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Biomimicry in Managing Daylighting and Energy Consumption in Office Buildings

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***Abstract*— Architects over the past half century have been trying to master nature with the aid of technology, machines and over rated energy consumption, this increased the gap between nature and the built environment. Biomimicry, where flora, fauna or entire ecosystems are emulated as a basis for design, is a growing area of research in the fields of architecture, design, engineering and business, problems .Interest in using daylighting as a major design element has varied with the social and economic forces of the time. The proposed designs are based on how some organisms (animals, plants) manage daylight and sunlight. Also the research discusses some of the broad problems that come up for consideration in planning for daylight and sunlight in office building, and to review briefly some of the steps that have been taken in advancing scientific daylighting of interior. Energy savings achieved through the use of daylight also translate into energy cost savings from reduced electricity consumption for lighting and cooling as well as from reduced needs during peak demand periods in many building.**

Keywords— Biomimicry, Sustainability, Sustainable building, Sustainable Design, Bio-inspired design, Daylighting, Ventilation, Thermal comfort, Energy consumption, Efficiency, Low Energy Architecture, Office buildings, Glare, High solar radiation.

I. INTRODUCTION

The best way to predict the future is to design it. Humans have learned much from nature. Nature has always inspired human achievements and has led to effective materials, structures, processes and the results have helped surviving generations and continue to secure a sustainable future. The inspiration from nature is driving force in architecture, resulting in majestic works of architecture. For any sustainable building design, need to consider structural efficiency, water efficiency, zero-waste systems, thermal environment, and energy supply. Biomimicry is an alternative solution, it is a new way of viewing and valuing nature, based not on what we can extract from the natural world, but what we can learn from it. Designers draw their inspiration from multiple sources to address challenging design problems. One method is to study nature, and attempt to comprehend the ways in which it has evolved to address environmental challenges..

II. REVIEW

Opinions of some scientists about the Biomimicry:

“Is a branch of the design branches that searches for sustainable solutions for the human problems through consultation and simulation of the nature’s principles that last for long ages.” Stephanie Watson- 2004. (1)

“Is to explore the principles notable in nature that we can learn from it and apply it within the design.” Carl Hastrich– 2009. (1)

“Is the process of having a design problem and then say: "What is the thing in the natural world, which is already solving the same problem," and then try to simulate it.” Janine Benyus – 2010.(2)

III. CASE STUDY

The case study is selected to investigate energy problems, to reach the maximum use of daylighing, the minimum energy consumption and to help the users feel visual and thermal comfortable.

Engineering consultant group (ECG) headquarter in the Smart Village in Giza, Egypt was chosen to be the discussed case study.

Figure 1. ECG Headquarter, Smart Village, Giza, Egypt. (3)

A. Building information

The whole information about the building are listed is table 1.

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Table 1. Building information. (3)

Project name	Engineering consultant group (ECG) headquarter.
Location	Smart Village- Cairo – Alex Road, Giza- Egypt.
Project Type	Administrative Building.
Owner	ECG- Engineering Consultant Group.
Employer	ECG- Engineering Consultant Group.
Consultant	ECG- Engineering Consultant Group.
Building size	15538 m2 (8505 m2 above ground and 7033 m2 underground).
No. of floors	6 floors (2 underground and 4 above ground).
Value	65 million Egyptian Pound.
Duration of construction	17 months
Completion Date	May 2009

B. The building plans

Building mass and thermal strategy: a cubic glass form with linear louvers shading the west, south and east elevations. The square shape enhances the thermal strategy of the building, since the square has the least external perimeter and accordingly decreases the areas exposed to external environment

Floor shape and size: square shape 2125 m2 with 2 sides' cores.

Planning grid: 60 cm and the structural grid is 8.4*12 m.

Floor depth: 20 m.

Slab to slab height: 3.80 m.

Floor to ceiling height: 2.85 m.

Access: there are two separate entrances to access the building. The main entrance to the building is for the visitors and staff and it was equipped with ramp for disable. The goods entrance is secondary from the back area. (4).

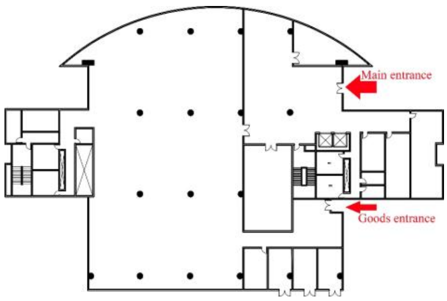

Figure 2. Ground floor plan. (17).

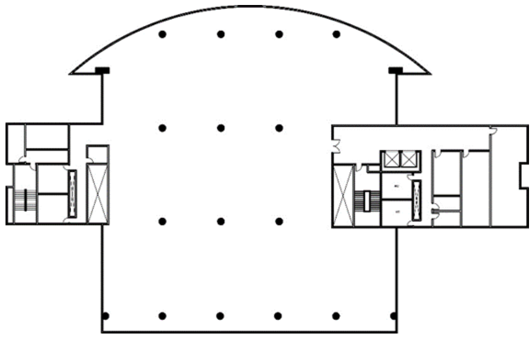

Figure 3. Typical floor plan. (17).

C. Skin issues

- Openings: No openings in all facades, results in the absence of natural ventilation and the permanent use of air-conditioning system accordingly increases the running cost of the building.
- Solar control: 57% of the façade's area is tinted double glass.
- Glass transmission in the south elevation is 50%, north elevation is 57%, east and west elevations are 60%.
- Louvers on south, east and west elevations. (4).

Figure 4. South elevation louvers. (3)

Figure 5. East elevation louvers. (3).

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D. Mechanical system

HVAC system: the building is fully air-conditioned, the HVAC systems with fresh air intake from the roof floor and VAV system is used to make the AC system energy efficient. (4).

E. Electrical system

Traditional linear fluorescent, 500 lux at the desk as per the IES standards for office buildings. Lighting control through standard manual lighting switches except for the second floor, light sensors were used for the top management department. (4).

Figure 6. Lighting system in office space. (3).

F. Power strategy

Drawn from providing the building with two separate power inlets, beside a generator for the backup power source. UPS system is used for IT and emergency system. (4).

G. Costs

The following table illustrates the annual running cost of different elements and the cost per meter is calculated regarding to the ground gross internal area. (17).

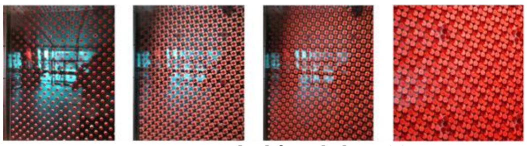
Table 2. Annual running cost of ECG building according to current situation. (17).

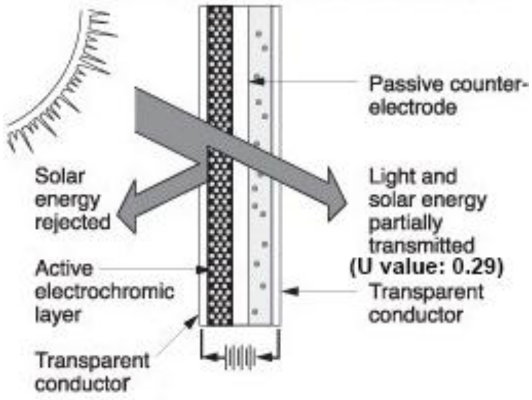
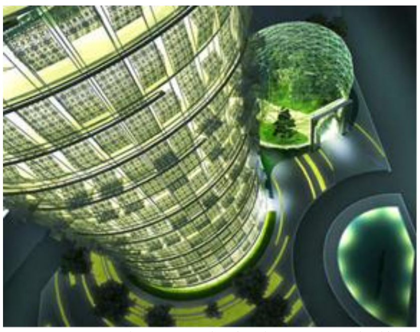
	Annual cost (EGP/ Year)	%	Annual cost (EGP/ m²)
Electricity	358,000	10.3%	42.2
HVAC	1,820,000	51%	214
Water	24,000	0.7%	2.8
Cleaning	528,000	15%	62.0
Security	384,000	11%	45.0
Maintenance	450,000	12%	53.0
Total	3,564,000	100%	419.0

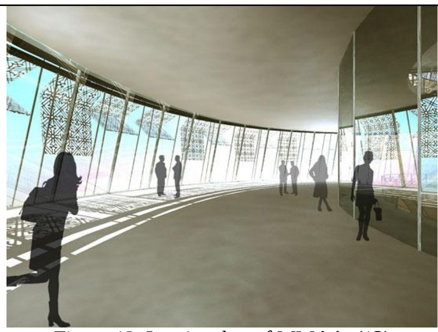
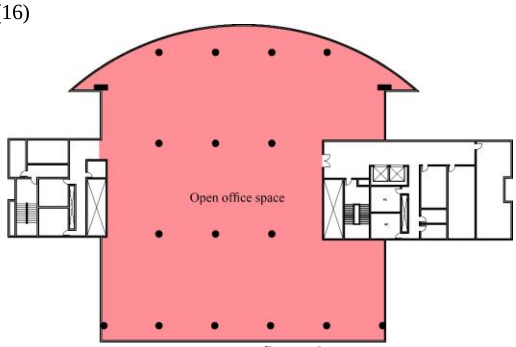
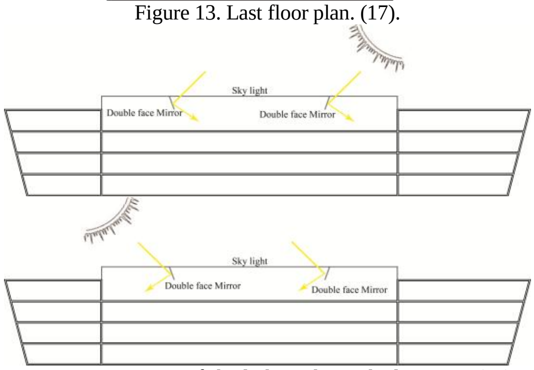
H. Suggested proposal

Biomimicry can be applied to the building to decrease its running cost and energy consumption and to get the maximum use of day lighting.

Some suggested proposals to be applied on the building are illustrated in table 3.

Existing situation	Proposed solution
Tinted double glass	Tinted double glass can be replaced by adaptive fritting glass by Hoberman associates. It simulates the Namaqua Chamelelon as it changes the color of its skin depending on the sun. The adaptive fritting technology utilizes a graphic pattern in order to control heat gain and modulate light while allowing sufficient transparency for viewing. It can control its transparency and modulate between opaque and transparent states. It is real-time dynamic motion motorized panels. This performance is achieved by shifting a series of fritted glass layers so that the graphic pattern alternatively aligns and diverges. It becomes darker gradually while the sun becomes higher and then it becomes lighter till reaching transparency while the sun is low. (5).  Figure 7. The Namaqua Chameleon. (6).  Figure 8. Standard fritted glass. (7).

	 Figure 9. Adaptive fritting glass section. (8). It can reflect up to 71% of the solar heat so the use of the artificial air conditioners (HVAC) can be decreased to only 10-15 % ; so about 35-40 % of the annual cost can be deducted and also the energy consumed by the HVAC can be decreased to 60%. (17)
South, east and west elevation louvers	Cactus' spines main function is to help shade the plant from the intense sun. These spines shade the plant enough to keep the internal temperature low enough to where the water that the plant stores does not evaporate. (9) Cactus' spines can be simulated in automated sun shades. So the louvers on the south, east and west elevation can be replaced by these shades. They are sun shades that act like filters with the sunlight that is penetrating the spaces. They have the ability to automatically fluctuate up and down, open or close, depending on the desired interior temperature, to regulate the amount of sunlight and heat that is transferred into the space. (10). This solution allows this building to lower the size and amount of artificial cooling necessary for the building to 5-10 % ; so about 40-45 % of the annual cost can be deducted and also the energy consumed by the HVAC can be decreased to 50%. (16)  Figure 10. Cactus' spines. (11)  Figure 11. Cactus' spines sun shades in MMAA building. (12)

	 Figure 12. Interior shot of MMAA. (13)
Traditional linear fluorescent	A sky light can be applied for the last floor as it is an open office space. Mirrors can be attached to focus light and separate it all over the whole space. Here Dolichopteryx long pipes (brownsnout spookfish) is simulated as it employs a mirror, in addition to a lens, to focus an image in its eyes, hundreds of tiny crystals that collect , gather and focus light. (13) So we can dispense the use of artificial light in this floor except on cloudy days only and this would decrease the energy consumed by electricity to 40% and so the annual cost to 4%. (16)  Figure 13. Last floor plan. (17).  Figure 14. Sections of sky light with attached mirrors. (17).
Normal white paint	To reduce the cleaning cost, the normal paint can be replaced be Sto's lotusan paint. It enables buildings to be self-cleaning as it simulates the lotus flower cleaning itself from swampy water. (14). This would decrease the cleaning cost to 10%. (16)

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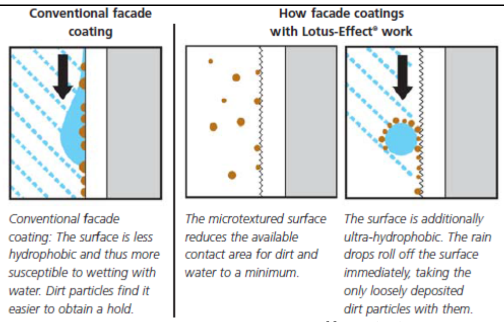
<tr><td></td><td>

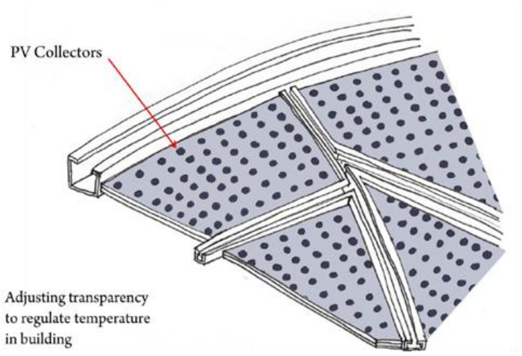
Figure 15. Lotusan paint effect. (16).</td></tr>
<tr><td>Power strategy</td><td>A thin solar panels can be integrated to the adaptive fritting glass so it can collect solar energy without transmitting it and then transform this energy to electricity using it for artificial lighting and lifts. (7). so the percentage of energy consumed for lighting and lifting can de decreased to 50 % and so as the running cost decreased to 5%. (16).


Figure 16. Possible Integration of Thin Film Solar Collectors. (7)</td></tr>
</table>

I. *Findings*

Annual cost according to Existing situation is illustrated in table 4.

Table 4. Annual running cost of ECG building according to current situation. (17).

	Annual cost (EGP/ Year)	%	Annual cost (EGP/ m$^{2)}$
Electricity	358,000	10.3%	42.2
HVAC	1,820,000	51%	214
Water	24,000	0.7%	2.8
Cleaning	528,000	15%	62.0
Security	384,000	11%	45.0
Maintenance	450,000	12%	53.0
Total	3,564,000	100%	419.0

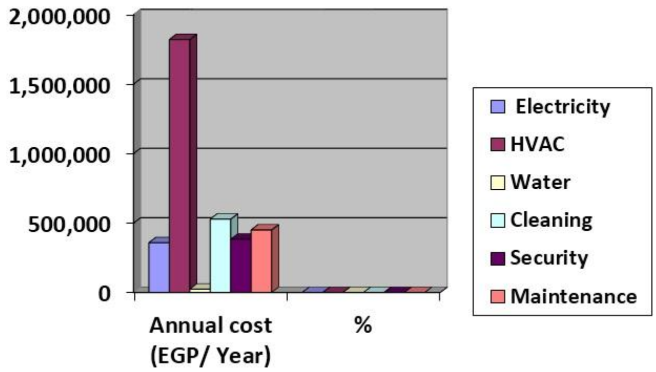


Figure 16. Annual running cost of ECG building according to current situation chart. (17).

Annual cost according to suggested proposal id illustrated in table 5.

Table 5. Annual running cost of ECG building according to suggested proposal. (17).

	Annual cost (EGP/ Year)	%	Annual cost (EGP/ m$^{2)}$
Electricity	139,029	4%	16.4
HVAC	356,862	10%	42
Water	24,000	0.7%	2.8
Cleaning	352,000	10%	41.3
Security	384,000	11%	45.0
Maintenance	450,000	12%	53.0
Total	1,705,891	47.7%	200

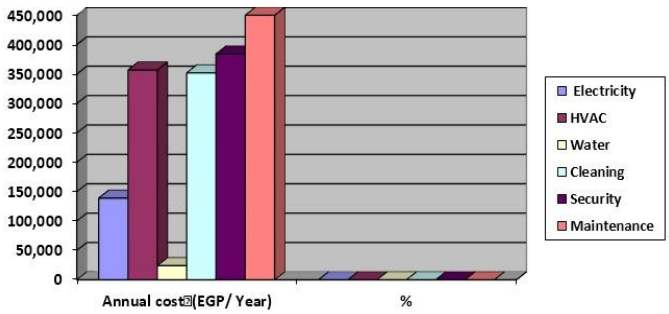


Figure 17. Annual running cost of ECG building according to Suggested proposal chart. (17).

The total percentage of the annual cost was decreased from 100% to 47.7%.

The total running cost spent on the building decreased from 3,564,000 LE/Year to 1,705,891 LE/Year.

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IV. CONCLUSION

This paper discussed the Engineering consultant group head quarter in the smart village in Giza, Egypt. The main problems in this building are high energy consumption and high annual running cost of the building.

Based on the comparison conducted between the existing situation and the proposed solutions; it was found that:

- Replacing the tinted double glazing used with Adaptive fritting glass would reduce 60% of the energy consumed and decrease the percentage of annual cost spent on the HVAC to 15% instead of 51%.
- Applying thin solar panels within the glass would help in producing renewable energy to be used in electricity so the energy consumed on electricity would be decreased to 50% and the percentage of annual cost spent on electricity decreased to 5% instead of 10.3%.
- Using of automated movable sunshades instead of fixed louvers- addition to the using of adaptive fritting glass- would reduce the energy consumed by HVAC to 50% and the annual cost spent on it to only 10%.
- Applying a skylight with attached mirror to the last floor roof would help in making maximum use of daylighting in this floor. In additional to the solar panels, it would decrease the energy consumed by electricity to 40% and the annual cost spent on it to only 4%.
- Replacing the normal paint with Sto’s loutsan paint which is self-cleaning would decrease the annual cost spent on cleaning to 10% instead of 15%.

So it is concluding that applying Biomimicry to our building would change to become sustainable, environmentally friendly and also would save a lot of energy consumed by the buildings and so as a lot of money spent.

REFERENCES

[1] Faragallah, Dina El-Sayed Saleh., “Biomimicry in Interior Design”, Master degree thesis, the Décor Department, Faculty of Fine Arts, Alexandria University, December 2011. P. 84-86.

[2] https://biomimicry.org/.

[3] http://www.ecgsa.com/smartvillage/.

[4] Nosh, Amira Ellia., “integrating value engineering in the design of intelligent buildings”, Master degree thesis, Architecture department, Faculty of engineering, Ain shams university, Egypt, 2012, P. 116-119.

[5] Maglic, Michael J., “Biomimicry: Using nature as a model for design”, Master degree thesis, Department of Art, Architecture and Art History, The University of Massachusetts Amherst, May 2012, P. 46.

[6] http://m4.i.pbase.com/.

[7] Drozdowski, Ziggy. and Gupta, Shawn., “Adaptive Fritting as Case Exploration for Adaptivity in Architecture”, Hoberman transformable design, 2009, P.106-108.

[8] https://yazdanistudioresearch.wordpress.com/.

[9] Anderson, Edward F., “The Cactus Family”, Pentland, Oregon: Timber Press, 2001, P.15.

[10] Meinhold, Bridgette., “Qatar Sprouts a Towering Cactus Skyscraper”, Inhabitat, March 17, 2009, P.1.

[11] https://yt3.ggpht.com/.

[12] http://inhabitat.com/.

[13] http://www.designboom.com/architecture/aesthetics-architects-go-group-minister-of-municipal-affairs-agriculture-building-doha-qatar/.

[14] Wallace, John., “Double-duty deep-sea fish eye has one mirrored and one refractive lens system”, Laser focus world, March, 20, 2014, P. 1.

[15] Pedersen Zari, Maibritt., “Biomimetic Approaches to Architectural Design for Increased Sustainability”, School of Architecture, Victoria University, Wellington, New Zealand, The SB07 NZ Sustainable Building Conference. Auckland, 2007, P. 2, 3.

[16] http://www.talfordstore.com/.

[17] The researcher.