Thesis Project Portfolio

Capstone: Autonomous & Water-Free Solar Panel Cleaner

(Technical Report)

An Actor-Network Theory Analysis of Solar Panel Use in Singapore

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Spring, 2023

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April 24, 2023

Introduction

Solar power production is often recognized as one of the key elements in a global shift towards renewable energy. For instance, the World Bank predicts over half of renewable energy production output coming from solar energy (World Bank Group, 2022). Much study can be devoted to not only its technical aspects, but also to the social, economic, and environmental factors at play regarding solar panel technology. For the technical project, my team considered the best mechanism by which solar panels can be cleaned so that their effectiveness may be maintained.

Reductions in efficiency due to the accumulation of dust on the surface of a solar array are called soiling losses. These losses are much more significant in areas like North Africa and the Middle East, where the environment is conducive to dust accumulation. One 2001 study in Iran found that "the power output of a [photovoltaic] system decreased by more than 60% because of air pollution that covered the surface of the PV panel which obstructed the sunlight" (Asl-Soleimani et. al as cited in Maghami et. al, 2016, p. 1312). In the United States, soiling losses can lead to a 7% reduction in efficiency (Hicks, 2021). Cleaning mechanisms ranging from electrically charged plates to soap and water systems were considered.

The social aspect of my research considers the broader, underlying influences on solar panel technology and its implementation. While the necessity of clean power generation due to the ongoing climate crisis are seen as its primary drivers, other factors such as human resources, government policies, and its effects on communities also play a special role in what makes solar energy an effective or non-viable alternative. Without implementation of technical solutions to

dust accumulation, we further delay the global shift away from fossil fuels, thus exacerbating climate change. Further, without considering the broader social, economic, and environmental aspects, we risk this renewable technology occupying a position in which it is not only non-viable, but also potentially detrimental to its users and/or producers.

Capstone Project Summary

My capstone project deals with a mechanism for cleaning dust and debris off of solar panels. Before coming up with solutions, there were several challenges that my team had to discuss including factors such as weather conditions, ease of installation, cost, and mechanical simplicity. After ranking different solutions to the various challenges, we combined concepts and chose a system including a brush and electrified plate moving along a track over the solar cells.

This system consists of an Arduino microcontroller, two 12-volt DC motors, two leadscrews, two journal shafts and journal bearings, four limit switches, and various other auxiliary components along with the brush and plate. This system was specifically designed to conserve water by using cleaning techniques other than the common soap and water methods. For this reason, our design will work even in dry and dusty climates which suffer especially from dust and debris coverage impacting total energy captured from solar arrays.

STS Research Summary

My STS research focuses on solar power deployment in Singapore. I focus on this nation for two main reasons. The first being that its rise to prominence under a capitalist system allows it to serve as an example for other developed countries. Secondly, Singapore's geography (i.e. its location near the equator) makes it an ideal nation for capturing sunlight. Their successes and

shortcomings should serve as learnings for the nations which are most responsible for emissions. The use of actor-network theory allows my analysis to identify the key players and their relationships to each other. The process of using this conceptual framework reveals that the ever-increasing gross domestic product (GDP), or economic output, of the nation is directly related to increased energy demand, primarily coming from the industrial sector. This growth limits the effect solar power can have on Singapore's energy landscape. Therefore, an infinite growth economic model is at odds with net-zero carbon emissions goals. Alternative models, such as Kate Raworth's "doughnut economics" should be adopted by Singapore and other capitalist countries.

Reflection

The social research informed my technical project by forcing me to look at the issue as less of a customer problem and more like a social problem. I began to ask myself who specifically could potentially benefit from this design rather than just thinking about my market as anyone with solar panels. This thought process also allowed me to see the importance of not wasting water even though it is very practical for this task.

The technical project informed the social research by bringing to light the problem of dust accumulation. The dust will block light and affect the overall efficiency of the panel. In my STS research, the panels themselves count as actors under ANT. I found that even though engineers can make state-of-the-art semiconductor solar cells, the panels can be affected by factors such as cloud coverage, dust, and heat, which can be considered the sub-actors of the natural environment. Unfortunately, the confluence of these effects, though seemingly small, can have great impacts on the actual output of a solar array.

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