Design of a Solar Panel Cleaning Device

An Investigation of the Current Impact and Potential of Solar Energy on Society, the Economy, and the Environment

A Thesis Prospectus

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By

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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

At its core, the present climate crisis is an energy issue. Over a century of burning fossil fuels has produced effects such as, water and air pollution, land degradation, extreme weather events, and ocean acidification (Denchak, 2022). These conditions come from an excess of byproducts of non-renewable energy use, like carbon dioxide, sulfur dioxide, and other greenhouse gasses. In order to have a biosphere that continues to support our species and countless other forms of life, a transition to meeting the majority of the planet's needs with renewable sources. Unfortunately, such systems have their own challenges and pitfalls that must be addressed as well.

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 will consider 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 will be considered along with their motion and/or distribution to the rest of the solar panel array.

The social aspect of my research will consider 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. Additionally, efficiency is just one factor that determines the effectiveness of solar panels over time. A life cycle assessment “considers the environmental impacts, the primary renewable and non-renewable energy consumption, the resources depletion, and the emissions during the entire life cycle of a technology” (Muteri et al, 2020, p. 2). This takes into account the impacts of raw materials, manufacturing processes, and waste of solar panels. 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.

In the energy sector, I propose a diverse set of solutions using a combination of different sources of renewable energy along with more efficient power distribution. My primary investigation will concern the place of solar power in the energy transition. I predict that low-efficiency, ubiquitous, sustainable solar cells will be the best option for densely populated areas with expansive surface areas on buildings. However, in rural communities, standard solar panels with higher efficiencies may be deployed.

Technical

The technical aspect of my paper 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 (Patringenaru, 2013), 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.

Considerations for this dynamic model will involve transmitting power from a motor into linear motion, as well as hardness considerations for the brush, and electricity use for the electrified plate. The final design will include machine elements like shafts, bearings, and gears. Elastic theory, gear theory, and dynamics concepts along with industry standards will provide the design's conceptual backing. Knowledge of the photovoltaic effect and, more importantly, the surface finishes of panels will be particularly useful in order to keep the design from inhibiting the performance of the panel. An automatic pool cover system is a similar technology that shows these problems have been solved before in different settings. Therefore, our design should work as it is influenced by similar technologies.

The project was split into four parts for each of the members. The brush and electrified plate will work in conjunction with each other and will specialize in different grain sizes. The electrified plate was developed at Massachusetts Institute of Technology in order to cut back on the use of water in solar panel cleaning techniques. Current techniques are estimated to use around 10 billion gallons of water each year (Chandler, 2022). The brush and electrified plate will be connected to the motion system and managed by some kind of microcontroller, like an Arduino.

Anticipated key challenges include choosing a brush that won't damage the panel surface, keeping both sides in rectilinear motion, and protecting the device from the elements. The brush has to make contact with the panel so its material cannot be harder than the glass surface. Even so, the effect of constant wear on solar panel surfaces must be considered. Secondly, powering the system will be difficult because it must both be powered and mounted from the sides of the panel. Thus, keeping both sides of the device at the same speed will cause difficulty. Lastly, the device will need some kind of casing that protects it from the elements. A "home" that the cleaner can return to with environmental protection will also be needed.

STS Topic

A working knowledge of solar power systems and their place in society will require thorough research into their effect on natural and human resources. The extraction of natural resources, manufacturing of materials, and disposal of waste after the cell array's expiration must be considered (Atasu, 2021). This information can be summarized in a life cycle assessment. Regarding human resources, implementing increasingly large-scale solar projects will exacerbate any inequities in power structures within the growing global industry. Labor surrounding mining for precious metals necessary for panels and the struggle for power independence in rural communities will be considered. Discussion surrounding the confounding factors of this clean energy source will lead to informed conclusions regarding whether or how solar energy should be promoted with policy decisions.

According to the EPA, "by 2030, the United States is expected to have as much as one million total tons of solar panel waste." While this was only 0.34% of U.S. municipal solid waste when compared to 2018, "by 2050, the United States is expected to have the second largest number of end-of-life panels in the world, with as many as an estimated 10 million total tons of panels" (US EPA, 2021). This recycling problem can become a glaring issue down the line if large-scale solar projects are to be undertaken. The problematic aspects of solar panel waste mainly come from the harmful materials present in cells like lead and cadmium, which are harmful to human health and the environment (US EPA, 2021) when they leach into soil and water. Additionally, the mining and disposal of metals involved in battery storage must be considered as well since renewable technologies need such storage in order to reliably supply energy to the power grid. Therefore, a truly sustainable solution will involve benign materials or materials which have health and environmental costs that can be neutralized by other processes. Somehow, the solar cells of the future must be made of clean materials, utilized in clean processes, have high efficiency, and long lifetimes. Due to the pressing issue of climate change, will these factors be overlooked to benefit the greater good?

Solar energy has a notable effect on the arrangement of power in political systems. In an ethnographic study, one researcher, Dustin Garcìa, recorded the attitudes of residents of a rural area who had newly installed solar systems, but were in the process of transitioning their power source to the national grid (2020). He found that, "residents' engagement with solar energy and the upcoming energy changeover reveals how they are caught in a development paradox. Both solar energy and grid electricity represent infrastructure technology intended to help overcome social and economic disparities, yet both re-inscribe rural residents' status as secondary citizens with little claim to infrastructure rights" (García, 2020, p. 254). In the developing world, solar installations can serve as an intermediate stage for a rural community's connection to the stronger national power grid. This gives communities access to independent power and protection from national blackouts, while leaving them vulnerable to fluctuating weather conditions, solar companies, and a government that wants to eventually integrate them into a centralized power system. Nonetheless, García's work showed that citizens in these rural areas often preferred their solar arrays over the national grid. Writing on this phenomenon, Langdon Winner remarked, "solar energy accommodates the attempts of individuals and local communities to manage their affairs effectively because they are dealing with systems that are more accessible, comprehensible, and controllable than huge centralized sources" (Winner, p. 130). Thus, solar power systems should be preferred for their promotion of equity and resistance to centralized power structures.

The Social Construction of Technology (SCOT) is a theory that considers four factors key to the development and acceptance of artefacts. These factors include relevant social groups, interpretive flexibility, stabilization, and closure. Relevant social groups are the actors which have an interest in the success or failure of a given technology. For solar panel technology to come to fruition, four major groups are involved: The general public (made up of urban and rural communities) which has a demand for power, researchers and environmentalists who are concerned with climate change, manufacturers and corporations who are concerned with profitability, and the government.

Interpretive flexibility challenges the idea that there must be a "one size fits all" solution. In the words of Pinch and Bijker, "There is not just one possible way, or one best way, of designing an artefact" (1984, p. 421). Under this aspect of SCOT theory, other solar photovoltaic artefacts should be utilized. For example, organic solar panels though low in efficiency, are cheap in cost (*Organic Photovoltaics Research*) and may work well in certain areas with abundant glass surface area, like cities. The idea that technology is not inevitable, but is rather malleable in its formation (Jasanoff, 2021) adds further credence to welcoming other kinds of solar cells into sustainable solutions.

Stabilization is brought about by the satisfaction of the Core-set. These actors create the conditions that allow closure for a technology (Pinch & Bijker, 1984, p. 424). Closure occurs when key problems regarding an artefact are considered solved, even though other problems may remain. According to Pinch and Bijker, “The key point is whether the relevant social groups see the problem as solved” (1984, p. 427). For solar technology, this would involve bills passed in the government (*Biden-Harris Administration Announces $56 Million to Advance U.S. Solar Manufacturing and Lower Energy Costs*, 2022), profitable companies (Lovins, 2021), and communities receiving electricity. Due to these considerations, this theory will be helpful when synthesizing the demands and concerns of the relevant groups.

Research & Methods

Is solar power an efficient, ethical, and sustainable way to distribute power to the masses? Efficiency refers to a solar cell’s ability to turn the available light energy which reaches its surface into electrical energy that can be used or stored (*Solar Photovoltaic Cell Basics*, n.d.). Ethical considerations involve the effect of solar panels on human flourishing, including both producers and consumers of solar power systems. Sustainability will be used as both an environmental and economic factor. Environmental effects of solar panels are summarized in a life cycle assessment while economic factors consider its profitability and viability as a product. Studying this key question will help one truly understand the place of solar power among other renewable alternatives. Cost is often inflated, while other factors, such as waste, ethics, etc., are overlooked when assessing a solution's viability. In fact, cost is one of the main reasons that solar and wind energy share prominence among other renewable energy sources (Pistilli, 2022). Answering this research question will then give a more holistic answer to whether solar energy should be heavily promoted.

The primary method for answering this question using data and facts will come from literature reviews/syntheses. These reviews are able to summarize several studies, considering the strengths and weaknesses of each article. This method allows for more certainty regarding any conclusions from data as well. One review that will be utilized covers life cycle assessments of solar panels (Muteri et. al, 2020). Another review considers how solar energy technology can be implemented in various ways in Bangladesh (Abdullah-Al-Mahbub et al., 2022). Additionally, another study discusses recycling and toxic waste management (Rabaia et al., 2021). These reviews will allow for the formation of informed conclusions regarding the sustainability and ethics of solar energy.

Conclusion

The anticipated deliverables for the technical aspect of this effort is a working prototype of a solar panel cleaning system. This design should be as close to a viable product as possible. A report including a description of each part will provide the dimensions and intended use of the machine. The solar panel cleaner should be able to take in power from a motor and move across an area of size comparable to a commercial solar array, cleaning the surface as it moves. The research regarding the scientific, technological, and societal aspects of solar energy should result in an increased understanding of the social systems that give rise to solar photovoltaic cells.

Successful completion of this technical project will result in consumers having a new way to clean their solar displays that is comparable in cost and easy to use when compared to current systems. Architects who worry about upkeep should be encouraged to include solar panels in their designs with such cleaning technology. Furthermore, a satisfactory answer to the aforementioned research question should add fuel to the implementation of an equitable, environmentally-sound, economically viable power generation system. This research will be helpful for all relevant social groups (policymakers, researchers/manufacturers, the general public and corporations).

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