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Sustainable and Green Academic Buildings in Al-Azhar University: Case Study

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Abstract- Egypt's Vision 2030 adopted a strategy for sustainable development (SDS), The primary goals of sustainable design are to decrease resource depletion, including energy, water, and raw materials, and to mitigate environmental damage caused by buildings and facilities over their lifetime; create better building environments, also referred to as green buildings. This paper presents the situation of the current implementation state of a green strategy in Egyptian universities based on sustainability international rankings, such as the UI Green Metric world ranking. This paper considers the implications of implementing a green university's strategy. it has been interested in the use and apply even a few appropriate green approaches in Al-Azhar University and trying to integrate and link them to the Egyptian country's comprehensive strategy for sustainable development, this assures that the situation will improve soon. This case study focuses on implementing green initiatives in higher education academic university buildings to achieve sustainability by providing green indicators that are linked to the economic, social, and environmental dimensions of sustainability focusing on energy, education, and environmental pillars mentioned in Egyptian Vision. This study proposes a smart building implementation criteria based on using an efficient LED lighting system that introduces energy saving tacking environmental reduction effect for Co2 based on applying Leadership in the Energy and Environmental Design (LEED) rating system standard as energy and environmental design leadership, also design of a solar system as a generation unit supplying a part for the proposed academic sustainable building electrical loads, and represent it as penetration of a renewable energy source (RES) for the green campus in AL-Azhar University.

Keywords Sustainable Development(SD); UI Green Metric World Ranking; Energy Saving; Lighting System; Renewable Energy Sources(RES).

1. Introduction

Universities occupy a unique societal position. They represent knowledge disseminators, powerful drivers of innovation at the global, national, and local levels, to achieve economic development, and community well-being. Universities, therefore, play a crucial role in achieving the Sustainable Development Goals (SDGs), in addition to benefiting greatly from participating in them. The United Nations (UN) adopted the SDGs also known as the Global Goals, on 25 September 2015, as part of a new sustainable development agenda, this set of global goals was adopted as a universal call to action to end poverty, protect the planet, and ensure prosperity for all. Each goal has key goals to be met over the next 15 years to ensure that all people enjoy peace and prosperity by 2030 [1]. A general logo and 17 individual icons have been designed to raise awareness of the SDGs.

These guidelines are intended to facilitate information sharing, engagement, and collaboration and identify three major components: the first is the words "Sustainable Development Goals," the second is a color wheel visual identifier, and the third is the names for each of the 17 SDGs, as shown in the figure (1) [1, 2]. The 17 SDGs are interrelated, and they recognize that deeds in one area affect outcomes in others and that innovation must strike the right balance between social, economic, and environmental sustainability. The SDGs have been developed, and government agencies have dedicated themselves to emphasizing progress for those who are the most oppressed to solve their problems. To accomplish the SDGs in any context, everyone's imagination, knowledge, technology, and financial resources are needed [3].

Fig. 1 UNs guidelines for 17 SDGs include a color wheel [1].

Egypt's Vision 2030 is a deep political, economic, and social vision. It was created by the United Nations (SDGs) [4]. This vision exposes the (SDS), which is viewed as a foothold on the road to comprehensive development, reviving Egypt's role in regional leadership, and achieving the development of the path of prosperity through economic and social justice. The Egyptian SDS represents a roadmap to optimize competitive advantage to achieve Egyptians' aspirations for a high-end and dignified life [4]. Also, SDS Undertakes the strategic planning approach based on participation and cooperation between all representatives of civil society, national and international development partners, and government agencies to set cross-cutting objectives for all pillars and sectors of the state [4,5]. The SDS addresses three major dimensions: economic, social, and environmental as a general framework. and also SDS is divided into ten main pillars, adding to domestic policy, foreign policy, and national security, as shown in figure (2) [5]. The economic dimension is comprised of four pillars, including Energy, economic development, Knowledge, Innovation and Scientific Research, and Governmental Institutions' Transparency and Efficiency. The social dimension also includes four pillars, detailed as Education and Training, Heath, Culture, and Social Justice. The environmental dimension as well as domestic policy, foreign policy, and national security include two pillars Environment, and Urban Development[5].

Fig. 2 The (SDS): Egypt's Vision 2030 -main pillars [5].

Egypt's Vision 2030 adopted strategic visions, key performance indicators with strategic results, and outcomes, programs, and projects for all Pillars. This research plays attention to some of the pillars mentioned earlier with the presentation of strategic visions of these pillars as follows[5]:

- **Second pillar: Energy**

An energy sector maximizing the efficient use of various traditional and renewable resources complying with SDGs.

- **Third pillar: Knowledge, innovation, and scientific research**

A society that produces science, technology, and knowledge based on creativity and innovation to achieve national goals

- **Seventh pillar: Education and training**

A high-quality educational and training system for students and trainees that provides the skills necessary for creative thinking, and enables them technically and technologically.

- **Ninth Pilar: Environment**

A clean, safe and healthy environment that integrates into all economic sectors to conserve natural resources and support their efficient use and investment.

2. Energy Sustainability

As a consequence of the world's current environmental challenges related to climate change and global warming, sustainability is rapidly evolving from a simple issue to an important agenda item. As a result, higher education institutions (HEI) must implement green initiatives to support SDGs such as waste reduction, energy efficiency, water usage reduction, healthy working environments, and clean indoor air, these initiatives can bring about improved quality of life for all, better economic vitality and a reduced environmental footprint [6,7]. In terms of urban characteristics and population size, HEI is similar to smaller cities and various activities take place on campus that has effects on the natural environment, therefore education sector or universities has a strong relationship with SDGs which developed as a solution to global problems as climate change mitigation, depending on the positive steps have taken on a different scales such as in university campus. As a result, universities must implement green practices and provide multidisciplinary green technical solutions to assist in achieving SDGs, therefore, the management of sustainability activities on campus has piqued the interest of university leaders at local and global levels [7,8,10,11].

In the last years, green projects, academic studies, and the number of publications containing the "green campus" increased rapidly supporting the sustainable campus concept[8]. University rankings cover a wide range of topics, including research, academic reputation, environmental problems, and so on, and recently these rankings have become popular and representative of a university's reputation alongside academic publications[8,9]. The world ranking systems like the QS ranking system ranks universities according to; academic reputation, employee reputation, academic staff/student ratio, international student, and citation per faculty. However, other ranking systems that highlight sustainability in Higher Education consider the green campus concept, one of the pioneer and famous systems is the Sustainability Tracking Assessment and Rating System (STARS) [12,13]. The UI Green Metric which was designed based on sustainability assessment systems included the

Holcim awards, Greenship based on the LEED system, (STARS), and the College Sustainability (Green) Report Card [14,15].

2.1. UI Green Metric World University Rankings

Where the UI green metric is gaining popularity around the world because it does not require any prerequisites or fees for applications [12], in 2010, Universitas Indonesia (UI) launched world university rankings, later renamed UI GreenMetric World University Rankings, to track campus sustainability efforts. It was introduced to create an online survey to portray sustainability policies and programs for universities all over the world, it has also been identified as the world's first and only university ranking on sustainability [15-17].

The design phase of UI GreenMetric based on sustainability systems included the Holcim sustainability awards, (GREEN SHIP) (the rating system recently developed by the Green Building Council of Indonesia which was based on the LEED system, STARS, and the College Sustainability (Green) Report Card [15]. The UI Green Metric has been regularly updated since the beginning, where now The UI GreenMetric has six categories which are; “Setting and Infrastructure” (SI), “Energy and Climate” (EC), “Waste” (WS), “Water” (WR) “Transportation” (TR) and “Education and Research” (ED) in the current scoring system[15]. The EC category remains has the greatest and highest impact with 21%. The WS, TR, and ED categories have 18%, and in terms of overall impact, the SI category ranks fifth with 15%, while the WR category has the last six place in terms of impact with 10% of the UI GreenMetric total current score [8], [15], [17].

After 2012, there was no change in the categories’ percentage weight, while the indicators within the categories continued to change. In 2015, new indicators related to carbon footprint were added to the EC category [8,15]. In 2017, a massive change in methodology was implemented to account for new trends in sustainability issues. The subject for 2018 was Universities, Impacts, and (SDGs), and the new indicators were introduced, and old indicators such as “energy efficient appliances usage, elements of smart and green building implementation, transportation initiatives to decrease private vehicles on campus, the transportation program designed to limit or decrease the parking area on campus, pedestrian policy on campus, shuttle services, Zero Emission Vehicles (ZEV), the greenhouse gas emission reduction program,...etc” were updated to strengthen relations between SDGs and universities, as indicated in the UI GreenMetric Guideline, where the 17 aspects of SDGs are caught in the UI GreenMetric assessment criteria, as seen in figure (3)[8,15].

2.1.1. UI Green Metric World Rankings For Egyptian Universities

In UI GreenMetric world ranking 2021, universities ranking are carried out at different levels as follows [15]:

1- Overall ranking
2- Ranking by Region
3- Ranking by Country
4- Ranking by Category
5- Ranking by campus Setting
6- Ranking by Campus Type
7- Ranking Top 50 Under 50

Fig. 3 UI Green Metric and (SDGs) [15,18].

Egyptian universities take advanced ranking and classification related to these different levels, where according to the overall ranking, there are twelve Egyptian universities in the overall world rankings, Egypt is topped by an American university in Cairo and occupies No. 159 ranked out of 956 universities. Also, according to Ranking by Region, Egypt tops the rankings in the African continent and occupies the first place topped by an American university in Cairo and occupies the No. 1 ranking out of 20 African universities. Also, according to Ranking by Country, American University in Cairo tops the rankings and occupies the first and takes the No.1 ranking out of 12 Egyptian universities as detailed in table (1). According to Ranking by Setting and Infrastructure Category, Sohag University tops the rankng and occupies first place at the local and African levels and take No.241 at the overall international level, also according to Ranking by Energy and Climate Change Category, kafrelsheikh university tops the rankng and occupies first place at the local and African levels and take No.51 at the overall international level, also according to Ranking by Waste Category, American university in Cairo tops the rankng and occupies first place at the local and African levels and take No.105 at the overall international level, also according to Ranking by Water Category, kafrelsheikh university tops the rankng and occupies first place at the local and African levels and take No.147 at the overall international level, also according to Ranking by Transportation Category, American university in Cairo tops the rankng and occupies first place at the local and African levels and take No.196 at the overall international level, also according to Ranking by Education and Research Category, American university in Cairo tops the rankng and occupies first place at the local and African levels and take No.34 at the overall international level [18]. According to Ranking by campus Setting, an American university in Cairo leads Egyptian universities and takes No.55 with Suburban ranking, Cairo university leads Egyptian universities and takes No.120 with Urban ranking, and Alexandria university takes No.46 with City center ranking [18]. According to Ranking by campus Type, the American University in Cairo leading Egyptian universities and taking No.55 in the Comprehensive Higher Education Institution ranking, and Sohag university leading Egyptian universities and takes No.109 in the Specialized Higher Education Institution ranking [18].

Table 1. Egyptian universities in the UI green metric world rankings [18].

Universities	Overall ranking		Ranking by Region	Ranking by Country	Setting and Infrastructure	Energy and Climate Change	Waste	Water	Transportation	Education and Research.
	Overall ranking	Total Score	Africa	Egypt						
American University in Cairo	159	7500	1	1	875	1300	1575	650	1375	1725
Kafrelsheikh	217	7075	2	2	725	1625	1275	850	1175	1425
Cairo	242	6975	3	3	1025	1100	1500	600	1150	1600
Benha	347	6375	4	4	825	1475	750	700	1125	1500
Sohag	400	6000	5	5	1050	1125	900	600	1150	1175
October 6	429	5850	6	6	675	950	900	550	1375	1400
Alexandria	432	5825	7	7	825	1600	450	400	1200	1350
Ain Shams	436	5800	8	8	675	1300	1275	350	875	1325
Damietta	462	5675	9	9	925	875	825	650	1000	1400
Misr University for Science and Technology	483	5525	10	10	800	1200	975	250	1150	1150
Tanta	566	5125	12	11	775	1050	525	550	1075	1150
South Valley	771	3900	14	12	1025	825	525	350	550	625

2.1.2. Indicators For Energy and Climate Change Criteria in UI Green Metric World Rankings

According to Egypt's Vision 203, The Egyptian country considers energy to be the 2nd most important of the ten SDS pillars, therefore this paper focuses on the energy pillar and forms UIGreenMetric's six categories, this article is interested in Energy and Climate (EC) category and presents all indicators EC according to the UIGreenMetric 2022 Guideline as detailed in the table(2) [15].

The energy and Climate (EC) category based on ten indicators has the first place with the highest impact on overall results with 21 % and 2100 points of the UI GreenMetric total score[15].

This article is concerned with four indicators from all ten indicators, which are as follows [15]:

1- EC2 indicators called "Smart building implementation" with appendix NO 2 in UI Green Metric 2022 Guideline as shown in figure (4).

2- EC3 indicators called "Number of (RES) on campus".

3- EC5 indicators called "The ratio of (RES) production to total energy consumption per year.".

4- EC7 indicators called "Greenhouse gas emission reduction program".

Table 2. Indicators for energy and climate change criteria in UI Green Metric world rankings [15].

NO	Criteria	Point	Weighting
EC-1	Use of energy-efficient appliances.	200.	
EC-2	Implementation of smart buildings.	300.	
EC-3	The number of renewable energy sources available on campus.	300.	
EC-4	Total electricity consumption divided by campus population (kWh per person).	300.	
EC-5	The ratio of renewable energy production divided by total energy usage per year.	200.	
EC-6	Green building implementation elements as reflected in all construction and renovation policies.	200.	
EC-7	Program for reducing greenhouse gas emissions.	200.	
EC-8	Total carbon footprint divided by campus population (metric tons per person).	200.	
EC-9	The number of innovative energy and climate change program (s).	100.	
EC-10	Impactful university climate change program(s).	100.	
	Total:	2100.	21 %

Fig. 4 List and Description of Smart Building Requirements as in appendix No.2 in UI Green Metric 2022 Guideline [15].

Field		Requirement		Description
B	Automation	B1	BMS	Presence of Building Management System (BMS)/Building Information Modelling (BIM)/Building Automation System (BAS)/Facility Management System (FMS) **(recommended requirement)**
		B2	APP	Interactive support for users via APP or online service
S	Safety	S1	Intruder Alarm System	Intruder alarm system (recommended: interfaced with BMS)
		S2	Firefighting	Firefighting system (recommended: interfaced with BMS)
		S3	Video surveillance	Video surveillance system (recommended: interfaced with BMS)
		S4	Anti-flooding	Anti-flooding system (recommended: interfaced with BMS)
E	Energy	E1	Monitoring	Automatic acquisition and logging system of energy consumption (recommended: interfaced with BMS)
		E2	Management	Automatic management system for energy supplies and production (recommended: interfaced with BMS)
A	Water	A1	Monitoring	Automatic acquisition and logging system of water consumption (recommended: interfaced with BMS)
		A2	Recovery	Rainwater recovery system for covering the flushing and irrigation
I	Indoor environment	I1	Thermal comfort	Monitoring (recommended: interfaced with BMS) of environmental parameters related to thermo-hygrometric comfort (i.e., air temperature, relative humidity, air velocity, etc.)
		I2	Air quality	Monitoring (recommended: interfaced with BMS) of pollutants (i.e., VOC, PM, CO_2 ...)
		I3	Real-time	Programming and management in real time according to the occupancy profile of the premises (recommended: interfaced with BMS)
		I4	Passive system	Passive cooling and/or exploitation/limitation systems for free supplies
L	Lighting	L1	LEDs	High-efficiency luminaires (LEDs)
		L2	Sensors	Automatic lighting control (recommended: presence/illuminance sensors interfaced with BMS)
		L3	Shielding	Shielding adjustment and solar control
		L4	Natural light	Passive systems for natural light exploitation

2.2. Green Buildings Rating Systems

A green building is a structure that is designed, built, renovated, operated, or reused in such a way that it enhances the environment and reduces pollution while using the fewest natural resources possible, intending to increase human comfort. The shape of green buildings influences their design because it has a substantial impact on energy performance and construction costs. As a result, to meet the green building requirements, the building's design must consider a variety of factors [19,20]. Countries around the world have also begun to draught legislation to govern the construction of green buildings. For example, the United States Green Building Council (USGBC), is recognized for its Leadership in Energy and Environmental Design (LEED), which certificate buildings that save resources and money and also have a positive impact on the comfort and health of their occupants, while promoting clean and renewable energy [20], Building Research Establishment Environmental Assessment Methodology (BREEAM), which assesses potential building impacts on the economy, environment, and society, and play an important role in identifying the sustainability level in the construction industry [21]. In accordance with Egypt's SDS and vision 2030:the expected residential increase with the population in Egypt reaching 140 million by 2050, there is an urgent need to provide guidelines and strategies for the development of the construction sector as a catalyst for green construction, so the Egyptian Green Building Council introduces the Green Pyramid Classification System (GPRS) which contributes significantly to a broader debate on green buildings in Egypt [21,22]. As shown in Table 3, LEED and GPRS assign different weights and priorities to each category, with LEED assigning the most weight to the energy category [23]. The Energy and Atmosphere LEED category's objectives are to reduce both the building energy demand, energy-related emissions, and dependence on energy generated from fossil fuels, and increase the use of renewable energy sources [24].

Table 3: The priority of every category in the LEED and GPRS systems [23].Categories

Categories	LEED		GPRS	
	Percentage	priority	Percentage	priority
Sustainable Sites	23%	Medium	15%	Medium
Water Efficiency	9%	Low	30%	High
Energy and Atmosphere	32%	High	25%	Medium
Materials and Resources	13%	Low	10%	Low
Indoor Environmental Quality	14%	Low	10%	Low
Innovation in Design	5%	Low	0 %	No
Regional Priority	4%	Low	0 %	No
Management	0 %	No	10%	Low

2.3. Reduce Building Energy Demand and Energy Saving

Green buildings use design and construction methods and techniques to reduce the energy use and environmental impact corresponding to buildings. Since energy saving measures and methods are of great importance as they refer to the efficient use of energy, the acquisition of domestic renewable energy, and the reduction of consumption where energy efficiency is defined as energy density, which refers to the use of less energy to provide the same level of energy service or to do more work with the same power unit in addition to that give a lot of long-term energy saving [19,25].

The university building is one of the high-consumption buildings and the high demand for energy in university buildings is due to the nature of its function, where educational institutions provide a complete infrastructure with large numbers of teaching and learning activities to ensure maximum quality, however, these activities contribute to the high consumption of electricity and thus increase the cost of operation at the university. Therefore, if the energy consumption of the university buildings is not well planned and managed, then in the long run this will affect the cost and energy waste [26]. Therefore, it is recommended to use an energy-efficient lighting solution and solar technology which represents one of the most efficient and appropriate ways to enhance the energy saving of the academic building proposed in this paper [25-27].

2.4. Reduce Emissions from Energy Use

To encourage energy conservation practices, action must be taken to reduce consumption in buildings, which account for a significant portion of global energy consumption and total CO_2 emissions. As a result, the concept of energy-free buildings (ZEB) is gaining prominence around the world as a viable technology to improve energy efficiency and thus reduce the environmental impact of buildings, as well as help drive and obtain the SDGs. This concept can also be implemented in the field of education to be identified as a Zero Energy educational Building [28,29]. While energy security is critical to economic growth and development, the energy sector accounts for 41% of global CO_2 emissions. As a result, these emissions are one of the most pressing global issues and challenges, and all visions of sustainable development rely on the reduction of carbon effects CO_2 emissions [30,31]. within the scope of which the Egyptian state launched Vision 2030 aimed at promoting energy efficiency and renewable energy technologies to achieve green and sustainable construction [31,32]. Finally, a reduction or saving in electrical energy yields a reduction of CO_2 emissions, and hence the environment improves [33].

2.5. Maximize the use of energy generated by Renewable Energy Sources

A green energy plan based on the shift from traditional resources to alternative green sources of sustainable energy production is required for any country's sustainable development and environmental preservation, which will help meet energy demand optimally and lead to the combination of RES and energy sustainability [34].

Applying this at the Egyptian level can aid in improving energy security, reducing environmental impacts, and contributing to the development of a "green economy" (or low-carbon development society) [33]. The energy sector has been ranked as the most important cornerstone among the ten pillars of SD in Egypt's Vision 2030 and the country's long-term growth plan report. The vision evaluation advises that energy resources be used efficiently in the presence of a diverse mix of power generation that includes alternative fuels as well as renewable resources in the form of environmentally friendly power plants [31].

Egypt has a relatively high potential for renewable energy production. Wind and solar, in particular, could provide continuous energy services, thereby enhancing energy security [31], where RES contributed 4% to primary energy generation in 2009/2010, with hydropower 3% and wind power 11%, accounting for the majority of this donation 1%. The Egyptian government's strategy is to increase the share of RES-generated power to 20% by 2022 and 42% by 2035, with wind energy accounting for 14%, hydroelectricity accounting for 2%, and solar energy accounting for 25% of total electricity generated by RES, as seen in figure (5) [32,35]. The International Renewable Energy Agency (IRENA) captures the evolution of Egypt's installed renewable energy capacity over time, with an estimated 19.2 GW of generated power by RES in 2021. Aspiring for 50.5 GW in 2029/2030 and 62.6 GW in 2034/2035, which would contribute 42 percent of Egypt's total electricity output by 2035 [35]. The vast majority of these renewable capabilities are expected to be provided by the private sector in the near future. The New and Renewable Energy Authority (NREA) issued a presidential proclamation in collaboration with the Ministry of Electricity and Renewable Energy (MERE) devoting 28 areas to allocate resources to the progression of large-scale renewable energy projects [32,35].

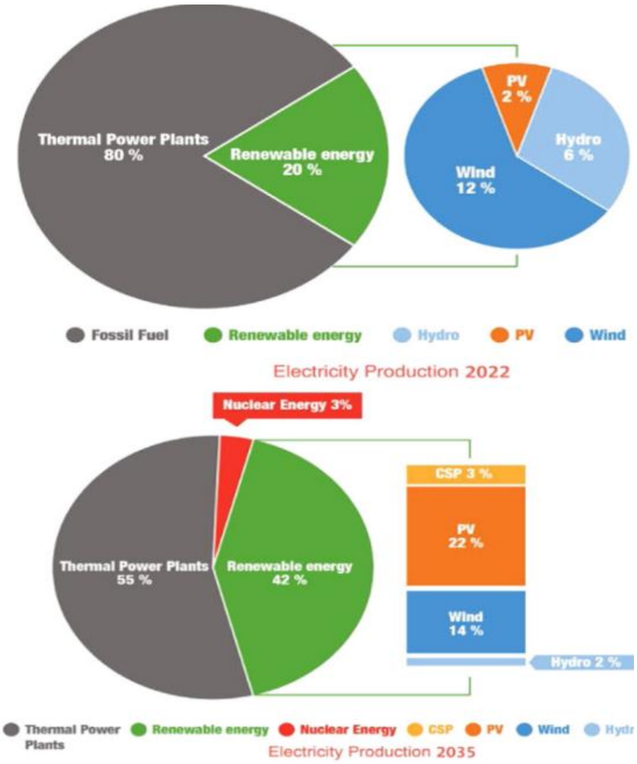

Fig. 5. Egyptian electricity production strategy [32,35].

3. The Motivations and Contributions of This Paper

In line with the orientation and vision of the Egyptian state toward implementing the standards and goals of sustainable development and its greater interest in the energy pillar. Therefore, this research motivates and contributes to adopting these goals and applying them at the campus level of one of the most prestigious universities in Egypt, namely Al-Azhar University, as a foothold in this subject. According to this, the contribution of this research to the motivational direction is based on two main parts: a research part and an applied part. This is as follows:

Firstly, in the research part, in previous sections, the sustainable development plan adopted by the Egyptian state was presented in accordance with the United Nations standards for sustainable development goals SDGs, with a focus on presenting the details of four main pillars among the twelve pillars, and the greatest interest in the energy pillar on which the search engine depends. İn addition to the above, the contribution of universities and their connection to SDGs were also presented, and the criteria for university ranking were explained showing the current situation of Egyptian universities according to one of the most important criteria for university ranking, namely UI Green Metric world university rankings, an attempt to take a step as a starting point to make Al-Azhar University follow the same path of these universities to become with time it has an advanced ranking within regional and international universities.

Secondly, from an applied point of view, inside an academic building within the campus of Al-Azhar University, four indicators were applied from all ten indicators for energy and climate change criteria indicated in table (2) and presented according to successive two scenarios as follows:

Scenario (1): Referring to a smart building implementation “EC-2 indicator” based on the field of the lighting system, saving in consumption for the building after replacing the old fluorescent lighting system with an efficient LED lighting system using (LEED) standard to meet energy saving and environmental design considering cost and Co2 carbon emissions reduction to reach a clean educational environment campus.

Scenario (2): Based on the lighting system calculation in scenario (1), exploiting the available renewable energy sources and trying to design a rooftop photovoltaic (PV) system on a roof area of the proposed academic building on faculty campus for electricity power generation and aimed to partially supply the new estimated LED lighting loads, and its surplus power at other times is fed to the utility grid.

The following is how this paper is organized: Section 1 describes and focuses on Egypt’s Vision 2030 which is compliance with the UN (SDGs). Energy Sustainability is detailed in Section 2. Section 3 introduces the paper's motivations and contributions, and Section 4 introduces the case study including theoretical work and results. Finally, Section 5 provides the work to a conclusion.

4. Case Study: Theoretical Works and Research Results

4.1. Energy Efficient Lighting System Design

Lighting systems consume the most energy, particularly in buildings. As a result, designing energy-efficient systems would significantly contribute to building energy savings.[36]. The majority of installed lighting systems are obsolete and inefficient in terms of energy efficiency. As a result, there is an urgent need for smart LED lighting systems that are energy efficient, simple to install, and affordable [37].

Lighting energy consumption reduction and LED development have had a significant impact on the lighting industry. LED technology used in lighting systems can save energy, and LED technology development and applications are constantly evolving. LED technology can be used to reduce lighting power requirements while also improving durability and environmental protection [37].

4.1.1. Building Discerption and its Electrical Loads

The faculty building is the Electrical engineering department Building, Al-Azhar University, Nasr City, Cairo, Egypt which consists of four floors and is divided into two Zones, the first left zone consists of offices and classrooms with Light loads but the other right zone has offices, lectures halls, and laboratories with heavy equipment. Where effective lighting management results in a higher rate of energy savings, and The reliable estimates of energy consumed by lighting in a building must consider the interaction of lighting with other loads or consumers, such as power and (HVAC) loads. Therefore, all-electric load distribution of the faculty building is indicated before and after the replacement of the lighting system and also indicates all types of luminaires with both the existing old and proposed new systems according to Philips supplier.

As indicated in table 4, The operating hours of the lighting loads were calculated according to the nature of the study days at the university, whether it is a full study day and the lighting loads work fully within 8 hours and that period represents about 120 days, or a day during the summer vacation period the lighting loads do not work during the hours of the day but is limited to a smaller number of hours approximately representing 20% hours of the full day of the normal study day and therefore represents approximately 24 days, or an official day off there is no operation for lighting loads in the building and does not count any operating hours corresponding to that period.

Table 4: The average total number of lighting loads operation days per year

Different periods	Lighting loads operation Periods	
	Hours / Day	Days / Year
Study period (125 Days)	8h	1 *125=125
Summer period (120 Days)	20% * 8h	0.2 *125=25
Holiday period (120 Days)	0h	0h
Average Total Days / Year	150	
Average Total Days / Month	12.5	

I. One month's energy consumption:

(8 hours x 12.5 days) = 100 hours per month. (1)

II. One year's energy consumption:

(8 hours x 12.5 days) = 100 hours / month x 150 days / year = 15,000 hours per year. (2)

4.1.2. Existing and Proposed New Lighting Systems

Due to the high quality, lifetime, and light output efficacy of LEDs in comparison to Fluorescents, a new Light-Emitting Diode (LED) lighting system is proposed as an efficient model and optimized solution for existing and future lighting systems. Furthermore, the environmental, economic, and visual spectrum performance benefits of LED technology make it a lighting system revolution. For the existing lighting system, there are five types of Fluorescent luminaries that are found in the building. Table 5 and figure (6) indicate the quantities of the fluorescent luminaries distributed among the building's different floors.

Table 5: Quantities of the fluorescent luminaries among the building floors

Fluorescent luminaries	Quantity				Total
	Ground	First	second	Third	
60*60cm - 61W	127	186	227	301	841
30*120cm - 31W	41	57	43	43	184
30*120cm - 55W	2	2	2	2	8
60*120cm - 61W	0	27	0	0	27
Spot - 55W	86	38	48	37	209
Total					**1269**

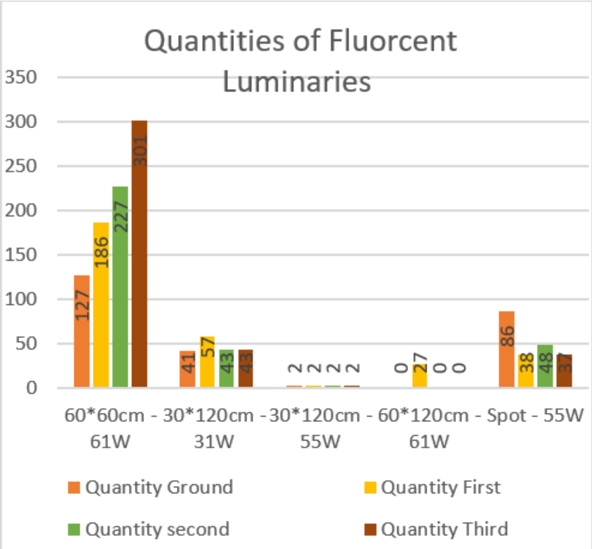

Fig. 6 Distribution of fluorescent luminaries.

The annual estimated energy consumption (kWh) for the fluorescent luminaries' type selection is illustrated in Table 6. For example: TCS461 2xTL5-25W fluorescent luminaries.

I. Consumption energy in (W) for one luminaire:

1-luminaire x 55 W = 55 W

II. Consumption energy in one day (kWh):

(55 W x 8 hours) / 1000W = 0.44 kWh

III. Consumption energy in one month (kWh):

0.44 kWh x 12.5 days = 5.5 kWh

IV. Consumption energy in one year (kWh):

5.5 kWh x 12 months = 66 kWh

Table 6: Annual estimate energy consumption in (Kwh) for fluorescent luminaries type selection

Fluorescent luminaries type	Power per unit of luminaire (Watt)	Units of electricity used (kWh) per year
TCS165 4XTL5-14W	61	73.2
TCS260 1XTL5-28W	31	37.2
TCS461 2xTL5-25W	55	66
TPS762 2XTL5-28W HFP AC-MLO TPS760	61	73.2
Targetti 402414 MINI	55	66

According to the website of the Egyptian Ministry of Electricity and Energy, currently, in 2020 the tariff of electricity in Egypt is (1.4) LE for up to 500 kWh for commercial loads [38]. Table 7 indicates the annual cost for energy consumption related to the old existing fluorescent lighting system.

Table 7: Annual cost for Energy Consumption related to the old existing Fluorescent Lighting System

Fluorescent luminaries types	Total Power for all Luminarie type Units (kW)	Energy consumption per Year (kWh)	The annual cost for paying EGY. tariff rates (LE)
TCS165 4XTL5-14W	51.301	61561.2	86185.68
TCS260 1XTL5-28W	5.704	6844.8	9582.72
TCS461 2xTL5-25W	0.44	528	739.2
TPS762 2XTL5-28W HFP AC-MLO TPS760	1.647	1976.4	2766.96
Targetti 402414 MINI	11.495	13794	19311.6
Total	**70.587**	**84704.4**	**118586.16**

All features and advantages for LED like the lifetime, Step power rating, luminaire efficacy (lm/watt), Dimming option, and Payback period make this proposed system better than the old and existing one with fluorescent, as a result, a new building lighting system is required to implement energy efficiency and minimize energy loss. The exact illumination (lux) level required for each area (space) in the proposed building and the brightness for each workplace area are calculated to achieve illuminance according to IES lighting standards and Lighting Power Densities (LPD) according to ANSI/ASHRAE/IESNA Standards [39].

The new proposed LED lighting system contains six types of luminaries and the quantities of the LED luminaries distributed among the building's different floors are shown in table 8 and figure (7). Also, the annual energy consumption cost related to the new proposed LED lighting system is shown in table 9 and also calculated according to the Egyptian tariff.

Table 8: Quantities of the LED luminaries among the building floors

LED luminaires	Quantity				Total
	Ground	First	second	Third	
60*60cm - 30W	42	181	219	168	610
60*60cm - 33W	50	0	0	108	158
30*120cm - 42.5W	0	29	0	0	29
Spot - 22W	100	27	24	24	175
Spot - 15W	0	101	94	80	275
Total					**1247**

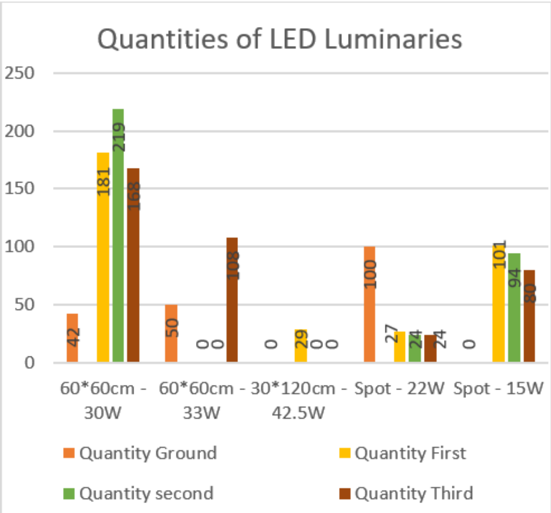

Fig.7 Distribution of LED luminaries.

The Annual energy consumption (kWh) estimated for the LED luminaries' type selection is illustrated in Table 9.

Table 9: Annual estimate energy consumption in (Kwh) for LED luminaries type selection

LED luminaries type	Power per unit of luminaire (Watt)	Units of electricity used (kWh) per year
SM400C LED36S/830 PSU W60L60	30	36
RC461B LED40S/BU840 PSD W60L60 PCV W	33	39.6
SP402P PSD W31L125 D-I LED50S/840 NO	42.5	51
CL261 DS Oyster 22W 30-40-65K IP54 ANZ and SUPERNOVA XS 260 274 87 2515 2600LM	22	26.4
SUPERNOVA XS 260 274 87 2515 1580LM	15	18

Table 10 indicate the annual cost for energy consumption related to the new proposed LED lighting system.

Table 10: Annual cost for Energy Consumption related to the new proposed LED Lighting System

LED luminaries types	Total Power for all Luminaire Type Units (kW)	Energy consumption per Year (kWh)	The annual cost for paying EGY.Tariff rates (LE)
SM400C LED36S/830 PSU W60L60	18.3	21960	30744
RC461B LED40S/BU840 PSD W60L60 PCV W	5.214	6256.8	8759.52
SP402P PSD W31L125 D-I LED50S/840 NO	1.2325	1479	2070.6
CL261 DS Oyster 22W 30-40-65K IP54 ANZ and SUPERNOVA XS 260 274 87 2515 2600LM	3.85	4620	6468
SUPERNOVA XS 260 274 87 2515 1580LM	4.125	4950	6930
Total	**32.7215**	**39265.8**	**54972.12**

Referring to the results in table 11, it can be concluded a final comparison between old existing and new lighting systems.

Table 11: Final comparison between old existing and new proposed lighting systems.

Luminaire types	Existing old system	Proposed new system
Luminaire quantity	1269	1247
Operating hours	8 hours	8 hours
Power in (KWh)	70.587	32.7215
(KWh)/day	564.696	261.772
(KWh)/month	7058.7	3272.15
(KWh)/year	84704.4	39265.8
Yearly energy saving (KWh)	84704.4 – 39265.8 = 45438.6	
% Saving in Energy consumption per Year (kWh)	(45438.6/84704.4) *100 = 53.64 %	
Cost energy saving per year (LE)	45438.6 KWh * LE 1.4 = LE 63614.04	
Total cost for luminaire purchase (LE)	232900	408800
ROI	(LE 63614.04+LE (408800-232900))/ LE 63614.04 = 3.765	

The extracted results show that the new lighting system requires fewer luminaires than the old existing lighting system, saving approximately 22 luminaires. Because of this notable difference, the new lighting system directly saves energy consumption through the lighting system while also providing better lighting conditions. Also, the annual power consumed by the new lighting system is about 45438.6 kWh lower than the old existing lighting system, with a cost-saving of about LE 63614.04. The ROI obtained from the new lighting system is about 3.765 years.

The Return On Investment (ROI) is obtained and calculated by using equation (3) [26].

ROI = [Energy Saving Cost + Different in Cost for luminaire Purchase] ÷ [Energy Saving Cost]

4.1.3. Automation Lab Space Sample

As a sample for implementation of standards, automation lab areas are taken and all results are according to Dialux simulation software and actual manufacturer technical data, For classrooms laboratory spaces (areas), the target illumination (lux) level according to IES lighting standard is ≥ 500 and Lighting Power Densities (LPD) according to ANSI/ASHRAE/IESNA 90.1.2010 Standards is 1.28 watt/sf as shown in figure (8), which equal to 13.77 watt/ m2.

1 square feet(sf) = 0.09290304 Square Meters (m2).

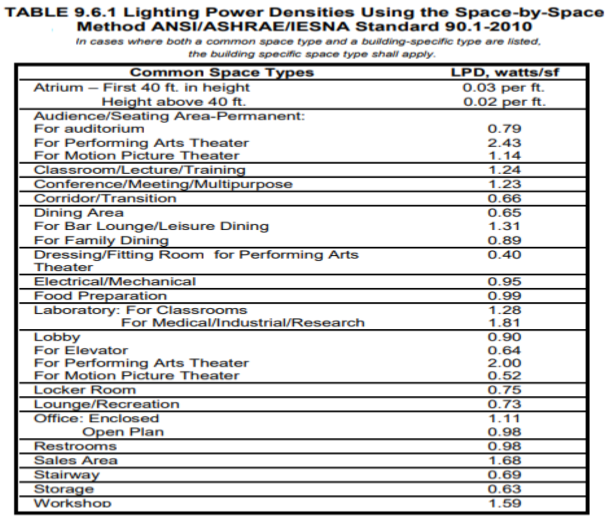

TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method ANSI/ASHRAE/IESNA Standard 90.1-2010
In cases where both a common space type and a building-specific type are listed, the building specific space type shall apply.

Common Space Types	LPD, watts/sf
Atrium – First 40 ft. in height	0.03 per ft.
Height above 40 ft.	0.02 per ft.
Audience/Seating Area-Permanent:	
For auditorium	0.79
For Performing Arts Theater	2.43
For Motion Picture Theater	1.14
Classroom/Lecture/Training	1.24
Conference/Meeting/Multipurpose	1.23
Corridor/Transition	0.66
Dining Area	0.65
For Bar Lounge/Leisure Dining	1.31
For Family Dining	0.89
Dressing/Fitting Room for Performing Arts Theater	0.40
Electrical/Mechanical	0.95
Food Preparation	0.99
Laboratory: For Classrooms	1.28
For Medical/Industrial/Research	1.81
Lobby	0.90
For Elevator	0.64
For Performing Arts Theater	2.00
For Motion Picture Theater	0.52
Locker Room	0.75
Lounge/Recreation	0.73
Office: Enclosed	1.11
Open Plan	0.98
Restrooms	0.98
Sales Area	1.68
Stairway	0.69
Storage	0.63
Workshop	1.59

Fig. 8 ANSI/ASHRAE/IESNA 90.1.2010 Standerd.

Table 12 shows the following date for space case study space. Also, case study lighting design criteria are shown in table 13. And calculation results and their analysis are shown in tables 14,15. and Dialux calculations are shown in figures (9), (10).

Table 12: Sample case study automation lab data.

Automation Lab Space Data	
Classification (ASHRAE – 9.6.1 table)	Class / training
Area (m^2)	76.1
No. of luminaires	16
Height (m)	3.0
Average number of op. hours per day	8
Average number of op. days per year	150

Table 13: Lighting design criteria for the case study.

Lighting Design Criteria	Fluorescent	LED
Supplier	Philips	Philips
Arrangement	Regular	Regular
Mounting Height (m)	3.0	3.0
Luminaire Wattage	61	34
Lamp Flux (Lumen)	3215	3598
Luminaire Effecacy (Lm/watt)	52.7	105.8
Light intensity (watt/m^2)	12.83	7.15
Light intensity (watt/sf)	1.192	0.69

Table 14: Calculation results for the case study.

Results	Fluorescent	LED	Standard (IES)
Eav[lux]	505	530	≥ 500
E_{min}[lux]	281	276	-
E_{max}[lux]	615	642	-
E_{min}/ E_{max}	0.46	0.43	≥ 0.4
E_{min} / E_{Av}	0.56	0.52	≥ 0.5

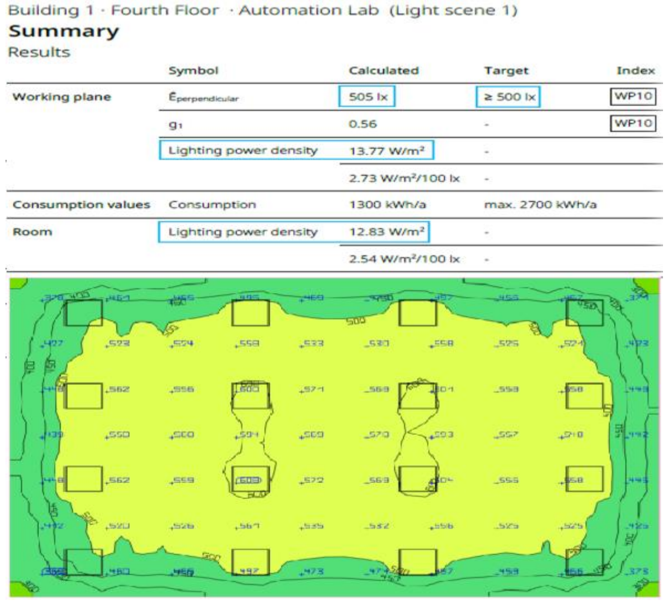

Fig. 9 Dialux calculatios fluorescent luminaires.

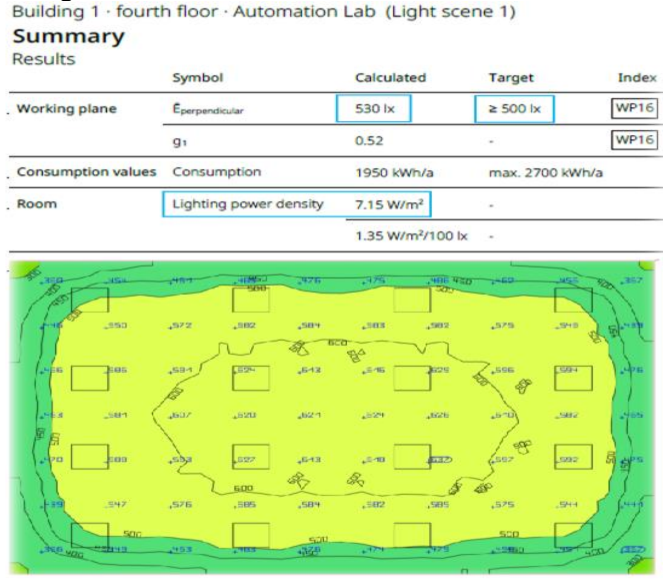

Fig. 10 Dialux calculatios LED luminaires.

Table 15: Case study calculation results analysis conclusion

Results Conclusions	Fluorescent	LED
Fixture nos. per space	16	16
power consumption (watt/m^2)	12.83	7.15

Energy consumption ($kWh/m^2/year$)	15.396	8.58
Energy Saving by using LED instead of Fluorescent	**44.27 %**	
Elec. Tariff Price (L.E)	L.E 1.4	
Consumption Running cost ($LE/year/m^2$)	21.5544	12.012
Total Running Cost (LE /year) (Space area = $76.1m^2$)	1640,28984	914,1132

4.2. Carbon Footprint Calculation Per Year

Referring to table 16 and figure (11), with the existing old lighting system, the total power in (kW), annual energy consumption in (kWh), and percentage value for each load type are calculated, then table 17 and figure (12) repeat these values with the new proposed lighting system.

Table 16: Power and energy consumption for each load type per year with the existing lighting system.

Load type	Total Power for each Load type (kW)	Total Energy consumption for each Load type per Year (kWh)	% Energy consumption for each Load type
Lighting	70.587	84704.4	20.5 %
Sockets	163.1	195720	47.3 %
HVAC	111.2	133440	32. %
Total	**344.887**	**413864.4**	**100** %

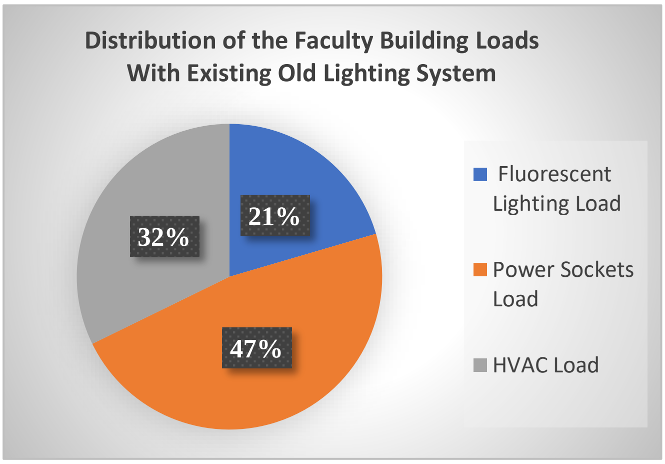

Fig. 11 % Value for each Load type with the existing system.

Table 17: Power and energy consumption for each load type per year with the proposed new lighting system.

Load type	Total Power for each Load type (kW)	Total Energy consumption for each Load type per Year (kWh)	% Energy consumption for each Load type
Lighting	32.7215	39265.8	10.7 %
Sockets	163.1	195720	53.1 %
HVAC	111.2	133440	36.2 %
Total	**307.0215**	**368425.8**	**100** %

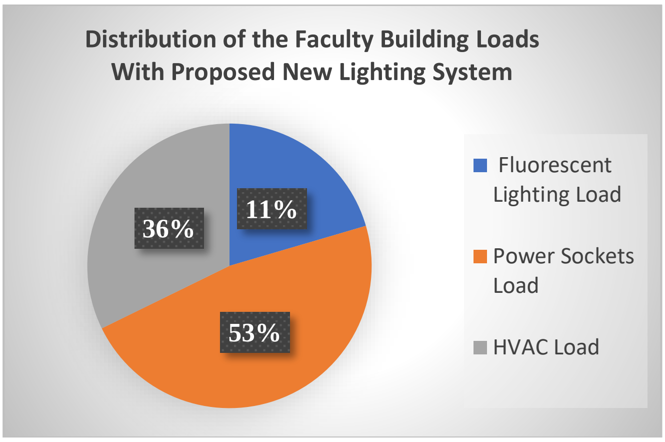

Fig. 12 % Value for each Load type with the new system.

The annual electricity usage is used to calculate the carbon footprint.

The calculation of CO_2 emission from electricity (in metric tons) = (Annual electricity usage in kWh/1000) x 0.84 according to [15].

i. CO_2 emission from electricity with old system = (84704.4/1000) x0.84=71.151696 metric tons
ii. CO_2 emission from electricity with new system = (39265.8/1000) x0.84=32.983272 metric tons

The calculation of % Saving in energy yields a reduction of CO_2 = (Yearly energy saving (kWh) ÷1000) x 0.84 (in metric tons) according to [15],[33].

iii. % Saving in energy yields a reduction of CO_2 = (45438.6/1000) x0.84=38.168424 metric tons

Finally, CO_2 emission reduction by (53.64 %)which is the same saving percent value in energy consumption per Year (kWh) as shown in figure (13).

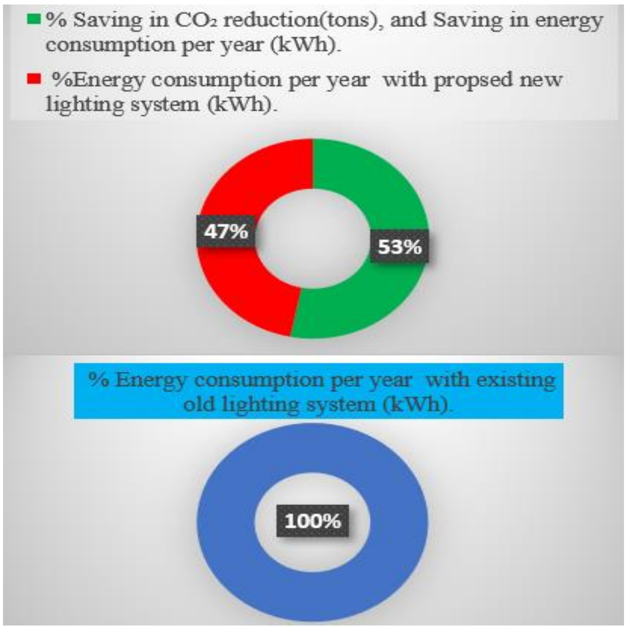

Fig. 13 % Saving in CO_2 reduction (tons) and saving in energy consumption per year (kWh).

4.3. Design of a rooftop photovoltaic (PV) system

Solar energy has recently emerged as one of the most common and inexhaustible renewable energies, playing an increasingly important role [40,41]. The evaluation of solar energy potential in a location where a PV system is scheduled to be installed is essential and would influence the system's success, and much depends directly on the local exposure to sunlight. The architectonic building is one of the most important aspects to consider when evaluating solar energy potential for roof-mounted Photovoltaic systems. Computer simulation tools are widely used to estimate PV system performance before constructing the actual system, thereby limiting materials and installation costs, whereas modeling and simulation of solar energy require a large amount of input data of solar irradiation, on-site weather conditions, and technical parameters of components [42].

The current study simulates and analyses a rooftop photovoltaic (PV) system on a roof area of the proposed academic building on the faculty campus for electricity power generation and its roof surface area as shown in figure (14) which is calculated using Google Earth TM Polygon feature.

Fig. 14 Map of electrical engineering building in AL-Azhar university generated from Google Earth ^{TM}.

A 148.2kW grid-connected photovoltaic (PV) system with a schematic diagram as in figure (15) is installed on the rooftops of proposed buildings with (1555 m2) roof surface area. The system employs a Chinese manufacturer of high-quality PV modules, as well as a general-purpose simple maintenance inverter that is suitable for small-scale applications. The PV system can provide the building loads electricity by both the PV module and grid, and the surplus PV module-generated energy is supplied to the utility [43].

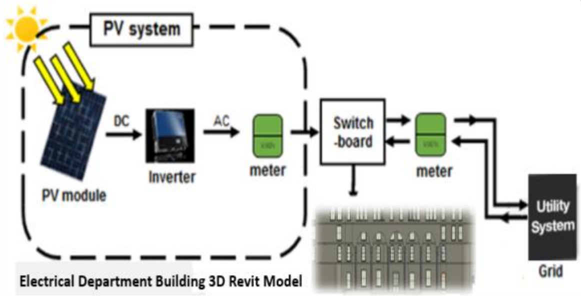

Fig. 15 Schematic diagram for proposed grid-connected photovoltaic (PV) system.

4.3.1. The Grid-Connected PV System Methodology

The Proposed case rooftop photovoltaic (PV) with technical data for location, PV module, inverter, cables, load, and system energy production is indicated in Table 18.

Table 18: Rooftop PV system technical data

Al-Azhar University, Faculty of Engineering, Electrical Dept,		
1	location	Egypt, Cairo, Nasr City
2	Latitude	30.06 N
3	Longitude	31.32 E
4	Altitude	95 M
5	Time Zone	UTC+2
6	Roof Total Area	1555 m^2
7	Percentage Used Area	45%
8	Roof Used Area	694 m^2
9	Azimuth Angle	180°
10	Slope Angle	26°

11	PV Module Type	Jinko solar PV module
12	Module Family Name	Tiger Neo N-type78HL4-BDV
13	Module Efficiency	21.46%
14	PV Module Capacity	600Wp
15	Number of String	13
16	Number of Modules Per String	19
17	Total PV Module Numbers	247
18	PV Total Power	148.2 KW
19	System Efficiency	70%
20	PV Output Power	103.74 KW
21	Average PV energy per year	216.4 MWh
22	DC cable	TUV 1×4 mm^2
23	AC Cable	4*70 mm^2 CU XLPE /PVC
24	MC4 Number	273
25	Smart String Inverter	Huawei Company
26	Inverter Type	SUN2000-185KTL-H1
27	Number of Inverters	1
28	Inverter Max. power	185 KW
29	Number of MPPT	9
30	Inverter Max. output current	134.9A
31	Inverter Max. Efficiency	99.03%
32	Total Demand Building Load	214.91505 KW
33	Annual Building Load Energy	257.8981 MWh
34	Percentage of the Annual PV Energy to Building Load Energy	83.9 %
35	Total Demand LED Lighting load	22.90505 KW
36	Annual LED Lighting Load Energy	27.48606 MWh
37	Percentage of the Annual PV Energy to LED Lighting Load Energy	12.7 %

The roof with effective surface area for mounting PV modules is determined based on the fitting of solar panels to the roof with about (45%) of the total roof surface area, the PV modules are installed in accordance with the roofs directions and tilted, i.e., 26o from horizontal taking shading calculation on the PV module to get slope angle of 36.5o. The PV panel's theoretical sitting and placement for proposed building roof orientations are shown graphically in figure (16).

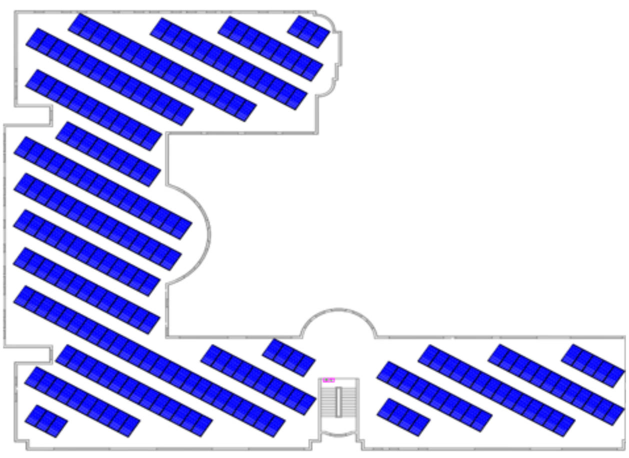

Fig. 16 PV panels theoretical placement for proposed building orientation.

The assessment of a specific location's solar energy potential necessitates the collection of site-specific meteorological data such as solar irradiation, humidity, and temperature [44]. The Sun path or technical parameters for the proposed site location in Egypt and PV energy production in (MWh) over a year are shown in table 19 and figures (17), (18).

Table 19: Global Radiation and Total Energy Production for the PV system.

Months (2021)	Monthly Global Horizontal Radiation	Total Number of days Per month	Total PV Energy Production (MWh)
January	3.48	31	11.1914712
February	4.27	28	12.4031544
March	5.56	31	17.8806264
April	6.64	30	20.665008
May	7.41	31	23.8301154
June	7.93	30	24.679746
July	7.71	31	24.7948974
August	7.19	31	23.1226086
September	6.28	30	19.544616
October	4.98	31	16.0153812
November	3.82	30	11.888604
December	3.23	31	10.3874862
Annual PV Energy Production (MWh)			216.4037148

The capacity simulated module capacity is 600 kWp per case, and the total production energy is estimated by multiplying (scaling up) the results with the appropriate roof capacity as (600*247) /1000 = 148.2 kW).with 70% PV system efficiency, then the total PV output power is calculated as (148.2*0.7) /1000 = 103.74 kW).

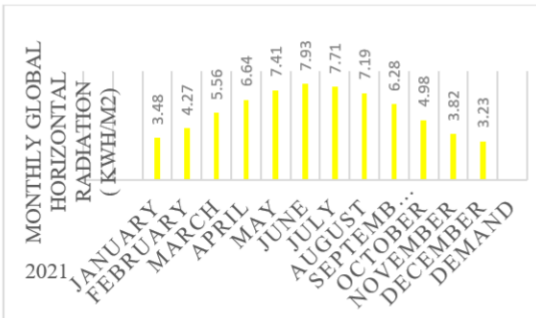

Fig. 17. Monthly global horizontal radiation per year for proposed site location.

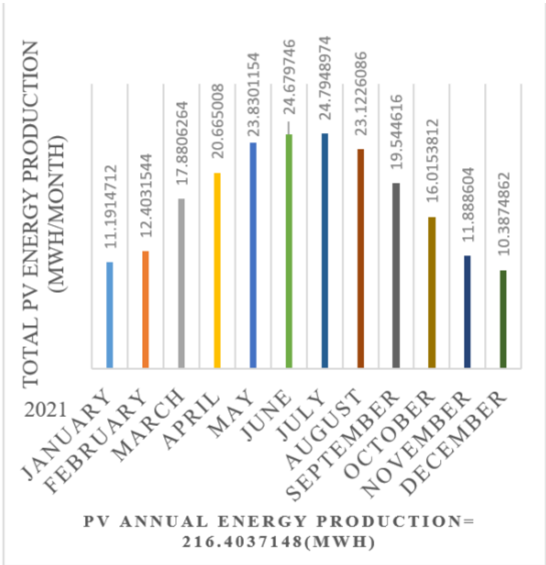

Fig. 18. PV Annual Production Energy in (MWh).

4.3.2. Comparison Between PV and Building Demand

According to results obtained in table 17 and table 18, in the presence of the proposed new LED lighting system with a load of (32.7215 kW) a demand value of (22.90505 KW) and annual energy of (39.2658MWh) and its demand value is (27.48606), where LED load is apart from a total building load with (307.0215kw) and its demand value is estimated as (307.0215*0.7) = (214.91505 kW). Also, the total annual building load energy consumption is (368.4258MWh) and its annual demand value is (257.8981 MWh). With the grid-connected PV system with an annual energy production value of (216.4037148MWh), its cover (58.74 %) of total annual building load energy consumption and supply about (83.9%) of its annual energy demand. and with comparison in the presence of an LED system, the PV system cover (18.145%) of total annual LED load energy consumption and supply about (12.7%) of its annual energy demand.

5. Conclusion

As seen in (Table 1), green activities are being implemented on Egyptian university campuses to achieve sustainability. Therefore, this study used data from international and local insights, studies, documents, and standards on sustainability in the Presentation of how implementing green practices to achieve sustainability in part at the level of the campus of one of the world's oldest and most prestigious universities, namely Al-Azhar University. Also in line with the direction and vision of the Egyptian state, which is also in line with the international trend toward achieving SDGs.Based on UI Green Metric world universities ranking, a criterion was adopted that holds the highest percentage in the ranking as well as receives the greatest attention as one of the most important pillars adopted by Egypt's vision 2030, which is the energy and climate change criteria, Therefore, it was agreed on the partial application of the most important criteria detailed in the ranking, which are four indicators in line with the current situation of the university campus under study and aim to achieve energy savings, carbon emissions reduction, and exploit the renewable energy sources available trying to change the current situation and create a situation that achieves those desired goals.

Case study results show that it was reached concerning the first criterion to provide a percentage of (53.64%) saving in consumption for the building, after replacing the old lighting system with a modern LED one that meets the standards and takes into account the cost, and concerning the second criterion, a solar energy unit was reached an average annual value of (216.4 MWh) according to the area of power of the building aimed at partially feeding the loads, and at other times the network is fed with the surplus of it, and considering the ratio of its generation to the building's annual consumption which about (83.9%) from its annual energy demand according to the third criterion, this was calculated. The fourth criterion was taken into account, and it is an estimated reach (53.64 %) reduction in CO2 carbon emissions with the new proposed situation, and also roof-top PV (RTPV) gives more reduction for carbon footprint as mentioned in [45], this more CO2 reduction according to RTPV shall be taken into account in the future. Finally, with SDGs [46], the proposed research achieves its main goals and takes even a step toward applying sustainability standards within the campus of Al-Azhar University.

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