Journal of Al-Azhar University Engineering Sector

Vol. 17, No. 63, April 2022, 639 - 652

USE OF VERTICAL GREENERY SYSTEMS TO CONSERVE ENERGY IN ADMINISTRATIVE BUILDINGS IN EGYPT

Mahmoud Ibrahim[1]*, Ahmed Atef[2], Ashraf Nessim[2]

[1]Master student, Department of Architecture, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

[2] Department of Architecture, Faculty of Engineering, Al-Azhar University, Cairo, Egypt.

*Corresponding Author E-mail: Mahmoudbeder20@gmail.com

Received: 17 Nov. 2021 Accepted: 30 Dec. 2021

ABSTRACT

Urban development in Egypt has led to increased energy consumption. At the same time, development sometimes comes at the expense of green spaces, and this is another problem. Many of the green spaces and large trees that had already existed over the years were removed, whether to develop a road network or other encroachments on green areas.

Administrative buildings have a large share of energy consumption in Egypt, so the aim of this study is to rationalize energy consumption in administrative buildings, as well as increase green spaces in Egypt.

Therefore, the research studies in detail the types of vertical green systems, their use, their structural and technological systems. The study aims to prove the effectiveness of vertical greenery systems in Egypt by simulating a three-story administrative building. The vertical greening system is applied to the southern facade using the Design Builder program.

KEYWORDS: Vertical greenery systems, administrative building, green wall, Energy consumption

استخدام أنظمة التخضير الرأسي لترشيد استهلاك الطاقة للمباني الإدارية في مصر

محمود ابراهيم [١]*، أحمد عاطف[٢]، أشرف نسيم [٢]

[١]طالب ماجيستير، قسم الهندسة المعمارية، كلية الهندسة ، جامعة عين شمس، القاهرة ، مصر

[٢] قسم الهندسة المعمارية، كلية الهندسة، جامعة عين شمس، القاهرة، مصر

* البريد الإلكتروني للمؤلف الرئيسي: Mahmoudbeder20@gmail.com

الملخص

أدى التطور العمراني في مصر إلى زيادة استهلاك الطاقة. في نفس الوقت يأتي التطوير أحياناً على حساب المساحات الخضراء وهذه مشكلة أخرى. تمت إزالة العديد من المساحات الخضراء والأشجار الكبيرة التي كانت موجودة بالفعل على مر السنين ، سواء لتطوير شبكة طرق أو التعديات الأخرى على المساحات الخضراء.

للمباني الإدارية نصـيب كبير من اسـتهلاك الطاقة في مصـر ، لذا فإن الهدف من هذه الدراسـة هو ترشـيد اسـتهلاك الطاقة في المباني الإدارية ، وكذلك زيادة المساحات الخضراء في مصر.

لذلك ، يدرس البحث بالتفصيل أنواع أنظمه التخضير الرأسي ، واستخدامها ، وأنظمتها الهيكلية والتكنولوجية.

تهدف الدراسـة إلى إثبات فعالية أنظمه التخضـير الرأسـي في مصـر من خلال محاكاة مبنى إداري من ثلاثة طوابق. يتم تطبيق نظام التخضير الرأسي على الواجهة الجنوبية للمبني باستخدام برنامج Design Builder.

الكلمات المفتاحية : أنظمه التخضير الرأسي , المباني الاداريه , الحوائط الخضراء , استهلاك الطاقه.

1. INTRODUCTION

1.1 General background

Undoubtedly, energy conservation has become an important topic all over the world due to the increasing in population density and urban expansion and consequently energy consumption has become more. Countries began to find various and varied solutions in order to balance civilization progress and large energy consumption.

Egypt is one of the most energy consuming countries in its region, and the country is facing a rapidly growing demand for energy due to population growth and economic expansion. (1) According to the reports of the New Urban Communities Authority, there is a creation of new cities that contain different types of buildings (residential, administrative and commercial), the area of the new urban cities is about 1.28 million acres.

Figure 1.: Map of Egypt in 1990 and 2019 showing the expansion of urbanization
Source: Google Earth

The previous figure shows a difference of about 29 years, which is the map of Egypt in 1990 and 2019, and confirms that the development in urbanization comes at the expense of green spaces. In 2019, the urban expansion appears noticeably, but there is also a lack of green spaces compared to the map of Egypt in 1990. One of the reasons for the difference between the two maps (1990-2019) is the lack of awareness of the development of green spaces, instead. From encroaching on agricultural land and increasing residential and commercial buildings and roads at the expense of only green spaces, awareness of the importance of green spaces had to be raised.

1.2 Problem Statement

There is no doubt that Egypt suffers from a large consumption of energy in various fields, and this is on the rise. Therefore, some solutions turned to renewable energy, how to develop it to accommodate current energy consumption. (2)

The problem of research is the continuous growth and increase of energy consumption, especially from administrative buildings and the expansion in urbanism, making energy consumption increase more and more. According to the statistics of the International Energy Agency, Egypt is the largest consumer of oil and natural gas in Africa. And also, Total electricity consumption increased from about 126934 MKwh in 2010 to 151908 MKwh in 2019, which is a rapid and rising annual growth rate About 20% increase in electricity consumption. (3)

2. RESEARCH OBJECTIVE

The main objective of the research is to reduce energy consumption within administrative buildings and improve thermal performance through a single technology of vertical greening systems. And analyze the effect of the green wall on the annual energy consumption rate of the administrative building.

The secondary objectives which achieve the main objective are:

- Identifying the energy consumption problems of administrative buildings in Egypt.
- Identification of the different types of vertical green system
- Increasing green areas inside Egypt.
- Recognize the importance of the vertical vegetation system.
- Evaluation of the effect of the green wall on the thermal performance of administrative buildings.

3. RESEARCH METHODOLOGY

In order to achieve the aim of research by following these criteria

- Review the different systems for vertical greenery systems.
- Analyze energy consumption in administrative buildings.
- Apply VGS on administrative building façade with different percentage and see to what extent the energy is conserved.
- Use simulation program to see how energy is saved.
- Comparing the energy consumption of the administrative building through simulation results after using vertical greening system.

4. REVIEW OF VERTICAL GREENERY SYSTEMS

In order to achieve the goal of the research, it is necessary to define and describe the types of vertical green systems, which is divided into living walls and green walls. (4) Each type has some branches, as shown in **fig2**.

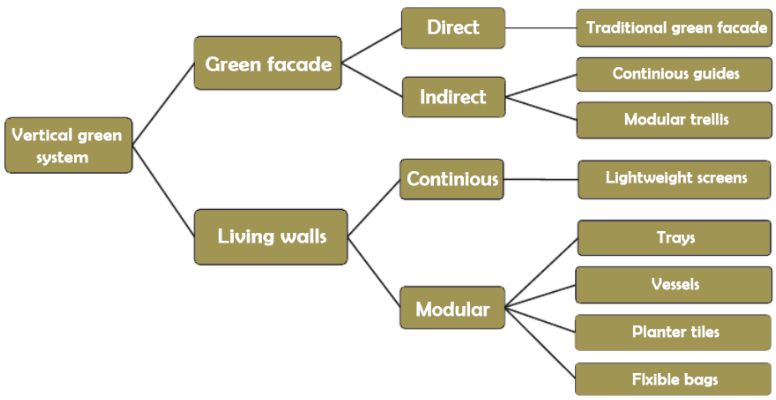


Figure 2: Classification of Vertical green systems according to their construction characteristics

In general, the difference between green walls and live walls is that the first depends on climbing plants, while the live walls are more technological and more advanced and allow greening of high heights of buildings, and also their aesthetic form is better because they allow the use of different types of plants. (4)

Vertical green system in general has many benefits, although it is applied to a specific building, but their benefits are general to everyone because they give an aesthetic view to the onlookers. Also, the use of vertical green systems works as a cover for the building to protect it from the sun's heat. It also works on the occurrence of natural cooling processes. Furthermore, to slow and cool the air, vertical green systems have the ability to create enough turbulence to break the vertical airflow. (5)

The research aims to take the advantage of vertical green systems to rationalize energy consumption in administrative buildings by making a simulation model for an administrative building and applying a living wall to it in different percentage. And monitoring energy consumption in the administrative building and analyzing the results.

5. SIMULATION PRCOESS

It was necessary to define the simulation software that will be used in analyzing the administrative building data and presenting the results in a clear and easy way, which is the Design Builder program. Also, a model of an office building must be created to make a simulation using the Design Build program. The three-story building was chosen as proposed by ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers). (6)

The simulation process will be done on the building three times.

- Base scenario, the southern facade of the building will be covered with 0 greening,

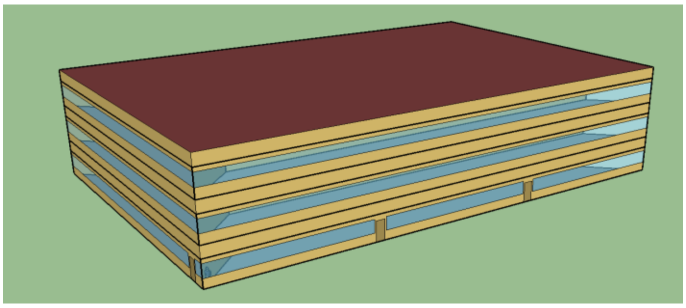
- First scenario, the southern facade of the building will be covered by 100% greening except for the windows.
- Second scenario: The southern facade of the building will be covered by 60-70% greening except for the windows.

Finally, the comparison between the three scenarios will determine the effectiveness of vertical greenery system and their role in reducing energy consumption in administrative buildings.

The simulation stages start during this program by entering the complete data in terms of the office building's location and it was imposed in Cairo, Egypt and the climatic data for the area which is provided by the program and also the orientation of the office building, which was assumed to be that the green wall is facing the south direction.

The main information of the administrative building is shown in **table 1** which is the ratio of windows to walls 33%, the number of floors of the building and others.

Table 1: Description of office building prototype (6)

Item	Description
Building Prototype	Medium Office
Building shape	
Total Floor Area (sq. feet)	4970 (49.9 m x 33.2 m)
Aspect Ratio	1.5
Number of Floors	3
Window Fraction (Window-to-Wall Ratio)	33% (Window Dimensions: 49.9 m x 1.30 m on the long side of facade 33.2 m x 1.30 m on the short side of the façade)
Floor to floor height (feet)	13
Glazing sill height (feet)	1 m (top of the window is 2.3 m high with 1.3 m high glass)
Shading Geometry	None

One of the important characteristics of the building is the external walls, which were assumed to consist of three layers, as shown in **Fig 3**. The two outer layers consist of a mortar with a thickness of 2 cm. The second layer of red brick is about 25 cm thick

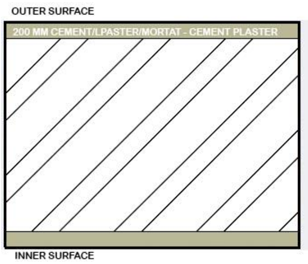


Figure 3: Wall section of administrative building model for all scenarios

Since the building has three floors, the occupied floor area is about 4907 square meters and to determine the occupancy rate of the designer's builder, the ratio is already variable.

But the individual ratio inside the administrative building does not exceed 23 square meters if the occupancy density in the building is low, and the individual ratio is not less than 9 square meters if the occupancy density is high. (West, 2001).

Therefore, the occupancy density (people/m2) for the research scenarios is 0.07.

The office building is assumed to operate from 8 a.m. to 6 p.m. 6 days a week and Fridays off as shown in **table 2.**

Table 2: Administrative building operating schedule throughout the week for all scenarios.

Profiles

Mo...	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Jan	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00
Feb	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00
Mar	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00
Apr	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00
May	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00
Jun	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00
Jul	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00
Aug	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00
Sep	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00
Oct	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00
Nov	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00
Dec	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	8:00 to 18:00	Off	8:00 to 18:00	8:00 to 18:00

Regarding the environmental control of the office building, it was assumed that the set temperature was 24 °C and the cooling setbacks were 30 °C as shown in **fig 4.**

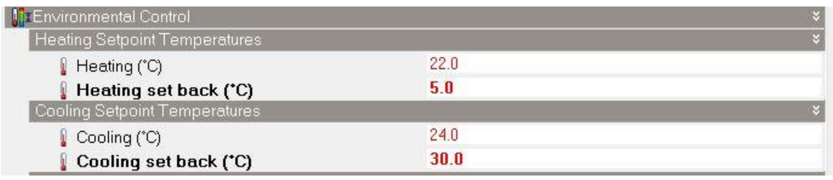


Figure 4: The environmental control of the administrative building for all scenarios

The previous figure shows that in the case of the absence of users of the building if the temperature reached 30 ° C, the air-conditioners will be made and the place will be cooled. Also, if the temperature reaches 5° C inside the building, heating will be done automatically.

The following table shows the properties of glass, its size, and the properties of the walls used in the building.

Table 3: properties of administrative building construction for all scenarios

Glass	Wall
Window to wall ratio 33% **Window Height: 1 m** **Sill Height: 1.31 m**	
U value: 2.3 w/m2-k	U value: 1.85 w/m2-k

Table 4: administrative Building model characteristics for all scenarios.

Item	Description
HVAC	**System: Spilt** **Operation schedule: 6 days a week, from 8:00 to 18:00** **Nature Ventilation:**  **Figure 5: Natural ventilation properties** for all scenarios

<table>
<tr>
<td>Lighting</td>
<td>

System: Led with Linear control

Operation schedule: 6 days a week, from 8:00 to 18:00

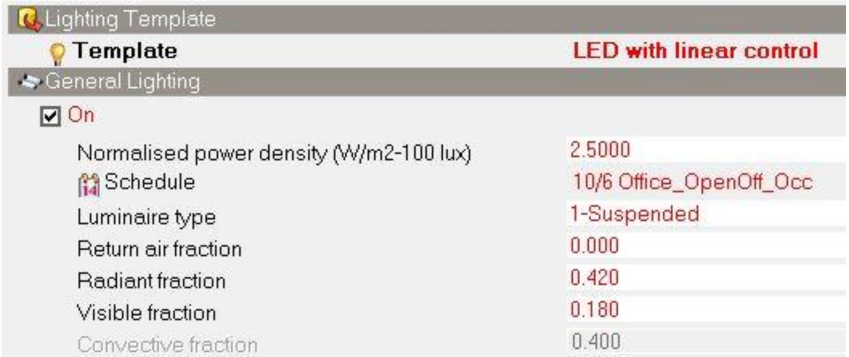


Figure 6: Lighting template properties

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

Constant rate: 0.2

Figure 7: Airtightness properties

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

The previous table shows some other information entered into the Design Builder program such as HVAC system, system of lighting and constant rate of infiltration.

After entering all the previous information for the Design Builder program, a simulation of the building will be done three times. **Fig8,9,10** shows the three scenarios of the simulation.

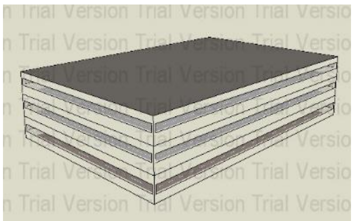


Figure 8: Base scenario

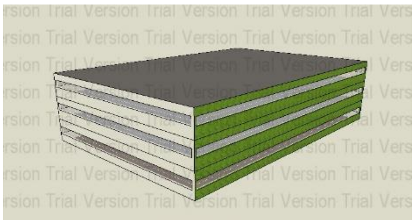


Figure 9: First scenario

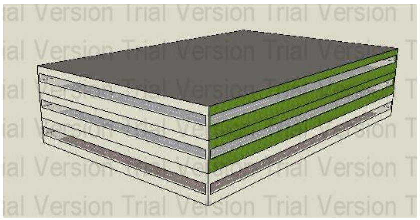


Figure 10: Second scenario

Table 5: Green wall properties of building scenarios

Green wall	
Height of plant (m)	0.15
Leaf area index	5
Leaf reflectivity	0.220
Leaf emissivity	0.950
Minimum stomatal resistance (s/m)	180
Max volumetric moisture content at saturation	0.5
Min residual volumetric moisture content	0.01
Initial volumetric moisture content	0.15

As shown in previous figures, base scenario has no greenery, first scenario has 100 % greenery on southern façade and the second scenario has 67% greenery on southern façade.

Table 5 shows the characteristics of the plants attached as they are in the Design Builder program. Therefore, the green layer was added to the existing primary wall in both first and second scenario.

6. RESULTS AND CONCLUSION

As for the base scenario, according to **fig11, table 6** shows that consumption of electricity for cooling is at a minimal rate in the first months of the year (January, February, March and April) and also the last months of the year (November and December). The rate of electricity consumption increases in the middle months of the year.

Also based on the monthly electricity consumption's table, The maximum electricity consumption throughout the year in two months (July and August) with a value of 22859.47 KWH and 23537.71 KWH

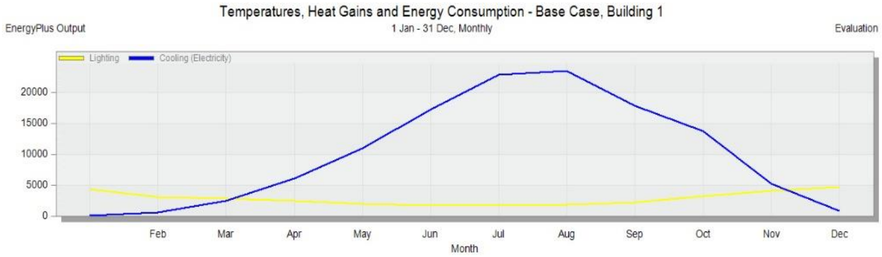


Figure 11 : Results of Monthly Electricity consumption of Base scenario .

Table 6: Monthly Electricity consumption values of Base scenario

Month	Electricity consumption KWh
January	24.80
February	508.67
March	2414.96
April	6135.75
May	11003.84
June	17186.82
July	22859.47
August	23537.71
September	17837.14
October	13749.76
November	5268.15
December	868.86

As for the first scenario, according to **fig12, table 7** shows the rate of electricity consumption increases during the mid-year months, but consumption is less than the first scenario, that is before the use of green walls.

Also based on the monthly electricity consumption's table, The maximum electricity consumption throughout the year in two months (July and August) with a value of 21537.56 KWH and 22053.7 KWH.

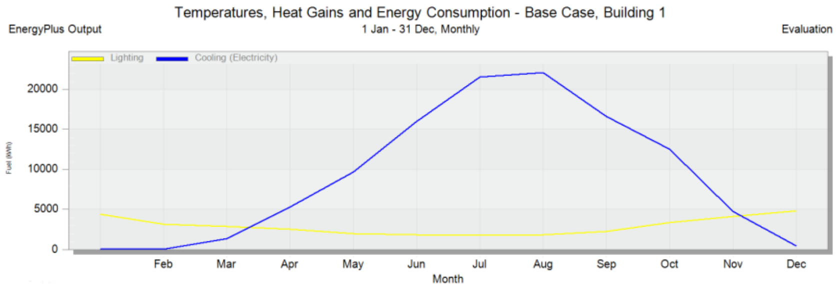


Figure 12: Results of Monthly Electricity consumption of first scenario.

Table 7: Monthly Electricity consumption values of first scenario.

Month	Electricity consumption KWh
January	0.78
February	48.90
March	1336.5
April	5320.65
May	9700.90
June	15955.72
July	21537.56
August	22053.7
September	16623.24
October	12500.6
November	4742.50
December	454.05

As for the second scenario, according to **fig13, table8**, it shows also, as is the case in simulations that took place in the base scenario and the first scenario, the rate of electricity consumption increases during the mid-year months. The maximum electricity consumption throughout the year in two months (July and August) with a value of 21824.2 KWH and 22541.88 KWH. And the lowest rate of electricity consumption throughout the year in January, February and December with a value of 4.20 KWH, 85.98 KWH and 558.64 KWH.

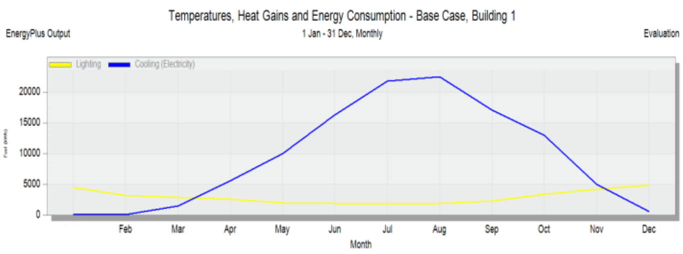


Figure 13: Results of Monthly Electricity consumption of second scenario.

Table 8: Monthly Electricity consumption values of second scenario

Month	Electricity consumption KWh
January	4.20
February	85.98
March	1458.41
April	5520.487
May	9933.22
June	16302
July	21824.2
August	22541.88
September	17125.32
October	12991.08
November	4939.99
December	558.64

Finally, the three scenarios were similar in the shape of the building, its orientation, the number of floors, as well as the proportions of windows and walls, and the only difference was in the percentage of greening of the southern facade of the building, and the simulation was conducted on the same dates as the building's schedule,

The difference between the three scenarios is based on electricity consumption, the first scenario was better in saving energy, the second scenario comes after it, then the base scenario.

According to **fig14**, it shows the difference between electrical energy consumption between the three scenarios and shows how greening the southern wall has a significant impact on reducing energy consumption. The first scenario was greening the entire surface of the southern wall and the annual energy consumption equal to 110,275.1 KWH, so the first scenario works to reduce energy by almost 9% annually.

The second scenario was greening the southern façade by 67%, and based on the simulation results, the annual consumption of electric energy was 113255.4 KWH so the second scenario works to reduce energy by 7 % annually.

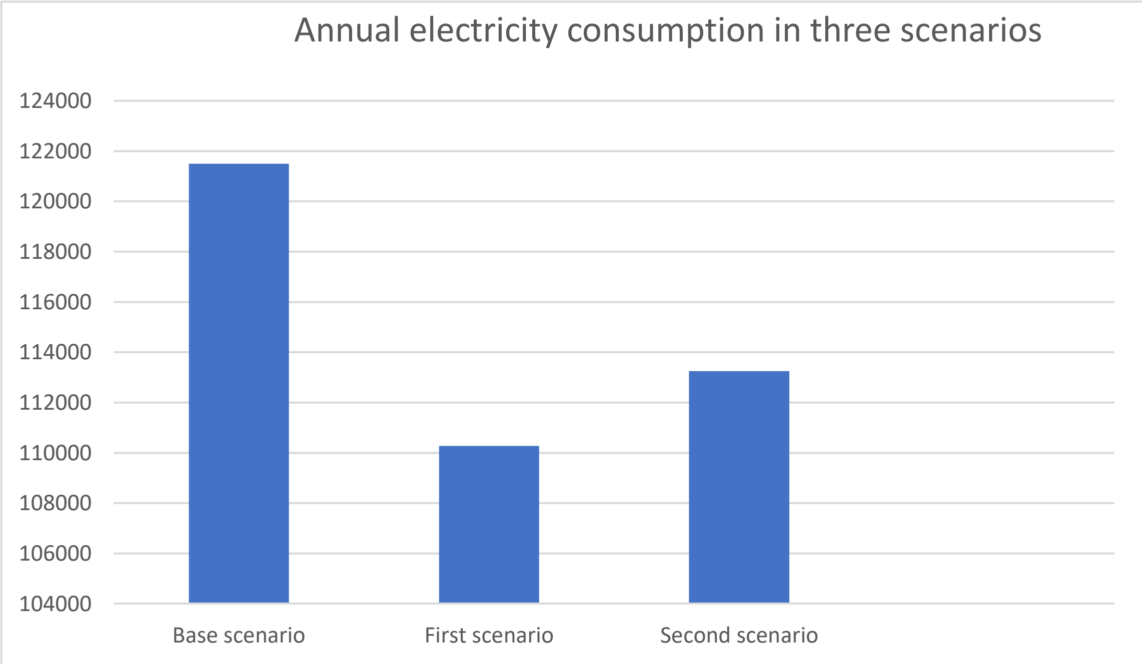


Figure 14: Comparison between annual electricity consumption of three scenario

The research proved that vertical green systems have a major role in rationalizing energy consumption in administrative buildings in Egypt. The application of vertical greening systems can be greater than the three scenarios, and the result will become a greater rationalization of energy consumption, but we must take into account the higher the rate of greening, the greater the periodic maintenance, irrigation, etc.

REFERENCES

1. RCREEE. (2021, December 18). Retrieved November 12, 2021, from https://www.rcreee.org/.
2. country energy overview IAEA. Egypt 2021. (n.d.). Retrieved November 12, 2021, from https://cnpp.iaea.org/countryprofiles/Egypt/Egypt.htm
3. *annual reports of the Egyptian Electricity Holding Company*. The Ministry of Electricity and Renewable Energy. (2021). Retrieved December 25, 2021, from http://www.moee.gov.eg/english_new/home.aspx
4. Manso, M., & Castro-Gomes, J. (2015). Green Wall Systems: A review of their characteristics. Renewable and Sustainable Energy Reviews, 41, 863–871. https://doi.org/10.1016/j.rser.2014.07.203

5. Radić, M., Brković Dodig, M., & Auer, T. (2019). Green facades and living walls—a review establishing the classification of construction types and mapping the benefits. Sustainability, 11(17), 4579.

6. Goel, S., Athalye, R., Wang, W., Zhang J., Rosenberg, M., Xie, Y., Hart, R., Mendon, V. 2014. "Enhancements to ASHRAE Standard 90.1 Prototype Building Models".