Simulation Analysis for evaluating Smart technique of Energy Performance in Egypt

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Abstract. Building envelopes acts as the boundary between the outdoor environment and the indoor working spaces. The smart thing to do is think in terms of interaction, minimum use of materials and energy to reduce the environmental impact of this major human activity called building. Smart materials technologies are the keynote to 21st-century economic improvement. This paper represents a smart method to simplify the invention of design concepts and develop the improvement of building envelopes that are better suited to their environments. Smart envelopes can significantly increase levels of functionality, which include smart material of envelopes, play a significant role in the way systems adapt to environmental conditions, and provide a multi-operative boundary to control heat. The aim of the paper to emphasize the functional role of smart envelopes for environmental adaptation provides an analytical study of the types of smart materials available, giving new insight into innovative methods and techniques, understanding the search for smart envelope applied in architecture, and adaptation of an environmental sustainability. In this study, a BASE CASE model simulated with “Design Builder” software based on “Energy Plus” with the application of Smart technique as a part of achieving sustainable buildings. The results showed that the smart application in Egypt had the main impact on enhancing performance and as a result, a reduction in energy usage.

Keywords: Energy efficiency, Smart envelope, Smart materials, Energy consumption.

1. Introduction to Buildings

Energy consumption rates have been increasing rapidly worldwide due to the growth of the population and their direct power consumption, manufacturing power needs, weather variations, and additional aspects. However, the limited availability and cost of natural resources have raised the need for more efficient and lower power-consuming buildings. The extra energy-efficient building can be recognized at the design period but also in operation through smart decision-making about building controls, equipment, and materials. Egypt consumes more than 22% of petroleum in Africa in 2016, which is the largest natural gas and oil user in Africa [1]. Natural gas: Egypt developed a net importer of natural gas in 2015 for the reason of increasing domestic demand and decreasing production levels as shown in Fig.1. The decrease in energy supports may reduce consumption development in a close period, but the energy consumption is probable to remain growing in a long period [2].
2. Energy Efficiency
Here we will discuss mainly remarkable energy efficiency methods that are exactly related to the energy consumption in buildings and that would be close to combining all the aspects related to that in construction. Figure 2 presented a general classification of the stimulating systems [3].

2.1. HVAC
The HVAC systems are generally proposed for the worst situation in terms of environment and users. For example, the designers design the system to maintain the building at 22° on the hottest day of summer when it is at its maximum capacity (heat produced from people), with the equipment at full working hours (heat generated from equipment). Therefore, the over-costs due to initial investment and operation will be higher than if the equipment is designed to cover the 95% (instead of 99%) of the time of the year instead. The aims of health and comfort will be static as high as before during the whole year [4].

Wigginton & Harris (2002) mention various concepts and elements for minimizing energy usage in ventilation: [5]

**Mixed-mode approach:** intelligent control systems are utilized and required to sense and decide to activate mechanical ventilation when it is needed. It is possible to increase natural ventilation and reduce energy usage by using mechanical ventilation only in extreme conditions.

**Air circulation system:** This system passes on the building structure and can be related to the human circulation structure. The system may be users depended, with local fan units operated only when user attendance is detected.
2.2. Lighting
Daylight usage: Finding a good balance between reflectivity and heat gain can generate energy savings up to 60% (Delaney et al, 2009) of the total lighting usage [6].

2.3. Windows
Low emissivity: Windows that have the capacity to control the radiant emissions coming from the sun will permit reducing the heating effects and therefore, decreasing the cooling necessities.

2.4. External walls and roof
Insulation: The first and most recommended measure application to take is insulation. It will be swift, easy to operate, suitable for previously existing buildings and cost-effective. The insulation aim is to decrease the impacts of the external climatic conditions inside the building and reducing energy usage drastically. On the other hand, surfaces with insulation will reduce the danger from moisture and other damaging procedures, reducing the maintenance costs and increasing the beneficial life of the facade.

3. Definition of Smart
The definition ‘smart’, ‘functional’, ‘multifunctional’ and ‘intelligent’ are frequently consumed replacing. This is acceptable, if unclear, for the primary three conditions, but the last almost certainly suggests a degree of awareness that does not exist in any non-biological system [7].

| Definition of Smart   | Not-Smart | Semi-Smart | Smart                          |
|-----------------------|-----------|------------|--------------------------------|
|                       | Don’t have any particular structure | Able to exchange their form in reply to environment effect, for once or short period | These changes will be repeatable and revocable, known as "flexible" and "adaptive", and this is due to their particular feature in adjusting to environmental conditions |

3.1. Historical background of smart buildings
The intelligent building pyramid, which was created during the European Intelligent Building Study by researchers, is supposed in Fig. 3:

![Figure 3. The intelligent building pyramid [9].](image)
3.2. **Smart Building Technologies**

Smart buildings contain efficient technologies with automated controls, networked sensors, and meters, evolved building automation, data analytics software, energy organization, and information systems. In the following, we analyze key building systems and technologies.

3.3. **The smart building material for comfort & energy efficiency.**

3.3.1. **Phase Change Materials.** A Phase Change Material (PCM) is a material with the extreme heat of production which fluxing and hardening at certain temperatures (termed phase change) is able to save or moving huge amounts of energy.

3.3.2. **Smart Building Materials and Techniques.** There are many new categories of building materials and techniques being used in architecture and engineering, with new developments in materials and technology, some even taking new rotations on ancient practices [10].

3.3.3. **Kinetic Architecture.** Kinetic Architecture is primarily a technique of saying buildings that have qualities with a certain type of organization to them. The type of kinetic architecture that could be extremely useful in the hot arid zone has to do with blocking out the hot summer sun, while still being able to open the surface back up once the sun has passed or temperatures cooled. These systems are typically measured by computer software and sensors that pathway the sun, informing each shade when it should open or close [11].

3.3.4. **Elastic kinetic approaches to façade shading.** As the latest method to flexibility without the demand of mechanically, systems elastic kinetics are employed. Flecto_Fin is a sample of bio-motivated elastic kinetic shading system. The shading is combined with two lamellas controlled to an activated ray component [12]. The building scale with the elastic kinetic façade system for the
Thematic Pavilion at the EXPO 2012 in Yeosu (Fig.6a) is a practical theory for the Elastic kinetic facade [13].

![Thematic Pavilion Yeosu Expo 2012; B: IBA-Soft house in Hamburg.](image)

Figure 6. A: Thematic Pavilion Yeosu Expo 2012; B: IBA-Soft house in Hamburg.

4. Smart Glazing Systems for Low Energy Architecture

Smart glazing systems, comparable to breathing organisms, have the capability to achieve both sensing and motivating performance and adapting to the changes in the external environment. In other words, smart glazing systems can replace themselves in reply to an outside stimulus or respond to the stimulus by producing a signal of some sort. Hence, smart glazing systems can be exhausted as "sensors", "actuators" or "self-sensing actuators" in general [14].

Electrochromic windows on precise materials that have electrochromic properties. "Electrochromei" describes materials that can vary of the color when empowered by an electrical stream. Essentially, electricity returns off a chemical reaction in this type of material. This reaction (like any chemical reaction) changes the properties of the material [15].

5. Simulation structure

The study has examined the impacts of high technologies system on the building, using the values of sustainability; such as using local - reused or recycled materials, which supplies to decrease a maintenance operation, has a low toxic gas. Furthermore, methods consumed in building facade should assist to apply for the economic benefits over the life cycle, allow light transmission without heat, and reduce energy consumption for sensible cooling, heating and lighting loads [17].

Design-Builder has shown innovative modeling tools in an easy to use boundary for the most widely used energy simulation mechanism Energy-Plus. So, it is selected as simulation software for energy simulation [16]. It supplies output of energy consumption, thermal comfort, daylight, cost and other parameters responsibility for any building selected for analysis. The base case was studied two times; first of all the simulation was performed while not PCM, and so with it [18].

5.1. Study Models design & Office Building model description

General office building design data:
### Table 2. Office Building Architectural Data.

| Building type | Office building |
|---------------|-----------------|
| Room 1        | 12 person/100 m²|
| Building floors numbers | Ground floor + (3) typical floors |
| Typical office floor height | 4.0 m (slab to slab), 3.70 m ~ 3.0 m (clear height) |
| Building total height | (4.0 m * 4 floors) + 2.0 m parapet of façade = 18.0m |
| Ground floor area | 15.0 m 15.0 m = 225 m² |
| Ventilation system | For "Base-Case" building: Artificial Mechanical ventilation (Full HVAC) system. |
|                | For smart case study: 'Mixed-Mode' (Hybrid) system all of the year. |

#### 5.2. Weather data file
The weather data file used for this study is EGY_AL QAHIRAH CAIRO, AIRPORT ETMY.stat. Weather Data File: AIRPORT ETMY. Epw, Type: Hourly weather data, Location: Cairo, Egypt.

![Figure 7. A) Architecture plans of case study, b) view of base case Models, Design Builder Screen shoot.](image)

![Figure 8. The framework of practical models.](image)
**Figure 9.** Construction Details for External wall, Design Builder Screen shoot.

**Figure 10.** Construction Details for Internal Partition's, Design Builder Screen shoot.

**Figure 11.** Thermochromics glazing Example, Design Builder Screen shoot.

**Figure 12.** Construction Details for Flat Roof, Design Builder Screen shoot.

**Figure 13.** Construction Details for shading device, Design Builder Screen shoot.
6. RESULTS AND FINDINGS

Figure 14 shows the annual air temperature for Hybrid Ventilation modes with the base case (without PCM) with Full (HVAC) Mechanical Ventilation (Fully Air-conditioned) for all the working hours’ working days. This clearly shows that the best ventilation mode was the hybrid case (with PCM) which made a reduction in air temperature more than 150°C. Applying the hybrid case the maximum air temperature reached 26-28°C, while the base case, the air temperature reached 38°C and 43°C was the temperature reached by the base case (without PCM).

Upon reviewing the annual energy consumption of each model configuration examined within the office area, it was clear that the smart model is the configuration, which was the minimum efficient in terms of annual energy consumption.

As such, the most efficient configuration of the smart model case study examined was the mixed-mode ventilated. The annual energy consumption has a value of 45.366 kWh/m², approximately 62% more efficient than the conventional base case model (72.292 kWh/m²) as shown in Figure 15.

Figure 16 Shows the Effect of applying the smart technique on annual sensible cooling with 247565 kWh compared to the base case 325947 kWh.
Figures 16, 17. In applying the Fanger PMV on the different techniques of smart system configuration and the base case it is clear that all lay between arranging of (-1 to 1). while the base case reached above 4. but still the most effective was the multi DSF.

7. Conclusion
All designers are invited to practice this methodology in order to reach to the best results: first, identify the building and climate zone; second, indicate the conditions for functioning; third, adapt parameters depending on the stage of technology (low or high); fourth, simulate the interrelated parameters. In the end evaluate the design options and construct a conclusion.

Referring to the aim of this research about the importance of adopting the suitable technology for building envelopes in the office buildings in Egypt, the results have exposed that the suitable technology can support the best thermal comfort with hybrid HVACs, save energy consumption, in addition to providing natural daylight and considerate economic conditions.

Energy analysis has been done by using Design Builder software for the base case and smart technique technology. When we use insulation on external walls, internal walls, and roofs, use double glazed windows instead of single glass windows, change the air infiltration rate and keep hybrid ventilation in smart building case than annual energy consumption is reduced from 325947 kWh to 247565 kWh.
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