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A Review on Life Cycle Assessment of Solar PV Panel

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Abstract: Solar energy plays an important role in the move towards clean and green energy. By generating energy through photovoltaic (PV) solar technology and reducing carbon dioxide emissions into the environment, the solar energy industry can present one of the best clean energy sources to the market. However, to introduce an environmentally safe product to the market, companies need to study the full life cycle of the panels, from cradle to- grave. The electronics industry has failed to account for its product's end-of-life into consideration in the manufacturing process and result in the spreading of toxic chemical pollution. The solar energy industry can avoid a similar mistake by not only minimizing the need for the materials used during manufacturing, but also the transportation of PV panels, disposal, and these problems can be minimized by the reuse of the material.

This paper attempts to present a safe and sustainable method for the disposal of PV solar panels. A detailed study of current PV solar battery disposal practices is mentioned, likewise because the practicability of implementing utilization processes within the alternative energy trade. A theoretical life cycle analysis study has also been done with the consideration of present disposal techniques.

Keywords: Solar power generation; Photovoltaics; Solar cells; Economics; Module degradation;Recycle;

I. INTRODUCTION

Over the last 2 dacades, however, these conventional sources of energy have diminution. This can be thanks to the ever-growing population and hence, their increased need of energy. This need for energy won't decrease within the coming time. (Vourvoulias, 2020). Solar power from the sun is one in all the most important sources of renewable energy on earth. This is only happen because of the bontiful heat and light-weight available from the sun. This heat from the sun is mobilized using different types of technologies to be utilized in different fields. Some of the technologies utilized in mobilizing the sun's energy are PV, solar thermal energy, and solar heating. (Singhal, the solar labs, 2020). The intutions by the IEA expects a growth of 700 to 880 GW, as shown in Figure 1, in international capability of PV generated power. The number of sunlight that falls on the planet is about half of the whole radiation. Within the last 20 years, the value of solar power has largely dropped. (gupta, 2020). For example, the electrical device cost has decreased from about \$26,000/kw in 1982 to about \$2000/kw in 2019. This might mean that by April 2020, PV become the prominent sustainable energy source with the most important installed capacity. (Gangal, the solar labs, 2020)

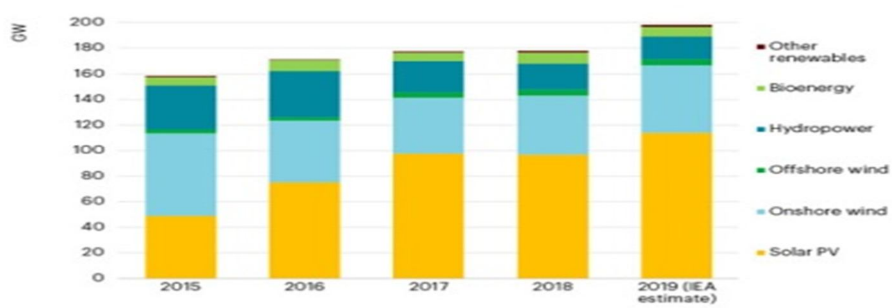

Figure 1: International Energy Agency forecasts 115 GW of new solar; source: IEA

As awareness is incraesing, demand for renewable energy sources also increasing , Alternative energy presents the chance to get clean electricity, which may cause a viable life style. However, if Solar industry is really present a viable method, then PV panel end-of-life phase must be addressed . (Mulvaney D. e., 2011).

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A. *Why Go Solar*

1) Solar power is cheaper than electricity
2) Be the visionary in your neighbourhood
3) Benefits Now >> Lower Solar system cost tomorrow
4) Save your Health
5) Solar with raised solar roofs ((Singhal, the solar labs, 2020))

B. *Solar Panel Components*

There are 4 main components of any typical crystalline silicon PV module :

1) The front covering
2) An Encapsulate,
3) Solar PV cells,
4) Back glass cover (Figure 2.)

The rear cover is tedlarfilm which is formed from polyvinyl fluoride(PVF), providing a long time reliability , weatherresistance back sheet for PV modules (Pern, 2009).

The outer glass cover composes the foremost important share of the entire mass of a finished crystalline PV module followed by the aluminum frame (~20%), the EVA encapsulant (~7.5%), the PVF substrate (~2.5%), and also the junction box (1%). The star cells themselves solely represent in the percentage (4%) of the mass of a finished module. (Sander, 2007).

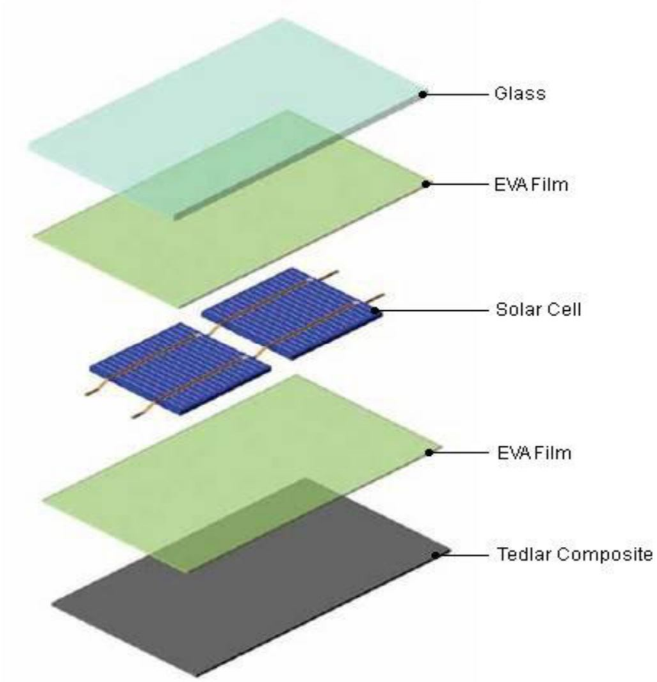

Figure 2: crystalline module structure; (Pern, 2009)

C. *Disposal of Solar PV Panel Concerns*

Safe disposal of solar panels suggests the demilitarize of PV panels in such a simplest way that none of the tiniest harmful material are released to the environment. As mentioned in Section 1.2, solar panels are assembled by different components and every component has different funstions as seen with harmful|Non harmful and reprocessable|non reprocessable. (Karen Ann Brouwer, 2011). The most common available components of the solar panels are glass , aluminum frame and solar cells and hence do not pose any risk to the nature. The ethylene vinyl acetate encapsulant and polyvinyl fluoride substrate are generally not redeemable and are removed through a thermal method. If not properly decommissioned, the best end-oflife health risk from crystalline solar modules arises from lead containing solders. Under the right conditions it's possible for the cause leach into landfill soils and eventually into water bodies. (Company, 2008)

II. PROBLEM STATEMENT

For best Renewable energy source only Alternative energy is taken as a clean energy solution . However, if the PV companies is really present a sustainable way it must taken as account for the PV panels' Fatiuge life phase. The solar industry has an aim of providing an substitute method for a sustainable energy. There are basically 3 major stages of an eco friendly product's life cycle are usuage, manufacturing, and fatigue life. (Mulvaney D. , 2014). PV panels don't omit greenhouse gasses during the usage phase, may be wont to reclaim detorite land, and reduces the need for enthalpy generation from renewable energy sources. During usage stage PV panels actually reduce their atmosphere impact , Industries should expertise in the Nature impact of the assembling and reprocessing stage. Assembling processes within the companies are generating amounts of harmful byproducts of Life's cycle . Industry has lack concern for the right discarding of the product and therefore it effects on nature. If the PV companies is to supply a Clean way, it could learn from the faults of companies to vary their path of action within which they assembled their product. (Mulvaney D. e., 2011). While solar power will be generated employing a form of technologies, the overwhelming majority of solar cells today start as quartz, the foremost common kind of silica (silicon dioxide), which is refined into elemental silicon. There's the primary problem: The quartz is extracted from mines, putting the miners in danger of 1 of civilization's oldest occupational hazards, the lung disease silicosis.

III. LITERATURE REVIEW

A. *Working Of Solar Pv Plant*

Sunlight, the rays coming form the sun on the surface of the earth, is formed of little energy fragments called photons which each individual electric cell is made up of a positive and negative layer which have the capability to make an electrical field (similar to the one observed and made up in batteries). As photons are absorbed within the cell the energy of the photons causes electrons to move free, and that they move to the underside of the cell, and exit through the connecting wire which generates electricity as soon as the electrons begin to flow The larger amount and intensity of the sunlight, the greater the flow of electrons is, as shown in Figure 3 and therefore the more electricity gets produced within the process. It's a property of sensor (in that context its electrical characteristics e.g. Current, voltage, or resistance vary once light is incident upon it) that, once exposed to light, it will generate and support an electrical discharge while not being hooked up to any external energy supply, but doesn't require any external load." (Ashok Upadhyay, 2014) "Pure Si could prove to be a poor conductor of electricity. Doping, the process of introducing impurities into an pure semiconductor to alter and improve its electrical conduction properties. Samples of n-type dopants – Phosphorus (Ph), Arsenic (As), Antimony (Sb). Samples of p-type dopants –Boron (B), Aluminium (Al). Doping helps in carrying of charge (holes and electrons) which will carry electrical current. The electric field generated will force electrons to flow in a very certain direction. This force field is achieved by bringing together p-type and n-type semiconductors together to form a diode. Holes and electrons from p-region and n-region respectively recombine, creating a depletion region and finally creating an electrical field as shown in Figure 4. The movement of holes and electrons is represented below with the help of a diagram. Depletion region which was created to carry out electric current, continues to grow till the electrical field becomes large enough to stop the flow of charge being carried from one side to the opposite. Now, if the diode is exposed to light, it frees the electrons in n-region and these electrons, repelled by the electrical field, flow through the load to p-region. These electrons define current. (Ashok Upadhyay, 2014)

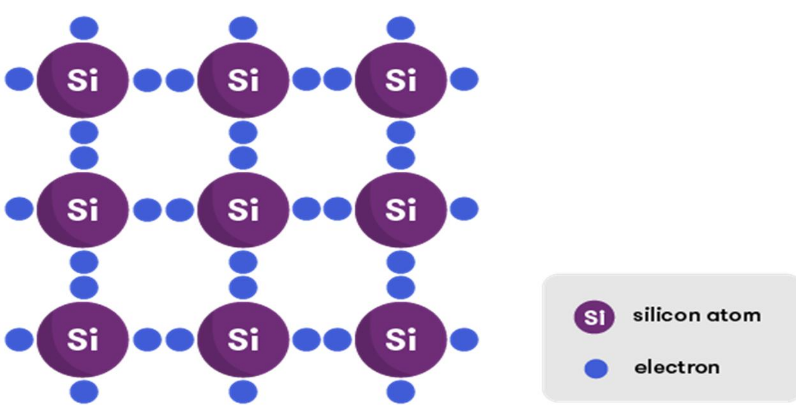

Figure 3: The flow of electrons and hole

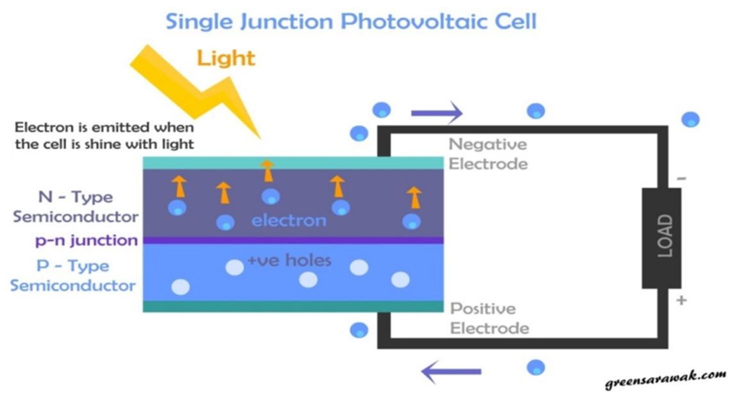

Figure 4: generation of electricity by Solar PV panels;
source: https://greensarawak.com/

B. *Electrical Components*

The solar PV system consists of the many components starting from solar cells to net meter. The no. Of components are different within the grid-connected and stand-alone PV system. The conversion starts with the PV cell, which may be a semiconductor material. It's two forms of particles: the positive and also the charged particles. This cell technology is employed in designing solar cells and a solar PV system with high energy conversion technology. The daylight is absorbed by the cell so the electrons get separated from it. (gupta, 2020)

The following are some components of a solar PV system shown in **Figure 5**:-

1) *Material:* The most important component of the panels is silicon. N-type or P-type silicon is formed using a infiltrating process known as 'doping'. These two different behaving charged silicon are then placed together to make a cell and several other such cells are connected nonparallel to finally create a panel. Most panels are of two kinds, namely: Polycrystalline and Monocrystalline.
2) *Arrays and Array DC Disconnect:* An Array is a bunch of panels connected together to every other during a series configuration. The dimensions of the array commonly used, may range from 5 to 100 counting on a scale of the scheme being installed. A DC Disconnect array is also installed. In case of regular schedules repairs or work it disconnects the array from the inverter and repairs can be conducted. (Gangal, How Solar Energy works: Panels and Components, 2020)
3) *Inverters:* A power deriving electrical equipment which converts DC power into AC power is commonly termed as an Inverter. The generated output of PV panels is DC which is required to be converted into AC voltage since almost every appliance used in residential uses are using AC. The AC power obtained from an inverter, connected to solar panels may also be transferred to the national grid if there is excess of power generation.

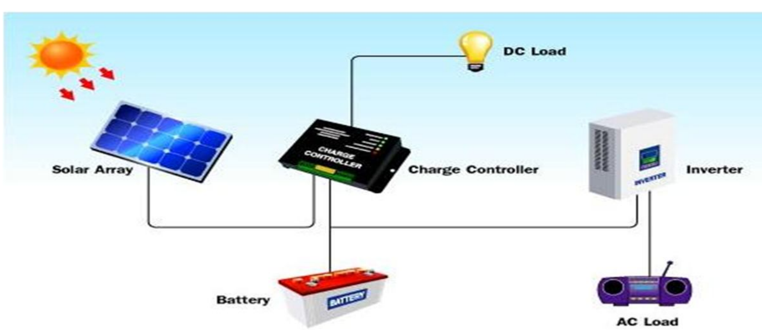

Figure 5: Solar power generation components;
source: http://www.leonics.com/)

4) *Batteries:* Batteries are mainly employed in an off-grid PV systems. "Whenever there is excess of electricity generated than usually required, the surplus electricity is stored in batteries or a series of batteries for future or emergency usage as there may be power faluts due to low sunlight presence". Due to certain sircumstances, when sufficient electricity isn't generated, the surplus electricity stored in batteries will come into play and help in being utilized. Electricity from batteries are often used when there's an absence of sunlight for the generation of electricity (during night time).
5) *Solar Charge Controllers:* Solar charge controllers are employed to regulate the flow of electrical current. They are used for limiting the speed of current supplied which is either added to a battery or withdrawn from the controller. The voltage and current which is being supplied from solar panels and then going into the battery is being regulated by solar charge controllers. (rushali, 2020)

C. Solar Cells

Photovoltaic cells or "PV cells is manufactured in many various ways and from a range of various materials. Despite this difference, all of them perform the identical task of harvesting solar power and converting it to useful electricity." "The most common material for PV panel array construction is silicon which is semiconductor in nature and possess semiconducting properties. Several of those solar cells are required to construct an electrical device and plenty of panels form up a photovoltaic array.

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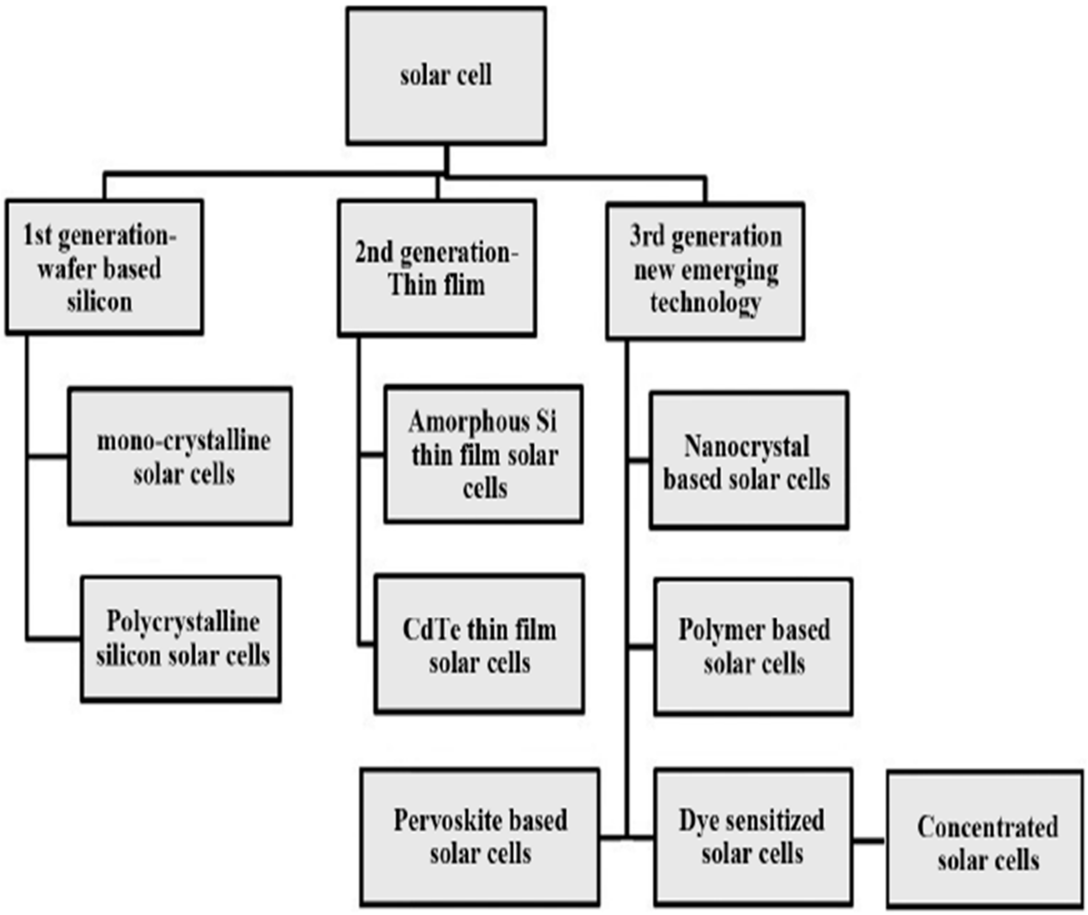

Figure 6: Various types of solar cell technologies; source: (Shruti Sharma, 2015)

There are 3 kinds of PV cell technologies that dominate majority of the market: Monocrystalline silicon, Polycrystalline silicon, and Thin film as shown in **Figure 6**. Higher potency PV technologies, as well as gallium arsenide and multi-junction cells, area unit less common because of their high value, however area unit ideal to be used in focused electrical phenomenon systems and area applications. (al., 2018)

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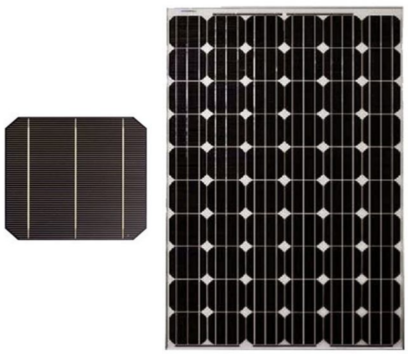
1) *Monocrystalline Silicon Solar Cell:* The initial, commercially available solar cells were made up of monocrystalline silicon arrays, which is a legitimate and real kind of silicon. In need to supply these, a seed crystal is pulled out of a mass of molten silicon creating a cylindrical ingot with one, continuous, space lattice structure shown in Figure 7 and Figure 8. This crystal is then mechanically sewed into thin wafer like protusions, polished and doped to form the desired tangency and size. After an anti-reflective coating is added, the front and rear metal contacts are added, the cell is finally wired and packaged alongside many other cells into a full solar array. Monocrystalline silicon cells are highly efficient, but their manufacturing process is slow and labour intensive, making them difficult than their polycrystalline or thin film counterparts." (Shruti Sharma, 2015) Beyond being most effective in their output of wattage, monocrystalline solar cells also are the foremost space-efficient. "This is often logical since you'd need fewer cells per unit of electrical output. During this fashion, solar arrays made from monocrystalline take up the littlest amount of space relative to their generation intensity. Another added advantage of monocrystalline cells is that they last the longest in the time period of all kinds." Many manufacturers offer warranties of up to 25 years on monocrystalline forms of PV panel systems.



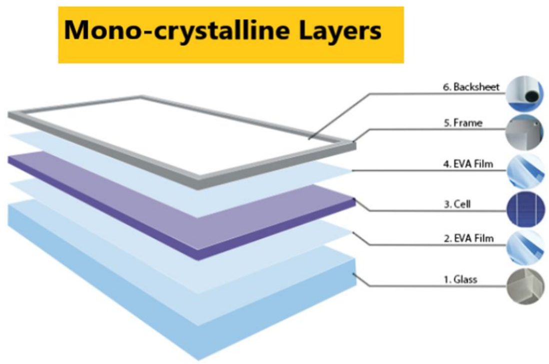


Figure 7:Monocrystalline solar cell

Figure 8: Monocrystalline solar cell structure. (Askari Mohammad, 2015)

2) *Polycrystalline Silicon Solar Cells:* Polycrystalline silicon solar cells also called polysilicon or poly-Si, could be a high purity, polycrystalline kind of silicon, used as a stuff by the solar photovoltaic and industry. Polysilicon is produced from a special metallurgical process called Siemens process which in turn produces a good grade industrial type silicon shown in Figure 9. This method involves distillation of volatile silicon compounds, and their decomposition into silicon at high temperatures. Another emerging and alternative process for refinement uses a fluidized bed reactor. Polysilicon contains impurity levels of however one half per billion (ppb), whereas crystalline solar grade silicon (sogsi) is often less pure. (Krebs et. al., 2009) While polysilicon and multisilicon are often used as synonyms, multicrystalline usually refers to crystals larger than 1 mm. Multicrystalline solar cells are the foremost common variety of solar cells within the fast-growing PV market and consume most of the worldwide produced polysilicon. About five many polysilicon is needed to manufacture power unit (MW) of standard solar modules. (al, 2004)

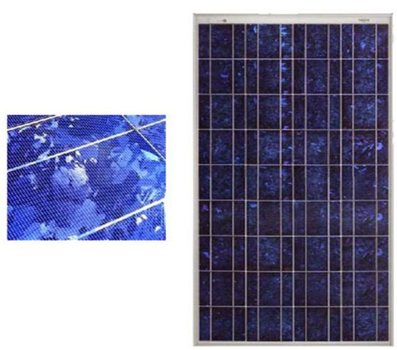


Figure 9: Polycrystalline silicon solar cells

3) *Thin-Film Solar Cells:* After more than 20 years of R&D, thin-film solar cells are beginning to be deployed in significant quantities. "Thin-film solar cells are comprised of successive thin layers, just 1 to 4 µm thick, of solar cells deposited onto an outsized, inexpensive substrate like glass, polymer, or metal. Thin films are often packaged into flexible and light-weight structures, which may be easily integrated into building components (building-integrated PV, BIPV). Second generation of solar cells they account around 20 you look after the overall panels sold in past year." (Kiran Ranabhat, 2016).

The commonly used and seen types of thin film PV cells that have been used commercially are as follows:

a) Amorphous silicon (a-Si and a-Si/µc-Si);
b) Cadmium Telluride (Cd-Te); and
c) Copper-Indium-Selenide (CIS) and Copper- Indium-Gallium-Diselenide (CIGS).

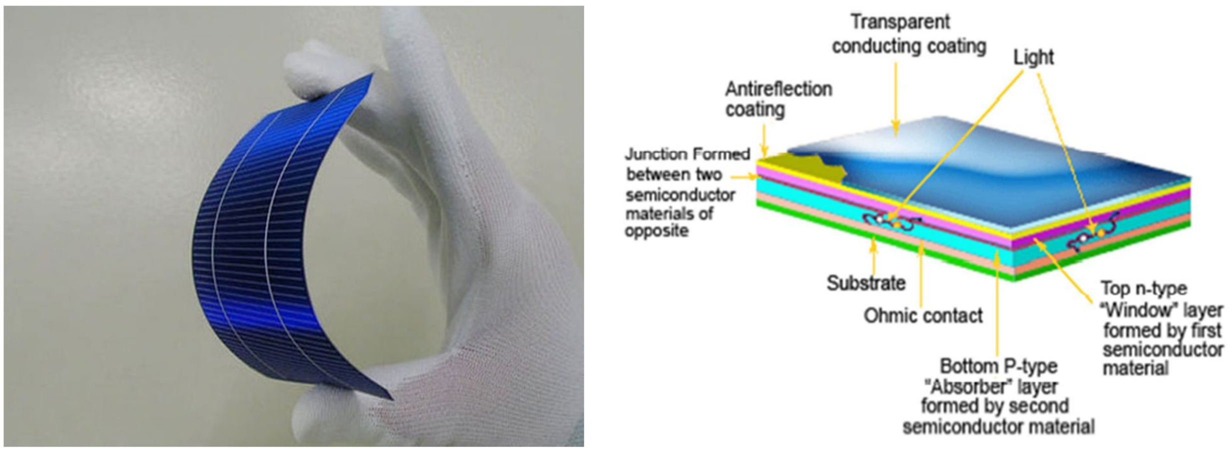


Figure 10: thin film solar cells; source: https://www.saurenergy.com/

The thickness of the film varies from minutest nanometres (nm) to tens of micrometers (µm), that is much lesser than competiting technologies, the quality, first-generation crystalline silicon electrical device (c-Si), that uses silicon wafers of up to 200 µm as shown in Figure 10. Other commercial applications use rigid thin film solar panels which is sold and made as being sandwiched between two pieces of glass, as they are in a number of the world's largest photovoltaic power stations. Thin-film has forever been cheaper however less economical than standard c-Si technology. The technology considerably has improved over the years, and workplace cell potency for cdte and CIGS area unit currently on the far side twenty first, outperforming alternative multicrystalline chemical element, as this material being the most dominant material currently utilized in most of the solar and PV panels. (Askari Mohammad, 2015)

Type:	Mono crystalline solar cells	Poly crystalline solar cells	Thin film solar cells
Efficiency	14% - 18% cell efficiency	12% - 14% cell efficiency	5% - 6% cell efficiency
Temprature tolerance	0% +5%	-5% +5%	-3% +3%
Lifetime	25-30 year lifespan	20-25 year life span	15-20 year life span
Durability	Hail resistant 25 year p &m warranty	25 year p &m warranty	25 year p &m warranty
Cost	Cost is higher than the polycrystalline modules. 1.589 USD	Cost is lower than mono crystalline modules. 1.418 USD	Cheapest of the three 0.67 USD

Table 1: Differences between solar cells types; source (Svarc, 2020)

IV. PHOTOVOLTAIC MODULE

In photovoltaic panels, maximum cells combine to make a solar panel and battery in which a plenty of panels combine to create an array. “Typically, residential buildings use panels made up of 60 solar cells, whereas in commercial buildings use panels made up of atleast 72 solar cells. As the number of cells is increased, the voltage and power generated also increases.” They’re insulated and framed to be protected against harsh environmental conditions and to safeguard the user from getting indulged into accidents. (Singhal, An Introduction to Photovoltaic Modules, 2020)

A. Module Degradation

1) *Introduction:* The deteroiation of solar power modules with temperature and time contributes significantly to the ultimate yield of the panel. Lifetime of the module is one among the four factors besides system price, system yield and capital rate of interest which decides the value of electricity produced from the module, and this lifetime is determined by the degradation rate. (Sharma, 2011). The effect of degradation of PV solar panels and arrays and their respective components loss of performance incorporates a serious impact on the whole energy generation. And with relevance this maximum power at standard test conditions, (Pmax at STC) is that the most important characteristic of the photovoltaic module or array for all of its operational life. (Ewan D. Dunlop, 2002). Most manufacturers claim their panels will produce 90% of the utmost power after a period of 10 years, and 80% of the utmost power after 25 years. Hence, most of the solar power plants are designed to run for a lifespan of 25 years.
2) *Causes of Degradation:* The tests of module degradation are performed using practical data and laboratory tests. “The instutions like the Fraunhofer Institute, the National Renewable Energy Laboratory, alternative energy Research Institute of Singapore and so on. These tests have been conducted successfully and provided with the result that there is a constant module degradation in the solar panels (usually but 1% per year), and hence, the possible reasons for this degradation is the slow breakdown of a module’s encapsulant (usually ethylene vinyl acetate; EVA) and back sheet (polyvinyl fluoride films), the gradual obscuration of the EVA layer between the module’s front glass and therefore the cells themselves, and also the deterioration of solar cells because of temperature increase. The silicon cells themselves have infinite life, aside from the slight degradation thanks to thermal effects.” (Sharma, 2011). Module encapsulant protects the cells and the electrical connections from the moisture present in the air. Some amount of moisture does enter, and is forced back out on a day to day, as module temperature increases. The trapped moisture chronologically results in corrosion at the electrical connections of the cells, leading to higher resistance at the affected connections and, ultimately leading to decreased module operating voltage. The second source for output degradation occurs as UV light breaks down the EVA layer between a module’s front glass and therefore the silicon cells. The silicon solar cells are fragile in nature and an encapsulant is very much required to shield them against cracking and breaking . This gradual breakdown of the fabric isn’t usually visible to the eye, but over time this obscuration limits the amount of sunlight which will hit the cell. (Peter Klemchuk, 1997). The third cause of degradation is inherited to the silicon cells, resulting from the exposure to the sunlight which leading to defects called metastable dangling bonds. These may be removed by Heating the cell to a warmth, something that's unacceptable in practice. Research has shown that this way of degradation ends up in a 15-20% reduction in efficiency” (Johnston, 2003)

Module Type	Power (W)	P_{max} Rate (% / year)	I_{sc} Rate (% / year)	V_{oc} Rate (% / year)
Single #1	11	-0.88	-0.59	-0.12
Single #2	16	-0.76	-0.60	-0.14
Poly #1	9	-0.70	-0.25	-0.14
Poly #2	18	-0.53	-0.24	-0.08

Table 2: Power degradation, Source: NREL

B. Heat and Temperature Effect on PV Panel

Photovoltaic panels, "modules and cells are meant to convert the sunlight into electricity. It suggests the hours and hours of exposure to the sun's heat for the PV modules. The way solar cells are arranged to make a PV module, features a drawback which physically affects the PV module.

The arrangement of the solar cells into a module changes the flow of warmth in and out of the module. A changed flow of warmth means the change in temperature at which the module operates increases. This increase in the temperature causes a lowered output voltage for the PV module which means low electric supply.

This phenomenon suggests a reduced output power." A rise within the temperature also leads to the degradation or failure of a PV module as increased temperatures are linked with thermal expansion. Moreover, increase in the temperatures also increase the degradation rate. "The operating temperature of a PV module is decided using the equilibrium between the warmth of the PV module produces, the warmth that the PV module loses to the environment, and therefore the ambient operating temperature." (Gangal, The Effect of Heat and Temperature on Photovoltaic Modules, 2020).

The PV panel being employed now a days have a mean module efficiency of about 15-20%. This implies, on a median, only fifteen to simple fraction of the sunshine that's incident on a PV module is converted into electricity. What about the remaining of the light? PV modules generate heat as a by-product.

The light excluding the sunlight that is converted into electricity is turned into heat. When sunlight becomes incident on PV modules, not all of it's absorbed. As shown within the image above, PV modules have reflective top surfaces that don't let the module absorb the whole light incident on that. The reflected light isn't useful because it doesn't produce any electric power. And so, any light reflected from the highest surface of a cell or module is taken into account to be a source of power loss. (Kurdgelashvili, 2011)

C. 25 years of testing at nrel

The OTF continues to run tests on photovoltaic (PV) panels made by companies which keep on fascinating. The OTF is provided to perform accelerated testing on PV panels, which discovers problems within their design or in the materials used. It's difficult to make long-term performance predictions for various environments with accelerated testing. Multi-year outdoor testing is employed to enhance and validate accelerated testing.

That's critical feedback to present to the manufacturer . (Schroeder, 2020)

Within the first 1990s, the U.S.. Amongst the companies participating in research the use of cdte for solar panels was Solar Cells Inc., which later became the first. Cdte solar panels are the second most common solar technology within the globe silicon, which they're widely used for utility-scale power generation. (WESOFF, 2020)

A key point of a cell performance is how long it'll last. Solar cells lose efficiency over time. Having a measurement of that change enables manufacturers to supply a guarantee on their panels.

The initial studies on First Solar panels revealed that after five years, the solar panel performance loss amounted to a relative 0.6% per year and their stability compared favourably to silicon modules.

First Solar's technology reached a milestone at NREL this year after 25 years of continuous monitored performance testing and becoming the longest-running research at the OTF The people at NREL have constantly worked to identify and study the gradual degradation and working of the PV panel. (WESOFF, 2020)

V. LIFE CYCLE ASSESSMENT OF SOLAR PV PANEL

Lifecycle of photovoltaic (PV) plants are mainly observed in common studies. Since, the end-of-life has been forgotten and not talked of because of the analysis as a very low number of panels reach up to that level and the lack of information about the safe disposal of the panels has not been fully studied and discussed yet. This may be an arising environmental issue in the coming decades.

A. Inroduction to LCA

The analysis of a product from its design process to finally getting disposed off is reffered to as the life cycle analysis of a product. In an LCA, the idea is to analyse every stage of life: manufacturing, transportation, usage, and end-of-life stages. An LCA is effective because it not only accounts for the materials that the particular product is formed of, but also the machines or vehicles wont to manufacture or transport the merchandise . In an exceedingly sense it takes into consideration the entire picture. (Karen Ann Brouwer, 2011)

The key stages in the Life Cycle Analysis of the panels are: - "Goal and Scope definition, Inventory Analysis, Impact Assessment, and Interpretation". Figure 11.

1) *Goal Definition and Scope:* What is the end goal of the product to be launched into the market by analysing the details of need of the consumer, its environmental impacts is also set and every detail is checked.
2) *Inventory Analysis:* This process is amilly concerned with the production and supply of the raw products and spare parts. A collection of data inclusive of raw materials used, products, waste, and emmissions is prepared. This all constitutes in LCA.
3) *Impact Assessment:* This information is collected and recorded when the product strts working . it basically measures the environmental impact of the product.
4) *Interpretation:* This process helps in making right decisions when impact is calculated. (Baumann, 2004)

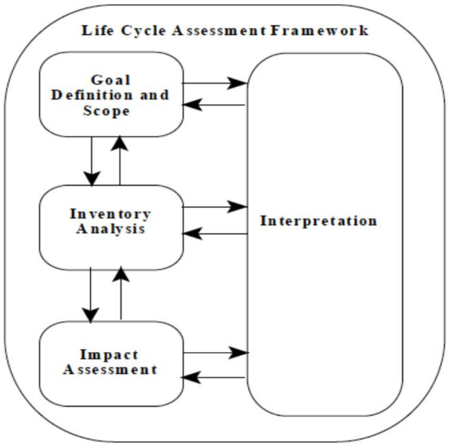


Figure 11: LCA phases; source: (Krebs et. al., 2009)

B. End Of Life Management

The systems and processes that takes place at the final stages of the life cycle of a product is known as End-of-Life (eol) management. "As the economic and ecological factors come into play these products are declared as hazardious. Additionally, the notice of ecological questions is rising". "In keeping with various regulations, hazardous materials should be collected and treated in a very special way so as to reduce the negative effects on the environment". (m. masoumian, 2015)

In life management cycle four different strategies will be chosen. "These are (the 4-R): Reduce, Reuse, Recycle and Recover (**Fig. 12**). The smallest amount favorable strategy is landfilling. During this pyramid, the varied strategies are ordered top-down. During this pyramid, the assorted strategies are ordered top-down".

Figure 12: EOL Pyramid; soucrce: (m. masoumian, 2015)

1) *Reduce:* The first and most favourable strategy is that the reducing of the number of primary material that's used for a product. Therefore, this strategy is that the most favourable for eol. This suggests that reduce has got to be taken under consideration during the planning phase of the merchandise. (m. masoumian, 2015)
2) *Reuse:* This process is giving a second life to a product. The product is not fully dismanteled but repaired and reused and sent into markets.
3) *Recycle:* The third best alternative is that the recycling of the fabric that may be extracted from a tool. When the new products are of a more robust quality than the origin device, the method is named "upcycling", while "down cycling describes the method of manufacturing new products of a lower quality than the origin device." (m. masoumian, 2015)
4) *Recover:* The main motive of the process is to recover the products which are labelled unusable. The main advantage of the process is tat the wasteage is reduced.

VI. RECYCLING

A. General Recycling Methods

The first step of the strategy is that the transport.The PV waste panels are expected to be collected in numerous locations. Due to the big heterogeneous distribution of the PV plant into the territory, it's unattainable to precisely estimate the transport distances.Waste have been assumed to be initially transported to local collection points by trucks with a maximum capacity of 7.5t. These local collection points could include a number of the gathering centres that already cope with the gathering of WEEE in various regions.Successively, the PV waste are presupposed to be loaded into apposite large trucks (with maximum capacity of 32 tr) and transported to the PV recycling site.The distance from the gathering point to the P V recycling site is assumed to be 400km . Successively,the PV waste is unloaded by using fork lift and Transferred into convey or belt that may bring the modules to the Dismantling process. (Cynthia E.L.Latunussa, 2016).

The method is anticipated to unload 1000 kg of PV waste per hour. At the tip of the convey or belt, an auto- mated system issued to dismantle the PV waste panel. First of all, a Cartes in an robot will supply the PV waste into the dis-mantling part.. As a result, the layer of PV cells, glass is separated from the aluminium frame and the BOS".The waste panels with outframe and cable are introduced in to a glass separation process. during this process the glass layer is detached from the remaining layers of polymer and cells. (Cynthia E.L.Latunussa, 2016)

The mechanical detachment of the glass is go by a high-frequency knife button, modulated in amplitude and speed. (SASIL, 2015)The outputs of this process are pieces of PV glass and therefore the PV sandwich. Subsequently, the sepieces of glass are delivered to the glass refinement process. During this process, the pieces of glass are separated in numerous sizes (from 1mm to 2.5mm and from 2.5 mm to 5mm, in diameter) by sieving. Afterwards, an opticalbased separation system allow store move pieces of glass with impurities (around 2% in mass),which are sent to disposal (Ecoinvent Centre, Eco invent Version 3, 2015)

Table 3: mass composition of 1000kg PV panel; source: (Cynthia E.L.Latunussa, 2016)

Component	Quantity	Unit	Percentage (%)
Glass, containing antimony (0.01–1%/kg of glass)	700	kg	70
PV frame, made of aluminium	180	kg	18
Polymer-based adhesive (EVA) encapsulation layer	51	kg	5.1
Solar cell, containing silicon metal	36.5	kg	3.65
Back-sheet layer (based on Polyvinyl Fluoride)	15	kg	1.5
Cables (containing copper and polymers)	10	kg	1
Internal conductor, aluminium	5.3	kg	0.53
Internal conductor, copper	1.14	kg	0.11
Silver	0.53	kg	0.053
Other metals (tin, lead)	0.53	kg	0.053
Total	**1000**	**kg**	**100**

$$\text{Total cost of PV Recycling} = \sum \text{Private Cost} + \sum \text{External Cost} - \sum \text{Benefits}$$

$$\text{Private cost of PV recycling} = P.C_{Inv} + P.C_{P,m} + P.C_{P,e} + P.C_{F} + P.C_{Fee}$$

$$\text{External cost of PV recycling} = E.C_{P} + E.C_{T} + E.C_{L}$$

$$\text{Benefits of PV recycling} = B_{.R,e} + B_{.R,m.}$$

Table 4: recycleable material prices; source: (Cynthia E.L.Latunussa, 2016)

Item	$/lb
Aluminum	1.504
Glass	0.104
#2 Plastics - HDPE	0.55
PVC	1.33
LDPE	1.98
Bimetal Cans	0.26
#1 Plastics - PETE	0.93
PCS	4.18
PP	0.31
#7	0.37

B. *Process of Making and Recycling Glass*

Glass has several properties and characteristics and is seen in various shapes and forms such as jars, bottles, glassware, etc. Glass making industry is extremely diverse and uses various technologies.

Production of glass comprises of two different steps reckoning on what we are attempting to make:

1) The float glass process-produces sheet

2) Glass blowing-produces bottles and containers

In 2007 institute of glass packaging, explains the procedure utilized in the assembly of Glass as follows:

Batch home is one amongst the initial steps required within the production of inclose raw materials and are visually reviewed to generate sure their size are precise and standard. The raw materials are then sent to the storage and before going into the furnace, they're divided into a different sections then weighed. Then, they're put into the mixer which is found above the boiler just after weighing the raw materials . To decrease the chance of isolation, water is sometimes add to the mixed batch before it went for the heating system. (Environmental Overview, 2007)

C. *Advanatges of Glass Recycling*

Advantage of recycling of “glass material is that cup is re-processed an indeterminate times, which implies they will be reprocessed on repeat intervals, with zero percent loss on purity or quality of the glass material. Glass Bottling companies that mass produce bottles for soft drinks and beverages are much more pocket friendly once they produce bottles from reprocessed glass. Everything you mostly wanted to grasp about reprocessing (2011) states that producing glass from reprocessed glass (cullet) makes the glass cheaper to supply, because for each ton of reprocessed glass 1.2 tons.” (Idiano D’Adamo, 2017).

Figure 13: Recycling glass;
source: (http://www.recyclingfactsguide.com/advantages-of-recycling-glass)

The method of producing new glass means quencing sand and other substances to increasingly high temperatures, “which needs lots of energy and also produce plenty of pollution. New glass from raw materials, because cullet (**Figure 13**) melts at a way lower temperature. Less energy converts to less fuel being burned creating 20% less pollution and reducing the water pollution by 50% (West, 2011) Glass reprocessing also means less trash taking over landfill space.” Reusing saves the glass material that might rather be thrown into the landfills

D. Economy

In order to make the optimal techniques for PV modules Eol management, the economics is needed to be taken into consideration. The evaluation categories are:

1) *Valuable Material:* PV cells are categorized in keeping with the materials that are used because the semiconductor material. For eolpurposes, the materials that are valuable for economy available within devices are essential, as this information determines the value of a tool crucially. (m. masoumian, 2015)
2) *Hazardous Material:* Another category that's supported the fabric composition is that the possible presence of harmful materials. These materials, e.g. Lead or cadmium, should be thrown out separately from the opposite (PV Cycle recycling, 2014)
3) *Energy Efficiency:* The energy efficiency is a crucial factor that influences the energy payback time. It is calculated because the ratio between the amounts of energy won by a solar module divided by the theoretical amount of energy supplied by the sun. (Dávid Strachala, 2017)
4) *Life Time:* Just Because the cells that are produced today aren't within the marketplace for an valuable time, these numbers can just be approximations.

VII. CONCLUSION

Solar energy has recently gained popularity thanks to its abounding acessiblity. This can be done using PV technology, a technology that explains the conversion of solar energy directly into electricity. Solar cells possess all photovoltaic applications, which are made of semiconductor materials.

Various styles of solar module cells were discussed within the report namely mono-crystalline cells, poly-crystalline cells and thin film solar cells. Comparison was done on the bqsis of cost, efficiency, lifetime etc. There are various benifits of using solar energy like it being a clean source of energy, its feasibility, abundance, and low maintenance costs. Also, while there are not any emissions from using solar energy.

However, their degradation over time may be a serious concern. There are various challenges for this industry, including lowering the price of production, public awareness and best infrastructure. The improvements in automation and quality has reduced this degradation considerably by time passes. Several manufacturers are proposing extended warranties although with a security of margins.

This project attempted to review and review a secure and cost-effective process for the disposal of PV solar panels. A theoretical study on life cycle assessment has been done. Further it are often shift practically with the assistance of softwares and equations. With the rising cost of electricity and advancement in PV automation, therewill be a rise for the demand of solar technology within residential and commercial markets. In a time span of about 20 to 25 years these panels will reach their “fatigue life and also the accumulating amount of PV waste will force the solar company to be more conscious about developing an ecofriendly and value sustainable strategy of disposing this industrial toxic byproducts.

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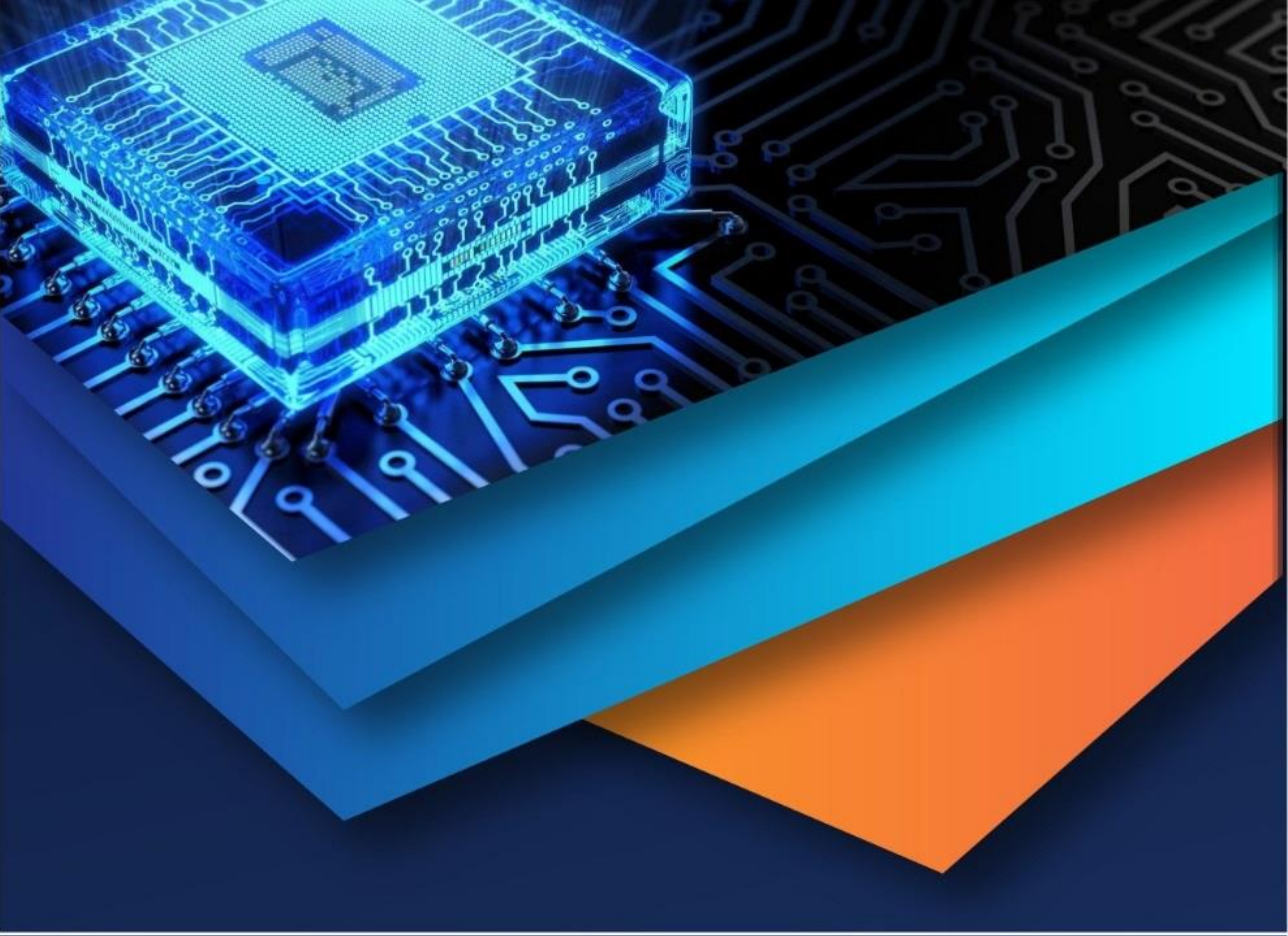

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