

# International Journal of Innovative Research in Science, Engineering and Technology

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## Retrofit Alternatives Priorities To be applied To Residential Spaces [In Cairo& Delta climatic zone-Using Information Technology tool]

Rasha Ahmed Reyad Ahmed Ibrahim, Almoatazbellah Gamal eldine Abdelazem<sup>2</sup>

Lecturer, Department of Architecture, Faculty of Engineering, Benha University, Egypt<sup>1</sup>

Lecturer, Department of Architecture, Faculty of Engineering, Benha University, Egypt<sup>2</sup>

**ABSTRACT:** Sustainability revolution responds to the great environmental crisis, global warming, and greenhouse gases (GHG) emissions, thus the growing dangers of climatic change, in addition to the economic impact of raising the energy and electricity prices by triple and more in last decade in both developed and advanced countries. Generally, building sector represents the most energy consumer with up to (50%) of energy produced, thus There is no doubt it is the time to focus on existing buildings, which contributes up to (30%) of global (GHG) emissions and consumes more (40%) of all energy primarily through the operational phase [1].

Although, there are many green Retrofit strategies, technologies that could be imbedded into existing building, but the capability of application in Egypt, with a compromised methodology for assessing with local available techniques and materials, and even individual budget.

The research aims to propose a suitable methodology/matrix to help: [Owners –Tenants–Building Investors] to differentiate among the most effective retrofit alternatives can applied to the existing residential spaces, to get both: Reduction of Residential energy consumption, then become more green, and with-in accepted retrofit budget compromised with the Egyptian market with conventional finishing systems and materials.

By the aid of reliable Information Technology tool (Energy Plus simulation engine –"Design Builder") and the comparative analytical study the research finds the priorities of space retrofit items were: Lighting alternatives, then glazing alternatives, then shutters and window curtains are the most effective retrofit alternatives with (38%:25%) of energy reduction, otherwise, the author space items such as: Ceilings, then Internal Partitions, then flooring are the least effective / un-tangible reduction in energy consumption percentage less than (5%:10%) compared to "Base-case" and prior to be applied as retrofits alternatives to residential spaces.

**KEYWORDS:** Building Retrofit, Energy consumption, Residential buildings, Sustainability, Space orientation.

### I. INTRODUCTION

Building sector (existing and new ones) constitutes the major Energy consumer comparing other human activities sectors with percentage near (50%) of the produced energy, Existing (running) buildings represents the overwhelming percentage of the building stock up to (62%) [2], thus are the key to improving overall sustainability and efficiency, because of buildings account for a major share of the climate change crisis.

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According to many technical official reports of Egyptian environmental affairs and analytical studies about the energy and situation of Egypt (Eldemirdash and others) [3], concluded that, Egypt as a developing country facing many [Economic – Environmental – Energy] challenges such as follows:-

- Limitation of the traditional energy resources, which depends mainly on the fossil fuel.
- The vast increase in population rates (1.35 m/y). The more need for energy supplies [4].
- The old technology in construction industry which consumes high intensive energy more than needed.
- The vast rising of energy /electricity prices for both: residential and commercial sectors exceeding the triple times by the last decade.
- Egypt occupying the rank 27 of (GHG) emissions (CO<sub>2</sub>) due to fossil fuel, non-controllable agriculture wastes.

The most effective environmental impact and the energy consumption occurs during operational stage of the building along its Life-cycle, which means the operated (running) existing buildings are the meant by energy reduction strategies

The most significant barriers towards a green retrofit of any existing building are: its additional initial cost, high construction and implementation cost, and lack of awareness of what are the prior item to be retrofitted than others [3].

So, it is the time to get quick strategy help individuals (Owners – Tenants – small building Investors) to choose the suitable retrofit alternatives of residential spaces items depending on energy consumption and space suitability to renovate their residences more green and energy saving.

## 1. Research Problem

Problem of the research have many vital sides can be concluded as follows:-

- Existing residential buildings represent more than 50% of all buildings stock, but (Operation – Maintenance) along building life-cycle is neglected, which can be more passively impacted, if there is a guide-line strategy/plan to be retrofitted to become green ones.
- Economic side: the vast rising in energy demand of the building stock, especially by Residential sector, in addition to the doubled electricity prices and still rises in Egypt, which becomes a heavy economic load on individuals of a developed country, but it, can be adapted by individuals' more than public and commercial building sectors [5].
- Environmental side: the rising in energy demand the more rising of gas emissions amount, global warming problems, and fasting of climate change rates.

## 2. Research Goals

The research main goal is to develop a methodology or a matrix/guide-line to help the residential sector decision makers (Government – Owners – Tenants) to take their retrofits discussions based on the most prior retrofit alternatives in greening any existing residential building, through the followings:-

- Investigating the current energy and electricity situation in Egypt (Economic – environmental).
- Exploring the concept of building Retrofit [strategies – benefits – barriers].

## 3. Method and Technical aids

The application approach of the research was done by using the aid of "Design Builder" – [v.5.0.3.007] software (it is IT application) linked to (Energy Plus), which is considered as the most widely used, popular, reliable, and accurate simulation engine among recently thermal and visual simulation tools. By design the existing building simulation model as a "Base-Case" model, then made multi runs for each residential spaces retrofit alternatives, with different finishing systems and materials, with respect to different space orientations.

## 4. Research Methodology

Research methodology as shown in (Fig.1), compromises between:-

- Theoretical approach: this covers the literature review of building retrofits and current energy situation in Egypt, concerning on residential building sector.

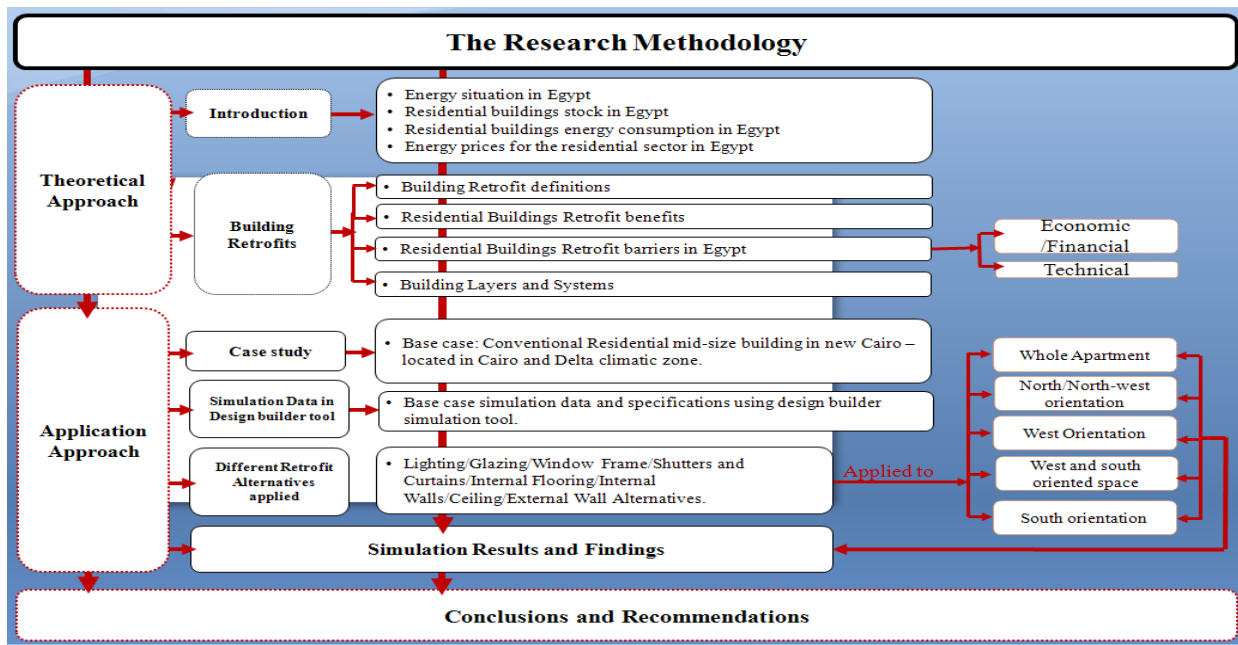
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- Application approach: using an Information Technology credited tools “Design Builder” application on the “Base-case” model for a real existing residential building to get the different impacts of retrofits alternatives of the residential spaces.



(Fig.1) – Research Methodology chart, [Ref., Authors].

## II. ENERGY AND ELECTRICITY SITUATION IN EGEYPT

### 1. The Egyptian building stock

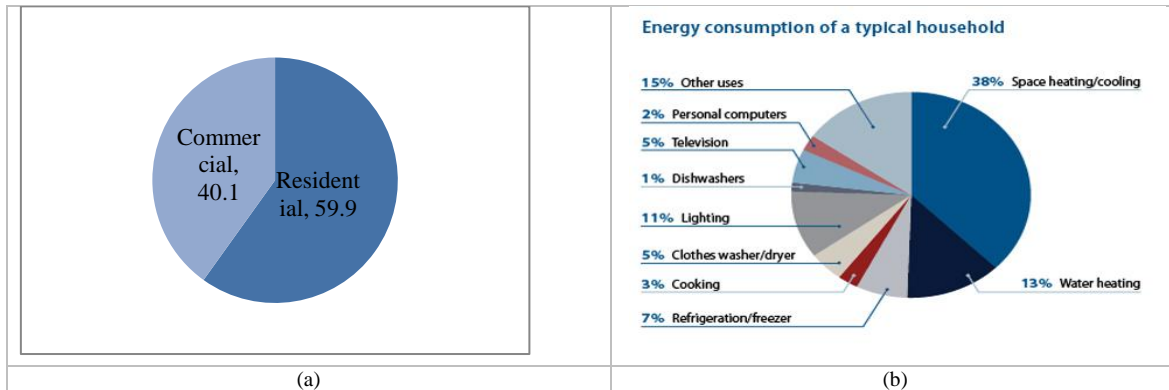
The Egyptian building stock encompasses about 12 million buildings, nearly (60%) of buildings are residential, and (40%) are commercial [6], which indicates to the importance of residential buildings sector in the total amount of energy consumption, thus priority of more analytical studies to make them green (Fig.2 a,b).

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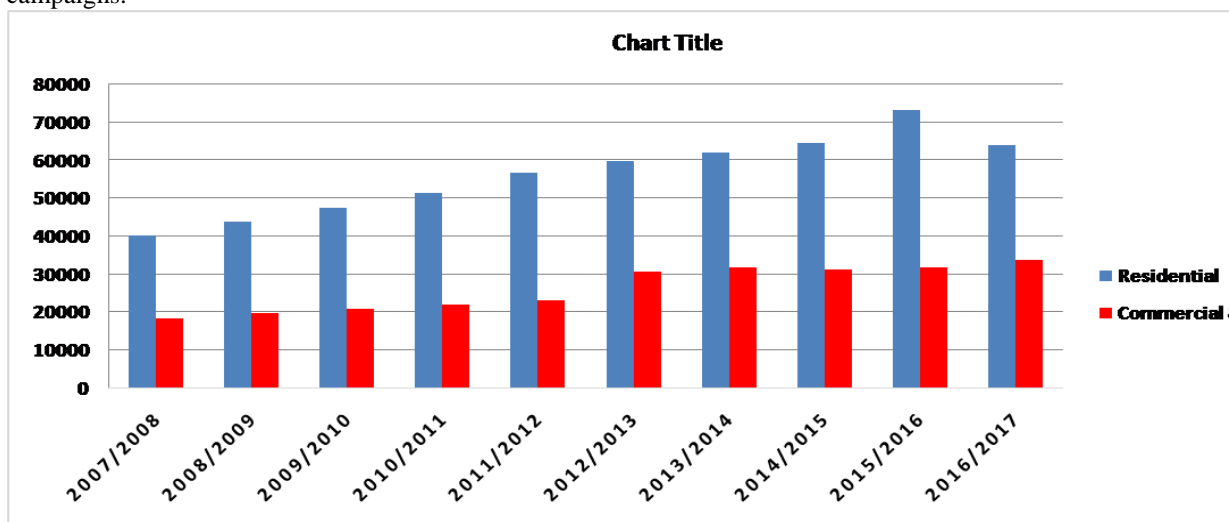
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(Fig.2) Building stock patterns in Egypt 18/ 2019-(a): Energy consumption by sector, (b): Energy consumption by pattern in residential sector. [Ref. Authors based on ministry of Electricity reports]

## 2. The residential building stock energy consumption

The residential buildings as a whole consume more energy than commercial buildings. In Egypt, the residential sector electricity consumption increased by (42.9 %) from 2008 to 2017 [7], as shown in(Fig.3). But it is noticed that the residential consumption has decreased in 2017/2016, due to the use of (LED) lamps in lighting and multimedia awareness campaigns.



(Fig.3), Electricity consumption (by GWh) along 10 years) in Egypt by sector (Residential vs commercial) 2008-2017. [Ref. Authors, based on ministry of Electricity reports ]

## 3. The energy prices:

Household uses electricity sales tariff has been raised rapidly, by moretriple times, and still rising, as in (Table: 1), and illustrating in (Fig.4) the comparativeannual development of electricity prices of residential sector with respect to each Consumption Brackets, first consumption category raised more than three times (340%), also the mid-category

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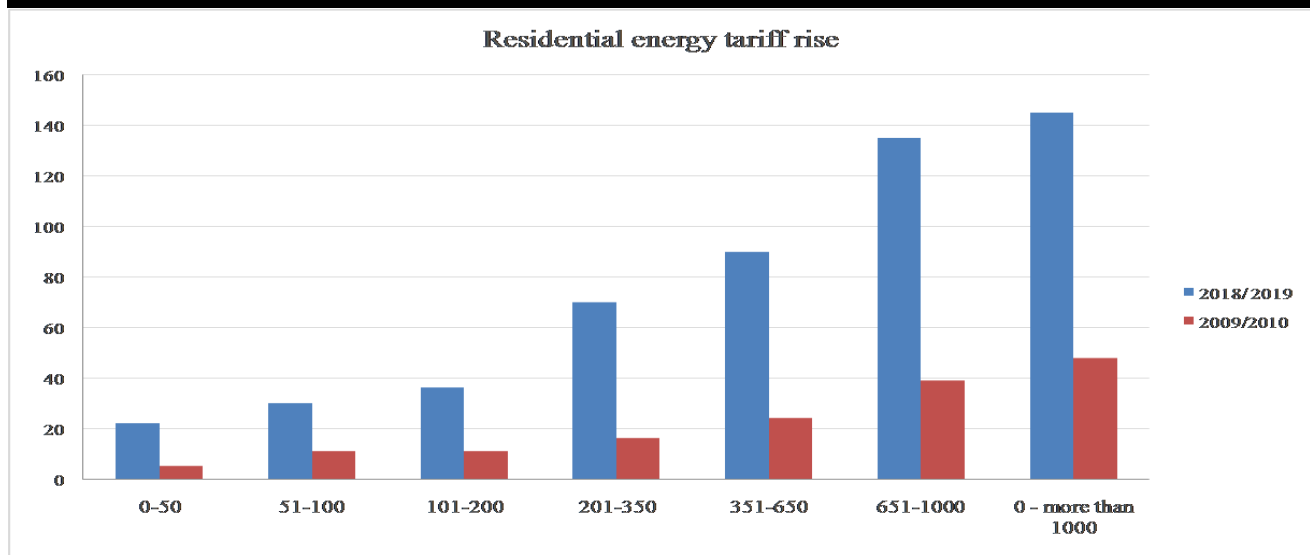
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consumption raised by (338%) with-in last ten years, which represents a heavy economic load on individual residents budget monthly.

(Table:1) Household uses electricity sales tariff 2009-2019, [7]

Consumption Brackets (KWh/ month)	2018/ 2019	2009/2010	% of increase
	Pt./KWh	Pt./KWh	
0-50	22.0	5.0	340
51-100	30.0	11.0	173
101-200	36.0		227
201-350	70.0	16.0	338
351-650	90.0	24.0	275
651-1000	135	39.0	246
0 - more than 1000	145	48.0	202



(Fig.4), Comparative Development of Electricity prices (by Egyptian Pound along 10 years) in Egypt - (Residential sector) 2008-2017.  
[Ref. Authors, based on ministry of Electricity reports ]

### III. BUILDINGS RETROFITS [CONCEPT & BARRIERS]

The green retrofit of an existing building generally, and residential sector especially has tangible and in-tangible benefits to the owners, tenants, and investors, it can reduce the energy consumption, it also improves the quality of in-door built environment, and reduces the negative impact of buildings occupants. The main challenge of retrofitting the existing buildings is to demonstrate achievement while still within budgets, addressing tenants/occupant resistance to change.

#### 1. Benefits of Retrofitting Existing Residential Building to go green

##### A. Benefits Directly to the Building Owner

The most significant benefits to the building owner are classified into two main categories. First: increased income through higher rental rates, higher occupancy growth, and higher rental growth. Second: are lower costs through lower

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operating cost in the reduction of energy and water use; direct costs are represented in energy and water consumption, security, cleaning, repairs and maintenance. However, this cost category also includes indirect costs such as property taxes, insurance[8].

In addition, green buildings offer a healthier living environment; increased air ventilation, improved day light space, and low toxicity finishes, as well as the lower operation costs. This makes green buildings more appealing to the public. As a result, it is faster to sell and lease compared to conventional buildings in the same area.

### B. Benefits Directly to the Tenants

Tenants are placing a higher value on the intangible benefits, which include higher personal productivity, and better indoor environmental quality, in addition the tangible benefits represented in lower operational costs.(Table: 2) concludes the green retrofits benefits corresponding building industry contributors[9], which varied among (Tenants – Owners – Investors – Contractors – Subcontractors).

(Table:2)Benefits of Green Retrofit

User	Benefits of Green Retrofits
Tenants	<ul style="list-style-type: none"> <li>▪ Potential for reduction in operational costs –enhancing the indoor built-environment as a result an increased productivity– Improved comfort –Enhances sustainability goals reputational image.</li> </ul>
Owners	<ul style="list-style-type: none"> <li>▪ Reduction in operating costs – Improved efficiency results a longer equipment life due to “right-sizing”. (Less need for refurbishment).</li> <li>▪ Higher rents - Greater occupancy – lower tenant turnover – enhanced marketability.</li> </ul>
Investors	<ul style="list-style-type: none"> <li>▪ Improved long-term value through reduced performance risk – Higher resale value.</li> </ul>
Contractors	<ul style="list-style-type: none"> <li>▪ Reputational position for contractors.</li> </ul>
Subcontractors	<ul style="list-style-type: none"> <li>▪ Opportunity to be recognized as the energy efficiency expert in your local community.</li> </ul>

## 2. Barriers to Retrofitting Existing Residential Buildings

### A. Economic/Financial

- High cost of green systems, materials, and technologies[10].
- Tenants not willing to pay for retrofits in rented residents.
- The investor has no interest in paying for green practices.
- Long payback periods.
- Lack of funding or financing difficulties.
- Relatively low energy prices despite the increase in tariffs
- Lack of Research Investments.

## 2. Lack of funding programs concerning retrofits in buildings.

### A. Technical

- Uncertainty of the comprehensive benefits of green retrofits.
- Shortage of maintenance stable program and sometimes ignored in projects.
- Shortage of environmental information for the construction materials and products.
- Shortage of professional and specialized contracting retrofit companies.
- Lack of experienced labors for fast maintenance.

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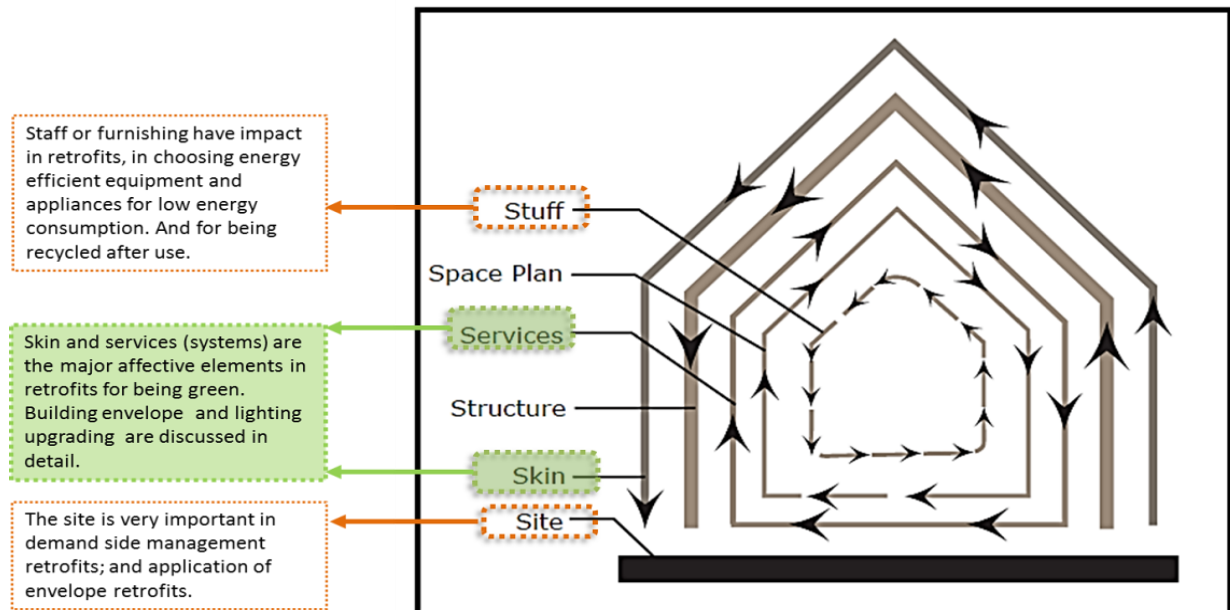
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### 3. Building Systems

To plan a retrofit strategy to be assessed, it should be an analytical study of any residential building systems which can be retrofitted and have a tangible impact in reduction of energy consumptions, and environmental feed-back, then according to Stewart Brand [11], a building is composed of six layers of change as illustrated in (Fig.5) as follows:-

- **Site:** The geographical settings, the urban location, and the legally defined lot.
- **Structure:** The foundations and load bearing elements. (Doesn't count in green retrofits).
- **Skin (Envelope):** Exterior surfaces of a building, Walls and Roof, (A major element in green retrofits).
- **Services:** The working guts of a building, communication wiring, electrical wiring, plumbing, sprinkler system, HVAC, and moving parts like elevators and escalators. (A major element in green retrofits, but will not be discussed but for the electrical lighting system upgrade).
- **Space Plan:** The interior lay out, walls, floors, ceilings, and doors.
- **Stuff (Furnishings):** Chairs, desks, phones, pictures, appliances, etc. (Energy efficient appliances play an important role in green retrofits).



(Fig.5), Building Layers and Systems can be retrofitted, [Ref., 11].

### 4. Retrofit items of the Residential spaces

This research will focus on the residential buildings space retrofits not the building envelope, Nor Stuff (appliances – furniture), these items are [Lighting system upgrade – Glazing alternatives – shuttering and Curtains – Window Frame Alternatives – Internal Flooring Alternatives External/Internal Wall Cladding – Ceiling Alternatives]. To get the direct, real and tangible impact for individual residential users, research focusing on residential spaces has many reasons as follows:-

- More Reliable and controllable by individuals.
- The retrofit procedures give a direct, fast and real economic impact for the residential users.
- The variety of choice the suitable retrofit items/alternatives to be applied for each available budget.

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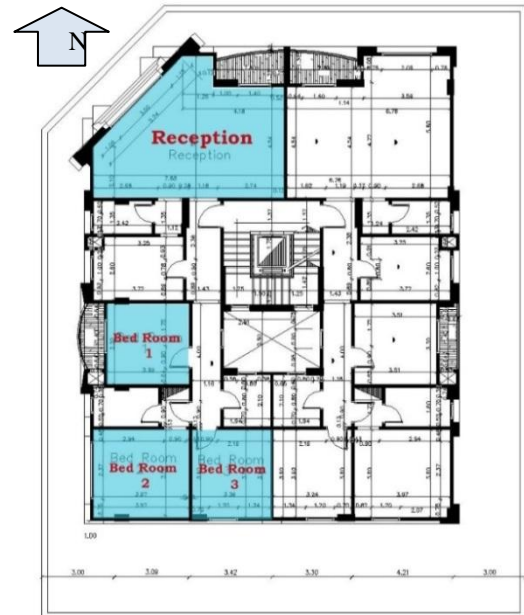
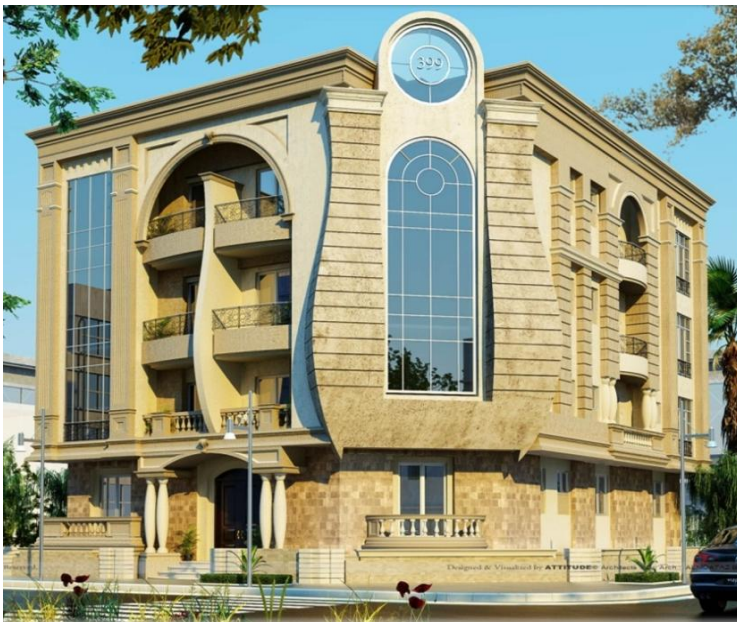
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- With the proposed space retrofits items / alternatives no need for sophisticated procedures or special technical workers, most of them could be done by the owner or tenant of the unit.

## IV. RESIDENTIAL “CASE-STUDY” & SIMULATION MODEL

The selected case-study is a residential building located in New-Cairo district, Cairo/Egypt is composed of ground floor level in addition to 3 typical floors. The typical floor is composed of 2 apartments as illustrated in (Fig.6, a&b).



(Fig.6) – Residential building located in New-Cairo district, Cairo - (a) Exterior view, (b) Typical floor plan with tested spaces, [Ref., Authors].

The climatic zone of study, in Cairo, Egypt with (Latitude 30.1° North and 31.4° East Longitudes) - was established by parametric study of thermal and ventilation performance. Climatic conditions of simulation model will follow the Egyptian Energy Code for residential buildings, 2009, as shown in (table:3).



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(Table: 3) –Climatic Conditions for 'Cairo & Delta climate zone', [Ref., Egyptian Energy Code for Residential buildings, part: I, EECB- 2009 ]

City	Location			Winter						Summer				
				Out-door climatic conditions			In-door climatic conditions			Out-door climatic conditions		In-door climatic conditions		
				Dry temperature design values			Moisture temperature design values			Degree (C°)		Relative Humidity (%)		
				1%	2.5%	5%	99.6%	99%	Degree (C°)	Relative Humidity (%)	Degree (C°)	Relative Humidity (%)		
Cairo	31.4	30.1	74.0	42.1	38	37	26	27	24	50	13.3	70	21	40

### 1. Simulation tool used - “Design Builder”

“Design Builder” The most popular interface developed for “EnergyPlus” that includes a simplified CAD interface, templates, wizards, and most compact air system configurations of “EnergyPlus”. The typical usage of “DesignBuilder” includes evaluation of facade options, day lighting analysis, visualization of site layouts and solar shading, thermal simulation of natural ventilation, and sizing of HVAC equipment and systems [12].

### 2. Simulation strategies

Simulation will be done using "Design Builder" tool between:” Base-Case" conventional finished spaces model to be compare with Retrofit alternatives, then research will compare the energy consumption ratios for each alternative.

### 3. Case-study building design data

(Table: 4) illustrates design data of the simulation model of the residential building of the “Base-case” model.

(Table: 4) - Residential building Architectural Data, [Ref. Author]

- Building type	Isolated Residential building / Fully finished spaces
- Space organization	12 cms. Perforated Clay bricks Thick Partitioned spaces.
- Occupants rate	Reception space (8) persons / Bed rooms (2) persons
- Building floors	Ground floor + (3) typical floors
- floor height	3.30 m ( slab to slab) , 3.00 m ~ 3.0 m (clear height)
- Building total height	(3.30 m X 4 floors)+ 1.4 m parapet of façade= 15.00m
- Ground floor area	15.0 m X 21.0 m = 315.00 m <sup>2</sup>
- Typical Bedrooms floor area (Dimensions are suitable for Architectural module+ structural and parking lots design assumptions)	24.0 m (8.0 m X 3 typical units) X 24.0 m (8.0 m X 3 typical units) = 576.00 m <sup>2</sup>
- Ventilation system	“Base-Case” model: Artificial Mechanical ventilation (Full HVAC) system with set point (24 °C).

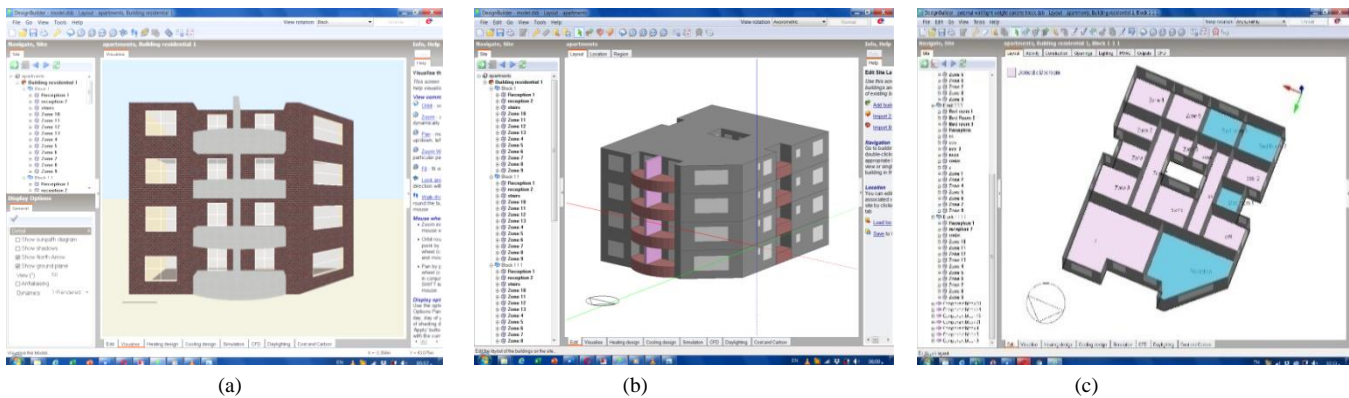
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Simulation will be done using "Design Builder" software (it is IT application) linked to (Energy Plus), which is considered as the most widely used, popular, reliable, and accurate simulation engine among recently thermal and visual simulation tools, its interfaces shown in (Fig.7), the selected unit with (north/south/west) orientation, which the most bad one [13].



(Fig.7)-Residential building "Design builder" Simulation Model - (a) Material model, (b) Exterior model, (c) Tested Zones model, [Ref., Authors].

Thenext (Table: 5) illustrates –“Base-case” modeling assumptions and simulation assumption in “Design-Builder”.

(Table: 5)–“Base-case”Simulation Data and Specifications, [Ref. Authors]

Simulation data	Included/Excluded	Notes/Illustration
Cooling energy consumption	Included	The cooling set point <sup>1</sup> temperature is 24 °C.
Heating energy consumption	Excluded	No heating energy is calculated (as the general case in residential buildings)
Natural ventilation	Included	Allowed during calculations
External walls	-	12 cms brick wall with no insulation
Glazing	-	Single glazing – Clear glass – 6mm
External Shading devices or shutters	Excluded	No shading in the base-case
Internal curtains	Excluded	-
Lighting system energy consumption	Included	Incandescent light is used

#### 4. Retrofit alternatives

The research proposed retrofit finishing alternatives that cover the most nominal finishing elements:-

- Lighting Alternatives
- Shutters and Curtains
- Ceiling Alternatives
- Glazing Alternatives
- Internal Flooring Alternatives
- External Wall Cladding
- Window Frame Alternatives
- Internal Wall Alternatives

#### 5. Simulation Results

##### A. Considering a whole apartment (Unit)Energy Consumption Reduction [Important to the Owner]-(Fig.8).

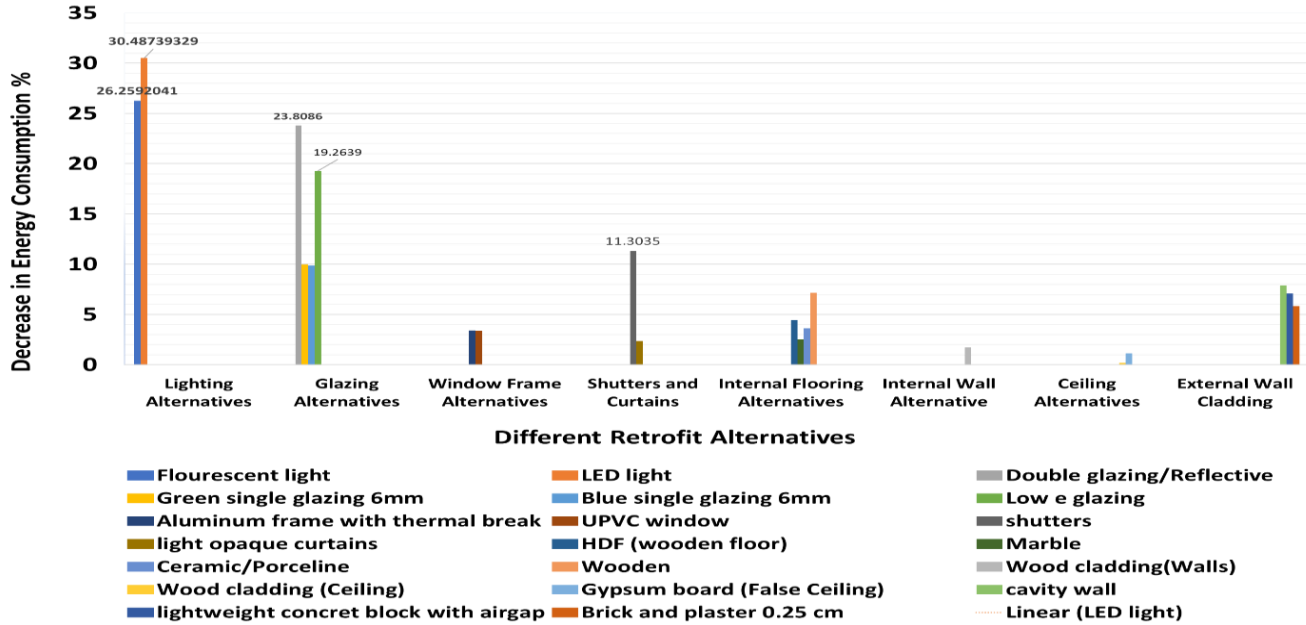
- The top priority retrofit alternatives are lighting alternative; which are the (LED light), and (Fluorescent light) with more than (30%) and (26%) reduction in energy consumption in the whole unit respectively, next glazing system with more than (23%) and (19%) reduction, then shutters and curtain with more than (11.3%) reduction.

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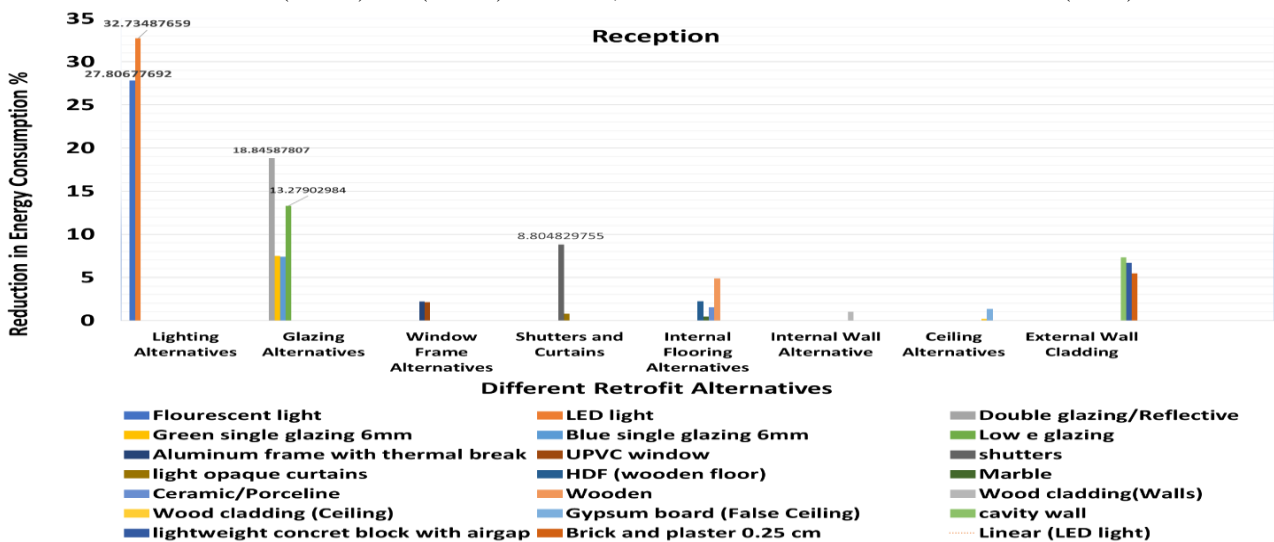
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## B. Considering (Reception) Energy Consumption Reduction [North and North/West orientation] - (Fig.9).

- The top priority alternatives are lighting alternative; which are the (LED light), (Flourescent light) with more than (32.7%) and (27.8%) reduction in energy consumption in reception space respectively, next glazing system with more than (18.9%) and (13.3%) reduction, then shutters and curtain with more than (8.8%) reduction.



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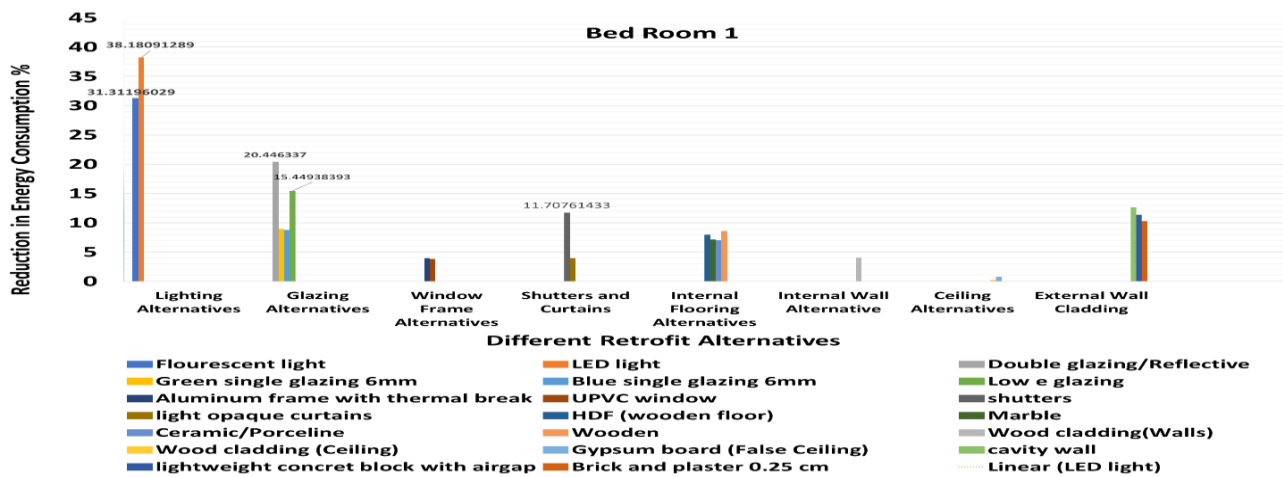
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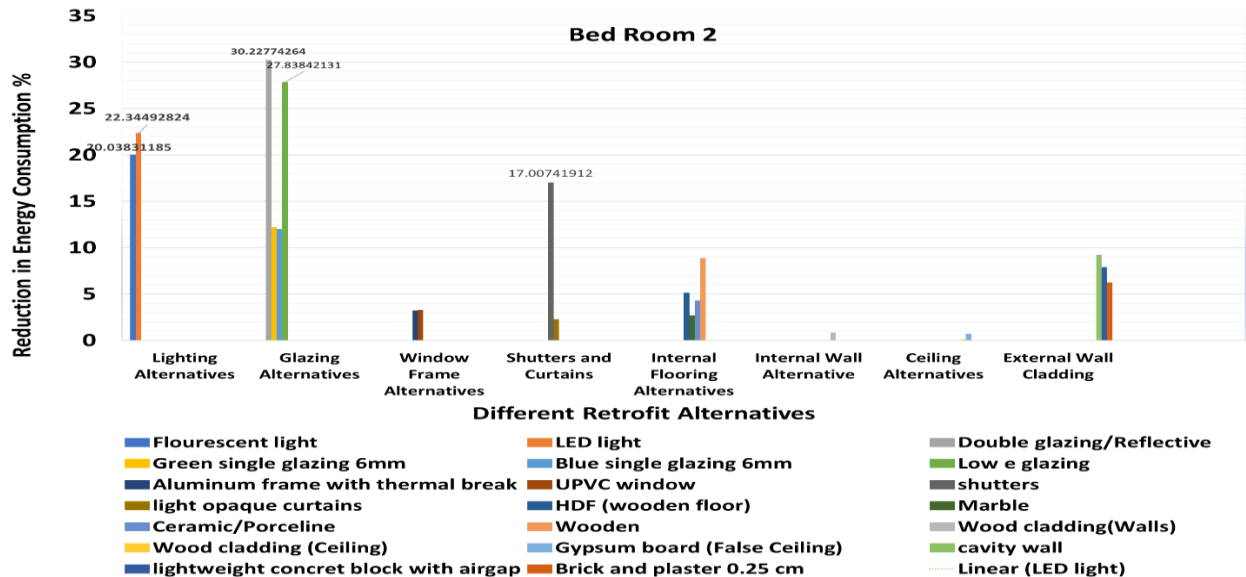
### C. Considering (Bed Room-1)Energy Consumption Reduction [West orientation]- (Fig.10), [Ref. Authors].

- The top priority retrofit alternatives are lighting alternative; the (LED light), (Fluorescent light) with more than (38.0%) and (31.0%) reduction in energy consumption respectively in (Bed Room-1), next glazing system with more than (20.5%) and (15.5%) reduction, then Ext. cladding and shutters with (11.7%) and (12.6%) reduction.



### D. Considering (Bed Room- 2)Energy Consumption Reduction [West and south oriented] - (Fig.11)

- The top priority retrofit alternatives are Glazing alternative; which are the (Double Reflective glazing), and (Low-e glazing) with more than (30%) and (27%) reduction in energy consumption in (Bed Room-2) respectively, next lighting alternative; the (LED light), (Fluorescent light) with more than (22.0 %) and (20%) reduction, then shutters and curtain with (17.0%) reduction.



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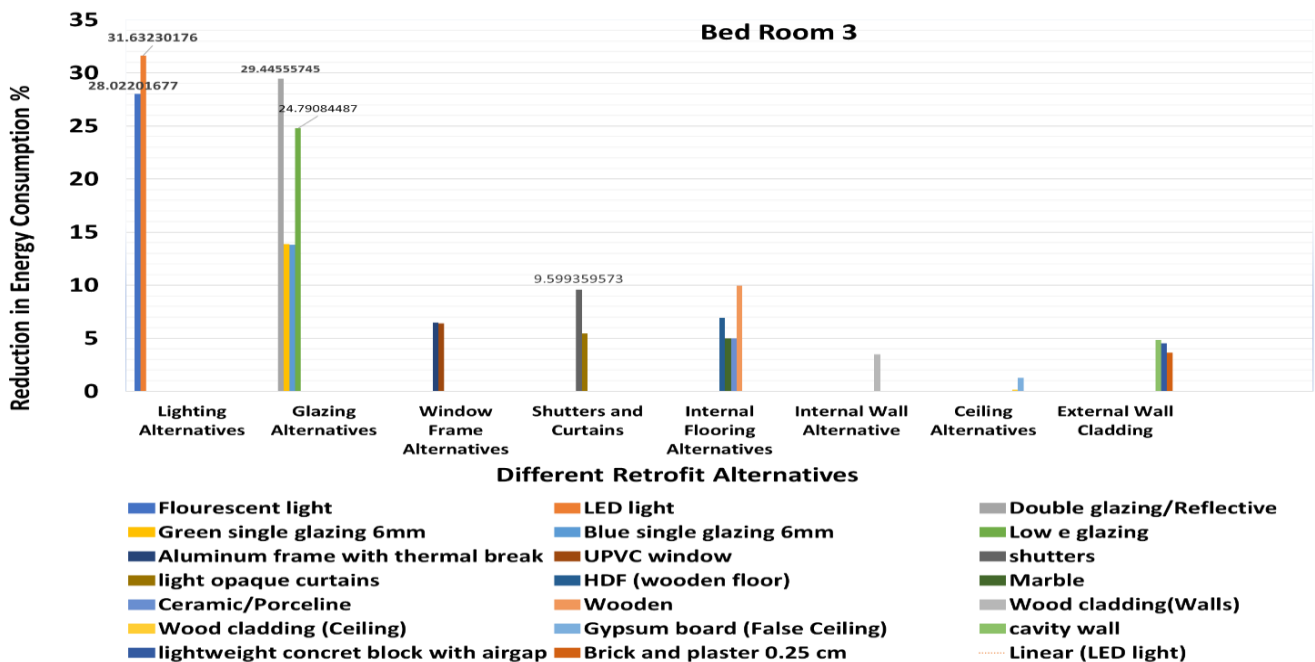
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## E. Considering (Bed Room-3) energy consumption reduction [South orientation] -(Fig.12)[Ref. Authors].

- The top priority retrofit alternatives are lighting alternative; the (LED light), (Fluorescent light) with more than (31.6%) and (28.0%) reduction in energy consumption respectively in (Bed Room-3), next glazing system with more than (29.4%) and (24.7%) reduction, then shutters with (9.55%)reduction.



## 6. Priorities of Retrofit alternatives

After testing all proposed retrofit alternatives resulting from model simulation of each space, and compared to the “Base-case” values, we can conclude and matrices the final total simulation results as, with respect to each space orientation as detailed shown in ( Table:6). By exploring the final results with respect to each retrofit nominal (conventional) item we can categorize retrofit alternatives into two groups corresponding the energy reduction percentage as follows:-

### A. Effective Reduction items such as:-

- LED Lighting is the top alternative with (22.3:38.2) %.
- Double glazing with reflective outer paneis the top alternative with (18.9:30.2) %.
- Wooden/Foamed Shutter is the top alternativewith (9.6:17.0) %.
- External wall with (5 cms. Air Cavity wall)is the top alternative with(4.9:12.6) %.

### B. Non-Effective Reduction items such as:-

- Wooden flooringis the top alternative with(4.9:10.0) %.
- UPVC or Aluminium frame with thermal break is the top alternative with (2.2:6.4) %.
- Internal wall cladding with (1.1:4.0) %.
- Gypsum board ceiling with (0.7:1.3) %.



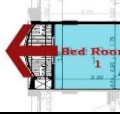


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(Table: 6)–Retrofit alternatives&Reduction in Energy Consumption percentage (%) compared to “Base-case” and space Orientation, [Ref. Author]

Spaces & Orientation		Reduction in energy consumption percentage %					
		Whole Apartment	North/North-west orientation	West Orientation	West and south oriented space	South orientation	
Retrofit Alternatives							
	Lighting Alternatives						
	Glazing Alternatives						
Lighting Alternatives	Incandescent (base case)	0.0	0.0	0.0	0.0	0.0	
	Fluorescent light	26.2592	27.8	31.3	20.0	28.0	
	LED light	30.48739	32.7	38.2	22.3	31.6	
	Glazing Alternatives	single glazing (base case)					
		double glazing/Reflective	23.80864	18.85	20.45	30.23	29.45
green single glazing 6mm		9.989905	7.50	8.94	12.20	13.86	
blue single glazing 6mm		9.869686	7.40	8.79	11.99	13.80	
Low e glazing		19.2639	13.28	15.45	27.84	24.79	
Window Frame Alternatives	Wooden frame (base case)						
	Aluminum frame with thermal break	3.415829	2.19	3.94	3.22	6.47	
	UPVC window	3.382384	2.13	3.83	3.29	6.41	
Shutters and Curtains	shutters	11.30356	8.80	11.71	17.01	9.60	
	light opaque curtains	2.341621	0.78	3.96	2.27	5.46	
Internal Flooring Alternatives	HDF (wooden floor)	4.422918	2.25	7.97	5.15	6.93	
	Marble	2.527208	0.43	7.18	2.68	5.00	
	Ceramic/Porceline	3.6149	1.52	7.05	4.30	6.03	
	Wooden	7.171214	4.85	8.60	8.85	9.93	
Internal Wall Alternative	Brick and plaster (Base Case)						
	Wood cladding	1.734046	1.01	4.05	0.84	3.49	
Ceiling Alternatives	Brick and plaster						
	Wood cladding	0.171569	0.19	0.24	0.12	0.15	
	gypsum board	1.129366	1.37	0.81	0.70	1.28	
External Wall Cladding	Brick and plaster 0.12 cm (Base Case)						
	cavity wall	7.884991	7.32	12.64	9.21	4.85	
	lightweight conc. block with air gap	7.078497	6.71	11.34	7.89	4.52	

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Brick and plaster 0.25 cm	5.824112	5.47	10.33	6.22	3.66
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## V. FINDINGS AND CONCLUSION

### A. General Findings:

1. Descending, Lighting alternatives ;( LED/Fluorescent) lamps, then glazing alternatives ;( Double Reflective glazing / Low-e glazing), then shutters and window curtains are the most effective / tangible reduction in energy consumption percentage between (35%: 25%) compared to “Base-case” and prior to be applied as retrofits alternatives to residential spaces.
2. Descending, Ceilings alternatives, then Internal wall alternatives, then flooring alternatives are the least effective / un-tangible reduction in energy consumption percentage less than (10%: 5%) compared to “Base-case” and can be neglected to be applied as retrofits alternatives to residential spaces.

### B. Focused Findings:

1. With respect to the whole unit (tested apartment) noted that:-
  - Retrofit the whole residential unit with: Lighting with (LED lamps) + enhancing of windows glazing with (Double Reflective glazing panes) + provide external window shuttering, will reduce the total amount of energy consumed by the unit compared to the conventional “Base case” by amount of (65%: 70%).
2. With respect to (each Space Orientation) noted the following:-
  - [North & North West Orientation- (Reception space)]: the reduction of energy consumption was (60%).
  - [West Orientation-(Bed room-1)]: the reduction of energy consumption was (70.36%).
  - [West + South Orientation-(Bed room-2)]: the reduction of energy consumption was (69.54%).
  - [South Orientation-(Bed room-3)]: the reduction of energy consumption was (70.60%).
3. The Retrofit alternatives priorities in Energy Consumption Reduction With respect to Space Orientation:-  
The next (table: 7) illustrates in descending the priority of retrofit strategy in the residential spaces,

Retrofit Alternatives priorities		Space Orientation	Energy Reduction Ratio(%)
1	Lighting	West	LED :38.2 , Fluorescent:31.3
2	Glazing	West + South	Double glazing/Reflective:30.23,Low-e:27.9
3	Shutters and Curtains	West + South	Shutters:17.0
4	External Wall Cladding	West	(5 cm.) Cavity wall: 12.64
5	Internal Flooring	West	Wooden : 8.6, HDF :7.9
6	Window frames	South	Aluminum frame with thermal break: 6.5
7	Internal Partitioning	West	Wooden cladding : 4.05
8	Ceiling	North + N. West	Gypsum board: 1.37

## VI. RECOMMENDATIONS

### A. General Recommendations

1. Retrofit of residential building sectors should be a vital strategy to: [Government – Owner – Tenant] because of the vast rising in electricity prices, then negative Environmental impact.
2. Government should provide legalization and building codes to organize the refurbishment in existing buildings.
3. Government should offer a reward to retrofitted buildings and units to help incentivize individuals' users.

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4. Awareness by the economic importance of retrofit building and units, from (electricity prices, future and environmental impact of enhancing the built-environment) points of views.

## B. Owner and Tenant Recommendations

1. Lighting alternatives are the Top priority to be applied in residential retrofits due to the followings:-
  - The most effective energy reduction impact.
  - The most economic along its operational time.
  - Quick and ease of application.
  - The most various in types, efficiency and prices.
2. Glazing alternatives become the next priority to be applied to residential retrofits especially in (West & South west) orientated spaces.
3. Shuttering of windows becomes the third priority to be applied to residential retrofits especially in (South west & west) orientated spaces, because it is economic, quick and ease of application.
4. West, South, and South West oriented spaces are the most recommended spaces to be retrofitted with high effective impact on reduction of energy consumption.
5. Ceiling and Internal Partitioning alternatives can be neglected to be applied to residential retrofits.

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