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Spotsylvania Solar Farm: Watershed Environmental Analysis: Material and Chemical Impacts

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Abstract

The purpose of this compiled review is to answer the research question: *What are the implications of the materials being used in the Spotsylvania sPower solar farm and the impacts of any contributing chemicals?* I will approach this question using a theoretical framework to investigate the public participation (PP) process (Munch-Petersen, 2017) in the preliminary environmental analysis research done by sPower (in accordance with their special use permit [SUP]). This will be a context-specific framework, in which I will navigate the discrepancies between the environmental SUP information and citizen concerns about the chemicals and materials used in the sPower solar plant. The ultimate goal of this research is to address the most pertinent concerns of Spotsylvania's citizens and present the most up to date and easy to understand information in the form of condensed informational flyers. As part of a larger informational project, this paper will elaborate on, and supplement, the content of these flyers. I hope to build on the theoretical framework of this project by presenting a report that properly addresses the questions and needs of the PP in sPower's SUP. In the end, the larger informational product, *Spotsylvania Solar Farm: Watershed Environmental Analysis* (story map), will incorporate this paper's core conclusion that the larger problem in the sPower debate is a lack of streamlined information to citizens about sPower's SUP. Overall, by illuminating and further clarifying these discrepancies, we hope to contribute to a larger literature of EIA analysis to better incorporate and address the citizens directly involved.

Background

Introduction

In 2018, the University of Richmond (UR) announced a plan to match 100% of the campus' electricity demand with renewable energy (Andrejewski, 2019). Part of this plan includes the purchasing of offsite solar energy. Therefore, UR entered a power purchase agreement and invested in 20 megawatts worth of energy (Andrejewski, 2019) in Spotsylvania, VA - where a 500 megawatt sPower solar project has recently been approved for construction (Kenning, 2019). However, this approval was not without local opposition. Despite a preliminary environmental analysis for a special use permit (SUP) by sPower, the citizens of Spotsylvania are still very concerned about the impacts this project will have on their county. Some of the major environmental concerns focus on Fawn Lake, which is very close to the approved solar site (Protect Spotsylvania, 2019). In addition to the concerns involving runoff, erosion, sediments, and threats to endangered species - hazardous materials and chemicals are a major concern throughout the surrounding Fawn Lake watershed. Within the overarching aim to address all of these environmental concerns that are delineated throughout the encompassing watershed, this paper will specifically focus on the materials and chemicals of this solar project.

Methods

Theoretical Framework

The theoretical framework chosen for this paper was heavily utilized throughout the research process. Broadly, this framework investigates the PP process in environmental impact analysis (EIA) processes. The approach makes a comparison between the PP process and the proposed EIA process, from which "discrepancies are identified and analyzed to ascertain the difficulties that are experienced and what this implies in terms of decision making" (Munch-Petersen, 2017, p. vii). A recent case study used this context-specific approach to analyze the citizen involvement in the EIA process of three large-scale hydropower plants in Nepal: "It is the theoretical standpoint of this paper that improvement to the PP process can be implemented only within a given context, wherein the proponent allows sharing of decision making with citizens" (Munch-Petersen, 2017, p. vii). Their conclusions highlight how it is important to use a framework such as this to bridge the gaps between environmental law making and citizen involvement. Without this approach, many more environmental energy developments could receive just as much pushback as the one in Spotsylvania. This is why I have chosen this framework to navigate the discrepancies between sPower's SUP information-decision making process and Spotsylvania citizen concerns about the chemicals and materials used in the solar project. In parallel with the case study in Nepal that made recommendations for improving the citizen experience of the PP process, my methodology will be a heavily context-specific approach that is designed to overcome the discrepancies identified (Munch-Petersen, 2017). While sPower will not have to conduct an entire EIA based on the restrictions of the SUP, this EIA based framework serves as a comparable foundation for PP analysis in the context of the SUP analyses. This will hopefully contribute to a future of EIAs that not only concern the environment, but the surrounding citizens' needs.

Methods

The theoretical framework presented surrounding this research directly drove the methods of this analysis. Therefore, this final product is not meant to be an exhaustive list of the chemicals and materials used in this particular solar project, but instead a method of properly identifying and effectively addressing specifically the citizens' utmost concerns surrounding these issues.

Throughout the research process, three main areas of citizen concern were identified: (1) The chemical compound Cadmium Telluride (CdTe); (2) The health and safety of photovoltaic (PV) solar materials and maintenance; and (3) Project construction and materials. These three areas were selected as they appeared to have the most overlap in the Spotsylvania citizen discourse about the sPower solar in terms of chemicals and materials (Protect Spotsylvania, 2019). They were numerously referenced throughout the concerned citizens' compiled references of information, and therefore need to be properly addressed with the most relevant information.

First, CdTe was the chemical most commonly mentioned in opposition to sPower. It appeared that the citizens' most pertinent concerns included the chemical compound's stability and environmental safety, and how this will impact the surrounding watershed. There was frequent confusion about CdTe versus raw cadmium (Cd) - a highly toxic and unstable chemical

(OSHA, 2019). These identified discrepancies were used as the main focus points in the graphic flyer on CdTe research.

Second, the "health and safety of PV solar materials and maintenance" was broken into four identified sub-categories of citizen concern: (1) Cleaning agents: panel washing; (2) Site maintenance: vegetation control; (3) Fire safety: PV materials; and (4) Leaching: toxic chemicals. These areas were the most mentioned in citizen discourse opposing sPower and therefore needed to be addressed. In terms of panel washing, the citizens repeatedly voiced concern over toxic chemicals being used to keep panels clean. Additionally, citizens questioned the hazards of site maintenance and chemical vegetation control. In terms of PV materials, fire safety continuously appeared as a number one concern. Citizens mainly felt the solar farm would increase their fire risk in the surrounding areas and despite rigorous performance standards, fire safety remained the highest concern out of potential material hazards and failures. Lastly, in terms of the overarching watershed, leaching was also a main concern. sPower received a large source of pushback surrounding questions about the hazardous chemicals that may leach into the surrounding environment (Protect Spotsylvania, 2019).

Third, "project construction and materials" was also broken into four identified sub-categories of citizen concern: (1) Installation; (2) Panel Construction; (3) Non-Panel components; and (4) Materials end-of-life. These four areas give a general overview of the most pertinent citizen concerns surrounding the construction and overall materials of the solar farm. Citizens repeatedly voiced concerns about hazardous cooling components, invasive installation processes that will harm the environment, toxic panel components, and the wastefulness of end-of-life management of PV panels. This is why these four components were selected and further researched in order to address these discrepancies between sPower claims and the concerns in an effective way.

These three main areas of citizen concern, identified using the overarching theoretical framework (Munch-Petersen, 2017), were used as an outline for informational flyers. The following results section elaborates on the research and most relevant information behind each infographic created surrounding these highlighted discrepancies. The end goal of this product is to properly address these main areas of concern in a condensed and effective manner.

Results

Graphic 1: Cadmium Telluride (CdTe)

This first graphic addresses one of the main and most voiced citizen concerns surrounding solar chemicals. This concern was identified as the stability and safety of the chemical, CdTe. Using the most recent research on CdTe and solar, it is concluded that in this context the chemical is completely **safe**. The graphic informs on some of the most basic aspects of CdTe while also highlighting the environmental benefits of using it in the context of utility solar. CdTe is a non-toxic semiconductor material used in PV solar panels. This material is ideal for absorbing and converting sunlight into electricity (First Solar, Inc., 2017). The actual layer of CdTe used in PV solar panels is only a few microns thick, about the thickness equivalent to 3% of a human hair (First Solar, Inc., 2017). For protection, this thin layer is enclosed between two sheets of glass and sealed with an industrial laminate - limiting the potential for release into the environment. However, even in research that ran worst-case leaching scenarios (assuming all the CdTe from a PV module leaches into the surrounding environment and watershed), the amount released into the soil is still considered below conservative human health screenings (Sinha et al., 2012). More specifically, the exact amount of CdTe that will be contained in each sPower PV panel is 7 grams (inert). With sPower proposing to put 440,000 CdTe panels on site, this is the equivalent of 3,080,000 grams or 6.79 lbs of CdTe, which is also considered inert (sPower, 2019a). This means even if the entire amount of CdTe contained in the sPower solar farm was released in its entirety all at once, it would not have any negative impact on the environment (Sinha & Wade, 2015).

Additionally, there are numerous environmental benefits of using CdTe panels. As the leading PV eco-efficient technology, these thin film panels have superior energy yield comparable to their size and have the smallest list cycle environmental impacts (First Solar, Inc., 2017). These modules have been tested not only in the field but also during manufacturing. They are shown to have the smallest carbon footprint and lowest life cycle water use and air pollutants of any PV technology on the market (Figure 1; First Solar, Inc., 2017).

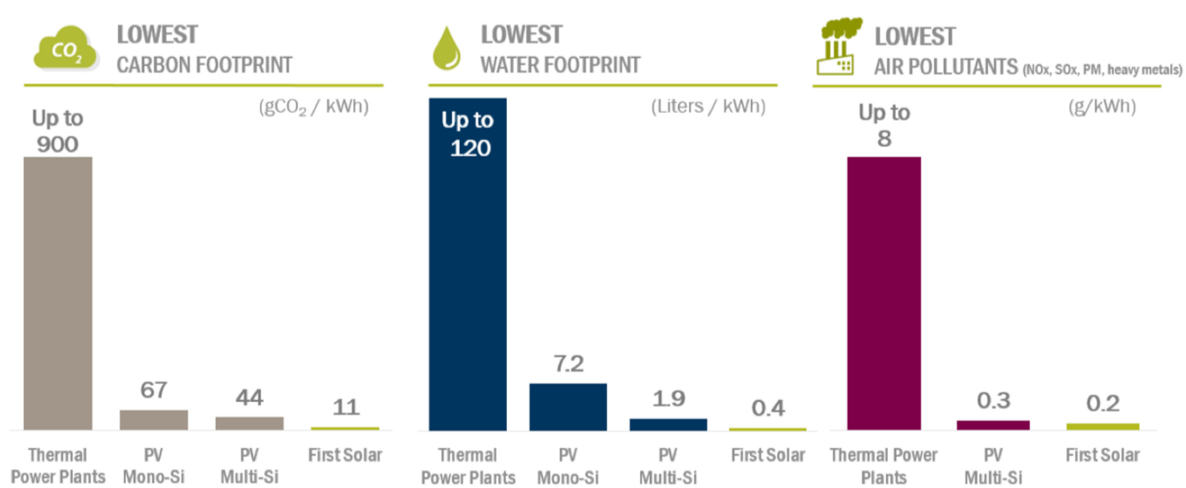

Figure 1. Source: First Solar, Inc. (2017). CdTe PV FAQ. *Centre for Renewable and Sustainable Energy Studies*.

Throughout their entire life cycle, CdTe panels are confirmed to uphold these environmental benefits and especially in the case of accidents such as fire, breakage, or disposal. These specific panels have been rigorously tested and meet safety standards in the case of breakage, fire, flooding and hail storms. They are certified to specific quality and durability standards following numerous industrial performance tests (First Solar, Inc., 2017). Despite these rigorous standards that are continuously met and exceeded by these CdTe panels, there is still only an approximate 1% chance that a module will break over 25 years (First Solar, Inc., 2017). Even in the face of hurricanes, such as Hurricane Matthew and Hurricane Sandy that severely impacted areas along the East Coast, PV structures suffered little to no damage (Unger, 2012). Despite wind speeds of up to 150 miles per hour and severe flooding, the utility solar in these areas were still functional and intact immediately after these storms (Rogers & Phillips, 2017). In the event of a fire, research shows that even when exposed to high temperatures, 99.96% of the Cd content of CdTe Pv modules would be encapsulated in molted glass, preventing further release (Sinha et al., 2011). In a worst case scenario that a fire was large enough to release this remaining Cd content, the emission concentration would still be below conservative air pollution exposure limits for the public, emergency responders, and surrounding environment (Seitz et al., 2013).

These safety features are mostly due to the high chemical and thermal stability of CdTe as a compound. When combined with tellurium, Cd is converted into an extremely stable and non-volatile chemical compound (Kaczmar, 2011). Unlike highly toxic and unstable Cd alone, CdTe is insoluble in water, has a high melting point of 1041 °C (1905 °F) and high boiling point 1050 ° C (1922°F) (OSHA, 2019). In addition, it has a low evaporation rate and low vapor pressure (OSHA, 2019). These inherent features make CdTe an attractive clean energy alternative.

Graphic 2: Health and Safety

The second identified group of citizen concerns are addressed here under the category of *Health* *and Safety*. This graphic addresses the citizens' four most pertinent health and safety concerns surrounding the PV solar materials and maintenance.

The first concern is the need for panel washing with toxic chemicals. Due to Spotsylvania's unique geographical location in the eastern United States, it is anticipated that the panels will not need to be cleaned because of the high amount of reliable precipitation in the county (sPower, 2019a; NCSU, 2017). Comparative research on other similar size utility solar in surrounding regions shows that this rainfall reduces, if not eliminates, the need for cleaning agents to be used (Andrejewski, 2019). Therefore, there will be not toxic runoff into the surrounding watershed concerning cleaning agents at sPower's solar plant. Addressing the worst case scenario, if over the panels lifetime dirt build up justifies a need for washing, previous studies show only non-toxic soap and water are required for cleaning (NCSU, 2017).

The second concern is the need for site maintenance and more specifically, toxic chemicals used in vegetation control. PV facilities require that vegetation be maintained to avoid shading of the panels. Similar to other large solar facilities in the same climate, limited-height species of native plants will be used at the site to decrease the need for further maintenance (NCSU, 2017). Two main methods of physical control will be used by sPower: mowing and grazing. This site will require mowing about once a month during peak growing season, while sheep can also be employed to graze the site. These livestock not only reduce the human effort required for vegetation maintenance but also produce high quality lamb meat (Sun Raised Farms, 2019). Neither of these two sustainable practices require toxic chemicals to be used on-site. If there is a need to use some herbicides for vegetation maintenance, this will be done with a commercial pesticide applicator license. This helps ensure that all applicators are adequately educated about proper environmental herbicide use and application (NCSU, 2017). This license must be renewed annually and includes a certification exam within the context of the application area. However, based on previous data, similar solar facilities use generally less herbicides per acre than most commercial agriculture or lawn maintenance services (Six & Smolders, 2014).

The third concern is overall fire safety of the PV materials. It was found that concern over fire hazards should be limited because only a small portion of materials in the PV panels are actually flammable and cannot self-support a significant fire. These include the thin layers of polymer encapsulates surrounding the PV cells, polymer backsheets (framed panels only), plastic junction boxes on rear of panel, and insulation on wiring (NCSU, 2017). The rest of the panels consist of non-flammable materials, including the one to two layers of protective glass. Heat from a small flame is not enough to ignite the flammable materials, however it has happened before that a more intense fire from an electrical problem can ignite a PV panel (Hong-Yun et al., 2015). It should be noted that this event is extremely rare (Fountain, 2015) and in the case that it does happen, sPower has composed an extensive emergency response plan for the site (sPower, 2018).

The fourth concern is the leaching of toxic chemicals from PV panels into the surrounding watershed environment. While this was already addressed as a non-risk in terms of CdTe, overall chemical research also concluded no environmental hazard. Worst case scenario models predict chemicals leached from PV panels are below health screening levels, background levels, and common levels in agricultural fertilizers (Six & Smolders, 2014). The benefits of these environmentally safe and non-toxic chemicals will be elaborated on in the end-of-life solar section.

Graphic 3: Project Construction and Materials

The third graphic addresses the last identified group of citizen concerns under the category of

Project Construction and Materials. Within this category, four main areas of concern include project installation, panel construction, non-panel components, and materials end-of-life process.

In terms of installation, neither the system installation or construction process requires toxic chemicals (NCSU, 2017). The Spotsylvania sites are already cleared of vegetation, meaning the only land alteration will be digging minimally invasive trenches for underground wiring. Support posts will be placed next, with solar panels bolted to these support structures, and then the panels wired together. Once inverted pads are installed with transformers on each pad, the system is simply tested and turned on (NCSU, 2017).

In terms of panel construction, solar PV panels consist of glass, polymer, aluminum, copper, and semiconductor materials that can be recovered and recycled at the end of their useful life (IRENA & IEA-PVPS, 2016). The same safe materials used for cell encapsulation, plastic ethylene-vinyl acetate, are commonly used in car windshields and hurricane windows for durability (Jordan & Kurtz, 2015). This material helps keep the panel layers intact in the case of breakage - another beneficial safety feature of PV panels.

In terms of non-panel components, no non-panel system components pose any health or environmental dangers. Racking, wiring, the inverter, and the transformer make up the four main components of the non-panel system. Racking is the largest component, making up the mounting structure of the rows of panels. It's primary materials are aluminum and galvanized steel - both extremely common and benign building materials (NCSU, 2017). The inverters (converts solar electricity to the grid) also have steel enclosures that protect the components and wires. The electrical transformers (used to boost the inverter output voltage to the voltage of the utility connection point) will require liquid cooling oil. However, these transformers will use non-toxic and biodegradable cooling oils. These have an additional benefit of being much less flammable than traditional cooling oils (NSCU, 2017).

Lastly, in terms of panel end-of-life management, research shows that PV panels can be responsibly recycled and are toxic-safe if disposed of in landfills. These panels pass the Toxic Characteristic Leaching Procedure (TCLP) Test, which is regulated by the EPA and is designed to simulate landfill disposal and determine the risk of leaching hazardous substances (Weckend et al., 2016). Further testing has been done with damaged panels exposed to acid rain, and the panels still only leaked a negligible amount under the specific threshold to pass the safety test (Sinha & Wade, 2015). Ideally, the panels will be recycled for their end-of-life management to promote environmental sustainability. Global PV recycling plants have shown that over 95% of PV material (semiconductor) can be recovered and over 90% of the glass in a PV panel (Weckend et al., 2016). However, while these recycling programs have been successful in Europe, their infrastructure is not yet established on a large enough scale in the U.S. (SEIA, 2019). Despite this structural gap, the recycling capacity of PV panels is encouraging for future sustainable energy.

Discussion

Conclusion

Overall, by following a clear theoretical framework (Munch-Petersen, 2017), this paper identifies the main areas of Spotsylvania's citizen concerns and highlights important discrepancies in the flow of knowledge between sPower and these citizens. The citizens have repeatedly voiced that they feel sPower has not fully answered or avoided directly addressing their most important questions (Protect Spotsylvania, 2019). While the company began moving forward with the project as early as 2016, the citizens were not fully informed until 2018 with a round of public hearings (sPower, 2019b). After realizing the preliminary environmental analysis had started two years earlier, it is apparent that the citizens felt undermined, threatened, and confused. It is important to understand how this has led to the intense pushback of the solar farm in Spotsylvania. While an environmental analysis process can prove a project 100% safe for the environment, without citizen support, projects can be stalled, delayed, or even rejected (Cuppen et al., 2016). This is where sPower failed to properly address the citizen stakeholders, and this is stark in the amount of concerns they repeatedly voiced about the solar chemicals and materials (Protect Spotsylvania, 2019). Observed throughout this paper, there is an informational gap between perceived citizen risks and actual research proven risks. While the citizens conducted extensive research on potential solar energy impacts, many of their findings were from non-peer reviewed sources and local news articles (Protect Spotsylvania, 2019). Discrepancies like this, that pervade around what has been proven as safe solar, are a direct result of this lack of communication. This same problem of PP was seen in Nepal, where lack of public involvement in the EIA hydropower process also resulted in citizen pushback (Munch-Petersen, 2017). This comparable scenario promoted the context-specific PP framework, and supports the sharing of decision making with citizens.

Streamlining information to citizens in the form of informational fliers, like those presented here, can be part of the solution to overcome these discrepancies. As illustrated by the discrepancies between citizens and sPower, unclear communication can result in confusion and provoke irrational fear. My goal was to avoid this confusion by providing the most important and accurate information in an easy to understand format. Infographics are easy for the intended citizen stakeholder audience to comprehend. Going forward, I hope my infographics set a model for effectively translating even the most complicated scientific knowledge to address all stakeholders properly and include them in the research and decision making process. In the future, being aware of and avoiding these communication problems will help make project environmental analysis processes more successful.

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