Design & Analysis Of 30kw Photovoltaic System for MBC Library Building in Kuttikkanam.

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Abstract: The main objective of this paper is to design and analysis of solar PV system for an isolated building. The 30Kw of stand-alone roof top solar PV system for MBC library building at Kuttikkanm, Kerala, India (Latitude:9o35'N Longitude:76o56'E) is designed with the help of PV-Syst software. The detailed designed equations for estimating different types of load are given here. Although cost analysis of different AC loads (LED, CFL, Tube-light, T5 lamp) and DC loads are done. The panels required for different loads are calculated both manually and using PV-Syst software. The effective and performance analysis of 30kwp solar p-v roof top plant is done using PV-Syst software and the result are presented here. The characteristic of PV array, normalized energy, irradiation and daily array output are analyzed for this system and results are presented here. The design of battery equation required for this system are presented here. The installing cost and total expenditure of different lighting load are compared and suggested the suitable one for the system. The Co2 emission for various lamps in AC and DC was analyzed and is included.

***Index Terms* - PV; Design of Stand-alone PV Systems; PV-Syst; Poly-crystalline PV Panel.**

I. INTRODUCTION

Nowadays, all the world countries believe that the renewable energy is the alternative solution instead of using the traditional types of energy. Considering all other renewable energy types, solar energy is one of the most important renewable energy due to the advantages of clean, carbon-free and the availability. The electricity sector in India supplies the world's 6th largest energy consumer, accounting for 3.4% of global energy consumption by more than 17%of global population. The Energy policy of India is predominantly controlled by the Government of India's, Ministry of Power, Ministry of Coal and Ministry of New Renewable Energy and administered locally by Public Sector Undertakings (PSUs). Photovoltaic is a technology that reliably converts solar radiation into electricity standalone p-v system which supplies electricity to the load without being connected to the electric grid. A complete working of standalone p-v system comprises two main parts PV array and other components. A PV array is produced from a combination of PV modules to increase the electrical power. All components in standalone PV except PV modules are called balance of system components such as storage, cables, combiner box, Inverter and structures. Sunlight is the most dependable and a viable source of energy available to us. How-ever India solar energy installation today constitute only a small percentage of installed electricity generation capacity in the country. There is an urgent need to develop cost effective technologies to harness sunlight in order to generate significant percentage of clean energy and thus gradually reduce dependence on environmentally degrading non-renewable and expensive resources.

II. ESTIMATION OF LOAD REQUIREMENTS

A. Design of AC load estimation.

Electrical installations in domestic buildings basically include lighting, ventilation, domestic appliances and gadgets. If the actual wattages of the appliance and light points are not known, the load requirements can be calculated based on the recommended ratings from the inspectorate handbook. The National Electric code also recommends the minimum number of points to be provided in various domestic buildings. Here, the number of points to be provided on the basis of plinth area of the building. National Electric Code also provides the details regarding the minimum number of socket outlets required for various sizes of residential buildings. Also, when installing a new wiring system, AC power can run on much smaller gauge wiring, lowering materials costs. Lighting design by lumen method is used by studying the site plan and elevation of the insulation and also determined the lighting needs in consultation with the standards and the end user. Initially Fluorescent luminaries is selected as the light sources and luminaire, based on installation geometry, the room index (RI) is calculated using the equation (1),

$$\text{Room index (RI)} = \frac{length\ x\ breadth}{(length+breadth)x\ mounting\ height} \quad [1]$$

Based on room index, coefficient of utilization (COU) value can be obtained from the COU table for the selected luminaire LED. These COU values are determined based on the RI and room surface reflectance which are generally 70% for light colored, 50% for average and 30% for dark Walls and 50%,30% and 10% for corresponding ceilings. The light loss factor (LLF) is chosen as 0.8. Since accepted values are 0.8 for A/c rooms, clean rooms etc. Similarly, 0.7 and 0.6 for industrial environment and dusty areas. The quantity of luminaries is determined using the equation (2), the luminaries are planning to arrange symmetrically to achieve uniformity of illumination.

$$\text{Number of luminaries} = \frac{\text{Area x Illumination}}{\text{CU x LLF x Lumen output of luminaire}} \quad [2]$$

$$\text{Area per luminaire (fixture)} = \frac{\text{Room area}}{\text{Number of fixtures}} \quad [3]$$

Here the design procedure for lighting load is given for a particular room (library reading room) the length, breadth, height of the room is 19.46m ,10.38m and 3m. Hence area of the room is 202m^2. For this particular room the illumination level is selected as 300lux since this value is recommended for study room in the Inspectorate handbook. 18W Fluorescent lamp with 1800 lumen is chosen for this calculation. The RI value 2.5 is calculated using equation (1). COU value is obtained as 0.70 from inspectorate handbook for corresponding a value of RI. LLF is selected as 0.8 (for clean rooms). Number of luminaires is determined as 60 Nos using equation (2). Area per fixture is determined as $5m^2$ using equation (3). The lamps are arranged in length wise as 10 Nos and breadth wise as 6 Nos. Similarly, the number of luminaires required for various rooms and types of loads are listed in table.

Fig. 1. Proposed plan of MBC library building

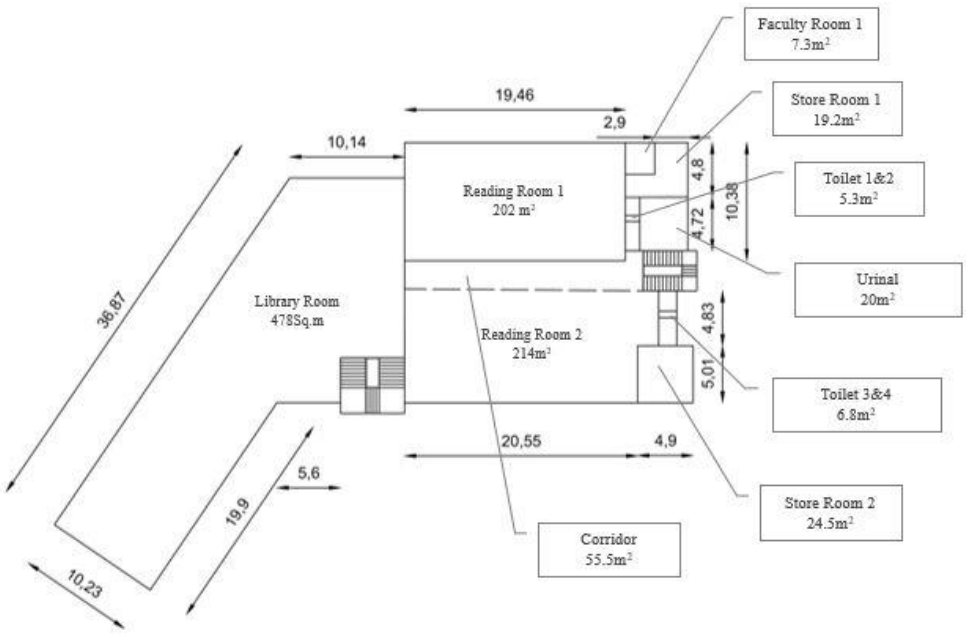


TABLE: I ESTIMATION OF LOAD FOR THE PROPOSED PLAN

From the table (I), total connected load=41564 W, the details given are the minimum requirements and the owner of the building is at liberty to decide to opt for higher number of points for their buildings in consultation with the design engineer so as to meet the present as well as the future anticipated loads. Once all the light points, fan points and the socket points are decided, the total connected loads of the building can be calculated.

Sl. No:	Rooms	Area m^2	LED Tube	T5 Tube	Tube	CFL	DC Lamp	6A Sockets	16A Sockets
1.	Library Room	$478m^2$	142Nos	142Nos	94 Nos	112 Nos	142Nos	4Nos	4Nos
2.	Reading Room 1	$202m^2$	60Nos	60Nos	40Nos	48Nos	60Nos	4Nos	2Nos
3.	Reading Room 2	$214m^2$	64 Nos	64Nos	42Nos	50Nos	64 Nos	4Nos	2Nos
4.	Faculty Room 1	$7.3m^2$	3Nos	3Nos	2Nos	2Nos	3Nos	2Nos	1Nos
5.	Storeroom 1	$19.2m^2$	6Nos	6Nos	4Nos	4Nos	6Nos	2Nos	1Nos
6.	Storeroom 2	$24.5m^2$	8Nos	8 Nos	5Nos	5Nos	8Nos	2Nos	2Nos
7.	Toilet 1	$2m^2$	1Nos	1Nos	1Nos	1Nos	1Nos	Nil	Nil
8.	Toilet 2	$3.3m^2$	1Nos	1Nos	1Nos	1Nos	1Nos	Nil	Nil
9.	Toilet 3	$2.8m^2$	1Nos	1Nos	1Nos	1Nos	1Nos	Nil	Nil
10.	Toilet 4	$4m^2$	1Nos	1Nos	1Nos	1Nos	1Nos	Nil	Nil
11.	Urinal	$20m^2$	3Nos	3Nos	2Nos	2Nos	3Nos	Nil	Nil
12.	Corridor	$55.5m^2$	8Nos	8Nos	6Nos	6Nos	8Nos	Nil	Nil
	Total	$1032.6\ m^2$	298Nos	298Nos	199Nos	233Nos	298Nos	18Nos	8Nos
	Total Watts	Nil	5364W	5364W	7960W	6990W	5364W	1800W	8000W

B. Design of DC load estimation.

DC lighting has the advantage of being very energy efficient. A smaller solar panel or wind generator can be used to run a DC lighting system than would be required for an AC system. Also, since DC lighting can be powered directly from the battery bank, the added expense of installing an inverter is not necessary. Although DC lighting fixtures are more difficult to find. DC lighting has the advantage of being very energy efficient. A smaller solar panel or wind generator can be used to run a DC lighting system than would be required for an AC system. Also, since DC lighting can be powered directly from the battery bank, the added expense of installing an inverter is not necessary.

III. DESIGN OF SOLAR PV SYSTEM FOR DIFFERENT TYPES OF LOAD

Solar Photovoltaic power generator consists of solar modules in series and parallel connections, these panels will convert solar radiations into DC electrical power at the pre-determined range of Voltages whenever sufficient solar radiation is available. In order to achieve a higher system Calculated number of strings is connected in parallel by cables in Junction Boxes. Outputs from many such junction boxes are connected in parallel in the Main Combiner Box MCB). This Main Combiner Box output is fed to the central inverters/Power Control Unit (PCU)to invert solar generated DC power in to conventional 3 phase AC power.AC power from inverters will be fed LV panel. The solar P-V system is designed for different types of load such as LED tube(18W), CFL (32W), Tube lights(40W) and T5 tube light(18W) initially the total usage of unit per day is tabulated for these loads is tabulated in table [II] similarly the sockets 6A and 16A sockets usage of unit is also tabulated in table[II]. The minimum solar irradiation for this particular site (Kuttikkanm) is considered as 4.74kW/m^2/day using PV-Syst software.

A. Solar PV panel

Solar cells produce Direct Current (DC) electricity from light, which can be used to power equipment or to recharge a battery. Cells required protection from the environment and are usually packaged tightly behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules, or solar panels. A photovoltaic module is a packaged, interconnected assembly of photovoltaic cells, which converts sunlight into electrical power. Photovoltaic (PV) panels, which use sunlight to produce electricity, can be very useful in northern climates. While the manufacturing process and the mechanism by which they work is technical, they are simple to install and maintain. Stand-alone PV systems are designed to operate independent of the electric utility grid and are generally designed and sized to supply certain DC and or AC electrical loads. They are most suited for remote locations where there is no utility supply.

TABLE II. CONSUMPTION PER DAY AND PANELS REQUIRED

Sl. No.	Lamp	Watt	Consumption per day(8hrs)	Nos.	kwhr	Panels Required (250Wp)
1.	LED tube	18	8	298	91.912	125
	6A Sockets	100	5	18		
	16A Sockets	1000	5	8		
2.	CFL	30	8	233	104.92	142
	6A Sockets	100	5	18		
	16A Sockets	1000	5	8		
3.	Tube-Light	40	8	199	112.68	154
	6A Sockets	100	5	18		
	16A Sockets	1000	5	8		
4.	T5 Tube	18	8	298	91.912	125
	6A Sockets	100	5	18		
	16A Sockets	1000	5	8		
5.	DC light	18	8	298	91.912	125
	6A Sockets	100	5	18		
	16A Sockets	1000	5	8		

B. Estimation of solar panels for particular lamp.

In this building, Watt hour used by LED tube per day can be estimated as 18W LED lamp used 8hours per day,18 x 8 x 298 Nos is 42.912 kWh/day, Watt hours used by 6Asockets per day can be estimated as 100W by 5hours per day, Ther100 x 5 x 18Nos is 9.000 kWh/day, Watt hours used by 6A sockets per day can be estimated as 100W by 5hours per day, Therefore 1000 x 5 x 8Nos = 40.000 kWh/day, Total watt-hour required per day estimated as 91.912 kWh/day, Minimum solar irradiation of this site from PV-Syst Software will be 4.74Kwh/m^2/day, By calculation, Total watt-hour required per day will be 91.912 kwh/day, Watt hour need to produce by the panels is 1.3 x 91.912= 119.486 kwh, Panel generation factor (without MPPT controller) was 4.74 x 0.062=2.94 Wh/day, Kw-h/ day for appliance taken together was 91.912 kwh/day, Panel size required by calculation can be 91912/2.94 is 31262.58Wp and it is 31.263kwp

We are choosing 250Wp module, Number of p-v modules is 31262.58 / 250 is 125.05Nos, Approximate 126 modules we may choose for better arrangement of panels. The arrangement of panel was 14 panel in parallel and 9 panel in series and the required size per panel was 1.68m^2 and roof area required for installing the 126module solar p-v system will be 126x1.68=211.68m^2

TABLE: III COMPARISON OF DIFFERENT LAMPS AND CONSUMPTION PER DAY

Sl.No.	kWhr	Charge Consumption (Whr)	Battery Capacity (Ah)	Battery Nos.
1.	**91.912**	432500	150	120
2.	**104.92**	493700	150	140
3.	**112.68**	53000	150	150
4.	**91.912**	432500	150	120
5.	**91.912**	432500	150	120

IV. Design using PV-Syst software

PV-Syst V6.70 is a PC software package for the study, sizing and data analysis of complete PV systems. It deals with grid-connected, stand-alone**,** pumping and DC-grid (public transportation) PV systems, and includes extensive meteo and PV systems components databases, as well as general solar energy tools. This software is geared to the needs of architects, engineers, researchers. It is also very helpful for educational training. Within the framework of a **"project"**, the user can perform different system simulation runs and compare them. He has to define the plane orientation (with the possibility of tracking planes or shed mounting), and to choose the specific system components. He is assisted in designing the PV array (number of P-V modules in series and parallel), given a chosen inverter model, battery pack or pump. In a second step, the user can specify more detailed parameters and analyze fine effects like thermal behavior, wiring, module quality, mismatch and incidence angle losses, horizon (far shading), or partial shadings of near objects on the array, and so on.
Databases: - The databases management for meteorological data and PV components are already included in the software. Creation and management of geographical sites, generation and visualization of hourly meteorological data, import of meteorological data from several predefined sources or from custom ASCII files are in the database. Database management included with manufacturers and PV components, including PV modules, Inverters, Regulators, Generators, Pumps, etc.

Tools: - when a PV system is running and carefully monitored, this part (located in the Tool part) permits the import of measured data (in almost any ASCII format), to display tables and graphs of the actual performances, and to perform close comparisons with the simulated variables. This gives a mean of analyzing the real running parameters of the system and identify even very small irregularities. Included are also some specific tools useful when dealing with solar energy systems that are tables and graphs of meteo data or solar geometry parameters, irradiation under a clear day model, PV-array behavior under partial shadings or module mismatch, optimizing tools for orientation or voltage, etc.

A. Stand-alone system: simulation parameters

Pre-sizing is a rough estimation of the PV system energy yield and user's needs satisfaction, based on a few very general parameters. Its aim is to determine the size of the optimal PV array power and battery pack capacity required to match the user's needs. The input solar energy is computed in monthly values (taking plane orientation and horizon into account) and requires only the monthly data provided by the “Sites” database. When sizing a PV stand-alone system, the basic constraints are the availability of solar energy during the year, and the satisfaction of the user's needs. The problem to be solved is the optimization of the size of the photovoltaic generator and the storage capacity, subjected to criteria which may take on different weights depending on the use of reliability of the supply, which is very important, for example in decentralized telecommunication installations. But in a domestic installation, this may be overcome with a small back-up generator. After sizing the PV system with this tool, it's real performances should be verified by performing a detailed hourly simulation (option "Project design"), using real components and taking all system perturbations into account.

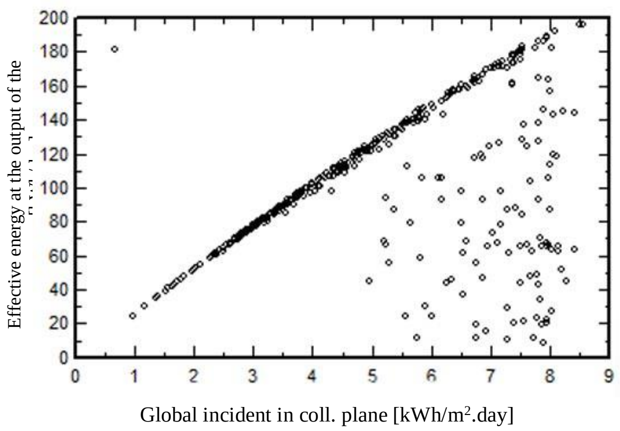


Fig. 2. Daily input/output diagram

The fig 2 shows the daily input output diagram that is the relation of global incident collected plane to the effective energy at the output of the array. As the irradiation changes as time per day the output of the effective energy of the array changes. The stand-alone system simulated in the PV-Syst software concluded that the geographical location of kuttikanam was 9.59° N latitude

76.98° E longitude. The minimum irradiation in kuttikanam from the software database was 4.74kWhr/m^2/day and the modules are tilted 15^0 to the south with a 0^{0}azimuth angle. The PV array choose was multi-crystalline with a nominal power of 250Wp and the total number of modules was estimated using software was 123 unit and it was approximately equal to the manual calculation. The 123 modules produce a global power of 30.8kWp and the total area required for the plant was 200m^2. The panels are arranged as modules in series and modules in parallel for the better production of output power. The storage of stand-alone system has the nominal capacity of each 4495 Ah with total no of units 232 and it was connected 8 in series and 29 in parallel.

Fig. 3. Normalized productions [30.8kwp]

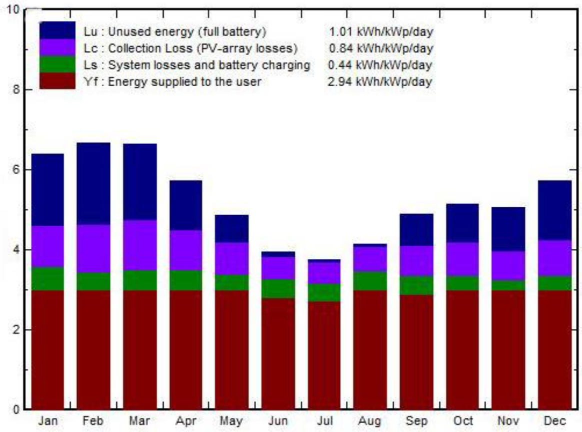


Fig 3. shows the normalized productions of 30.8kWp and the graph include different characteristics consist of energy supplied by the user that is shows by the red color about 2.94kWh/kWp/day and the green show the system losses and battery charging losses that is about 0.44 kWh/kWp/day. The violet plot shows the collection losses that is PV array losses that is about 0.84 kWh/kWp/day and the blue bars shows the unused energy that is the battery was full that is about 1.01kWh/kWp/day. From this graph the overall working of the plant can be analyze and the usage and unused can be easily identify and this helps in the proper working of the plant.

Fig 5. Characteristics of pv module

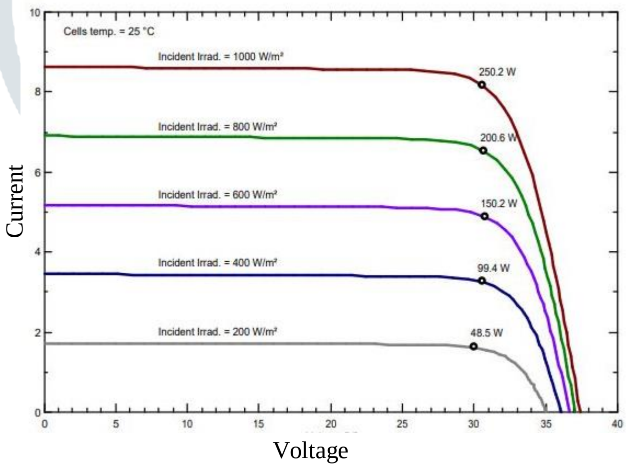
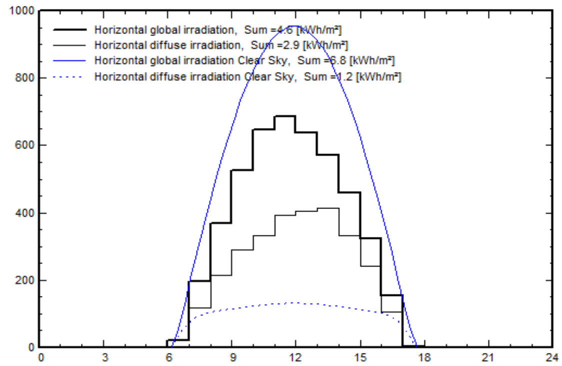


Figure IV shows the current-voltage (I-V) characteristics of a typical silicon PV cell operating under normal conditions. The power delivered by a solar cell is the product of current and voltage (I x V). If the multiplication is done, point for point, for all voltages from short-circuit to open-circuit conditions, the power curve above is obtained for a given radiation level. With the solar cell open-circuited, that is not connected to any load, the current will be at its minimum (zero) and the voltage across the cell is at its maximum, known as the solar cells open circuit voltage, or Voc. At the other extreme, when the solar cell is short circuited, that is the positive and negative leads connected together, the voltage across the cell is at its minimum (zero) but the current flowing out of the cell reaches its maximum, known as the solar cells short circuit current, or Isc.

Fig: 4. Meteo of Kuttikanam



In figure v the meteo of kuttikanam with horizontal global irradiation was shown, it includes horizontal global irradiation of sun with 4.6kWh/m^2 by the dark black plot. The dark blue line was the horizontal global irradiation of clear sky with 6.8kWh/m^2 and the light black color shows the horizontal global irradiation with 2.9kWh/m^2. The dotted lines show the horizontal global irradiation with clear sky of 1.2kWh/kWp/day.

IV. COST EFFECTIVE ANALYSIS

A. Installing Cost for Different Lamps

The installing cost for various types of lamps for both AC and DC loads are calculated by multiplying the total number of lamps required with the cost per lamp and adding it with the cost of the solar inverter used. Thus, the initial cost for various luminaires are tabulated on table (IV). From the table we can see that DC light has low initial cost as compared to AC loads, but it is effective only when DC wiring is taken place or else LED has very low initial cost as compared to other light loads. When compared to AC, Dc does not require inverter, so the initial cost is less.

TABLE: IV INSTALLING COST FOR LAMPS

Lights	Watts	Total Lights	Cost Per Lamp (Rs)	30kW Solar Inverter Cost (Rs)	Total Initial Cost
LED Tube	18W	298Nos	290/-	1,40,000/-	226420/-
T5 Tube Light	18W	298Nos	320/-	1,40,000/-	247280/-
Tube Light	40W	199Nos	650/-	1,40,000/-	269350/-
CFL Light	32W	241Nos	390/-	1,40,000/-	233990/-
DC Light	20W	298Nos	300/-	40,000	129400/-

Fig. 6. Initial cost for different lamps

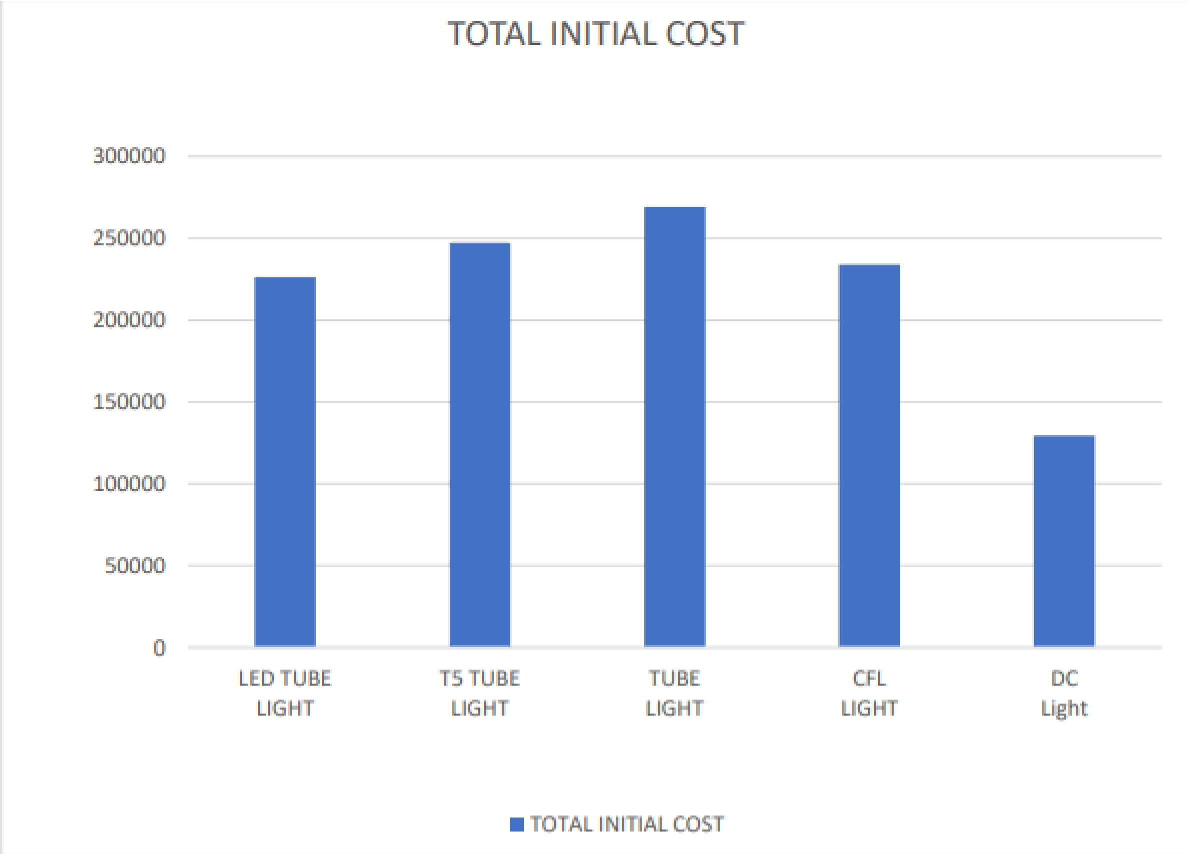


Fig 5.1 Installing Cost for Different Lamps

B. Total Expenditure Per Year

From table (V) we can understand the total watts of each lamps, and the total watt hour per year is found out by multiplying total watts with total number of working hours per year. The Electricity provider supplies energy at Rs.8/ Per Unit. The total cost per unit is found out by multiplying unit per year with energy providing rate. Now the total expenditure is estimated by adding the total cost per unit of each of the lamp with initial cost.

TABLE: V TOTAL EXPENDITURE PER YEAR

Lights	Total Watts	Watt-Hour Per Year	Unit Per Year (Kwh)	KSEB Rate Rs:8/Unit	KSEB Rate For 5 yrs	Total Expenditure for 5 year (Rs)
LED Tube Light	5364W	10770912	10770.91	86167.28/-	430836.4/-	657256.4/-
T5 Tube Light	5364W	10770912	10770.91	86167.28/-	430836.4/-	678116.4/-
TUBE Light	7960W	15983680	15983.68	127869.44/-	639347.2/-	908697.2/-
CFL Light	6990W	14035920	14035.91	112287.28/-	561436.4/-	853417.84/-
DC Light	5364W	10770912	10770.91	86167.ss28/-	430836.4/-	560236.4/-

TABLE: VI TOTAL EXPENDITURE FOR FIVE YEAR

Lights	Total Watts	Watt-Hour Per Year	Unit Per Year (Kwh)	Total cost per unit	Total Expenditure
Led Tube	5364W	10770912	10770.91	86167.28/-	312587.28/-
T5 Tube	5364W	10770912	10770.91	86167.28/-	333447.28/-
Tube Light	7960W	15983680	15983.68	127869.44/-	397219.44/-
Cfl Light	7712W	15485696	15485.696	123885.568/-	357875.56/-
Dc Light	5364W	10770912	10770.91	86167.28/-	215567.28/-

C. Total Expenditure for Five Year

The total expenditure for five years is calculated in order to estimate the running cost after 5 years of installment. The Electricity provider supplies energy at Rs.8/- Per Unit. The total cost per unit is found out by multiplying unit per year with

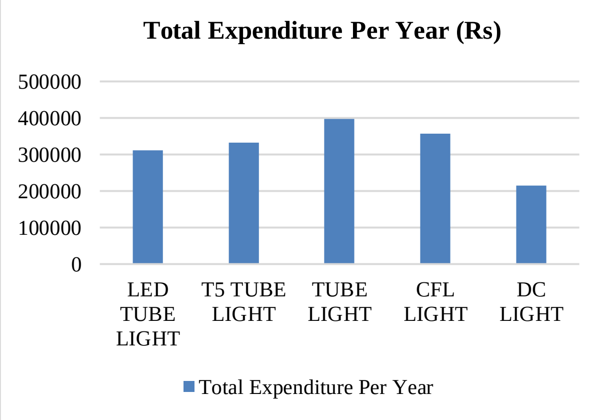


Fig. 7. Total expenditure per year

energy providing rate. Now to found out total rate to be paid distributer for using energy for 5years is calculated by multiplying unit per year with 5. And in order to find the total expenditure for 5 year the total unit per 5 year for each lamp is added with the total initial cost and are tabulated in the table (VI), also the total expenditure for each lamp are plotted in the figure (VIII).

D. Total Expenditure for Ten Year

The total expenditure for ten years is calculated in order to estimate the running cost after ten years of installment. The Electricity provider supplies energy at Rs.8/- Per Unit. The total cost per unit is found out by multiplying unit per year with energy providing rate. Now to found out total rate to be paid distributer for using energy for ten years is calculated by multiplying unit per year with ten. And in order to find the total expenditure for ten year the total unit per ten year for each lamp is added with the total initial cost and are tabulated in the table (VII), also the total expenditure for each lamp are plotted in the figure (VIII).

TABLE: VII TOTAL EXPENDITURE FOR TEN YEAR

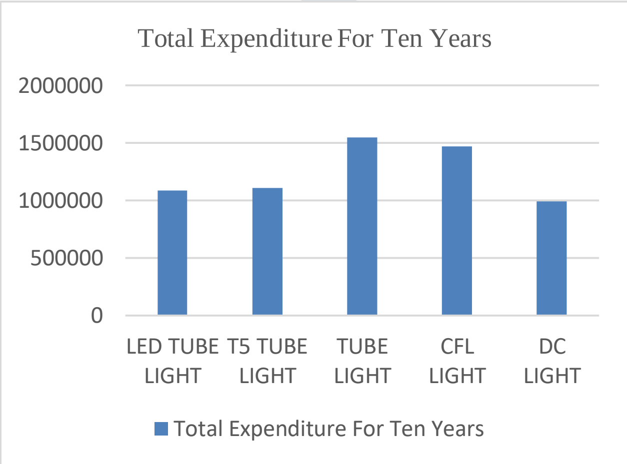


Fig. 8. Total expenditure Ten year

Lights	**Total Watts**	**Watt-Hour Per Year**	**Unit Per Year (Kwh)**	**Kseb Rate Rs:8/Unit**	**Kseb Rate For 10 Yrs**	**Total Expenditure For ten Years**
LED Tube Light	5364W	10770912	10770.91	86167.28/-	861672.8/-	1088092.8/-
T5 Tube Light	5364W	10770912	10770.91	86167.28/-	861672.8/-	1108952.8/-
Tube Light	7960W	15983680	15983.68	127869.44/-	1278694.4/-	1548044.4/-
CFL Light	6990W	14035920	14035.91	112287.28/-	1122872.8/-	1472845.6/-
DC Light	5364W	10770912	10770.91	86167.28/-	861672.8/-	991072.8/-

V. COMPARISON OF CO2 EMISSION OF LAMPS

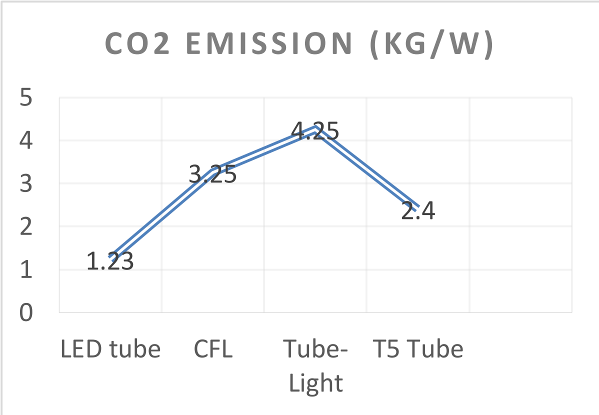


Fig. 9. COMPARISON OF CO2 EMISSION

TABLE: IX COMPARISON OF CO2 EMISSION

Lamps	Watts	Co2 Emission
LED tube	18	1.23kg/w
CFL	32	3.25kg/w
Tube-Light	40	4.25kg/w
T5 Tube	18	2.4kg/w

VI. CONCLUSION

The estimation of different AC and DC loads was done. From the PV-Syst software the required Panel size and battery size was estimated, and these values are verified with manual calculation. The module layout was drawn using the PV-Syst software. The CO2 emission of different lamps was plotted. Comparison of AC and DC lamp for cost effective analysis was done and concluded that LED was better than other lamps. The cost of CFL was high by considering both initial and running cost as compared to the cost of t5 tube and led tube. But the cost of CFL was less as compared to tube light but it has high CO2 emission. For initial cost of 5yrs and 10yrs, the Lamps T5 tube, CFL, Tube was higher than LED and DC Lamps. So, we can avoid the tube light, CFL and T5. When DC and AC lamps are comparing, the DC lamps need less cost for installing because AC load needed an inverter.

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