Using Green Facades to Improve the Thermal Impact of Educational Campus Buildings with Special Reference to the Universities of Canada in New Capital, Egypt.

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Abstract: Many buildings nowadays are designed with sustainability considerations. However, a large portion of the building stock was constructed prior to the implementation of sustainability principles. These buildings, which were designed using traditional methods, are the primary consumers of energy and resources. Although energy-efficient new construction applications are an important step toward sustainability, existing buildings must be retrofitted to achieve the desired ecological impact. The building envelope is the most accurate predictor of the energy used for heating, cooling, lighting, and ventilation. The building envelope is defined as the interface of energy losses due to its direct interaction with the external environment conditions. Building energy requirements must be reduced, energy efficiency must be increased, and systems that support the use of sustainable energy sources must be put in place to reduce energy use in buildings. The main aim of the research is to find the best solution of educational buildings facades to improve its efficiency and save energy. This research will discuss the problem of thermal impact through literature review and simulation in case study the university of Canada in Egypt.

Keywords: Sustainable facades, energy efficiency, thermal impact, design builder simulation

Introduction

In 2015, the United Nations General Assembly formally adopted the universal, integrated, and transformative Agenda for Sustainable Development 2030, which proposes 17 main objectives, one to "make cities and human settlements inclusive, safe, resilient, and sustainable" [1].

One of the actions that can be taken to achieve this goal is to promote green and resilient cities. Green walls, among the most innovative and eco- friendly solutions, can be envisioned as a key strategy to meet the challenge of sustainable development [2].

Living walls and green facades play an important role in improving urban microclimate and the energy performance of buildings [3]. These green walls techniques provide numerous environmental, economic, and social advantages [4]. Green walls, like other types of green infrastructure, can lower the internal temperature of a building, resulting in less energy consumption [5]. The use of green vegetated facades in the building envelope creates an air layer that acts as an insulator [6].

This reduces the heating load in the winter and the cooling load in the summer [3] and protects the wall from external factors such as ultraviolet ray radiation and excessive heat. Wide temperature fluctuations and driving rain, which are the sources of humidity in the building envelope, will be reduced [7], and they will act as a wind barrier to prevent cooling the building facades by reducing wind speed along the building facades [8] depending on the foliage and facade orientation [9].

Finally, Green walls could reduce the Annual energy consumption up to 8% as it working as a shading for both solid walls and also, windows, thereby air conditioning load reduced up to 23% [10].

Sustainable development:

The United Nations adopted "The 2030 Agenda for Sustainable Development" in 2015, which includes 17 Sustainable Development Goals SDGs.

to provide cities peace, wealth, and prosperity. To ensure a sustainable living and a better world by 2030, all governments, stakeholders, and decision-makers must adhere to the SDGs. Figure 1, contains a description of the 17 United Nations goals [11-12].

Figure 1: (The 17 sustainable development goals SDGs [13])

Green facades types:

are vertical vegetation that runs the length of an upright structure. Unlike others, we distinguish between five varieties based on cost and maintenance. Vertical Greenery is a term used by botanists and horticulturists to describe a variety of upright barriers made of flora. These vegetation walls can, in fact, be independent or connected to a vertical structure.
Freestanding hedges and rows of trees are common in Europe and were "invented" by the Romans. Apart from its aesthetic value, these Green Walls safeguarded against near-ground wind pressures, thereby preventing erosion and shielding people. (14)
There are many types of green facades some of them ground base and the others wall-structured base. (Figure 2)

Figure 2: Green facades types (14)

a- An extensive green wall 1

Simply said, it is a self-climber that ascends a structure on its own. This is feasible for less than 3400 LE, and the plants cover 120-180sf of wall in around 2 years. Because there are options, it can be a combination of evergreen climbers and summer green climbers with blooms and fruits. Birds, in particular, enjoy nesting in these types of Green Walls. This undoubtedly improves diversity on all levels and across all levels of a system. A desire for purely native species in this form of Green Wall can be difficult. Because a variety of plants can adapt to urban heat islands and temperature extremes. Later on, self-climbing Green Walls provide a support for vines that need to grip. (14)

b- An extensive green wall 2

A structure is required to grab onto. Of course, until it is covered by flora, such a structure is also a design element. As a result, design options range from simple ropes to wires, meshes, and ornate trellises. Overall, a low-cost solution with increasing diversity in appearance over time. (14)

c- Semi-intensive green walls.

Semi-intensive Green Walls are commonly utilized to generate shade for buildings without covering the entire surface of the exterior. Semi-intensive systems provide excellent food and habitat for wildlife. When compared to intensive systems, they undoubtedly have an excellent cost-benefit ratio. (14)

d- Intensive green walls 1&2

Vertical Hydroponic Systems are made up of small planter cells and modular parts. Others are pocket style facade coverings that are individually made. Obviously, all of these sorts exist in various versions, and each manufacturer claims to have discovered the innovative solution. The marketing of intensive green walls is revolutionary. We consider it a work of art because of the constant high input of resources. In truth, sustainability and resilience are not the primary objectives. (14)

Thermal impact of Green Facades:

Green wall enables 6.1 °C temperature reduction in sunny days compared to bare wall. Temperature reduction in cloudy days is still promising by 4.0 °C. (15)

On the other hand, there was another study done by (16) made three experiments of green façades with different leaf coverage areas, namely the Bare Wall (BW) model, 50% leaf coverage area (GF-50%), and 90% leaf coverage area (GF-90%), were carried out to investigate the effect on overall heat transfer, radiative heat transfer, and Long Wave Infrared Radiative (LWIR) exchange on the wall. The average of the heat transfer calculations revealed that the BW model gained 2.10 W/m2 heat from the outer environment. While GF-50% received 1.81 W/m2 and GF-90% received 1.46 W/m2, respectively. According to the contribution of leaf coverage area, BW absorbed 4% and 7% more radiation heat transfer than GF-50% and GF-90%, respectively. The GF-90% LWIR exchange was 6.76 W/m2 and 10.18 W/m2 lower than the other. The findings suggest that increasing the leaf coverage area of a green façade can improve the thermal insulation ability of a building wall.

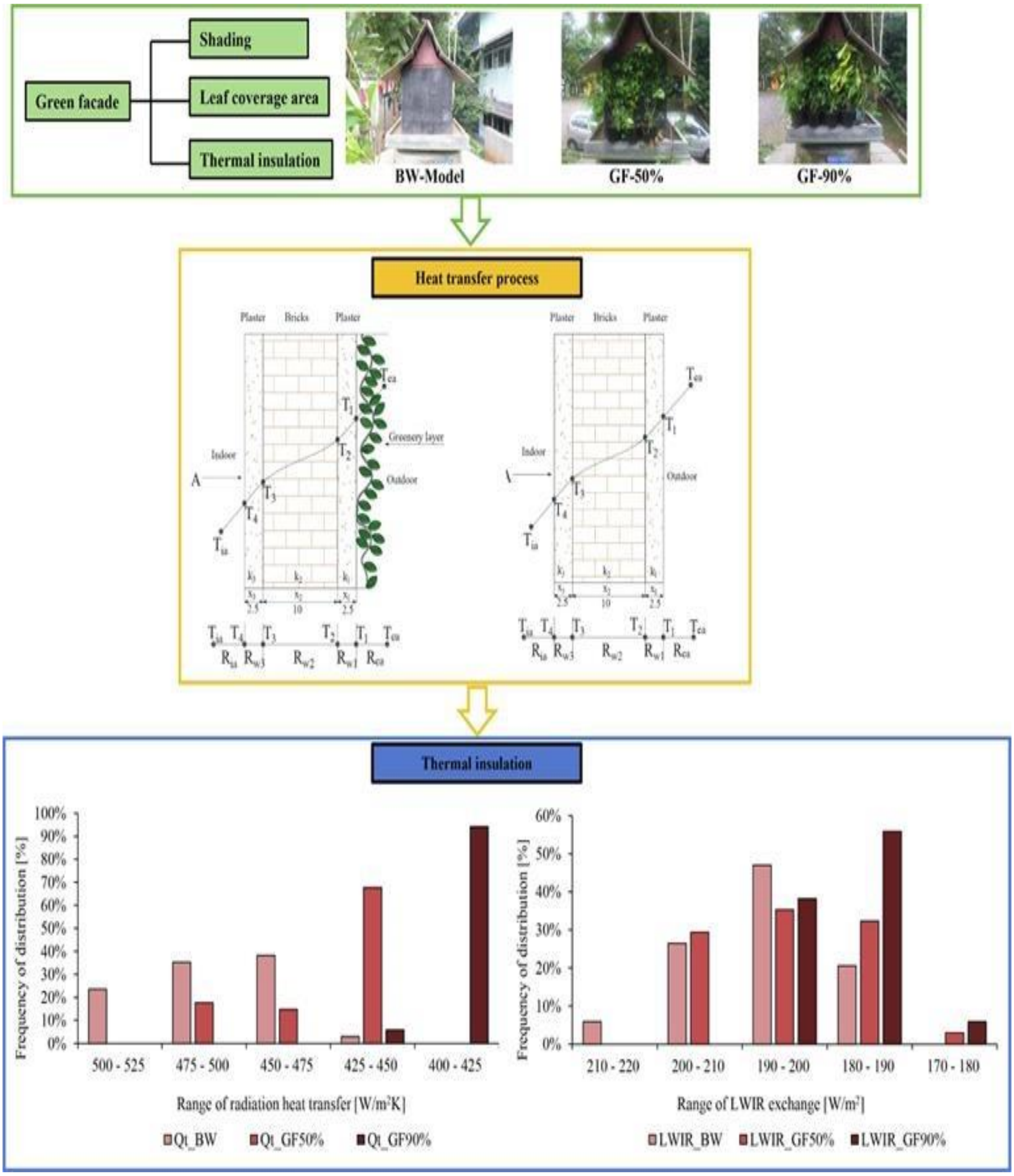


Figure 3: The Frequency distribution after and before adding extra green wall system (16)

Also, Greening city building facades with climbing plants can alter the building-environment connection. This interaction reduces the outer temperature of the building and cools the appropriate internal spaces. Plants absorb huge amounts of solar light and biological functions in order to flourish. It acts as a natural barrier against the sun's excessive sunlight. Vertical vegetation system (VGS) becomes a technique for greening the city by using larger wall spaces accessible in urban canyons, lowering heat and energy consumption, and enhancing cooling effect on all regions surrounding the building. (17)

Finally, after reviewing the sustainable developments goals (SDG) and the benefits of green facades the below figure (Fig. 4) shows how the green facades could achieve some of these goals (highlighted by red)

SDG01	End poverty in all its forms everywhere.
SDG02	End hunger and achieve food security and improve nutrition and promote sustainable agriculture.
SDG03	Ensure healthy lives and promote well-being for all at all ages.
SDG04	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
SDG05	Achieve gender equality.
SDG06	Ensure availability and sustainable management of water and sanitation for all.
SDG07	Ensure access to affordable, reliable, sustainable, and modern energy for all.
SDG08	Promote sustained, inclusive, and sustainable economic growth, full productive employment, and decent work for all.
SDG09	Build resilient infrastructure, promote inclusive, sustainable industrialization, and foster innovation.
SDG10	Reduce inequality among countries.
SDG11	Make cities and human settlements inclusive, safe, resilient, and sustainable.
SDG12	Ensure sustainable consumption and production patterns.
SDG13	Take urgent action to combat climate change and its impacts.
SDG14	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.
SDG15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss.
SDG16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.
SDG17	Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Figure 4: (Description of the 17 sustainable development goals SDGs [18])

The Experimental Study:

The experimental study will be on The Universities of Canada in Egypt, in the educational building. (Fig.5) The university is located in the new administrative capital, Cairo, Egypt which its climate is considered hot dry climate, its located between 31.7135992 and 29.9997833 east longitude and north latitude respectively.

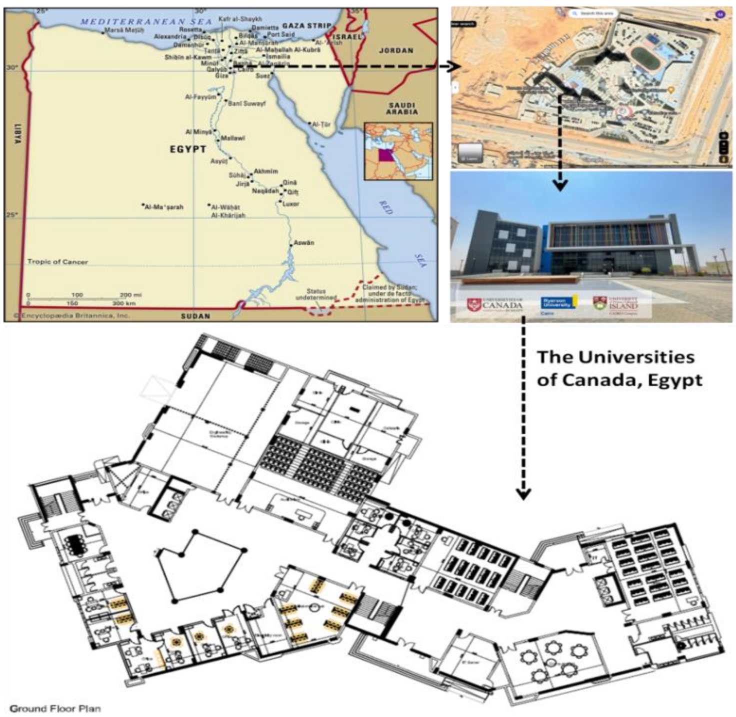


Figure 5: the universities of Canada (Experimental Study)

Since the vegetated facades considered as a new technique of building's facades which is not only improve the thermal impact of the buildings but also provide a visual beauty for the users and improve the indoor and outdoor air quality and according to that the research chose the green façade to improve the thermal impact of the building with taking into consideration the students' feeling of beauty. And to ensure a maximum thermal improving which reflected on the energy consumption of the building, the research is comparing between the direct and indirect green façade to study the effect of the system thickness on the needed heating and cooling load.

The comparative analysis will be done by comparing the application of indirect green façade with 60 cm air gap in both south east and south west elevations. The simulation will be done through creating an energy analytical model for the building in Revit Program and then use the Design-Builder Revit Plugin to be able to run the energy simulation.

The green facade will be installed as:

- Outdoor Installation: Free Standing System with vegetation grows directly on the Free-Standing System with air-gap 60cm (Table:1)

Table 1: the simulation input data for initial model and green façade installation model

Data	**Initial Case**				**Vegetated Facade Installation**			
Building type	University							
Space Function	Educational							
Space Area (m2)	2272							
Space Volume (m3)	9088							
No. of Floors	7							
Input Data								
Cooling Point	23° C							
Heating Point	21° C							
RH (Calculated)	42%				46%			
Number of People/Floor	300							
Layers thickness and thermal properties	**Initial Case**				**Vegetated Facade Installation**			
	Sp.H J/kg.K	**Den. g/m^3**	**Cond. W/m.K**	**Thickness m**	**Sp.H J/kg.K**	**Den. g/m^3**	**Cond. W/m.K**	**Thickness m**
Water vapor [19]	--------	-------	--------	--------	1966	0.60	5.56	0.002
Vegetation [19]	--------	-------	--------	--------	2.8	533,28	0.36	0.20
Air gap [19]	--------	-------	--------	--------	1004	1.3	5.56	0.15
Stainless steel	--------	-------	--------	--------	460	7900	17	0.05
Plaster	1000	600	0.16	0.005	1000	600	0.16	0.005
Mortar	896	1570	1.00	0.02	896	1570	1.00	0.02
RC Wall	2400	2500	2.5	0.3	2400	2500	2.5	0.3
Mortar	896	1570	1.00	0.02	896	1570	1.00	0.02
Plaster	1000	600	0.16	0.005	1000	600	0.16	0.005

The vegetation layer of green façade will be added in Revit as a kind of insulation material that applied to the wall by adjusting the vegetation height and its properties such as; LAI, specific heat, density, conductivity … etc. The chosen plant will be "Hedra Helix – Ivy" with LAI: 0.005 m2/leaf [19] - 100% coverage, H-VAC: split with no fresh air, occupancy rate: 0.0196 people/m2, Lighting Energy: 1.00 w/m2 and Infiltration: 0.7 ac/h. (Fig. 6)

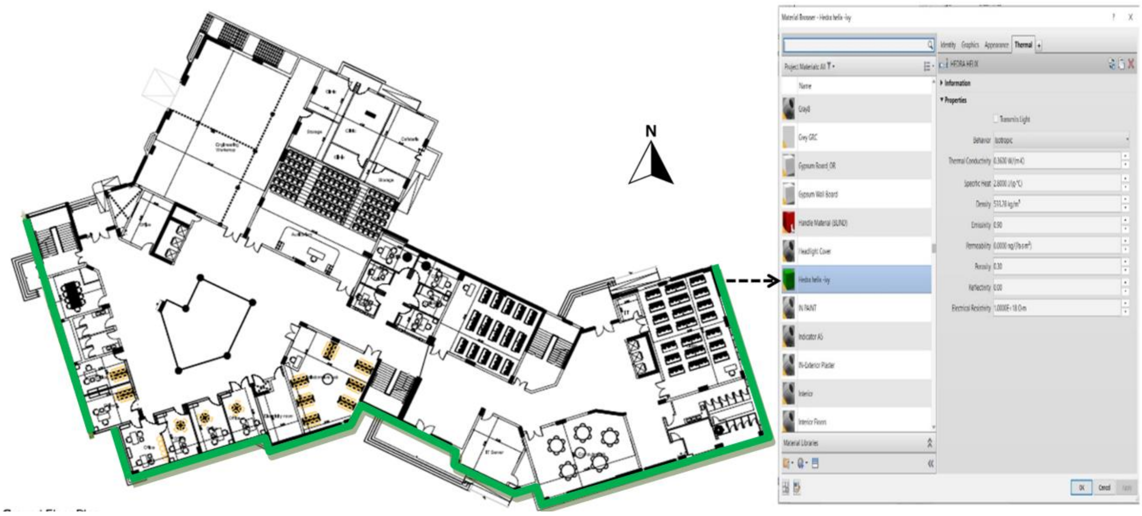


Figure 6: The location of green façade installation and its thermal properties in the Revit program

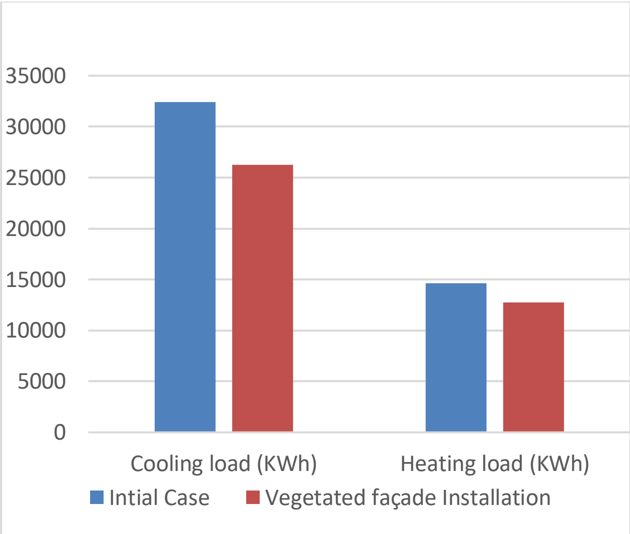
Results

The installation of the vegetated facades on both south east and south west orientation is reduced the heating loads by 12.94% and the cooling loads by 19.4% (Table: 2) which reflected on the electricity bills as a 1KW equal 1.60 EGP [39], and that means that the electricity bill on August after the installation costs 75277.056 EGP before GW installation and it reduced to 62380.608 EGP after GW installation with 60 cm air gap, which means the energy bill cost reduced by 17.13%. (Fig.7)

Table 2: The design-builder simulation results

Data	**Initial Case**	**Vegetated Facade Installation**
Building type	University	
Space Function	Educational	
Space Area (m2)	2272	
Space Volume (m3)	9088	
No. of Floors	7	
Input	**Initial Case**	**Vegetated Facade Installation**
Cooling Point	23° C	
Heating Point	21° C	
RH (Calculated)	42%	50%
Number of People/Flor	300	
Results	**Initial Case**	**Vegetated Facade Installation**
Total Cooling Load (KWh)	32390.4	26226.24
Total Heating Load (KWh)	14657.76	12761.64
Month & Hour with highest cooling load	August 02:00pm	August 02:00pm
CO2 Emissions (Kg)	14991.96	10757.44
Saving Ratio%	**Initial Case**	**Vegetated Facade Installation**

Cooling Load Saving		19.14%
Heating Load Saving		12.94%
CO2 emissions decreasing		28.43%



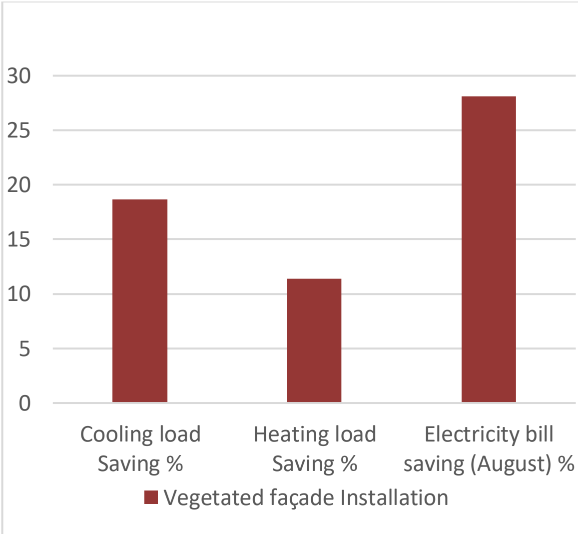


Figure 7: The heating and cooling loads before and after vegetated façade installation (left), The saving ratio of heating, cooling loads and electricity bill before and after vegetated façade installation (right)

Conclusion

According to the harmful effect of Building environment on natural environment the UN put an agenda for sustainable development 2015 to be achieved on 2030 so that most of architects are went to use green facades as a new technique for eco-friendly building facades as it improves the facades' thermal behavior which reflected on the amount of building's energy consumption with respecting the surroundings, improve the air quality and reduce the urban heat islands effect (UHI)

And to show the environmental, economic & social effect of green facades the researchers use design-Builder Simulation program to measure the reduction of needed heating and Cooling loads after green facade installation and the results showed that the heating loads reduced by 12.94% And the cooling loads reduced by 19.14% and that's also effect on the CO2 emissions as it reduced by 28.43% which shows that the green facades (Fig. 7). Not only effects on the Environment by reducing the required heating & cooling loads but also, reduced the co2 emissions which effect directly on the users' comfort and health

Finally, the green facades also have a huge economic effect as it reduced the august monthly electricity bill by 17.13% (Fig. 7) which means the building's owner saved about 12896.448 EGP.

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