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Weather Data Requirements for Planning and Modelling an Electric Vehicle Charging Station in the UK

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Abstract

Weather events such as calm, overcast periods (anticyclonic gloom) can cause renewable energy droughts and seriously disrupt green energy productivity and reliability.

This research investigates type of weather data elements and length of historical time series of data records necessary for yield simulation. The aim is to gain an accurate picture of expected output for an electric vehicle (EV) charging station over the next ten years. The case study is Marwell Zoo, and the renewable energy generators supplying the charging station are assumed to comprise one 6.2 kW wind turbine and 40 of 300 W solar panels.

Suitable models of wind and solar generation are analysed by statistical analysis.

The occurrence of resource droughts is quantified. A unique definition of energy drought, specific for the renewable generators modelled in this instance, is derived.

Preliminary results indicate one average historic year of weather data is sufficient for accurately assessing the predicted renewable energy available to the charging station. Findings can be of importance for anticipating and quantifying the risk of lack of supply.

Data and Methods

Hourly wind data was obtained for 2021 from Solcast [1], a satellite-based resource. Electrical yield was calculated by firstly converting the wind speed data from measurement height to hub height using the log law. Wind yield i.e. power (kW) was simulated by interpolation of the manufacturer's power curve [2]. (Aventa AV-7 WT power curve, rated power of 6.2 kW.) Finally, the hourly data was aggregated to daily and the capacity factor was calculated.

Hourly wind and solar panel yield data for 2011-2020 from PVGIS [3] was used. PVGIS simulates photovoltaic yield and creates an average (Typical Meteorological Year, TMY) of weather data as described in the user manual [4]. Again, hourly data was aggregated to daily.

Various methods of identifying weather patterns / energy droughts from the literature were trialled (see table in Results). These included 0.2 and 0.5 times the mean daily production of the location under study [5] and k means/hierarchical clustering.

RESULTS

Finding 1. Yield Differences between values simulated from each of ten years of weather data and ten simulations of "average" year (TMY).

Marwell System: 1 of 6.2 kW wind turbine and 40 of 300 w solar panels	
Difference between 10 times TMY and 10 years of data for combined wind and solar	-1.4%
Combined wind and solar difference in poor year	-8.0%
Combined wind and solar difference in good year	4.0%
Difference between 10 times TMY and 10 years of data for solar only	-1.4%
Solar difference in poor year	-8.3%
Solar difference in good year	4.6%
Difference between 10 times TMY and 10 years of data for wind only	3.5%
Wind difference in poor year	-3.0%
Wind difference in good year	7.0%

INFERENCE: Not much difference over entire time period. However, a single year may have larger difference.

Finding 2a. Energy Drought Detection.

Focusing on wind generation in 2021 because wind speeds reported as 15% below the annual average (The Times, The Conversation, Sky News).

Definition of Wind Drought	No. of Drought Days in 2021	Ratio	Comment
Capacity Factor (CF) = 0	3	< 1 in 100	Due to turbine cut-out at high wind speed, not drought!
< 20% of daily mean CF	14	1 in 26	**Selected this method, so far.**
< 20% of the TMY daily mean for that day of the year CF	17	1 in 21	Similar results to above.
< 50% of daily mean CF	58	1 in 6	Too many!
< 50% of the TMY daily mean for that day of the year CF	58	1 in 6	Too many!
<= first percentile of daily CF	38	1 in 10	Too many? Similar distribution to daily.
Data grouped into 3 day blocks	8	1 in 45	Similar distribution to daily.
Data grouped by week	0		Nothing detected.

Finding 2b. Energy drought detection.

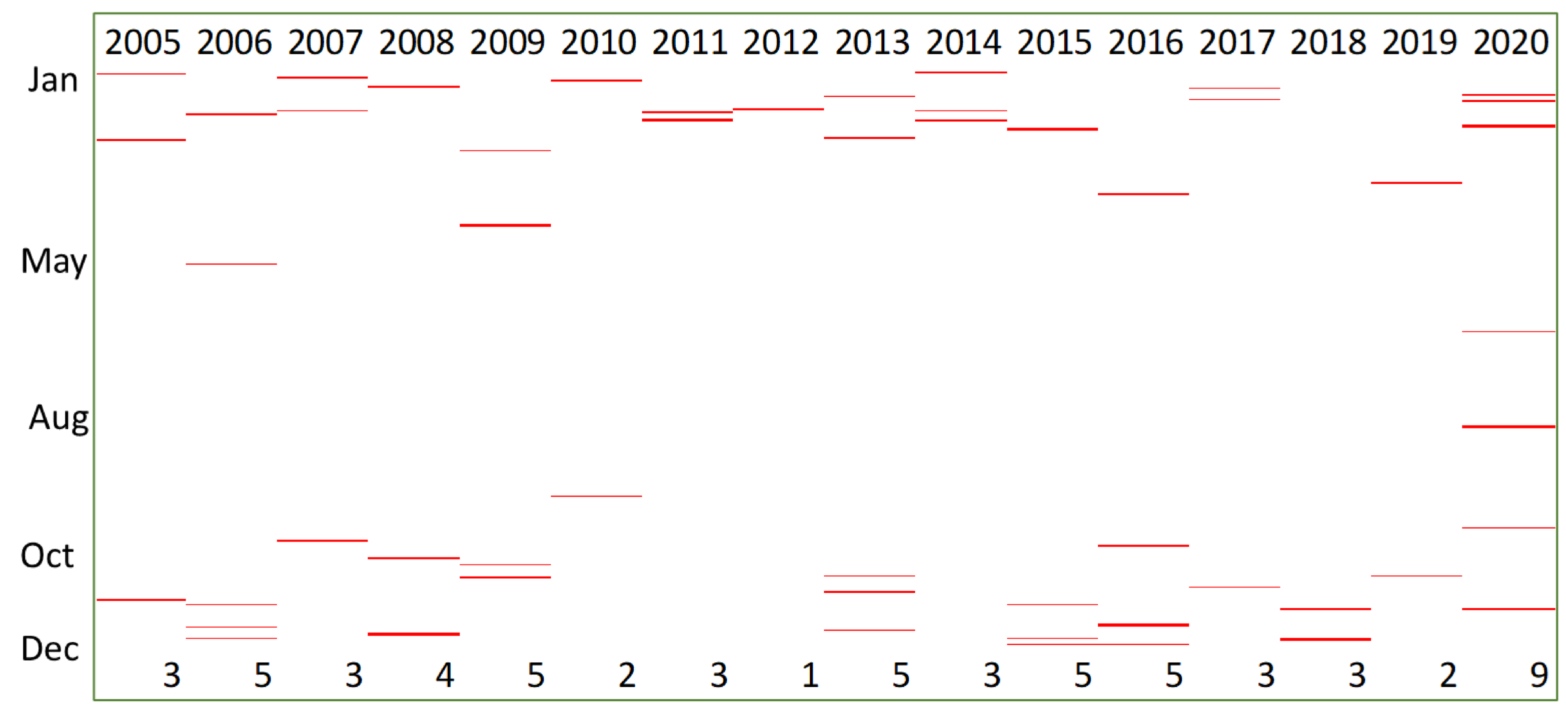
If a wind drought is detected, 2021 results should be different to TMY for Marwell 6.2 kW turbine. But defining a drought as < 20% of daily CF gives 14 days for both 2021 and TMY, albeit with a different distribution (March, May, July and September for 2021, June and October for TMY.)
INFERENCE: Wind droughts not easy to detect for a specific location. We need a precise definition, fit for our own purpose.

Finding 2b. Energy drought definition for Marwell (wind and solar combined).

Definitions tested:

- Wind and solar generation together gives no zero output days.
- < 20% of the TMY daily mean combined production for that day of the year - initial results promising, see graph below.
- K-means Clustering - disappointing, no division into groups.
- Hierarchical Clustering - groups not very distinct but results reasonable, 4-6 days detected per year 2005-2020. Needs more work.

Energy Drought Days < 20% of TMY daily mean combined production for day of the year



Total Energy Drought Days per year

No drought days between beginning of May and end of September, except for 2020

INFERENCE: Energy droughts at Marwell generally occur in the winter. This is useful because there will be fewer visitors.

Conclusions

- One "average" historic weather year is sufficient for energy modelling for the type of EV charging station simulated in this research. This is in contrast to many previous studies which have concentrated on wind production alone, rather than combined renewable resources. Weather data for non-academic use represents a significant investment. So, reducing the number of years of data necessary for modelling yield can represent a large budgetary saving, especially if several EV sites are to be simulated.
- Energy droughts are difficult to detect, not as obvious as suggested by news bulletins. A definition of "resource drought" is derived specific to the particular needs of the case study.
- Initial results suggest EV charging station resource droughts are most likely to take place in the winter months.

Next Steps

- Group energy drought days by month and season for easier interpretation.
- Establish number of days between droughts per season.
- Examine causes of droughts e.g. turbine turned off due to high wind, lack of wind, cloud cover.
- Investigate why 2020 has more drought days. Any link to lockdown?
- Predictability of droughts – link to:

  - high pressure in the winter with cold, dry, clear, frosty days and light winds (anticyclone)

  OR

  - Winter high pressure with cloud and light wind (anticyclonic gloom).

References

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[2] Naderi, M, Al-Wreikat, Y, Palmer, D, Smith, M, Khazali, A, Fraser, E, Gladwin, D. T., Foster, M. P., Ballantyne, E. E. F., Cruden, A., Stone, D. A., "Techno-economic planning of a fully renewable energy-based autonomous microgrid studying single and hybrid energy storage systems", Ready for submission.

[3] PVGIS, https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html, 2023

[4] PVGIS User Manual, https://joint-research-centre.ec.europa.eu/photovoltaic-geographical-information-system-pvgis/getting-started-pvgis/pvgis-user-manual_en, 2023

[5] D. Raynaud, B. Hingray, B. François, J.D. Creutin, Energy droughts from variable renewable energy sources in European climates, Renewable Energy, Volume 125, 2018, Pages 578-589, ISSN 0960-1481, https://doi.org/10.1016/j.renene.2018.02.130.

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