

Evaluation of Energy Performance for an Institutional Building and Proposing Remedial Measures

Richard Fernandes

M.E Civil (Environment) Student
Dept. Civil Engineering, Sinhgad
College of Engineering, Pune
rich.fnds@gmail.com

V. S. Limaye

Asso -Prof. (Civil Dept.)
Dept. Civil Engineering, Sinhgad
College of Engineering, Pune
vslimaye.scoe@sinhgad.edu

S. S. Shastri

Prof. & Head (Civil Dept.)
Dept. Civil Engineering, Sinhgad
College of Engineering, Pune
ssshastri.scoe@sinhgad.edu

Abstract — Currently India is one of the major energy consumer among the developing nations globally. Buildings in India generally are responsible for at least 30-40% of energy use and this demand is growing annually almost twice the average electricity growth in the economy. Green buildings leave a lighter footprint on the environment through conservation of resources and at the same time are energy-efficient and cost-effective. Energy efficiency is the first step towards achieving sustainability in buildings. Energy efficiency helps in controlling rising energy costs, reduce environmental footprints and increase the value and competitiveness of buildings.

The following paper will focus on the utilization of alternative sources of renewable energy for satisfying the energy demand in an institutional building. The primary aim is to assess the energy performance, based on monitored data for the existing institutional building and thus demonstrating the potential for energy conservation and thereby proposing optimised energy conservative techniques and also studying the feasibility and effectiveness of those techniques both energy and cost wise.

Keywords: institutional building; renewable energy; energy performance; conservative techniques.

I. INTRODUCTION

With the recent industrial development and GDP magnification, India has emerged as major energy consuming nations among the developing countries. According to the Government of India, Ministry of Statistics and Programme Implementation, the per capita energy consumption has increased almost four-folds in four decades during 1970-2010 year. But in last three decades during a period of 1980-2010, India's annual energy consumption has increased five-folds. This owes to the improved urban life standards and advanced means of

energy consumption. Energy efficiency is the first step toward achieving sustainability in buildings and organizations. Energy efficiency keeps a check on rising energy costs and reduce environmental footprints as well.

II. AIM AND OBJECTIVES

A. Aim

To evaluate energy performance for an institutional building and propose remedial measures.

B. Objectives

- To understand energy needs of the existing institutional building.
- Utilization of alternative sources of renewable energy, for satisfying the energy demand in an institutional building.
- To assess the energy performance, based on monitored data of the existing institutional building thus demonstrating the potential for energy conservation by providing with remedial measures.

III. LIMITATION OF PROJECT STUDY

Energy should be conserved for all types of buildings at a global level, but this work is limited to an educational institute with case study of Sinhgad College of Engineering.

IV. BENEFITS OF ENERGY EFFICIENCY

- Reduction in energy bills
- Improving business competitiveness

- Decreasing native air pollutants

V. TECHNIQUES FOR INCREASING ENERGY EFFICIENCY

Energy efficiency is increased by the use of following techniques:

- Utilization of solar energy using solar panels
- Utilization of wind energy using wind turbines.
- Installation of energy efficient lighting.
- Installation of energy efficient fans.

A. Solar Panels

Solar panel electrical energy systems, also commonly known as solar photovoltaics (PV), capture the solar energy using photovoltaic cells. These cells don't require direct sunlight to work i.e. even on a cloudy day they still generate some electricity. The cells convert sunlight into electricity, which can be then used to run various electrical appliances and lighting.

a) Benefits of solar electricity

Reduction in electricity bills.

Reduction in carbon footprint.

b) Working of solar panels (PV) cells

Photovoltaics cells are manufactured from layers of semi-conducting material, usually consisting of silicon. When sunlight is incident on the cell it generates an electric field across the layers. More the intensity of sunlight, more electricity is generated.



Fig. 1. PV Panels

(Source- Photo captured from SCOE D1 Block terrace)

Groups of PV cells are mounted together in panels either on the roof or the ground. The measurement of power of a PV cell is kilowatts peak (kWp). That's the energy generation rate at peak performance in maximum direct incident sunlight during the summer. Most PV systems consists of panels that are fitted on top of an existing roof or terrace.

B. Building Integrated Wind Turbines



Fig. 2. Wind Turbines

(Source: <http://www.climatetechwiki.org/technology/building-integrated-wind-turbines>)

Wind power or wind energy is harvested from air current with the help of wind turbines which generate mechanical or electrical energy. Wind energy can be a substitute to fossil fuels. It is renewable, abundant, clean, widely distributed, releases no greenhouse gases during its operation, and requires little land. Therefore, harmful effects on the environment are less than those of non-renewable power sources. Electricity which is generated from wind energy can be highly variable and uneven at different timescales: hourly, daily, or seasonally. Hence it must be substituted by other power sources during low wind periods. Wind energy is capital intensive, but doesn't include any fuel costs. Therefore, the price of wind power much more stable as compared to volatile prices of fossil fuel sources.

C. LED Lighting

The light-emitting diode or LED is today's one of the most rapidly-developing and energy-efficient lighting technologies. LED light bulbs with quality are more durable, last longer, and offer comparable or even better light quality than other types of conventional lighting. The basic principle of LED is that it uses a semiconductor to convert electricity into light. LED bulbs can be several times (6-7 times) more energy efficient than conventional lighting e.g. incandescent lights and reduce energy consumption by around 80 %

LED bulbs of good-quality can have a life of 25,000 hours or more, that means they can last 20-25 times longer than conventional light bulbs. That is equivalent to a life of more than 3 years if run 24 hours a day and 7 days a week. Unlike incandescent bulbs, which generally release 80-90 % of energy as heat, LEDs use energy far more efficiently and effectively with little wastage of heat.

a) LED Lights Vs Florescent Lights

LED is the greenest option in all forms of lighting available. The reason being:

It does not contain any mercury, which is harmful for environment unlike the fluorescent bulbs and tubes.

It lasts much longer (about 10 to 20 years) and thus their disposal is less of a concern.

Fluorescent lights on the other hand contain mercury which can harm the environment and hence their disposal is a concern. And this is a major problem with both fluorescent tubelights and CFLs.

b) Lumens or brightness of the light

LEDs are excellent for spot lighting because of unidirectional source. LED lights that are used for general lighting purpose have inbuilt reflectors that spread the light in all directions. In fluorescent lights the use of reflectors causes decrease in brightness per watt. This results in their reduced efficiency. Brightness for 40 W fluorescent tubelight is 2400 lumens, whereas for 20 W LED tube is 2100 lumens

D. Energy Efficient Fans

Superfan: India's first Energy efficient ceiling fan.



Fig. 3. Superfan

Source: snapdeal.com

a) Advantages

- Energy savings, more than 50% savings, lower electricity bill.
- Remote control, no regulator needed, saves space on switchboard.
- High air delivery.
- UPS friendly – Runs twice longer, no extra noise, no speed drop.
- No speed change due to supply variations or low voltage.
- No heat generated.
- Powder coated Aluminium die cast body & leaves – no rust.

TABLE I: Comparison: Ordinary Ceiling Fan v Superfan

Type	Power consumption in Watts
Ordinary Ceiling Fan	75
Superfan	35

VI. OBSERVATION AND ANALYSIS

A. LED Lighting

The tubelights installed in D1 block of Sinhgad College of Engineering are of 40 Watts i.e. T12 tubelights. However, by measuring the actual Watt Consumption using a Wattmeter it was observed the tubelight consumes 70 Watts instead of 40 Watts that is printed on the surface of tubelight. This is due to Electronic ballasts. The term “ballast” used in fluorescent lighting applies to the device that controls the lamp current (milliamp) at the proper operating parameter for the lamp, provides proper open circuit voltage to start the lamp reliably without excessively damaging the cathodes, and provides the proper cathode heating voltage (3.6 - 1.2 volts) for rapid start lamps.

These tubelights can be replaced by 20 Watt LED tubes. An LED tube by nature only emits light unidirectionally which means all of the light is focused in front and no light is wasted by illuminating the wall behind. This increases brightness of the room dramatically despite the fact that the lumen output is lesser.

TABLE II. Energy Consumption (Tubelights)

Building	Total number of Tubelights	Energy Consumption 70 Watt per hour	Replaced with LED Tube of 20 Watt
D-1	421	29750	8420

Therefore, potentially 21,330 Watts can be saved per hour i.e. energy efficiency will be increased by 71.4%.

Cost of 20 Watt LED tube = Rs. 1,500

If all the lights are replaced: Total replacement cost will be $421 \times 1500 = \text{Rs. } 6,31,500$

It was observed that out of the total number of lights present, not all lights were switched on in working hours at a given instance.

Assuming 50% of the lights are on at a given instance. Total college working hours = 8 hrs.

Energy consumption per month = 50% of Maximum energy consumption $\times 8$ hours $\times 26$ days

a) Maximum energy consumption of 40 W tubelights = 29,750 W.

50% of Maximum energy consumption of 40 W tubelights = $0.5 \times 29,750 = 14,875$ W

b) Maximum energy consumption of 20 W LED tubes = 8,420 W.

50% of Maximum energy consumption of 20 W LED tubes = $0.5 \times 8,420 = 4,210$ W

Payback period

With 40 Watt tubelights:

$14875 \times 8 \times 26 = 30,94,000$ W per month = 3094 units

Cost in Rupees for 1 unit = Rs. 5.6

Estimated bill per month due to tubelights alone = $5.6 \times 3094 =$ Rs. 17,326

(Note: 1 unit = 1 kWh)

With 20 Watt LED tubes:

$4210 \times 8 \times 26 = 8,75,680$ W per month = 875 units

Cost in Rupees for 1 unit = Rs. 5.6

Estimated bill per month after replacing with 20 Watt LED tubes = $5.6 \times 875 =$ Rs. 4,900

Total savings per month = Rs. 17,326 – Rs. 4,900 = Rs. 12,426

Payback period = Total installation cost/ Total savings per month

Payback period = $6,31,500 / 12,426 = 50.8$ months i.e. approximately 4 years.

Therefore, the initial installation cost can be recovered in 4 years period with overall increase in energy efficiency by 71.4 %.

B. Energy Efficient Fans

TABLE III. Energy Consumption (Fans)

Building	Total number of Fans	Energy Consumption 75 Watt per hour	Replaced Superfan (35 Watt)
D-1	176	13200	6160

Therefore, potentially 7040 Watts can be saved per hour i.e. energy efficiency will be increased by 53.3%.

Cost of Superfan = Rs. 3,400

If all the existing fans are replaced:

Total replacement cost will be $176 \times 3400 =$ Rs. 5,98,400

It was observed that of the total number of fans present, not all fans were switched on in working hours at a given instance.

Assuming 80% of the fans are on at a given instance. Total college working hours = 8 hours.

Energy consumption per month = 80% of Maximum energy consumption x 8 hours x 26 days

Maximum energy consumption for ordinary fan = 13,200 W.

80% of Maximum energy consumption = $0.8 \times 13,200$ W = 10,560 W.

Maximum energy consumption of Superfan = 6,160 W.

80% of Maximum energy consumption for Superfan = $0.8 \times 6,160 = 4,928$ W

Payback Period

Ordinary Ceiling Fan:

$10,560 \times 8 \times 26 = 21,96,480$ W per month = 2196 units

Cost in Rupees for 1 unit = Rs. 5.6

Estimated bill per month due to existing fans = $5.6 \times 2196 =$ Rs. 12,298

(Note: 1 unit = 1 kWh)

Superfan:

$4,928 \times 8 \times 26 = 10,25,024$ W per month = 1025 units

Cost in Rupees for 1 unit = Rs. 5.6

Estimated bill per month after replacing with Superfan = $5.6 \times 1025 =$ Rs. 5,740

Total savings per month = Rs. 12,298 - Rs. 5,740 = Rs. 6,558

Total savings for 8 months = $6,558 \times 8 =$ Rs. 52,464 (Assume fan usage for 8 months)

Remaining 4 months savings = $12,298 \times 4 =$ Rs. 49,192

Total savings per year = Rs. 52,464 + Rs. 49,192 = Rs. 1,01,656

Payback period = Total installation cost/ Total savings per year

Payback period = $5,98,400 / 1,01,656 =$ approximately 6 years.

Therefore, the initial installation cost can be recovered in 6 years period with overall increase in energy efficiency by 53.3 %.

Cost in Rupees for 1 unit = Rs. 5.6

Estimated bill after replacing with Superfan = $5.6 \times 1281 =$ Rs. 7,174

Total savings for 6 months = Rs. 8,203 (Assume fan usage for 6 months)

Remaining 6 months savings= Rs. 15,377

Average savings= $(8203+15377)/2 =$ Rs. 11,790

Payback period = Total installation cost/ Total savings per month

Payback period = $5,98,400 / 11,790 = 50.8$ months i.e. approximately 4 years.

Therefore, the initial installation cost can be recovered in 4 years period with overall increase in energy efficiency by 53.3 %.

C. Solar Panels

Currently 2 kW power solar panels are installed which are not in full use due to lack of proper maintenance.

Reactivation and repairing cost of existing 2 kW power solar cells = Rs. 70,000. Installation cost for 1 KW power solar panels = Rs. 1,00,000

Scenario 1: If all existing tubelights run on Solar

Total power required = 50% of Max. energy consumption i.e. 50% of 29.75 kW = 14.87 kW

Since 2 kW is already present, panels capacity required = 14.87 – 2 = 12.87 kW

Installation Cost = (12.87 x 1,00,000) + 70,000 = Rs. 13,57,000

Savings per year = 17,326 x 12 = Rs. 2,07,912

Payback period = Installation Cost / Savings per year i.e. 6 ½ years.

Scenario 2: If all existing fans run on solar

Total power required = 80% of Max. energy consumption i.e. 80% of 13.20 kW = 10.56 kW

Total power required = 10.56 kW

Since 2 kW is already present, panels capacity required = 10.56 – 2 = 8.56 kW

Installation Cost = (8.56 x 1,00,000) + 70,000 = Rs. 9,26,000

Savings per year = 12,298 x 12 = Rs. 1,47,576

Payback period = Installation Cost / Savings per year i.e. 6 ½ years.

Scenario 3: Existing tubelights + fans run on solar

Total power required = Total power required by tubelights + Total power required by fans

$$= 14.87 + 10.56 = 25.43 \text{ kW}$$

Since 2 kW is already present, panels capacity required = 25.43 – 2 = 23.43 kW

Installation Cost = (23.43 x 1,00,000) + 70,000 = Rs. 24,26,000

Savings per year = (Total savings by tubelights + Total savings by fans) x 12

$$= (2,07,912 + 1,47,576) \times 12 = \text{Rs. } 3,55,488$$

Payback period = Installation Cost / Savings per year i.e. 7 years.

Scenario 4: Only tubelights replaced

Total power required = 50% of Max. energy consumption i.e. 50% of 8.42 kW = 4.21 kW

Since 2 kW is already present, panels capacity required = 4.21 – 2 = 2.21 kW

Installation Cost of Solar Panels = (2.21 x 1,00,000) + 70,000 = Rs. 2,91,000

Installation Cost of LED tubes = Rs. 6,31,500

Total Installation Cost = Installation Cost of Solar Panels + Installation Cost of LED tubes

$$= 2,91,000 + 6,31,500 = \text{Rs. } 9,22,500$$

Savings per year = 17,326 x 12 = 2,07,912

Payback period = Installation Cost / Savings per year i.e. 4 ½ years.

Scenario 5: Only fans replaced

Total power required = 80% of Max. energy consumption i.e. 80% of 6.16 kW = 4.93 kW

Since 2 kW is already present, panels capacity required = 4.93 – 2 = 2.93 kW

Installation Cost of Solar Panels = (2.93 x 1,00,000) + 70,000 = Rs. 3,63,000

Installation Cost of Superfan = Rs. 5,98,400

Total Installation Cost = Installation Cost of Solar Panels + Installation Cost of Superfans

$$= 3,63,000 + 5,98,400 = \text{Rs. } 9,61,400$$

Savings per year = 12,298 x 12 = Rs. 1,47,576

Payback period = Installation Cost / Savings per year i.e. 6 ½ years.

Scenario 6: Both tubelights and fans replaced

Total power required = Total power required by LED tubes + Total power required by Superfans

$$= 4.21 + 4.93 = 9.14 \text{ kW}$$

Since 2 kW is already present, panels capacity required = 9.14 – 2 = 7.14 kW

Installation Cost of Solar Panels = (7.14 x 1,00,000) + 70,000 = Rs. 7,84,000

Installation Cost of LED tubes = Rs. 6,31,500

Installation Cost of Superfan = Rs. 5,98,400

Total Installation Cost = Installation Cost of Solar Panels + Installation Cost of LED tubes + Installation Cost of Superfans

$$= 7,84,000 + 6,31,000 + 5,98,400 = \text{Rs. } 20,13,400$$

Savings per year = (Total savings by tubelights + Total savings by fans) x 12

$$= (2,07,912 + 1,47,576) \times 12 = \text{Rs. } 3,55,488$$

Payback period = Installation Cost / Savings per year i.e. 5 ½ years.

VII. CONCLUSION

- Use of renewable energy sources like solar energy can be used to increase the energy efficiency in buildings effectively.

- Simple techniques like replacing conventional lighting with LED lighting and ordinary fans with energy efficient fans helps in reducing energy consumption thus making the building more energy efficient.
- By adopting the above techniques, load on State Electricity Board is reduced.

REFERENCES

- [1] P. Loganthurai, S. Parthasarathy, V. Rajasekaran, Energy Conservation Measures in a Technical Institutional Building in Tamilnadu in India, 2011 2nd International Conference on Advances in Energy Engineering (ICAEE 2011), Energy Procedia 14 (2012) 1181 – 1186.
- [2] R. Komurlua, D. Arditib, A.P. Gurgun. Gurgunca, Applicability of LEED's energy and atmosphere category in three developing countries, Energy and Buildings 84 (2014) 690–697.
- [3] R. Joshia, M. Pathak, A.K. Singh, Designing Self-Energy Sufficient Buildings in India, 2013 ISES Solar World Congress, Energy Procedia 57 (2014) 3110-3119. [8] Energy Efficiency in Buildings – Guidance for Facilities Managers, UNEP, Skanska, Sustainable United Nations.
- [4] Energy Efficiency in Buildings – Guidance for Facilities Managers, UNEP, Skanska, Sustainable United Nations.
- [5] <https://www.engineersaustralia.org.au/>
- [6] <http://www.savemaxsolar.com/>
- [7] <http://efreshglobal.com/>
- [8] <http://superfan.in/>
- [9] <https://www.bijlibachao.com/>