Sustainable Energy Production Solutions in Railway Stations

Reham Eldessuky Hamed

Assoc.Prof. Beni-Suef University, Architecture Dep., Faculty of Engineering, Beni Suef, Egypt, Reham011299@eng.bsu.edu.eg

Abstract

The global energy recession is one of the biggest challenges and characteristics of our time and requires the activation of sustainable energy use and the application of the necessary environmental solutions. The focus will therefore be on developing green and sustainable railway stations that reduce emissions, generate energy, improve operational performance, and increase protection rates. This is reflected in Egypt's current development strategy in the existing and new railway station sectors, which encourages sustainable management, resource efficiency, user convenience, and economic viability. A case study of the Beni Suef railway station, a pole of urban development between Cairo and Upper Egypt, whose railway station became the most influential in the Upper Egyptian Railways' central region There are three stages to the analytical methodology: first, an assessment stage of the station's current situation, including buildings, service, and sustainability. Second, the energy consumption rating evaluation stage leads to sustainable energy production solutions. The third is energy design modification, which includes building retrofit, piezoelectric retrofit, and context retrofit.

Keywords: *Sustainable Energy, HumanitariaArchitecture, Senses of Place, Beni Suef railway station, Piezoelectric energy.*

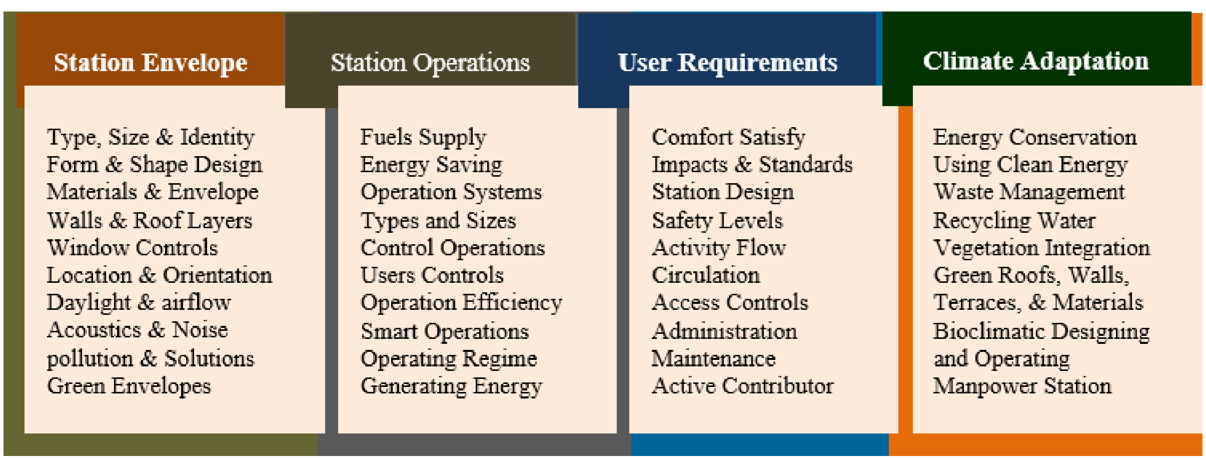
1- INTRODUCTION

Sustainability and its potential implications for railway systems are becoming increasingly popular. Sustainable development takes into account the natural constitutional motivation to positively impact a place and leave a positive and lasting legacy [1]. Generally, transit needs to achieve a climate where cultural, environmental, and financial factors are all taken into account when making transportation plans. Strategic sustainable development purports through socio-economic and ecological characteristics, which relate to a set of "sustainable railway key targets, and measurable indicators are preferred in strategic and long-term management. Railway stations have high occupancy rates and are often open all the time, so it is necessary to save energy as it is considered one of the busiest government facilities by increasing the efficiency of environmental architectural design and energy conservation requirements. Accordingly, reducing energy consumption is critical in designing and operating railway station buildings, which include buildings, train lines, passenger circulation, and movement tracks. This generally requires energy savings of at least 50% when compared to existing stations, following special international recommendations for railway buildings with high energy efficiency and low emissions [2].

2- Railway Energy Performance

The problems users currently face are a lack of ventilation, lighting, and thermal comfort in general. Although the lanes and directions of movement towards the departure and arrival stations are determined by sensing other changes to reduce energy consumption rates, energy savings cannot be limited to reducing the use of artificial lighting and ventilation. This negatively affects user comfort, which requires direction to implement alternative environmental solutions. Energy and environmental railway performance could be improved further by changing the insulation layer of the buildings and using green energy systems that rely on charging and discharging operations throughout their life span [3]. However, with the complexity of railway station design and the importance of energy efficiency gains, architectural solutions must be thoughtfully implemented and operated with a multi-integrated approach to reduce energy consumption. such as passive design, control system operations, and energy-saving equipment upgrades. Most architects do not highlight integrated energy management systems when designing buildings, particularly railroad stations, because they are more concerned with electrical design and information technology. There are four factors influencing railway station energy consumption [4], shown in Fig. 1. The first is the station envelope, which includes the type and size, form and shape, materials and window controls, location and orientation, daylight and airflow, acoustics, and pollution. The second category is station operations, which includes fuels and energy, system types and sizes, control operations, and users. Third, user requirements include comfort and environmental standards, station design and safety, activity flow and access controls, administration, and maintenance. Fourth, climate change adaptation strategies include encouraging energy conservation, clean energy use, waste recycling, incorporating vegetation into roofs, walls, and green terraces, and designing and operating bioclimatic stations.

Fig.1. The Four Factors Influencing Railway Station Energy Consumption



Based on the current conditions and capabilities of railway stations, investing equal amounts of time and resources in all aspects will be critical in finding solutions for energy production. Compact stations use less energy in hot climates because heat loss and gain are important factors influencing energy and environmental performance [5]. Poor front facade design results in higher costs for comfort and operating costs throughout the various stages of environmental architecture treatments. As a result, a successful energy-saving plan that includes design, construction, installation, commissioning, and commissioning should be highlighted. Energy-efficient building strategies for energy savings in railroad stations include passive building design, energy-saving electromechanical equipment, and energy operations management. Sustainable technical solutions could be achieved at existing stations as well as through participation techniques [6]. Table 1 shows the energy consumption analysis of the railway station for the various design spaces.

Table.1: Railway Station Energy Consumption Approach, Primary Design Phase

Railway Station Energy Consumption Approach Primary Design Phase			
Design Stages	**Architectural Concept**	**Energy Impact**	**Comfort Requirements**
Location & Layout Orientation	-Accessible and secure entrances -Proximity to the ticketing gates - Train departure with shorter wait times - Generating, waiting spaces - Simple distances and corridors - Availability of service and interaction with management. - Building orientation is a critical factor in energy conservation. - User convenience, pleasure, smooth movement, and a distinct impression; promoting thermal, visual, ventilation, acoustic comfort, and environmental friendliness.	- Space distinctions (temperature, airflow, air-conditioning) - Variations in air conditioning loads and air circulation - Heat gain or loss in corridors and open spaces - The amount of energy saved is determined by the design concept of the exterior context, interior spaces, and envelope cross sections. - Achieve compatibility between the user's thermal, ventilation, visual, and energy conservation senses.	**- Achieving thermal, visual, and acoustic comfort and pure ventilation.**
Architecture & Construction Design	-Saving large interior spaces that facilitate the user's movement and needs -Energy design solutions are examples of the building envelope, roof shading, glazing, and openings revisions. - Daylighting and ventilation design - Create integrated vertical stations in temperate climates for extreme and side-line stations. - A higher window-to-wall ratio results in more solar gain. - High	-Increases air conditioning demand. - Halls, open spaces, meeting halls, waiting areas, and reservation zones must be energy efficient. - Increased passenger flow can be a source of energy. - Redesign of passenger paths, vehicle routes, railway tracks, and ancillary power generation building spaces. -The form factor of the building has the potential to save significant energy and is	**- Improves architectural function and is environmentally friendly.**

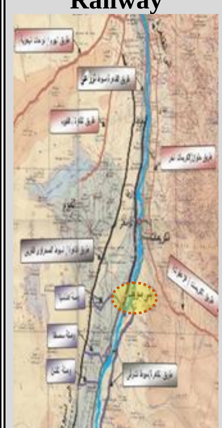
	ceilings based on a steel structure. - A building's surface area to volume ratio determines the extent of heat gain and loss. The greater the surface area, the greater the heat gained and lost.	associated with mechanical, electrical, and plumbing design. - The distribution of interior space enhances the efficiency of both space and facilities.	
HVAC Systems	- Recovery devices for cooling and heating with fresh air units - A central air conditioning plant with a high-performance coefficient - Networks for integrating cooling, heating, and power generation - Building automation for HVAC control. - Energy conservation, efficiency, and alternative energy sources	- Energy savings from exhaust air recovery could reach 60%. - Continuous appliance improvement and performance - By implementing procedures, energy efficiency can be increased. - Inadequate energy integration management: reducing consumption while increasing energy productivity - Towards zero energy consumption	**- Standards for air-conditioning and air filtering.** **- Monitoring and control systems.** **- Maintain the quality of the indoor environment.**
Lighting Systems	- Use energy-efficient lighting for safety and security (all-night lighting) - Control intelligent lighting systems - Stations integrating LED systems	- Making an effort to use both energy-saving and energy-producing appliances. -Solutions for lighting overlapping level issues in spaces. - Effective rates of reducing energy consumption	**- Illumination Standards**
Power and Energy Supply	-Using renewable energy sources (gear/hydro heat pumps). - solar photovoltaic energy (Piezoelectric energy)	-Selecting suitable designs, fixtures, and systems - Relying on renewable energy sources for feeding	**- Clean, Green, Sustainable Resources**

Long-term conceptual solutions include light tunnels, high-permeability walkways, piezoelectric systems, lignocellulosic panels, plexiglass concrete, air-filtering masonry, and hydro-ceramics [7]. The international community would also have highlighted the significance of climate change mitigation, reducing emissions, and using less energy. Railway stations are required to be environmentally friendly.

3- Beni Suef Railway Station

The Egyptian railway sector is important to the country's economy and is developing infrastructure through investment to improve operational efficiency and safety. Recently, with the rapidly growing awareness of achieving environmentally sustainable development, railway stations have played a crucial role in the operation of urban transport systems in Egypt. Much remains to be desired in raising the efficiency of existing stations and establishing new sustainable stations [8]. Egyptian Railways' restructuring efforts focus on improving the standardization, performance, and efficiency of railway services by increasing the station's performance of buildings, tracks, and operational processes to meet economic, social, and environmental performance standards. This also requires, in parallel, improving the railway station environment and saving energy. Beni Suef station is 124 km from the Upper Egypt line and 250 km from Assiut. Also known as the Cairo/High Dam line, it is 878 km long and serves as the center of the second Upper Egypt line after the city of Wasta. The Green Nile Valley is 22 km wide in Beni Suef, which is the widest section of the valley. The railway area covers about seventy acres and connects the train station with the eastern and western railway areas. According to the assessment of Egypt's annual report on transport, which follows Cairo and Tanta, the traffic volume at the Beni Suef railway station ranks third. Table 2 presents the recent numbers of freight trains and passenger trains, the total number of trains, the current and future line capacities, the distribution of technical buildings along the lines, and the current status of the Beni Suef railway station [9].

Table.2 Beni Suef Railway Station Informationation.

Beni Suef Railway Station		
Beni Suef Governorates Population	3,377,325= (22.7%Urban+ 77.3% Rural)	
The Capacity of the Cairo/Beni Suef Rail Line		
No. supplies trains (present)	In total, fifty-four units per day.	
No. passenger trains (present)	ninety units per day.	
Σ No.of trains(supplies+passengers)	144 trains every day	**Beni Suef Railway**
The present ability of the line	160 units per day.	
The Future ability of the line	286 units per day.	
The Technical Development of Circulation through the Railway		
Regional Traffic Monitoring System	1 at Bashtil + 1 at Minya Stations	
No.Main Technical Building	19 Cairo/Beni Suef + 15 Beni Suef / Assiut	
No.Secondary Technical Building	Not yet at Cairo/Beni Suef +24 Beni Suef / Assiut	
The Current Progress of Beni Suef Assiut Line		
Overall Progress (66%)	Trenches (54%)- Building (51%)- Power Supply(42%) – Installation (42%) - Testing and Commissioning (37%)	

They are related to the governorate's location between Cairo and Upper Egypt and students' and staff's daily use of trains. However, to improve safety, the 250 km Beni Suef–Assiut line is being upgraded to an electronic control system (EIS) with a central control system (CTC) installed [9]. Figure 2 depicts the Beni Suef Train Station Panorama. According to the executive summary of the Egyptian Railways, the direction is to activate the Upper Egypt

Railway, which consists of 70 bumps and 53 stations, 25 of which will be changed to an automated integrated control unit. Existing rails and some buildings will be demolished. The station also provides servicing facilities and rail crossing shelters. The increased number of railway passengers in Upper Egypt has had an impact on the existing environment and infrastructure, resulting in urban change, increased energy consumption, service deterioration, and identity loss. As a consequence of all of these factors, the performance of the environment in the railway station has decreased significantly, which requires the activation of sustainable urban planning applications. Government officials in Beni Suef have been able to achieve several developments in the station square, where a statue of Imam al-Busairi stands in the center. The advanced planning strategy is distinguished by adding new traffic lanes and paths that had previously been closed as traffic hazards. A parking space was also planned to help users while also serving as a financial resource. The square was repaved, traffic was arranged, and lighting units, decorative lights, and artificial grass were designed to enhance the spatial quality of the train station facade and entrance zone.

Fig.2. Beni Suef Train Station Panorama.

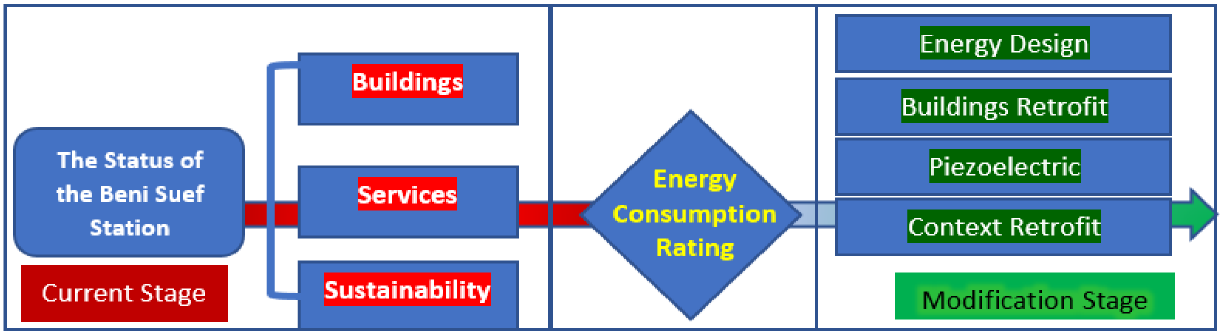
The master plan of the Beni Suef railway station depicts the various architectural characteristics of zones, as shown in Fig. 3. The Entrance Zone, which includes an entrance hall with ticket gates, faces the passageway leading to the platforms. The tunnel zone provides access to the sidewalks of the railways, leading in the direction of Cairo and Upper Egypt. Platforms and track lines are accessible to passengers waiting in designated areas via two stairways on each platform.

Fig.3. Master plan of the Beni Suef Rail Station

5. Research Methodology

The analytical research is addressed in three stages, as shown in the following Fig. 4. First is an assessment of the station's current situation, including buildings, service, and sustainability. Second, the energy consumption rating evaluation stage leads to sustainable energy production solutions. The third stage is energy design modification, which includes building retrofit, piezoelectric retrofit, and context retrofit.

Fig.4. Research Methodology Stages



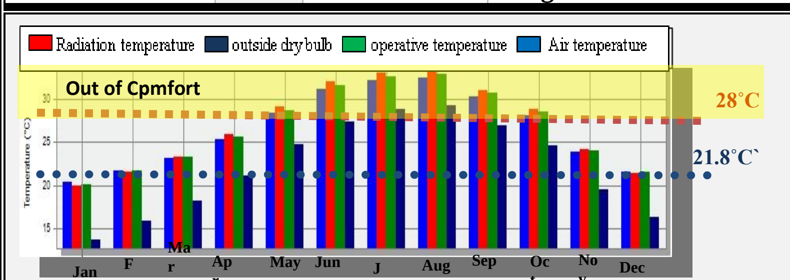
6. Results and Discussion

The station is currently set up as follows: The research looked into the R and SHGC values for the code tables for roofs, external walls, and openings in the case of railroad buildings. Through the resulting values, the proposed modifications will be identified and applied to reach the code values. And then develop a strategy to improve the efficiency of the outer envelope, as the main goal is not only to reach the lowest possible temperature but to lower the PMV rating for feeling comfortable inside, according to ASHRAE, taking into account the economic aspect.

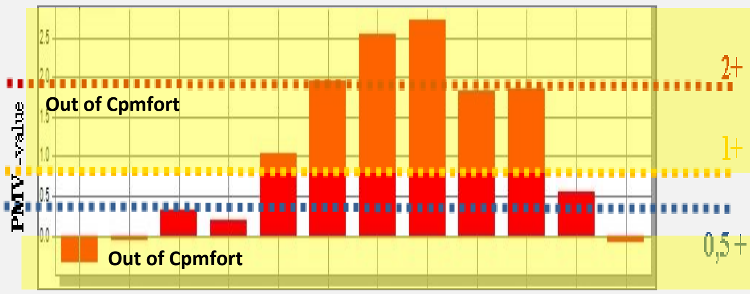
a. Rail Station Office Spaces: Energy Consumption Current Stage: Using Design Builder as a simulation tool, this phase assesses temperature ranges and predicts the mean value (PMV) and heat balance indicators for office space and services in Table 3. Temperature analysis (radiation temperature, external dry bulb temperature, operating temperature, and air temperature) is included as an acceptable thermal comfort range for the study conditions ranging from 21 to 28 degrees. The PMV indicators are based on seven rating points on the thermal sensation rating scale (hot, warm, warm, neutral, cool, cool, and cool), with thermal comfort ranging from -0.5 to 0.5 for offices. The solar gain is important, as are external windows, walls, roofs, ventilation, glazing, and partitions.

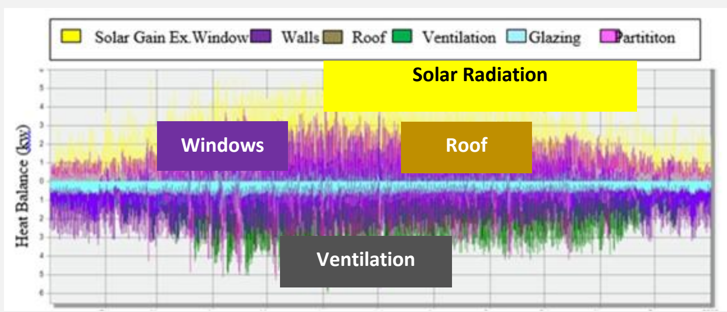
Table.3. Energy Consumption Evaluation

Ex. Envelope		**R-value**	**Egyptian code**		
Roof	**Not air-conditioned**	**1.791**	**3.00**		
Walls		**0.980**	**1.1-1.6 N**	**1.4-1.9 S-W**	**1.5-2.00 S**
Openings		**Single-Poorly**			
SHGC		**60% N-50%S**	**R-Value1.00 N-light-1.1 S-light**	**Not allowed for N & S**	



Analysis: By comparing results with the values recommended in the Egyptian Energy Code and the PMV scale of ASHRAE, all spaces are far from the comfort zone, especially in summer. The comfort range of the PMV ranges from -0.5 to +0.5. Solar radiation, subsequently reflected by the





covering of the roof and then the exterior facade cross-section, is the source of thermal gain in the hottest months. Thermal conduction is the main reason for building heat loss in the winter. Besides, passenger aisles, passenger waiting areas, and movement paths need shading systems, passive technologies, and energy-saving solar systems due to their reliance on natural lighting and ventilation during the day. The station's northeastern direction was not considered when integrating the openings, the opening and closing system, the passive strategies for providing airflow and daylight, and enhancing thermal performance in the main station hall and offices. By examining one of the administrative offices in the southern direction, it was found that the problem of the roof, the southern wall, and the closed windows caused a sense of thermal discomfort inside the administrative offices.

b. Rail Station Service, Architectural Analysis Current Stage: The scope of the development strategy includes not only painting the exterior facade of the train station building, but it must also be modified to fit modern and smart requirements for architectural, environmental, and sustainable energy identities to align with government directives towards the sustainability of railway stations. Figure 5 represents the conceptual diagram of the Beni Suef railway station. The context shows that: parking berths lack shade; the tunnel connecting the two directions between Cairo and Upper Egypt is poorly lit and ventilated; turning tracks do not accommodate the number of passengers; there are no escalators or elevators at all; restrooms need maintenance; and there are no cafeterias. No gathering places or public activity areas exist, and passenger itineraries are unidentified. The entire space is separate from services and inquiries, which creates challenges regarding visual continuity. In addition, there is an increase in waste and emissions and a lack of green space.

Fig.5. The conceptual plan of the Beni Suef Rail Station Context

The Beni Suef-Assiut line is being updated, including electronic signals based on the central control unit instead of the current electro-mechanical system; connecting the line to control towers along the line via a fiber-optic network to transmit communication signals; an automatic control system for train approach; and digitization. The new control project includes 39 technical buildings along the line from Beni Suef to Assiut. These technical systems include centrally controlled traffic in Minya, 14 digital overlapping devices, and 24 supplementary systems and equipment. 17 stations need to be widened and extended. At the same time, 84% of the signal electrification upgrade of the Beni Suef-Assiut railway line has been completed. The sidewalks will be extended by 50 km, including the removal of diversion fixtures on the rails. To increase safety, damaged rails will be replaced with 600 km of concrete railings, and 86 rails will be upgraded and equipped with alarms, mechanical barriers, train approach indicators, and a control room for all terminals according to the Egyptian Railways website [9].

c. Rail Station sustainability evaluation Current Stage: Railway stations are evaluated using architectural criteria such as comfort, connection, maintenance, priority, design efficiency, and safety. Energy criteria include energy conservation, water recycling, and HVAC systems. Environmental factors include heat gain, acoustics, vibration, and user comfort. Table.4 illustrates the views of passengers and station users taken into account about the current train station's architectural, environmental, and energy assessments.

Table.4: The Beni Suef train station's architectural, environmental, and energy assessments

Assessments	Criteria	Entrance	Tickets	Offices	Circulation	Walkways	Waiting	Railway	Parking	Greens	Open Spaces	Cafeterias	Toilets
Station Architecture	Comfort	2	2	3	1	1	1	2	4	----	1	1	1
	Connection	5	3	2	3	2	2	2	5	----	1	1	2
	Maintenance	4	3	2	4	3	1	4	5	----	1	1	1
	proportionality	2	2	2	4	2	2	4	3	----	4	1	2
	Design Efficiency	4	4	2	3	4	2	4	5	----	2	1	2
	Safety	3	3	5	5	3	3	1	4	----	0	1	2
Station Saving Energy	Saving Energy	0	0	0	0	0	0	0	0	0	0	0	0
	Water	0	0	0	0	0	0	0	0	0	0	0	0
	Recycling	0	0	0	0	0	0	0	0	0	0	0	0
	HVAC	0	0	0	0	0	0	0	0	0	0	0	0
Station Env. Quality	Thermal	3	3	3	4	3	3	------	0	----	1	3	3
	Noise	3	3	3	2	2	2	2	2	----	1	2	2
	Vibration	3	3	3	2	2	2	2	2	----	1	2	2
	Users Comfort	2	2	2	4	2	2	-----	3	----	1	1	2

 Energy consumption evaluation: The northern orientation of the station was not fully taken into consideration, whether in the design of the openings, the strategy of opening and closing, or passive design techniques towards providing natural lighting and ventilation, as well as reducing heat gain in the main reception hall and administrative offices. And a ground corridor connecting the two directions. By examining one of the administrative offices in the southern direction, it was found that the problem of the roof, the southern wall, and the closed windows caused a thermal sensation inside the administrative offices. Both ecological and economic retrogression cause significant harm with negative long-range repercussions. Due to the railway station being located in the heart of the capital, it is overlooked by residential buildings and surrounded by a youth exhibition, a high-pressure area, administrative buildings, workshops, and warehouses. There appears to be almost nothing in terms of economic feasibility, necessitating investment, particularly in sustainable energy production solutions. This generally requires a detailed analysis of management strategies to detect progress in financial outcomes, which need to provide opportunities for investment and address climate challenges by providing job opportunities, environmentally friendly work, and technological participation. The station is considered unsustainable and requires immediate solutions to achieve gradual resilience over the station's lifecycle.

- Energy Design Modification: Energy-saving strategies for existing railway stations include train design and track planning, energy-efficient strategies, passive design techniques, energy-saving electromechanical systems, intelligent operations design, traffic control, and building context retrofit. Station operations and energy management should be enhanced to improve railway functionality, meet environmental requirements, provide safety, generate energy, report energy management, carry out energy assessments, improve energy-saving technologies, change investments and funding systems, and formulate public-private partnerships. Accordingly, the power design modification includes station energy modification, office space retrofit, piezoelectric systems applications, and context station modifications.

a. Station energy modification: The stage of improving train design and track planning that affects railways in terms of reducing the amount of energy required for movement and the power of train services, including train types, and improving performance. Level of electric traction: Relies on improved line electrification, increased use of electric trains, and connecting traction to rail networks other than traction for energy in train systems, stations, and maintenance units. The level of process Modernization and implementation of efficient manual, automatic, and mechanical driving modes; efficient stop distribution, optimum traffic control, and fewer train lanes. The level of sustainability and artificial intelligence where the railroad is no longer a closed system but rather includes network interaction and the ability of intelligent anticipation and energy return to the network based on generation state; the ability to cut off supply completely or reduce power. Through the calculations of the lighting at the station (Table 5), it was found that lighting units that are not provided consume a large amount of electrical energy per day, exceeding hundreds of kilowatts

Table.5: Calculations of Non-Energy-Saving Lighting Units and Electrical Devices Used in The Station

No. of lighting units (non-energy-saving)		No. of lighting units	Value w/h	KW. / hr. x No. units	W/hr.	The total KW. /hr.
1	The Main Facade of the Station	10 Ex. Flashlight 18 In.Flashlight	400	400*10 400*18	4000 7200	11200 W 11.2 KW
2	Minia Train Platform (line1)	Fluorescent Units 18 R+34 L 17 Flashlight	40 400	40*52 400*17	2080 6800	8880 W 8.8 KW
3	Cairo Train Platform (Line 2)	44 Fluorescent Units 17 Flashlight	40 400	40*44 400*17	1760 6800	8560 W 8.56 KW
4	Lighting Units (Sidewalks + the Rail Lines)	14 Sidewalks 10 Rails Line	200	200*14 200*10	2800 2000	4800 W 4.8 KW
5	Headlights Energy Consumption (Sidewalks +Station Front)					33.36 KW
6	The Total Electrical Energy Consumption/10 hrs. operating (headlights: sidewalks + Station Front)					333.6 KW
7	The Tunnel between Train Platforms	Fluorescent Units 12*2	40	24*40	960	9.6 KW
8	Spotlights above Cameras for Sidewalk Coverage	10 Flashlight	200	200*10	2000	2 KW
9	Lighting (Offices+ Cafeteria and café+ Ticket windows)	Fluorescent Units (52+12+24)	40	40*88	3520	3.52 KW
10	Station Energy Consumption (Offices +Tunnel + Flashlight above the Cameras)					15.12 KW
11	Station Energy Consumption/24 hrs. (Offices +Tunnel + Flashlight above the Cameras)					362.88 KW
	The Total energy consumption Non-Energy-Saving Lighting Units				**696.48 KW. /hr.**	
	Consumption Cost= (600-1000)KWS = 1.45 EGP				**1009.896 LE /KW/hr.**	

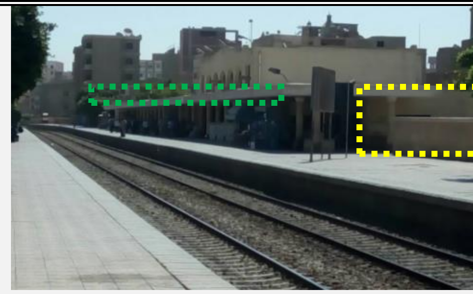
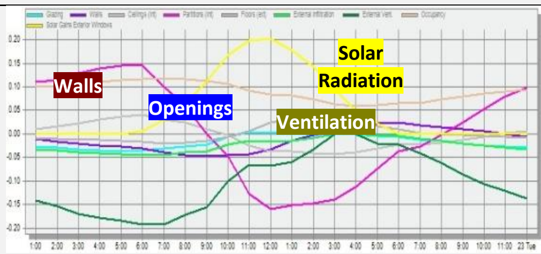
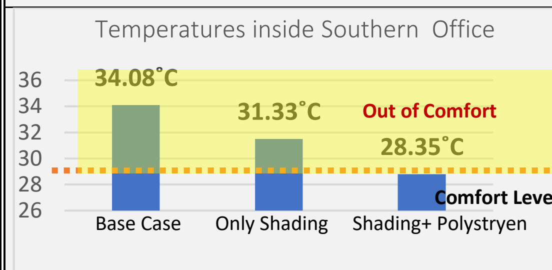
LED is characterized by its high availability of electricity as a sustainable lighting system compared to other searchlights and the heat it loses. It is very simple and, in addition to improving the lighting quality, can save a lot of electrical energy compared to the lighting systems mentioned above. Therefore, light-emitting diode (LED) lamps, light bulbs, and smart network concepts are the ideal types of efficient lighting to improve green performance. which has the best advantages such as a higher operating life, a 40% lower consumption of electricity, and lower operating costs. It is also preferable to use solar lighting units on the sidewalks while waiting for the train back and forth, saving the energy consumed during the day and reducing carbon dioxide emissions by almost half. LEDs are roughly seven times more powerful in light generation performance than incandescent types, producing 75–110 lumens per watt and extending the lighting system's operational lifespan [10]. (Table 6), shows Calculations of energy-saving lighting units and electrical devices [11].

Table.6: Calculations of Energy-Saving Lighting Units and Electrical Devices

No. of lighting units (non-energy-saving)		No. of lighting units	Value w/h	KW. / hr. x No. units	W/hr.	The total KW. /hr.
1	The Main Facade of the Station	10 Ex. Flashlight 18 In.Flashlight	80	80*10 80*18	800 1440	2240 W 2.24 KW
2	Minia Train Platform (line1)	Fluorescent Units 18 R+34 L 17 Flashlight	40 80	40*52 80*17	2080 1360	3440 W 3.4 KW
3	Cairo Train Platform (Line 2)	44 Fluorescent Units 17 Flashlight	40 80	40*44 80*17	1760 1360	3120 W 3.12 KW
4	Lighting Units (Sidewalks + the Rail Lines)	14 Sidewalks 10 Rails Line	100	100*14 100*10	1400 1000	2400 W 2.4 KW
5	Headlights Energy Consumption (Sidewalks +Station Front)					2.03 KW
6	The Total Electrical Energy Consumption/10 hrs. operating (headlights: sidewalks + Station Front)					20.3 KW
7	The Tunnel between Train Platforms	Fluorescent Units 12*2	40	24*40	960	9.6 KW
8	Spotlights above Cameras for Sidewalk Coverage	10 Flashlight	100	100*10	1000	1 KW
9	Lighting (Offices+ Cafeteria and café+ Ticket windows)	Fluorescent Units (52+12+24)	40	40*88	3520	3.52 KW
10	Station Energy Consumption (Offices +Tunnel + Flashlight above the Cameras)					14.12 KW
11	Station Energy Consumption/24 hrs. (Offices +Tunnel + Flashlight above the Cameras)					359.18 KW
	The Total energy consumption Energy-Saving Lighting Units				**379.48 KW**	
	Consumption Cost= (600-1000)KWS = 1.45 EGP				**550.25 LE /KW/hr.**	

b. Building Retrofit: By comparing the station's current condition to the Northern Upper Egypt standards for non-air-conditioned buildings as determined by simulations, it was noticed that heat pickup and loss are the most important components of discomfort and energy loss. As a result of direct solar radiation exposure without the presence of treatments to prevent heat gain and loss. Then the roof layers, and finally the southern facade. The most appropriate treatments will be chosen to modify the envelope, roof, and openings to meet the required values and improve the station's energy efficiency (Table 7).

Table.7: Architectural Modifications Improve The Station Energy Efficiency

<table>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Examining the offices revealed that the weaknesses with the roof layers, the southern façade, the absence of shading devices, the opening ratio, and the closed windows all affected heat transfer insides.</td>
<td>The station's north-eastern orientation has not been fully supported in the design of windows, opening and closing strategies, passive ventilation, and daylighting techniques, resulting inheat gain.</td>
</tr>
<tr>
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>Heat gain and loss analysis: It is clear from the table that the openings, walls, and roof are. Solar radiation is the primary source of heat gain in internal spaces, necessitating the need to address these elements. After designing the shading devices, the solar gain values decreased significantly, with the percentage of decrease approaching half of the value when compared to the base case. The solar radiation located on the openings in the southern facade is the most important reason for solar gain, which requires shading the openings according to the recommended values in the code and resulting intheir The sunlight energy radiation upon southern facade openings is a particularly significant cause for heat gain, which necessitates shading the openings by the code's stated by protrusion to determine the value of PF, the protrusion, and the indication of the breaker, where PF = W / (A + B) for the southern facade. As for the northern façade, shades are not required. Based on the SHGC value of 0.8, the SHGC value according to the table of code requirements is (0.64) for openings less than 10 < 20%, and from the glass shading coefficient table.

Glass shading coefficient for the aperture

= (0.25 + 0.13)/2 = 0.19

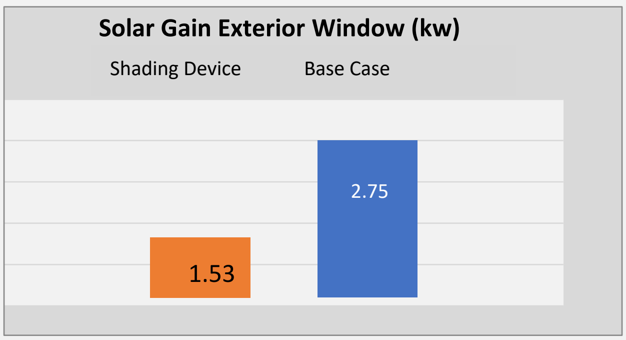
For the openings on the southern façade, the most</td>
<td>The external roof is subjected to high thermal loads as a result of its daily exposure to solar radiation. Different solutions are needed to treat the roof layers to reach the R-value according to the Egyptian Energy Code requirements. 2cm mosaic tiles; 6 cm sand and mortar; 7 cm mil concrete; 8 cm expanded polystyrene (density 15 kg/m3); 4 cm moisture insulator; 2 cm cement plaster; 12 cm reinforced concrete; 2 cm internal interior paint) is considered to be a significantly well-known concept for reducing thermal loads on roofs. However, alternative architectural solutions are available to reduce thermal loads and meet the character of the station. Shading the roof by extending passenger waiting covers to cover the roof of the administrative offices to reduce the thermal loads on it and comparing the thermal loads on the roof with the basic condition before modification and various modifications to add expanded polystyrene 8 cm (density 15 kg/m3) or shading only or shading + 4 cm polystyrene (density 15 kg / m3) to choose the best modification economically, environmentally, and architecturally, and accordingly, a comparison is made between the internal temperatures before and after the modification.</td>
</tr>
</table>

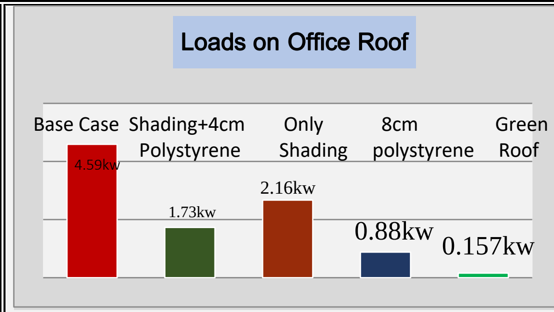
effective solution is horizontal shading protecting appliances. Through the glass shading coefficient (SGR) table resulting from the use of breakers and according to the southern orientation, it is clear that the glass shading coefficient = 0.19, i.e., between 0.17 and 0.35, where it is matched in the table by the protrusion coefficient (PF) between 0.10 and 0.20 and based on the following calculations:

Protruding factor (PF) = 0.10 + (2×0.005) = 0.11

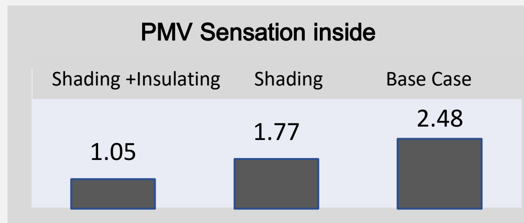
From the law: W/ (A+B) = (PF) - W = (0.257) m

Accordingly, a comparison was made between the current situation and the addition of a shading device according to the equation of the Egyptian Energy Code to compare the solar heat gain of the external window to gain solar energy and compare it to the base case before adding the shading device on June 21.



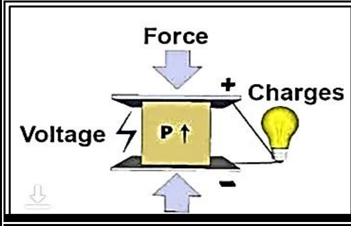


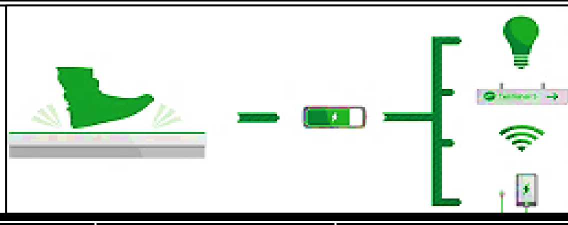
Recommended PMV values are based on approaching rates **-0.5** < **PMV** < **+0.5** as it is required to transform from very hot to relatively warm values.

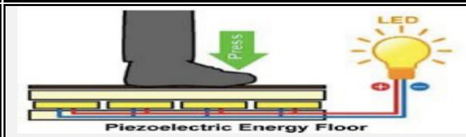
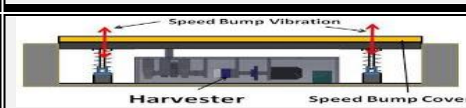
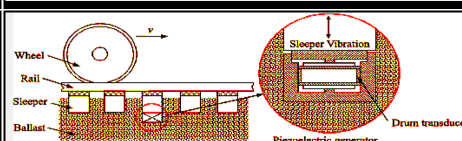
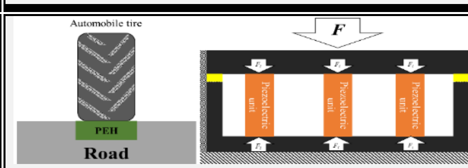


C- Piezoelectricity Application Performance: Many solutions involve a combination of architecture and technology. Recently, the integration of kinetic piezo with design concepts has been identified as one of the flexible solutions that save energy, have high dynamics, are scalable, and are adaptable to the nature of crowded spaces. There are many types of piezoelectricity for different uses and applications in high-traffic and crowded places, achieving promising amounts of generated energy [12]. Architectural and urban projects must use alternative energy sources resulting from capturing untapped energy from walking activities in crowded areas. Where the electrical power produced by the stress on the piezoelectric components is to be utilized as a power source from electromagnetism. [13]. Consequently, piezoelectricity applications include commercial centers, shopping centers, large companies, warehouses, and various traffic routes, including railway stations. The design of energy-harvesting technology for rail applications shown in Table 3 can provide the energy needed to operate ticket gates, lighting, and display screens. Furthermore, piezoelectric approaches in all user movement paths are geared towards integrating human density in crowded areas as a readily available and clean source of energy generation [14].

Table.8 Piezoelectricity Application Performance





Piezoelectric Type	Generated Power	Station Location
Piezoelectric Flooring [15]	2-10 watts/step	
Piezoelectric Bumps Piezoelectric power generation from piezoelectric road bumps 30 kW. hour[16]	30 kW/h	
Piezoelectric Trains Rails Piezoelectric power generation from railway tracks 120 kWh from a distance of 1 km [17]	120 kW/h	
Piezoelectric Parking Tiles Obtain 1 km of piezoelectric roads from road lanes to obtain 44,000 kilowatt-hours of electrical energy per year [18].	44000 KWh/yr. =120.55 KWh/day	

By applying kinetic piezoelectric energy generation methods to the Beni Suef train station (flooring, bumps, train rails, and station parking) as shown in (Table 9). Data source: Beni Suef Railway employees and the website of the National Authority for Egyptian Railways.

Table.9. applying kinetic piezoelectric energy generation methods to the Beni Suef train station

Piezoelectric (Type/No.)		Installation location	Rush Hrs	Produced Energy kWh .hrs day
1. Bumps	1	The Parking side	17	1*30 kWh .hrs= 30*17 hrs day=510 KW day
	2	Station Entrance	17	2*30 kWh .hrs= 60*17 hrs day=1020 KW day
Dimensions of the piezoelectric bump = 3.00 meters long x 0.40 meters wide				
				Σ Total energy generated per day= 1530 KWh. day
2. Trains Rails		**The Value**		**Statement**
The average number of trains		54		The average train traffic rate

The amount of energy generated from a distance of 1 km = 120 KWh-Day			
Generated electrical energy= 54*120 = 7560 KWh .hrs day			
Σ Average energy generated (kw) =7560*365/1000=2792.25 megawatt /day			
Dimensions of the generator placed inside the railway rail flanges= 4cm x 14cm x 2cm thick			
The operational life of a piezoelectric system for railways = 10yrs.			
3. Piezoelectric flooring [19]			
Locations	**Area (m2)**	**Piezoelectric Tiles**	**Electricity Generation**
Parklet (cars)	1561.5	50 cars *5.01 KWh/day= 251.15 KWh/day	= 251.15 KWh/day
(Persons)	3000	300/0.75*0.75= 533 tiles*80 Person*5W	= 213.200 KWh/day
Entrance Hall	334.67	334.67/0.75*0.75 = 565 tiles *500person	= 1412.500 KWh/day
Platforms	1121.20+2432.52	3553.72/0.75*0.75= 6317 tiles * 500 person * 5W	= 15792.500 KWh/day
Tunnel	91.80	91.80/0.75*0.75= 163 tiles * 500 person * 5W	= 407.500 KWh/day
Σ Average total energy generated (kw) = 18076.85 /1000 = 18.10 megawatt /day			
Total = Bumps 1530 + Trains Rails 7560 +Flooring 18076.75 =27,166.75 KWh/day/1000= 27.17 megawatt /day			
The Total energy consumption of Non-Energy-Saving Lighting Units =696.48 KW. /hr.			
The Total energy consumption Using Energy-Saving Lighting Units = 379.48 KW. /hr			

 Thus, the daily production of the types of piezoelectric energy used in the station is equivalent to 27.17 megawatts per day, which is equivalent to operating more than 2825 200-watt LED light lamps. Noting that 1 megawatt per hour is the amount of energy required to operate 10,000 100-watt bulbs for one hour, equivalent to one million watts consumed per hour. And it is necessary to obtain the highest efficiency Regarding lowering the consumption of electricity in railway stations through energy-application systems, which include the outer envelope of the building in terms of energy loss and gain, and to take advantage of the largest amount of piezoelectric energy generated from the movement of users and vehicles, achieving high efficiency, preventing energy loss, reducing fees, encouraging investment, and conserving energy. There are many energy-saving options readily available that involve crucial modifications to the building envelope, line system, and technical facilities.

Reference

[1] Vorisek, D. L., & Yu, S. (2020). Understanding the cost of achieving Sustainable Development Goals. World Bank Policy Research Working Paper, (9164).

[2] Nason, F., 2022. Smart mobility: state of the art and emerging trends for Italian municipalities.

[3] Rahman, H. Z., Berawi, M. A., Susantono, B., Miraj, P., Petroceany, J. S., & Maya, R. (2018).

[4] Cities, C. C. (2018). The Sustainable Cities Index 2018. Arcadis: Amsterdam, The Netherlands.

[5] XiuE, Y. (2017). Building Energy Efficiency Design for Waiting Halls of Railway Stations in the Hot-summer and Cold-winter Regions. Journal of Engineering Science & Technology Review, 10(2).

[6] Dursun, E. R. K. A. N., NESE, S. V., & KILIC, B. (2020). Green building certification of urban public railway transport systems for sustainable cities. Balkan Journal of Electrical and Computer Engineering, 8(1), 7-15.

[7] Wernery, J., Brunner, S., Weber, B., Knuth, C. and Koebel, M.M., 2021. Superinsulation materials for energy-efficient train envelopes. Applied Sciences, 11(7), p.2939.

[8] Elshabrawy, W.A., 2021. Egypt, Arab Republic of-MIDDLE EAST AND NORTH AFRICA-P101103-Egypt National Railways Restructuring Project-Audited Financial Statement.

[9] Egyptian National Railways. (2020). Developing Projects. Retrieved August 20, 2022, from https://www.enr.gov.eg/Ar/Default.aspx

[10] Franco, I. G., & Marcos, E. S. (2016). Technologies and potential developments for energy efficiency and CO2 reductions in rail systems. Technical report, International Union of Railways.

[11] Lighting Solutions for train stations (no date) Lightronics. Available at: https://lightronics.eu/applications/station-areas/train-station (Accessed: April 26, 2023).

[12] Anand, H. and Singh, B.K., 2019. Piezoelectric energy generation in India: an empirical investigation. Energy Harvesting and Systems, 6(3-4), pp.69-76.

[13] Laskar, M.A.R., 2017. Piezoelectricity: An energy source for future railway stations. SEU Journal of Science and Engineering, 11(2).

[14] del Castillo-García, G., Blanco-Fernandez, E., Pascual-Muñoz, P. and Castro-Fresno, D., 2018. Energy harvesting from vehicular traffic over speed bumps: A review. Proceedings of the Institution of Civil Engineers–Energy, 171(2), pp.58-69.

[15] Solban, M. M., & Moussa, R. R. (2019, November). Piezoelectric Tiles Are a Sustainable Approach for Designing Interior Spaces and Creating Self-Sustain Projects. In IOP Conference Series: Earth and Environmental Science (Vol. 397, No. 1, p. 012020). IOP Publishing.

[16] Palanivendhan, M., Logeshwaran, S., Naresh, G., Ankush, K., Sidhaant, A., & Shivam, S. (2020, December). Design and fabrication of speed bump for energy generation. In IOP Conference Series: Materials Science and Engineering (Vol. 993, No. 1, p. 012149). IOP Publishing.

[17] Najini, H., & Muthukumaraswamy, S. A. (2017). Piezoelectric energy generation from vehicle traffic with techno-economic analysis. Journal of Renewable Energy, 2017.

[18] Pravin Wale, 2Chetna Patil, 2Aditya Thakare, 2Ajeta Vinchurkar, 2Purvi Pagare (2021). Generation of electricity from Roads by using piezoelectric sensors. International Journal of creative research thoughts,2021.

[19] Abdalla, A., El'eshy, A., & Eltantawy, A. (2017). “Life Energy Architecture” Crowd Farms as Human Power Plants (Main Entrance for Mansoura University “El-Baron Gate”). Energy Procedia, 115, 272-289.