Water-less and Autonomous Solar Panel Cleaner

(Technical Paper)

America's Solar Waste Crisis

(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

As the concern over the use of fossil fuels and their effect on the environment has increased, many countries are looking to the solar energy sector for alternative power. Solar energy is one of the fastest growing green energies with a growth rate of 35-40% each year (Seo et al., 2021). This solar energy is purported to be pollution-free, but their end-of-life (EoL) disposal is often ignored. A lifespan of 25-30 years is the average expected use of Photovoltaic (PV) solar panels, but factors such as incorrect installation, use, and cleaning, as well as major weather events can decrease this number drastically. With a rapid increase in production and use, these panels will all need to be replaced at about the same time, leading to a potential crisis since there are not adequate regulations to handle their collection and disposal (Marcuzzo et al., 2022).

PV solar panels contain toxic metals such as cadmium, selenium, and tellurium which are known to be toxic and harmful to the environment if disposed of incorrectly. In addition, PV cells also contain rare and expensive materials such as copper, silver, and other polymers. Not only would sending solar panels to landfills be harmful to humans and the environment, it would also be a waste of these rare and expensive materials (Seo et al., 2021).

My technical project focuses on the design and testing of a cleaning apparatus for PV solar panels using electrostatic induction. This method makes minimal contact with the delicate surface of the solar panels and removes dust particles. Left unchecked, those dust particles could decrease the efficiency of solar panels by as much as 30 percent (Chandler, 2022). The minimal contact involved electrostatic induction could cause fewer abrasions on the glass surface of the solar panel, increasing its useful lifespan.

The STS portion of this paper focuses on solar panels once they reach their end of life (EoL) stage. I will be comparing the solar panel regulations of the major countries adopting them. Through this comparison I hope to shed some light on why the United States has no specific regulations on solar panel recycling.

Technical Project

The technical section of this paper will consist of the design of a cleaning apparatus for PV solar panels. The current method for cleaning solar panels involves wiping down the surface of the panel with a damp cloth. This method runs the risk of scratching the glass surface as dust and dirt are trapped between the surface and the cloth. Scratches caused by the current method of cleaning, scatter light as it hits the PV cells and reduce the efficiency of energy production. Additionally, traditional methods require water, which can be expensive in many areas where dust is the biggest problem. The apparatus described in this paper will clean the surface of the panel using a combination of electrostatic induction, to remove dust and dirt particles without contact with the panel, and a soft rolling brush, to remove larger debris. The use of contactless cleaning through electrostatic induction will reduce the risk of scratching the glass surface of solar panels and increase their expected efficiency throughout their useful lifetime.

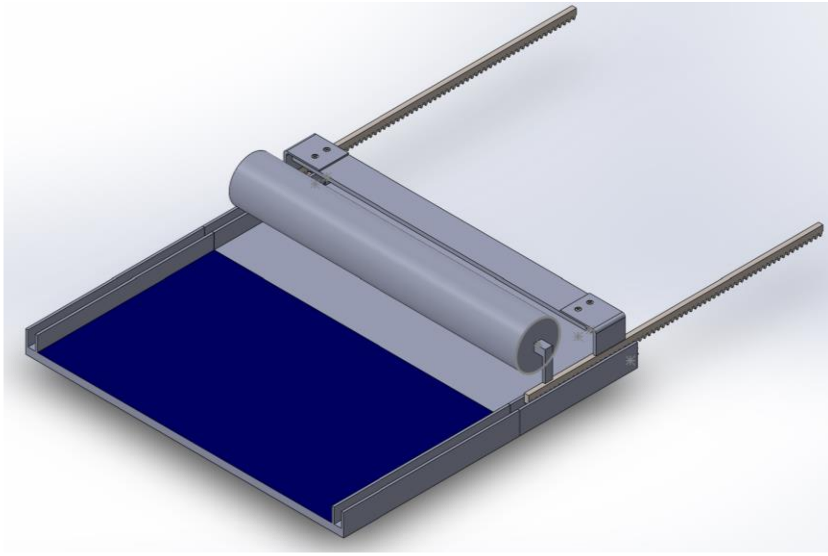

Fig. 1. Above is a SolidWorks assembly of the design. The surface of the solar panel is pictured as blue. The brush and plate translate across the plate's surface.

The design of our cleaner consists of a thin, steel strip that will be charged to 12,000 Volts (Panat & Varanasi, 2022). The strip will then translate across the length of the solar panel, attracting dirt and dust particles as it moves along a gear train. The strip sits between 1.5 and 3.0 centimeters above the surface of the PV cell to maximize the number of debris attracted to its surface. Following behind the metal strip is a microfiber brush that rotates as it moves across the surface of the panel. The brush is designed to pick up any larger debris including leaves and bird droppings that will be left behind by the metal strip. While the brush still makes contact with the glass surface of the panel, the risk of scratching the glass is reduced since the metal strip will pick up the majority of the small, sharp debris on the panel.

This design will reduce the damage to the surface of the panel and reduce inefficiencies caused by improper cleaning, increasing the effective lifespan of PV cells. Another goal of the design is the ability to scale up to larger arrays. In other words, the same brush and plate could clean a whole row of panels.

STS Project

In this section of the paper, I will be focusing on the recycling of solar panels once they have reached the EoL stage. To do this, I will be examining how different countries: China, Germany, Japan, India, and the United States regulate the disposal and recycling of solar panels. Using this information, I will be able to analyze the technology of solar panel recycling through the lens of actor-network theory (ANT). It is important that major players in the global production of solar energy plan for the future of recycling solar panels because if current trends continue, by 2050, the five countries listed above will have 51.3 million tons of solar waste to deal with (Marcuzzo et al., 2022).

If solar panels are sent straight to landfills, there will likely be many adverse environmental effects. Cadmium, and Tellurium are toxic and known to cause cancer in humans, if exposed for too long. Some panels also contain lead-based perovskite (Seo et al., 2021).

Relevant Groups

China

China is the largest market for PV solar panels and also the largest manufacturer of them. It is predicted that by 2050, China will have between 13 and 20 million tons of solar waste. China currently has no laws or regulations regarding the disposal of solar panels since they do not fall under electronic waste (e-waste), though they have announced a government funded R&D program for safely disposing of PV waste (Majewski et al., 2021).

Germany

The largest PV market until 2015, when they were overtaken by China, Germany generated almost 40 Gigawatts of power that same year. That energy was collected by 1.5

million PV power plants across the country and accounted for 6 percent of the nation's consumption. By 2050, Germany is predicted to accumulate between 4.3 and 4.4 million tons of PV waste (Weckend et al., 2016). Germany adopted the EU regulations regarding e-waste known as the Waste Electrical and Electronic Waste Directives (WEEE). Under WEEE, companies that sell devices classified as e-waste must set aside a certain amount of funds for each device sold. This fund must be used for the EoL treatment of said devices. Unlike in China, Germany classifies PV cells as e-waste (Majewski et al., 2021).

Japan

Japan is a major player in the solar sector and hosts a rapidly growing market for PV panels; 45 percent of the worlds PV cells are manufactured in Japan (GENI). With the introduction of tariffs in 2012, the PV market surged. It is predicted that by 2050, Japan will reach 6.5 to 7.6 million tons of PV waste (Majewski et al., 2021).

India

India has made a huge surge ahead in the installation of PV panels in recent years making it into the top ten producers of solar energy. In 2012, 1 Gigawatt of solar power was installed. By 2019, this number reached 85.9 Gigawatts. In 2022, the Indian government surpassed its goal of installing 100 Gigawatts of solar power capacity ahead of schedule (Rathore & Panwar, 2022). Like China, India does not have any specific rules regarding the disposal of solar panels. Solar panel distributers are required to follow the WEEE regulations regarding management and handling of e-waste, but India does not have the infrastructure to support large-scale recycling (Rathore & Panwar, 2022). Because of the lack of infrastructure and despite the WEEE regulations India has adopted, only 4 percent of ewaste was recycled between 2015 and 2017 (Suresh et al., 2019).

United States

The United States is currently the fourth largest market for PV solar panels. Between 2008 and 2018 the average annual growth of the deployment of solar panels was 65% and projections into 2030 show the growth increasing exponentially (Domínguez & Geyer, 2019). The Environmental Protection Agency (EPA) has no federal regulation over the EoL disposal of solar panels; although, a few private companies such as First Solar and Solar World voluntarily recycle their products. It is left up for state governments to make their own laws regarding PV recycling and the majority have not, with the exception of Washington State. By passing the Solar Incentives Job Bill, Washington requires solar manufacturers to completely "finance the takeback and recycling system" (*Solar Panels - Washington State Department of Ecology*, n.d.) of EoL solar cells.

Methodology

This paper will analyze solar panel recycling using the ANT framework. ANT holds that technologies can be understood by examining the connections between relevant groups – known as actors. Using this approach, I will highlight the incongruities between what is required for effective climate action and what is being done. There are multiple processes for recycling solar panels that have been shown to be technologically feasible and economically viable, (Papamichael et al., 2022). This paper's goal is to develop a network of actors for solar panel recycling through research and comparison between different countries regulations. Members of this network are likely to include the owners of large solar farms, solar panel manufacturers, individual owners of solar panels, state and national governments, and supporters of climate action.

Key Texts

“Overview of global status and challenges for end-of-life crystalline silicon photovoltaic panels: A focus on environmental impacts” by Seo et al. is a literature review that explores predictions of PV waste generation and preforms a life cycle assessment to evaluate solar panel affect on the environment. They argue that recycling must be implemented soon to avoid a global problem.

“End-of-Life Management and Recycling on PV Solar Energy Production” by Papamichael et al. details several methods of PV recycling and how they compare economically. This source is useful in determining the most efficient means of recycling and shows that these processes are feasible.

“Photovoltaic waste assessment of major photovoltaic installations in the United States of America” by Domínguez et al. specifically examines large scale PV power generation sites. The authors construct a model to predict future PV waste as well as what materials will be reclaimed and the economic value of those materials.

“Recycling of solar PV panels – product stewardship and regulatory approaches” by Majewski et al. argues that while many nations are pushing for accelerating adoption of solar energy, very few are worried about regulations surrounding them. This paper examines the laws surrounding PV waste and the lack of action from governments.

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