Solar e waste recycling technology

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Abstract

The main objective of the solar e waste recycling technology to deal with the solar e waste management in efficient way instead of traditional landfill practices. To assess solar w waste, its environmental impacts and efficient way of management of solar e waste through recycling technologies. Much PV waste currently ends up in landfill. Given heavy metals present in PV modules, e.g. lead and tin, this can result in significant environmental pollution issues. Furthermore, valuable metals like silver and copper are also present, which represents a value opportunity if they can be recovered. Hence, the landfill option cerates additional costs and it does not recover the intrinsic values of the materials present in the PV modules. Hence, methods for recycling solar modules are being developed worldwide to reduce the environmental impact of end-of-life modules and to recover some of the value from old PV modules of air pollutant concentration levels monitored on any given day.

Keywords: Solar e waste, environment impacts, recycling technologies.

I. INTRODUCTION

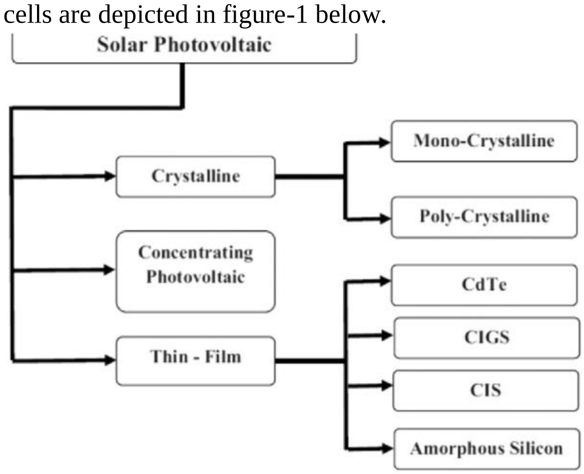
Solar power may promise a bright future for India's energy requirements, but behind the sheen is a growing mountain of waste. While the national government is pushing an ambitious solar power programme for India, it has, so far, failed to put in a mechanism to address the problem of waste, including environmentally hazardous materials, from solar photovoltaic panels that can be hazardous to the environment.

A recent report by renewable energy consulting firm Bridge to India (BTI) said that the solar photovoltaic (PV) panels waste volume in India is estimated to grow to 200,000 tonnes by 2030 and around 1.8 million tonnes by 2050 – almost 200 times the weight of the Eiffel Tower.

India's current solar power target is 100,000 megawatts (100 gigawatts) by 2022, raised from 20,000 MW in June 2015 by the National Democratic Alliance (NDA) government. This 100-gigawatt target includes 40 GW rooftop and 60 GW through large and medium grid-connected solar power projects and India has advanced towards this target with the installed solar power capacity increasing from 2,631.93 MW in March 2014 to 28,180.71 MW in March 2019. However, this also means the amount of solar panel waste has increased during this time, with cases of early retirement of the panels. The lifetime of each PV panel is usually 20-25 years. Panels may be discarded earlier because of site accidents and poor quality. As per MNRE, it is estimated that for each MW of solar power, 75 MT (metric tonne) of PV modules are needed.

Introduction to solar power technologies:

Solar power involves the conversion of radiant energy from the sun into electricity by using photo-voltaic (PV) or concentrating solar power (CSP) devices. When sunlight strikes the surface of the PV cell, some of the photons are absorbed and release electrons from solar cell that are used to produce electricity. A solar cell consists of two layers of materials, one that absorbs the light and the other that controls the direction of current flow through an external circuit. The absorbing materials can be silicon (Si), thin films of light-absorbing inorganic materials such as cadmium telluride (CdTe) or gallium arsenide (GaAs). Various photovoltaic solar cells are depicted in figure-1 below.



Solar energy technology.

- **Justification of study:**

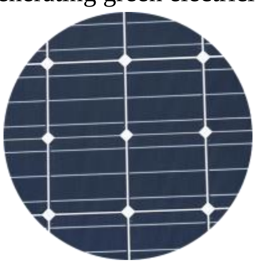
Much PV waste currently ends up in landfill. Given heavy metals present in PV modules, e.g. lead and tin, this can result in significant environmental pollution issues. Furthermore, valuable metals like silver and copper are also present, which represents a value opportunity if they can be recovered. Hence, the landfill option cerates additional costs and it does not recover the intrinsic values of the materials present in the PV modules. Hence, methods for recycling solar modules are being developed worldwide to reduce the environmental impact of end-of-life modules and to recover some of the value from old PV modules. Manufacturing a photovoltaic (PV) solar cell requires huge amount of energy starting from the mining of quartz sand to the coating with ethylene-vinyl acetate – most often derived from the burning of dirty fossil fuels. While there is no carbon emission associated with the generation of electricity from solar energy, there are emissions associated with various stages of the PV life-cycle, including in the extraction of raw materials, materials production, module manufacture, and system/plant component manufacture.

PV modules at the end-of-life (EoL) could become a new e-waste stream and pose some of the problems associated with e-waste as they contain toxic metals. PV modules are expected to become a critical part of the waste stream in the next ten to fifteen years, when a large number of EoL modules will be available for recycling. The European Union has already formulated a Waste Electrical and Electronic Equipment Directive (WEEE), which sets Extended Producer Responsibility (EPR) requirements for electronic products, including PV modules. India, without comprehensive end-of-life management legislation for PV modules, doesn't require PV manufacturers/developers to have extended producer responsibility programs. Considering heavy reliance on imported PV cells and modules and also considering the massive deployment of thin film PV modules, India's ambitious solar capacity addition targets raise serious issues related to health, safety and environmental damage which need to be internalized into the life cycle costs.

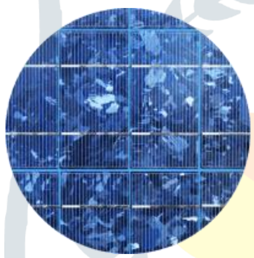
India is among the leading markets for solar cells in the world, buoyed by the government's commitment to installing 100 GW of solar power by 2022. So far, India has installed solar cells for about 28 GW, and this has been done mostly from imported solar PV cells. Therefore, the time is ripe for the country to put in place a comprehensive policy to address environmental issues.

➢ Types of Solar Panels:

There are different types of solar panels that are used for generating green electricity as listed below.



Monocrystalline Solar Panels



Poly-SI

Thin-Film Solar Cells

Concentrated PV Cell

➢ Composition of Solar Cell

Solar Module Parts	Material used
Frame	Aluminium
Module Cover	Glass, Silicon
Solar Cell	Cadmium, tellurium, indium, gallium and Selenium compounds
Solar Cell Coating	Silver, copper, lead, gallium/boron/phosphorous, aluminium
Cell and Module Interconnections	Lead, Copper Tin
Back sheet, Encapsulates	Polymer

➢ Discussion on recycling technologies

Photovoltaic systems are becoming increasingly affordable for producing electricity. The total installed capacity of PV systems is estimated around 222GW at the end of 2015. Crystalline-silicon PV technology dominates the market with 85–90% of the share because of its low cost and high efficiency. Off-grid PV systems can be used for both domestic and low energy non-domestic purpose. Globally around 6 million homes were electrified with off grid PV systems till 2015.

Many photovoltaic systems are at their end phase of life cycle and a lot of e-waste will be generated in the coming years. The average lifetime of crystalline silicon photovoltaic module is about 25–30 years. The global cumulative PV panel waste is expected to reach 60 million tons by the end of 2050.

Three different process approaches to PV panel recycling are distinguished and detailed in the remainder of the section: physical treatment and EVA dissolution with organic solvents, thermal treatment, and chemical processes.

Full Recovery End Life Photovoltaic (FRELP):

The FRELP project had the objective of developing an innovative recycling process (successively defined as 'FRELP process) for Crystalline SiPV waste aiming at maximizing the recovery of all the material. This method implies combination of various methods with innovative approach to recover solar panel component materials.

- At first all waste PV panels are collected at most optimized location by consideration of transport. Transport is generally ignored in recycling calculations.
- FRELP aims to choose optimized location for recycling, collecting and landfill sites.
- Mechanical devices are utilized to dismantle PV waste panel. In this phase, aluminum frame, cables, photovoltaic cell, glass, plastic parts are separated.
- Glass is separated by mechanical detachment with prior treatment by short and medium wave infra-red to PV panels. By using sieving and optical based separation system, glass is separated from impurities.
- Incineration process is used for recovery of PV cell materials such as aluminum and silicon.
- Output of incineration process is treated with acid (HNO_3) leaching process. This process separates metal and silicon from incineration ash. With leaching process, up to 95% of silicon can be recovered.
- Lastly, electrolysis is used to recover silver and copper from leaching process solution and waste sludge is collected to landfill it.

▪ Physical Treatment:

In this study the physical treatment are including crushing, Attrition etc. In solar panel recycling the physical process are also known as primary treatment. The solar penal are made by different types of material which are reusable directly So that in physical treatment the dismantling the solar penal and the separate the materials like reusable and recyclable. After dismantling the solar penal the separated recovered materials like solar cells, Plastic, Glass, PCBs are goes to recycling process.

For this process, trial run was taken at one of Gujarat first E waste recycling plant, E coli Waste Management Pvt. Ltd. located at Plot no. 98/99/100, Sabar Industrial Park, Village: Asal, Tal:Bhiloda, Dist:Sabarkantha. The machinery required for dismantling of Solar Penal are magnetic separator, Crusher, Shredder, etc. Results are shown along with results discussion section later on.

- **Chemical Treatment:**

Chemical processes are mainly aimed at the recovery of the module metal fraction. These processes require, as compared to physical treatments, larger costs, becoming economically feasible only if high value metals can be recovered. For example, the treatment for thin film modules is made cost-efficient by the value of the recovered rare elements. Development of chemical processes to recover Ag, Al and the Si wafer in Si type panels.
The process includes the application of HNO3 to extract Ag, KOH to remove Al metal coatings, and the successive combined application of HNO3, HF, ethanoic acid and Br to remove the anti reflective layer. Fabricated Pb-free panels by using the wafers recovered from Si-panels.
The Si wafer was immersed into HNO3 and then KOH solutions to extract Ag and Al, respectively. The anti reflective layer was removed by the application of an etching paste containing H3PO4 and by heating.
Leaching of the finer fraction was then performed with 64% nitric acid and subsequent addition of NaCl, allowing obtaining an AgCl precipitate. This process made it possible to concentrate 94% of the silver contained in the modules.
To this purpose, the possibility to recover rare and precious metals can make the chemical treatments cost-efficient,especially if thin film technologies are concerned. Recycling processes targeting the recovery of Ag from Si crystalline panels can also be veryinteresting. The economic feasibility of this route is largely influenced by the year of manufacture of the processed panels, which significantly influence the Ag content.

- **Combined physical and chemical treatment:**

Several studies have investigated the optimization of the PV panels recycling by combination of different types of treatments.
The different types of photovoltaic panels by a process route including two main steps: a physical treatment (crushing and hammering) and a chemical treatment. According to the trial run, three different fractions were obtained by crushing: an intermediate fraction directly recovered as glass, a coarse fraction mainly composed of Si cells fragments and glass particles glued to EVA, and a finer fraction composed of a glass powder and metals.
Coarse fraction get glass and other components while 3 h chemical treatment of the finer fraction with H2SO4 and H2O2 at 60 °C allowed dissolving metals and thus obtain an additional recoverable glass fraction. The overall process allowed recovering 91% of the treated panels.

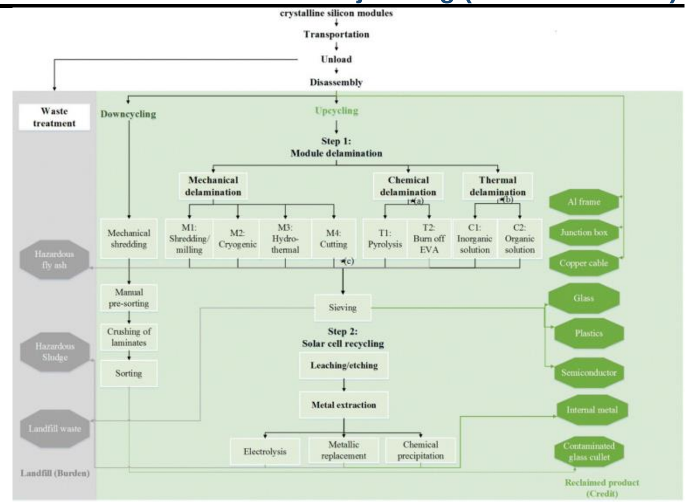


Figure: Feasible Pathway to recycle silicon PV Modules

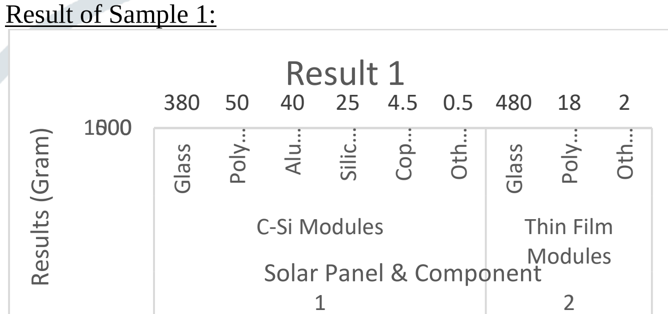
- **Results and Discussion**

The environmental and economic impacts of the recycled materials are inevitably important for every product type, especially glass and metal, including wastes such as PV modules. The installation of PV modules has risen enormously in Gujarat and India in recent years owing to being a renewable energy source for rising energy need.

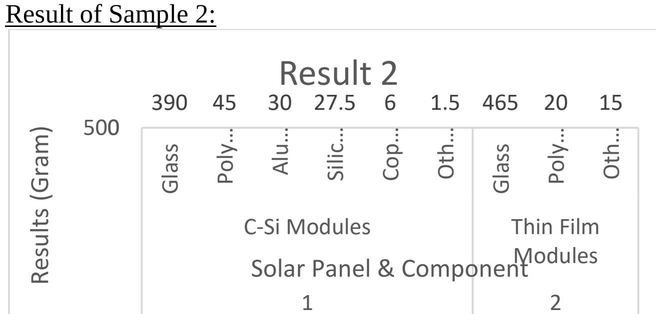
The composition of PV modules would be highly valuable if they go to the process of recycling. The average lifetime of PV modules is between 20 to 30 years, which means they will end their usage life and will be replaced with higher performed versions somewhere between 2040 and 2050. The average module unit capacity was determined as 0.252 KW. Plus, reusing these recycled compounds for reproducing the PV modules would decrease the production costs of the material and support to diminish the carbon footprint.

In India the trail run purpose we are perform the practical for Solar Panel recycling at E Coli Waste Management Pvt. Ltd. In trail run we are take 10 samples of solar panel with weight around 500 Gram of panel and the results of 10 sample are as under

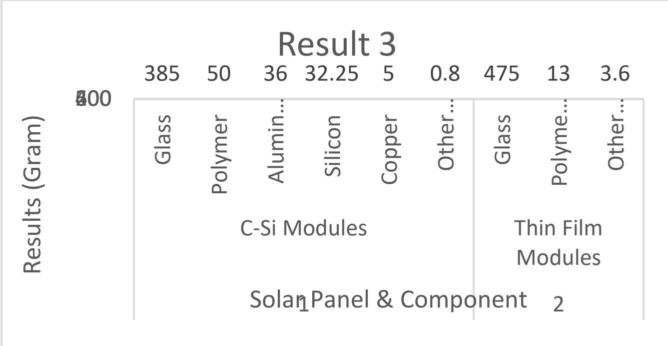
Result of Sample 1:



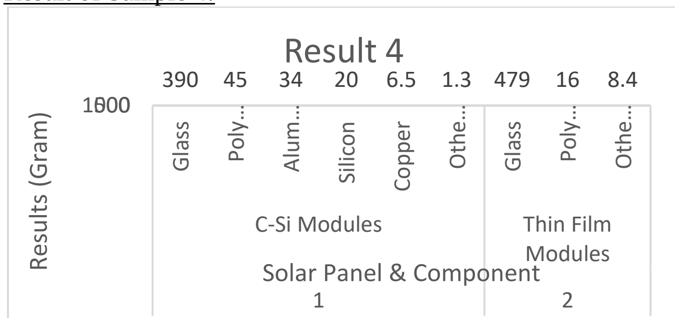
Result of Sample 2:



Result of Sample 3:



Result of Sample 4:



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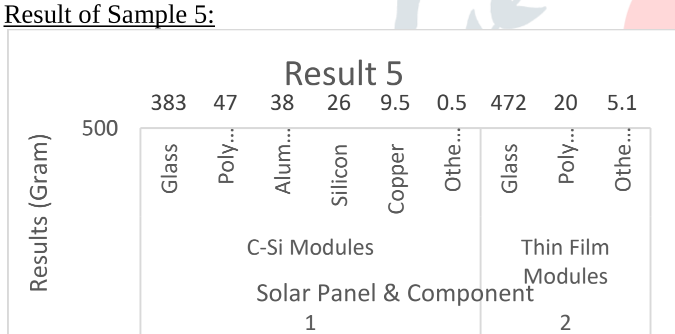
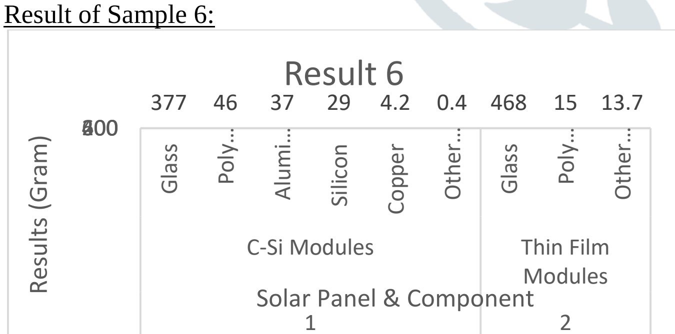
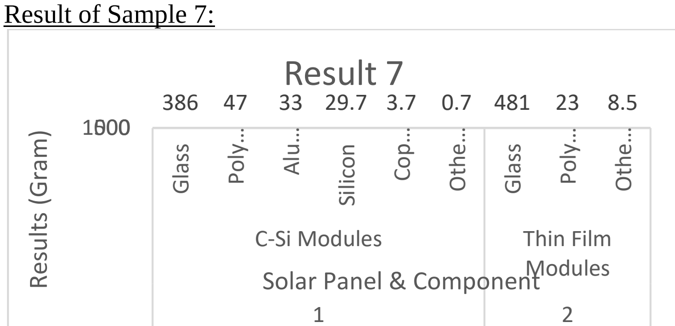


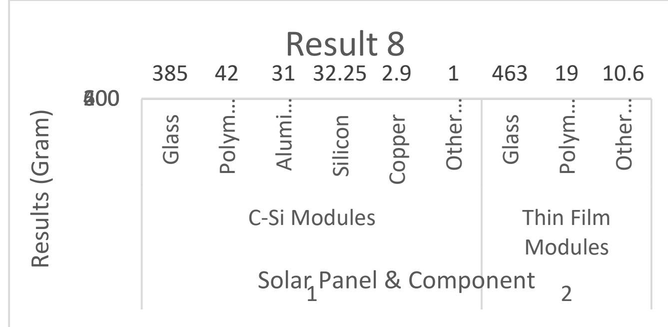
Result of Sample 6:



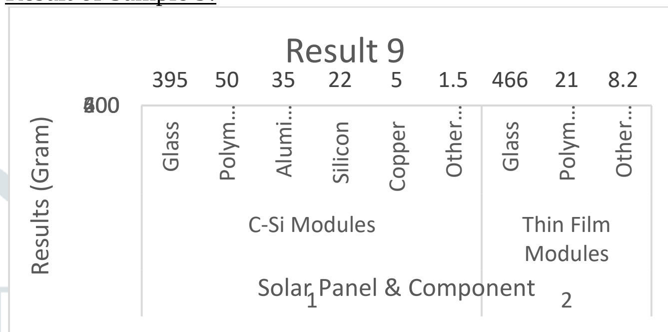
Result of Sample 7:



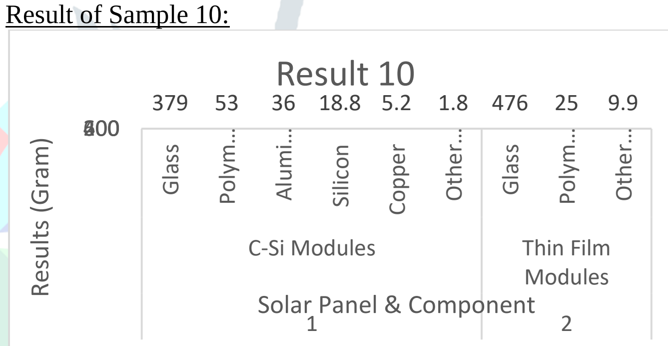
Result of Sample 8:



Result of Sample 9:



Result of Sample 10:

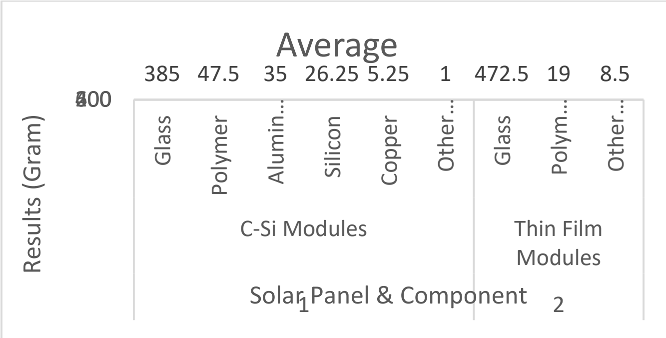


Data Analysis:

Sr. No.	Types of Solar panel	Component	Result 1	Result 2	Result 3	Result 4	Result 5	Result 6	Result 7	Result 8	Result 9	Result 10	Average
1	C-Si Modules	Glass	380	390	385	390	383	377	386	385	395	379	385
		Polymer	50	45	50	45	47	46	47	42	50	53	47.5
		Aluminium	40	30	36	34	38	37	33	31	35	36	35
		Silicon	25	27.5	32.25	20	26	29	29.7	32.25	22	18.8	26.25
		Copper	4.5	6	5	6.5	9.5	4.2	3.7	2.9	5	5.2	5.25
		Other Metal	0.5	1.5	0.8	1.3	0.5	0.4	0.7	1	1.5	1.8	1
2	Thin Film Modules	Glass	480	465	475	479	472	468	481	463	466	476	472.5

		Polymers	18	20	13	16	20	15	23	19	21	25	19
		Other metal	2	15	3.6	8.4	5.1	13.7	8.5	10.6	8.2	9.9	8.5

In study of Solar Penal manufacturing and recycling with reference of physical treatment and Chemical treatment we are conclude that the recovery of C-Si module and thin film modules are as under



▪ Conclusion:

The economic perspective, renewable energy resources are demanded to replace the fossil-based energy production owing to their lower carbon emissions. However, the production of the content of these renewable energy resources consumes a huge amount of energy and emits carbon and GHGs, which have been underestimated while selecting and using. In order to reduce environmental effects of production processes, raw material saving and waste minimization are important factors. Commonly, environmental effects of processes are measured by the life cycle assessment. Recently, there have been many publications related to life cycles assessment of the PV modules. Liang Xu reports that PV module production includes many steps, such as material mining, semi raw material production, solar cell production, assembling PV module, transporting, installing and end-of-life recycling. They indicated that especially silicon ore mining, industrial silicon smelting and solar grade silicon purification have a relatively higher environmental impact in terms of toxic pollutants production, wastewater creation and high energy consumption. This is why recycling PV modules is highly effective to prevent the adverse environmental effects that are coming from raw material production steps. For 1 kW PV module production, it is estimated to release 80,113 kg of CO2 for subsidizing the raw material. However, compared with fossil-based coal burning systems, for the same amount of electricity power generation, the PV modules production phase emits 3.3% less.

In this manuscript, at the end-life of PV modules, the expected waste amount is 3.3 million modules, equal to 832.5 MW solar power panels. Only 65% of this PV module power is assumed to be recycled, which would be 540 MW. As previously mentioned, the major part of the CO2 emission of the panel production comes from raw materials. Hence, if these metals are regained and reused for panel productions or other applications, from the recycled 540 MW PV modules, 43 millions of tonnes of CO2 will be saved. On the one hand, recycling the wastes of PV modules brings waste minimization and raw material saving, but on the other hand it is a great source of carbon release to the atmosphere and so decreases the countries carbon footprint. Today, this release can be observed at a country level, yet, in the years that recycling will be taking place, it is going to be much more important than today because of climate change and increasing levels of industries and population.

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