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Energy Conservation in Institutional Buildings: A Case Study in India

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Abstract: ***Energy consumption is an important aspect with respect to operating costs of buildings. Modern buildings are being designed considering their energy performance and carbon footprints. However, there is scope to reduce the energy consumption and carbon footprints in existing old buildings by suitable retrofitting. A case study is discussed where in the energy audit of an academic institution in northern India revealed several opportunities where energy consumption can be reduced considerably. This paper presents the analysis to achieve about 33% reductions in energy consumption and around 178 tons reduction in carbon footprint in an institutional building, Govt. Girls College Buildings Village Palwal Kurukshetra, India. It recommends measures that can be implemented with moderate investments and payback period. Another important feature is the utilization of roof-tops of institute building to install solar PV power plants apart from retrofitting measures. Presently 7% energy requirement is being met through installed solar PV power plant on the rooftop of institute building. After installing such power plants at all the roof-tops of building about 25% of energy needs can be met by solar energy source.***
Keywords: Energy Audit, Energy Conservation, Carbon footprint, Institutional Building

I. INTRODUCTION

The increased comfort level and growth in population are the major factors contributing to high energy consumption and greenhouse gas emissions in the world. The energy consumption in buildings alone is about 40 percent of the total energy consumed and accounts for around 30 percent of CO_2 gas emissions in the world [1]. Various studies have been undertaken to investigate the potential energy saving measures for enhanced energy performance of existing buildings [2-9]. These studies have been limited to retrofitting. In India, per capita energy consumption has risen from 12781 Mega Joules to 17731 Mega Joules from 2014-15 to 2023-24. The electricity consumption has more than doubled from 411887 GWh to 948328 GWh in the corresponding period. The net imports of crude oil have also increased sharply from 99.41 million tons (MTs) to 189.43 MTs from 2014-15 to 2023-24 [14]. As per Central Electricity Authority, India faced electricity shortage of 8.5% in the year 2023-24 and this gap is increasing every year. There is a need to provide energy security and conserve energy resources to meet the growing energy demand.

Energy auditing plays a vital role to identify the domains of energy wastage. Energy audit is conducted at three levels, namely, walk through appraisal level, energy survey and analysis level and detailed energy audit. The analysis of the energy audit report can suggest appropriate energy conservation measures to realize energy savings and decrease in carbon footprints of a building.

Since most of the existing institutional buildings in India are decades old and were built without much consideration for energy performance in their times, there is lot of scope to reduce energy consumption in these buildings. Further with the proliferation of renewable energy technologies for energy generation, roof tops of large buildings offer space that can be utilized for installing solar PV power systems. In the present study, walk through assessment for energy audit has been carried out for the buildings of Govt. Girls College Buildings Village Palwal Kurukshetra, India. The analysis of pollution generation in context with carbon footprints has also been carried out and strategies to reduce the greenhouse gas discharge has also been proposed. Apart from retrofitting an important aspect presented is the installation of solar PV power plant in Govt. Girls College Buildings Village Palwal Kurukshetra.

II. METHODOLOGY

The methodology employed to examine the energy consumption and performance was walk through energy assessment. The data regarding energy consumption was collected through bimonthly electricity bills. The necessary information consisting of covered area of different blocks, data of lighting equipment, fans, air conditioners etc. were collected for each of the building blocks. Computers, printers and projectors have not been taken into account since their usage pattern is not well defined. Detailed analysis of the data collected has been done so as to categorize the energy consumption based on type of equipment used for different purpose. Thereafter, areas of energy wastage and potential energy saving opportunities were identified. Financial evaluation for various retrofit measures along with their payback period against their life span has been made.

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Brief details of installed solar PV power system and its further potential is presented. The energy savings upon implementation of these measures has been projected. Some realistic assumptions have been made for average operating time of each type of equipment for computation purpose.

III. PRESENT STATUS

The Govt. Girls College Buildings Village Palwal Kurukshetra was established in the year 2021 under, Government of Haryana. The institute undertakes a wide spectrum of activities ranging from Education and Training Programmes, Curriculum Development, Instructional Material Development, Research and Development and Extension Services. The campus is located in northern part of India having composite climate, situated at Latitude 29°95´20 N and Longitude 76°87´07 E.

The institute building used for academic and administrative work comprises of three blocks. Each block is three storied and these are spread over about 8 acres of land comprising a total covered area over 9700 sq. meters. These are RCC framed buildings. Table I shows the covered area and the year of construction of each block of the institute building.

Table I. Buildings Area And Year Of Construction

Sr. No	Name of Buildings	Covered Area in sq.m.	Year of Construction
1.	Block-A	3970	2021
2.	Block-B	2740	2021
3.	Block-C	2970	2021
	Total Covered Area	9680	

Presently, there are about 140 employees comprising of faculty and other staff working in this institute. The working hours are from 9 am to 5.30 pm for five days in a week. The space occupation in these buildings includes laboratories, seminar hall, conference room, library, class rooms, administrative and accounts sections, faculty rooms and staff rooms. A rooftop grid interactive solar PV Power plant of 50KWp is also installed on roof top of academic block-A in the Institute.

A. Energy Consumption

The data regarding energy consumption has been collected through energy bills. On an average per day electricity units consumed in the institution varies from 100 to 250 units. Average energy bills per month varies from Rs. 1,38,00 to Rs. 3,42,00. The annual energy consumption of the institute is 881000 kWh after offsetting the 66,000 kWh of energy generated annually by rooftop grid interactive solar PV Power plant of 50KWp installed on roof top of academic block A in the institute. As seen from Fig. 1 the consumption of electricity peaked during the months from June to September when the weather is hot and humid and there is extensive usage of air conditioners. In December-January again the weather is cold and blowers and heaters are employed.

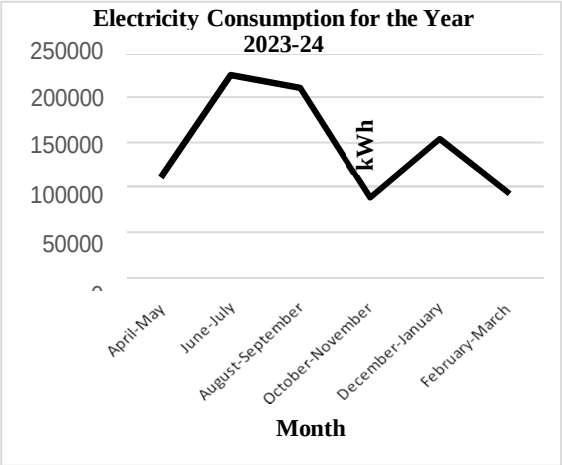


Figure 1. Electricity Consumption for 2023-24

The annual energy consumption data is for all institutional buildings in the institute campus. The energy consumption for institutional building is estimated to be two third (66.67%) of the total units of 8,81,000 based on the ratio of inventory of electrical appliances provided at the institute and hostels. Most of the energy intensive appliances has been installed in the institutional building. This indicates that about 5,88,000 kWh of energy is consumed in the institutional building annually.

B. Inventory of Electrical Appliances

Walk through energy audit has been carried out in the institute to observe and note the energy consumption by various electrical appliances. Table II shows the summary of electrical appliances installed in all blocks of the institute buildings which includes lights, fans and air conditioners.

Table II. Inventory of Electrical Appliances

Details of Electrical Appliances	Total
T8 Fluorescent Tube Light (36 Watts) with electromagnetic choke	212
CFL (14 Watt)	159
T5 Fluorescent Tube Light (14 Watts)	1830
LED Light (36 Watts)	118
LED Light (12 Watts)	56
Ceiling Fan (70 Watts)	423
Wall mounted Fans (50 Watts)	66
Exhaust Fans (80 Watts)	29
One star AC window type (1.5 Tons)	122
One/two star AC split type (1.5 Tons)	106

IV. ENERGY CONSERVATION SCOPE

The collected data regarding energy consumption has been analyzed which indicate that there are several energy conservation opportunities. These energy saving measures require retrofitting with financial investments which are discussed in the subsections below. The sensitization and awareness generation among employees and students requires very meagre costs. The reduction in energy consumption through these training measures have not been evaluated.

A. Replacement of T8 Tube Lights with LED Lights

The installation of LED lights over traditional lighting system generates savings in electricity consumption. LEDs are environment friendly as they do not contain harmful pollutant and are recyclable.

From the inventory of appliances, there are 212 numbers of T8 tube lights of 36 Watts each with electromagnetic choke, 1830 numbers of T5 tube lights of 14 Watts each and 159 CFL of 14 Watts each, which work on an average for 2430 hours in a year. Calculations are based on lights operating for 9 hours working per day for 5 days a week and twelve months in a year. Life span of LED light is taken as 30,000 hours. The lux depreciation of LED light is considered as 70%.

The annual energy savings with replacement of T8 tube lights with equivalent lumens of LED lights is estimated to be 5,322 kWh with investment of Rs. 1,78,750. Payback period is 5.79 years against lifespan of 12.5 years. Total savings after payback period is Rs. 2,07,124. Saving in annual operating cost @ Rs 5.80 per unit is Rs. 30,868. The cost of LED light of 20 Watts is estimated as Rs.650 each. Reduction of CO_2 foot print achievable is about 4.8 tons with installation of LEDs.

There is very small difference in energy efficiency of T5tube lights and CFL compared to LED lights. Since LED lights are greenest option for lighting, it is proposed that the replacement of T5 tube lights and CFLs can be done as and when these lights go bad.

B. Replacement of Existing Fans with Five Star Rated Fans

There are three types of fans installed in the buildings, namely, ceiling fans, wall fans and exhaust fans. The energy performance analysis for wall fans, installed in lobbies, laboratories and exhaust fans installed in rest rooms has not been performed as these fans are operated for few hours in a day. The ceiling fans installed are 423 in numbers with a rating of 70 Watts. At present, super efficient fans are available in the market having consumption of 35 Watts.

Replacement of high energy consuming fans non star fans with five star rated energy efficient fans will produce annual energy savings of 21911 kWh with 1480 running hours per annum. Calculations are based on fan operating for 8 hours working per day for 5 days a week and nine months in a year. Investment on purchase of five star rated energy efficient fans is at the rate of Rs. 2200 per fan. Salvagevalue of existing fan is Rs.300 per fan. Total capital investment will be Rs. 803700. Payback period is 6.33 years against a lifespan of 20 years. Total saving after payback period will be Rs. 1,649,700. Reduction of CO_2 foot print with installation of five star rated fans will be about 20 tons per annum.

C. Replacement of Existing Air Conditioners with Inverter type Split Air Conditioners

There are total of 228 air conditioners of 1.5 ton capacityeach, out of which 122 are window type and 106 are split airconditioners. They are one star rated. These need to bereplaced in context with energy saving and eco-friendly refrigerants. So the replacement of existing window and split air conditioners with Inverter type split air conditioners is recommended to achieve maximum energy savings.

Annual running hours of each AC is assumed to be 1200hours. Calculations are based on ACs operating for 8 hours per day for 5 days a week and 7 months in a year.

Per hour consumption of power (kW) by one AC is 1.92 units per hour while per hour consumption (kW) by proposed Inverter-type split AC is 1.3 units per hour. Total annual energy savings will result in 90768 kWh. Investment on purchase of proposed air conditioning system is Rs.33000 per AC. Salvage value of existing window type air conditioner system is Rs. 8000 per AC. Total Capital investment for 122 window AC is Rs. 30,50,000. Payback Period will be 5.79 years against a lifespan of 10 years. Total saving after payback period will be Rs. 22,16,371.

Replacement of existing 106 one star rated air conditioners with inverter type air conditioners will lead to annual energy savings of 78864 kWh. Investment on purchase of proposed system is Rs.33000 per AC and with salvage value of existing split type air conditioner is Rs.15000 per AC. Total capital investment is of Rs.19,08,000. Payback period is 4.17 years against a lifespan of 10 years. Total saving after payback period will amount to Rs. 26,66,706.

Reduction of CO_2 foot print with complete installation of inverter type split of air conditioners is 152.7 tons per year with costing of Rs. 49,58,000.

V. CARBON FOOTPRINTS

The CO_2 emission in the institute campus is generatedthrough vehicles and use of LPG cylinders. On an average 2.5 numbers of LPG cylinders are used per month for cooking purpose. CO_2 emissions are also produced from approximately 60 cars and 70 two wheelers being used by employees for commuting to the workplace. This vehicular emission is generated in the institute campus during enteringand while leaving the parking. Therefore, this pollution from vehicles is very minimal. For instance a car at a time of parking or leaving the parking utilizes 50 ml of fuel either petrol or diesel. One liter of petrol releases 2.3 Kg of CO2 on complete combustion. Similarly one liter of diesel releases 2.7 kg of CO2 [11]. As per ISO 14064 CO2 sink is available in the institute campus in the form of trees and plants. Around 800 trees are there in the campus. A single tree has capacity to absorb CO2 at a rate of 48 lb. or 21.7724 kg per year. The carbon footprint generated by the institute is indicated in Table III.

Table III. Carbon Footprints Of The Institute

Type of Fuel	Amount of Fuel (per annum)	CO_2 Emission Factor ($kgCO_2$ /unit	Total CO_2 Emission (per annum)	CO_2 Absorption Capacity of Trees	Total CO_2 Generated in the Campus
Diesel DG sets	3330 L	2.7	9 tons	Total CO_2 offset with 800 trees is 17.5 tons/ Annum	54 tons
Diesel Vehicles	500 L	2.7	1.5 tons		
Petrol Vehicles	500 L	2.3	1.2 tons		
LPG	12957.5 kg	3.03	39 tons		

CO_2 sink in the form of 800 trees in the institute campus are sufficient to maintain a lower differential CO_2 level of 530 ppm in all regularly occupied areas. There is a need to offset 36.5 tons of CO_2. The proposed energy saving initiatives can reduce the carbon footprints of the institute building by 177.5 tons. The carbon dioxide emission reduction has been computed with conversion factor of 0.9 in context with energy generation by northern region power grid of India as per Central Electricity Authority of India.

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VI. SOLAR PV POWER PLANT

The institute has undertaken green energy initiative for reducing greenhouse gas emission. The institute has installed 50 kWp grid interactive solar PV power plant at rooftop of the academic block-A since September 2021. It is generating 66,000 kWh every year on an averageand there is a corresponding reduction in the energy consumption bills by 7 percent.

Another 15 kWp grid interactive and 20 kWp stand alone with battery bank solar PV plants are presently under installation at rooftop of block-B and Administrative Block and will be functional within a month.Estimated power generation from these solar PV power plants is 45000 kwh per year which will provide additional savings and carbon footprint reduction by 4.75 percent.

There is potential of installing 40 kWp capacity of solar PV power plant at the rooftop of block-C proposedto be taken up in future. It will reduce energy consumption bills by further 5.6 percent.

Even at present levels of energy consumption, 11.75 % of total energy including institutional building will be contributed by renewable energy source, which has potential to reach 17.35%. After implementation of retrofitting measures this contribution will be around 25%. Estimated life span of solar PV power plant is 25 years.

VII. RESULTS AND DISCUSSIONS

The data collected for energy consumption has been analyzed to assess the feasibility of implementing measures for improving energy performance of the institutional building. Table IV highlights the energy conservation opportunities with their respective estimated energy savings,payback period and reduction in greenhouse gas emission.

Table IV. Energy conservation potential

Energy Conservation Opportunity	Investment(Rs.)	Energy Saving (per annum) (kWh)	Pay Back Period (Years)	CO_2 Footprint Reduction per annum (tons)
Lights and Fans				
Replacement of T8 Tube lights with LED lights	1,78,750	5,322	5.79 against lifespan of 12.5 years	4.8
Replacement of Fans with energy efficient fans	803700	21911	6.33 against a lifespan of 20years	20
Air Conditioners				
Replacement of window AC with inverter type split AC	30,50,000	90768	5.79 against lifespan of 10 years	81.7
Replacement of single star rated split AC with inverter type split AC	19,08,000	78864 kWh	4.17 against lifespan of 10 years	71
Total	58,86,720	2,08,018		177.5

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The assessment of energy consumption pattern ofequipment and items for retrofit reveals their potential of 35.4% energy savings annually with modest investments.

Some additional measures which can be taken for saving energy are as following.

1) Energy management policy regarding operation and maintenance of buildings with an endeavor to adoptgreen practices and for retrofitting reducing the environmental impacts needs to be formulated.

2) Awareness training programmes are required to be organized for the faculty and staff of the institute in context with energy conservation and sustainable development.

3) Provision of special bus service for the employees of the institute to commute to and fro for institute during working days is required to reduce the greenhouse gas pollution.

4) The exposed area on roof can be covered with reflectivetiles or high SRI coatings in order to reduce heat island effect on roof areas.

5) The regular maintenance of HVAC systems and other equipment is required.

6) Installation of Energy management system and Building management system with separate meters and monitoring system is needed.

7) There is need to encourage the use of electric vehicles. A separate place for electric vehicles with charging point is to be provided.

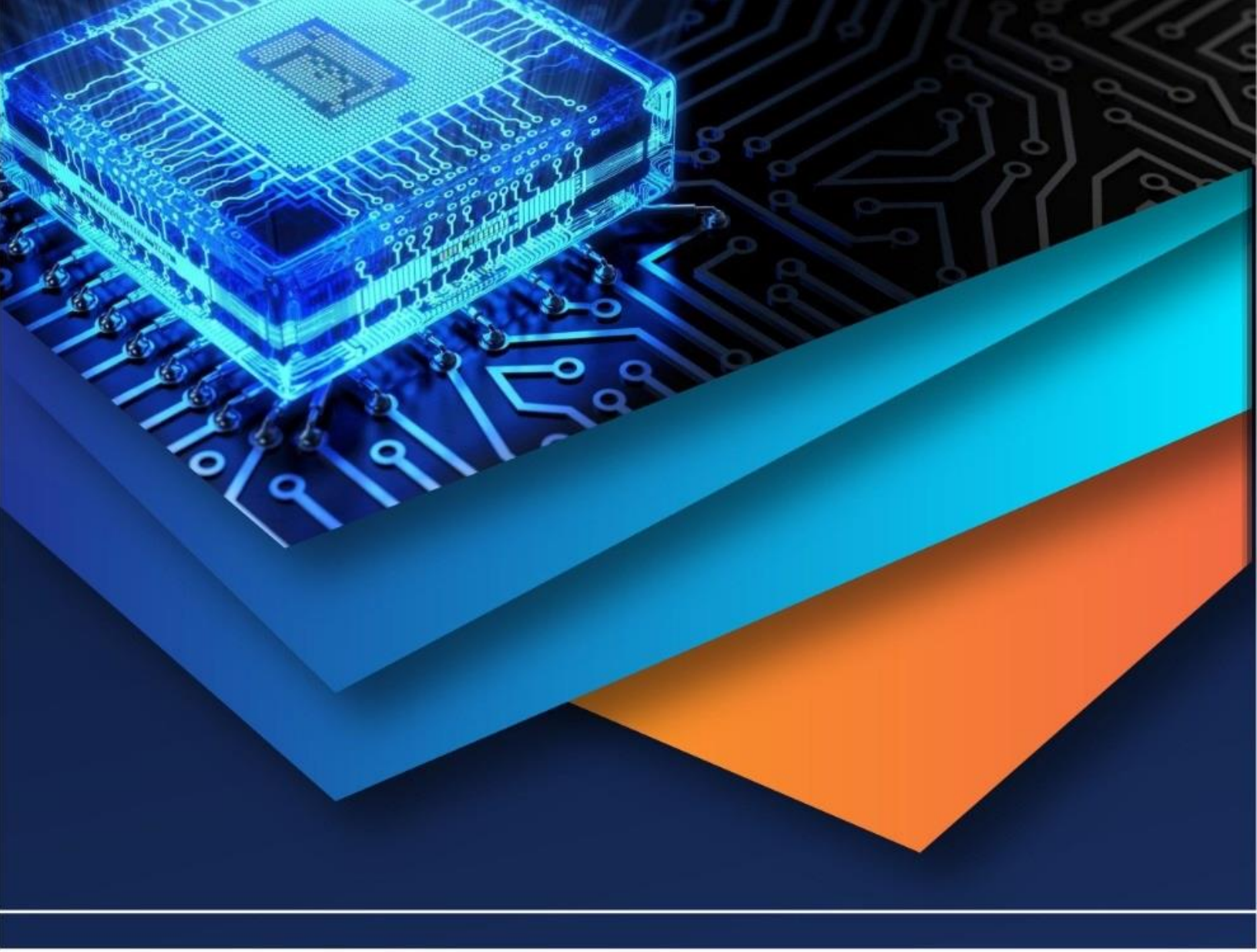
The inference drawn from this study indicates that buildings of Govt. Girls College Buildings Village Palwal Kurukshetra, upon implementation of recommendations, will set an example of retrofitting of existing building into energy efficient building. This will motivate and influence to enhance energy efficiency of other office buildings and towards betterment of environment.

VIII. CONCLUSION

The data in context with energy audit at Govt. Girls College Buildings Village Palwal Kurukshetra, India has been presented in this paper. An effort has been made to assess the gaps and propose energy saving opportunities to reduce annual energy consumption by 33 %. This includes retrofitting for lighting, fans, air conditioning with moderate investment of Rs. 58,86,720. Payback period estimated for lights to be replaced by LED lights is 5.79 years, for replacement of fans with energy efficient fans with energy efficient fans is 6.33 years, for one star rated split type AC replacement by inverter type split air conditioner is 6.33 years and for single star rated window type air conditioners replacement by inverter type split air conditioners is 5.79 years. This also leads to reducing 178 tons of greenhouse gas emission. Presently the institute has 50 kW grid-interactive solar PV plant installed at rooftop of block-B. At therooftop of block-B building 20 kW stand alone and 15 kW grid interactive solar PV power plant is being installed and will be operational in a month. There is scope to install a solar PV power plant of 40 kWp capacityto generate green energy and further reduce the carbon footprints. It is estimated that after implementing the retrofitting measures and solar PV power plant on roof top about 25% energy needs of Govt. Girls College Buildings Village Palwal Kurukshetra Buildings can be met from renewable energy sources.

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