Benchmarking the EE of Administrative Buildings

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***Abstract*— This paper reflects and focuses on Energy Efficiency (EE) for commercial institutions and public utilities. The EE of a building is the extent to which the energy consumption per square meter of floor area of the building (kWh/m^2/annum) measures up to established energy consumption benchmarks for that particular type of building under defined climatic conditions. Building energy consumptions benchmarks are representive value for common building types against which a building actual performance can be compared. Benchmarks are applied mainly to heating, cooling, air conditioning, ventilation, lighting, fans, pumps and controls, office or other equipment and electricity consumption for external lighting.**

In Egypt, there are important opportunities to improve EE in government facilities, operations, and public infrastructure and services. Benefits include lower government energy bills, reduced greenhouse gas emissions, less demand on electric utility systems, and reduced fuel.

In the paper five case studies are carried out. The steps are preparing the auditing, monitoring the electrical parameters, analyzing the measurement result and inspection data and option solution to provide EE improvement.

I. Energy Audit

Governments have a responsibility to ensure that there is secure supply of energy to ensure economic growth. In many countries there is normally very little margin between existing power supply and electricity demand. With increasing electricity use from existing consumers and new connections, new generations needs to be brought on line to meet increasing demand.

To reduce the energy consumption and costs, and to improve the indoor environment, it is necessary to renovate and implement EE measures in the building. To identify the actual potential and ensure sustainable results, projects should be developed and implemented in a structured and efficient way. This requires good energy auditing, management methods and tools, as well as good skills of specialists.

Energy auditing includes an inspection of the building, an evaluation and analysis of the existing situation and the different measures that could be implemented to reduce the energy consumption and improve the indoor environment. The results are presented in an energy audit report describing the recommended measures with corresponding investments, savings and profits. Energy auditing should be done by specially trained and experienced energy auditors. When performing an energy audit, all the factors influencing the energy consumption and indoor environment must be evaluated:

- Building envelope (windows, roofs, area)
- Air conditioning system.
- Lighting system.
- Automatic control systems.

In addition, it is also necessary to take into consideration how the building and its installation are being operated and used.

II. Energy Efficiency (EE)

Saving energy through EE improvements can cost less than generation, transmission and distribution energy from power plants, and provides multiple economic and environmental benefits. EE also helps reduce air pollution and greenhouse gas (GHG) emissions, improves energy security and creates jobs.

The EE of building can be improved with the following measures:

- EE building cooling.
- Reducing consumption of office equipment and appliances.
- Reducing energy use for lighting.

III. EE Building Cooling

A. Room air conditioners

For air conditioners, proper sizing, selection, installation, maintenance and correct use are keys to cost-effective operation and lower overall costs.

The advantages are:

- Less costly than central systems.
- Less costly to operate than central system.
- Individual rooms may be kept at different temperatures.
- Easy installation.
- Don’t require a duct system

B. Whole-house fans

Whole-house fans work in many climates and help cool space by pulling cool air through the place and exhausting warm air through the attic. Use the fan most effectively to cool down space during cooler times of the day, the space will stay cooler through the hotter times of the day without using the fan.

Recommendation:

- Set the thermostat at as high a temperature as comfortably possible in summer, and ensure humidity control if needed. The smaller the difference between the indoor and outdoor temperature, the lower cooling bill will be.
- Avoid setting thermostat at a colder setting than normal when turn on air conditioner. It will not cool space any faster and could result in excessive cooling and, therefore, unnecessary expenses.
- Consider using an interior fan along with window air conditioner to spread the cooled air through space without greatly increasing power use.
- Avoid placing appliances that give off heat such as lamps or TVs near a thermostat.
- To optimize the performance of room air conditioner, select an EE model that is properly sized, and has EER (energy efficiency ratio) of 11 or more.

IV. Reducing consumption of office equipment and appliances

The typical measures to reduce consumption are:

- Switching off or enabling power down mode reduces the energy consumption and heat produced by equipment.
- Upgrading existing equipment, some EE appliances may cost more to buy but will return savings over the lifetime of the equipment.
- Taking benefits of energy labeling schemes.

Table (1) summarizes the benefits of some energy labeling office equipment and appliances.

Table (1)
Labeled EE equipment and appliance [1]

Appliance	Benefit
Computers	Use 70% less electricity than computers without enabled power management.
Monitors	Use up to 60% less electricity than standard models.
Printers	Use at least 60% less electricity and must automatically enter a lower power setting after a period of inactivity.
Fax machines	Use almost 40% less electricity.
TVs	Consume 3 watts or less when switch off, compared to a standard TV, which consumes about 6 watts on average.
Light bulbs (CFLs)	Use two-third less energy than a standard incandescent.

V. REDUCING ENERGY USE FOR LIGHTING

This can be done through:

- Making maximum use of daylight.
- Using task lighting to overcome excessive background lighting levels.
- Installing EE fixtures with a high light output to energy ratio.
- Selecting lamps with high efficacy.
- Providing effective controls that avoid lights being left on unnecessarily.

To save up to 70% electricity for lighting, without any impacts on comfort:

- Make optimum use of daylight.
- Make a good lighting plan.
- Use high EE lamps.

VI. ENERGY EFFICIENT LIGHTING

Lighting is a large and rapidly raising load source of energy and GHG emissions. At the same time the savings potential of lighting energy is high, even with the recent technology, and there are new EE lighting technologies coming onto the market. Currently more than 33 billion lamps operate worldwide, consuming more than 2650 TWh of energy annually, which is 19% of the global electricity consumption [1].

Benefits of EE lighting improvements are:

a) For the customer

- Lower energy bill.
- Save on air conditioning costs.
- Less frequent bulb replacement (i.e. O&M cost saving).
- Improved work environment.

b) For electric utility

- Reduced energy use and related energy supply needs.
- Reduced environmental impact.

The EE of lighting installations can be improved with the following measures.

1- The choice of lamps
   - Incandescent lamps replaced by CFLs or LEDs.
   - Mercury lamps by HPS or MH or LEDs.
2- The choice of ballast
   - Magnetic ballasts (MB) replaced by electronic ballasts (EB).
   - The usage of controllable EBs with low losses.
3- The use of efficient luminaires.
4- The use of lighting control systems.

Table (2) summarizes the advantages of EBs

TABLE (2)
The advantage of EBs

Advantage	Description
Greater efficiency	• Greater 15% to 20% than MB. • Don’t generate as much internal heat. • Reduces the losses
Better control and design flexibility	• Provides continuous, flicker free dimming, dimming ranges: 100% to 10%; 100% to 5% or 100% to 1%

	• Linear relationship between wattage and light output.
Ability to drive more lamps	• Single ballast can drive up to 4 lamps. • Reduces ballast cost.
Reduced cooling load	Losses (generated heat) are minimized and the air conditioning load is reduced.
Reduced lamp flicker	High frequency operation of lamp cycles, the lamp so rapidly that flicker is imperceptible.
Lighter in weight	Not as heavy as the MBs.
Quieter operation	Don’t hum as the MBs.
End of life sensing	EBs for small diameter lamps (T5 or smaller) are available that detect the end of life of the lamp and shut it off before the lamp overheats enough to melt sockets.

Electricity consumption for lighting could be further decreased by installing lighting control systems. The main lighting control systems are presented in table (3)

TABLE (3)
Characteristics of lighting control systems

Type of device	Description	Used place
Dimmer switches	Used to manually vary the intensity of the light output, by decreasing or increasing the mean power of lamp.	In room.
Time switches	Programmed to turn on and off the light at specified time.	• Outdoor areas: parking, corridors, stairs. • Indoor public areas, hall, lobby.
Motion detectors	Turn on light when they detect any presence, decrease energy consumption up to 80%.	Low trafficked outdoor areas, parking, corridors, stairs, public WC.
Light level sensors	Turn on artificial lighting when detect that the ambient light falls below a predetermined level.	• Outdoor areas, corridors, stairs. • Indoor areas, hall, lobby.

VII. SUCCESS CASES

In order to define the current EE level of administrative building, an analysis was carried out which focused on a set of energy improvements applied and recommended.

The specific goals defined were the following:

- Define improvement proposal related to building equipment in order to reduce the current energy consumption level of them.
- Analysis of energy saving actions of building to improve efficiency after applying new practices and techniques.

The energy audits are carried out for five administrative buildings.

The energy audit pointed out several problems, of which the main were:

- Lighting quality did not correspond to existing local and international standards.
- Low cleaning and maintenance of the system, causing dust settlement reducing the quality of the light.
- Some of the bulbs were replaced with inappropriate bulbs causing bad interconnection and as result some of the wires were burned.
- High monthly electricity consumption.
- Lighting power densities for different spaces are exceeded the standard limit.

The dominated electric loads are lighting system, fans and low number of air conditioning.

The types of lamps are: incandescent lamp, tube fluorescent lamps (T8:60cm, 120cm length, 26mm diameter) with magnetic ballasts (MB_S), and high pressure sodium lamps.

The EE opportunities are:

- Change the MBs to EBs, the primary advantage of EBs is that they draw less power and therefore provide energy saving.
- Change incandescent lamps to CFLs.
- Change high power sodium HPS lamps to the lower rating.

Tables (4) summarize the EE opportunities for five buildings under studies.
Table (5) represents the numbers of proposal EB_S needed.
Table (6) shows the results when will be implemented the EE opportunities in lighting systems.

TABLE (4)
EE opportunities

Case study	Use EBs	Use CFL_S	Use HPS (lower power)
Building 1	√	√	√
Building 2	√	√	
Building 3	√	√	
Building 4	√	√	
Building 5	√		√

TABLE (5)
Number of suggested EBs

Case study	T8, 120 cm		T8, 60 cm		
	1 lamp	2 lamps	1 lamp	2 lamps	4 lamps
Building 1	207	464	7	81	177
Building 2	45	554	18	77	78
Building 3	6	36			988
Building 4		105			670
Building 5	158	397	2	3	2161

TABLE (6)
Power and energy saving in lighting system

Case study	Power saving (kW)	Power saving (%)	Energy saving (KWh/yr.)	CO_2 reduction (Ton)	Payback period (year)
Building 1	23.357	28.01	41479.7	22.4	3.27
Building 2	20.141	28.4	38363	20.7	3.4
Building 3	44.56	37.12	64166.4	34.65	2.7
Building 4	29.67	43.83	42724.8	23.1	2.9
Building 5	27.386	30.86	39435.4	21.3	3.4

VIII. LIGHT POWER DENSITY (LPD)

LPD determined by the interior lighting power allowance (watts) by the space area (m^2). The interior lighting power allowance is the sum of the lighting power allowances for all spaces. The lighting power allowance for a space is the product of the gross lighted floor area of the space times the allowed LPD for that space. Table (7) respects LPD for space-by-space method.

TABLE (7)
LPD using [4] space-by-space method

Common space type	LPD (w/m^2)
Office – enclosed	11
Office – open plan	11
Conference / meeting / multipurpose	13

Lamp efficacy, in an interior lighting scheme, plays a very crucial role. A lighting scheme, which utilizes lamps with lower efficacies, will result in increased number of lamps and hence increases the LPD of the space. The increased LPD will not only increase the lighting power consumption, but also indirectly increase the heating load on the HVAC equipment and further add to energy consumption. The reduction in energy consumption is possible with the proper choice of lighting fixtures, ballasts, and lamps types.

Fig (1) represents LPD calculated for number of space in 5 case studies building.

Table (8) shows the positive side when change the MBs by EBs, and helping in decreasing LPD.

TABLE (8)
LPD decreases if installed EBs

LPD (w/m^2) (existing MBs)	LPD (w/m^2) (if install EBs)	Decrease in LPD %
17.36	13.64	21.43
11.83	9.26	21.72
12.25	9.59	21.71

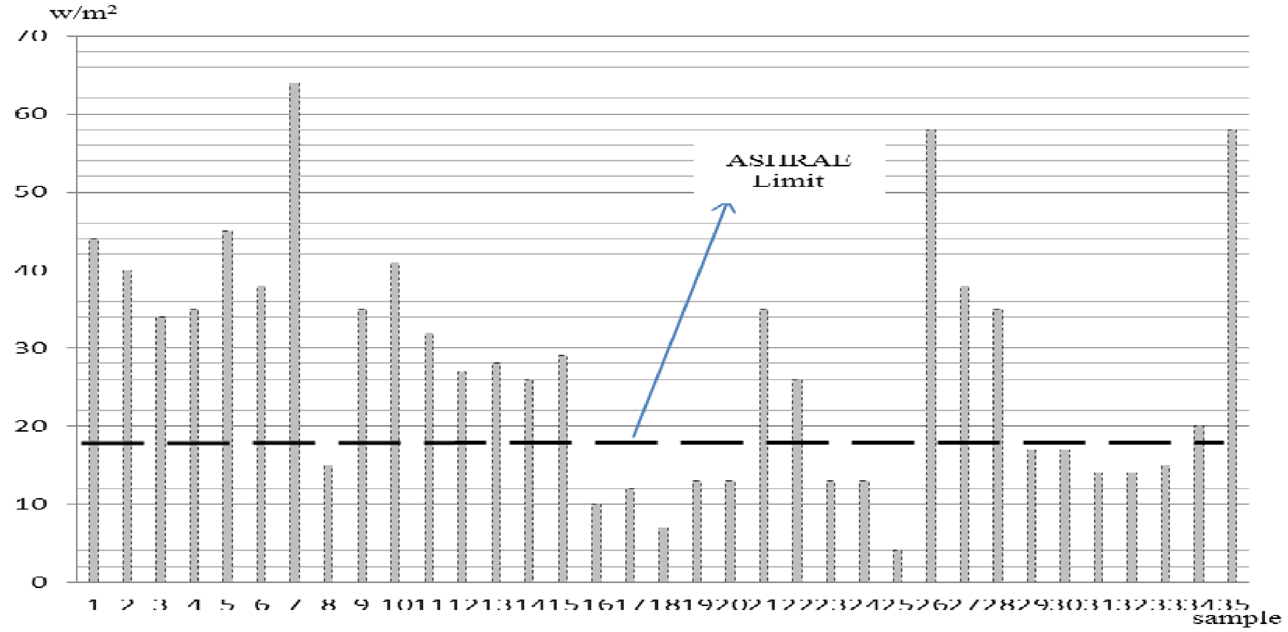

Fig (1) LPD (in w/m^2) calculated for many samples

IX. CHARACTERISTICS OF ELECTRIC LOADS

Power quality has been a problem ever since the conception of power electricity, but only over last several years, it has received considerably more attention from researches, with increasing non-linear loads.

Extensive measurements and monitoring of electrical parameters, one-day-period are carried out. Analyzers are used for measuring the electrical parameters on the LV three phases for each case study. The electric parameters are; voltage, current, power, power factor, total harmonic distortions for current and voltage.

Figs (2) to (6) represent the variation of electric parameters over one week period for case study (3).

Table (9) summarizes the range of measured electrical parameters.

TABLE (9)
Results for case study (3)

Parameter	Range of measurement
Irms (Amp)	46.44 – 955.6
PF	0.52 – 1.0
Power (kW)	22.9 – 497.15
ITHD %	4.84 – 45.23
VTHD %	0.92 – 5.85

The results of power quality are:

- The maximum VTHD % meets the standard IEEE 519- limit [5].
- The maximum ITHD % matches the minimum loads.
- The minimum ITHD % matches the maximum loads and meets the standard IEEE 519-limit.

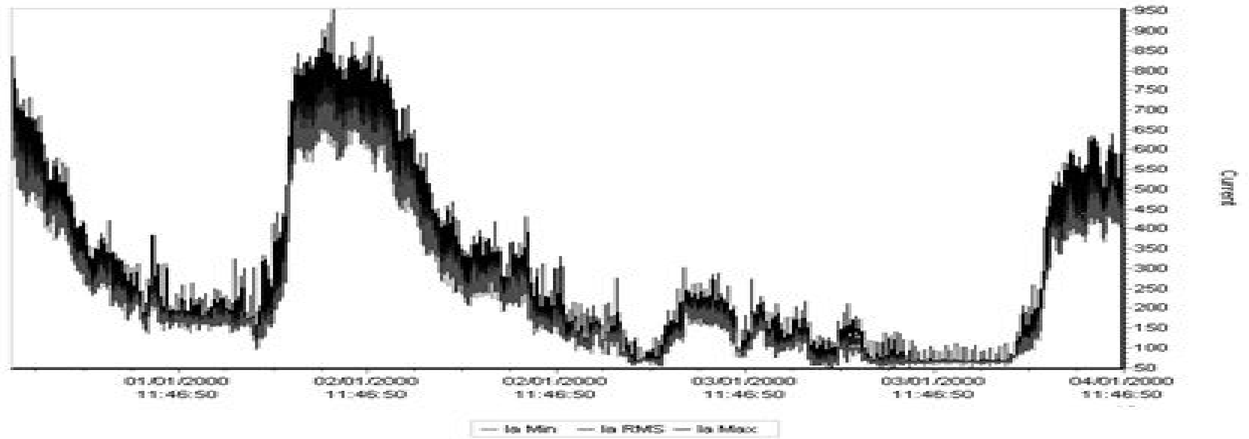

Fig (2) variation of current

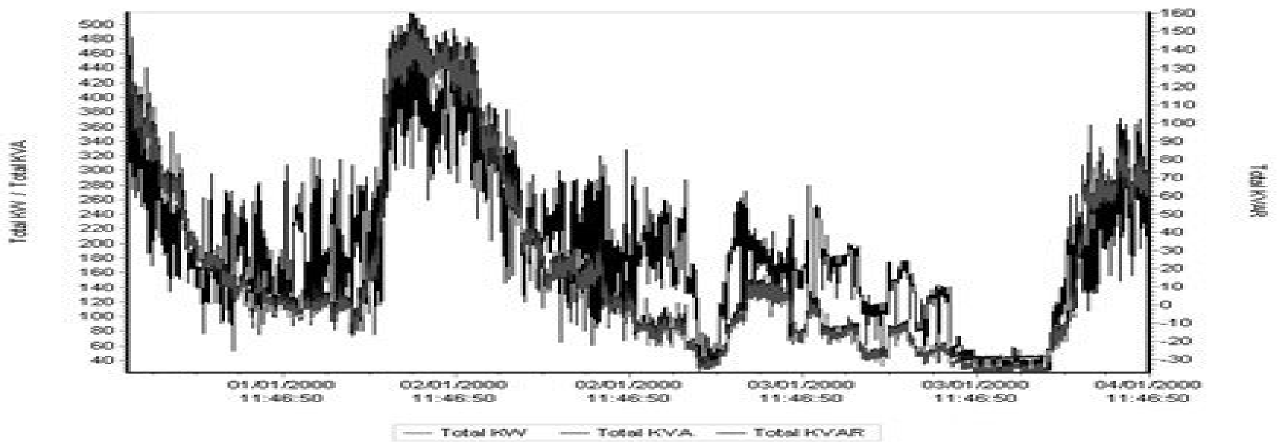

Fig (3) variation of power

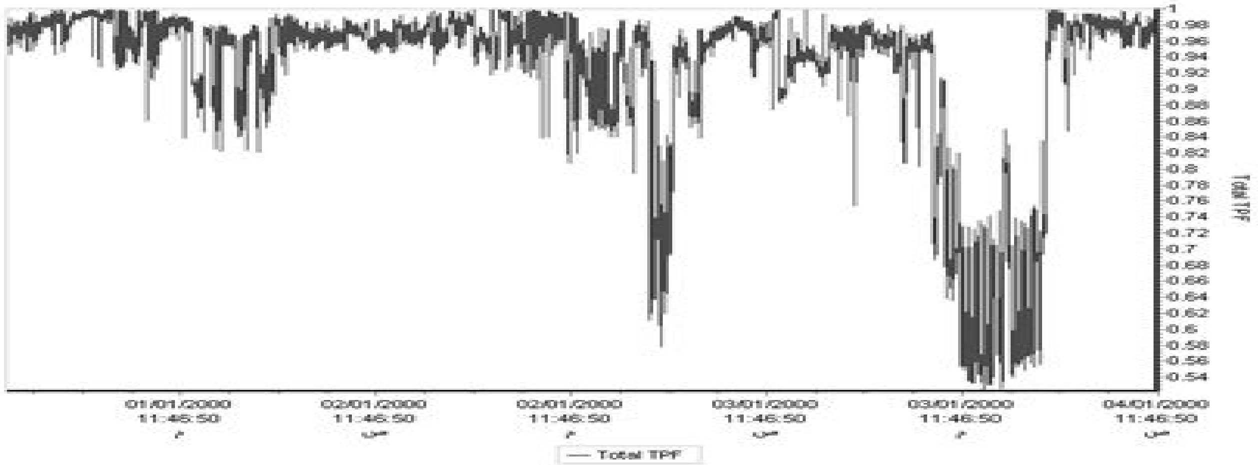

Fig (4) variation of PF

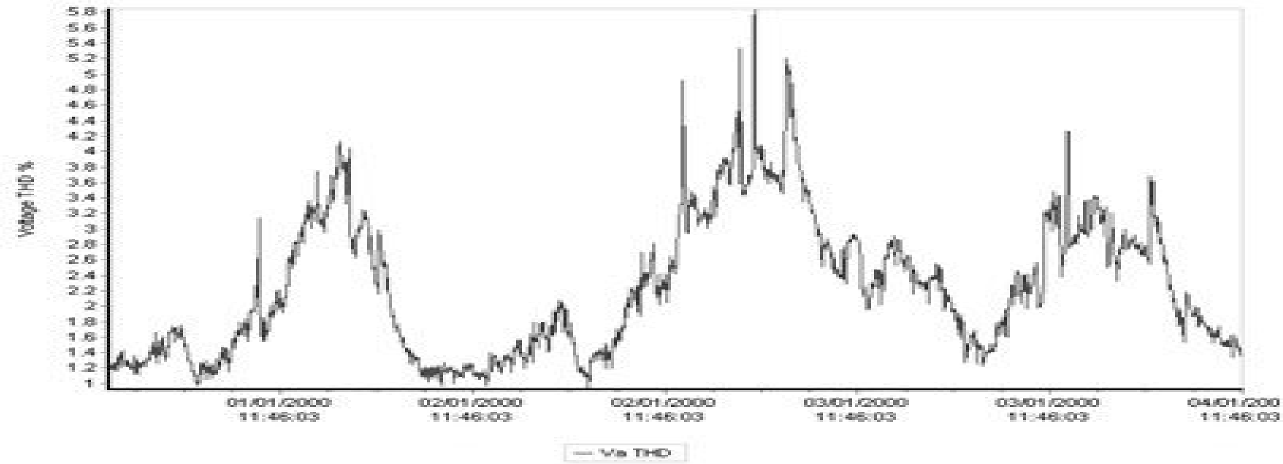

Fig (5) variation of VTHD %

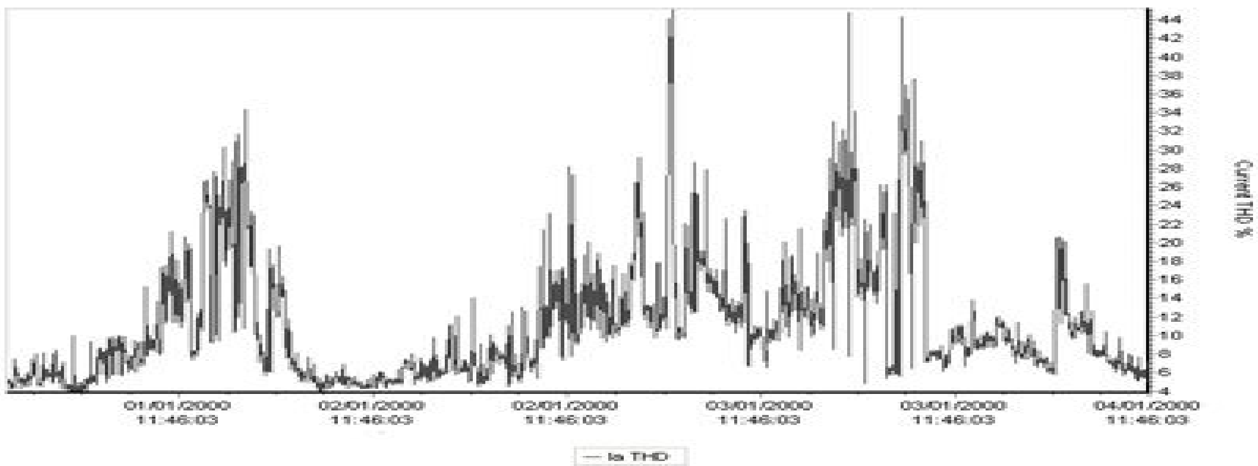

Fig (6) variation of ITHD %

X. Conclusion

EE is environmentally, economically, politically responsible and lends itself to the concept of going green.

The main benefit from measures to improve EE buildings is lower energy costs but there are usually other benefits to be considered too.

EE measures are meant to reduce the amount of energy consumed while maintaining or improving the quality of services provided in the buildings. Among the benefits likely to arise from EE investments in buildings are:

- Reducing energy use for space heating, cooling and water heating.
- Reducing electricity use for lighting, office machinery and appliances.
- Lower maintenance requirements.
- Improved comfort.

XI. References

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