Analysis of Wind & Solar Generation Potential

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1. Introduction

Improving their renewable generation portfolio is of interest to several utilities in the US and understanding the potential for wind & solar generation at various sites can provide valuable insights for business decisions. This analysis provides such insights at two sites in the Midwest US using publicly available weather data. The basic questions that this aims to answer are:

- What is the overall scale of solar and wind generation at these sites?
- What inferences regarding patterns and predictability may be drawn from this data?

2. Dataset

The dataset that was used for this analysis is from the AgriMet Weather database for 2014.[1] This dataset contains hourly weather information (8760 data points) for two sites: Ashton, Idaho and Deer Lodge, Montana. The factors in the dataset can be categorized as:

- Ambient conditions: Air Temperature (˚F), Relative humidity (%)
- Wind information : Wind direction, Peak Wind Gust (mph), Wind Speed (mph)
- Solar information : Solar radiation (langleys/hr)

A summary of the factors in the dataset for each site is shown in Table 1 & 2. From the summary it is clear that although the nature of air temperatures is similar for both sites, on an average, Ashton has a higher relative humidity. This could be attributed to the higher precipitation at the Ashton site.[2]

One concern with the dataset is the size, which is useful for understanding trends *within* a year of solar or wind production, but is not useful for further quantifying trends over a few years. However, as this report shows, there are interesting patterns and correlations which could be useful for determining the potential for renewable generation at both sites.

Table.1: Summary of factors for the Ashton site

Factor	Mean	Median	Q1	Q3
Air Temp (˚F)	41.50	42.68	29.94	56.12
Rel. Humidity (%)	73.97	68.33	50.17	87.50
Wind direction	152.3	114.5	82.5	232.1
Peak wind gust (mph)	11.25	9.10	6.14	14.03
Wind Speed (mph)	7.097	5.730	3.720	8.830
Solar radiation (langleys/hr)	15.82	0.45	0.01	26.28

Table.2: Summary of factors for the Deer Lodge site

Factor	Mean	Median	Q1	Q3
Air Temp (˚F)	41.67	41.92	30.18	54.84
Rel. Humidity (%)	63.39	66.69	47.47	81.20
Wind direction	181.15	193.0	64.99	266.00
Peak wind gust (mph)	11.18	8.55	5.04	15.34
Wind Speed (mph)	6.644	4.880	2.860	9.130
Solar radiation (langleys/hr)	15.24	0.49	0.00	25.60

3. Analysis

3.1 Analysis of solar potential

3.1.1 Patterns in solar radiation data

As a first step in understanding the scale of potential solar generation at each site, it is useful to identify the underlying trends in solar radiation. The solar radiation curve can be decomposed into a seasonal curve that represents periodic/repeating patterns and a trend curve that shows the overall nature (increasing/decreasing) over the whole year. These curves shown in Fig.1, highlight two important observations:

- There is a seasonal variation in the solar radiation over a year (Fig. 1a), since the summer (May - July) months would be exposed to more solar radiation than the winter months. This implores that understanding the solar potential would be advantageous rather than naively defining the potential for solar radiation over a year.

- There is a daily pattern to the solar radiation received, due to the sunrise-sunset cycle and this pattern is different over summer and winter as well. As Fig. 1b, shows, solar production can start early and last for longer in summer during the day

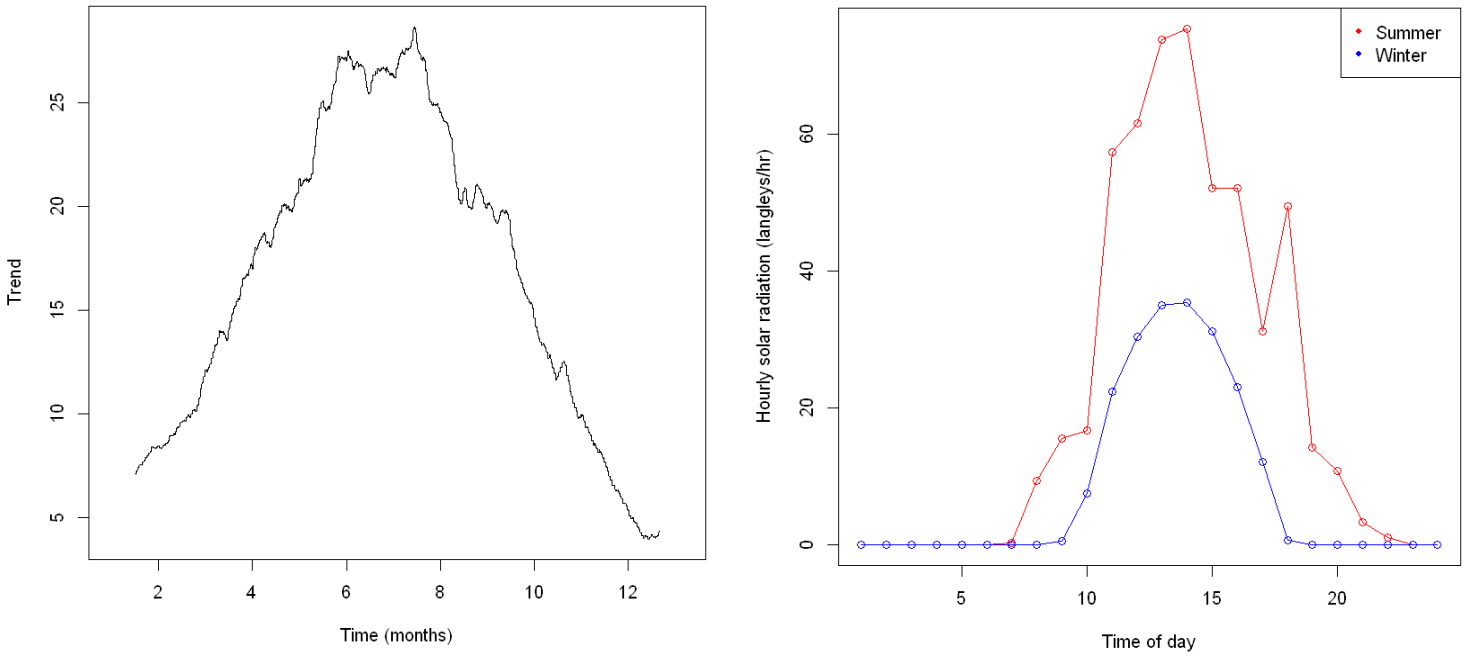

Fig.1 Plot showing the trend in solar radiation and a representative day of solar radiation in winter and summer for the Ashton site

3.1.2 Quantifying solar potential

Since the hourly solar radiation curve is in terms of solar insolation per hour, one metric for understanding solar potential can be obtained by summing up the total non-zero solar insolation every hour. This would essentially be an area under the radiation curve, and would give a measure of energy/area. As discussed in the previous section, looking at the summed potential across months provides a good understanding for both sites. As shown in Fig.2, it can be inferred that the Ashton site is nearly always better, with higher solar radiation incident over a year and the overall summed potential at Ashton is about 4% higher than at Deer Lodge. However, since this potential is in terms of energy/area, the difference in absolute energy production could be significant.

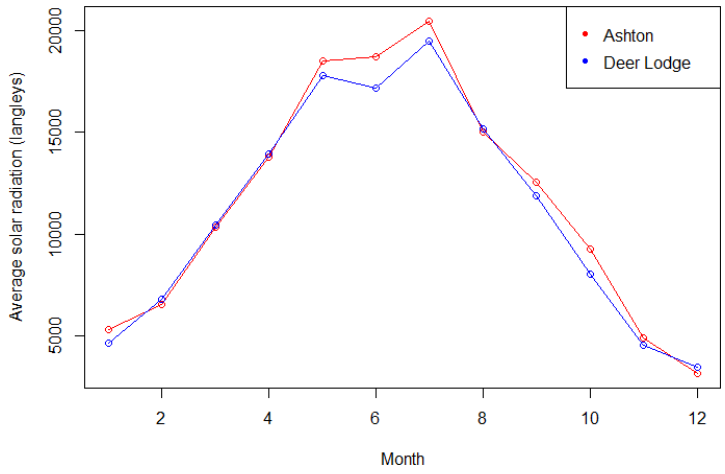

Fig.2 Plot comparing the solar generation potential for both sites over a year

3.1.3 Predictability & relationship with other factors

The auto-correlation curves at both sites (Fig.3a) for the solar radiation shows strong correlations (~0.8) in periods of 24 hours. This means that the solar radiation is highly predictable in periods of one day and this is true for both sites. The cross-correlation between solar incidence and the air temperature at both sites (Fig.3b) also shows a similar trend of periodicity in 24 hour intervals. This predictability makes solar an attractive option for a primary renewable source.

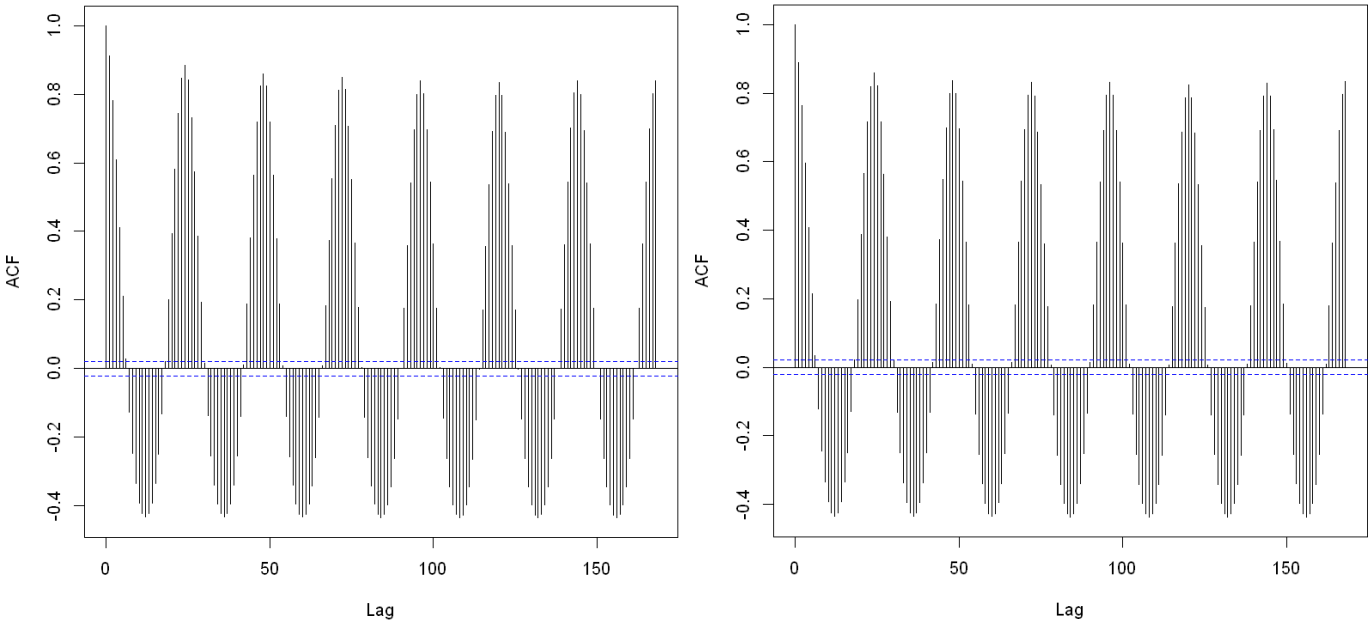

Fig.3a. Auto-correlation curves for solar radiation for Ashton (left) & Deer Lodge (right)

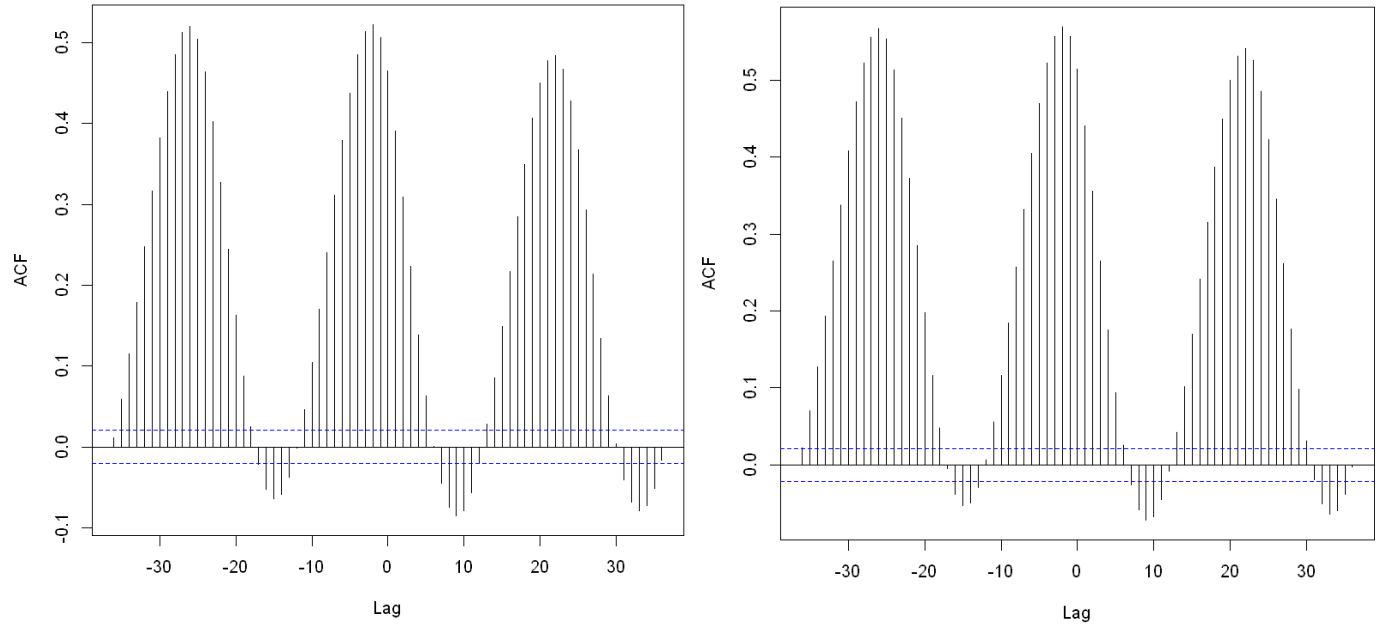

Fig.3b. Cross-correlation curves of Solar Radiation & Air Temp for Ashton (left) & Deer Lodge (right)

3.2 Analysis of wind potential

3.2.1 Patterns in wind data

Similar to the analysis for solar potential, basic patterns in wind speed and direction were explored. However, unlike solar data, wind data is not inherently periodic and trends are identified by other means. From Fig.4a, it is clear that the wind direction in both sites are clustered around two different sets of values, representing day and night.

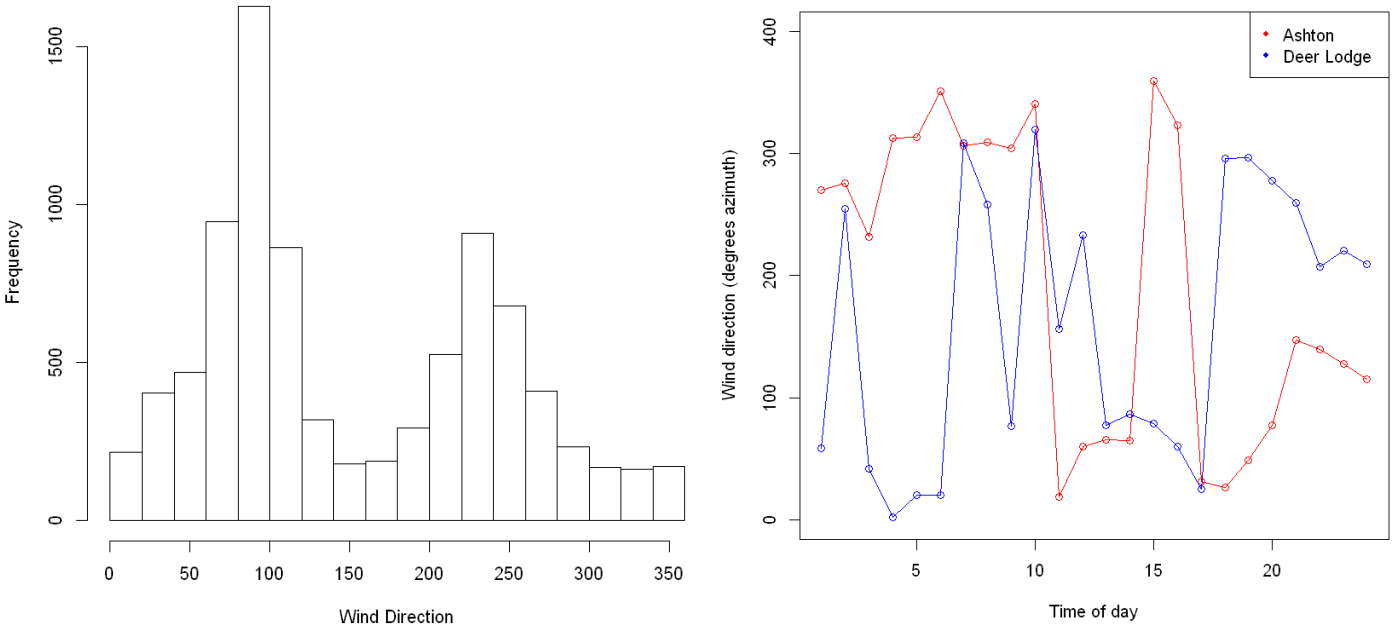

Fig.4a. Distribution of wind direction for Ashton (left) & plot showing the time of day for wind direction (right). Note that the two clusters correspond to night and day variation

Explorations in wind speed (Fig. 4b) revealed that the wind speed with highest frequencies are at different ranges in for Ashton (3 – 6mph) and Deer Lodge (2-4mph). This shows that on an average we can expect wind speeds to be higher at Ashton. But understanding how that correlates to wind generation potential has to be explored.

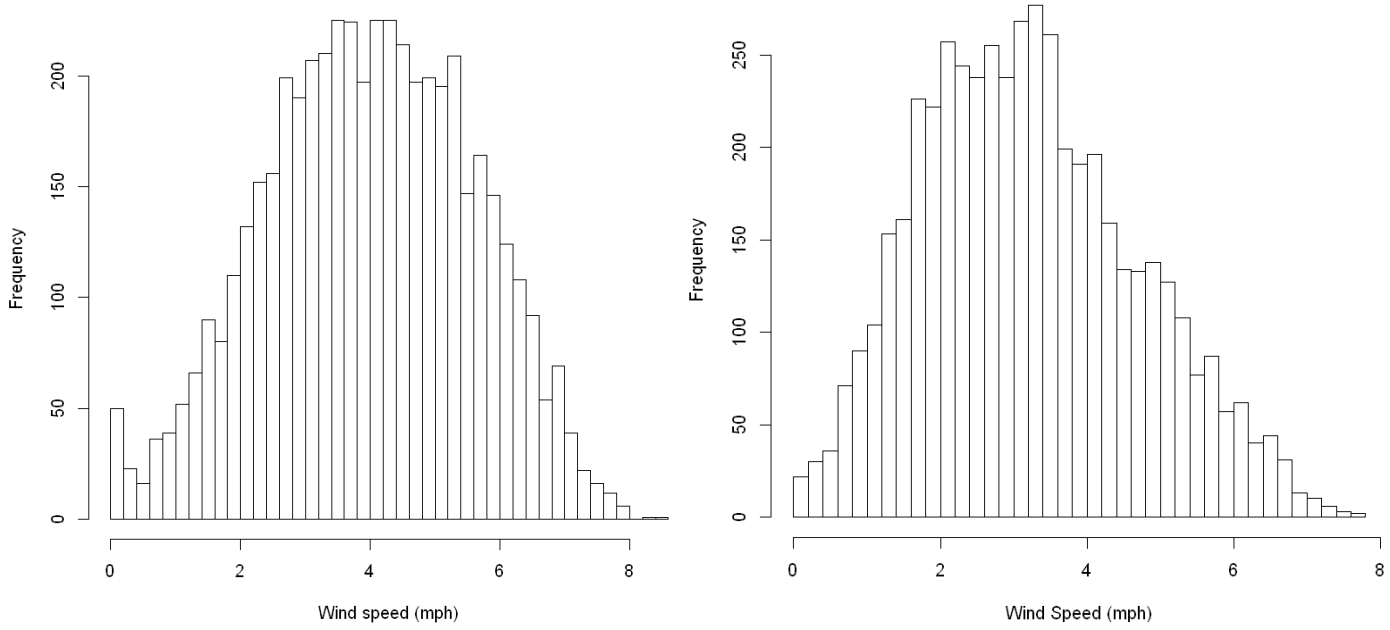

Fig.4b. Distribution of wind speeds for Ashton (left) & Deer Lodge (right)

3.2.2 Quantifying wind potential

In general, wind generation potential is not as straightforward to measure as the solar potential, since it depends on more than factor. However, for the purposes of this analysis, the average wind speed over a day was considered as a measure of wind generation potential. This average when plotted over the months (Fig 5), shows that although the Deer Lodge site has larger variation in wind speed, the Ashton site has consistently higher average wind speed during the summer. The Deer Lodge site having extremes in wind speed could be attributed to its valley location. Using this metric, the Ashton site seems to be a better candidate for wind generation.

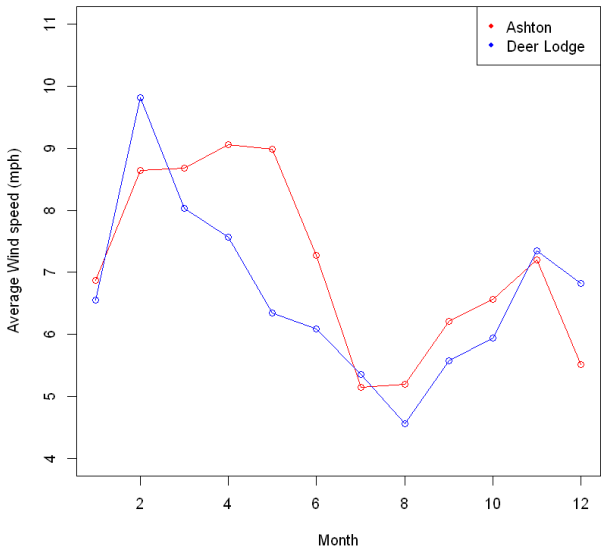

Fig.5 Average wind speed for both sites over a year

3.2.3 Predictability and relationship with other factors

The auto-correlation curves at both sites (Fig.6a) for the wind data, shows some correlation (~0.2) in periods of 24 hours. The cross-correlation between wind speed and the relative humidity at both sites (Fig.6b) also shows a similar trend of periodicity in 24 hour intervals. These correlations, however are much smaller in case of wind compared to solar data, once again reiterating the fact that wind generation is not as predictable.

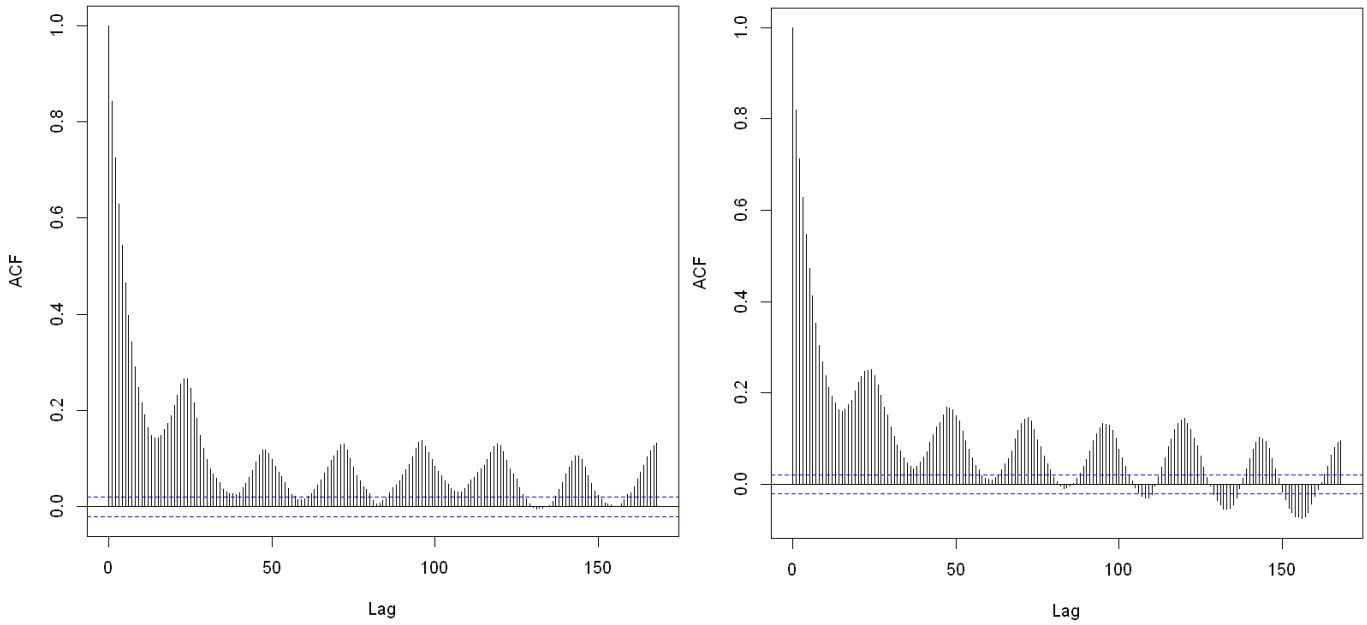

Fig. 6a. Auto-correlation plots for wind speed at Ashton (left) and Deer Lodge (right)

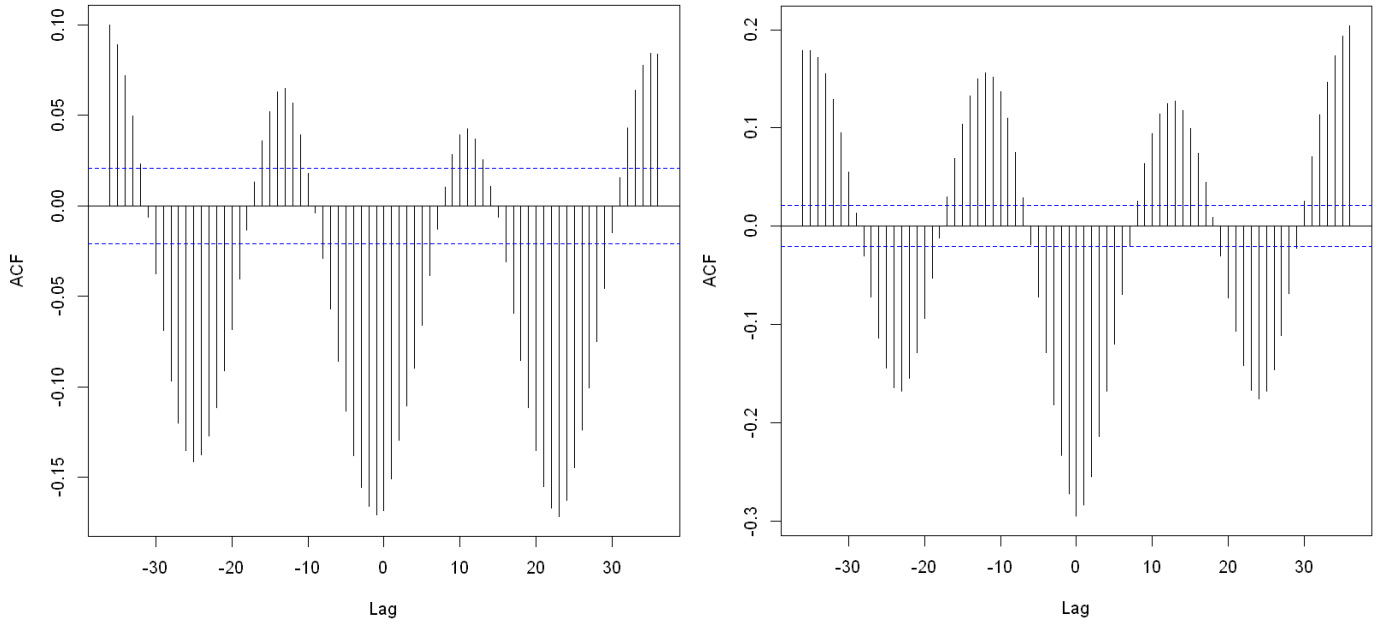

Fig. 6b. CCF plots for wind speed and rel. humidity at Ashton (left) and Deer Lodge (right)

4. Conclusions

The analysis provided insights into the factors affecting wind and solar generation potential at the two sites. These can be summed up as:

- Solar radiation is seasonal and depends on the time of day, hence solar generation is expected to be periodic, but is highly predictable using historical data
- Wind speed is a good measure of wind generation potential and it has significant variations over seasons. Similar to solar, the generation is expected to be erratic, but much less predictable.
- Comparing the two sites:
    - The Ashton site shows higher potential for both solar and wind when compared to the Deer Lodge site
    - Wind potential is however, more predictable in case of the Deer Lodge site albeit only marginally
- Due to the high predictability of solar radiation at both sites, a renewable portfolio with solar generation as the primary source would ensure better grid reliability
- On an ensemble level, the Ashton site is "better" than the Deer Lodge site, however only marginally and at the cost of slightly lower predictability

5. References

1. https://www.usbr.gov/pn/agrimet/webaghrread.html
2. https://en.wikipedia.org/wiki/Ashton,_Idaho