Introduction, Background, and Methods Revised

Introduction:

Renewable energy sources are essential for the future of reducing carbon emissions (Ritchie, 2022), However, transitioning from non-renewable energy comes with many issues including concerns of environmental impacts presented by new clean energy sources. Solar energy is emerging as a cheap and efficient way to both reduce carbon emissions and provide massive amounts of electrical energy (California Energy Commission, 2022). Many logistical issues arise when inspecting transitions to solar energy such as environmental impacts to soil and organisms (Hernandez et al., 2014), proper disposal (Tsoutsos et al., 2005), and optimized efficiency. Land usage must be considered during this process due to the large space which solar panels inhabit (Fthenakis & Kim, 2009). These potential long-term effects could be disastrous to the future environment and could hinder solar energy in the future. Our team plans to discuss these negative impacts and address proper implementation of solar energy. To achieve this our group will inspect negative impacts of solar energy and present possible solutions to minimize environmental impact of these systems.

Background

Efficiency

The first major issue that causes solar panel farms to require a huge amount of land is that they are relatively inefficient compared to more traditional sources of power generation, so they require a huge amount of land to produce the required amount of energy. Solar panel farms take space depending on the energy needs of the consumers, but typically produce 5MW using almost a million sq ft of land. (McCloy et al., 2022). Solar panels take solar radiation falling on the panels and convert it into electricity (TPC Training, 2021). The photovoltaic cells embedded on the panels do not absorb 100% of the photons falling on them, because many get reflected, and out of the ones that get absorbed, some are converted to the side product of electricity generation, heat, while the remaining ones are used to create electricity (Stauffer, 2017). Energy generation intensity is the energy produced in a year per square meter of land used. A study shows that the EGI of solar panels can be almost doubled if the right type of solar tracking is used for the location. The study tested four types of solar tracking systems and saw two outperformed the other two by almost two times the efficiency. Solar tracking is a mechanical feature that can be installed on solar panels to increase their efficiency. Solar tracking is a process where the solar panel tries to follow the sun by tilting and rotating on one or two axes to make sure the solar panel is absorbing the maximum number of photons (Alkaff et al., 2019). There are four kinds of solar panels, optimally fixed orientation, vertical single axis, horizontal single axis, and dual axis. Dual axis takes the best of both horizontal and vertical and allows for the most maneuverability of the panel (Racharla & Rajan, 2017). Dual axis solar tracking can track the sun and move horizontally and vertically, whereas the single-axis solar tracking mechanisms can do either one of them. Optimally fixed orientation does not track the sun but rather is a fixed panel, as suggested by the name, that has been put into a certain position by the engineers to harvest the most intensity of solar energy in the day by staying in that fixed position (Lane, 2018).

Solar tracking and its proper usage are important because it can greatly affect the efficiency and power generation of solar panel farms. This would require a smaller amount of land to be used by the farms to produce the same amount of energy as fixed solar panels. The extensive land-usage of solar panels cannot be fixed but using solar tracking greatly reduces the environmental impacts caused by enormous land usage of these solar farms (Marzouk, O. A. ,2022).

Location

The location of solar farms is an important factor to consider when analyzing the environmental impacts of solar panels. This is because certain attributes of the location of solar farms, such as land cover type and slope, can have direct and indirect effects on the ways in which solar farms impact the environment.

The land that large scale solar PV farms are built on generally needs to be within a certain set of conditions for the solar farm to function efficiently. For example, the land must be relatively flat, level, and continuous before constructing the solar farm (Katkar et al., 2022). In terms of slope, any land that slopes above 7% is considered poor or unsuitable for solar development (Katkar et al., 2022). The land cannot have any trees where the PV panels are being installed. Also, having trees nearby that block the sunlight can greatly reduce the efficiency of solar panels during early and late hours of the day. In order to build solar farms on forests or other land with trees, the timber must be cut, and the land must be stumped and grubbed (Harris, 2020). Not only is this more expensive, but it also contributes to deforestation.

Often the best place to build solar farms on is agricultural land (Katkar et al., 2022; Watson et al., 2020). Agricultural land generally fits the criteria required for a solar farm, as it is flat, level, and continuous for large stretches of land. Agricultural land can be utilized for solar power generation whether it has crops on it or not. The use of land for growing crops and generating power with solar power simultaneously is known as agrovoltaics. The use of agrivoltaics can increase landowners' revenue by up to 30% and decrease the amount of land being used for agriculture and solar power (Dinesh et al., 2015).

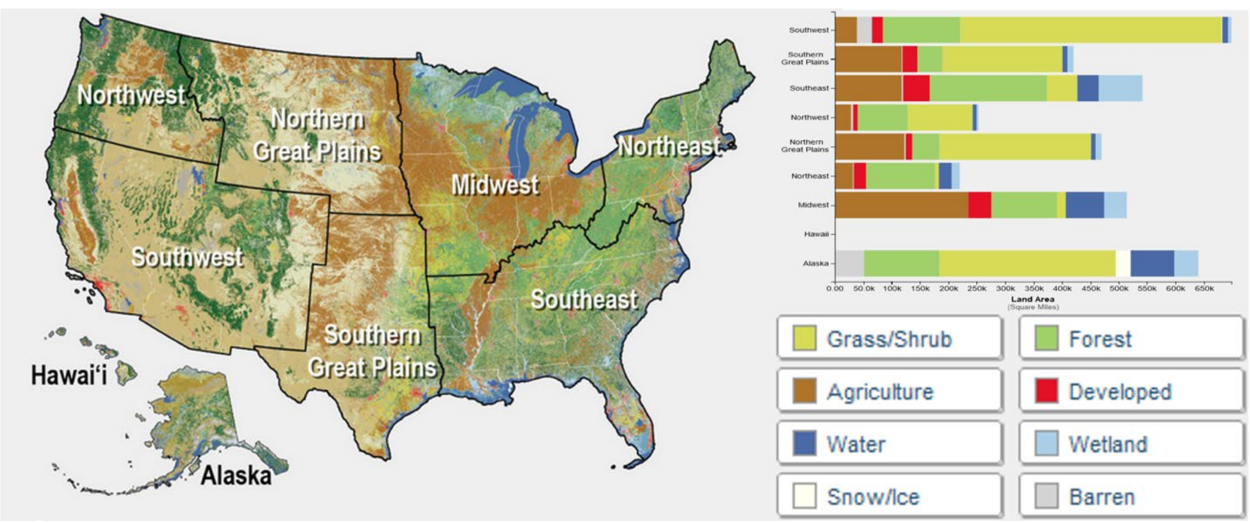


Figure 1. "Land-Use and Land-Cover Composition" by Benjamin M. Sleeter is in the Public Domain. This visual shows the amounts and locations of different land cover types in the US. Some regions have land that is better suited for solar farm development than others. This means that the construction of solar farms in some regions will have a greater impact on the environment than in other regions.

As solar power becomes increasingly popular, it is becoming more important to be mindful of what land these large-scale solar farms are being developed on. The total of all solar farms in the United States account for approximately 1034 square miles, or around the size of

Rhode Island (Venditti, 2021). This is not a trivial amount of space, and it is only going to grow. As the land used by solar farms increases, then so will their effects on the environment unless there are changes made to the ways in which solar farms use land.

Soil/Organisms

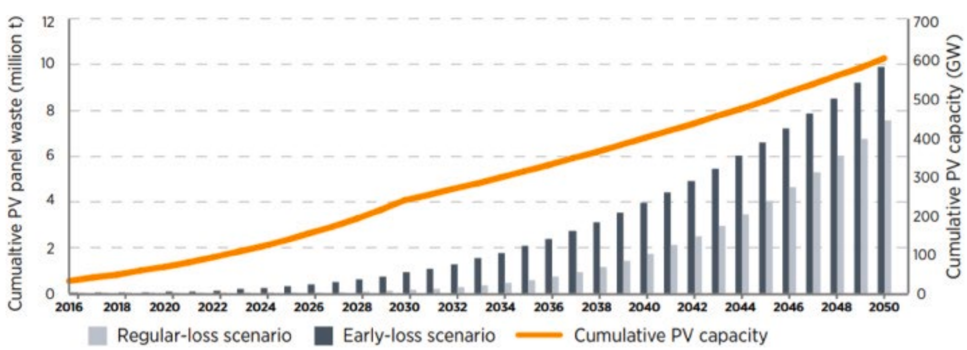
Inspecting soil and organisms is essential when examining solar energy at utility scales. Solar energy farms require shaping and changing land, which alters the habitats of animals and vegetation (Hernandez et al., 2013). Significant amounts of land can be disrupted to produce enough power to be comparable to other energy sources. The land-use intensity of energy (LUIE) of solar energy is high with the median LUIE of ground- mounted PV panels being 2000 ha/TWh/y. For comparison, the median LUIE of nuclear plants is only 7.1 ha/TWh/y (Lovering, 2022). Alongside this land usage, solar energy plants will commonly be placed atop agricultural land or turfed grasses as mentioned before. Creating this unnatural environment can present major concerns for pollinator populations, carbon retention in soil, water retention, and sediment retention (Walston et al., 2020). However, these effects can be resolved through careful planning and consideration. Using native seed mixes when installing solar energy farms can have inverse effects, being beneficial to the surrounding soil. Areas such as brownfields, which are already contaminated and uninhabited land, can be restored using this method (Adelaja et al., 2010). Solar energy farms also cause an apparent threat to biodiversity. For example, soil insects like Tenebrionid beetles (Tsafack et al., 2022) can be affected by grazing animals brought to plants to help with vegetation. Animals such as birds can collide with solar panels resulting in death, and predator/prey relationships can be disrupted by new obstacles. (Hernandez et al., 2014).

If solar energy is a path to clean energy in the future, properly inspecting the effect they have on the soil and organisms around them is vital to mitigate impacts on the ecosystems they inhabit. Mentioned above, when carefully considering impacts on soil and organisms, decisions can be made that will mitigate impacts while still providing energy. Proper implementation and guidelines can not only save money but be beneficial to the soil and organisms that are native to the land.

Recycling/manufacturing

Currently, the United States recycles less than 10% of solar panels, and it is estimated that there are over 1.47 million solar panels across the country. (Becker, S.,2022) That would mean less than 147,000 solar panels will be recycled out of the 1.47 million in the country. Something to ask ourselves is, where do the other 90% go? Solar panels are only intended to last from 25-30 years, so many will need to be recycled (Vargas, 2021). The idea of burning or putting something in a landfill meant to be a green source of energy is contrary to the objective of our research group's project.

A notable issue with solar panels is how complex their recycling process is. Solar panels are structured in a very complex format which is difficult to undo. For example, a plastic water bottle can be recycled with only a few steps (Water, P., 2019). They can be shredded and melted down into pellets, making them ready to be manufactured into a new water bottle. As for solar panels, they are constructed with many parts that need to be separated for everything to be properly recycled. This requires specialized equipment and workers to recycle solar panels completely, which allows them to only be recycled in glass recycling plants because of the specialized equipment needed (Daniela-Abigail,2022). The problem with this is how much money it would cost to recycle a solar panel, and the workers needed to keep up with the amount of solar that needs to be recycled (Wang, 2022). By 2050, the United States expects to be 45% (Connor O'Neil and Harrison Dreves, Feb. 7, 2022) run by solar energy sources which is 42% more than it is today. Since the country is running off 3% solar power and only 10% of solar panels are recycled, something needs to be changed so that the future of green energy is possible.



(Figure 2)-"End-of-Life Management – Solar Photovoltaic Panels" by S. Weckend, A. Wase, G. Heath is licensed under CC BY 4.0
This graph shows the expected influx of solar panel waste in the United States. This information is estimated on the amount of recycling that is done in the U.S. and if the amount recycled stays consistent the amount of waste will only increase.

There are about 2,000 glass recycling plants that can process and recycle solar panels. Unfortunately, the number of factories in the world now could never handle the number of solar panels there are to come. An upside is that the upcoming factories can be powered by renewable resources to ensure that the process creates no emissions and has no impact on the environment.

Methods

The goal of this project is to create a guide for the implementation of a solution that mitigates the effects solar panels have on the environment. To accomplish this goal, there are three objectives that must be achieved. The first objective is to research solar panels and the ways in which they affect the environment. We have divided this research into four different categories: efficiency, location, recycling and manufacturing, and soil and organisms. Research into these subtopics is conducted using secondary sources, such as peer reviewed journals and government reports, using the green energy simulation tool Energy3D, and by interviewing our contacts at Tesla. The second objective is to research a wide range of potential solutions that could mitigate the effects of solar panels on the environment. Research for this objective is mainly focused on reviewing relevant scientific literature and using this information to compare the different types of solutions. The last objective is to research the implementation of a specific solution and develop a guide for the implementation of this solution. The methods of creating this guide include analyzing the scientific literature related to the chosen solution, deciding on the optimal method of implementation, and creating the guide for the implementation of this solution.

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Authorship

Jack:

- Attended all meetings
- Wrote location section of background
- Co-authored methods section
- Reviewed other sections

Josh:

- Attended all meetings
- Wrote introduction
- Wrote soil/organism section
- Revised other sections

Ming:

- Attended all meetings
- drafted outline
- Co-authored methods section
- Reviewed other sections

Dawson:

- Attended all meetings
- Wrote recycling/manufacturing section
- Reviewed other sections

Sid:

- Attended all meetings
- Wrote efficiency section
- Co-authored methods section
- Reviewed other sections