Journal of Sustainability Perspectives: Special Issue, 2023, 572-580

Journal of Sustainability Perspectives

journal homepage: https://ejournal2.undip.ac.id/index.php/jsp/

Towards Efficient Energy Usage at Ain Shams University Campus

Walid El-Khattam[1], Adel ElSabagh[2], Ghada F. Hassan[3], Mohamed Ayman Saleh[4], Mahmoud El Meteini[5]

[1]*Electrical Power & Machines Engineering Department, Faculty of Engineering, Ain Shams University, Professor, El-Khalyfa El-Mamoun Street Abbasya, Cairo, Egypt*

[2]*Design & Production Engineering Department, Faculty of Engineering, Ain Shams University, Professor, El-Khalyfa El-Mamoun Street Abbasya, Cairo, Egypt*

[3]*Urban Design & Urban Planning Engineering Department, Faculty of Engineering, Ain Shams University, Professor/Vice President for Community & Environmental, El-Khalyfa El-Mamoun Street Abbasya, Cairo, Egypt*

[4]*Cardiovascular Department, Faculty of Medicine, Ain Shams University, Professor/Vice President for Postgraduate Affairs & Research, El-Khalyfa El-Mamoun Street Abbasya, Cairo, Egypt*

[5]*General Surgery Department, Faculty of Medicine, Ain Shams University, Professor/ President, El-Khalyfa El-Mamoun Street Abbasya, Cairo, Egypt*

*corresponding author: president@asu.edu.eg

Article Info

Received:
23 May 2023
Accepted:
13 November 2023
Published:
15 November 2023

DOI:
10.14710/jsp.2023.21646

Presented in the 9th International Workshop on UI GreenMetric World University Rankings (IWGM 2023)

Abstract. In the light of global energy transition to renewable resources and energy efficiency usage, Ain Shams University (ASU) developed an ambitious plan to transform its campus into Green Campus. From an energy perspective, energy consumption data were continuously collected and audited to calculate the university campus carbon footprint. An energy usage strategy was established to tackle various pillars such as electrifying the campuses' transportation system, improving energy efficiency usage, generating Renewable Energy (RE) for self-consumption, etc. Extensive research has been initiated on electric vehicles, wind and solar Photovoltaic (PV) energy generation with students' activities/competitions. Thus, electric cars and buses were manufactured at the Faculty of Engineering (FoE) for elderly people and staff movement in ASU campus. Solar PV lighting poles with batteries were installed in the main campus. A small-scale Wind Turbine (WT) is manufactured and installed at the FoE and a pilot solar PV system is installed as well. Currently, an energy efficiency project is under implementation in various buildings/faculties and a parking lot that targets energy efficiency and solar PV energy generation. An energy efficiency measure is under implementation through replacing lamps with LED lamps, installing motion sensors, setting up a control center for monitoring and operation that is supported by Artificial Intelligence decision making algorithms. Rooftop solar PV energy systems are under design with smart meters. The project is targeting energy saving and bill reduction by at least 30% and as a result a reduction of carbon footprint will be achieved following the COP27 recommendations.

Keyword:

Efficient Energy Usage, Energy Efficiency Retrofit, Green Campus, Renewable Energy, Segmented Blade, Sustainable Energy

1. Introduction

Natural gas, oil, and coal prices have risen to their highest levels in decades because of cost unaffordability of these resources, desire for rapid economic growth of post COVID19 pandemic period, and the current world-wide political instability. In the meanwhile, the energy transition concept from conventional energy generation to RE generation took place a couple of decades ago. The contribution of RE generation did not cover the energy demand, however, CO2 emission showed minor reduction. As a result of fossil fuel prices increases and insufficient RE generation, energy prices are soaring, and reasonable amount CO2 emissions still exists. Thus, countries were forced to adopt efficient energy usage strategies in their demand-side.

In 2014, the Egyptian government issued a 5-Year plan to remove electricity's subsidy. However, due to the economic issues and consequent devaluation of the Egyptian currency started in 2017, the plan was extended to 2025. Furthermore, Egypt took measures to reduce the use of its natural gas consumption in power generation, instead exporting it and use oil-fired technology in power plants. In the meantime, the energy generation plan was shifted to RE capacity; 3.1 GW of installed wind and solar PV, 2.8 GW hydropower, and an additional 2.8 GW of planned RE to be commissioned by the end of 2023. On the other hand, in August 2022, Egypt adopted demand-side measures to reduce electricity consumption targeting reductions in lighting and air conditioning in buildings, and street lighting and advertising panels [1].

Reducing energy consumption/bills and carbon footprint have become a need [2]. Concentrating on educational buildings, efficient use of energy can be achieved in new and existing building [3]. For new buildings proper energy efficient design must be taken into consideration: building orientation, use natural ventilation, rely on daylighting, perform thermal mass analysis [4]. On the other hand, for existing buildings, implementing energy efficiency retrofitting concept through renovation and refurbishment of existing buildings can upgrade the energy performance of building assets for their ongoing lifetime. This can be achieved while reducing the operational cost (electricity bills) and saving the environment. Various energy strategies can be used to reduce energy consumption such as: installing RE technologies, applying energy efficiency measures, and utilizing building automation systems. First, installing RE-based distributed generation such as rooftop solar PV systems or small-scale Wind Turbines (WTs) for self-consumption result in decreasing electricity demand from the grid [2 and 10]. Second, implementing energy efficiency measures that include installing high efficiency lighting fixtures, replacing traditional lamps by LED lamps to save at least 50% of the energy consumption, using high efficiency appliances for example air conditions with efficient energy label grades, and installing proper wall shading, irrigation, and insulation technologies [11]. In the meanwhile, installing motion sensors that disconnect the supply if rooms are unoccupied thus reduce unnecessary energy usage. Third, applying building automation systems can be used to control lighting, cooling/heating such as Building Measurement Systems (BMS) to provide advanced programming measures by reporting real-time energy usage, allowing online decision-making to reduce energy consumption [8].

ASU developed an aspiring plan to transform its campus into green campus. From the energy perspective, ASU is following the government approach for applying energy efficiency retrofitting concept in its buildings to reduce energy consumption and lower the campus carbon footprint. In this paper, the energy efficiency retrofitting concept under research and implementation are reported, discussed, and concluded.

2. ASU Energy Efficiency Retrofitting Concept

ASU is one of the oldest and most prestigious universities in Africa and the Middle East. It was founded in July 1950. ASU has +250K students, +14K faculty staff, 19 faculties, 1 postgraduate institute, +10K employees, 19 libraries, 11 hospitals, an innovation hub, and five centres of excellences; Centre of Excellence for Energy, Water, Waste to Energy, Agriculture, and Sustainability. ASU realized the importance of building capacity in the fields related to clean and RE many years ago. Many research projects have been implemented in these fields. These projects were funded by the European Union (EU) under Tempus and Erasmus+ programs, USAID, KFW Development Bank, and Science, Technology & Innovation Fund (STDF-Egypt). Since 2010s, ASU campus is going under major renovation taking into consideration energy efficiency measures and climate impacts. The ASU in-place energy efficiency retrofitting concept includes:

i) Installing RE-based distributed generation: small scale WTs & solar PV.
ii) Applying energy efficiency measures: replacing fluorescent lamps by LED lamps & installing motion sensors.

Utilizing building automation systems: smart meters & control centers.

3. ASU Energy Efficiency Retrofitting Concept Implementation

The in-place energy efficiency retrofitting concept and research activities implemented by ASU are reported and discussed in the following subsections:

3.1 Installing RE-based distributed generation

a. In the field of wind energy at ASU:

In 2010, one of the main projects started under the title of “Innovative Techniques for the Design and Manufacturing of WT Blades” was funded by STDF-Egypt. This project was the seed for wind energy activities at ASU. In 2016, the ASUWind team has been established with the objective of developing a new generation of engineering graduates who possess the necessary engineering skills in the field of wind energy. ASUWind team was the first non-

European university team to participate in the International Small WT Contest (ISWTC) organized annually in Netherlands. Every year, new engineering students are enrolled to the team to design and manufacture a WT of rotor diameter 1.6m, to be tested at the wind tunnel facilities of TU Delft. Several achievements have been realized by the ASUWind teams including the best Annual Energy Production (AEP) award in 2019 and 2022, Figures 1 and 2.

Figure 1. ASUWind Team preparing for the test in 2018 at TU Delft.

Figure 2. ASUWind Team celebrating the best Annual Energy Production Award in 2019.

Recently, the ASUWind team has been invited to participate in another students' competition in Netherlands which is the Racing Aeolus Den Helder; one of the largest sustainability races in the world. Since 2016, +150 multi-disciplinary engineering students from different engineering programs have joined the ASUWind and many of the graduates are now working in fields related to RE in Egypt and Europe. The ASUWind team is now operating under the umbrella of the Energy Technology and Climate Change (ETCC) Lab. which was established in the Acoustics Building in 2021. The ETCC lab. addresses the local and regional energy challenges for which the energy technology solutions are investigated to achieve sustainability. This lab. disseminates and creates knowledge in the fields of energy technology; hybrid energy systems; hydroelectric energy storage; WTs design and manufacturing; life cycle management and assessment of wind farms; and energy-water-food nexus. Additional priority themes include biomass valorization to sustainable fuels; shallow geothermal systems; and high-performance computational science applications. Currently, the lab. is responsible for several research projects such as: Co-fermentation of agricultural residues and organic wastes for biogas production, and geothermal energy capacity building in Egypt.

As a result of seven years of work, the ASUWind team adopted the objective of being a research leader in small-scale wind energy systems for commercial use in Egypt. The team aims at building on-grid and off-grid wind energy generation systems. Those systems consist of a Horizontal Axis WT whose diameter ranges between 5 to 10 m fixed on a tower of height 12 to 18 m, connected to a Permanent Magnet Generator and control circuits to produce electrical energy with constant AC voltage and frequency within an output power in the range of 5-15kW. This system can be used to provide electricity to remote and urban areas with clean electrical power. A preliminary feasibility study proved the financial feasibility of the proposed product in case of producing and selling at least 500 systems annually. The study also shows the savings which will be achieved by customers consuming more than

1,500 kWh per month. A prototype of the proposed system is already designed and established at FoE, ASU. The prototype includes a WT with a rotor diameter of 5.5 m, the tower is 10 m high and supported by an active yawing system. The 5 kW permanent magnet generator generates 3-phase electrical power which is converted to DC current by means of a charge controller. The power is then stored in a bank of nineteen 12V deep cycle batteries to be converted into single phase 220V AC supply by means of an electric inverter. Measurements were taken at different locations at FoE to identify best places with uniform wind speed to install the WT. It was decided to install the WT on top of the Mechanical Engineering Building mounted on an unused water tank on the roof. The WT is equipped with a controlled erection system to facilitate maintenance and modifications during the testing period. Figure 3 shows the turbine during erection. The whole system except for the tower was fully manufactured within the laboratories of FoE, ASU. Figure 4 shows the turbine after full installation. The WT is currently operating, and measurements are recorded to identify the amount of developed power at different wind speeds.

Figure 3. The WT tower during erection tests

Figure 4. The 5 kW WT is up and running at FoE, ASU

ASU supports scientific research aiming at finding breakthroughs for the design and implementation of wind energy systems. The project, mentioned earlier, aimed at constructing blades out of several segments to facilitate the manufacturing and transportation techniques. Figure 5 shows the construction of the proposed segmented WT blade, which was constructed as a prototype and tested for durability to external loads [12]. Recently, more innovative approaches are investigated at FoE, ASU. One of those innovative ideas which was fully developed by FoE, ASU is the use of Inflatable WTs fabricated from polymer materials. The research team has published several publications which prove that this purpose is achievable [13 – 15]. Figure 6 shows 3D laser scanning that was utilized to check the geometry together with aerodynamic testing in wind tunnels of Chalmers University in Sweden to test the aerodynamic performance of the fabricated blade sections. This innovation can achieve new designs which are less expensive, safer, and friendly to the environment when compared to conventional blades fabricated from fiberglass materials.

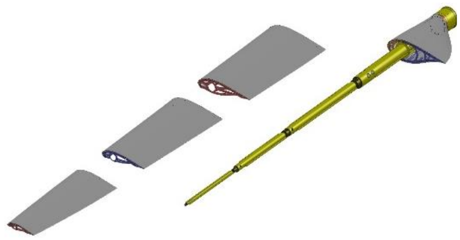

Figure 5. Innovative segmented blade designed and manufactured at FoE, ASU

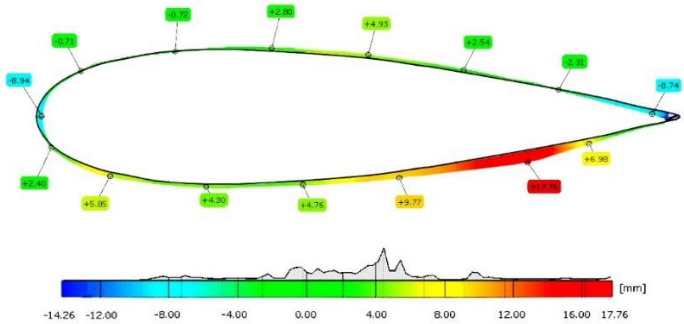

Figure 6. 3D laser scanning of the inflated blade as compared to the original design

b. In the field of solar PV energy at ASU

ASU renovated its main campus taking into consideration environmental measures, for example, solar PV lighting poles with batteries were installed in campus sides-walks and greenery areas. A pilot 2kW solar PV system installed at the roof of the Centre of Excellence for Energy at FoE for teaching and research activities. Furthermore, regarding the electrification of the transportation system inside the campus, eight electric cars and buses were manufactured by FoE for elderly people and staff movement in the campus and hospitals.

In 2010, ASU Racing Team was established to carry out research related to design and manufacture energy efficient cars for students' competitions. In 2015, the team worked on manufacturing an electric car and won the 1st place in the Egyptian Electric Cars Rally "EVER" in 2018.

In 2022, ASU won a 2.2 million Euros project from KFW entitled: "Energy Efficiency–Accompanying Measures in Egyptian Universities." The aim of the project is to use energy efficiency retrofitting concept to reduce the energy consumption. The ASU team chose eight buildings and one

Table 1. Candidate building number and its total roof area, installed solar PV system capacity and cost, and solar PV energy generation benefits

Building #	**Total Roof Area^{+} (m^2)**	**Solar PV System**		**Energy Generation Benefits^{++} (Million LE/Year)**
		Capacity (kWp)	Cost (Million LE)	
1	5,300	450	12.15	1.0692
2	2,500	340	9.18	0.8078
3	1,600	130	3.510	0.3089
4	2,700	200	5.400	0.4752
5	6,600	500	13.50	1.1880
6	1,300	210	5.670	0.4990
7	2,300	225	6.075	0.5346
8	1,500	120	3.240	0.2851
9	1,800	160	4.320	0.3802
Total	25,600	1,885	63	6

$^{+}$ Approximate total area. The actual available area is calculated case-by-case due to shading and roof geometric shape. $^{++}$ Energy generation benefits shown is calculated for the 1st year. Consequent years' benefits took into consideration the grid electricity tariff annual increase.

Parking lot to install rooftop solar PV systems. The generated electricity is used for self-consumption as it is limited by the available rooftop buildings' areas. The lifetime of the solar PV panels is 25 years, thus, the inverters are replaced three times during the project life. A cost-benefit analysis was carried out taking into consideration time value of money, yearly degradation of the solar PV panels, and yearly increase of the grid tariff. A simulation software was implemented to calculate the solar PV system capacity, design, and amount of expected energy generation. Table 1 shows a summary of available rooftop areas, solar PV installed capacity and cost, and the resultant yearly benefits from installing these solar PV systems. The benefits include both cost of unused energy consumption from the grid which is equal to the amount of solar PV energy generation plus the benefit resulting from reduction in peak hour charge. The payback period was calculated to be around 15 years. Table 2 shows solar PV system design results for building_1 with a daily measured design solar radiation of 2.85 kWh/m2 that obtained a total of 781 MWh annual energy generation and CO2e savings of 456 million Ton.

Table 2. Building_1 solar PV system design results

# of PV Module+++	# of Series PV Modules	# of Parallel PV Strings	# of Inverters
837	27	31	6

+++ PV module nominal power is 540Wp

3.2 Applying energy efficiency measures

For the same Energy Efficiency project mentioned above, the ASU project team applied many measures to reduce its energy consumption. This section concentrates on replacing fluorescent lamps by LED lamps to achieve the following benefits: reducing lighting consumption by at least 50%, lowering energy consumption during peak hours based on the installed LED lamps capacity, and improving the power factor as fluorescent lamps power factor is 0.55 and LED power factor is 0.95. A cost-benefit analysis was carried out taking into consideration time value of money and yearly increase of the grid tariff. For example, Table 3 shows lighting system replacement results for building_1. The CO_2e savings was calculated to be 52.4 million Ton and the payback period is around 4.5 years.

Table 3. Building_1 lighting system replacement design results

# of 10 W Lamp	# of 20 W Lamp	Lighting System Replacement (Million LE)	
		Cost / Replacement Cycle+++	Benefit ++++/ Year
3,384	2,027	0.6815	0.1391

+++ Lamps replacement cycle is every 6 years based on the lamps' lifetime, i.e. four times in the total lifetime of the project, 25 years. ++++ Benefits shown is calculated for the 1st year. Consequent years' benefits took into consideration the grid electricity tariff annual increase. The benefits includes both cost of savings in unused consumption from the grid which is calculated from lamps technology replacement plus the benefit of reduction in peak hour charge.

A number of 100-motion sensors was calculated to be used in Building_1 as one of the used energy efficiency measures to disconnect the supply for unoccupied rooms. The benefit is estimated to reach 10% of the energy consumption in places where sensors are installed.

However, actual savings need extensive actual measurements after installation.

3.3 Utilizing building automation systems

In the Energy Efficiency project, each building will be equipped with a smart meter that communicates directly to a BMS and to a control centre. This centre will be located at FoE where energy management decisions will take place. Control of lighting, heating, and cooling operations will be an added value for this project to reduce the electricity consumption and buildings carbon footprint. The benefits estimated to be 5% of the energy consumption in the controlled lighting systems and appliances. Actual savings need extensive actual measurements after installation.

4. Conclusions/Summary/Future Perspectives

ASU drafted an ambitious roadmap to transform its campus into a green campus. The energy efficiency retrofitting concept was relied on to reduce energy consumption and carbon footprint. Combination of energy consumption reduction strategies were implemented such as installing wind and solar PV energy systems, applying energy efficiency measures, and utilizing building automation systems. ASU is working on implementing real life projects, as well as, involving students into clean energy fields through local and international competitions. Finally, ASU is aiming at marketing porotypes resulting from graduation projects and research activities. For example, promoting the use of small wind energy systems on top of buildings. Currently, ASU is investigating the possibility of installing WTs with one of the major Egyptian organizations to be placed on top of their buildings.

References

[1] IEA, *Electricity Market Report 2023*, Available online at https://www.iea.org/reports/electricity-market-report-2023, accessed on 20 April 2023.

[2] P. Marrone, P. Gori, F. Asdrubali, L. Evangelisti, L. Calcagnini, and G. Grazieschi, "Energy benchmarking in educational buildings through cluster analysis of energy retrofitting," Energies, vol. 11, p. 649, March 2018.

[3] Z. Ma, P. Cooper, D. Daly, and L. Ledo, "Existing building retrofits: Methodology and state-of-the-art," Energy Build, 2012, 55, pp. 889–902.

[4] H. Zhao and F. Magoulès, "A review on the prediction of building energy consumption," Renewable & Sustainable Energy Review, 2012, 16, pp. 3586–3592.

[5] Z. Ma, R. Yan, and N. Nord, "A variation focused cluster analysis strategy to identify typical daily heating load profiles of higher education buildings," Energy, 2017, 134, pp. 90–102.

[6] F. Ascione, N. Bianco, R. F. De Masi, G.M. Mauro, and G. P. Vanoli, "Energy retrofit of educational buildings: Transient energy simulations, model calibration and multi-objective optimization towards nearly zero-energy performance," Energy Building, 2017, 144, pp. 303–319.

[7] F Asdrubali, G Grazieschi "Life cycle assessment of energy efficient buildings," Energy Reports, 2020, vol. 6, pp. 270-285.

[8] H. Ibrahim, M. S. Elsayed, W. S. Moustafa, and H. M. Abdou, "Functional analysis as a method on sustainable building design: A case study in educational buildings implementing the triple bottom line," Alexandria Engineering Journal, vol. 62, pp. 63–

73, Jan. 2023.

[9] L.-R. Jia, J. Han, X. Chen, Q.-Y. Li, C.-C. Lee, and Y.-H. Fung, "Interaction between thermal comfort, indoor air quality and ventilation energy consumption of educational buildings: A comprehensive review," Buildings, vol. 11, p. 591, Nov. 2021.

[10] F. Asdrubali, L. Calcagnini, L. Evangelisti, C. Guattari, and P. Marrone, "Effectiveness of materials, technologies, and renewable energy in educational buildings through cluster analysis of energy retrofitting," Sustainable Building for a Cleaner Environment, pp. 25–37, Springer International Publishing, July 2018.

[11] S. Grigoryeva, A. Baklanov, D. Titov, V. Sayun, and E. Grigoryev, "Analysis energy efficiency of automated control system of LED lighting," International Siberian Conference on Control and Communications (SIBCON), IEEE, June 2017.

[12] T. Elnady, A. Elsabbagh, AH Abdulaziz, Testing and Validation of a Novel Segmented Wind Turbine Blade, *Journal of Testing and Evaluation* 47(5), 2018.

[13] S. Okda, V. Chernoray, A. Elbanhawy, W. Akl, and A. Elsabbagh "Testing of the Aerodynamic Characteristics of an Inflatable Airfoil Section," *Journal of Aerospace Engineering* 33 (5), 2020.

[14] S. Okda, W. Akl, A. Elsabbagh, Structural behaviour of inflatable PVC fabric cylindrical tubes, *IOP Conference Series: Materials Science and Engineering,* 610 (1), 2020.

[15] A. Elsabbagh, Nonlinear Finite Element Model for the Analysis of Axisymmetric Inflatable Beams, *Thin-Walled Structures*, 96, 2015, pp. 307 – 313.