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## ABSTRACT

High petroleum prices and issue of global warming have created a big question mark on electricity generation through the non renewable energy sources. Solar photovoltaic (SPV) systems play a significant role in electricity production for remote areas. SPV based electricity generation is considered to be free from fossil fuels usage and green house gas (GHG) emissions but a considerable amount of non renewable sources utilized during its manufacturing, installation and transportation of solar PV modules and its components..

A detailed literature review has been carried out and it is found that EPBT for amorphous, mono-crystalline and poly-crystalline solar PV systems vary in the order of 2.5-3.2, 3.2-15.5, 1.5-5.7 respectively. Similarly GHG emissions are 15.6-50, 44-280, and 9.4-104 g-CO2 /kWh respectively. Two LCA studies have been carried out for SPV systems one 50 $kW_{p,\ situated}$ at Bazak (Bhatinda) and the other for 200 $kW_p$ situated at Khaterkalan. It was found that highest energy consumption and GHG emissions are in manufacturing of PV modules. Inverter and power wires accounts for 8.4% of the total embodied energy and GHG emissions. The initial cost of installing this type of system is quite high and having less efficiency.

For estimating the potential of solar radiation which can be converted into usable form (electricity) a detailed feasibility research is carried out so as to estimate the average potential which can be harnessed. Since India consists of places having different climatic conditions so sensitivity analysis is carried out to evaluate the performance of a plant located at different places. Various parameters which affect the performance or output of the plant are identified and how their change affects the final outcome is studied. Conventional sources of energy produce a definite level of emissions; it is desirable to estimate the same for solar photovoltaic system to assess environmental impact.

To formulate the directional design protocols, parameters which affect the output of the plant are identified and their values are varied to study their effect on the performance. Various parameters so identified are tilt angle of the module ($\beta$), Geographical location of the plant i.e. latitude ($\phi$), Average daily radiation, type of cell used (Amorphous, Mono crystalline, Polycrystalline), Green House Gas (GHG) emission of energy mix per kWh, Autonomy day, Interest rate and Battery life. Based on the parameters a model is generated which estimates the radiation level received then PV array sizing is done and corresponding storage system is designed. Embodied energy is evaluated for the plant and in the last life cycle cost analysis is done. The angle of tilt is varied from $15^0$-$45^0$, radiation level is varied from 4-6 $kWh/m^2$ and the

area of the plant is taken to be $1000m^2$.Analysis is done for three types of module namely amorphous, mono crystalline and polycrystalline .The electricity mix for India at present is 0.4 which selected for design, and corresponding GHG emissions of energy mix per kWh is taken to be 600.Total embodied energy and $CO_2$ emissions of both types of solar photovoltaic plants namely Stand alone and Grid Interactive system is calculated.

Electrical output is maximum for $\phi=34^0$, $\beta=35^0$, and polycrystalline cell. Number of units produced per year =1, 85,386. Electrical output is minimum for $\phi=12^0$, $\beta=45^0$, and Amorphous cell. Number of units produced per year = 48,150. Emissions (g/kWh) = 50.7 g-$CO_2$ is minimum for $\phi=34^0$, $\beta=35^0$ and GHG emissions of energy mix per kWh=500, for poly crystalline cell and grid interactive system. Emissions (g/kWh) = 172.8 g-$CO_2$ is maximum for $\phi=26^0$, $\beta=25^0$ and GHG emissions of energy mix per kWh=700, for Amorphous cell and standalone system. Range of cost for Stand Alone system (Rs/kWh) is found to be 19.27 as maximum and 7.22 as minimum. Range of cost for Grid Interactive system (Rs/kWh) is found to be 11.66 as maximum and 5.41 as minimum. A figure of merit for grading different solar photovoltaic electricity producing systems has been proposed. This figure of merit depends upon three sustainability indicators, i.e. Electrical output, life cycle greenhouse gas (GHG) emissions and Life cycle cost of electricity. The values of figure of merit as found out for different solar photovoltaic electricity generating system has been given below. A higher Figure of Merit represents a better system and vice versa.

Figure of merit indicate that for sustainable electricity generation, wind and small hydropower systems are to be developed first and after that solar PV and solar thermal systems may be considered. Wind and small hydro systems are very favorable for sustainable development; provided the potential for installing such systems exists.

The limitation is that model generated here has been designed for one city from each climatic zone i.e. for five different latitudes in India only more places can be undertaken to analyze the performance of the plant. Only three different cell technologies have been taken care of namely Amorphous, Mono crystalline and poly crystalline. With advancement of technology more and more advanced cells of better efficiency are coming up, so their feasibility and effect on performance can also be taken care off. Due to lack of decommissioning data it is not taken in account as most of the plants in India are new and none of them has been decommissioned as yet. The area of module required to produce the desired electricity is large in solar photovoltaic plants, which is the biggest disadvantage of the system. With new advancements cells of higher efficiency are expected to come in near future which will not only increase the electricity produced but also reduce the space required to produce it enormously. At present maximum cell efficiency in the range of 17%-20% has been achieved which is expected to go up to 30% in the near future. As the results shows that cost per unit of electricity produced for a standalone system can be as low this can be further reduced considerably with better battery life and increased cell efficiency.