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Integration of Energy Efficiency measures and Renewable Energy technologies as an Approach to Sustainable development in Egypt

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ABSTRACT

Energy demand has been increasing worldwide and the building sector represents a large percentage of global Energy consumption. This is directly related to increasing global warming.

In Egypt, electricity consumption is increasing rapidly due to the rapid population growth, urbanization, economical development and increase in comfort levels. To solve the Energy problems, efforts need to be concentrated on the supply side, and the demand side as well. Energy efficiency is becoming an integral and important part of solving the Energy problem at the demand side. On the other hand, Renewable Energy technologies are promising as a solution at the supply side. Thus there is a need for integrated, adaptive, approach to reach the optimal combination of applying energy efficiency measures and Renewable Energy sources.

In this paper the energy related policies of Egypt have been presented. The present status of renewable energy utilization in Egypt has been discussed as well. The research introduces and examines the effect of combining Energy Efficiency measures with photovoltaic rooftop application in an air-conditioned office building in Egypt. Annual Energy reductions and Annual energy production due to the PV roof top installation was calculated by means of Energy Plus, a reliable Energy simulation software.The energy requirements for cooling, and lighting was evaluated as well.

It was proven that Reductions in Annual Energy Consumption reached about 48 % due to applying Energy Effeciency measures.The Annual electricity production due to the installation of 900 m2 PV Panels on the building roof coverd about 40% from the building Energy consumption. This demonstrates that it is technically possible to meet more than 60% reductions in building Energy consumption with the proper combination between Energy Efficiency measures and RE sources.

KEYWORDS: Energy Efficiency, Renewable Energy, Building Integrated Photovoltaics.

INTRODUCTION

As a result of the country's development, urban expansion and changing in people's life style, the energy consumption and consequently the electricity consumption has been rapidly increasing.

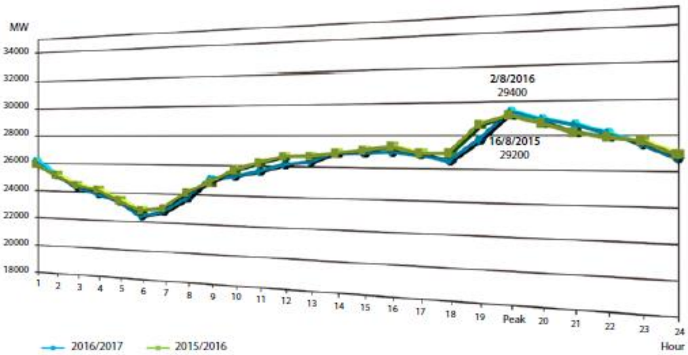
This increase in electricity consumption has increased the demands on the power sector, which mainly relies on fossil fuel. Thus there is an urgent need to formulate a comprehensive and integrated strategy to solve the Energy problem that should include the supply side, the demand side and the energy efficiency techniques employed on both sides. Efforts have been done by the Government to support sustainable and integrated Energy strategies by promoting generation of electricity from Renewable Energy sources. Yet these efforts has to be supported by decreasing consumption at the demand side. Promoting the application of Energy efficiency measures alongside with enhancing Renewable energy production and application can greatly contribute in solving Energy problems and ensure Energy security. A supply/demand strategy will formulate a solution for the energy problem and will provide an adequate balance that is expected to be more sustainable on the long run. In order to moderate the Energy requirements and ensure the Energy balance for the long run, enhancing Energy Efficiency and promoting RE integration in buildings represent a cost-effective technical and financial solution. There is a big opportunity to promote Energy Efficiency and not only depending on allocating resources to increase the supply side. Also by proper integration of RE applications, the energy problems in Egypt could be adequately solved. In order to assess the current problem, it is important to reflect the current status of the power sector in Egypt.

Nomenclature	
RE	Renewable Energy
PV	Photovoltaics

1. ELECTRICITY CONSUMPTION AND PRODUCTION IN EGYPT

Egypt's net electricity consumption, increased in less than a decade by 54% (from 1988 till 1997, (http://www.eia.doe.gov/emeulintemationallegypt.html), with an annual increase in electricity consumption between 6-7% (http://www.sis.gov.eg.). The built environment consumes about 52% of the gross national production of produced energy. In 1998 Egypt was ranked the 29th country among 125 countries assessed in electricity consumption; and the second major in Africa (after South Africa). In 2014/2015 the Peak Load reached 28,015 MW compared to 26,140 MW in 2013/2014 with a percentage rate of increase of about 7.2% While in 2016/2017, the Peak Load reached 29,400 MW compared to 29,200 MW in 2015/2016 at a variation rate of about 0.7% (Fig.1).

Figure (1) Peak load curve 2015/2014-2016/2017.



Source:Egyptian Electricity Holding Company report 2016/2017.

In 2017, the installed capacity reached 45,008 MW compared to 38,857 MW in 2016 at a variation rate of 15.8% (fig.2).

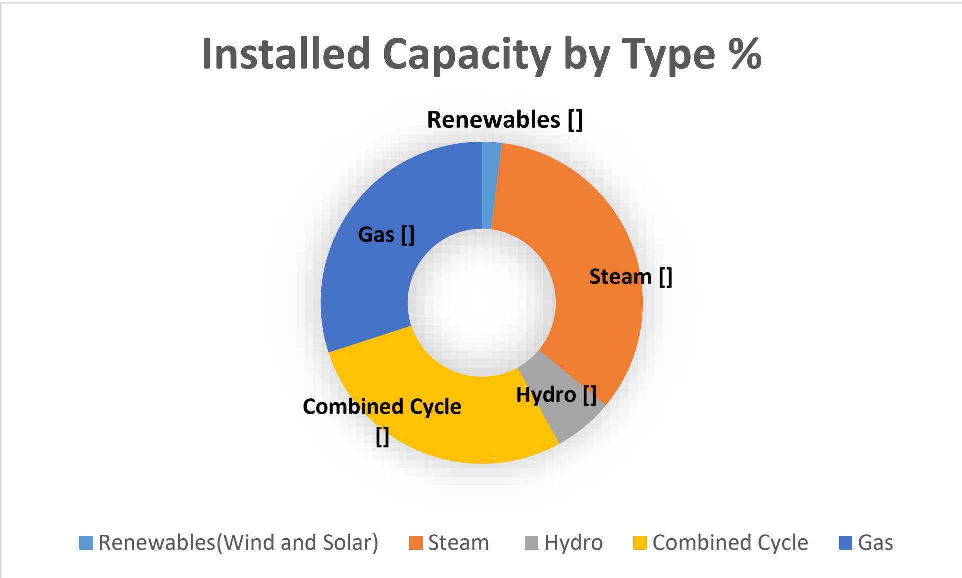
Production of electricity in Egypt depends mostly on fossil fuels while only 6 % of electricity is produced from hydro sources and 2% from Renewables (Wind and Solar).

The average growth rate of the peak load is 2.2% & installed capacity is 10 % per year during the period from 2012/2013 till 2016/2017.(EEHC 2016/2017)

Figure (2) Peak load and installed capacity.

Source: Egyptian Electricity Holding Company Annual report. (2016,2017)

Figure (3) Installed Capacity by type of generation percentage.



Source:Egyptian Electricity Holding CompanyAnnual report(2016,2017)

Electricity utilization in building sector has grown rapidly, with annual growth rate about 7% in 2002. This was attributed to the increase in urban population, growing income and comfort levels.

Figures (4) illustrates the Energy consumption in various building types, it can be noticed that both the commercial and residential buildings consume about 47% of the electricity consumption .

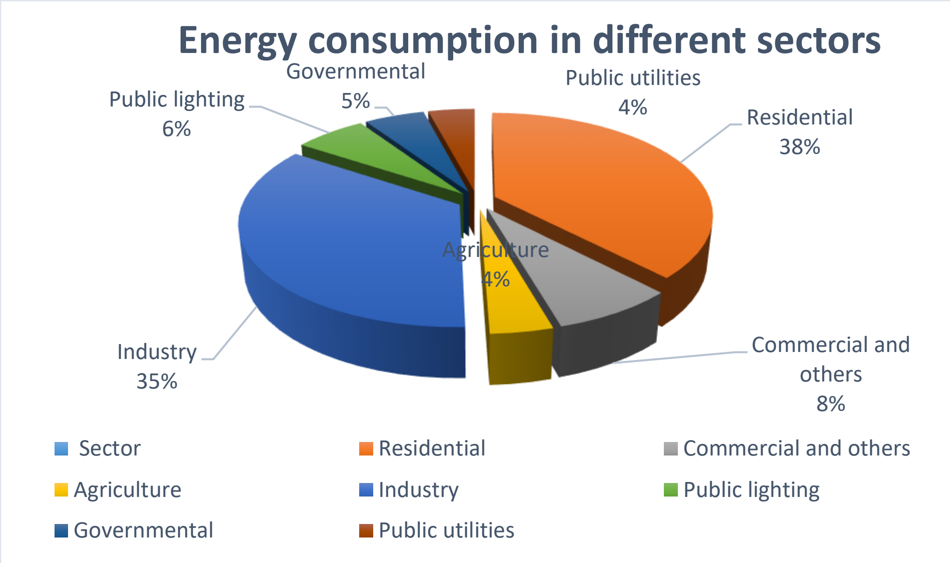
As shown in figure (5) , air conditioning and lighting account for over two thirds of electricity consumption in commercial and public sectors.

Table (1) Electricity consumption percentage in different sectors.

Sector	
Residential	37.8%
Commercial and others	7.7%
Agriculture	3.9%
Industry	34.8%
Public lighting	6.3%
Governmental	5.3%
Public utilities	4.1%

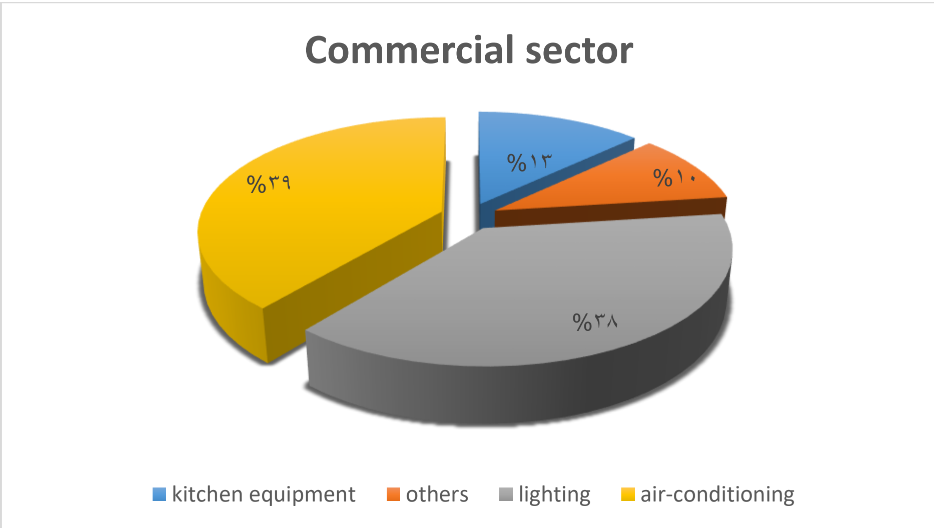
Source:Abdin.A. et al.(2006)

Figure (4) Electricity consumption in different sectors



Source:Abdin.A. et al.. (2006)

Figure(5) Electricity consumption in commercial sector.



Source:Abdin.A. et al.. (2006)

Many countries have adobted and fostered Energy Efficiency policies effectively which resulted in a noticeable reduction in their Energy consumption.

There is a strong need to focus more efforts on environmental policies and to properly push for energy efficiency promotion in all sectors.

2. ENERGY EFFECIENCY IN OFFICE BUILDINGS.

Over the last years, Sustainability has become one of the core public ideas of the current age. Since buildings and particularly office buildings are large energy consumers, the concept of sustaining office building has become the focus of interest amongst governments.

There is a chance to decrease energy use, conserve resources and make considerable progress toward achieving energy independence and reduced global warming emissions by applying energy efficiency measures.

As the climate of Egypt, imposes very hot and dry summers, in combination with the urban heat island found in big cities like Cairo, there is extended use of air-conditioning in office buildings. Large amounts of electricity could have been avoided by a more considerable use and consequently reducing the carbon footprint of buildings.

A large number of energy un-efficient office building stock exist which have a deep effect on national resources consumption. This suggests that office buildings needs an integrated approach for implementation of Energy Efficiency measures to improve their performance.

2.1 Energy Conservation Technologies in Office Buildings

Table (2) Energy conservation technologies in office Buildings.

Heating and cooling demand reduction-(Demand Side Management)	Building fabric insulation. (Roof, wall, etc.), Windows (i.e. .multiple glazing, low-E coatings, shading systems, etc.), Cool roof and cool coatings, Air tightness, etc.
Low energy technologies, Energy Efficient equipment. (Demand Side Management)	Natural ventilation, Lighting, Efficient Controls, Thermal storage, Energy efficient equipment and appliances, Heat recovery, etc.
Renewable energy technologies. (Supply Side Management).	Geothermal power systems, Solar thermal systems, Solar PV/PVT systems, Biomass systems, , Efficient Electric system.
Human factors. **(Energy conservation patterns)**	,Occupancy regimes, Comfort requirements, Occupant activities, Access to controls, Management and maintenance,

2.2 Incorporating Energy Saving Measures to Building Envelops

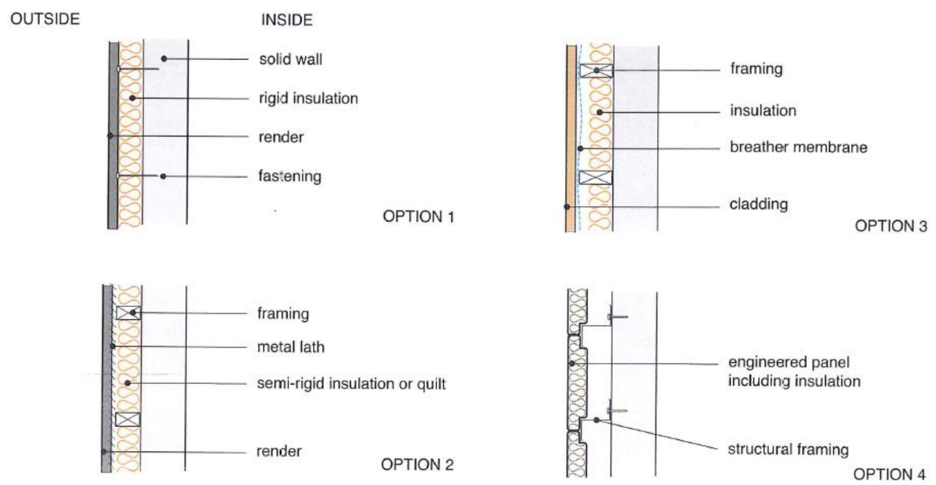
In spite of the fact that the mechanical system and how it operates plays the most essential role in determining the energy efficiency of our buildings, the building envelope also has a large impact on gross energy consumption. Improving the energy efficiency of buildings is achieved by means of incorporating energy saving measures to building envelops.

2.2.1 Wall Insulation.

Wall insulation is important for heat retention in cool conditions, heat exclusion in warm conditions, and preventing the ingress of solar gains made by the absorption of radiation on the outside of the opaque wall.

External insulation protects the structure from solar gains made on the external surface of the building. Insulation material may be added to the inside or the outside surface, or by filling the cavities within the wall structure.(Baker,N.2009).

Figure(6) Options for external insulation of solid walls.



(Source: Baker,N.2009)

2.2.2 Roofs

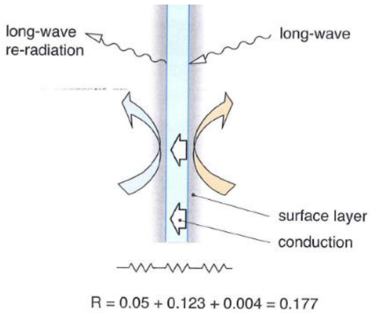
The most effective method of reducing heat transfer through the roof is to lower the "U" value of the roof by adding insulation. For buildings with large roof areas in proportion to floor area (single story buildings), consideration should be given both to insulating the roof and to reducing its absorption coefficient. (Baker,N.2009).

2.2.3. Improving day light penetration through Glazing improvements

Windows are the most energy- transmissive element in the Envelop. The kind of glass selected should give good visible light transmission for adequate daylighting, and have low solar heat transmission (Place et al., 1984). Single glazing conduct heat to the exterior and should be replaced with double glazing with air gap between glazing panels. In Double glazing, adding air gap between the glazing layers decreases the U-value. However, heat transfer between the two panes still takes place by radiation.

Reducing heat transfer by radiation can be achieved by coating the surface of inner leaf that faces the cavity with low-Emissivity coating, This very thin(less than a wavelength of light) metallic, layer transmits short wavelengths(visible light)but acts as a poor emitter for long wave infra-red(IR) .(Baker,N.2009).

Figure (7) The mechanisms of energy transfer through glazing by conduction and convection



Source: Baker,N.2009.)

3. RENEWABLE ENERGY

Rapid depletion of fossil fuel reserves as well as climate change has driven the world towards RE sources which are abundant, and environmentally friendly.

Their technologies for power generation are, reliable, mature and cost effective. Previous research have indicated that the use of Renewable energies can cover most of the energy needs in a building, reducing its carbon footprint.(Vourdoubas,2018)

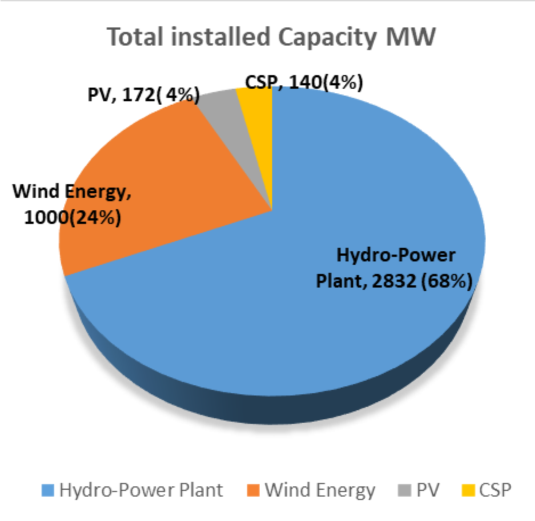
3.1 Renewable Energy Status and Egyptian Energy Policy

According to the NREA Annual Report 2018, the total installed capacity from renewable Sources reached 4100 MW, where Hydro power plants represents about 68% of total installed capacity from renewable Sources , while wind power represents 24%, and Concentrated solar power represents 4%. (Figure 8)

The total Produced Energy from Renewables reached 15600 Million KWh, where 12850 Million KWh are produced from Hydro Power plants representing 83%, 2200 Million KWh from Wind representing 14%, 480 Million KWh from Concentrated solar power representing 3% and 0.3 Million KWh from Photovoltaics.(Figure 9).

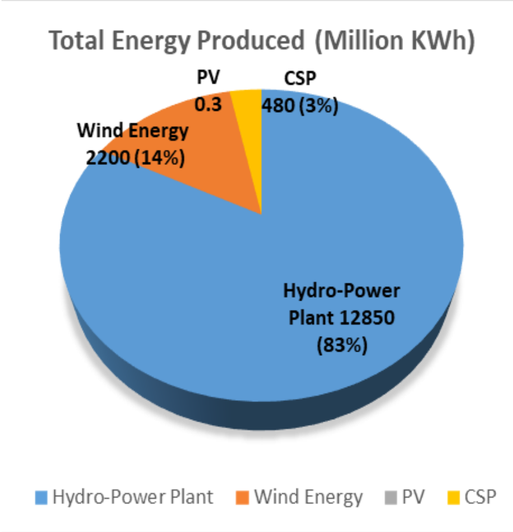
The fuel saving reached 4600 Million Ton of Oil Equivalent and 8.4 Million Ton CO2 Emission Reduction.

Figure (8). Total Installed Capacity



Source: NREA Ministry of Electricity &Renewable Energy Annual Report 2018

Figure (9). Total Energy Produced



Source: NREA Ministry of Electricity &Renewable Energy Annual Report 2018

Egyptian strategy for renewable energy

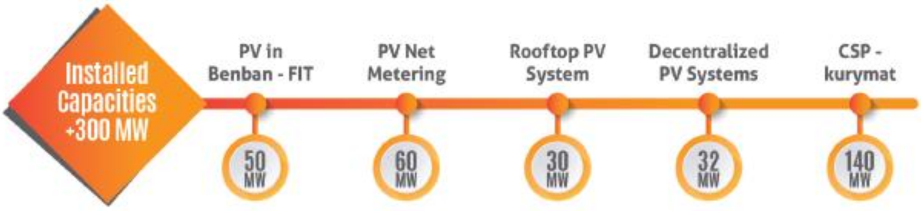
According to NREA 2018, Egypt is targeting to produce 20% of its total Energy production from Renewable Sources by 2022 as follows: 12% from Wind, 6% from Hydro-Power and 2% from PV. Renewable Energy Strategy will be implemented through two integral paths as follows:

Governmental Projects (about 33%from the total installed capacities) and Private Sector Projects (about 67% from the total installed capacities).

Encouraging the participation of the private sector in renewable energy projects requires taking on several procedures including setting supportive policies and motivational technical and financial mechanisms.

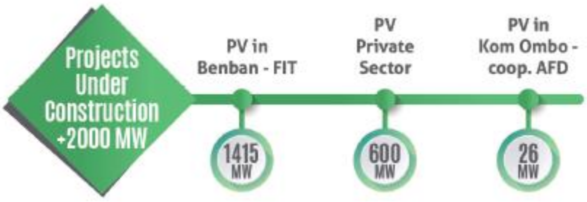
Supportive policies has been adopted by the government to increase the private sector 's contribution in Renewable Energy projects. Among these policies are, applying Feed-in-tariff (Aug.2009), Competitive bids and issuing tenders internationally requesting private sector to supply power from wind energy projects,Third Party Access (June 2012) where Investors are allowed to build &operate RE power plants to satisfy their electricity needs or to sell electricity to other consumers though the national grid. In Jan.2013, Egyptera Board approved to apply Net Metering system to encourage PV Roof Top systems implementation. In Sept.2013, Quota System was introduced, where heavy industries with large energy consumption will be obliged to produce a percentage of its electricity needs from RE sources starting from 2015.Financial incentives play an essential role in encouraging investors to utilize RE technologies that's why the government has adopted incentives policies such as exempting all Renewable Energy equipment from the customs duties.Several projects has been implemented or under preparation by the Ministry of Electricity &Renewable Energy, NREA and the Private sector as well.

Figure (10) Solar Energy Projects



Source: NREA Annual report 2018

Figure (11) Projects under construction



Source: NREA Annual report 2018

4. SOLAR PV SYSTEMS APPLICATIONS

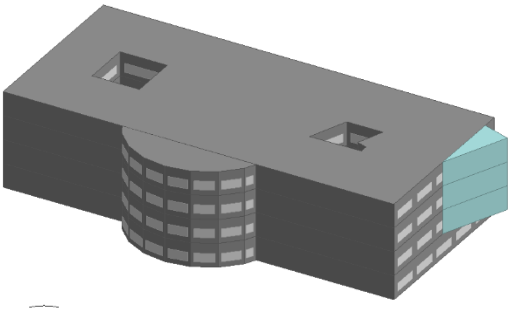
Salem et al. have investigated building integrated photovoltaics applications in Mediterranean countries. The authors have stated that Mediterranean basin is characterized by high solar irradiance, at 7.5 - 8 KWh/m2 annually. They concluded that solar-PVs applied to commercial buildings, which mainly operate during the day, can cover most of their electricity demands. Biyik et al. have reported on building integrated photovoltaic systems (BIPV). The authors have stated that in the last decade, BIPVs have attracted an increasing interest and they are considered as a feasible technology to cover part of the electricity load in buildings. They have also examined the possibility of ventilating the solar-PV system in order to decrease the temperature of the panels and to increase their efficiency. Hayter et al. have reported on solar-PVs applications in buildings. The authors have examined the performance of three solar-PV systems, at 7 KWp to 60 KWp, installed in three commercial buildings. They stated that these systems have reduced the electricity demands in the buildings.They suggested that solar-PV systems should be integrated into the building in its initial design phase. Tselepis investigated the PV market developments in Greece with reference to net-metering case studies. He analyzed two case studies presented for a commercial enterprise and a household He indicated the viability of the net-metering program.

5. CASE STUDY

A typical office building in Cairo,Egypt was simulated for its Energy consumption using Design Builder Simulation software.

In Fig.12 the modeled office building is shown. The main characteristics of the building and design conditions are reported in table 3.

Figure (12) Case Study building.



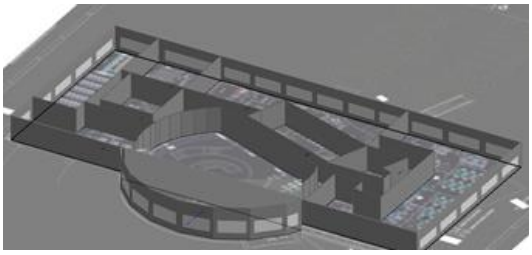


Table (3) Main characteristics of the analyzed building systems and climate

Building area	7,300 m^2
Window to wall ratio	30 %
T summer set point	24 °C
Occupancy level	0.11 person /m^2
Illumination level	300 lux
Occupancy scheduling	From 9:00 am to 18:00 pm 5 days/week

6. RESULTS

Figure (13) Base case Monthly Electric Consumption.

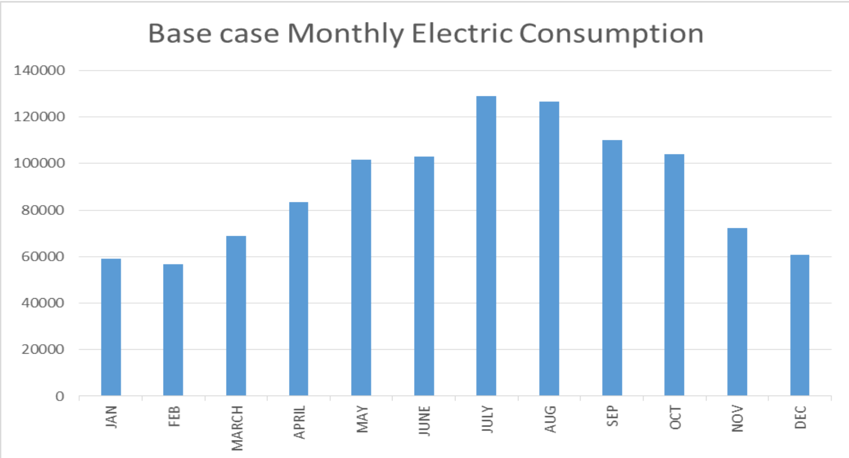


Table (4) Base case Monthly Electric Consumption.

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	Total
Electricity	58945.27	56684.91	68841.73	83393.54	101760.3	102881.9	129019.1	126803.3	109936.6	104066.2	72136.32	60816.47	1075286

Figure (14) Base case Monthly Electricity Break-down

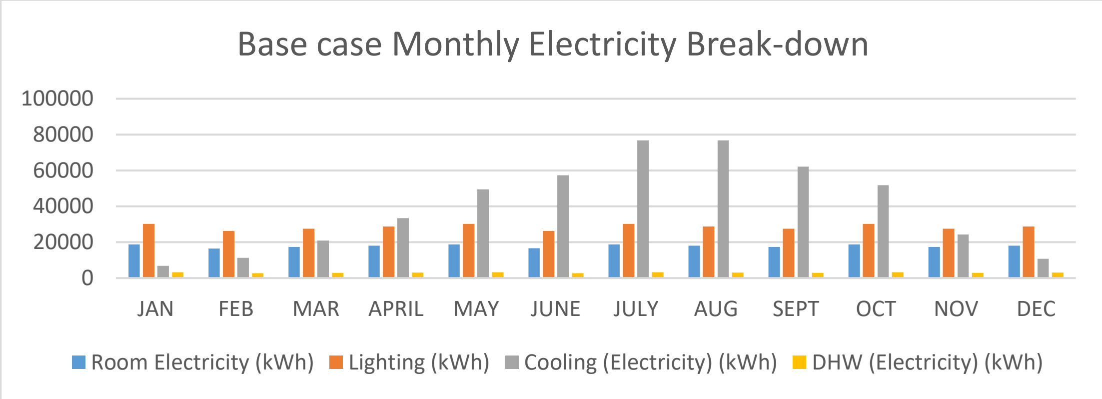


Table (5) Base case Monthly Electricity Break-down.

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	Total
Room Electricity (kWh)	**18824.46**	**16447.82**	**17390.93**	**18032.25**	**18824.46**	**16598.72**	**18824.46**	**18107.7**	**17315.48**	**18824.46**	**17315.48**	**18107.7**	**214613.9**
Lighting (kWh)	**30159.63**	**26225.76**	**27537.05**	**28848.34**	**30159.63**	**26225.76**	**30159.63**	**28848.34**	**27537.05**	**30159.63**	**27537.05**	**28848.34**	**342246.2**
Cooling (Electricity) (kWh)	**6756.86**	**11224.95**	**20988.06**	**33447.95**	**49571.86**	**57271.06**	**76830.72**	**76782.21**	**62158.36**	**51877.74**	**24358.1**	**10795.43**	**482063.3**
DHW (Electr.(kWh)	**3204.32**	**2786.37**	**2925.69**	**3065.01**	**3204.32**	**2786.37**	**3204.32**	**3065.01**	**2925.69**	**3204.32**	**2925.69**	**3065.01**	**36362.12**

Table (6) Base case Annual Electricity Break Down.

	Electricity KWH
Room Electricity (KWh)	214613.9
Lighting (KWh)	342246.2
Cooling (Electricity) (KWh)	482063.3
Domestic Hot Water (DHW)(Electricity) (KWh)	36362.12

Energy consumption was analyzed After adding the following Energy Efficiency measures:

- Using renewable energy sources such installing 900 m2 PV panels on the building roof and a Central solar water heater.
- Using LED lights in the building to reduce the Electricity Consumption.
- Using Low-Emmissivity Double Glazing in the structure glazing to reduce the thermal effect.
- Using occupancy sensors to reduce electrical consumption.

The Annual Electric energy Consumption was reduced from 1,075 MWh to 561 MWh, making Reductions in Annual Energy Consumption of about 48 %.

Electric consumption in Lighting was reduced from 342 MWh to 114 MWh making reductions of 66.6%

Cooling Load was reduced from 482 MWh to 231 MWh making reductions of 52%

Table (7) Modified case Monthly Electric Consumption.

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	Total
Electricity (kWh)	30048.91	26196.94	30842.28	38475.5	50525.11	55824.65	73000.94	74102.72	61472.25	55394.5	35744.86	29689.8	561318.5
Generation (Electricity) (kWh)	14331.5	16704	22593.6	23483.6	25740	23569.2	23320.7	22850.5	22117.1	20501	15651.9	13512.1	244375

Figure (15) Modified case Monthly Electric Consumption

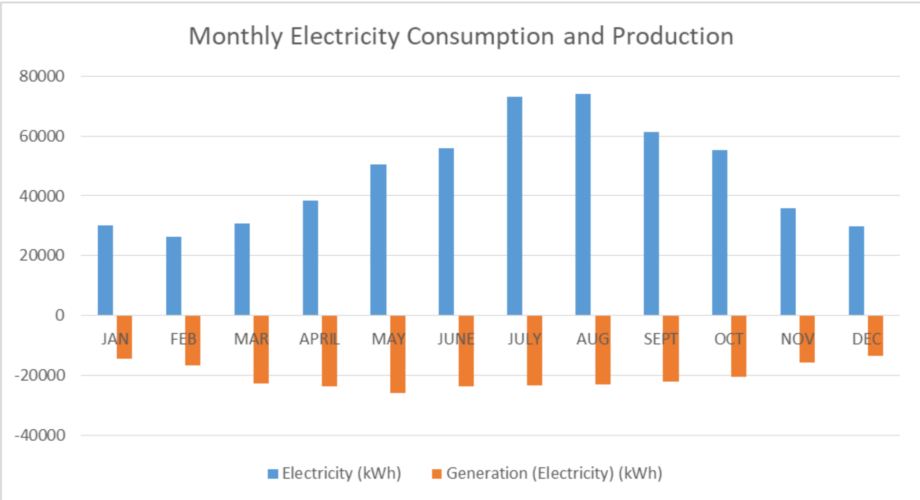


Table (8) Modified case Monthly Electricity Break Down

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	Total
Room Electricity (kWh)	18824.46	16447.82	17390.93	18032.25	18824.46	16598.72	18824.46	18107.7	17315.48	18824.46	17315.48	18107.7	214613.9
Lighting (kWh)	11209.4	9193.98	9372.63	9376.64	9245.19	7988.33	9153.45	8927.22	8988.32	10337.65	10021.41	10944.36	114758.6
Cooling (Electricity) (kWh)	15.05	555.13	4078.71	11066.61	22455.46	31237.6	45023.03	47067.81	35168.44	26232.39	8407.97	637.75	231946
Generation Electr(kWh)	14331.5	16704	22593.6	23483.6	25740	23569.2	23320.7	22850.5	22117.1	20501	15651.9	13512.1	244375

Figure (16) Modified case Monthly Electricity Break Down

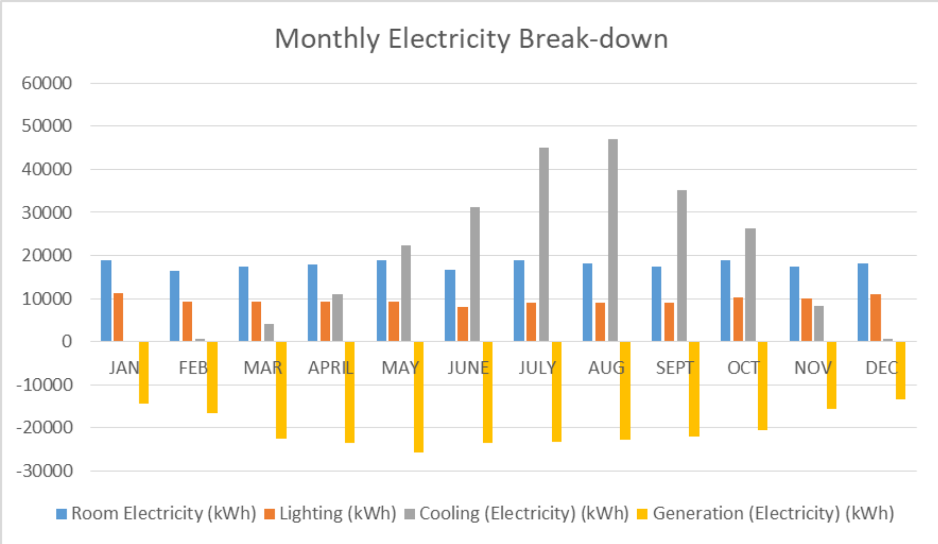


Table (9) Modified case Annual Fuel Break Down.

	Consumption(KWh)
Room Electricity (KWh)	214613.9
Lighting (KWh)	114758.6
Cooling (Electricity) (KWh)	231946
Generation (Electricity) (KWh)	244375

The Annual electricity production due to the installation of 900 m2 PV Panels on the building roof is 244.38 MWH which covers about 40% from the building Energy consumption.

Figure (17) Roof top PV application

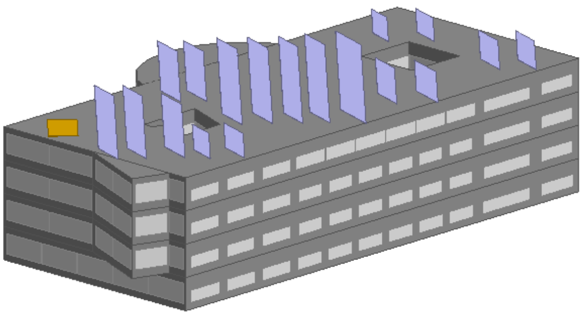


Figure (18) Reductions in Lighting, Cooling load and total consumption.

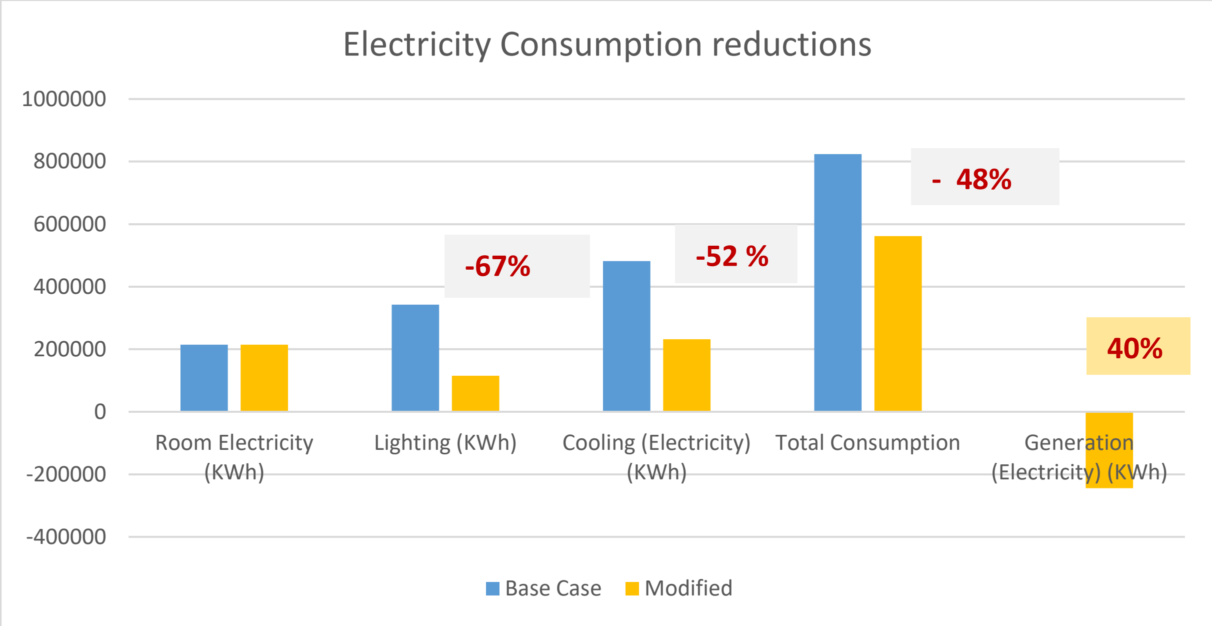


Table (10) Reductions in Lighting, Cooling load and total consumption.

	Base Case	**Modified**
Room Electricity (KWh)	214613.92	214613.92
Lighting (KWh)	342246.22	114758.58
Cooling (Electricity) (KWh)	482063.28	231945.95
Total Consumption	824309.5	561318.45
Generation (Electricity) (KWh)	0	-244375.14

CONCLUSIONS

- By investigating the current status of RE and particularly PV applications in Egypt, it could be observed that the government has put policies and ambitious plans to enhance the PV applications, yet there is still a need for more comprehensive plans to encourage investors and stack-holders to apply PV applications. Subsidies and incentives can contribute greatly to lower the cost and thus enhance PV applications.
- This research examines the effect of applying Energy Efficiency measures and roof top application of PV modules on energy consumption in an air-conditioned office building in Egypt. Annual Energy reductions was calculated by means of Energy Plus, a reliable Energy simulation software. The annual energy production due to the PV roof top installation was calculated as well. Also, the energy requirements for cooling, and lighting was evaluated.
- It was proven that the Annual Electric energy Consumption was reduced from 1,075 MWh to 561 MWh, making Reductions in Annual Energy Consumption of about 48 %. Electric consumption in Lighting was reduced from 342 to 114 making reductions of 67% and Cooling Load was reduced from 482 to 231 making reductions of 52%.

- The Annual electricity production due to the installation of 900 m2 PV Panels on the building roof is 244.38 MWH which covers about 40% from the building Energy consumption.
- It could be concluded that adopting an integrated methodology for applying Energy Efficiency measures and PV application offers a good opportunity to solve the Energy problems and could contribute significantly in reducing the total building energy consumption.

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