

Integrated use of Photovoltaic Solar Panels and Hybrid Solar Lighting System; A Case Study of K.I.T's College of Engineering, Kolhapur

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ABSTRACT: In the past few decades, the disastrous impact on the environment has brought us to time where we need to focus on renewable energies as it seems to be the most abundant and ideal concept for energy production, conservation and resource preservation.

The aim of this paper is to effectively use solar energy for day-lighting and electricity generation. The integrated use of photovoltaic panels and hybrid solar lighting explore an efficient avenue towards achieving self sufficiency in electricity with fairly low cost of implementation as compared to other renewable technologies. Investments of Rs 1.5 crores approximately and a payback period of 4 to 5 years is quite feasible for an institute like ours (K.I.T's College of Engineering). The paper also talks about the structural arrangement and orientation of the panels and collectors to achieve maximum efficiency. Furthermore, the project represents a new approach towards adapting sustainable technologies, maintaining aesthetic looks along with being environmentally sound by reducing release of 330 metric tons of CO₂ into the atmosphere.

KEYWORDS: Photovoltaic panels, Hybrid solar lighting, Renewable technologies.

I. INTRODUCTION

Integrated use of photovoltaic panels and Hybrid Solar Lighting (HSL) represents a new and innovative method in which natural sunlight is used as a source of energy during daytime in various parts of the **building**. The relation between different parameters of solar radiation, sun path, solar tracking and the degree of solar intensity with respect to the specific geographical location of the college have been thoroughly analyzed and discussed. The above parameters lay the base of the structural construction and precise alignment of the panels and HSL collectors.

KIT being situated in the vicinity of two major **consuming sites** i.e. Maharashtra Industrial Development Corporation (MIDC) and Kolhapur Cancer Hospital (KCH) **faces mundane yetsignificant** energy shortage. However the electricity demand can be met by the use of solar panels. The main advantage of the integrated use of solar panels and HSL is that it has a low cost of installation with respect to the electricity generated as compared to the system solely comprising of PV solar panels.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

II. SITE SPECIFIC CONSTRUCTIONAL DESIGN

a) Solar Path Orientation

Solar path analysis is the pre requisite for the installation of solar panels. KIT Kolhapur lies in the northern hemisphere having latitude $16^{\circ} 29' 13''\text{N}$ and longitude of $74^{\circ} 15' 51''\text{E}$. The sun path for a given location generally varies throughout the year. In summer, the sun is at the highest position; it rises and sets in the north of east west direction. Also it rises much earlier and sets later than in the winter, allowing to obtain greater exposure of sunlight to the panel. In winter, the sun is at the lowest position; it rises and sets in the south of east- west direction. The solar path varies on the basis of latitude and seasons. The solar path of the college is traced as per the Table 1 [1].

Table 1: Solar path for KIT, Kolhapur

Solstice/ Equinox	Date	Description
Summer Solstice	21 Jun	Sun will rise 99° east of due south and set 99° west of due south.
Winter Solstice	21 Dec	Sun will rise 83° east of due south and set 83° west of due south.
Autumn Equinox	21 Sept	Sun will rise 91° east of due south and set 91° west of due south.
Spring Equinox	21 Mar	

Type of material and Selection of solar panels

Solar panels are available mainly of monocrystalline, polycrystalline and thin film materials. We have selected the solar panels which is made up of monocrystalline material because of following advantages-

- High efficiency in moderate temperature conditions.
- High grade of silicon is used.
- Less space requirement for installation of solar panels.

a) Panel orientation

As per the latitude of the location of the building, the optimum angle is calculated by the following equation-

$$\begin{aligned} \text{Optimum angle} &= 0.87 \times \text{Latitude in degrees} \\ &= 0.87 \times 16.48 \\ &= 14.33^{\circ} \text{ (From horizontal)} \end{aligned}$$

The solar panel must be facing towards south as it gives the maximum solar irradiance values. Solar irradiance is the power received from the sun per unit area per day. The average monthly solar radiance at KIT is shown in Table 2. As per the thumb rule, 10 sq.m. of a roofing area can accommodate approximately 3 panels, considering the allowances for maintenance walkways, water seepage, circuit wirings etc.[2].

International Journal of Innovative Research in Science, Engineering and Technology

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Table 2: Monthly average solar radiance at KIT[3].

Month	Solar Irradiance (kWh/m ² /day)
January	6.18
February	6.53
March	6.76
April	6.41
May	6.18
June	4.25
July	3.58
August	3.63
September	4.63
October	5.21
November	5.78
December	5.85

b) Roofing

Since solar panels exert an average load of 10 to 20 kg/m², the RCC roofing is selected as the preferred solution to the sustain the load safely along with the construction of suitable number of support columns. Furthermore, to prevent water stagnation the slope provides excellent solution for water run-off.

III. PRINCIPLE AND WORKING

The photovoltaic phenomenon is used to convert direct sunlight into energy source. When a photon strikes a semiconductor, the negative transitional surface of the polarity ejects the electron which results in creation of free electrons and electron holes as shown in Fig.2.

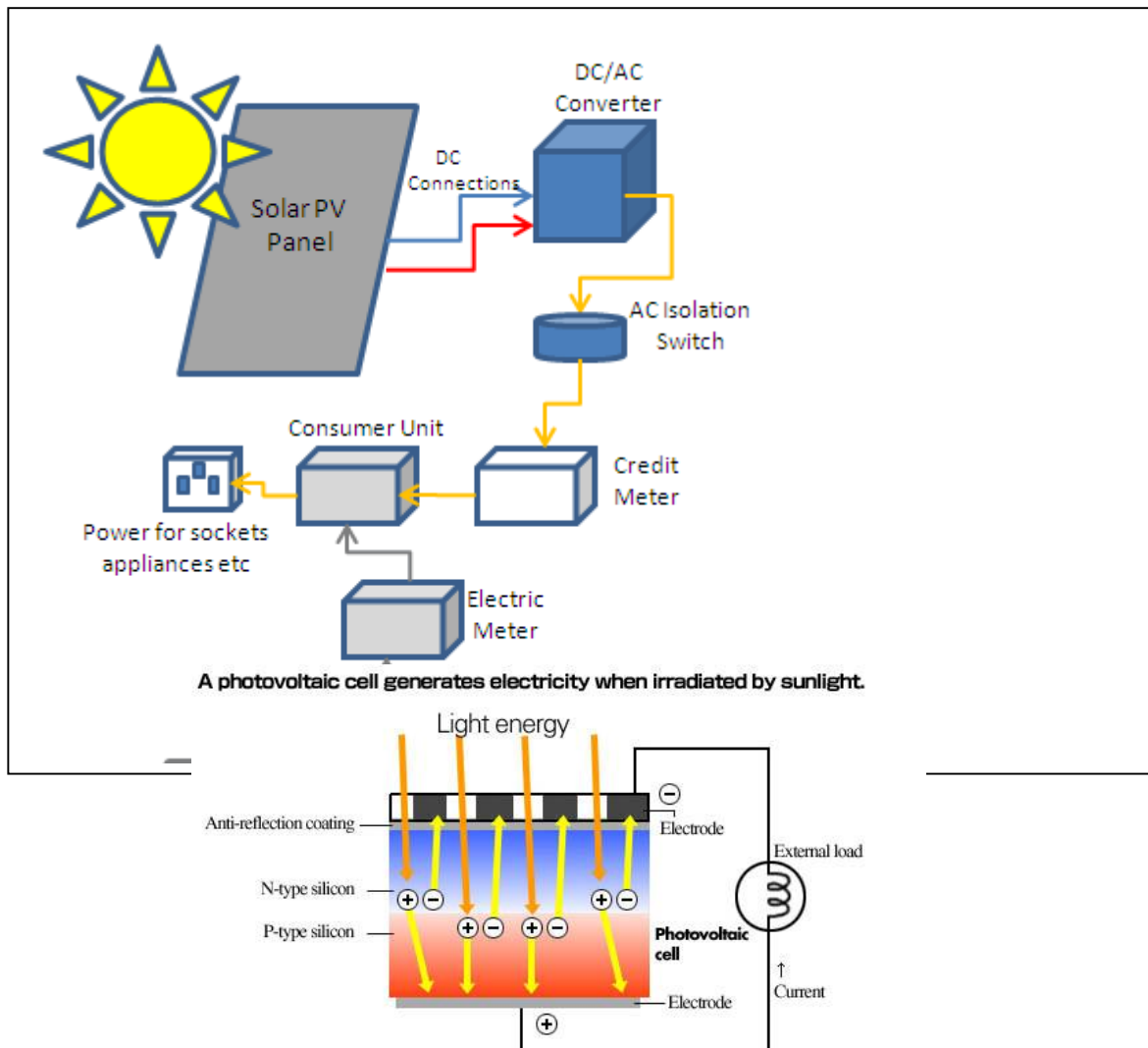
The released electrons move to the upper layer. In the bottom layer the electrons are deflected from one atom to the other in a way they fill the electric empty places. The free electrons are conducted from the upper layer into the electric field where the solar cells are located. This continuous process results in generation of electricity. The produced electricity is then sent to the inverter where it is converted from DC to AC. The transformed electricity is then transmitted to the junction box, from where it is used indoors accordingly. The above working is explained diagrammatically in Fig.1.

Due to high cost, low efficiency, and low life period of the batteries, a grid type of circuit system has been adopted. The excess units produced automatically taken up by the electricity board mains which is analyzed by the meter [4].

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The technology of hybrid solar lighting can capture ambient sunlight efficiently when mounted on roof top or side wall. The collected solar light is 'piped' or transmitted to longer distance up to 12 m or 40 ft and transported to the end face hybrid type of diffuser to disperse the natural light indoors.

The major features of the hybrid solar lighting system are as follows

1. High quality collector; capable of capturing even low angle sunrays
2. Easy to install and maintain
3. Has a significantly long life
4. Hybrid type of diffuser; larger spread of light; maintains constant luminosity indoors irrespective of the solar intensity.

The working of the system is based on the principle of transmission of light from one place to another with highest possible efficiency and lowest possible transmission losses by 'Total Internal Reflection'.

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The sun rays are captured by a dome shaped collector that collects the sun rays efficiently (even the low angle rays) and concentrate it into the pipe. The pipe further transfers it towards the diffuser which eventually diffuses it indoors, as shown in Fig.4.

An innovative feature of the system is its hybrid property, which collaborates both natural as well as artificial lighting in order to maintain stable luminosity. A photo-sensor senses the amount of solar intensity. Should the intensity be low, an amount of lumens equivalent to the shortage of natural light is diffused with the help of artificial lights, thereby maintaining the overall luminosity indoors. Fig.3 shows the working of hybrid solar lighting from the solar collector to the end diffusers [5],[6].

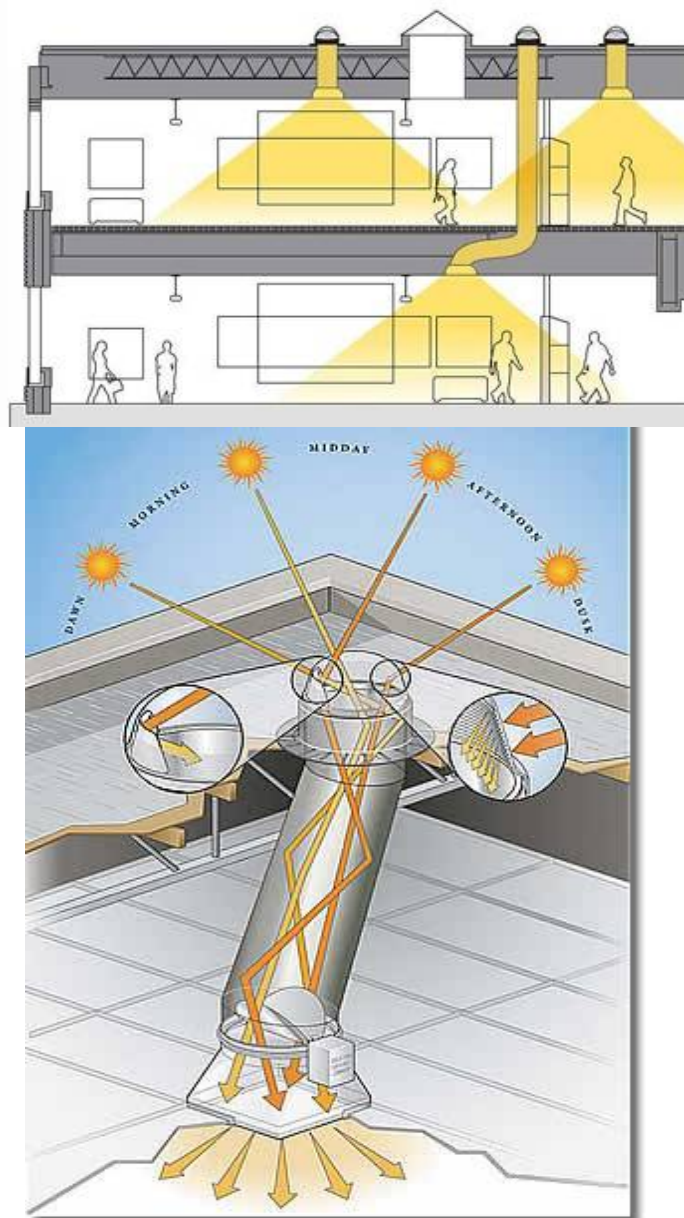
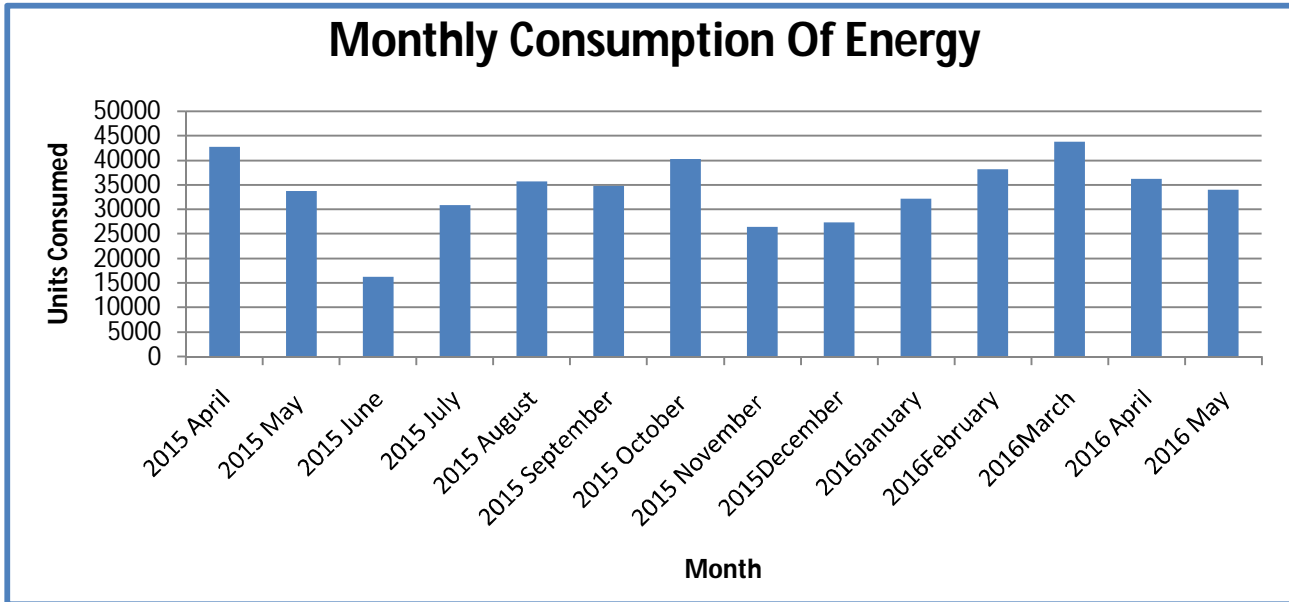


Fig.4: Working of HSL

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a) PV Solar Panels

The above figure (Figure 4) illustrates the number of units consumed per month. The average monthly consumption is about 38888 units.

Hence, the number of units consumed per day is 1296.27 units.

AS A THUMB RULE,
1 kW of solar panels cover an area of 10 m² and provides an overall output of about 4.5 units per day[7].

This is equivalent to 2880 m² (288 kW) of solar panels.

Referring to the pie chart, solar panels equivalent to 1 kW rating is worth Rs 65 including cost of inverter, panels, cables along with installation and labour.

The cost of the system would be equal to $288 \times 1000 \times 65$
= Rs 1, 87, 20,000 i.e. almost 1.9 crores.

Payback period = $1,87,20,000 / (3,39,826.4 \times 12)$
= 4.59 years

b) PV Solar Panels + H.S.L.

As per our survey almost 30 % of total units required accounts for daytime artificial lighting.

The number of units consumed in artificial lighting is equal to 388.881 units per day. Hence, the number of units required from the solar panels is equal to

$1296.27 - 388.88$
= 907.38 units per day

The required Kilo watt is of electricity from the panels = $907.38/4.5$

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=201.64 kW

This is equivalent to 2016.40 m² of solar panels.

The cost of H.S.L. system inclusive of installation and labor is Rs.27000 per 1000 sq. feet [8].

Total area for H.S.L implementation = 1,37, 748.55 sq feet.

Cost of pv panels + cost of HSL

(201.64*1000*65 = Rs.1, 31, 06,600) + (1, 37,748.55sq.ft.*27 = Rs.37, 19,210)

= Rs. 1, 67, 19, 210.83

Payback period = 1, 67, 19,210.83 / (3, 39,826.4*12)

= 4.09 years

Table 3: Cost and Payback period comparison between PV solar panels and PV-HSL system

	PV SOLAR PANELS	PV + HSL SYSTEM
Cost	Rs.1,87,20,000	Rs.1,67,19,210.83
Payback period	4.6 years	4 years

V. RESULTS AND DISCUSSION

- This project is set to achieve self sufficiency for the entire college and procure savings in the coming years.
- Furthermore, this project produces on an average 15 % extra units, which could be sold to the electricity board generating profits.
- As the lighting achieved by the H.S.L is entirely natural and devoid of infrared and UV rays, thus maintaining ambience and reducing extra load on fans, ACs due to heat generation by the artificial lights.
- Moreover, implementation of this project has contributed towards avoiding release of 330 metric tons of CO₂ into the atmosphere per annum which is equivalent to saving 312 trees aged years or more.

VI. CONCLUSION

The study was carried out to analyze the combination of photovoltaic solar panels and HSL in order to achieve self sufficiency in electrical energy demand for K.I.T, Kolhapur. As per the results, the integrated use of PV solar panels and HSL can be successfully implemented economically in the college campus to meet the energy demand in a profitable way. With the implementation cost of Rs.1.6 crores a payback period of 4 years will be achieved. A very low maintenance cost and extended life of the project proves it to be satisfactorily economic in the long run. This sustainable technology is environmentally sound along with imparting aesthetic beauty to the campus.

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