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Identifying Optimal Wind and Solar Co-location Sites in the United States

CLIENT

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PREPARED BY

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OBJECTIVES

Wind and solar projects are sprouting up across the United States at an accelerated rate, but a gap still exists between renewable electricity infrastructure projects and local, regional, and federal decarbonization goals. We seek to explore how hybrid wind and solar plants could play a role in the U.S. clean energy transition. With this project, we aim to answer the primary question; **what is the scale of wind and solar co-location potential in the United States?**

The project will address this question by using available meteorological wind speed and solar radiation data from the last three years, modeling solar photovoltaics (PV) and wind energy output capacities, constructing a simple linear optimization program, and factoring additional siting criteria to:

- Quantify how much solar PV and battery capacity can be retrofitted in existing wind farms in the US without transmission upgrades
- Establish the optimal ratio of wind to solar PV capacity and transmission sizing that minimizes curtailment and maximizes transmission usage
- Identify optimal locations for wind-solar colocated plants in the US based on transmission efficiency in addition to demographic, recent federal IRA incentives, and environmentally sensitive land use criteria

SIGNIFICANCE

As the United States aims to reach the monumental goal of a carbon-free electricity sector by 2035, reliance on renewable energy will inevitably increase [1]. PV and wind are two proven renewable energy technologies that will be deployed in vast, unprecedented quantities to meet these climate goals. Combining wind and solar power generation at one location is a solution that makes use of existing infrastructure and technology, while providing significant financial benefits. Studies have found that key financial benefits of wind and solar co-siting include reduced permitting time due to a common grid connection point and substation, and reduced capital investment by adding solar to existing wind generation sites [2] .

Other crucial benefits include increased efficiency in land use and a reduction in transmission requirements which can significantly speed up deployment rates given the challenging permitting and long lead times of transmission projects (5-10 years). Analyzing the potential scale of wind and solar colocation in the United States is a starting point for energy suppliers, policymakers, academic institutions, and advocates to confirm colocation viability and utilize it as a tool in their arsenal to fight climate change.

BACKGROUND

Colocated wind and solar power plants have proven successful in China, Australia and India; however these technologies have yet to emerge at scale in the United States [3]. There is only one known small-scale wind and solar hybrid system in the US installed in 2018 and located in Minnesota [2].

While historical concern for these co-location sites questioned if shading of the PV modules by the wind turbines resulted in solar PV generation losses, it has since been determined that the shading losses are negligible [3]. The other question as to whether flicker of the wind turbines affects solar generation has not been an industry concern from the existing colocated wind and solar plants as no reports or investigations have been conducted on this topic. To date, most of the recent literature addresses single hybrid wind and solar sites [4]. Thus, the proposed project's objective aims to address a missing factor in the literature and quantify how colocated wind and solar sites can be scaled and implemented most effectively in the US.

EQUITY

Part of this project is analyzing which sites are optimal for co-located wind and solar based on the federal Inflation Reduction Act (IRA) incentive policies in order to encourage just renewable energy developments. By analyzing the IRA data, the project will identify sites and promote projects that are located in certain areas where unemployment rates are above the national average or adjoining census tracts in which coal-powered infrastructure has been recently retired [5]. The project can also identify sites that qualify for additional investment tax credits for being located in low-income communities or on federally-recognized Indigenous land and help encourage development to support these communities [5].

DATA

Table 1: Data Sources

Parameter	**Source**
Existing Wind Turbines in U.S.	US Wind Turbine Database (USWTDB)
Environmental Sensitivity of Land Use	Nature Conservancy Data
Existing Transmission Lines in U.S.	Homeland Infrastructure Foundation Level Database (HIFLD)
Meteorological Wind Speeds	National Renewable Energy Lab (NREL) Wind Toolkit
Meteorological Solar Radiation	NREL National Solar Radiation Database (NSRDB)
Land Use	National Land Cover Data (NLCD)
Brownfield Location	EPA Re-powering America's Land
Demographics	US Census Data
Inflation Reduction Act Energy Communities	Resources for the Future (RFF)

COMPUTATIONAL TOOLS

To effectively complete our objectives, we will use the following computational tools:

- Programming Tools: RStudio, VS Code, JupyterLab & Github, specifically the pyomo optimization package in python
- Modeling Tool: System Advisor Model (SAM), a technology and economic modeling tool which will be used in this project to model the solar and wind output capacities based on the meteorological data. This tool is provided for public use, free of charge by the NREL.
- Optimization & Processing Tools: Gurobi, free solver, or NEOS, free server available for optimizer tools, in addition to the Bren Server "Taylor".

POSSIBLE APPROACHES

The below approaches were developed from discussions with Dr. Wu and builds upon some of the datasets, code, and programs she has previously utilized. We plan to pilot the outlined approach for existing wind sites to retrofit with solar and then use the applied methods to identify new wind and solar hybrid sites in the US.

- Data acquisition:
    - Extract time series data using the existing API for the solar meteorological data, provided by client, and update the code to download the wind meteorological data
- Data analysis:
    - Identify suitable retrofit sites by screening the existing wind locations for environmental sensitivity
    - Use the SAM modeling tool to estimate hourly wind and solar generation using the downloaded meteorological data
    - Determine the optimal mix of wind and solar that minimizes curtailment using the optimizer tool of choice
    - Identify key colocation sites using curtailment reduction and transmission sizing metrics
    - Evaluate identified sites with additional siting metrics to examine how other influential factors interact with identified colocation sites
- Data visualization:
    - Generate clear tables, maps, and graphs outlining the findings of the project

DELIVERABLES

In addition to the design plan, technical documentation, and oral presentations the project will include:

- Final Report
- Data Visualizations: Maps representing ideal co-location sites in the U.S. and optimal mixes of wind and solar in each potential project location or existing wind farm
- Github Repository: Detailing the project code and methods

  Stretch Goals:
    - Dashboard: Interactive map that allows users to toggle different layers of analysis in determining optimal co-location sites in the United States
    - Analysis and visualization on the transmission cost reductions associated with colocation versus single technology siting and on the role batteries play in minimizing curtailment losses in colocation sites

AUDIENCE

The deliverables for this project can be used by policymakers and regulators, project developers, load-serving entities, system operators, academic institutions, and clean energy advocates to steer wind and solar co-location projects implementation within the US while reducing land use needs and infrastructure requirements with potential to improve grid resilience and economics.

CITATIONS:

[1] The White House, Executive Office of the President. President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability[Press briefing]. 8 Dec. 2021.
https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/

[2] Vasiliki Klonari, Daniel Fraile, Raffaele Rossi, Michael Schmela. Exploring the Viability of hybrid wind-solar power plants[J]. 4th International Hybrid Power Systems Workshop, Crete, 2019.
https://hybridpowersystems.org/crete2019/wp-content/uploads/sites/13/2020/03/3A_1_HYB19_063_paper_Klonari_Vasiliki.pdf

[3] David Ludwig, Christian Breyer, A.A. Solomon, Robert Seguin. Evaluation of an onsite integrated hybrid PV-Wind power plant[J]. AIMS Energy, 2020, 8(5): 988-1006. doi: 10.3934/energy.2020.5.988.
https://www.aimspress.com/article/id/5f859256ba35de64f8a67487

[4] O. Lindberg, J. Arnqvist, J. Munkhammar, D. Lingfors. Review on power-production modeling of hybrid wind and pv power parks J. Renew. Sustain. Energy, 13 (4) (2021), Article 042702.
https://aip.scitation.org/doi/abs/10.1063/5.0056201

[5] Inflation Reduction Act of 2022. Pub L. 117-169. 16 Aug. 2022. Stat H.R. 5376.
https://www.congress.gov/bill/117th-congress/house-bill/5376/text

BUDGET & JUSTIFICATION

This project has no additional budget requirements outside of the $250 allocated for capstone projects by Bren School of Environmental Science & Management.

CLIENT LETTER OF SUPPORT

See below

UC SANTA BARBARA

Environmental Studies Department
Bren Hall, Santa Barbara, CA 93106

Client letter of support

To: Group project committee for the Bren MEDS program
Re. Letter of support for MEDS project proposal on wind-solar colocation potential

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I am writing to express my enthusiastic support for the proposed MEDS capstone group project led by Michelle Lam and Colleen McCamy. The project leverages existing publicly available datasets to examine the scalability of benefits in co-locating wind and solar in the US, an understudied renewable energy siting strategy that has the potential to reduce siting barriers, land use impacts, and transmission requirements. As the need for clean electricity grows 5-10 fold over the next three decades, power plant and transmission siting—the ability for places to accommodate these new infrastructure projects—will become one of the greatest challenges for meeting decarbonization goals in the US. The study seeks to quantify 1) the amount of cost-effective solar PV capacity that can be retrofitted in existing wind farms in the US and 2) the optimal locations for new wind-solar colocated plants in the US that maximize transmission usage.

Importantly, the results of the first objective could identify a significant 'no regrets' opportunity for quickly and cost-effectively developing utility-scale solar PV projects in the US by avoiding the transmission, road, and permitting costs and siting barriers associated with developing a new project. Project developers and energy planners (regulators, utilities, system operators) could use the results of this study to guide project procurement choices and areas to encourage further transmission investments.

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 the opportunity to work with a large variety of temporal and spatial datasets: high resolution times series meteorological data of wind speeds and solar radiation, spatial locations of existing wind farms and transmission infrastructure, raster data on various siting metrics (environmental sensitivity data, land use and land cover). The proposed approach will combine several analytical tools commonly used by renewable energy planning analysts. Students will gain familiarity with using APIs for accessing large quantities of solar and wind data stored on the cloud. Additionally, students will work with a free and open access software for simulating solar and wind generation using time series data–-and how to scale up and automate simulations across a large number of sites. They will develop a manageable linear optimization program to identify the optimal mix of PV and wind and transmission size that minimizes curtailment of generation. Lastly, the research questions posed allow students to gain familiarity with some of the key metrics in wind and solar infrastructure planning (e.g., curtailment, transmission sizing), and thus are highly relevant for students seeking careers in the clean energy industry.

UC **SANTA BARBARA**

I would be excited to work with the student team on this proposal. I have worked with several of the datasets the students will be using in this proposed and have experience using some of the needed analytical tools. However, I look forward to learning from the students on designing several novel aspects and developing opportunities for them to explore their own research interests through this project.

Thank you for the consideration,

Grace Wu
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