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Solar Cell: Advancement inTechnology and Its Effect on Cost in India

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ABSTRACT: Solar energy is radiant light and heat from the Sun that is converted using technologies such as solar heating, photovoltaics, solar thermal energy.Most of renewable technologies excluding hydroelectricity cannot compete economically with fossil fuels.Solar power in India is a fast growing industry. The country's solar installed capacity touched 37.627 GW as of 31 March 2020.Capital cost per MW in India is lowest to install solar power plants.As of the researchdone by manufacturers in multiple countries, a correlation exists between module costs and cell efficiencies over a period of time. While manufacturers find a negative correlation between efficiency and cost per watt but the degree varies.

KEYWORDS: Solar Cells, PV Module, PV Cell, Efficiency, Cost per Watt

I. INTRODUCTION

The world depends on energy for various uses such as residential, commercial,industrial, and transportation. While fossil fuels supply much of the energy consumedworldwide, renewable energy is the fastest growing form of energy. Solar energy is an essential source of renewable energy, and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power, and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favourable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.The large magnitude of solar energy available makes it a highly appealing source of electricity.

With about 300 clear and sunny days in a year, the calculated solar energy incidence on India's land area is about 5000 trillion kilowatt-hours (kWh) per year (or 5 EWh/yr).[1] The solar energy available in a single year exceeds the possible energy output of all of the fossil fuel energy reserves in India.

The India's solar installed capacity touched 37.627 GW. The Indian government had set an initial target of 20 GW capacity for 2022 and it was accomplished four years ahead of schedule. The target was raised to 100 GWof solar capacity (including 40 GW from rooftop solar) in 2015, targeting an investment of US$100 billion and scheduled to complete in 2022.Nearly 42 solar parks have been established in India to make land available for the promoters of solar plants. India expanded its installed solar power capacity by 233 times from 161 MW to 37,627 MW in a decade ending on 31 March 2020[2].

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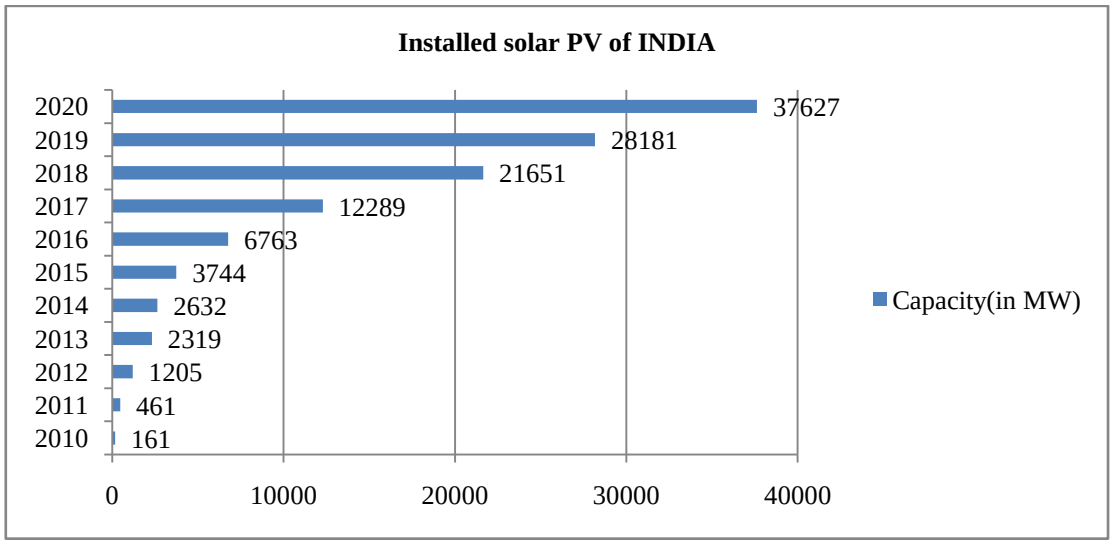


II. GENERATIONS OF PV SYSTEMS

PV systems can be classified as: PV modules, powerelectronics, and balance-of-systems. PV modules are made up with interconnection of PV cellswhich are designed to convert the light of the sun to electrical energy.

Solar panels can be classified on the basis of parameters: the number of junctions they have or the generation they belong to. There are single-junction and multi-junction solar panels that differ in terms of the number of layers in the solar panel. The other way of classification of solar panels with regards to the generation focuses on the material and efficiency of different types of solar panels.[3]

Existing solar cell technologies comprise three generations of innovation. Importantcharacteristics of each generation are its cost and efficiency.

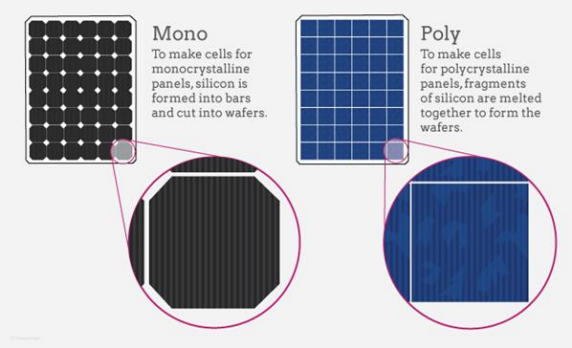
(i) 1st generation solar panelsare basic solar panels that are made up of monocrystalline silicon or polycrystalline silicon and are used in conventional surroundings.

(a) Monocrystalline solar panels (Mono-SI)are made up of mono-crystalline silicon. They have a dark look throughout the panel and rounded edges. Due to high purity silicon used, These panels have the highest efficiency rate. These are most expensive because theyoccupy less space, high power output and long durability..[3][4]

In India, monocrystalline solar panels are available in a panel efficiency range of 17%, 18% and 19%.The price of monocrystalline solar panels with 17% efficiency and a watt range of 250-above 300 W is Rs 47 per Wp.In the case of 18% efficient solar panels, the prices are Rs 48 per Wp for 250-300 W and Rs 50 per Wp for panels above 300W.Monocrystalline solar panels with 19% efficiency are the most economical. Their price ranges from Rs 42 per Wp for a watpanels within 0-50 W.

(b) Polycrystalline solar panels (Poly-SI)production technology is based on melting raw silicon. The outer structure of Poly-SI has square cells, angles that are uncut and they are blue in colour. They are cheaper than Mono-SI because they have lower efficiency, shorter life span and occupy more space to generate the same amount of energy as compared to Mono-SI, and cannot tolerate extremely hot temperatures.[3][4]

They are available in an efficiency range of up to 17%. The price of polycrystalline solar panels with less than 13% efficiency ranges from Rs 48 per Wp for 200-250 W to Rs 55 per Wp for 0-50 W.



MONOCRYSTALLINE AND POLYCRYSTALLINE SOLAR PANELS

(ii) 2nd generation solar panelscomprise different types of thin film solar cells that are primarily

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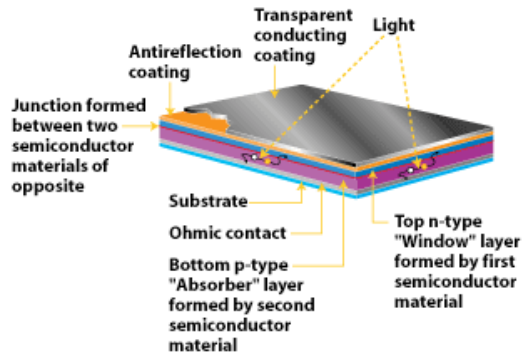
used to build solar power systems with low power output.

(a) Thin film solar panels (TFSC) are a less expensive option. They are made by placing one or more films of photovoltaic material onto a substrate. These are cheaper as less material is used in its manufacturing. They are not suitable for residential purpose because they require large spaces to generate sufficient energy. They have shorter warranties in comparison to their 1st generation counterparts. They are best suited for the areas that have ample open space for installation.[3][4]

(b) Amorphous silicon solar panels (A-Si) types of solar panels use a triple layer technology which is considered to be the best in the thin film variety. They are available at very low costs but provide efficiency of only 7%.[3][4]



CROSS-SECTION OF THIN FILM CELL

(iii) 3rd generation solar panelsbelonging to this generation use organic as well as inorganic materials. These include a variety of thin film panels and some of them, such as 'biohybrid solar cells', are still in the development phase.

(a) Cadmium Telluride solar panels (CdTe)are manufactured using Cadmium Telluride. They are efficient as their manufacturing cost is very low and require very less amount of water to be produced. The primary advantage of these panels is that they can reduce carbon footprints significantly while their only disadvantage is that they can lead to fatalities if ingested or inhaled..[3][4]

(b) Concentrated PV panels (CVP or HCVP) are the most efficient type of solar panels with an efficiency of 41%. They use curved mirror surfaces and lenses and cooling systems are also integrated to make them more efficient. These are multi-junction solar panels which can be best efficient when they receive sun rays at a perfect angle..[3][4]

III. SOLAR CELL EFFICIENCY

The efficiency of a solar panel is calculated by the amount of sunlight it converts into electricity per unit of area. Overall efficiency of the solar system increases with efficiency of a solar panel. A more efficient solar panel results in lesser number of panels to be installed and hence will entail less capital outflow.

$$Efficiency\% = \left(\frac{Output\ Power\ Per\ m^2}{Input\ Power\ Per\ m^2}\right) X\ 100$$

Several factors affect a cell's conversion efficiency value, including its reflectance, thermodynamic efficiency, charge carrier separation efficiency, charge carrier collection efficiency and conduction efficiency values. Because these parameters can be difficult to measure directly, other parameters are measured instead, including quantum efficiency, open-circuit voltage (VOC) ratio, and § Fill factor. [5]

There are other several factors that that solar cell researchers and manufacturers consider when designing and producing efficient solar panels:

(i) The type of material (monocrystalline silicon, polycrystalline silicon, cadmium telluride, etc.) impacts how light converts to electricity

(ii) The selection of wires and "busbars" on a solar panel that actually capture and transfer electricity impacts efficiency

(iii) Efficiency may be lowered if light is reflected away from a solar panel. Because of that the glass layer on top of silicon solar cells is so important.

Under laboratory conditions and with current state-of-the-art technology, Monocrystalline solar panelsare close to 25% efficient. However, commercially mass produced cells are typically only 18-19% efficient. The reason for this difference in efficiency is that the techniques used in the laboratory are not appropriate for commercial production within the photovoltaic industry and therefore lower cost techniques, which result in lower efficiency, are used.

Solar cell research continues to improve the efficiency of solar cells. For a given module cost, more efficient modules are also more cost effective because fewer additional costs (such as lade area, wiring costs, etc.) are needed to generate the same amount of power. Ultimately, this means that the more efficient a PV module is, and thus the more cost effective it becomes, the more attractive photovoltaics will be as an electricity source for both domestic and industrial use. The impact of

module efficiency on electricity cost is shown in the figure below.

Technology	Efficiency and Power Range	Cost per Watt
Monocrystalline solar panels(Mono-SI)	17% efficiency and a watt range of 250-300 W	Rs 47 per Wp
	18% efficiency and a watt range of 250-300 W	Rs 48 per Wp
	19% efficiency and a watt range of 250-300 W	Rs 42 per Wp
Polycrystalline solar panels (Poly-SI)	13% efficiency and a watt range of 250-300 W	Rs 52 per Wp
	14% efficiency and a watt range of 250-300 W	Rs 53 per Wp
	15% efficiency and a watt range of 250-300 W	Rs 37 per Wp
	16% efficiency and a watt range of 250-300 W	Rs 36 per Wp
	17% efficiency and a watt range of 250-300 W	Rs 34 per Wp

Note-Cost per Wp is based on average cost of different manufacturers.

IV. CONCLUSION

Our study focused on how technological advances in the conversionefficiencysolar cellaffect the cost of solar modules over time. It has focused on only one country or region. The analysis included some of the top PV solar cell manufacturers of country. The main conclusions are as- (i)Most of companies used first generation technology. (ii) Negative correlation exists between thecost per watt of module and the conversion efficiency- the higher the conversion efficiency, the lower the module costper watt. (iii) In generalthe module cost per watt varied acrossmanufacturers for different conversionefficiency. Wealso found that the selected manufacturers were investing and researching in 2nd and 3rd generation solar celltechnologies.

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