

# Renewable Energy Siting Predictors Observed from National Data for Wind and Solar (RESPOND Wind and Solar)



Source: Pixabay

## Authors:

Desik Somasundaram, Master of Environmental Data Science Student, Bren School of Environmental Science and Management, [desik@bren.ucsb.edu](mailto:desik@bren.ucsb.edu)

Joe DeCesaro, Master of Environmental Data Science Student, Bren School of Environmental Science and Management, [jdecesaro@bren.ucsb.edu](mailto:jdecesaro@bren.ucsb.edu)

## Client:

Dr. Grace Wu, Assistant Professor, Environmental Studies Program, UC Santa Barbara, [gracecwu@ucsb.edu](mailto:gracecwu@ucsb.edu)

## Faculty Advisor:

Dr. Ranjit Deshmukh, Assistant Professor, Environmental Studies Program, UC Santa Barbara, Affiliate, Bren School of Environmental Science and Management, [rdeshmukh@ucsb.edu](mailto:rdeshmukh@ucsb.edu)

## **OBJECTIVES**

The primary question that we seek to answer in this project is “What criteria best explain patterns of wind and solar power plant siting?” using logistic regression and machine learning approaches. The objective is to assist the client, Dr. Grace Wu, to expand a previously piloted study in the Western US by improving the statistical rigor of the analysis and the geospatial extent of the study to the entire US and a few other countries with readily available data. Variables that will be evaluated as potential predictors include: environmental sensitivity, land leasing or acquisition value, distance to the nearest road, slope, population density, socioeconomic indicators like median household income, distance to the nearest substations or transmission line, capacity factor, natural hazard risks, and renewable energy targets. To summarize, the objectives of this analysis are to:

1. Identify the historic drivers of wind and solar power plant siting
2. Evaluate the relationship of renewable energy siting with transmission, various socio-economic indicators, and local climate and other policies
3. Help policymakers and other stakeholders better understand the drivers of renewable energy siting
4. Leverage the results in future planning studies to spur rapid renewable energy development in a more equitable, sustainable, and deliberate manner

## **SIGNIFICANCE**

The deployment of renewable energy in a timely fashion to mitigate climate change is one of the greatest challenges facing the world today. There is significant pressure to achieve the increasingly prevalent, highly ambitious clean energy goals. Even where physical conditions are well suited for renewable energy, there is often significant variation in their potential and use (Pierce et al. 2021). Government policies have been shown to play a crucial role in accelerating renewable energy deployment (Shrimali and Kniefel 2011). However, without understanding the relationships between renewable energy development and local or regional siting criteria, clean energy policies could result in unintended consequences or end up being less effective. For example, there are concerns about the potential ecological impacts due to utility-scale solar and wind installations. Many of these concerns can be alleviated by avoiding ecologically sensitive areas through integrated land use and energy planning (Wu et al. 2020). This project could show whether siting practices have been in line with the intentions to minimize ecological harm. Similarly, there are concerns about whether property-value could be negatively impacted as a result of utility-scale solar and wind (Gaur and Lang, 2020; Dröes and Koster 2021). For example, it is unknown whether wind and solar have been disproportionately sited in lower income communities due to concerns about reducing property-values in higher income communities. Understanding the relationship between renewable energy siting and socioeconomic indicators could provide insight on whether aggressive clean energy development has been equitable.

## **BACKGROUND**

Based on the client’s literature review, there is currently a considerable knowledge gap on the topic of renewable energy siting predictors and potential explanatory variables. The client conducted a pilot study creating a prediction or probability map for future onshore wind and solar farms based on existing wind and solar farm locations in the 11 western states and various explanatory variables such as: environmental score, land value, roads, slope, population density, substations, transmissions lines, capacity factor, and renewable energy mandates. With the existing methodology being robust and well-tested, there is opportunity to expand this study to include other critical socioeconomic indicators

and other factors such as historical records of natural hazards based on the project team’s interests. One of the key limitations causing the pilot study to be limited to 11 western US states was the availability of the environmental sensitivity dataset. This dataset is anticipated to become available for the entire US by the project start date. Additionally, because the Midwestern states have among the greatest wind potential in the US, a study that includes this region in the US would have significant value for understanding wind siting trends nationally.

The pilot study downscaled electricity generation capacity expansion portfolios for onshore wind, offshore wind, utility-scale solar, urban infill solar, bulk transmission lines, and spur lines. Each portfolio’s annual energy generation by technology is spatially aggregated and reported at the state level (and by resource class bin for certain technologies). The goal of downscaling is to model the physical build-out of these portfolios by identifying or selecting specific locations where infrastructure projects could or are likely to be sited. The study downscaled onshore wind and utility-scale solar using the following three approaches: total levelized cost of electricity (generation and transmission), random forest, and logistic regression.

Random forest and logistic regression are both classification approaches. Both methods require a response variable that captures where solar or wind power plants do and do not exist—otherwise known generally as presence and absence locations. The pilot study generated these pseudo-absence “background” locations by randomly sampling points from within the suitable sites for wind and solar development (after removing the footprints of existing wind or solar farms), which represent locations where wind or solar farms could be sited but are not currently sited. Because some siting criteria (explanatory variables)—substation, transmission lines, roads, and population—vary over time, the pilot study limited the analysis to existing power plants built in or after 2018 within the 11 western states and used explanatory variable datasets representing the year 2017. This project could further expand this analysis temporally by including a combination of more historical data and newly available data. Therefore, this project will serve as a crucial stepping stone to filling the existing knowledge gap by expanding the geographic extent and increasing the statistical rigor of the findings from the pilot study.

**EQUITY**

By fulfilling the project objectives, the project will provide actionable insights on the potential social inequities resulting from the renewable energy siting process.

**AVAILABLE DATA**

Table 1: Data Sources for Explanatory variables

<b>Variable</b>	<b>Source</b>
Environmental score	Available from <a href="#">The Nature Conservancy for Western states</a> , and the rest of the US should be available through a non-disclosure agreement by January 2022.
BLM land value	<a href="#">BLM transmission land value</a> (Shapefiles available to client)
Roads	<a href="#">Census TigerLine 2017</a>
Slope	Derived from <a href="#">digital elevation model SRTM</a>

Variable	Source
Population density	<a href="#">LandScan 2017</a>
Substations	<a href="#">Ventyx - 2017 or HIFLD</a>
Transmission lines	<a href="#">Ventyx - 2017 or HIFLD</a>
Capacity factor	<a href="#">NREL WIND toolkit</a> ; Solar capacity factors will need to be generated using SAM (System advisory model) and NSRDB python API
Renewable Portfolio Standard or target	<a href="#">NCSL Website</a>
Existing wind farm locations	<a href="#">US Wind Turbine Database</a>
Existing solar farm locations	<a href="#">EIA</a>

## POTENTIAL APPROACHES

The previously conducted pilot study for the western US will be used as a foundation for our approach. The objectives of the project will be fulfilled by integrating the aforementioned datasets into a geospatially weighted statistical analysis including the following classification approaches:

1. **Geographically Weighted Logistic Regression:** Logistic regression is a standard statistical approach for binary classification and is often used for understanding explanatory variables. This analysis will yield statistical correlation coefficients along with the associated confidence level for the variables examined.
2. **Random Forest Machine Learning:** Random forest is considered a machine learning approach based on decision trees and is primarily used for prediction. The results of the logistic regression analysis will be used to “predict” the potential future build-out of wind and solar power plants of scale for the US and presented in the form of maps. An example map created from the pilot study is available in the Supplemental Materials section.

All necessary data processing and analysis can be conducted solely in R or Python so a combination of the two programming languages can be used. To contextualize and calibrate the findings of the project, our group will attempt to reach contacts at the leading renewable energy developers and survey key characteristics that the developers consider when siting their renewable energy projects. This would help understand the strengths and gaps of our study’s approach and make it more relevant for policymakers.

## DELIVERABLES

In addition to the final poster presentation, the following deliverables will included:

- **Final Report:** The key components of the report include an introduction, methods, results , and discussion sections.
- **Maps:** Visualization of the analysis (prediction maps) will be presented as professional-quality maps.
- **GitHub Repo:** A publicly-available GitHub repository of the analysis conducted will be shared with the client.
- **R Shiny (Stretch Goal):** An interactive R Shiny map will be created to display where wind and solar plants may be sited to reach a certain generation target in jurisdiction.

## SUPPORTING MATERIALS

### CITATIONS

Dröes, Martijn I., and Hans R. A. Koster. 2021. "Wind Turbines, Solar Farms, and House Prices." *Energy Policy* 155 (August): 112327. <https://doi.org/10.1016/j.enpol.2021.112327>.

Gaur, Vasundhara, and Corey Lang. 2020. "PROPERTY VALUE IMPACTS OF COMMERCIAL-SCALE SOLAR ENERGY IN MASSACHUSETTS AND RHODE ISLAND," 46.

Pierce, John C., Rachel M. Krause, Sarah L. Hofmeyer, and Bonnie J. Johnson 2021. "Explanations for Wind Turbine Installations: Local and Global Environmental Concerns in the Central Corridor of the United States?" *Energies* 14, no. 18: 5830. <https://doi.org/10.3390/en14185830>

Shrimali, Gireesh, and Joshua Kniefel. 2011. "Are Government Policies Effective in Promoting Deployment of Renewable Electricity Resources?" *Energy Policy* 39 (9): 4726–41. <https://doi.org/10.1016/j.enpol.2011.06.055>.

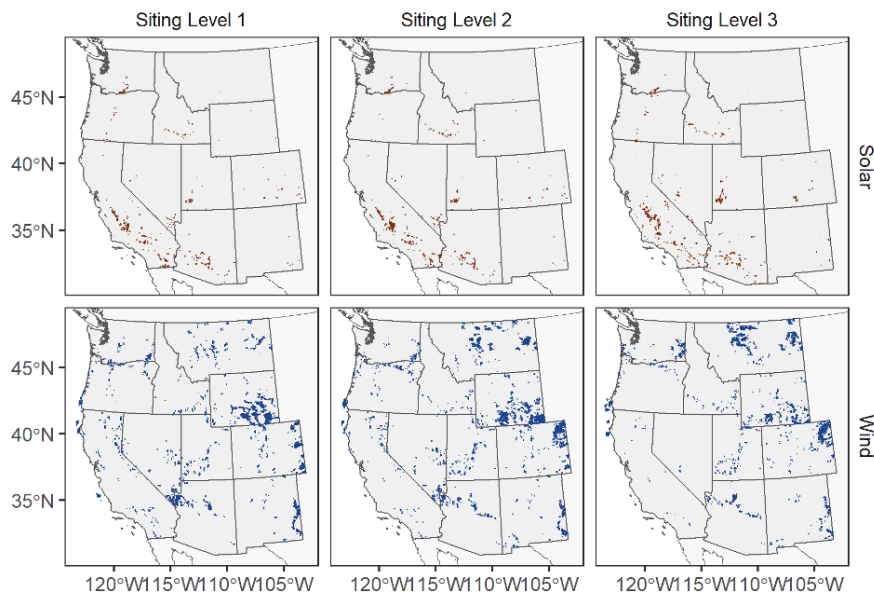
Wu, Grace C., Emily Leslie, Oluwafemi Sawyerr, D. Richard Cameron, Erica Brand, Brian Cohen, Douglas Allen, Marcela Ochoa, and Arne Olson. 2020. "Low-Impact Land Use Pathways to Deep Decarbonization of Electricity." *Environmental Research Letters* 15 (7): 074044. <https://doi.org/10.1088/1748-9326/ab87d1>.

### BUDGET

All datasets and tools are available online free of cost, therefore this project will not require any additional funding. Each student will receive \$50 from the Bren School to manage basic operations and printing for the project and will only be accessible by students. Project groups are expected to be 3-4 students for a total budget of \$150-200. Students will determine how to allocate funds. If additional funding is required for expenses such as software or tools it will be provided by the client.

### ADDITIONAL INFORMATION:

Figure 1: Western US Pilot Study - Predicted Future Build-Out Map based on environmental siting levels





## Client letter of support

To: Group project committee for the Bren MEDS program

Re. Letter of support for the Renewable Energy Siting Predictors Observed from Data for Wind and Solar (RESPOND Wind and Solar) project

---

I am writing to express my enthusiastic support for the proposed MEDS capstone group project. The results of this project can significantly improve our understanding of patterns of wind and solar power plant siting in the US. With this understanding, studies examining climate and clean energy policies can produce much improved estimates of social and environmental impacts of the renewable generation infrastructure required under those policies. Energy planners (regulators, utilities) can also use the results of the study to design more effective incentives to encourage lower impact projects and better align generation and transmission planning.

I believe this proposal has many qualities that would ensure a successful outcome for both the student team and myself as the client. As designed, the project provides an opportunity for the student team to learn and apply a variety of highly practical data science skills--machine learning, spatial analysis, and regression techniques. The research questions posed allow students to gain familiarity with some of the key concepts and terminology in wind and solar infrastructure planning, and thus are highly relevant for students seeking careers in the clean energy industry. Additionally, through my ongoing collaboration with The Nature Conservancy (TNC), I have access to unique pre-release spatial environmental datasets, land acquisition cost data, as well as historic electricity infrastructure data. I would be able to immediately apply the results of this proposed project in an ongoing study with TNC exploring the social and ecosystem impacts of net zero pathways for the US.

I am excited to work with the student team on this proposal. While I have the subject matter expertise and some of the data science skills to help guide the team, I am really looking forward to learning from the students and developing opportunities for them to explore their own research interests through this project.

Thank you for the consideration,

A handwritten signature in black ink, appearing to read "Grace Wu".

Grace Wu  
Assistant Professor, Environmental Studies, UCSB  
gracecwu@ucsb.edu