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An Applied Study for the Impact of the Initial Design Stages on Improving the Energy Efficiency of Residential Projects in Egypt

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ABSTRACT: Most countries in the world suffer from the energy crisis, as it is a global problem and not only a local one. Not only has this crisis extended to the industrial sector, but it has extended to the life needs of the citizen as well. One of the main reasons for that crisis is the massive consumption of energy for treatment design problems for buildings, such as ventilation, lighting, and others. Buildings consume more than 40% of the total energy (Elnazer 2019). Reports have proven that residential buildings in Egypt account for more than 80% of the buildings in the country (CAPMS 2017). The problem is that residential buildings consume 41.4% of the total electrical energy in Egypt (EEHC 2019). Thus, designers and researchers have to come up with design methods that contribute to reducing that consumption. This research paper aims to extract a design methodology to rationalize energy consumption in residential buildings during the stages of the initial design concept.

KEYWORDS: Initial Design; Energy Consumption; Residential Buildings.

I. INTRODUCTION

Since man's presence on Earth, he has tried to understand climatic phenomena and to adapt. Therefore, he made use of available building materials. Then, he built his home like a hut from mud, trees, and so on. Man kept learning from nature and using it until the machine appeared.

After the emergence of the machine, the beginning of development, and the rise of the industrial revolution, the designer tried to develop architectural formation and liberate the design. He tried to control the internal atmosphere of the spaces using the machine (e.g., air conditioning devices, lighting units, etc.), which contributed to a large consumption of energy.

Thus, it was necessary for the architect-designer to find design and implementation strategies to conserve energy, during all the phases of the building's life cycle.

II. RELATED WORK

1. Energy Concept

1.1. Energy Definition

Energy is defined in physics as "the ability to do something." Energy is neither created nor destroyed. The amount of energy in the universe is constant, but it changes from one form to another. This principle is known as energy conservation or the first law of thermodynamics. Energy has many forms, all falling into two main categories: kinetic energy and potential energy.

1.2. Types and Forms of Energy

There are several forms of energy (Figure 1), the most popular of which are heat, light, and sound, in addition to mechanical energy generated by machines and chemical energy liberated when chemical changes occur. Energy can be

converted from one form to another, such as converting stored chemical energy in the battery into light energy (Al-Esawy 2007).

1.3. Energy Sources

Energy sources are classified into several classifications according to several factors. However, according to the most popular classification, energy sources are divided into non-renewable and renewable sources.

- **Non-renewable energy:** It is formed as a result of exposure to various geological processes over long periods of time. These sources are used by converting them into various forms of energy. Examples of non-renewable energy are oil, coal, natural gas, and uranium.
- **Renewable energy:** It is a sustainable source that does not run out with consumption. These sources are constantly renewed. Renewable energy is clean energy that does not cause many polluting emissions. Examples of renewable energy are wind energy, solar energy, geothermal energy, biomass energy, and hydropower.

With all these advantages of renewable energy sources, the greatest reliance – for now – is on using non-renewable energy sources.

In Egypt, Figure 2 shows that the percentage of renewable energy production rose to 20% of electricity production in 2022, and the percentage will double to reach 42% in 2035 (NREA 2020).

1.4. Energy Problem

Energy is an essential element in all aspects of life. 80% of the global energy consumed is derived from non-renewable sources, which will run out in the future. In addition, these sources are the main sources of carbon dioxide emissions (Hamed 2020).

1.5. Energy Consumption in Residential Buildings in Egypt

Residential buildings represent part of the energy problem, but they can become part of the solution, as the percentage of residential buildings reaches 83% of the total percentages of buildings in Egypt (CAPMS 2017). Residential buildings consume the largest amount of electrical energy, which amounts to 41.4% of the total electrical energy consumption in 2020 (EEHC 2019).

Therefore, it became the responsibility of state institutions and individuals to rationalize energy consumption in residential buildings.

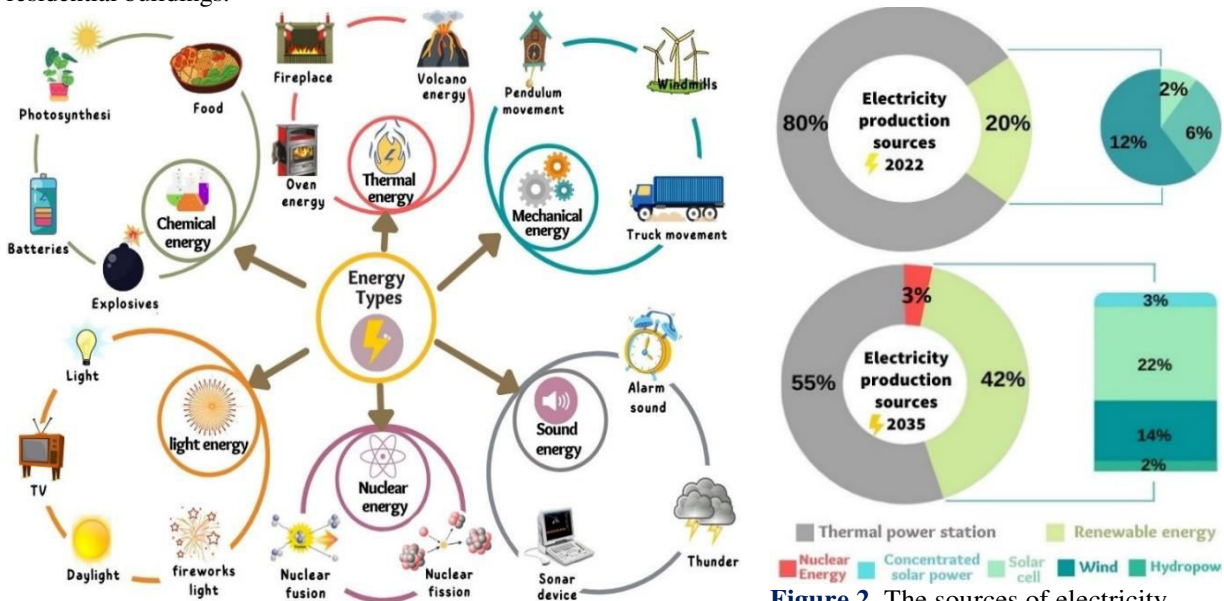


Figure 1. Types of energy. Source: Author.

Figure 2. The sources of electricity production during 2022 and 2035 in Egypt. Source: NREA 2020.

1.6. Rationalization of Energy Consumption

Rationalization of energy consumption takes place through two methods. One of them depends on the

rationalization of the current energy by reducing energy losses, and the other method depends on future energy, by replacing the current energy with sustainable or more efficient ones.

1.7. Axes of Rationalizing Energy Consumption in Buildings

Energy consumption in a building can be rationalized and can have improved efficiency according to three axes as follows:

- 1) **The building itself**, which is related to the building’s design and envelope.
- 2) **Devices and operating systems**, which are related to the equipment, tools, and systems that consume energy and are used in the building.
- 3) **Users**, which is related to the behaviour of the person who uses the building.

1.8. Stages of Rationalizing Energy Consumption in the Life of the Building

The building goes through several stages:

- | | |
|--|---|
| a) Initial design stages. | b) Development and documentation design |
| c) The construction stages. | d) The operation stages. |
| e) The demolition or modification stage. | |

Initial Design Stages of the Project

The initial design concept is the spirit of design, as it is the first and most important part on the design process. All the following stages depend on it, so it has a huge impact on energy efficiency. The designer in the initial design goes through several stages (Helal 2019).

- 1) **Insight First**: At this stage, the designer defines the problem and the project’s philosophy and objectives.
- 2) **Preparation**: It is the stage of collecting and analyzing information, to study the dimensions of the problem to determine the requirements and needs of the project.
- 3) **Incubation**: In this stage, the designer depends on his imagination to produce different concepts to solve the problem using design elements.
- 4) **Illumination**: The designer reaches realistic solutions, produces a final developed design concept, and then expresses it in one of architectural methods.
- 5) **Verification**: This is the final evaluation of the design concept.

III. METHODOLOGY

In this study, the author depends on applied methodology to apply the initial design stages on an unrealistic residential tower only to produce a strategy that can be used.

IV. EXPERIMENTAL RESULTS

2. An Applied Study of the Initial Design Stage for a Suggested Residential Tower Project

The project is located in Cairo, with an area of 566 m², floor area ratio (FAR) 30%. The following is a detailed presentation of the initial design stages of the project.

2.1. Insight First

The problem of the project can be identified in two main axes.

- 1) **Heat gain**: Egypt is located in the solar belt region, and the values of vertical solar radiation range between 2000 and 3200 kwh/m², with sunshine average 10 hours. This leads to an increase in heat gain (Younis 2017).
- 2) **Site determinants**: The project site contains only one view overlooking the main square (Figure 3).

The philosophy and objectives of the project are as follows:

- Reducing the value of solar radiation falling on the residential tower mass (**the main objective**).

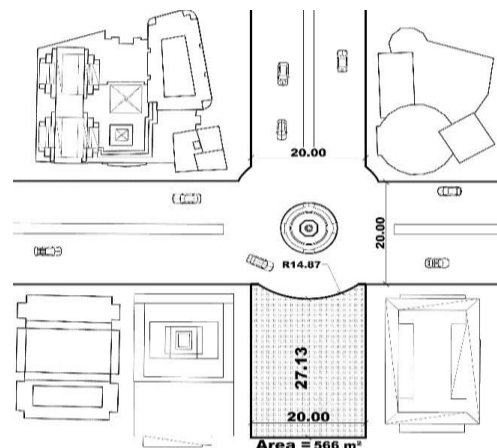


Figure 3. Project site. Source: Author.

- Increasing the proportion of the facade of the building overlooking the square as much as possible.

2.2. Preparation

At this stage, detailed information about the problem axes is collected and analyzed, and then project requirements are determined as follows.

2.2.1. The Analysis of the Increasing Heat Gain Problem

The simulation process shows that the values of solar radiation are high (Figure 4), especially in the southern orientation. Hence, the designer must take this into account in the design process.

2.2.2. The Analysis of the Site Determinants Problem

It is possible to determine the percentage of the facade overlooking the square by using a simulation program.

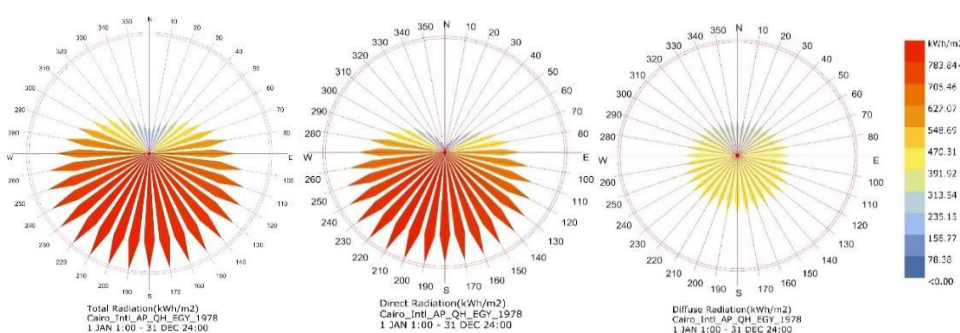


Figure 4. The total solar radiation for the proposed project site, showing the values of direct and scattered radiation. Source: Author.

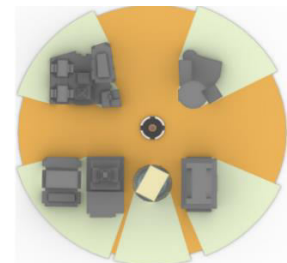


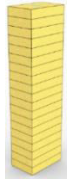


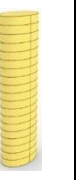

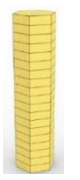
Figure 5. An image that simulates available viewing angles for the square. Source: Author

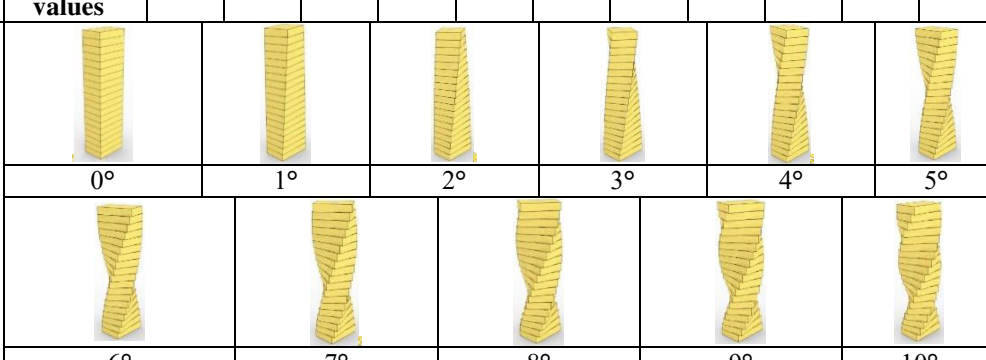
2.3. Incubation

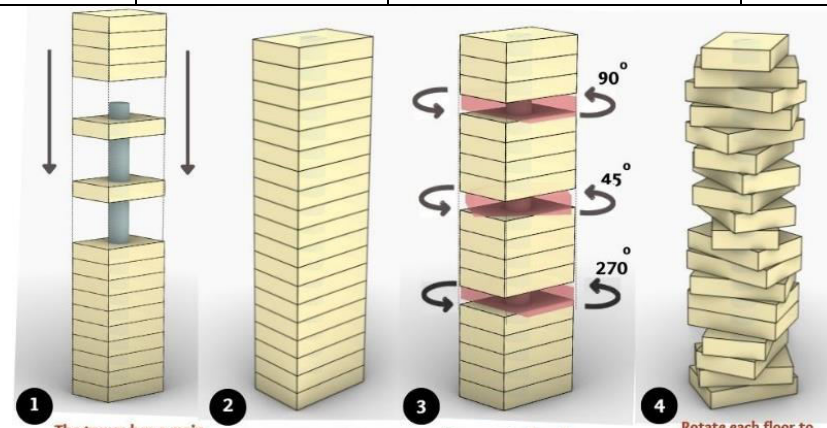
At this stage, the author suggests some design concepts to solve all design problems.

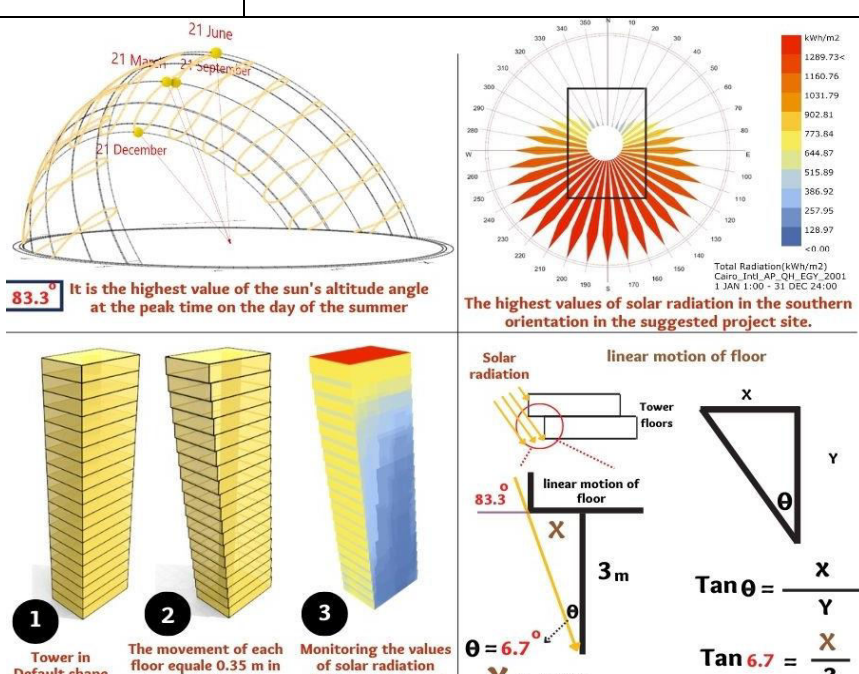
2.3.1. The Presentation of the Suggested Concepts See Table 1.

Table 1. The suggested design concepts to solve the problem axes. Source: Author.

| Concept (1) | Idea Description | Difference of plan shape | | | | | |
|-----------------|---|---|---|---|---|---|-----------------|
| | | Idea is based on changing the shape of plan with the stability of the target area (150 m ²) | | | | | |
| | Idea Variables | Independent variable | Plan shape | | | | |
| Variable shapes | | Rectangle | Square | Circle | Ellipse | Regular triangle | Regular hexagon |
| Idea sketches |  |  |  |  |  |  | |
| | Rectangle (2:3) | Square | Circle | Ellipse | Regular triangle | Regular hexagon | |

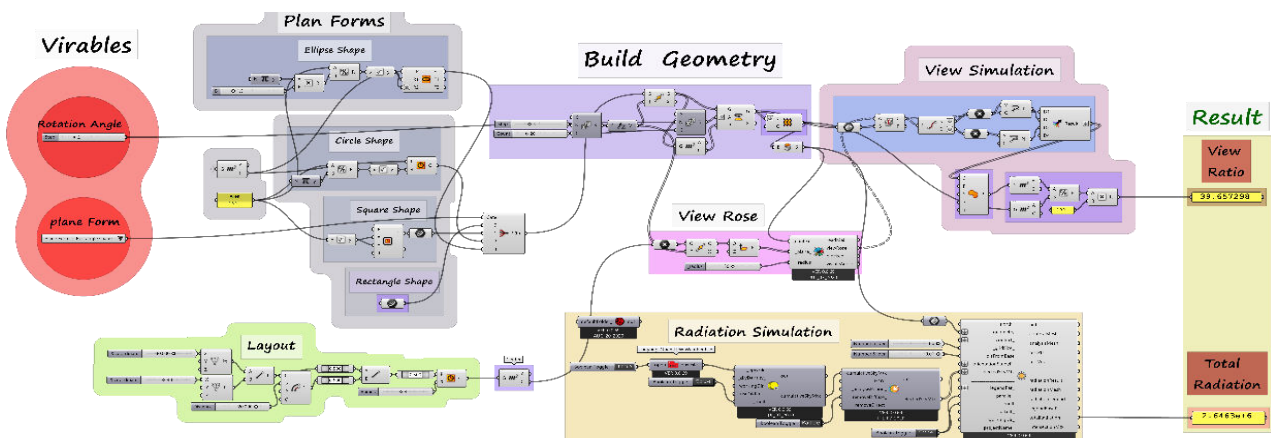
| | | | | | | | | | | | | | |
|-------------|---------------|---|---|---|---|---|---|---|---|---|---|---|----|
| Concept (2) | Description | Static movement | | | | | | | | | | | |
| | Idea | The idea is based on the rotation of each floor around the axis of the mass in a series value by a fixed angle. | | | | | | | | | | | |
| | Variables | Ind. variable | Rotation angle value per floor (sequentially) | | | | | | | | | | |
| | Idea sketches | Variable values | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | Idea sketches |  | | | | | | | | | | | |

| | | | | | |
|-------------|------------------|---|------------|--------------------------------|------|
| Concept (3) | Idea Description | Dynamic movement | | | |
| | Idea | The idea is based on the rotation of each floor around its axis per hour. | | | |
| | Variables | Ind. variable | No. floors | Rotation angle value per floor | Time |
| | Idea sketches | Variable values | 1:19 | 0 :360 | hour |
| | Idea sketches |  <p>1 The tower has a main concrete core in the center and each floor (prefabricated units) is placed in its place</p> <p>2 Tower in Default mood</p> <p>3 Movement of each floor independently</p> <p>4 Rotate each floor to achieve the lowest value of solar radiation</p> | | | |

| | | | |
|-------------|----------------|---|--|
| Concept (4) | Idea Descrip | Change in mass formation | |
| | Idea Variables | Independent variable | Value of movement per floor (sequentially) |
| | Idea sketches | Variable shapes | X |
| | |  <p>83.3° It is the highest value of the sun's altitude angle at the peak time on the day of the summer</p> <p>The highest values of solar radiation in the southern orientation in the suggested project site.</p> <p>1 Tower in Default shape</p> <p>2 The movement of each floor equal 0.35 m in a south direction</p> <p>3 Monitoring the values of solar radiation falling on the mass</p> <p>Solar radiation linear motion of floor</p> <p>Tower floors</p> <p>linear motion of floor</p> <p>3m</p> <p>$\theta = 6.7^\circ$</p> <p>$X = 0.35 \text{ m}$</p> <p>$\tan \theta = \frac{X}{Y}$</p> <p>$\tan 6.7 = \frac{X}{3}$</p> | |

2.3.2. The Analysis of the Suggested Concepts

After presenting the suggested concepts, must be analysed and evaluated all concepts, using simulation programs, and in this research, author use Ladybug plugin*.



* Ladybug is an open-source plugin for Grasshopper, the first version of which was released in January 2013. It depends on whether files on the Energy Plus website for visualization and analysis of the climate

Figure 6. Full definition, showing the main variables, inputs and outputs. Source: Author.

2.3.2.1. The Analysis of the First Design Concept

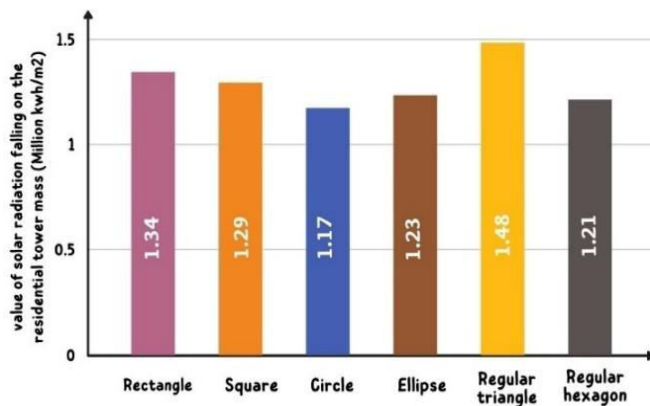


Figure 7. Values of solar radiation on the mass after applying the first concept. Source: Author.

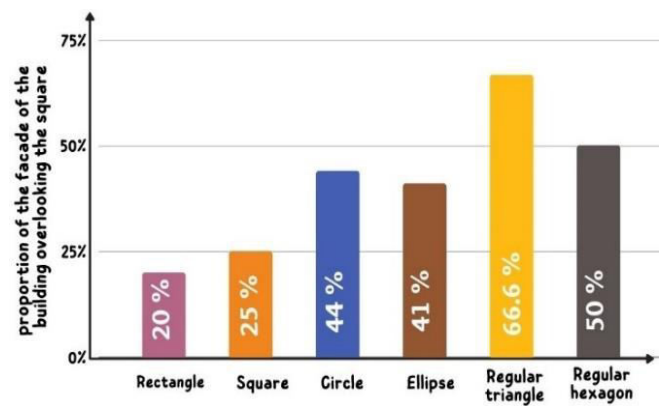


Figure 8. The proportion of the facade that overlooks the square after applying the first concept. Source: Author.

Results show that the circular plan achieves the lowest value of solar radiation, as it reduces solar radiation by 13% compared to the default position (rectangle plan). It also achieves the third largest percentage of facade overlooking the square by 44%.

2.3.2.2. The Analysis of the Second Design Concept

Results (Table 2) show that the rotation angle of 6° reduces the value of solar radiation by 4% and achieves 41.6% of the ratio of the facade overlooking the square. This is because the values of solar radiation are very close. The rotation angle of 3° can be preferred, as it achieves the largest percentage of the facade overlooking the square, which is 43.9%, and it has also the lowest construction cost.

2.3.2.3. The Analysis of the Third Design Concept

To evaluate this idea, millions of simulations are needed. There are 3 variables: rotation angle for each floor independently, floors, and time. Thus, this strategy is a complex process and requires a large time and computers with high performance. To quickly evaluate the concept, the author ran more than 100 simulations randomly for all the hours of the day (5 am to 6 pm) for all solstice days, with specific values for rotation angles (0, 45, 90, 135, 180, 225, 270, 315) (Figure 9, Table 3). With a total of around 5,600 simulations, we assess the success of the design concept in reducing the values of solar radiation on the building.

Table 2. The results of the simulation process for the second concept. Source: Author.

| Rotation Angle | Value of solar radiation (Million kwh/m ²) | Proportion of the facade overlooking the square |
|----------------|--|---|
| 0° | 1.34 | 20 % |
| 1° | 1.33 | 31.5 % |
| 2° | 1.33 | 39.7 % |
| 3° | 1.32 | 43.9 % |
| 4° | 1.31 | 43.7 % |
| 5° | 1.294 | 40.7 % |
| 6° | 1.291 | 41.6 % |
| 7° | 1.30 | 41.5 % |
| 8° | 1.30 | 42.3 % |
| 9° | 1.31 | 42.4 % |

| | | |
|-----|------|--------|
| 10° | 1.31 | 39.2 % |
|-----|------|--------|

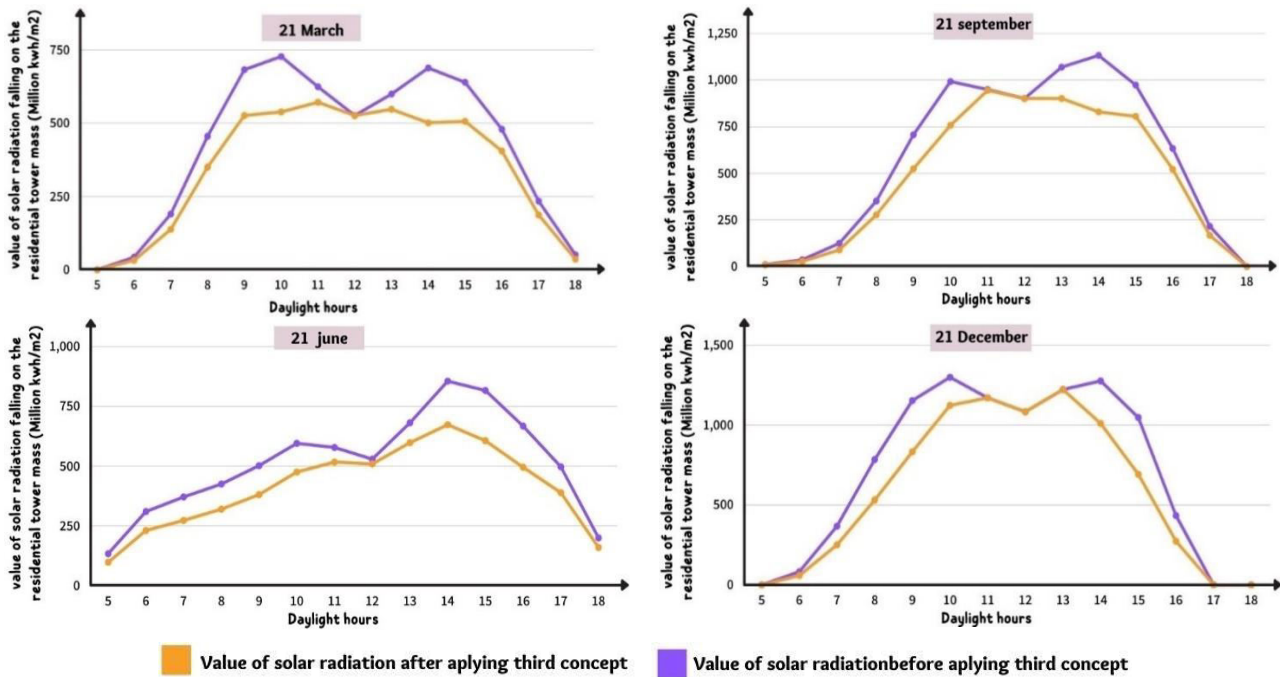


Figure 9. Simulation results for the values of solar radiation falling on mass in the hours of solstice days after applying the third concept. Source: Author.

Table 3. The proportion of the third concept success in reducing the values of solar radiation in solstice days. Source: Author.

| Solstice days | Spring solstice | Summer solstice | Autumn solstice | Winter solstice |
|-------------------------------|-----------------|-----------------|-----------------|-----------------|
| Proportion of concept success | 18% | 20% | 17% | 17% |

Results show that the solar radiation values decrease by an average of 18%. However, a quick strategy was used as an experiment to evaluate the concept, and it achieves 100% of the facade overlooking the square due to the full cycle rotation of each floor during the day.

2.3.2.4. The Analysis of the Fourth Design Concept

Two simulations were run to determine the value of the solar radiation before and after applying the concept. Results show that values of solar radiation decreased by 4.5%, which is a small decrease compared to the high construction cost. Also, it did not change the percentage of the facade overlooking the square (Table 4).

Table 4. Values of the solar radiation falling on the mass before and after the application of the fourth idea. Source: Author.

| The value of solar radiation falling on the residential tower mass | Before | After |
|--|--------|-------|
| | 1.34 | 1.28 |

2.3.3. The Summary of the Incubation Stage Assessment

Results show the success of the third concept to achieve the least value of solar radiation falling on the mass. It also achieves the largest proportion of the facade overlooking the square. However, it has the highest



construction cost because of the dynamic movement. If the cost is a major determinant, the first idea is the most appropriate idea.

2.4. Illumination

According to the previous stage, the first concept (circular plan) achieved the best performance. Therefore, the author suggests a final design concept. The author suggests using horizontal sun breakers on the southern facade with a depth of not less than 60 cm and the distance between each breaker 3 m – the height of the floor – after estimating the appropriate depth with the knowledge of the lowest altitude angle at the peak time, as well as using vertical sun breakers on the east-west facade with a depth of 60 cm and the distance between each breaker 1 m.

2.5. Verification

This is the last stage of the initial design stage, in which the author evaluates final design concept (Table 5).

Table 5. The results of the final concept. Source: Author.

| Concept description | Results | | | Cost notes |
|---------------------|--|---|--|------------|
| | Value of solar radiation falling on the residential tower mass (million kwh/m ²) | The percentage of solar radiation decrease compared to the default position | The proportion of the facade that overlooks the square | |
| Final | 0.77 | 43% | 44% | Lower cost |

V. CONCLUSION

The study concluded the importance of the initial design stage, as it is considered the most important pillar of the design process on which the following stages depend. Thus, it has a significant impact on energy efficiency. It can improve energy efficiency performance by more than 43% at the lowest possible cost.

REFERENCES

1. Al-Esawy, M. 2007. “The economics of environmental design”, Ph.D. thesis, College of Engineering, Cairo University, Egypt.
2. Annual report of New and Renewable Energy Authority in Egypt. 2020.
3. Central Agency for Public Mobilization and Statistics in Egypt. 2017. <https://www.capmas.gov.eg/>, accessed, July 2022.
4. Egyptian electricity holding company annual reports 2019-2020.
5. Elnazer, H. 2019. “Developing the standard of energy consumption for residential apartments in Oman”, Jordan green Building Council, p. 20.
6. Hamed, A. 2020. “The impact of solar energy on interior design, down to solar energy buildings”, Journal of Architecture, Arts and Humanities, V. 5. N. 23. Egypt.
7. Helal, N. 2019. “An analytical study of the design idea and its applications in interior design and furniture”, Journal of Architecture, Arts and Humanities, 4(17), 523-559.
8. Younis, M. 2017. “Map of renewable energy in Egypt 2016”, The Solar Atlas of the Arab Republic of Egypt, 2017. <http://www.nrea.gov.eg/Technology/SolarIntro>.



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