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A Comprehensive Study on Solar Energy to meet the Sustainable Development Goal in India

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Abstract: ***The share of non-conventional renewable energy in India is only 17.3%, where share of fossil fuel is 79.8% and causing cumulative GHG (Green House Gases) emission from electricity generation at a rate of 2,194.74 MtCo2. With the increase in population, the gross consumption of electricity in India was 16.3 kWh per capita in the FY 1947 to 1,181 kWh per capita as of FY 2018-19 and total generation (non-utilities and utilities) was 1,377 MW (megawatt)h to 1,54,6517 MW-h respectively.***

With the rapid increase in development and industrialization the electricity power has become a very necessary for mankind perhaps, in future it would trigger more in generation of electricity with the increasing development and advancement of technology.

Hence, the source of energy must be increase with time being with its necessity. There is various ways to generate electricity but the source of generation and process differ.

Few source of generation are eco friendly like; Solar, Hydro, Wind, etc and few causes adverse affect to our environment like; Coal, Oil, Gas, Nuclear, etc. In my present study it implies that due to increase in GHG and other polluting elements derived during electricity generation is invoking Global Warming. For mitigating the demand of excess electricity and keep the environment safe and clean by increasing the use of solar energy in various part of building structure as well as in other suitable infrastructure.

Keywords: Electricity, Pollutants, Non-conventional energy, Green house gas, Global warming, Solar energy.

I. INTRODUCTION

Solar energy is radiant light and heat from the Sun that is harnessed using various methods and technology, one of the very important sources of energy for the earth. The technologies use for harnessing the solar power are following solar heating, photovoltaic, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis. Its techniques also categorized into Passive solar and active solar depending on how they capture and distribute solar energy or convert it into solar power. Techniques include in active solar is, it use of photovoltaic systems, solar water heating and concentrated solar power to harness the energy.

The passive solar techniques include easterning a building to the Sun, particular materials with compatible thermal mass or light dispersing properties and constructing spaces that naturally circulate air. With the increase of population, the electricity generation also growing simultaneously alongside the pollution also. In India the use of solar power is not very initiative for the households. India has a very effective climatic potential for harnessing the solar energy as the Tropic of Cancer also lies through middle of the country.

During summer temperature exceed 40 degree Celsius in land locked areas, exceeds 35 degree Celsius in coastal areas and desert areas exceeds more than 45 degree Celsius. Even the highest temperature was recorded 51 degree Celsius in Rajasthan. Hence, with a very good infrastructure and policy, the solar energy can be harnessed very easily and detrimental effects of other sources of energy will be eradicated gradually. Rural areas of India nearly 0.28% (0.6 millions) have no access to electricity. Around 136million (11%) Indian use traditional fuels like; firewood, agricultural waste and animal dung fuel for cooking, heating purpose, source of light and so on. Such traditional fuels are burnt during cooking, also known as chulahs. These traditional fuel is a adverse source of energy for sustaining nature and its burning releases high levels of smoke ,NOX, SOX, PAHs, poly aromatics, PM10 particulate matter, formaldehyde, carbon monoxide and other air pollutants, affecting severely air quality, leading to haze and smog, chronic health problems, deteriorate to green forests, flora and fauna and global climate. According to WHO every year in India around 300,000 to 400,000 people in India die of indoor air pollution and carbon monoxide poisoning every year because of biomass burning and use of chulahs.

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II. MATERIALS AND METHODS

1) *Solar Thermal Collector:* A solar thermal collector also called solar heating collects heat by absorbing sunlight. The technique "solar collector" generally refers to a device for heating water by solar energy; it may refer to a large power generation, such as solar parabolic troughs and non-water heating device such as air heater by solar energy. Solar thermal collectors are either non-concentrating or concentrating. Like non-concentrating collectors, has an aperture area (i.e., area that receives the solar radiation) is roughly the same as the absorber area (i.e., the area absorbing the radiation). These types of collectors are built in a single self producer. The concentrating collectors are much bigger in aperture than its absorber area and only harvest the direct component of sunlight it is due to a additional mirror focus sunlight on the absorber. The non-concentrating collectors are usually used in households and commercial buildings for various heating purpose, and the concentrating collectors are used in solar power plants to generate electricity by heating heat-transfer fluid to drive a turbine connected to an electrical generator.

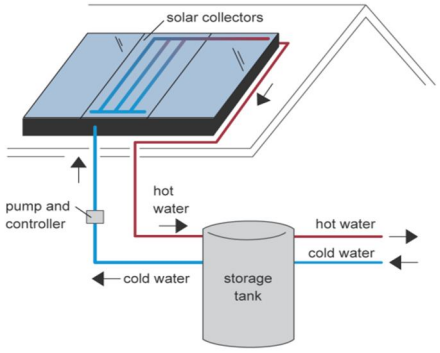

Fig: 1 Solar Thermal Collector mechanism

2) *Photovoltaics:* Photovoltaic (PV) is the conversion of solar energy or sunlight into electricity using various semiconductor material, that exhibit the photovoltaic effect, which is a phenomenon studied in physics, electrochemistry and photochemistry. The photovoltaics are known as a best method for generating electric power, by the use of solar cells to convert solar energy from the sun into a flow of electron by the photovoltaic effect. Basically solar cells produce direct current electricity from sunlight which can be used to power up various electronic equipments and recharge battery as well.

Fig:2 Photovaltiac solar cell

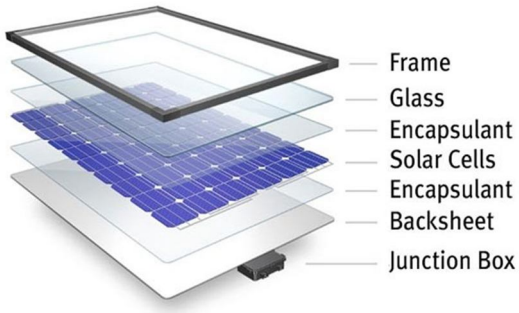

Fig:3 Constructive parts of a solar cell

The photovoltaic power generations employ solar module composed of a number of solar cell containing semiconductor material. Copper solar cables connects the modules (module cable), arrays (array cable), and sub-fields. The solar photovoltaic power generation has been seen as a clean energy technology since beginning which draws upon the planet's most abundant and widely distributed renewable energy source from the sun. Solar cells require protection from weathering and are usually packaged tightly in solar module. Photovoltaic module power is generally measured under Standard Test Condition (STC) in W_p (watts peak). The actual output of power at any particular place may be less than or greater than the rated value, depending upon the geographical location, duration of day, weather condition and other factors affecting the solar energy. The solar photovoltaic array capacity factors are typically under 25% which is very lower than many other industrial source of electricity.

3) *Artificial Photosynthesis:* The artificial photosynthesis is basically a chemical process driven naturally also artificially, that bio mimics the natural process of photosynthesis to convert the solar energy, water and carbon dioxide into carbohydrate and oxygen. The term artificial photosynthesis is generally used to refer to the technique or phenomena for capturing and storing the energy from sunlight in the chemical bond of fuel also known as solar fuel. The photo catalytic water splitting converts water into hydrogen and oxygen and it is a major research topic of artificial photosynthesis in chemistry. The very optimum technique light-driven carbon dioxide reduction is another process studied for replicating natural carbon fixation.

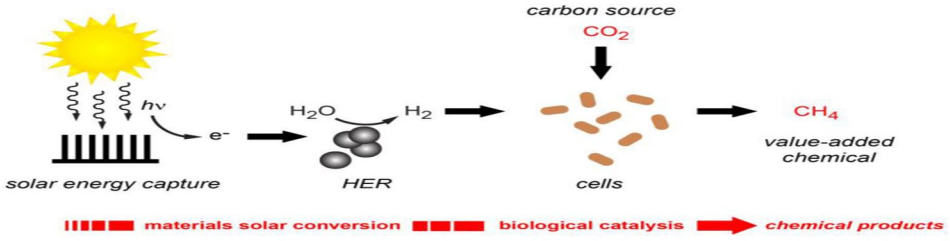

Fig:4 Basic technique of Artificial Photosynthesis.

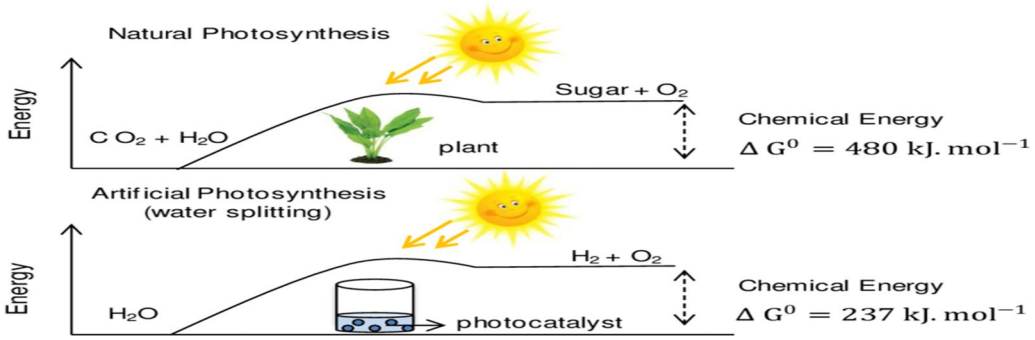

Fig: 5 Differences between Natural and Artificial Photosynthesis

III. DATA AND DISCUSSION

India's renewable energy sector has been increasing vigorously for the last decade. As of 31 March 2018, India had grid-connected installed power generation capacity of about 69.02 GW from non-conventional renewable technologies and conventional renewable power or major hydroelectric power capacity of 45.29 MW. But the total requirement of energy is higher than the generation, as report peak load met was 1, 75,528 MW where, 1,494 MW (-0.8%) below requirements. The total primary energy consumption from coal (452.2 Mtoe(million tones of equivalent); 55.88%), crude oil (239.1 Mtoe; 29.55%), natural gas (49.9 Mtoe; 6.17%), nuclear energy (8.8 Mtoe; 1.09%), hydro electricity (31.6 Mtoe; 3.91%) and renewable power (27.5 Mtoe; 3.40%) is total stands for 809.2 Mtoe (traditional biomass excluded) in the calendar year 2018.

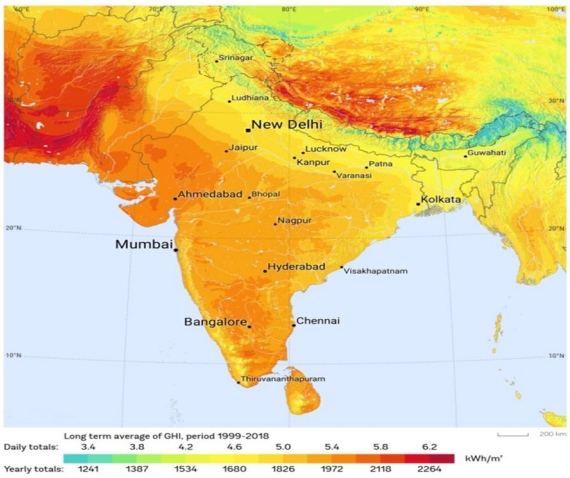

Fig. 6 Global Horizontal Radiation

In 2018, India's net imports are nearly 207.4 million tons of crude oil, 29.3 Mtoe of LNG and 142.7 Mtoe coal, totaling to 379.4 Mtoe of primary energy which is equal to 46.21% of total primary energy consumption. India is hugely dependent on fossil fuel import to meet its required energy demands. The highest dependency in India for generating energy is from, firstly coal and secondly crude oil, these sources of energy are not reliable at a peak as these are non-renewable source of energy, eventually we have depend on renewable energy such as solar energy. The pollutants are generating along with the power generation are very devastating for the present state of environment (Global Warming) and also for human health. With about 300 clear and sunny days in a year, India is endowed with vast solar energy potential. According to Ministry of New and Renewable Energy (MNRE), GoI about 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day. But the country's solar installed capacity reached 33.730 GW as of 31 December 2019. Further by the Ministry of New and Renewable Energy has planned to increase up to in addition 22.97 GW.

Year	Fossil Fuel			Nuclear	Hydro*	RES			
	Coal	Oil	Gas			Mini hydro	Solar	Wind	Bio mass
2011-12	612,497	2,649	93,281	32,286	130,511	na	na	na	na
2012-13	691,341	2,449	66,664	32,866	113,720	na	na	na	na
2013-14	746,087	1,868	44,522	34,228	134,847	na	3,350	na	na
2014-15	835,838	1,407	41,075	36,102	129,244	8,060	4,600	28,214	14,944
2015-16	896,260	406	47,122	37,413	121,377	8,355	7,450	28,604	16,681
2016-17	944,861	275	49,094	37,916	122,313	7,673	12,086	46,011	14,159
2017-18	986,591	386	50,208	38,346	126,123	5,056	25,871	52,666	15,252
2018-19	1,021,997	129	49,886	37,706	135,040	8,703	39,268	62,036	16,325

Table.1: Yearly gross electricity generation by source (GWh)

Pollutant Factors from various sources are following:

1) *Coal:* Coal comes from the remains of plants that died indefinite millions of years ago. It contain pure and highest degree of carbon of all fossil fuels. According to U.S. National Library of Medicine and other global sources, coal is the highest pollutant and emission disperser while it is most used for generating power. Coal-fired power plants account for 85 percent of the electric power industry's greenhouse gas emissions, including carbon dioxide. These plants also release smaller amounts of methane and nitrogen oxides, even sources of mercury and arsenic in the air. Mercury pollutes lakes, streams, and rivers, and builds up in fish. People who eat large amounts of fish from contaminated lakes and rivers are at the greatest risk of exposure to mercury.

Coal-fired power plants also emit:

a) Cadmium
b) Chromium
c) Dioxins
d) Formaldehyde
e) Furans
f) Hydrogen chloride
g) Hydrogen fluoride
h) Lead
i) Nickel
j) Particulate matter

k) Polycyclic aromatic hydrocarbons (PAHs)
l) Sulfur dioxide
m) Volatile organic compounds (VOCs)

It takes about one pound of coal to generate one kilowatt hour (kWh) of electricity and one pound of coal in India an average of 0.94 kg of CO2 is emits with efficiency of 34% coal burning in power plant.
During the year 2018-19 the energy generated in India by coal burning is 1,021,997 GWh.
Hence, the CO2 emitted by coal burned in India during FY 2018-19.

CO2 Emission
= (Po×1000×1000) kWh×940 gm**)**
= (1,021,997 ×1000×1000) kWh×940gm**)**
= (960,677,180,000,000÷1000) kg
= 960,677,180,000 kg
Total coal burned
= (960,677,180,000÷0.454×1000) kg
= 2,116,029,030.837 kg
Whereas,
Po = Power output.
1 kWh generation = 454 gm of coal.
940 gm = Emission factor (CO2 Emission per 454 gm of coal with 34% of burning efficiency).
Thus, the amount 960,677,180,000 kg of CO2 generated by a coal burned power plant in a year, which is beyond the permissible factor affecting the environment and leading to devastating habitat for living things.

2) *Oil:* Oil also known as petroleum – can be extracted and refined in order to make products such as gasoline, diesel and jet fuel. The study shows that oil (diesel) based generators (also known as diesel genset) are also the source of pollution. Diesel is commonly use in every power plant in the initial period for ignition or start the engine. In the particular diesel engine it is totally depends only on diesel for ignition and as energy both. It produces various pollutants during the electricity generation. Diesel emission stimulus development of cancer, cardiovascular and respiratory health effects, pollution of air, water, and soil, soiling, reductions in visibility, and global climate change. Pollutant emissions from diesel engines are carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM) and nitrogen oxides (NOX). Basically a diesel generator consumes an average of 400ml (.4L) of diesel as fuel for generating 1 kWh of electricity power and releases averagely 1.5 min – 3.5 max kg of CO2 in the environment by burning 1 liter diesel. During the year 2018-19 the energy generated in India by oil burning is 129 GWh. Hence, the CO2 emitted by oil burned in India during FY 2018-19.

CO2 Emission
= (Po*1000*1000 kWh *844.8) gm
= (129*1000*1000 kWh*844.8) gm
= (108,979,200,000/1000) kg
= 108,979,200 kg
Total diesel burned
= (108,979,200*0.85) lit
= 92,632,320 lit
Whereas,
P_o = Power output.
1kWh = for 320 ml of diesel.
00.85 = density of diesel.
844.8 gm = emission factor (Rate of CO2 Emission per 0.320 liter).
Thus, the amount 108,979,200 kg of CO2 generated during coal burning in a year is beyond the permissible factor affecting the environment and leading to devastating habitat.

3) *Gas:* Natural gas was formed from the remains of tiny coral reefs, sea plants and animals died millions years ago. It is mainly composed of methane and shell gas. A gas turbine is also called a gas combustion turbine, it is a continuous internal combustion engine. The main common elements of all gas turbine engines are:

a) An upstream rotating gas compressor
b) A combustor
c) A downstream turbine on the same shaft as the compressor

Natural gas is the pure most eco-friendly fossil fuel for electricity production. It generates one kilowatt hour of electricity in a power station and produces considerably huge CO2 emission. According to the study, natural gas emits around 50 percent less CO2 per kilowatt hour (kWh) than hard and brown coal. The average CO2 generated by burning natural gas is 564gm per kWh in India.

During the year 2018-19 the energy generated in India by gas burning is 49,886 GWh.

Hence, the CO2 emitted by gas burned in India during FY 2018-19.

CO2 Emission
= (Po*1000*1000 kWh *564) gm
= (49,886*1000*1000 kWh*564) gm
= (28,135,704,000,000/1000) kg
= 28,135,704,000kg
Total gas burned
= (28,135,704,000*0.7/35.3147) cft.
= 557,699,564.20414 cft.
Whereas,
P_o = Power output.
1kWh = for 10.03 cft gas.
Density of gas = 0.7 kg/m^3
564 gm = emission factor (Rate of CO2 Emission per 10.03 cft. of gas).
Thus, the amount 28,135,704,000kg of CO2 generated during coal burning in a year is beyond the permissible factor affecting the environment and leading to devastating habitat.

A. Solar Potential of India

In India the solar energy sector offers potentially enormous capacity, though a little of this potential has so far been exploited. According to Indian government the solar radiation of about 5,000 trillion kWh per year is incident over India's land mass, with average daily solar power potential of 0.25 kWh/m^2 of used land area. Solar power plants require mere nearly 2.4 hectares (0.024 km^2) land for per MW capacity, which is similar to coal-fired power plants when life cycle coal mining, consumptive water storage and ash disposal areas are taken into account, and hydropower plants when the submergence area of the water reservoir is included.

The mere cost of power generated by solar photovoltaic fell to ₹2.44 per kWh in May 2017 and ₹1.9 by FY 2030, lower than any other type of power generation in India. A 6.6 kw solar system can produce around 10,200 kWh a year which will reduce around 10.1 tonnes of CO2 emissions per year per system. On an average taking into account for two years to pay off the embedded energy in the panel, after 25 years a 6.6kw system will have a net saving of around 252.5 tonnes of CO2 emission.

IV. DISADVANTAGES OF SOLAR ENERGY

A. The very initial cost for purchasing a solar system is certainly high.
B. However, the solar energy can still be collected during cloudy and rainy days, only the efficiency of the solar system drops.
C. Land acquisition.
D. Solar Energy Storage Is Expensive.
E. Uses a Lot of Space.
F. Associated with trivial Pollution during production of PV Cell.

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The most efficient and effective way to utilize the solar energy is using of PV Cells. There are various kinds of PV Cells in the market but the four most used commercially and households. These are following.

1) *Monocrystalline:* The monocrystalline cells capture energy from the sun and turn it into electricity. It is basically made of silicon, which is used for solar panels due to its abundance and very durable element. The monocrystalline solar panels have solar cells made from a single crystal of silicon only. Monocrystalline solar panels are commonly considered as a premium solar product. The major advantage of moncrystalline panel is higher efficiency and sleek appearance. To make monocrystalline solar panels, the solar cell's silicon is formed into bar and cut into wafer. This type of panel is called monocrystalline to justify that the silicon used is single-crystal silicon. Due reason the cell is comprised of a single crystal and the electron that generates a flow of electricity that have more space to move. As a result, monocrystalline panels are more efficient than others similar types.
2) *Polycrystalline:* Polycrystalline solar panels are generally having lower efficiency than monocrystalline options, but only advantage is lower in price point. In addition, the polycrystalline solar panel tends to have a blue hue instead of the black hue like monocrystalline panels. Polycrystalline solar panels are also made of same silicon. During its making instead of using a single crystal of silicon it is manufacturered by melting many fragments of silicon together to form the wafer for the panel. The polycrystalline solar panels are also referred as a multi-crystalline or bond of many-crystal silicon. Because there are many crystals combined in each cell. There is very less freedom for the electrons to move in cell. As a result, polycrystalline solar panels have lower efficiency ratings than the monocrystalline panels.
3) *Amorphous Silicon:* It is a second-generation thin-film solar cell technology but has a short life span than others. The amorphous silicon is the non-crystalline type of silicon used for solar cells and a thin-film transistor in LCDs so comparatively the cost is also low. Basically used as a semiconductor material for Amorphous Silicon (a-Si) solar cell or thin-film silicon solar cell. It is combined in a thin film onto a variety of flexible substrates, such as glass, metal and plastic. Amorphous silicon cells are generally feature of low efficiency, one of the most environmental friendly photovoltaic technology, since they do not use any toxic heavy metals such as cadmium or lead and so on. It differs from all other allotropic variations such as mono crystalline, it is consists of small grains, also known as crystallites. One further advantage is that a-Si can be deposited at very low temperatures, e.g., as low as 75 degrees Celsius, can generate power in low light and temperature also.
4) *Concentrated PV Cell:* Concentrator photovoltaic (CPV) is a technology that generates electricity from sunlight. Unlike the remaining all other conventional photovoltaic system, it is basically uses a lens or curved mirror to focus sunlight onto small, it is highly efficient and multi-junction (MJ) solar cells. In addition the CPV system is often use solar tracker and sometimes a cooling system to further increase its efficiency. The cost of such panel is very high due to its complex construction. The modern CPV system operates most productive and efficiently in highly concentrated sunlight (i.e. concentration levels equivalent to hundreds of suns), as long as the solar cell is kept cool through the use of heat sink technology. During diffuse light sun, which basically occurs in cloudy and overcast condition, it cannot be highly concentrated using conventional optical components (i.e. macroscopic lenses and mirrors). The filtered light, which occurs during hazy and polluted condition, has immense spectral variations which produce mismatches between the electrical currents generated within the series connected junctions of spectrally tuned multi-junction (MJ) photovoltaic cells. Such CPV feature lead to a rapid decrease in power output when atmospheric conditions are less than ideal condition.
5) *Implementation Requirements:* Although the PV Cells cited above are the most effective and efficient for commercial, personal and for households use. Such technique can achieve the Sustainable Development Goal and mitigate the effect of Global warming and can develop a sustainable ecosystem for all the creatures and living things on the earth.

a) Such effective and beneficial technology with a proper technique can be implemented in every area space, which is very eco friendly and provides clean energy in its whole life span. Further it is the best way to save our earth and nature from global warming as compare to present technique of energy generation, which is responsible for CO2 emission.

b) PV cells are hardly disadvantageous due to its space occupancy tendency, but it would be enough advantageous also for its exchange theory. We can exchange various parts of our building, automobile, object which is exposed to sun and heat and so on.

c) It can provide a supplementary source of energy to every household, individual and other consumer cited above. It can be easily adopted by using exchange or modified technique of solar system.

Many of the commercial building, automobile and household uses glass framed door, wall, roof, window, etc... Such shape and size of these parts are enough good and capable to generate power from solar energy for effective general use. A decorative design of PV Cell can be equipped in all the suitable structure above mentioned.

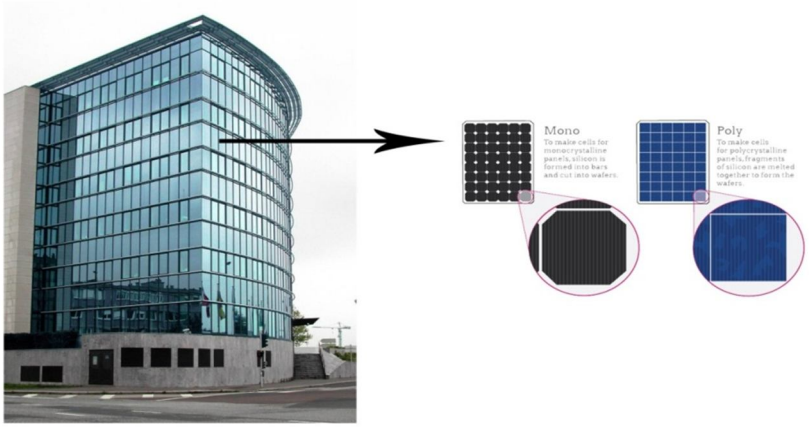

Fig.7 Poly Solar panel attachment fenestration on front facing.

In the fig.7 depicting pictorial representation that, how and where to implement the PV cells in a proper manner, it can be modified during implementation and a decorative design also.

Now days glasses are being used in the construction and building industry as a insulator material, in structural component, in external glazing material and as a cladding material also. It is used to make a sericeous look, fenestration on front facing as well as conventional windows. The solar power glasses are new technology, which is switchable glass projection screen and these are rarely a few of the newer use.

6) There are Four main types or Strengths of Glass

a) Annealed Glass. Annealed glass is a basic product formed from the annealing stage of the float process

b) Heat Strengthened Glass. Heat Strengthened Glass is semi tempered or semi toughened glass.

c) Tempered or Toughened Glas

d) Laminated Glass

In order to produce the amount of energy for a home it might need solar cells are wired together to create solar panels, which are installed in groups to generate solar energy in a series. The standard residential solar panel with combined regular 60 photovoltaic cells might generate approx 200 to 400 watts of power varying to sunlight condition. Because due to pollution occurs during energy generation, traps the potential solar insolation.

V. CONCLUSION

A comprehensive study on solar energy generation system, which would imply how to implement in a better and in a productive way for clean environment and for betterment of human cited above. Free or highly subsidized supplies for agriculture and subsidies to domestic consumers have resulted in uneconomic charges for industrial consumers. Decreases in global emission due to which our global warming can be eradicate.

Such kind of policy has driven many industries to depend more and more on self-generation of power. The second weakness of Indian situation is under investment in transmission and distribution relative to generation. This is due to the lack of proper return in the investment of the power stations.

This leads to the increase in price/unit and making the cost unreasonable for the common man. The use of solar energy in the production of electricity, it reduces the price per unit as low as 50 paisa. The only problem in this procedure is the high installation charges. So, if our engineers work in such a way so as to reduce that cost and in further developments of the equipment, we can definitely meet the power demand in the future and this will be an energy solution.

We have to reduce the use of non renewable source of energy which produces pollutants during power generation and lead to very unhealthy environment for the nature.

We have to slowly or gradually depend on renewable energy partially of fully, else the natural phenomena of our earth can be disturbed very easily as our nature is fragile and complex as well.

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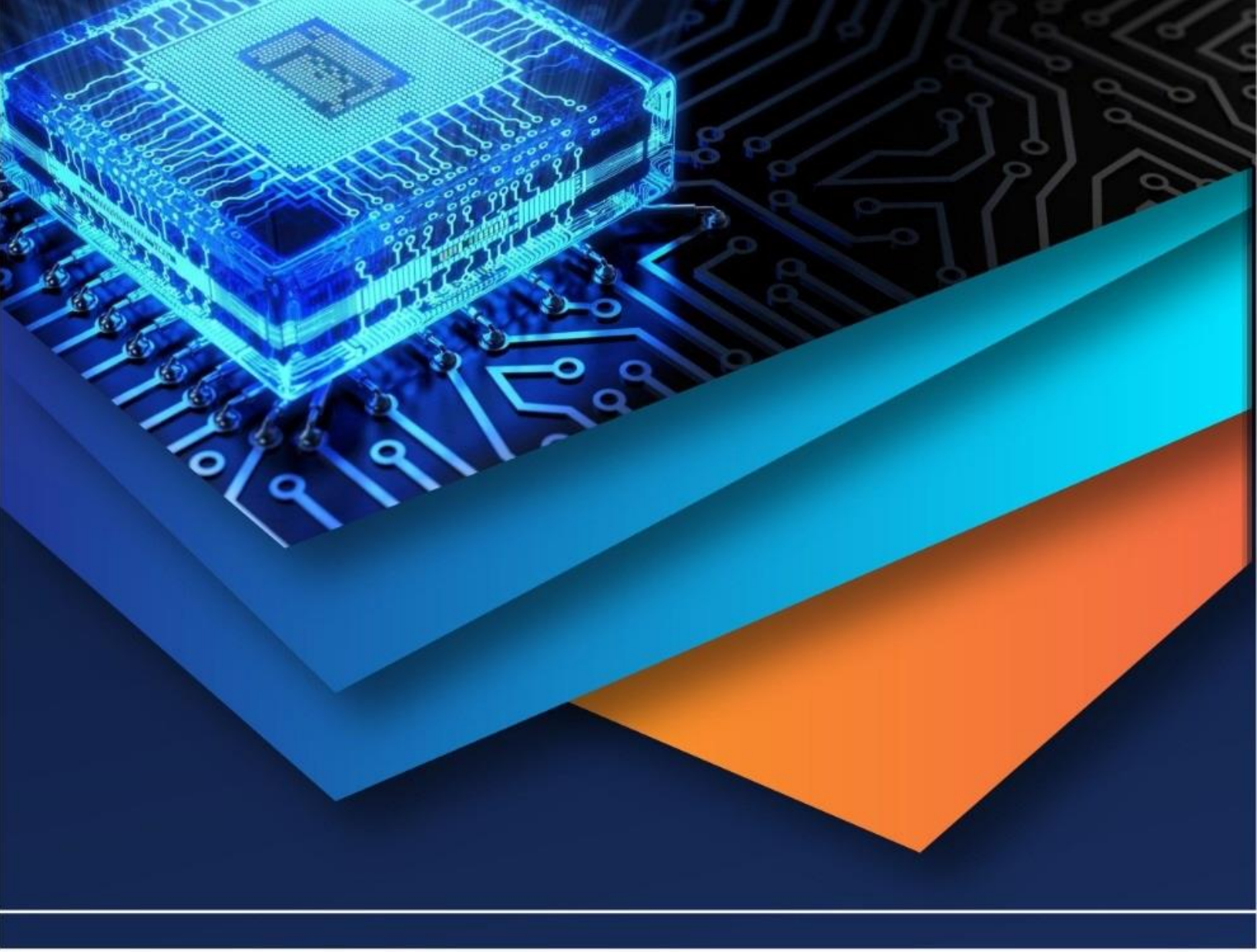

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