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Enhancing Energy Performance of Sports Stadiums "CASE STUDY BORG AL ARAB STADIUM"

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Abstract

Sport stadiums are the main elements of sports infrastructure, so it is worth reconsidering the development of those buildings in order to increase their efficiency, their life span, and save energy, through applying sustainable design concepts during the planning phase. This seems more relevant rather than doing some superficial renovations and replacing existing energy systems and finishes with higher efficiency. The design process should be considered as an integrated system that incorporate the application of passive design strategies and redesigning of building systems using natural ventilation and lighting. This necessitates integration of control systems and taking advantage of renewable energy sources to get the maximum possible energy saving, and reducing thermal loads of the building. An empirical study was conducted to develop the stadium of Borg Al Arab, Alexandria, which depends on building energy performance assessment through applying energy evaluation points derived from the various rating systems. Solutions and treatments are proposed to improve energy efficiency during the operating phase. The expected energy savings ratios after application sustainable solutions and treatments were achieved by using Revit and Ecotect software. A set of systematic steps for achieving sustainability of sports stadiums is concluded.

Keywords: Energy Efficiency - Sustainability - Sports Stadiums – Green Pyramid Rating System.

1. Introduction

In 1992, the UN Conference on Environment and Development published the Earth Charter, which declared the concept of sustainable development as a necessity for human life on the earth. It aims at reaching a society where living conditions and resource use continue to meet human needs without undermining the integrity and stability of the natural system. This is a global vision of the environment and sustainable development, which includes economic resource management in such a way as to preserve or improve environmental resources, to enable future generations to live a decent life.

Since stadium is the most important element of the sports infrastructure, it becomes imperative to reconsider its design in the light of the concept of sustainability. One of the problems facing the design of stadiums is the growing consumption of energy and consequently the increasing rate of carbon dioxide emission. Therefore it becomes important to increase their efficiency, their life span, and save energy, through applying sustainable design concepts during the planning phase. This is worth doing rather than applying some superficial renovations and replacing existing energy systems and finishes with higher efficiency. The sustainable stadium design development depends on a range of environmental standards derived from global evaluation systems such as (LEED, BREEAM, GREEN GLOBES, and GPRS).

2. Objective

The main objective is to investigate the effect of using design techniques such as (passive heating system, passive cooling system…) to reach the energy efficiency in existing stadiums, according to the points obtained from the selected environmental assessment systems. This will help identify design techniques in stadiums to achieve thermal comfort and better energy performance.

3. Methodology

A base case was inspired from Borg al Arab stadium in Borg al Arab, Alexandria, Egypt. The base case was taken under the same conditions and dimensions for simulation accuracy. The Stadium was selected for assessment. Simulation was conducted using the climatic data of Borg al Arab, Alexandria, Egypt (30°59′51″N 29°43′24″E) (fig1&2).

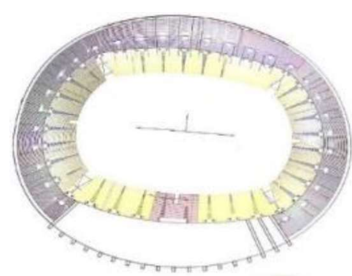

Figure 1: plan of Borg al Arab stadium at level 21.39

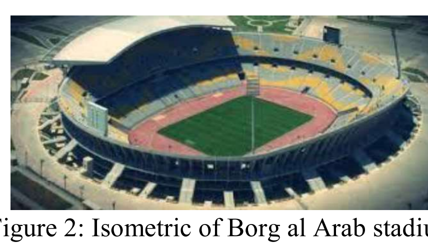

Figure 2: Isometric of Borg al Arab stadium

Reference: Egyptian Armed Forces Engineering Authority

Table 1 presents comparison of the relative weights of elements of Rating Systems such as (LEED, BREEAM, GREENGLOBES, and GPRS). Table 2 presets Comparison of the relative weights of energy efficiency elements of the same Rating Systems

Table 1: Comparison of the relative weights of elements of Rating Systems Reference: Researcher using Rating Systems

standards	GPRS	GREEN GLOBES	LEED	BREEAM
Sustainable site	10%	11.5%	26%	10%
energy efficiency	32%	38%	14%	19%
Water efficiency	20%	8.5%	35%	5%
Materials and Resources	12%	10%	10%	13.5%
Indoor Environmental Quality	16%	20%	15%	
Management Protocols	10%			12%
Innovation and Added Value	Extra points		Extra points	10%
health				15%
design		5%		
pollution		7%		8%
wastes				7.5%
Transports				10%
Total	100%	100%	100%	100%

Table 2: Comparison of the relative weights of energy efficiency elements of Rating Systems Reference: Researcher using Rating Systems

standards	GPRS	GREEN GLOBES	LEED	BREEAM
BuildingEnvelope improvement	8%	11.4%	19%	9.6%
Passive Heat Gain reduction	6%	10%	2%	
Renewable Energy Sources	5%	2%	7%	2.8%
Energy Efficient of HAVC System	5%	6.6%	2%	2.85%
Efficient artificial lighting System	5%		3%	
Vertical Transport	3%	8%		
performance			2%	3.8%
total	32%	38%	35%	19%

In this paper energy efficiency will be assessed through Green Pyramid evaluation system (GPRS).

<u>Base case</u>

Revit 2018 was used as a simulating tool (fig3). This simulation is depending on an analysis grid to measure air temperature at the terraces (fig 4).

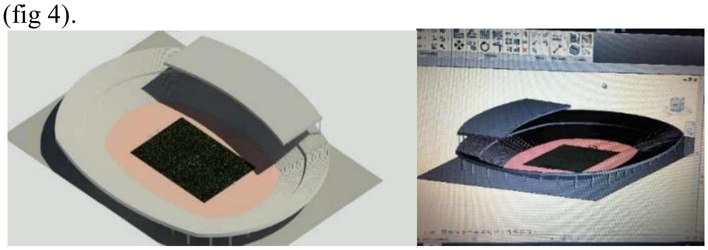

Figure 3: simulating model of stadium Borg al Arab in Revit Reference: Researcher by using Revit Program

Figure 4: Thermal model of stadium Borg al Arab in Revit Reference: Researcher by using Revit Program

Ecotect was used as a simulating tool. This simulation is depending on Graphic analysis to measure air temperature at one of stadium's room (fig 5&6&7).

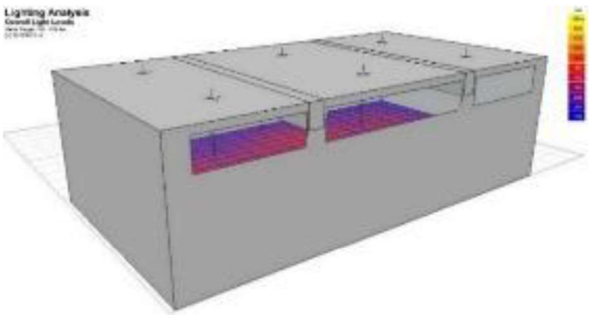

Figure 5: Model of a room inside the stadium in Ecotect

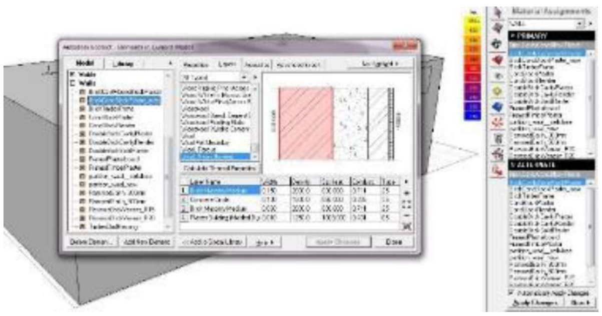

Figure 6: Selection of materials for walls in Ecotect

Reference: Researcher by using Ecotect Program

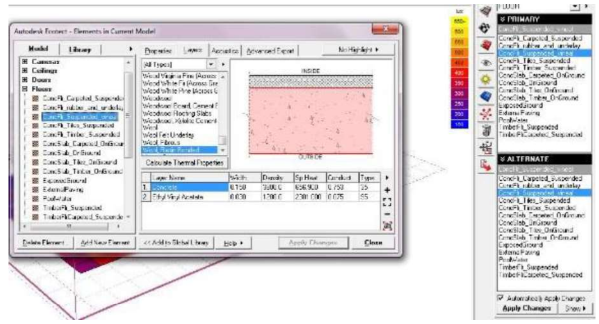

Figure 7: Selection of materials for Roof in Ecotect
Reference: Researcher by using Ecotect Program

Using Ecotect, the level of day lighting is calculated on a specific date and the overall lighting for day lighting and the combination with artificial lighting is also calculated (fig 8).

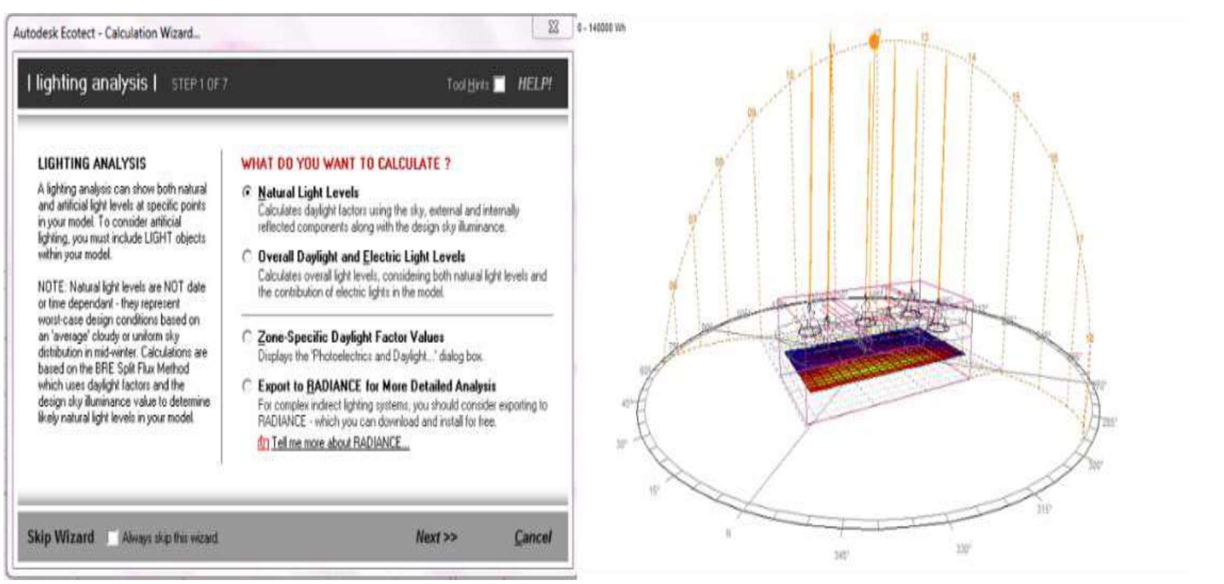

Figure 8: Track daily solar radiation and sun path
Reference: Researcher by using Ecotect Program

4. Discussion

The analysis of current lighting (fig 9) shows that highest level is achieved just below the windows. It is about 140 Lux. This is less than the required lighting level 400 lux.

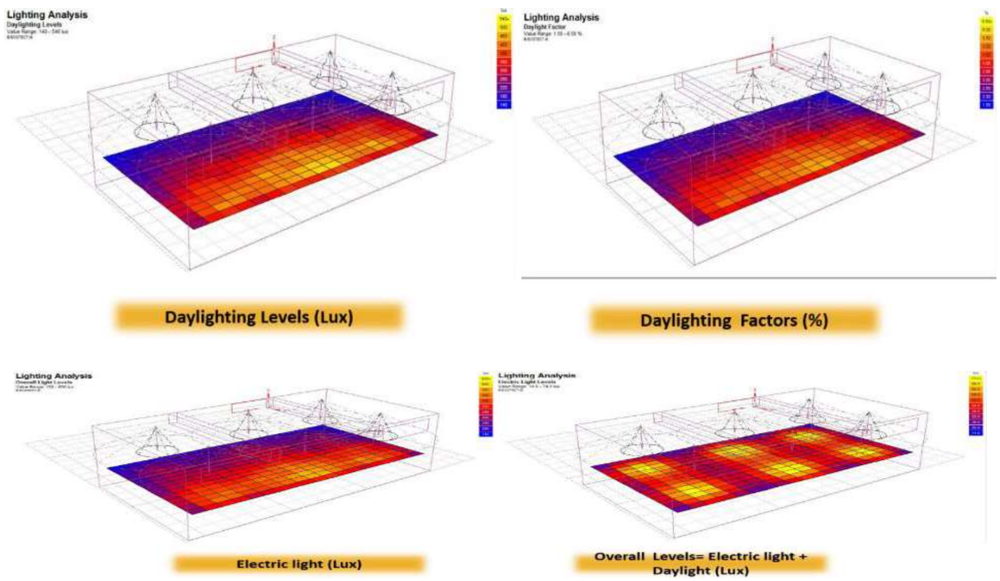

Figure 9: light analysis in Ecotect Reference: Researcher by using Ecotect Program

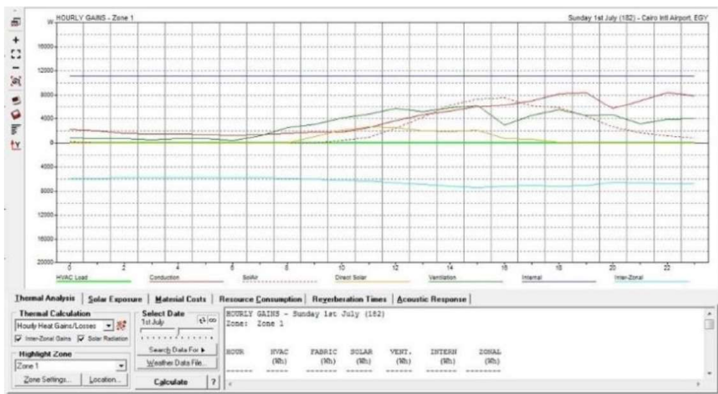

Figure 10: thermal analysis in Ecotect
Reference: Researcher by using Ecotect Program

The thermal analysis shows that thermal conduction of the envelope's materials is the main reason for gaining or losing heat (fig 10). This indicates that heat gain and loss will decrease if insulation was installed on the ceiling and walls (fig 11).

Figure 11: The difference between the temperature inside Room and outside the stadium.
Reference: Researcher by using Ecotect Program

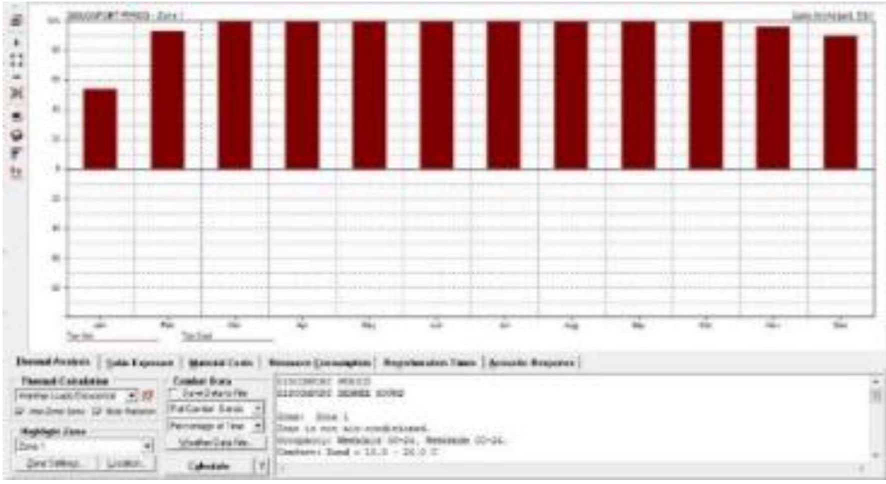

Figure 12: The amount of energy used in Havc to maintain temperature of 25
Reference: Researcher, by using Ecotect Program

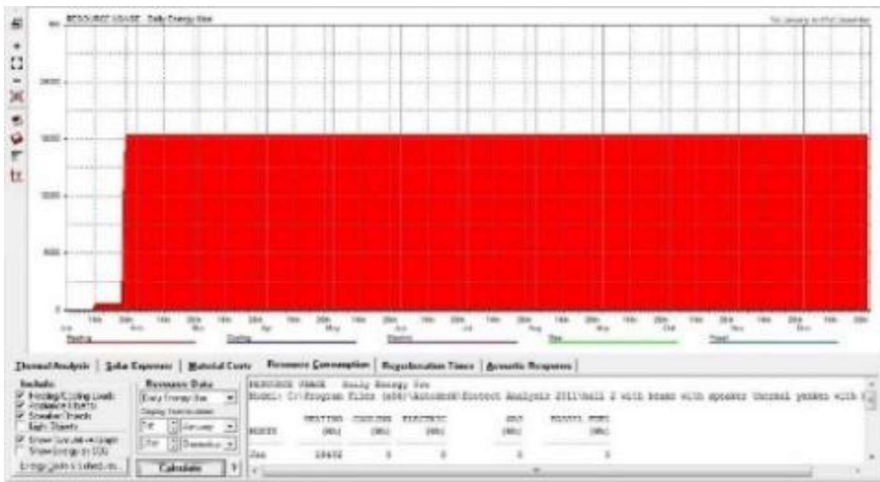

Figure 13: HAVC electricity consumption quantity

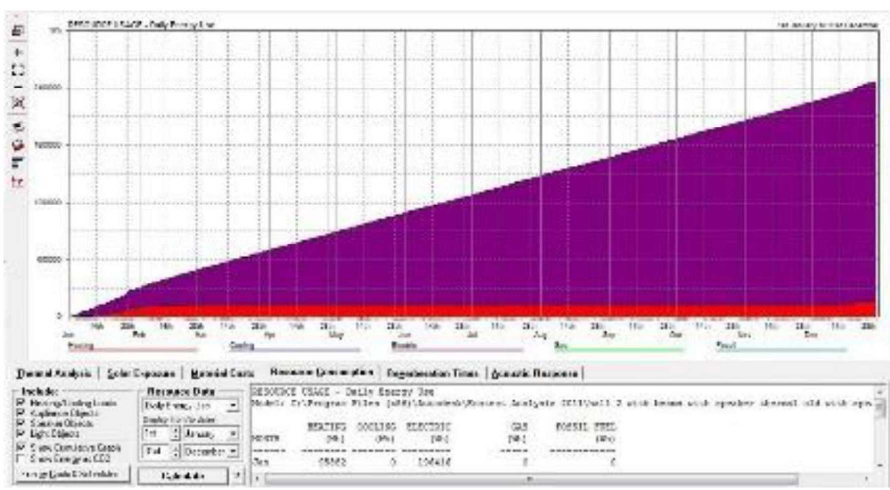

Figure 14: Havc & lighting & Acoustic electricity consumption quantity
Reference: Researcher by using Ecotect Program

The results of simulation show that the investigated room consumes 18000 kilowatt/hour for turning on the HAVC all the year around except for the months of January and February (fig 12). The consumption reaches up to 240,000 kilowatt/hour when considering HAVC, lighting, technical installations and other devices (fig 13&14).

Table 3: evaluating energy efficiency in base case Reference: Researcher by using GPRS Rating System

The evaluation elements		The rating level: Weak	medium	good	Very good	Excellent	Evaluation number	Total number	The evaluation Comment
Building Envelope improvement	Improvement in energy saving		■				5	14	No energy saving but Increased energy consumption
	No air leak rate (1.5 l/s.m2)					■	1	1	
	No leaking or water penetration.					■	1	1	
Passive Heat Gain reduction		■					2	12	thermal conduction of the envelope's materials is the main reason for gaining or losing heat
Renewable Energy Sources		■					0	10	Do not use renewable energy sources despite availability
Energy Efficient of HAVC System	using HVAC systems with Egyptian energy efficiency label.					■	8	8	
	Using sensors to slow down the HVAC systems operation during unoccupied hours.					■	1	1	
	The HVAC systems have installed a permanent refrigerant leak detection system					■	1	1	
Efficient artificial lighting System	The whole building is equipped with energy efficiency lighting system.					■	6	6	
	Lamp efficacy is greater than 60 lm/W.					■	2	2	
	Lighting systems using lighting control (daylight control, occupancy sensors, dimming,etc).					■	2	2	
Vertical Transport	Vertical transportations are visible and near the entrance.					■	1	1	
	Vertical transportations are close to the main stairs.	■					1	1	
	The escalators have automated start/stop function	■					0	2	
	All transportation systems have energy efficiency label at least (B).	■					0	2	
Total							31	64	

<u>Modified Situation</u>

Some modifications were added to the model of stadium Borg al Arab, in order to investigate their effect on the energy consumption. The entire stadium was covered with movable roof made of reflective transparent sustainable material (like a material PTEF or ETEF) (see fig 15). The roof reflects sun rays and allows transmission of light. So instead of the concrete wall, the walls were sustainable movable panels (see fig 16). Wind mills in the layout were used for generating electricity.

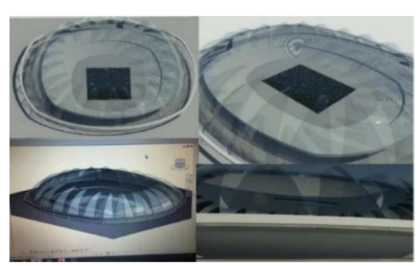

Figure 15: model of stadium Borg al Arab in Revit after add modification Reference: Researcher by using Revit Program

Figure 16: Thermal model of stadium Borg al Arab in Revit after add modification
Reference: Researcher by using Revit Program

As for the investigated wall, insulation was added. Reflective surface was applied on the bottom surface of the roof. Results of the program were examined (fig 17).

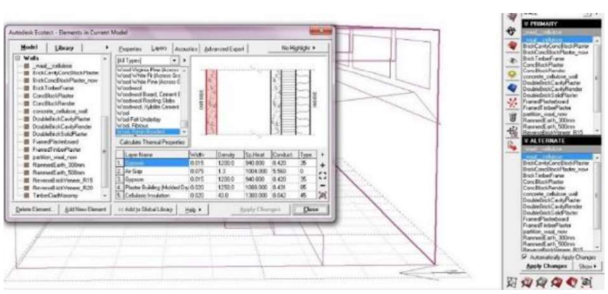

Figure 17: Adding thermal insulation to the walls and ceiling reflector Radiology
Reference: Researcher by using Ecotect Program

The analysis of lighting (fig 18) shows that the required lighting level 400 lux is achieved.

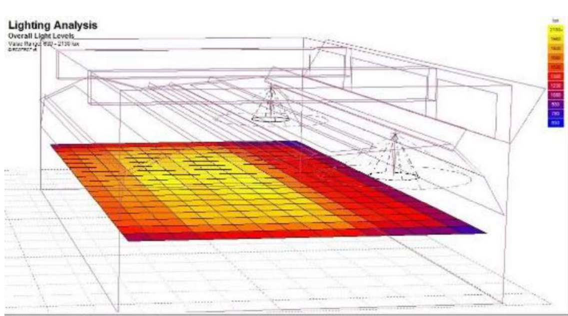

Figure 18: light analysis in Ecotect after add modification
Reference: Researcher by using Ecotect Program

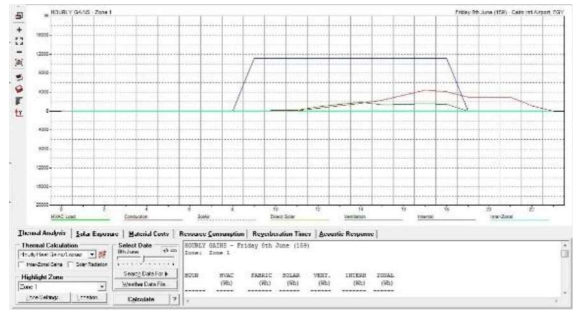

Figure 19: thermal analysis in Ecotect after add modification
Reference: Researcher by using Ecotect Program

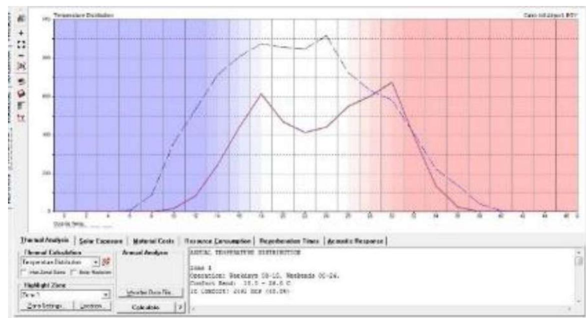

Figure 20: The difference between the temperature inside Room and outside the stadium after add modification
Reference: Researcher by using Ecotect Program

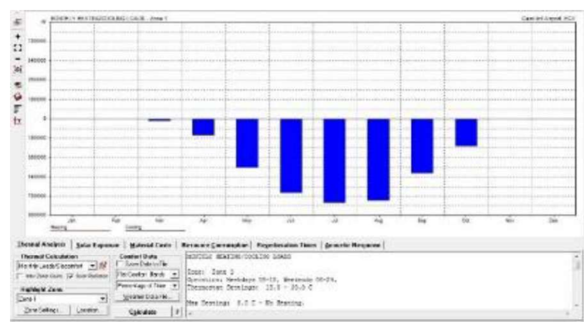

Figure 21: The amount of energy used in Havc to maintain temperature of 25 after add modification
Reference: Researcher by using Ecotect Program

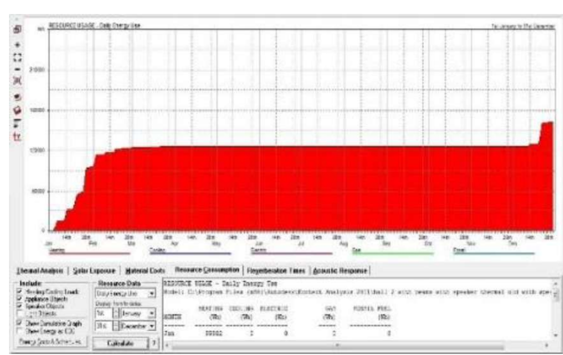

Figure 22: HAVC electricity consumption quantity
Reference:
Researcher by using Ecotect Program

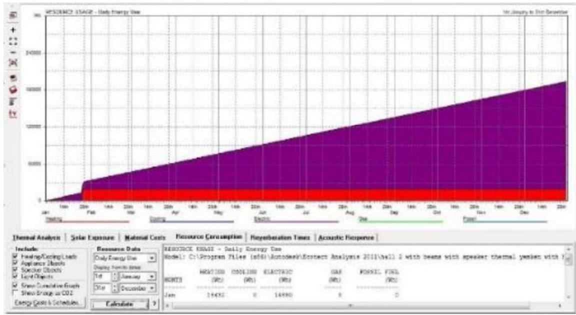

Figure 23: Havc & lighting & Acoustic electricity consumption quantity
Researcher by using Ecotect Program

The results of simulation show that the investigated room consumes 12000 kilowatt/hour for turning on the HAVC all the year around except for the months of January and February (fig 21). The consumption reaches up to 180,000 kilowatt/hour when considering HAVC, lighting, technical installations and other devices (fig 22&23). Energy efficiency calculated again by using GPRS.

Table 3: evaluating energy efficiency in Modified Situation Reference: Researcher by using GPRS Rating System

The evaluation elements		The rating level					Evaluation number	Total number
		Weak	medium	good	Very good	Excellent		
Building Envelope improvement	Improvement in energy saving						12	14
	No air leak rate (1.5 l/s.m2)						1	1
	No leaking or water penetration.						1	1
Passive Heat Gain reduction							9	12
Renewable Energy Sources							10	10
Energy Efficient of HAVC System	using HVAC systems with Egyptian energy efficiency label.						8	8
	Using sensors to slow down the HVAC systems operation during unoccupied hours.						1	1
	The HVAC systems have installed a permanent refrigerant leak detection system						1	1
Efficient artificial lighting System	The whole building is equipped with energy efficiency lighting system.						6	6
	Lamp efficacy is greater than 60 lm/W.						2	2
	Lighting systems using lighting control (daylight control, occupancy sensors, dimming,etc).						2	2
Vertical Transport	Vertical transportations are visible and near the entrance.						1	1
	Vertical transportations are close to the main stairs.						1	1
	The escalators have automated start/stop function						0	2
	All transportation systems have energy efficiency label at least (B).						0	2
Total							55	64

5. Results

From the environmental analysis of Borg al Arab stadium in energy Efficiency shows that the stadium doesn`t dependent on renewable energy sources and increasing energy consumption, which led to the low of energy efficiency consumption by obtaining 31 degree. Identified some techniques for maintaining sustainability. The proposed technique is to cover the entire stadium with movable roof made of reflective transparent sustainable material that allows penetration of light like (PTEF or ETEF). The use of passive ventilation system can be achieved through changing the stadium wall from concrete to sustainable moveable panels. The proposed techniques also include installing solar cells on the wall of the building. Adding insulation to the wall of the internal rooms of the stadium, and reflective surfaces on the internal roof of the rooms, will help conserving energy, then calculated again after the application of techniques. Energy efficiency gained 55 degrees.

6. Conclusion

The development of existing stadium design depends on the application of several sustainable technique, which can be manifested in the following: (Using Sustainable building materials in construction or development of stadiums, Install complete movable roof of sustainable materials transparent to natural light, Using recycled materials, using natural sustainable materials such as sustainable woods, Using Power generation system such as solar cells, Using a sustainable movement panels in elevations).

7. References

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