Automated Solar Panel Cleaner

(Technical Paper)

Solar Panel Electronic Waste Disposal Concerns

(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

Derek Habron

Fall, 2022

Technical Project Team Members

Chris Davis

Matthew Kim

Chris Le

Nicole Piatko

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

Signature Derek Habron Date 1/29/2023
Derek Habron

Approved ________________________ Date ________
Technical Advisor: Michael Momot, P.E., Department of Mechanical & Aerospace Engineering

Approved ________________________ Date ________
STS Advisor: Richard D. Jacques, Ph.D., Department of Engineering & Society

Introduction

Solar panels have been proliferating over past decades. But the rise of renewable solar energy has also led to an unintended consequence: the increasing generation of electronic waste that has the potential to pollute the earth and toxify water sources.

As the world increasingly turns to renewable energy sources in an attempt to combat climate change, the use of solar panels has increased substantially in recent decades. While solar panels are a clean and sustainable source of electricity, the disposal of these panels has raised concerns about the environmental impact of their production and disposal. The amount of E-waste generated by retired solar panels will only grow over the coming decades as solar panels in use today reach the end of their lifespans. By 2050, it is anticipated that there will have been a growth in end-of-life solar panel waste of more than 60–78 million metric tons (Weckend et al., 2016). The goal of this research project is to use the Social Construction of Technology framework to analyze the issue of solar panel electronic waste in order to determine how this problem came to be and what might be done to solve it.

The objective of the technical portion of this project is to design and build a prototype device that can be affixed to roof mounted solar panels in order to automatically clean them. An efficient design will increase the practical efficiency of roof mounted solar panels.

Technical Topic

It is projected that more than one in seven U.S. homes will have a rooftop solar PV system by 2030 (*Solar Energy in the United States*, n.d.). Dust and soiling of the solar panel can impact energy loss of up to 7% in parts of the United States or as high as 50% in the Middle East (Wayne Hicks, 2021). Leaves, bird droppings, and other debris left on impact the efficiency of the solar panel as well. The most common method to clean solar panels is using water, and brushes to scrub the dirt which depends on labor and solar panels cleaning experts (*Cleaning Solar Panels*, 2022). An annual solar panel inspection and cleaning costs ranges from $450 to $780 (*Learn How Much It Costs to Clean and Maintain Solar Panels*., n.d.). The goal of the capstone design project is to design an automated cleaning mechanism that can stay attached to the solar panel. The design aims to eliminate the need for climbing on to the roof every time a solar panel needs to be cleaned.

The design must be built to the specification of a 12" x 20" solar panel model, which is 1:3.25 to scale of a typical solar panel size of 39" x 65". The solar panel model will be a plywood platform. There are many requirements to successfully build an automated solar panel cleaning mechanism. When not in use the device must stay away from the occlusion zone, which is defined as on top of the panel and the area not included from a measurement by a 45° angle from the edge of the panel. The device must cost less than $600 to make and built to last against weather conditions such as sun, water, and snow. The safety of the attachment to the roof is important and must last against wind conditions. The goal of the automated solar panel cleaning mechanism design is to have a low cost, safely attached, weather durable, efficient cleaning device.

To come up with a final design idea there was an ideation phase, a concept screening phase, and a concept selection phase. In the ideation phase, each group member came up with five unique designs of a solar panel cleaner. In the concept screening, every member's five ideas were looked at to group together and narrow down comparisons. Factors considered included cost, cleaning efficiency, user friendliness, and manufacturability. At the end the ratings were added up to see which concepts had the highest rating. The methods with higher ratings were then combined with the mechanisms with higher ratings to finalize the concept screening. Concept scoring was done with the same factors as concept screening. The weighted rating was formed and added together for each concept, and the total weighted rating was compared. A "squeegee on rollers" design was selected as being optimal, having the highest score out of all other variants.

The chosen design comprises a horizontal squeegee that will be moved up and down the length of the solar panel along tracks that span the panel vertically. The horizontal squeegee will have wheels on either end allowing it to roll along the tracks with ease. The squeegee is driven by a winch system that operates along the top of the system. A high torque low rpm motor is connected to a horizontal shaft that runs through two bearings along the top of the solar panel. This shaft is connected to the squeegee by two steel cables. Rotating the motor one way will result in the shaft winding up the cables, pulling the squeegee to the top of the solar panels, and rotating it the other way will unwind the cables allowing the squeegee to move back to the bottom of the solar panel. The direction of the motor is provided by an H-bridge chip connected to the motor and a P2 microcontroller. The motor reverses direction according to a pre-programmed sequence, where the wiper position is determined using two photosensors as limit switches.

To provide force to pull the squeegee back to the bottom of the solar panel, two tension springs are placed on either end of the squeegee opposite the winch. When the squeegee is brought to the top of the panel, the springs are put into tension, allowing them to pull the squeegee back to the bottom of the solar panel when the winch is unwound. The winch method allows for the solar panel to be unobstructed while not being used for cleaning.

STS Topic

I will be examining the issue of environmentally harmful waste generated by the disposal of solar panels through the Social Construction of Technology (SCOT) framework. This is an STS framework originally developed by Pinch and Bijker that views technology as socially constructed and address both social and technical forces that shape development (Bijker et al., 1987). The basic tenets of this framework include the relevant social groups, interpretive flexibility, problems and conflicts, and closure and stabilization. These factors drive the technology and will help to understand the problems that come with it. In my paper, I intend to use the tenets of SCOT to identify the significant groups and factors of solar panel waste disposal as a socio-technical system.

There are several relevant social groups, or stakeholders, involved in the issue of solar panel electronic waste. These include governments, manufacturers, and consumers of solar panels. Governments incentivize the use of solar panels through subsidies or a federal tax credit in the US (EERE, n.d.). Governments can also play an important role in regulating the production and disposal of solar panels, such as in the EU. Some manufacturers have established voluntary programs that allow customers to return defective panels, and may have legal obligations to produce solar panels in a sustainable manner or to manage recycling programs if the government requires it. Manufacturers in the EU are required by the Waste Electrical and Electronic Equipment Directive (WEEE) to be financially responsible for the collection and recycling of products (Weckend et al., 2016). Consumers also have a role to play in the disposal of solar panels, as they must be involved in the disposal of their panels once the panels reach the end of their lifespan by necessity.

Solar panels are made up of a variety of materials which includes glass, plastic, aluminum, and silicon. Collecting and refining these materials requires energy and resources. Solar panels can also contain toxic materials such as lead and cadmium (Mishra et al., 2019). These heavy metals are potentially hazardous to the environment and human health in certain concentrations (US EPA, 2021a). The disposal of solar panels is a complex issue, as there is currently not one standardized method or plan for recycling these materials. Many solar panels currently end up in landfills. There is a concern that improperly disposed solar panels that contain toxic materials could potentially release toxic chemicals into the environment (Shellenberger, 2018). According to the EPA, some solar panels are classed as hazardous waste while others are not (US EPA, 2021b). The demand for new solar panels is also driving the production of raw materials, which could be a further source of environmental degradation (Mishra et al., 2019).

There are ethical questions regarding solar panel electronic waste. The potential impact on the environment, due to the release of toxic chemicals from improperly disposed solar panels, is one concern. The drive for increased production of raw materials for solar panels and its impact on the environment is another concern. The production and disposal of solar panels can have significant impacts on communities and ecosystems around the world, raising questions of social responsibility.

To complete this project, I will further investigate existing research on this topic. I will also interview experts in the field about their current practices. This research will be focused on the tradeoffs of solar energy, as well as potential solutions to the waste disposal issue and how they could be implemented in the socio-technical system. The economics of solar panel waste disposal will also be examined. Current end of life recycling methods will be detailed as well.

Conclusion

In conclusion, the issue of solar panel electronic waste is a complex problem that presents a challenge to developing a comprehensive solution. By examining the social and technical factors that contribute to this issue, we might better be able to develop and implement effective strategies for addressing solar panel waste disposal. In the final project, I will thoroughly detail the problems of solar panel waste disposal, and potential solutions. These potential solutions could include the development of standardized recycling programs, the improvement of solar panel production processes, and the engagement of consumers, which will be explored in more detail. The final conclusion of this project will indicate the potential for reducing the environmental impact of solar panel end of life disposal in order to increase the sustainability of future solar panel usage.

References

Bijker, W. E., Hughes, T. P., & Pinch, T. (Eds.). (1987). *The Social construction of technological systems: New directions in the sociology and history of technology*. MIT Press.

Cleaning Solar Panels: Why, When, and How You Should Do It. (2022, August 15). Energy Matters. https://www.energymatters.com.au/renewable-news/solar-panels-cleaning/

EERE. (n.d.). *Homeowner's Guide to Going Solar*. Energy.Gov. Retrieved January 29, 2023, from https://www.energy.gov/eere/solar/homeowners-guide-going-solar

Learn how much it costs to Clean and Maintain Solar Panels. (n.d.). Retrieved January 29, 2023, from https://www.homeadvisor.com/cost/cleaning-services/solar-panel-maintenance/

Mishra, S., Rout, P. K., & Das, A. P. (2019). Solar photovoltaic panels as next generation waste: A review. *Biointerface Research in Applied Chemistry*, *9*(6), 4539–4546. https://doi.org/10.33263/BRIAC96.539546

Shellenberger, M. (2018, May 23). *If Solar Panels Are So Clean, Why Do They Produce So Much Toxic Waste?* Forbes. https://www.forbes.com/sites/michaelshellenberger/2018/05/23/if-solar-panels-are-so-clean-why-do-they-produce-so-much-toxic-waste/

Solar Energy in the United States. (n.d.). Energy.Gov. Retrieved January 29, 2023, from https://www.energy.gov/eere/solar/solar-energy-united-states

US EPA, O. (2021a, August 23). *End-of-Life Solar Panels: Regulations and Management* [Guidance (OMB)]. https://www.epa.gov/hw/end-life-solar-panels-regulations-and-management

US EPA, O. (2021b, August 23). *Solar Panel Frequent Questions* [Guidance (OMB)]. https://www.epa.gov/hw/solar-panel-frequent-questions

Wayne Hicks. (2021, April 1). *Scientists Studying Solar Try Solving a Dusty Problem*. NREL. https://www.nrel.gov/news/features/2021/scientists-studying-solar-try-solving-a-dusty-problem.html

Weckend, S., Wade, A., & Heath, G. (2016). *End of Life Management: Solar Photovoltaic Panels* (NREL/TP-6A20-73852, 1561525; p. NREL/TP-6A20-73852, 1561525). https://doi.org/10.2172/1561525