendations with regard to the types of green roofing that should be used in these particular climatic conditions were drawn. [14]

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III. METHODOLOGY

The current study compares the energy and water efficiency of a Pearl-2 rated villa with a conventional villa. The conventional villa selected for this study was built in 2009 at Mezyad, Al Ain and the Pearl-2 rated villa under consideration was built in 2015 at Remah, Al Ain. Both the two-storeyed villas are having the same footprint and are designed and constructed by the same group of architects and engineers.

For comparing the energy efficiency of the chosen villas, eQUEST software is used as a simulation tool. Since eQUEST is not designed to evaluate the water efficiency, the Estidama Villa Water Calculator is used to estimate the interior water consumption of the chosen villas.

The eQUEST comes with three wizards, the Schematic Design (SD) Wizard, the Design Development (DD) Wizard and the Energy Efficiency Measure (EEM) Wizard. The SD and DD wizards are used to create building models and the EEM wizard is used to evaluate building design alternatives. SD Wizard can only create a building model having single shell, i.e., building areas which share the same footprint, HVAC zoning, and ceiling height and envelope construction for all floors. Whereas, the DD Wizard can be used to create models for buildings with multiple shells and also helps to modify the design later [11]. As the villas under consideration are not having the same footprint for all floors, DD Wizard is used to develop the model.

Buildings are complex physical objects that interact with their immediate surroundings while trying to provide a comfortable living and working environment to the occupants. The choices made in selecting building materials and components while designing the building envelope has a great influence in the performance of the building. The eQUEST requires the following input data:

- **Architectural Details:** The energy demand of a building greatly depends upon its architectural design. Basic architectural data needed for modelling are general building information, building orientation and location (for weather details), number of floors, floor area, floor-to-floor height, floor-to-ceiling height, conditioned/unconditioned/ventilated areas on each floor.
- **Envelope Construction Materials:** Building materials of all exterior walls, roof and floor slabs, windows, doors, external insulation, and floor finishes.
- **Fenestration Details:** Number, size and position of all exterior doors and windows, any overhangs, fins, blinds or drapes on windows, U-value and Solar Heat Gain Coefficient (SHGC) of glazing, window and door materials.
- **Mechanical Details:** Since HVAC systems are the highest energy consuming systems, accurate information regarding their size and zoning is very essential. Input data includes HVAC zoning of all floors, assigning these zones to different activities, the distribution of conditioned floor area into different spaces (zones) according to the Air-handling Units (AHUs) serving them, area allocation for various activities with the design maximum occupancy (sf/person) and design ventilation (CFM/person) assigned to it. Equipment description includes system type, cooling source, heating source and hot water source.
- **Electrical Details:** Electrical equipments are another major consumer of electricity in buildings. Input data includes lighting, internal loads data like peak occupancy (by zone), design max occupancy (sf/person), peak lighting load (by zone), Watts per square foot (W/sf) of all different lightings installed in building, peak equipment load (by zone), W/sf of all different electrical equipment in building.
- **Operations Details:** Input data includes number of seasons in a year with their starting and closing dates, opening and closing time of building, people density for all seasons, holidays, schedule for occupants, lights and miscellaneous equipment, thermostat schedules, temperature set-points for both occupied and unoccupied conditions, fan power and meter efficiency.

Figure.1 shows the 3-D model of the simulated villa on eQUEST and figure.2 shows the photograph of the Pearl-2 rated villa under consideration.

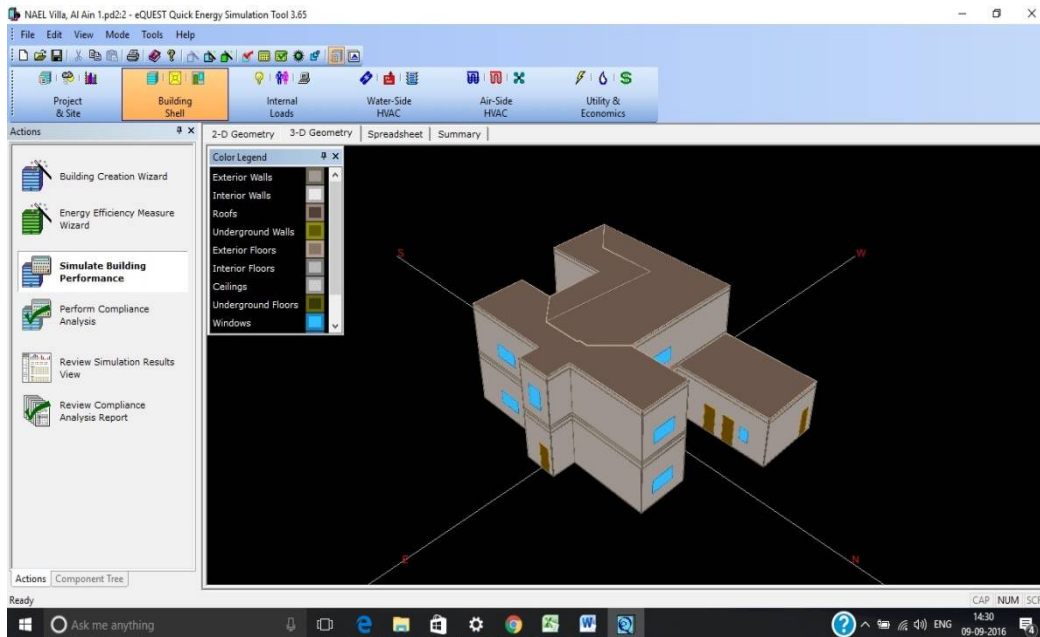


Fig.13-D view of the simulated villa on eQUEST



Fig.2 Pearl-2 rated villa at Remah, Al Ain, UAE

IV. ENERGY EFFICIENCY ANALYSIS

The main intent of PVRS is to create a villa which is more energy efficient and water efficient, and which improves the comfort of the occupants. In order to achieve Pearl-2 rating, 30 credits along with the mandatory credits must be achieved [10]. Selection of building materials plays a vital role in achieving the required credits. After creating the

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“base” building design using the DD Wizard of eQUEST, the simulation is done using the EEM Wizard by comparing the following input parameters for Conventional & Proposed villas:

1. Building Envelope

The construction materials used for the building envelope plays an important role in the Energy Efficiency Analysis. Table.1 shows the details regarding the input parameters for the building envelope creation in eQUEST for the chosen villas and the estidama criteria for the same.

Table.1. Input parameters for building envelope creation

Sl No:	Parameter	Estidama Criteria	Conventional villa	Pearl-2 rated villa
1.	Wall	RE-R1 target average U-value ≤ 0.32 W/m ² K RE-1 target average U-value ≤ 0.29 W/m ² K	2.202 W/m ² K	0.29 W/m ² K
2.	Roofs	RE-R1 target average U-value ≤ 0.14 W/m ² K RE-1 target average U-value ≤ 0.12 W/m ² K	1.291 W/m ² K	0.12 W/m ² K
3.	Exposed floor	RE-R1 target average U-value ≤ 0.15 W/m ² K RE-1 target average U-value ≤ 0.14 W/m ² K	0.15 W/m ² K	0.15 W/m ² K
4.	Glazing	RE-R1 target average U-value ≤ 2.2 W/m ² K and SHGC = 0.4 RE-1 target average U-value ≤ 1.9 W/m ² K and SHGC = 0.3	U = 2.5 W/m ² K SHGC = 0.8	U = 2.2 W/m ² K SHGC = 0.4

2. HVAC

To meet the estidama RE-R1 Minimum Energy Performance requirements, the air conditioning unit should have a minimum seasonal average Coefficient Of Performance (COP) of 3.4. For projects that aspire a higher pearl rating and have elected to target RE-1 Improved Energy Performance, a minimum COP of 3.8 must be achieved [10]. The COP of the chosen conventional villa is 3, which does not meet the above criteria. Table.2 shows the HVAC details of the chosen villas.

Table.2 HVAC details of chosen villas

HVAC	Input power (watts)	Output power (watts)	COP = Output/Input	Estidama criteria	Remarks
Conventional Villa	1964.15	5892.46	3	3.8	Failed
Pearl-2 Villa	1609.68	6216.20	3.86		Passed

3. Internal Load

Here eQUEST is analysing the overall performance of internal and external lighting systems. As per estidama criteria, compliance is based upon achievement or improvement beyond the target values outlined in ASHRAE 90.1.2007. Figure.3 shows that the Pearl-2 villa has achieved the estidama criteria for Lighting Load.



Fig.3 Internal Lighting Load Analysis of Pearl-2 villa using Estidama Lighting Calculator

V. WATER ANALYSIS

Water consumption in a villa greatly depends on the occupant behaviour, which cannot be estimated accurately. Hence only hypothetical results can be obtained by considering the flow rates of the water fixtures and average usage of the occupants. To estimate the interior water consumption of the chosen villas, the Villa Water Calculator of the PVRS is used. This calculator helps to assess the inputs and flows of water to and from the project with a holistic perspective, and assist in identifying how and where reductions in the use of potable water may be made [10].

Table.3 shows the estidama criteria for the water fixtures and fittings. The water fixtures and fittings of the Pearl-2 villa are more efficient than what is required as per the estidama criteria, thereby making a huge reduction in water consumption. Figure.4 and figure.5 shows the water consumption calculation in conventional and Pearl-2 villa respectively using Villa Water Calculator.

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Table.3 Estidama criteria for water fixtures and fittings (Source: www.estidama.upc.gov)

Sl. No:	Fixture/ Fixture Fitting	Estidama Criteria
1.	Bathroom taps	6 L/min at 413.7kPa
2.	Shower head	9.5 L/min at 551.6kPa
3.	Kitchen sink faucet	6 L/min at 413.7kPa
4.	Bidets	6 L/min at 413.7kPa
5.	Toilets (Dual flush)	6/4 L/flush cycle (full/low)
6.	Baths	20 L/min at 413.7kPa

		Baseline Building							
		FTE Uses per Day		Flowrate	Flow Duration	Water Consumption			
		Male	Female	L/min or l/use	min or use	Average /use	l/person/day	l/year	
Villas	Kitchen Taps	Yes	4.00	4.00	8.00	0.75	6.00	18.00	52,560
	Bathroom Washbasin Taps	Yes	7.43	7.23	8.00	0.69	5.52	30.49	88,607
	Toilets, Single Flush	No							
	Toilets, Dual Flush	Yes	3.93	3.93	6.50	1.00	6.50	18.33	55,933
	Bidets/Bidet Spray	Yes	0.65	0.65	7.50	0.15	1.13	0.59	1,601
	Showers	Yes	1.00	1.00	10.20	7.00	71.40	66.50	1,56,366
	Baths	Yes	0.05	0.05	22.00	1.00	1.10	1.00	2,409
	Ablution Fixtures	No	1.50	1.30	6.00	1.50	9.00	0.00	0
	Dishwashers	No			1.30			0.00	0
	Washing Machines	No			8.50			0.00	0
Total Interior Water Consumption									3,57,476

Fig.4 Water consumption in conventional villa

		Proposed Building							
		FTE Uses per Day		Flowrate	Flow Duration	Water Consumption			
		Male	Female	L/min or l/use	min or use	Average /use	l/person/day	l/year	
Villas	Kitchen Taps	Yes	4.00	4.00	1.90	0.75	1.43	5.70	12,483
	Bathroom Washbasin Taps	Yes	7.43	7.23	1.90	0.69	1.32	9.66	21,147
	Toilets, Single Flush	No							
	Toilets, Dual Flush	Yes	3.93	3.93	4.00	1.00	4.00	15.71	34,414
	Bidets/Bidet Spray	Yes	0.65	0.65	6.00	0.15	0.90	0.59	1,291
	Showers	Yes	1.00	1.00	6.00	7.00	42.00	42.00	91,980
	Baths	Yes	0.05	0.05	20.00	1.00	20.00	1.00	2,190
	Ablution Fixtures	No							
	Dishwashers	No							
	Washing Machines	No							
Total Interior Water Consumption									1,63,505

Fig.5 Water consumption in Pearl-2 villa

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VI. SIMULATION RESULTS

The EEM Wizard compares the input data of the conventional villa & Pearl-2 rated villa and then results are generated as graphs. The energy efficiency analysis of the chosen villas shows that the Pearl-2 rated villa has a potential of electricity reduction by 25.4%. The water efficiency analysis using estidama Villa Water Calculator shows that there is water consumption reduction of 54.3% in Pearl-2 villa compared to the conventional villa.

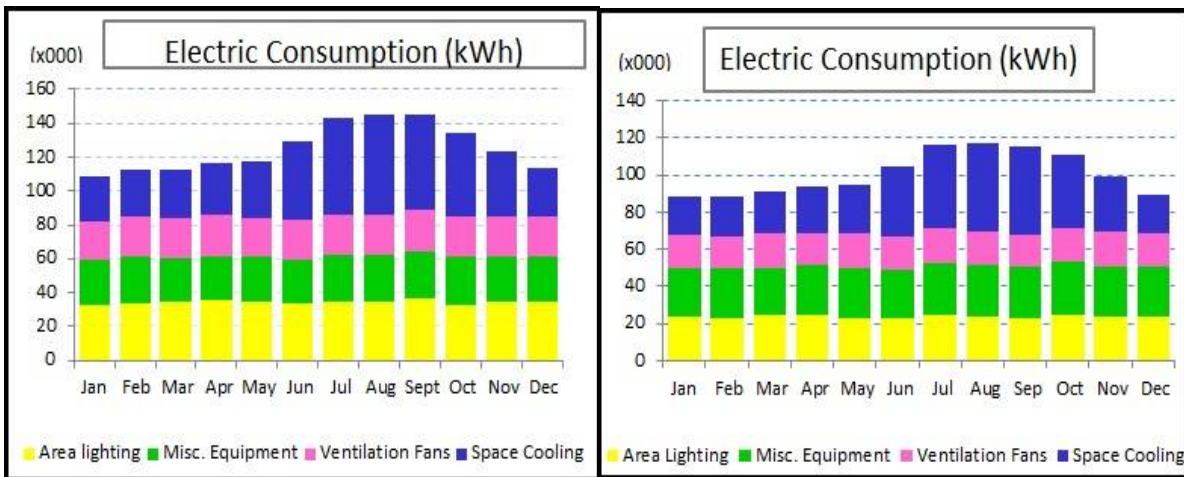


Fig.6 (a)

Fig.6 (b)

Fig.6 (a) Annual Electric Consumption trend in (a) Conventional Villa (b) Pearl-2 Villa

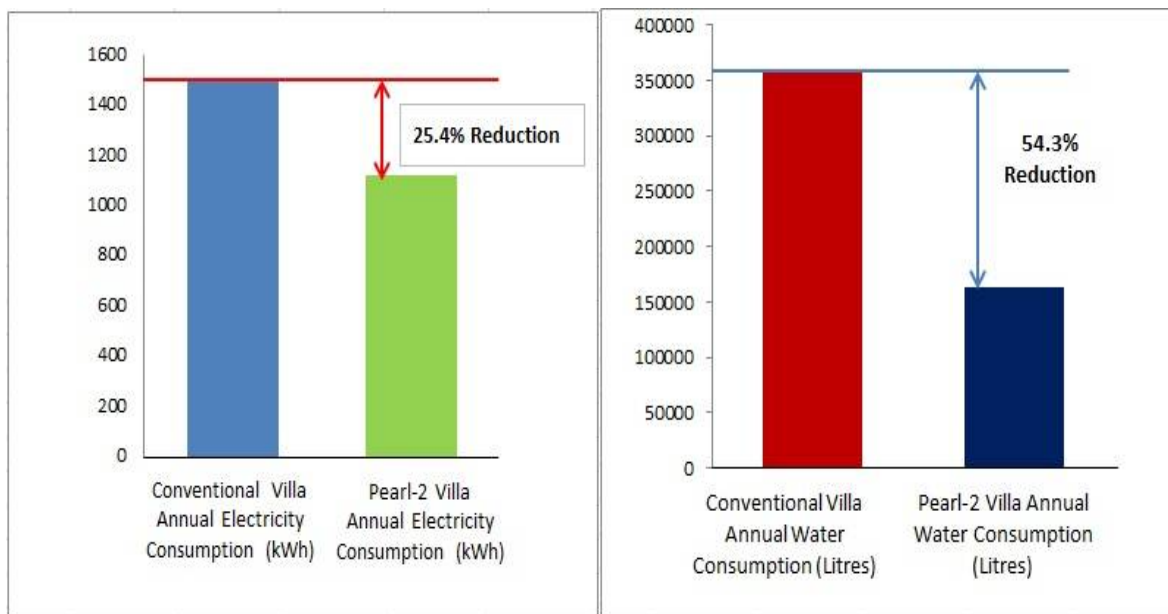


Fig.7 Potential of energy reduction in Pearl-2 villa

Fig.8 Potential of water reduction in Pearl-2 villa

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VII. CONCLUSION

The study reveals the importance of innovative practices to be implemented in the field of construction for the reduction of energy & water consumption. The energy efficiency analysis using eQUEST software shows that the Pearl-2 rated villa has a potential of electricity reduction by 25.4% compared to conventional villa. The water efficiency analysis using estidama Villa Water Calculator shows that there is water consumption reduction of 54.3% in Pearl-2 villa compared to the conventional villa. This shows that, implementation of estidama Pearl Villa Rating System to residential buildings make them energy and water efficient.

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