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Electric Potential Analysis of Contaminated Lands in Idaho for Utility-Scale Solar Energy

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ABSTRACT

In the state of Idaho, major electric utilities, such as Idaho Power, have shown a growing interest in solar energy. Because utility-scale solar energy (USSE) requires large land usage, this aspect may be especially problematic for indigenous communities and wildlife when siting USSE. Though less problematic, the proximity of transmission networks to a new USSE site may also be a drawback because of the cost associated with building new networks. However, the use of contaminated sites listed in EPA's RE-Powering Initiative may be an effective solution for reducing the difficulties associated with siting USSE. Within Idaho borders, the estimated electric potential of such contaminated sites within Idaho Power's service area was evaluated in this study. This was done through map overlays and simple mathematical calculations that consider factors that affect PV performance. The RE-Powering sites were found to be of use for providing energy to Idaho Power's customers in Idaho and reducing greenhouse gas. Thus, this study may be of use in mitigating the challenges associated with siting USSE so that further solar energy adoption may be achieved.

Introduction

Rise of Utility-Scale Solar Energy

The use of PV systems has been rising in popularity for utilities in recent years while awareness of climate change has become more widespread and solar energy has become increasingly more affordable. Transforming the electric power sector into one that provides electricity through renewable energy is necessary for fighting climate change and resource depletion [1]. CO2 composes the largest portion of greenhouse gasses [2], with human activities raising CO2 levels by 50% in less than 200 years [3]. The levelized cost of energy (LCOE) produced by utility-scale PV is on average cheaper than energy generated from fossil fuels [4], meaning that the present value of the total cost of building and operating a solar plant over its lifetime of 20-30 years is quite cheap. Additionally, solar PV has become the cheapest source of electricity in history [5], meaning that the current adoption of solar PV is extremely economically desirable.

As a result of the increasing popularity and economic feasibility of renewables, utilities across the United States are making clean energy goals and increasing their solar portfolio. Idaho Power, one of the biggest utilities in Idaho with service areas in eastern Oregon, set a goal in 2019 to provide 100-percent clean energy by 2045 [6]. As of 2021, roughly 50% of Idaho Power's generation comes from renewables [7]. In 2021, hydroelectric power not only accounted for 32.5% of Idaho Power's energy sources but also was its largest source of electricity out of both renewable and nonrenewable sources [7]. Idaho Power relied less on solar energy generation. Solar accounted for 4.1% of Idaho Power's energy sources in 2021 [7]. In the same year, Idaho Power also released a 20-year plan to add 1,405 MW of solar, meaning that solar will prospectively account for more than 30% of their new generation additions [8].

A diverse range of energy sources that includes solar as well as hydropower and wind power is beneficial for grid reliability because diverse generation helps provide households and businesses with consistent and thus reliable electricity. This consistency may be hindered when an energy source is not fully available because of variability in the climate. Therefore, consistency is worsened by ongoing climate change. Threats to hydropower generation include changes in rainfall patterns, flooding and intense rain, and air temperature [9]. Such threats result in negative effects such as disrupted water flow, damaged dam and turbine infrastructure, poor equipment efficiency, and more [9]. There are also threats to wind power generation. Changing wind speeds, air temperature, storm surges, and extreme weather events are climate variables that may reduce electric generation [9, 10]. Solar PV also faces challenges in reliability through cloud cover, higher temperatures, and precipitation [9, 10]. Because of the several environmental factors that negatively affect the performance of certain renewable energy sources, it is crucial to have a diverse range of renewable electricity sources. Because such diversity provides grid reliability, increasing the proportion of solar generated electricity in the grid is beneficial.

Specific forms of renewables, like hydroelectric and wind power, come with environmental and cultural challenges that are avoided or reduced in solar installations. Hydroelectric dams harm wildlife by disrupting aquatic migration. The decline of returning Chinook salmon and Steelhead trout to the Snake River and mid-Columbia River was a result of hydroelectric development [11]. Hydroelectric dams cause juvenile mortality when the fish migrate downstream through as many as nine dams to reach the ocean [11]. Low populations of the Columbia Basin salmon harm not only overall ecosystems, but also cultures and indigenous tribes in the region. Salmon return nutrients in their aquatic habitats, are a part of Pacific Northwest Tribal identity, and are used for religious services [12]. Siting solar PV can be less disruptive than installing hydroelectric dams because installing PV can be accomplished by utilizing previously contaminated land instead of further disrupting vital areas of the ecosystem that wildlife may migrate through.

Siting large-scale wind turbine energy farms also pose harmful cultural and environmental effects. The Lava Ridge Wind Project is a proposed 400 unit wind turbine farm, the largest one in the United States, and is in full view of the Minidoka National Historic Site [13]. In the 1,157 unique comments on the Lava Ridge project, commenters were most concerned about national parks (Minidoka National Historic Site being the top issue in that category), general wildlife, environmental justice and socioeconomics, and cultural resources and Native American concerns (Japanese American concerns being the top issue in that category) [14]. Spinning turbines also threaten flying wildlife such as birds and bats and have potential to reduce, fragment, or degrade wildlife habitat [15]. PV can be less harmful because it is less visible due to its close proximity to the ground and it is less likely to threaten flying wildlife. Solar PV allows room for solar projects such as growing crops underneath solar panels [16]. Because of the shade provided by the solar panels, many crops benefit from lower levels of photons and are protected from the extreme heat that overwhelms crops and decreases their yields [16]. Though created with the intent of being environmentally-friendly, hydroelectric dams and wind turbines still have negative effects on the environment and cultures that may be less severe in solar farms.

Barriers to Utility-Scale Photovoltaic Adoption

Though siting solar provides clean energy and is increasingly more affordable, it is not completely devoid of challenges. Large scale solar plants require the clearing of large amounts of land, causing disruptions in native vegetation, wildlife, and habitat [17]. In Brazil, the most significant barriers in introducing more PV technology were planning for siting power plants, lack of transmission network, and biodiversity impacts [18]. Because large-scale renewables take up large amounts of area, it is also important to consider indigenous communities to avoid situations like the Genesis CSP project and the Colorado River tribes [19] in which tribal communities were negatively affected because of siting USSE. Transmission networks, biodiversity, and respect towards indigenous peoples are factors that must be considered when siting USSE.

The availability of transmission networks may pose slight challenges to PV installations. Transmission networks are necessary because they allow the efficient movement of electricity over long distances by transporting high-voltage electricity so that less electricity is lost while traveling such distances. Transmission networks, along with distribution networks, make up the electrical grid. This means that in order for new generation sites to provide electricity to customers, there needs to be a connection to a transmission line. This fact may be a monetary barrier when new power plants, including solar installations, are far away enough to where building new transmission networks becomes necessary. Additionally, proximity to load centers and transmission infrastructure are factors that are not always captured in the LCOE for connecting solar PV sites to the energy grid, [20] and thus some data on the pricing of siting USSE may not always include costs associated with building new transmission networks. However, because the investment cost of transmission expansion is only a small percentage of the overall cost of providing consumers with electricity [21], building new transmission networks when necessary is a minor barrier to siting USSE.

Wildlife impacts when siting utility-scale solar are another important consideration. BrightSource's large-scale solar plant at Ivanpah made the plan to relocate and monitor tortoises, a threatened species, on the site in order to begin construction on the site [22]. This relocation has led to "animals crushed under vehicle tires, army ants attacking hatchlings in a makeshift nursery and one small tortoise carried off to an eagle nest, its embedded microchip pinging faintly as it receded" [22], ultimately threatening the livelihood and populations of wildlife. Moreover, USSE plants may cause biodiversity loss through the clearing of vegetation and leveling soil and cause landscape fragmentation in which species cannot migrate and spread their genes [23]. An inability for species to spread their genes due to the implementation of solar farms threatens species populations, species strength, and overall biodiversity. Thus, these negative impacts may pose as barriers to siting new USSE.

Because siting solar farms has the possibility of disrupting indigenous land and harming tribal cultures, it is important to consider these possibilities during solar installation. In 2011, the Genesis CSP project site upset Colorado River tribes by uncovering an ancient cremation site during construction [24, 19]. An affected tribal leader stated that this project had disrupted the peace with the tribe's ancestors and relationship with the land [19]. Historical displacement of indigenous people into steep and broken lands, infertile uplands, and arid areas means that many indigenous communities were forced to reside in areas suitable for hydropower, wind power, and solar power [25]. Government entities also frequently grant land titles to renewable energy companies without the full consultation, consent, or compensation from indigenous communities in the area [25]. Especially with the increasing adoption of solar farms, it is crucial that indigenous communities are respected to avoid threatening their culture and living conditions.

Potential Solutions for Further Photovoltaic Adoptions Through RE-Powering Sites

The conflicts with siting USSE may be prevented or mitigated through an effective solution: repurposing land that has been abandoned and previously contaminated into sites for solar installations. Economic benefits for such projects include "electricity cost savings, additional land lease revenue to the town or city site owner, and increased tax payments for the land and/or renewable energy systems to the local municipality and/or state" [26]. The Environmental Protection Agency (EPA) has developed such an initiative called "RE-Powering America's Land" which involves "renewable energy development on current and formerly contaminated lands, landfills, and mine sites" [27].

The goals of EPA's RE-Powering initiative are to provide technical and programmatic assistance, promote policies and practices that promote repurposing contaminated lands into areas for renewable energy, and partner with stakeholders and leverage agency efforts [27]. The EPA also has a mapping tool to locate these potentially or formerly contaminated lands, called the RE-Powering Mapper 3.0 [27, 28]. This mapper consists of federal and state data for over 190,000 landfills, mine sites, Superfund sites, brownfields, and other contaminated lands [28]. Superfund sites are abandoned sites where hazardous contamination is present and the federal government is involved in cleanup efforts [29]. Brownfields are real properties in which the presence of contamination complicates expansion, development, or reuse of the land [29]. Each potential site on the mapper has general information on renewable energy potential [28] such as the possibility of utility-scale PV, estimated PV capacity, solar installation potential, and more. However, it is important to note that each site has not been evaluated for land use constraints or other current conditions that are relevant to USSE development [28]. Site-specific analyses are necessary to further verify the feasibility of siting renewable energy on a particular site [28].

There are several successful cases of utilizing RE-Powering sites and creating renewable energy sites. The Vermont Asbestos Group mine was a potentially contaminated mine site that was repurposed into a solar PV system [30]. Scituate, MA had a defunct, 29-acre town landfill in 2010 and after considering recreational uses for the land, the town decided a solar PV system would be the most feasible and cost-effective option [31]. The Scituate solar landfill has 3 MW of solar PV installation over 12.5 acres, with the panels covering 6.1 acres [31]. In the Nellis Air Force Base in Nevada, part of the 140-acre solar facility included a 33-acre former landfill that had Polychloroethene (PVC) and trichloroethene (methyl chloroform) [32]. This transformation of the contaminated landfill allowed the Nellis Air Force Base to benefit from land that otherwise would have been vacant for years [32].

One disadvantage of developing a RE-Powering site is the need to be literate in Superfund and Brownfield law and potential liability for previously contaminated sites. The EPA addresses the potential liability of cleaning up contamination that new solar developers may have by stating that liability may be avoided through additional laws regarding Superfund and Brownfield sites and the siting of renewable energy on such sites [33]. Thus, it would be useful for solar development teams to be literate in Superfund and Brownfield law before embarking on a RE-Powering project to avoid inefficiency and legal complications.

Despite legal complications, RE-Powering sites still hold many solutions for avoiding the challenges that come with siting USSE. Because many of these potential sites were previously occupied, transmission systems may already be present for some RE-Powering sites. Wildlife threats induced by typical utility-scale solar may also be reduced. Because these potential RE-Powering sites are likely to be heavily contaminated, wildlife is less likely to reside in these areas. Additionally, contaminated lands such as mining sites have already caused habitat fragmentation and biodiversity loss [34]. This may mean that new developments of USSE on such lands are likely to not cause further ecological degradation. Contaminated lands are also not desirable to live on or near them, so the likelihood of negatively affecting indigenous communities may be reduced. Purchasing unappealing land may be cheaper, making the investment of USSE development on RE-Powering sites less costly.

Purpose

The primary purpose of this study is to determine an approximation of the potential PV electricity that could be generated through RE-Powering sites within Idaho Power's service area in the state of Idaho. This study also measures the possible quantitative impact that the usage of these RE-Powering would have on CO2 levels. This study may be helpful for Idaho Power and policymakers in expanding the solar energy supply at the state level in Idaho and general education on utility-scale solar energy. The study will not analyze the solar potential in Idaho Power's additional service territory in the eastern Oregon region.

Methods

General Overview

To estimate the solar potential in Idaho Power's service area in Idaho, I filtered the potential RE-Powering sites from the RE-Powering Mapper 3.0 into ones that were within Idaho state borders and considered to be viable for utility-scale PV through filter options on the mapper. To see which sites were within Idaho Power's service area, I cropped the service area and overlapped it onto a screenshot picture of the potential utility-scale PV sites within Idaho borders from the RE-Powering Mapper. I searched for the values of potential PV capacity (MW) that were provided by the RE-Powering Mapper 3.0 for each utility-scale PV site within Idaho Power's service area in Idaho. Each site's name and its potential PV capacity were recorded in a table. I calculated the electricity that could be generated in a year in MWh for each site by quantitatively accounting for the number of peak sun hours and the number of sunny days in the major Idaho cities that Idaho Power encompasses. Because sloped land is less feasible for USSE development, I verified that the data presented in the RE-Powering Mapper 3.0 had already accounted for this factor.

Finding Possible Utility-Scale PV Sites Within Idaho Power Service Area in Idaho

The potential RE-Powering sites were first filtered on the RE-Powering Map 3.0 [28] to show only Idaho sites that could support utility-scale PV using the filter options "State" and "Solar Type". Both the RE-Powering Map 3.0 and Idaho Power's service area [35] were screenshotted when the maps' scale indicators represented 100 km. By using Adobe Photoshop Software [36] on the screenshots, I matched the scale indicators of both maps to each other in terms of the number of pixels and the maps were thus altered to have matching land area distances per pixel dimension. The Idaho Power service area was then cropped and pasted onto the RE-Powering map and the service area layer was made transparent to be able to clearly see the RE-Powering sites (Figure 1).

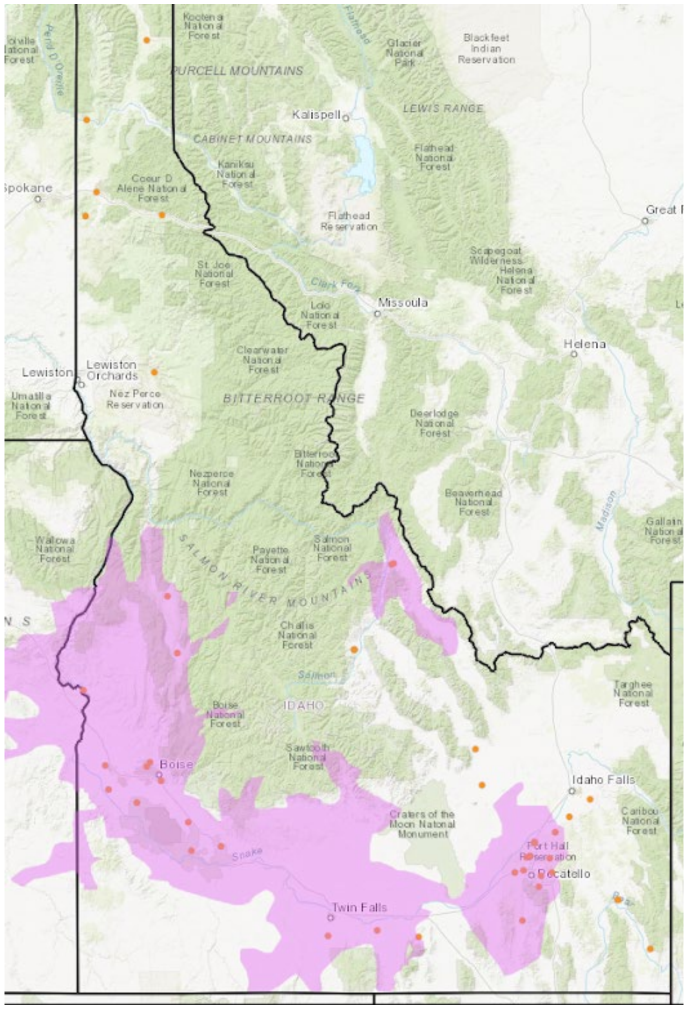

Figure 1. An overlay of Idaho Power's service area (magenta-colored) over the state of Idaho on the EPA's RE-Powering Mapper 3.0, which was filtered to only show utility-scale PV sites in Idaho. The orange dots represent potential RE-Powering sites that are suitable for utility-scale solar energy. Many dots may appear to be overlapped and may not be completely distinguishable in this figure. To zoom in to see each site more clearly, visit EPA's RE-Powering Mapper 3.0 [28].

Accounting for Factors that may Affect PV Performance

Factors that affect the ability for solar panels to receive photons from the sun were accounted for mathematically in order to provide the most reliable estimation of the annual electricity that could be provided by the potential RE-Powering utility-scale PV sites.

Shade and hours of sun a day were the factors mainly accounted for, as they are factors that are not controllable during maintenance. The average number of peak sun hours in a day in Idaho is 4.92 hours [37]. Although accumulation of dust, shade, and bird foul have significant effects on harvested PV energy, with shading conditions the strongest inhibitor in PV performance [38], dust and bird foul may be cleaned off through proper maintenance, so only shade would be accounted for out of those factors in this study.

I first calculated an average of the number of sunny days in major Idaho in order to only evaluate days that would be the most optimal for PV performance. The four major cities covered by the Idaho Power service area map in Idaho are Nampa, Boise, Twin Falls, and Pocatello. These cities have 210 [39], 210 [40], 210 [41], and 204 [40] days of sun in a year, respectively. The average of these values was taken, resulting in

208.5 days of sun. This number was rounded to 209 days of sun per year when used for the calculations for this study.

The ideal topology for large, utility-scale solar farms is flat, cleared land. The data presented in the RE-Powering Mapper 3.0 was assumed to have already accounted for sloped land, because the listed renewable energy potential in each RE-Powering site follows criteria from the National Renewable Energy Lab (NREL) [28]. NREL's study for U.S. renewable energy potential excludes areas that have slopes greater than or equal to 3% for both urban and rural utility-scale PV [42]. Thus, the less optimal land for USSE was also accounted for in this study.

Calculating Electricity Generation from PV Per Year

To calculate the electricity generated in MWh annually for each site, the formula below was used:

Formula 1.

$$E_{annual} = C_{PV} \times t_{peak} \times d_{sunny}$$

where:

- E_{annual} is the electricity generated per year (MWh)
- C_{PV} is estimated PV Capacity (MW)
- t_{peak} is average peak sun hours each day
- d_{sunny} is the average annual sunny days

Formula 1 was used in order to calculate an annual electric generation from the potential USSE RE-Powering sites in Idaho Power's service area within Idaho borders. By multiplying the estimated PV capacity by the average peak sun hours, a rough estimate of electricity produced in a day in megawatt-hours is given. To find an annual number for electricity output, average days of sun every year were multiplied.

Table 1. Electric Potential of RE-Powering Sites within Idaho Power's Idaho Borders

Site Name	**Estimated PV Capacity (MW)**	**Electricity Generated per year (MWh)**
Riverfront Park	5.07	5.21E+03
South Log Yard	5.8	5.96E+03
Ada County Landfill	21.74	2.24E+04
Hewlett Packard Inc. (HPI) Boise Campus	28.88	2.97E+04
Wabtec Motivepower	5.22	5.37E+03
Pickles Butte SLF	7.97	8.20E+03
Caldwell Downtown Area 2	7.39	7.60E+03
Simco Road Regional Landfill	117.39	1.21E+05
Mountain Home Air Force Base	600	6.17E+05
Bennett Road Landfill	115.94	1.19E+05
Hub Butte Landfill	18.41	1.89E+04
Milner Butte Landfill	20.29	2.09E+04

Albion Normal School and Campus	5.98	6.15E+03
Fort Hall Community District Lodge, Buffalo Lodge	5.8	5.96E+03
Brent Cleaves	5.8	5.96E+03
Lincoln Creek Community Building	5.8	5.96E+03
Gibson District, Eagle Lodge	5.8	5.96E+03
Eagle Lodge	5.8	5.96E+03
FMC Idaho LLC	210.14	2.16E+05
Eastern Michaud Flats Contamination	600	6.17E+05
Fort Hall Mine Landfill	12.17	1.25E+04
RPR3849001602 Bareground Property	8.7	8.95E+03
Miller Property	92.75	9.54E+04
Putnam Lodge Ross Fork District	5.8	5.96E+03
Bannock Creek Community Center	5.8	5.96E+03
Former Sunnyside Feedlot	10.97	1.13E+04
Lemhi County Landfill 1	5.8	5.96E+03
Lemhi County Landfill 2	24.64	2.53E+04
TOTAL	1935.41	2.02E+06

Results

Total Electricity Potential from PV in RE-Powering Sites

The summed total for estimated electricity generated per year at Idaho RE-Powering sites in Idaho Power's service territory that support utility-scale PV is 2.02×10^6 MWh, or 2.02×10^9 kWh. The following quantitative comparisons will be based off of this total in kilowatt hours.

Carbon Dioxide Reductions

Coal plants have CO2 emissions per kWh within the range of 0.91 to 0.95 kg/kWh [43]. 0.91 kg/kWh was used in the mathematical comparison for the sake of conservatism. If the solar from the Idaho RE-Powering sites replaced coal on a one-to-one basis, these RE-Powering sites would reduce CO2 emissions by 1.84×10^9 kg. This value was calculated by:

$$.91 \frac{kg}{kWh} \times (2.02 \times 10^9)\ kWh$$

CO2 emissions from natural gas are 0.41 kg/kWh [44]. If the solar from the Idaho RE-Powering sites replaced natural gas on a one-to-one basis, these RE-Powering sites would reduce CO2 emissions by 8.3×10^8 kg, which was calculated by:

$$.41 \frac{kg}{kWh} \times (2.02 \times 10^9)\ kWh$$

Significance for Utility

Idaho Power has approximately 600,000 customers in its service area, including east Oregon [45]. On average, an electricity customer in Idaho uses 13,332 kWh in a year [46], meaning that Idaho Power customers as a whole would likely consume around 8×10^9 kWh in a year. If all of the Idaho Power service territory RE-Powering sites were used for solar installations, the total energy potential in these sites would account for approximately 25% of Idaho Power's electricity load. This percentage was calculated by:

$$\frac{2.02 \times 10^9 kWh}{600{,}000\ customers \times 13{,}332\ kWh} \times 100$$

Conclusion

The adoption of USSE is rising in popularity because of its extremely affordable cost and its clean energy generation, but despite these appealing benefits, siting USSE still encounters a few obstacles.

The availability of nearby transmission networks may become a monetary concern if more networks need to be built near the new USSE in order to connect the generated electricity to the electrical grid. However, an investment in building more transmission networks may be still worthwhile because this investment cost is only a small fraction of the total costs in siting new USSE and money may be easily made back through economies of scale.

Because USSE will typically occupy large areas of land, this characteristic poses multiple challenges to siting solar. Habitat fragmentation and general harm to wildlife has been a result of several new USSE projects. Building new solar farms may also face conflicts with indigenous land and communities, especially when siting USSE destroys wildlife and lands that are of cultural significance. Additionally, it is very possible that many suitable areas for USSE conflict with indigenous land because of the historical relocation of indigenous people onto dry, arid, and infertile lands.

Siting USSE may be less challenging when partaking in EPA's RE-Powering Initiative because repurposing contaminated lands into large scale solar farms may lessen the likelihood of encountering challenges and negative impacts that come with typical USSE implementation. The multitude of potential RE-Powering sites in Idaho Power's Service area, within Idaho borders, that are optimal for utility-scale solar was collectively estimated to be useful for the utility, customers, and greenhouse gas reductions.

However, adding every potential RE-Powering site listed in this study into Idaho Power's solar energy portfolio in a short period of time is unrealistic due to large costs that may burden customers and generation capacity from coal and natural gas that public utilities commissions would prefer not to waste. The details of such policies are outside of the scope of this paper, but there are reasons and incentives that policymakers have when restricting the construction of utility-scale solar farms.

This study is useful in the context of Idaho Power's 20 year plan for solar implementation because potential RE-Powering sites for USSE have been evaluated and may be better options for siting solar than other potential sites. Selecting potential RE-Powering sites may reduce costs associated with building more transmission networks, threats to wildlife, and disrespect towards indigenous land and communities. This is not to say that evaluations regarding the aforementioned challenges should not be conducted. However, solar farm developers will encounter fewer obstacles with RE-Powering sites which will accelerate the process of solar siting.

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