# A Data-Driven Approach to Evaluation Hybrid Solar-Wind Systems in the U.S.

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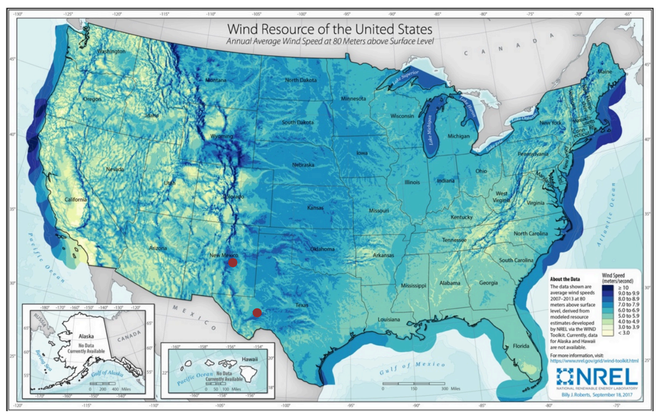
## Abstract

This study explores the potential of hybrid solar and wind renewable energy systems in the United States, focusing on two specific locations in the Southwestern region of the country: Vaughn, New Mexico and Fort Stockton, Texas. Using Python I created random forest regression models to predict power output from solar and wind energy at each of the two locations. The results indicate that both locations demonstrate strong potential for hybrid renewable energy, with different seasonal patterns for power output.

## Hybrid Energy

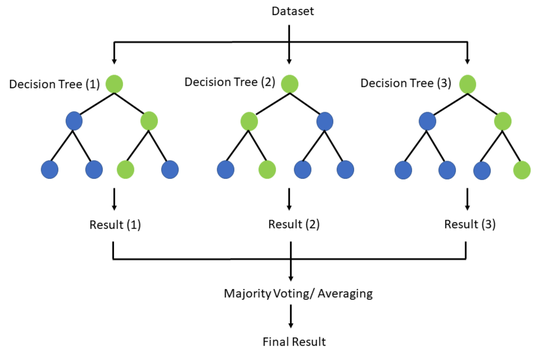
- Hybrid energy combines different energy sources such as wind and solar into a single energy solution.
- Using multiple sources can result in higher efficiency and/or grid stability.
- For this project specifically, differences in the seasonality of energy production for solar and wind at each of the two locations was a main focus.

## Geographic Data




- I used resources published by the NREL for location selection and the historical data needed for modeling (Sengupta et al. 2018)
- To choose the two locations, I took this map and a similar one for solar irradiance and found two sites that displayed strong solar and wind resources.
- Downloaded wind speed and Global Horizontal Irradiance data from 2018, 2019, and 2020.

## Random Forest Regression




- Random forest regression combines predictions of multiple decision trees. Each tree is its own model and is trained on a random subset of data.
- Fourier transforms were used to help the model capture the cyclical seasonality present in geographic data such as wind speed and GHI.

## Power Conversions

$$y = \frac{4301.07}{1 + e^{-(0.83x - 6.17)}}$$

- For wind power, a Vestas V-150 4.2MW was assumed, with a power curve that fits the equation above.
- For solar power, power conversions were done with the equation below, where predicted GHI values, represented below as *H* were plugged in and the other values assumed based on a similar study.

$$E = A \cdot r \cdot H \cdot PR$$

## Hybrid Power Output Predictions

| Investment | Output (1 year) |
|---|---|
| 1 Panel | 0.79 MWh |
| 300,000 Panels | 236,603 MWh |
| 600,000 Panels | 473,207 MWh |

| Investment | Output (1 year) |
|---|---|
| 1 Turbine | 11,894 MWh |
| 25 Turbines | 297,358 MWh |
| 50 Turbines | 594,717 MWh |

- Above are the hybrid power output predictions for Vaughn, NM
- Predicted GHI and wind speeds are plugged into the power conversion functions and return these values.
- Helena Energy Center in East Texas has 66 of the same Vestas turbines and 600,000 solar panels, rated 250MWac.

## Model Results

Results for the model predicting wind speeds in Vaughn, NM

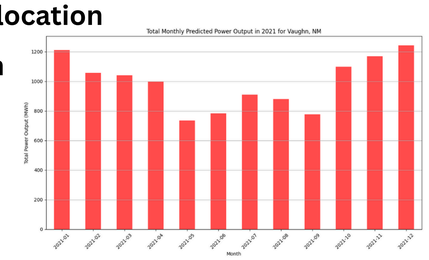
| Metric | Score |
|---|---|
| Train $R^2$ | 0.953 |
| Test $R^2$ | 0.678 |
| RSE | 2.533 m/s |
| Mean Wind Speed | 8.857 m/s |
| RSE as % of Mean Wind Speed | 28.6% |

Results for the model predicting GHI at Vaughn, NM

| Metric | Score |
|---|---|
| Train $R^2$ | 0.93 |
| Test $R^2$ | 0.85 |
| Test RSE | 124.6 W/$m^2$ |
| Mean GHI (Full Test Set) | 232.38 W/$m^2$ |
| RSE as a % of Mean GHI (Full Test Set) | 53.38% |
| Mean GHI (Daytime Only) | 469.87 W/$m^2$ |
| RSE as a % of Mean GHI (Daytime Only) | 37.51% |

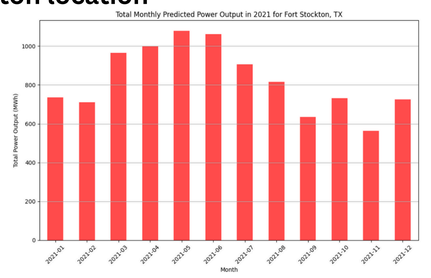
Predicted wind power output at the Vaughn location

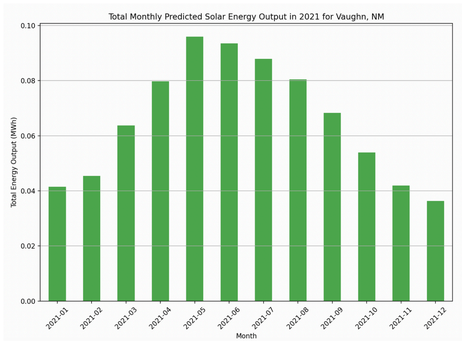
- Wind power output predictions for Vaughn show highest output during the colder months




Predicted wind power output at the Fort Stockton location

- Wind power output predictions for Fort Stockton show highest output during the spring/summer months




- The solar power predictions were nearly identical between the two locations.
- The predictions for Vaughn location are displayed in the green bar chart to the left.

## References

- Sengupta, M., Y. Xie, A. Lopez, A. Habte, G. Maclaurin, and J. Shelby. 2018. "The National Solar Radiation Data Base (NSRDB)." Renewable and Sustainable Energy Reviews 89 (June): 51-60.