Solar Panel Electronic Waste

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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

The demand for solar panels has increased dramatically over the past decade as solar energy has been pushed as a solution to combat climate change and save the environment. Solar power in the United States has increased from 0.34 gigawatts in 2008 to over 97 gigawatts in 2022 (EERE, n.d.-b). But the rise of renewable solar energy has also led to an unintended consequence that could have the potential to harm the environment as well. These unintended consequences take the form of increased mining to harvest the elements needed to manufacture photovoltaic cells, the increasing generation of electronic waste that has the potential to pollute the earth and toxify water sources.

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 Social Construction of Technology (SCOT) framework helps 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.

STS Framework

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 this report, the tenets of SCOT are used to identify the significant groups and factors of solar panel waste disposal as a socio-technical system.

The SCOT framework provides a comprehensive lens to analyze the dynamics at play in technological advancements, such as solar panels. It is grounded in the belief that the development and deployment of technology are not merely driven by inevitable progression or linear growth but are rather shaped and molded by social forces and human decisions.

Central to SCOT is the principle of symmetry, which postulates that the successes and failures of a technology should be appraised with equal weight. This is particularly relevant when discussing solar panels, where the triumphs in renewable energy generation are often lauded, but the challenges — especially the environmental consequences of their disposal — receive less attention. By employing this principle, a complete and unbiased view of the environmental implications of solar panels can be developed.

Identifying the relevant social groups is key in the SCOT framework. For this topic on solar panel waste disposal, these groups include manufacturers, environmentalists, governments, solar energy companies, private solar panel consumers, waste management agencies, and ordinary citizens. Each group has its vested interests, perceptions, and stakes in the solar panel lifecycle.

Another vital tenet is interpretive flexibility, emphasizing the various perspectives on a technology. In the realm of solar panels, while manufacturers might see them as a profitable venture and a technological masterpiece, environmentalists might be torn between their advantages of clean energy and the challenges of waste. Policymakers, on the other hand, might see them as tools for policy formulation, national energy goals, and international climate agreements.

According to SCOT theory, the evolution of any technology invariably reaches a point of closure or stabilization, where the dominant design emerges, and conflicts over interpretation subside. The current challenge of solar panel disposal might lead to innovations in recycling or more sustainable production methods. Once a consensus or a dominant practice is established among the relevant social groups, this phase will be reached.

Links between STS framework and topic

Given the current landscape of solar energy adoption and the impending challenges posed by solar panel disposal, the SCOT framework is exceptionally suited to dissect the issue. The inherent strengths of the SCOT methodology lie in its ability to bring to the fore the varied perspectives, vested interests, and forces that shape technological trajectories. Solar panels, despite their promises of green energy, are ensnared in a web of socio-environmental concerns, making SCOT an apt analytical tool. By unraveling these concerns through the SCOT lens, we can pave the way for informed solutions, policy formulations, and future directions.

Background Information

Crystalline Silicon (c-Si) photovoltaic (PV) cells are the most widely used PV technology in the solar industry, accounting for over 90% of the market share (D'Adamo et al., 2017). They are made up of a semiconductor material, typically silicon, which converts sunlight into electricity through the photovoltaic effect.

There are two types of c-Si PV cells: monocrystalline and polycrystalline. Monocrystalline cells are made from a single, high-purity silicon crystal, while polycrystalline cells are made from multiple silicon crystals. Both types of cells have similar recycling processes (Sawant et al., 2023).

The recycling process for c-Si PV cells starts with the dismantling of the panels. The first step is to remove the aluminum frame and glass cover, which can be reused or recycled separately. The cells are then cut into small pieces and cleaned to remove impurities. The cleaned cells are then processed in a high-temperature furnace, where they are melted down to remove any remaining impurities and separate the different materials (Sawant et al., 2023).

In addition to the silicon, c-Si PV cells also contain other materials, such as glass, silver, copper, and aluminum, which can also be recovered during the recycling process. The metals are typically separated by a combination of physical and chemical processes (Sawant et al., 2023).

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). Collecting and refining all the different materials found in solar panels requires energy and resources.

One of the main challenges facing the recycling of c-Si PV cells is the presence of impurities. The silicon used in PV cells is often not of the same high purity as the silicon used in computer chips, which can result in impurities such as boron, phosphorus, and aluminum being present (Heath et al., 2020). These impurities can affect the efficiency of the cells and make it more difficult to recycle the silicon (Heath et al., 2020).

Another challenge to recycling solar panels is the low volume of end-of-life panels available for recycling. Solar panels have a lifespan of 20-30 years, and most of the panels currently in use are relatively new. This means that there is a low volume of end-of-life panels available for recycling presently. This low volume makes it more difficult for PV recycling to turn a profit (Deng et al., 2019).

Analysis by STS framework

There are several relevant social groups, or stakeholders, involved in the issue of solar panel electronic waste. These include manufacturers, environmentalists, governments, solar energy companies, private solar panel consumers, waste management agencies, and ordinary citizens.

Environmentalists are concerned with climate change, but are also concerned with the potential issues of e-waste. Governments incentivize the use of solar panels through subsidies or a federal tax credit in the US (EERE, n.d.). Governments can also play a role in regulating the production and disposal of solar panels, such as in the EU. Manufacturers of solar panels are primarily concerned with turning a profit selling solar panels. The disposal of the solar panels at the end of their lifespan is not necessarily aligned with that goal, but 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). Solar energy companies are concerned with turning a profit while providing access to electricity. Private solar panel consumers that might mount solar panels on the roof of their homes or utilize larger solar farms for commercial properties also have a role to play in the disposal of solar panels, as they by necessity must be involved in the disposal of their own panels once the panels reach the end of their lifespan. Waste management agencies must either create and operate landfills that are capable of receiving solar panel e-waste without risk of leeching harmful materials into the ground and water supply or redirect solar panel e-waste to the appropriate recycling centers. Ordinary citizens are mostly a passive social group in this analysis. The people at large are affected by the potential benefits of solar panel usage, and also by the negative impacts of solar panel disposal.

Discussion

Solar energy, as a cornerstone of the renewable energy movement, is often touted as one of the most important solutions to our growing energy demands and climate change. Yet, the complexities of solar panel production, utilization, and disposal provide a more nuanced narrative of the socio-technical and environmental dimensions of solar panels.

Solar panels come with costs that aren't immediately evident. The environmental ramifications of their production and disposal necessitate a more comprehensive understanding. It's not enough to measure environmental impact merely by the reduction in carbon emissions in solar energy electricity generation compared to fossil fuel electricity generation. The downstream environmental costs, including e-waste, resource depletion, and potential pollution must all be considered.

While recycling solar panels is an enticing prospect, it's vital to address its practicalities. The initial costs of establishing a robust recycling infrastructure might seem prohibitive (Cucchiella et al., 2015). These costs must be weighed against the long-term environmental repercussions of e-waste. In order for solar panel recycling to be practical it must not just be feasible but also profitable.

By subsidizing solar panels, governments worldwide have accelerated their adoption (Akshay VR, 2023). The same stance could extend to the panels' end-of-life management. Subsidizing recycling initiatives or imposing stricter regulations on solar panel disposals could balance the scale and ensure that the encouragement to adopt doesn't result in other environmental challenges later on.

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.

Counterarguments

The discourse surrounding the disposal of solar panels and the environmental implications is multifaceted, touching on various economic and developmental concerns. One primary concern central to the debate is the potential economic repercussions of mandating recycling. There is the potential that if recycling solar panels results in a loss per ton, it could either diminish the adoption of solar panels or elevate their cost. This price increase would inevitably be relayed to the consumers, having a ripple effect on electricity prices.

Simultaneously, the current trajectory of research and development in the solar industry is largely centered on enhancing the efficiency of panels (Farrell et al., 2020). By channeling significant resources towards developing recycling techniques, there's a risk of diverting crucial capital and skilled professionals away from this pivotal objective. This diversion poses further challenges. For instance, if recycling of rare materials in panels becomes mandated, it might disincentivize the development of panels that are more resource-efficient. Moreover, with technological advancements and shifts in materials used for panels, specialized recycling plants tailored for one type of panel might find themselves rendered obsolete, necessitating either a comprehensive overhaul or the establishment of new facilities.

Then there's the matter of the materials themselves. In an ideal world, the vision is of a circular chain wherein recycled materials are seamlessly integrated into the production of new panels. However, given the intricate precision required for photovoltaic cells, achieving the purity level of newly sourced raw materials with recycled ones, especially at a feasible cost, remains a daunting challenge (Heath et al., 2020).

In addition, resource depletion isn't as immediate a concern as it's made out to be. The anxiety over the depletion of resources required for solar panels often emerges from a static perspective, assuming current technological constraints and known reserves. History has repeatedly shown that technological advancements, newfound reserves, and improved efficiency can overturn such predictions (Lynch, 2017). We've observed this with the erroneous predictions surrounding peak oil and similar projections (Maugeri, 2004). While it's crucial to be prepared to develop solutions to upcoming challenges, it's also important to realize that the future trajectory of solar technology might not linearly follow our current path.

Tying into the environmental thread, there's skepticism about the tangible benefits of recycling from a carbon footprint perspective. Some believe that predicting such benefits, particularly over an extended timeframe like 25 years, is inherently inaccurate. They also point out that transporting used panels to recycling facilities would have its own energy demands, as would all other actions along the recycling path (Munger, n.d).

Beyond these logistical concerns, there's a segment of critics who question the premise of mandatory recycling. A more overarching argument against mandatory recycling is based on the idea that recycling doesn't automatically equate to environmental preservation. The environmental costs of recycling have to be compared with the costs of landfilling (Munger, n.d). Critics highlight instances like the large-scale export of recyclable materials to countries such as China, which might sometimes cause more environmental harm than traditional landfill disposal (Humes, 2019). In their view, recycling's merit should be assessed based on its genuine environmental and economic benefits.

Lastly, delving into the composition of solar panels, it's highlighted that a significant proportion, roughly 75%, is glass (Weckend et al., 2016). Given the inherent challenges in recycling glass, both in terms of weight and cost, especially in the absence of a robust market for recycled glass, the feasibility of recycling panels in their entirety is called into question. This web of arguments underscores the complexities inherent in the solar panel disposal debate. A holistic examination of both environmental and socio-economic factors is needed to determine in what cases recycling solar panels is actually beneficial.

Conclusion

In conclusion, the issue of solar panel electronic waste is a complex problem that presents a challenge to developing a comprehensive solution. While solar panel recycling appears to present a promising solution for sustainable energy, it's essential to weigh its advantages against the practicalities and possible unintended consequences. While making recycling mandatory might seem idealistic, it may not be the optimal solution across the board. The goal should be a thorough approach that considers both the technical and societal implications of solar panel usage, recycling, and disposal.

In this exploration, I analyzed the multifaceted issue of solar panel e-waste through the lens of the SCOT framework. Key points raised in this discussion spanned from the potential negative environmental and health impacts of solar panel e-waste and the effectiveness of recycling practices in the solar industry. While the aspiration to create a sustainable and circular economy by recycling solar panels in order to minimize e-waste is admirable, the practicalities, costs, and potential environmental trade-offs cannot be overlooked. As the world continues to adopt renewable energy sources, it is crucial to take a holistic approach that marries both technological innovation and societal needs. It remains paramount to strike a balance between environmental responsibility and realistic, effective solutions in order to move towards a consensus.

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