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Experimental Analysis of Effect of Vegetation under PV Solar Panel on Performance of Polycrystalline Solar Panel

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Abstract

The polycrystalline photovoltaic cell has an efficiency around 11-14%. The efficiency is low because of different factor, out of which the temperature is one of affecting factor on efficiency. The solar cell efficiency decreases with increase in temperature. So it is necessary to cool the PV panel to improve its efficiency.

Cooling of PV panel is one of critical issue during the planning of installation of PV plant. In the present work cooling of photovoltaic panel via different vegetation and water tray is carried out. The aim of this project is to optimize the panel efficiency by controlling the panel surface temperature by cultivating different vegetation below the panel. The experiment is done for polycrystalline silicon cell. The plants selected for the experimentation has a good evapotranspiration effect except aloe vera. The numerical value of increase in instantaneous efficiency is 3-4%, 1.8-2.2%, 1.2 -2%, 0.2 -0.5% for water tray, peppermint, tulsi and aloe vera respectively. The economical benefits due to cultivation of peppermint, tulsi aloe vera and water tray and also due to increase in power production from 1MW solar plant per year is forecasted has Rs. /- 455250, 436012, 219150 and 778850 respectively.

Keywords: Polycrystalline silicon; Vegetation cover; Evapotranspiration

Introduction

Photovoltaic cells are devices which convert solar radiation directly into electricity. However, solar radiation increases the photovoltaic cell temperature [1-3]. The temperature has an influence on the degradation of the cell efficiency and the lifetime of a PV cell. But solar cells perform better in cold rather than in hot climate and as things stand, panels are at 25˚C which can be significantly different from the real outdoor situation [4-6]. For each degree rise in temperature above 25˚C the panel output decays by about 0.25% for amorphous cells and about 0.4-0.5% for crystalline cells. Thus, in hot summer days panel temperature can easily reach 70˚C or more. It means that the panels will put out up to 25% less power compared to what they are rated for at 25˚C [7,8]. Thus a 100W panel will produce only 75W in May/June in most parts of India where temperatures reach 42-44˚C and beyond during summer season and also the electricity demand is high. However, only a fraction of the incoming sunlight striking the cell is converted into electrical energy [9-11]. The remainder of the absorbed energy will be converted into thermal energy in the cell and may cause the junction temperature to rise unless the heat is efficiently dissipated to the environment [12]. Solar cell performance decreases with increasing temperature, shown in Figure 1, fundamentally owing to increased internal carrier recombination rates, caused by increased carrier concentrations. The operating temperature plays a key role in the photovoltaic conversion process [13-15].

The installation of MW scale power plant will leads to keep land to be barren and it leads to soil erosion in rainy season or in windy atmosphere. So to avoid such phenomenon we can use this barren land for cultivating the specific plant which provide good cooling effect by extracting heat from PV panel [16,17]. Hence due to the cooling of panel the performance of PV plant is enhanced also by cultivating specific plant certain economics benefit can be easily achieved. By this experimental method we can improve the performance of panel and ultimately the electricity production rate will increase [18].

Effect of Temperature on Polycrystalline

For polycrystalline PV panels, if the temperature decreases by one degree Celsius, the voltage increases by 0.12 V so the temperature coefficient is 0.12 V/C. The general equation for estimating the voltage of a given material at a given temperature is [19]:

$$Voc\ module = Temp\ coefficient * (Tstc - T\ ambient) + Voc\ rated$$

Where:

Voc, mod = open circuit voltage at module temperature

T stc [°C] = temperature at standard test conditions, 25°C, 1000 W/m^2 solar irradiance.

$$Voc\ new = 0.12 * (25 - T\ ambient) + Voc\ rated$$

The on field experimentation is needs to study actual effect of vegetation on PV panel. So due to this reason an experimental prototype is made on the college terrace.

The experimental analysis gives the on field result with consideration of all environmental factors, the methodology used during experimentation is has mention below [20],

- The selection of plant which have high transpiration rate for providing good cooling effect.
- Design of experimental setup with vegetation

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- Installation of Experimental Setup
- Testing and data collection
- Data Analysis
- Results
- Evaluating the economic benefits of vegetation as per present market value
- Conclusion, Limitations and Recommendations.

Plant Selection

There are many plants available for vegetation which will grow under the shadow (under the panel). But during the selection of plant need to consider some limitation of prototype setup (Figure 2) [21].

The plant selected (medicinal plants) as per it's economical as well as health benefits.

Main criteria consider during the selections of plant [22]:

1. The experimental setup prepared has the limitation of height from ground. Therefore the plant selects must have height less than panel height from ground surface.
2. Root length - As I have prepared the artificial bed for cultivation of plants.
3. Water requirement for plant growth is most considerable factors during selection of plants.
4. Temperature Requirement of specific plant
5. Soil properties. The cooling media can be classified into two categories

a) Medicinal Plant.

b) Water tray (keeping tray filled with water at the below of PV panel).

Experimental Setup

The 3- D model of experimental setup is design on Uni-Graphics. The actual setup may look like this as shown below in different view (Figure 3).

The experimental setup made on field for finding out the results is shown in Figure 4.

Experimental Testing Procedure

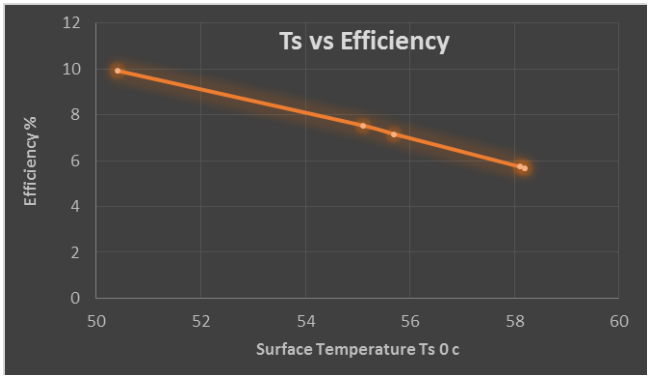

Figure 1: Ts vs Efficiency Graphs.

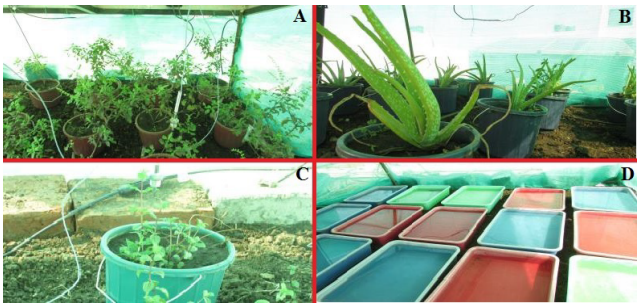

Figure 2: Selected Plant; A. Oscimum Sanctum (Tulsi); B. Aloe Vera (Korpad); C. Peppermint (Pudina); D. Water Tray.

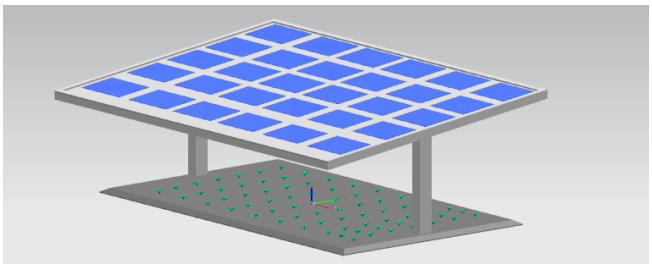

Figure 3: 3-D model on Uni-Graphics.

Figure 4: Experimental Setup.

Experimental setup is tested for two days and the reading on each day is mentioned in sheet. The different parameter are measured like voltage, current, radiation, panel surface temperature, chamber temperature, soil temperature, wind speed, atmospheric temperature etc. Various instrument are used to measure this parameter mainly data logger for recording temperature for half hour interval time, anemometer, multimeter, digital temperature gun, pyranometer for radiation measurement.

Procedure followed during testing is,

- All sensor of temperature data logger is fixed at a particular point to record the temperature of that point continually.
- The setting is set into data logger in such way that it record temperature with half hours of interval.
- For the same instant of time the radiation are measured with the help of radiation meter.
- The multimeter is used to measure the voltage and current at the

same instant of time.

- All the parameter is taken at same time but there might be a 1-2 min time difference.

The load power and efficiency is calculated as,

Power At load = $I_m * V_m$

Efficiency = $\eta = \frac{l_m \times V_m}{A \times Radiat}$

Therefore, the sample calculation,

Power = Im × Vm = 2.7 ×74.8 = 201.96 W

Efficiency = (2.7 × 74.8) ÷ (3.87 × 632) = 8.25%

Similarly the all calculation is done and the following table is prepared (Table 1) [23].

Results

From experiment it is seen that cooling effect from vegetation enhances the panel performance. The result obtains due to cooling by different vegetation and water tray are tabulated and plotted. The efficiency increased by water cooling is more as compare with other setup (Figure 5).

The increase in efficiency among the all setup is more for water tray setup and which will be in the range of 3-4%. Such increase in 3-4% efficiency causes the falling in the panel backside temperature upto 5-6°C.The water tray prototype gives very good cooling due to the high evaporation rate from the tray as it kept open. Peppermint also gives very good cooling due to its greenish nature. It has increase in efficiency in the range of 1.8-2.2 %. Tulsi also gives good cooling effect. The aloe vera has lowest increase in efficiency among the setup prepared for examining the cooling effect. The difference between cooling obtain from various setup is clearly indicated in the graph drawn below (Figure 6).

Model	Radiation (W/m²)	Im (A)	Vm (V)	Power (W)	Efficiency (%)	Ts
A	632	2.47	62.5	154.375	6.31	57.8
B		2.63	66	173.58	7.096	56.2
C		2.66	67	178.22	7.28	55.1
D		2.59	63.7	164.983	6.74	57
E		2.7	74.8	201.96	8.25	53.1
A	764	2.6	63	163.8	5.67	58.2
B		3.1	67.5	209.25	7.16	55.7
C		3.21	68.5	219.885	7.53	55.1
D		2.62	64	167.68	5.745	58.1
E		3.9	74.2	289.38	9.91	50.4
A	865	2.62	64	167.68	5.07	59
B		3.4	71.1	241.74	7.31	55.3
C		3.6	71.2	256.32	7.75	54.4
D		2.69	66	177.54	5.37	58.1
E		4.5	77	346.5	10.48	49.4
ABCDE color codes specifications: Model A: Empty setup; Model B: Tulsi setup; Model C: Peppermint setup; Model D: Aloe Vera setup; Model E: Water tray setup						

Table 1: Reading at different Radiation.

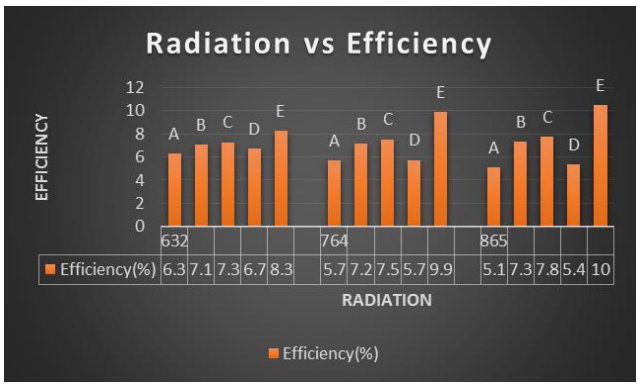

Figure 5: Radiation vs. Efficiency for all cases.

Analysis

The result obtains due to cooling by different vegetation and water tray plotted in graphs shown above. The efficiency is increased due to different type of vegetation and water tray, among of them water tray has highest efficiency. These results are analyzed by plotting the graphs between Radiation v/s Efficiency for each case, (Reading for analysis graphs are taken at no load on PV panel) [4-6].

1. The PV panel performance is improved due to the vegetation cooling.

2. Among the all cases efficiency increased for water cooling is more and which is 3-4%.

3. Aloe Vera does not give the good cooling has the efficiency improved for aloe vera is only 0.2-0.5 % because, aloe vera mainly grown in desert area it has characteristics of holding water for their survival.

4. As seeing the panel surface temperature (Ts where it is recorded) of panel if cooling is obtaining up to 1°C the panel efficiency will increase up to 0.33 -0.45%.

The graph plotted below show that there is increase in efficiency due to cooling via vegetation at the same radiation as comparing with empty model (A) [7,8] (Figure 7).

From above graphs plotted for empty case A show that the maximum efficiency obtain is near about 15 %.The panel surface is increased with increase in radiation level, as it starts increase above its rated temperature the efficiency goes on decreasing (Figure 8) [9-11].

The panel surface is increased with increase in radiation level, as it starts increase above its rated temperature the efficiency goes on decreasing. But due to the vegetation cover of tulsi under the panel it leads to a near about constant temperature inside the chamber. The graphs plotted for case B is clearly indicate that there is increase in efficiency doe to tulsi cover below the panel at same radiation as for empty case A. The maximum efficiency obtain is 22% (Figure 9) [12].

The panel surface temperature is increased with increase in radiation level, as it starts increase above its rated temperature the efficiency goes on decreasing. But due to the vegetation cover of peppermint under the panel it leads to a near about constant temperature inside the chamber as obtain in surface temperature vs. radiation graph. The efficiency is

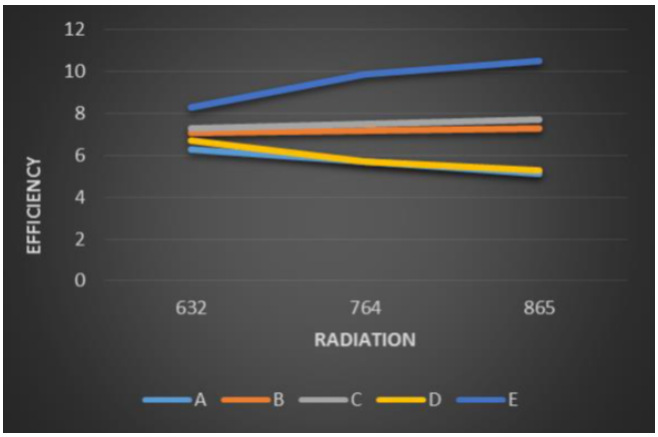

Figure 6: Increase in order of Efficiency for designed prototype.

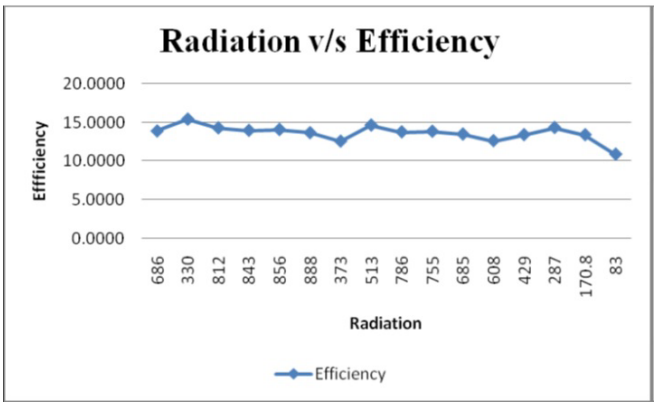

Figure 7: Radiation vs. Efficiency [Empty setup].

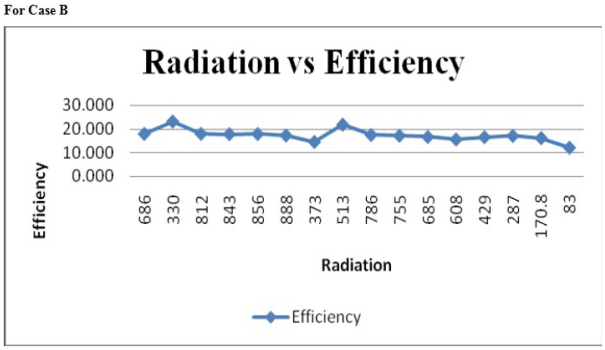

Figure 8: Radiation vs. Efficiency [Tulsi setup].

increased more than the tulsi setup due to the more greenish nature of peppermint. As the peppermint provide good cooling, the maximum efficiency obtain is 24% [13-15] (Figures 10 and 11).

The panel surface temperature is increased with increase in radiation level, as it starts increase above its rated temperature the efficiency goes on decreasing. But due the water tray kept under the panel it maintain the near about constant temperature inside the chamber as shown in surface temperature vs. radiation graph. The evaporation of water makes the panel back surface cool which leads to increase in panel efficiency due to decreasing panel temperature.

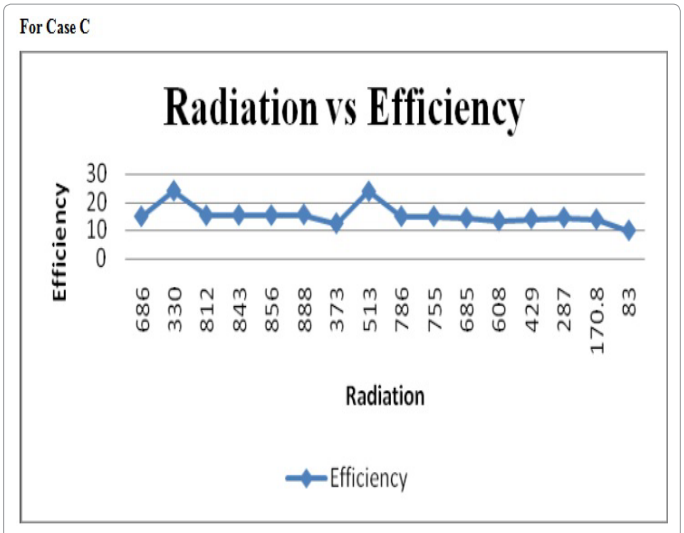

Figure 9: Radiation vs.Efficiency [Peppermint Setup].

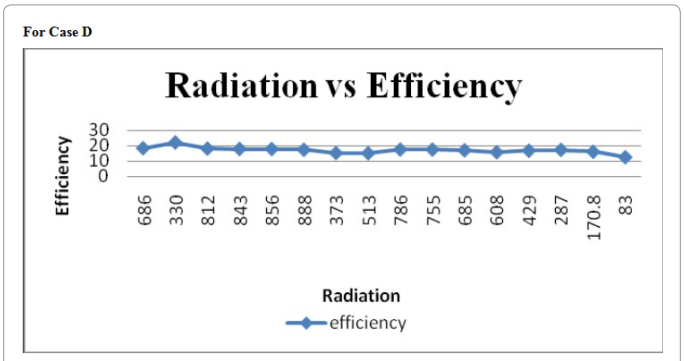

Figure 10: Radiation vs. Efficiency [Aloe Vera setup].

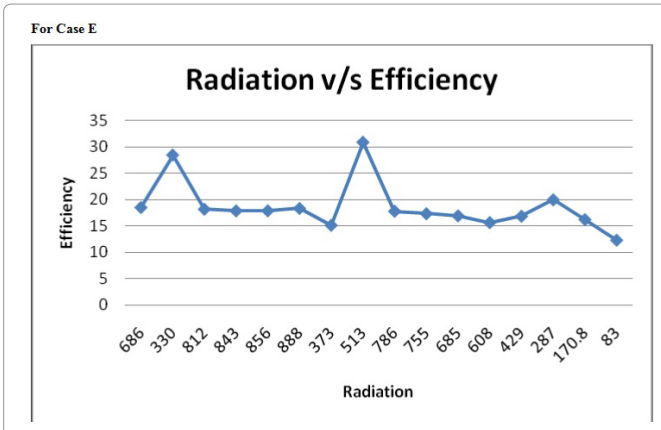

Figure 11: Radiation vs. Efficiency [Water Tray setup].

Among the all experimental prototype the water tray setup gives more increase in efficiency as shown in above graphs (Figure 12) [16].

The graph between Ts vs. Radiation clearly indicates that if there is increase in radiation will increases surface temperature of panel. Also it is possible to enhance the efficiency of panel due to cooling them by various cooling media likes vegetation and water tray as experimented in a project. The graph between radiations vs. efficiency show the increase in order of efficiency for various cases is Aloe Vera, Tuli,

Peppermint and water tray.

From all the above graphs and discussion it is concluded that the vegetation can made very good impact on panel cooling. The cooling effect due to vegetation enhances the panel efficiency as well as it will help to maintain surrounding temperature cool. For the same radiation the water tray case gives more increased in efficiency. On the graphs there are some pick out due to cloudy environment [17].

Combined result analysis graph: for surface temperature

For different radiation the surface temperature versus efficiency is plotted, the graphs show that with increase in temperature the panel efficiency goes on decreasing. The temperature profile as a constant nature during 48 to 53˚C and is slightly drop during next zone as shown in below graph (Figure 13) [24].

Economical Analysis

It has been proved by practical experimentation that the vegetation gives the cooling effect under the PV panel, which leads to increase panel output power. The increase in power increases the unit generated per year which add the additional income into the existing income coming from power production also the by selling the medicinal plants parts (leaves, flower etc) will also add into the total income. The economical analysis is carried for the experimental setup as well as for MW scale power plant [25] (Table 2).

As the bar chart (Figure 14) clearly indicates that the benefits obtain in terms of money is more from the set of PV panel below which water tray is kept, as the water evaporation rate from open tray is more so it will cool panel at optimistic value which leads increase more number of k-Wh [26]. Also the peppermint and tulsi gives appropriate benefits comparing with their initial capital investment. So when we cultivate such vegetation under PV panel for MW scale plant it will give income in both terms, also it will help to maintain environment cool (global warming effect) [27].

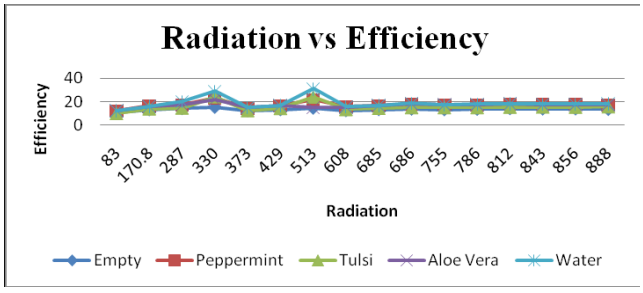

Figure 12: Combined Result Analysis Graph: For Efficiency (Radiation vs. Efficiency [At same radiation]).

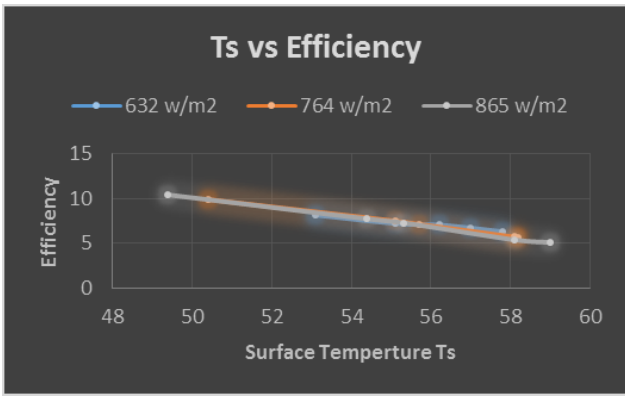

Figure 13: Ts v/s Efficiency.

Conclusion

1. The increase in temperature will decrease the efficiency; it has linear in nature with efficiency.

2. The efficiency is increased due to different type of vegetation and water tray, among of them water tray gives the highest efficiency.

3. The increase in efficiency due to water tray, peppermint, tulsi and aloe vera are 3-4%, 1.8-2.2%, 1.2-2% and 0.2-0.5%.

4. As the decreasing panel surface temperature by 1˚C the panel efficiency will increase up to 0.33-0.45%.

Limitations

1. The temperature data recorded as error of 1-2 degree Celsius due to sensor cable resistance.

2. The panel height from ground surface creates problem of maintenance so it is necessary to increase the panel height from ground surface.

3. The vegetation needs water so such cooling phenomenon creates the problem in the area of low water zone.

4. Need to select the plant having long life span.

Suggestions

- If the water bodies are available then install the PV panel above the water body as they provide very good cooling.
- The area where we want to setup PV plant; if the water quantity

Type of Vegetation	Benefits Due to vegetation/ Hectare in Rs./-	Benefits due to vegetation obtain Rs./- per year	Benefits due to power increased from 0.5 kW in Rs./-	Total Benefit obtain from experimental setup/year	Benefit obtain/ MW Plant/ year
Tulsi	84,575	169.15	559.97	729.12	436012
Pudina	55,000	110	678.27	788.27	455250
Aloe Vera	30,000	60	101.79	161.79	219150
Water	-	0	1339.05	1339.05	778850

Table 2: Benefits obtain in Rs. /-per year from experimental setup.

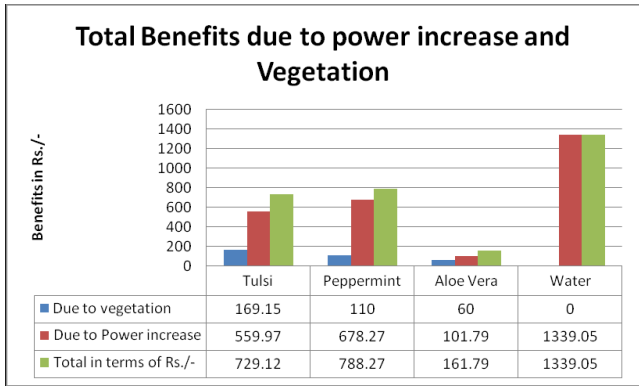

Figure 14: Economical benefits on bar chart.

available up to appropriate level then cultivate different type of vegetation suitable for that land. It will increase the annual income.

- But the area like Latur, Beed, etc. they have the problem of drinking water so for such area need to find out some alternatives for panel cooling.
- The way of cooling due to vegetation is make the surrounding temperature low also due to vegetation soil erosion reduces.

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