Comparison of Horizon Shading Models

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Background

PVSyst accounts for the loss of irradiance due to shading from far objects (i.e. mountains) through a horizon profile. The height (°) of distant objects are mapped onto a yearly sun path. Irradiance seen by the modelled plant is then decreased as follows: The beam component of irradiance is removed when the sun position is below the horizon profile. The diffuse component of irradiance is calculated as having a fixed loss throughout the year based on the geometry of the horizon profile. The albedo contribution is assumed to decrease linearly based on the horizon height, with zero contribution for horizon height >20° or for horizon objects that are sufficiently close.

There are currently three horizon shading profile calculators available in PVSyst: Meteonorm, PVGIS, and SolarAnywhere. All three use global digital elevation models to calculate the height of far objects from a given coordinate. Considering there is little variability in the actual topographic profile of a site, this piece of solar modelling should be consistent from source to source. However, that is not the case. The goal of this research is to model all three calculators for various sites around the Rockies and Sierra Nevada mountain ranges to understand the discrepancies between each model.

	Meteonorm	PVGIS	SolarAnywhere	USGS
Source	Copernicus GLO-30 Digital Elevation Model	SRTM	Proprietary	US Geological Survey
Resolution	30 meters	90 meters	30 meters	10 meters

Figure 1: Digital Elevation Models used in each calculator and their respective resolutions. The higher the resolution, the more elevation points are measured.

Methodology

Eight solar sites across the Rockies and Sierra Nevadas (Site 1-8) and two sites in the Midwest (Sites 9 & 10) were modelled in PVSyst. A hypothetical 100 MW site using the same wattage of modules, number of modules per string, number of strings per inverter, and number of inverters was modeled at each location. Solar irradiance and albedo values were provided by SolarAnywhere using version 4.0. Horizon profiles were provided by SolarAnywhere version 4.0, PVGIS version 5.3, and Meteonorm version 8. In addition, horizon profiles were calculated manually using USGS topography DEMs of either 10 ft or 20 ft contours for a "site specific" control.

The USGS DEMs horizon profiles were calculated as follows. A spoke model with a radius of between 10 and 40 miles was overlayed with the contour data for each project. The spokes represented each 10° angle from 60° to 300°. Each intersection of a contour elevation and a spoke were calculated and the distance from that intersection to the site coordinate was measured. The solar height was then calculated using the following equation:

$$Solar\ Height = \tan^{-1}\left(\frac{Elevation\ of\ Horizon\ Obstacle - Elevation\ of\ Coordinate\ Point}{Displacement\ between\ both\ points}\right)$$

The maximum solar height for each 10° was then used as input to PVSyst's horizon profile calculator.

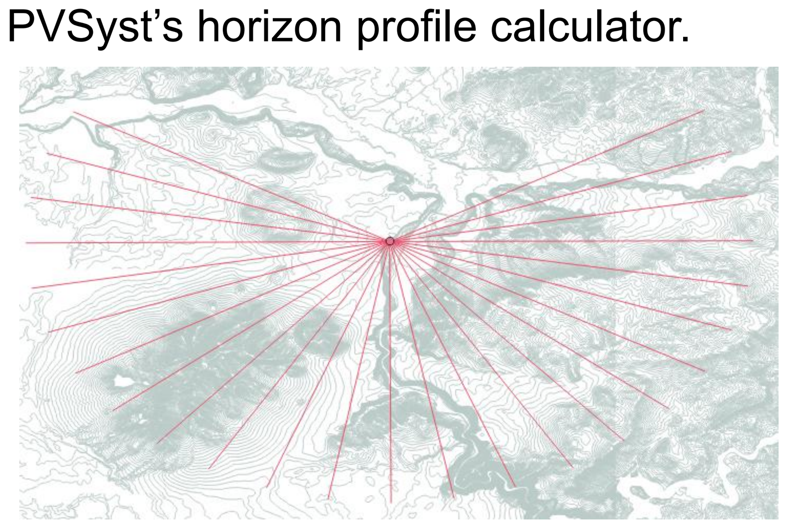

Figure 2: Site 5 contour data overlayed with spokes representing 10 miles at each 10° angle from 60° to 300°.

Results

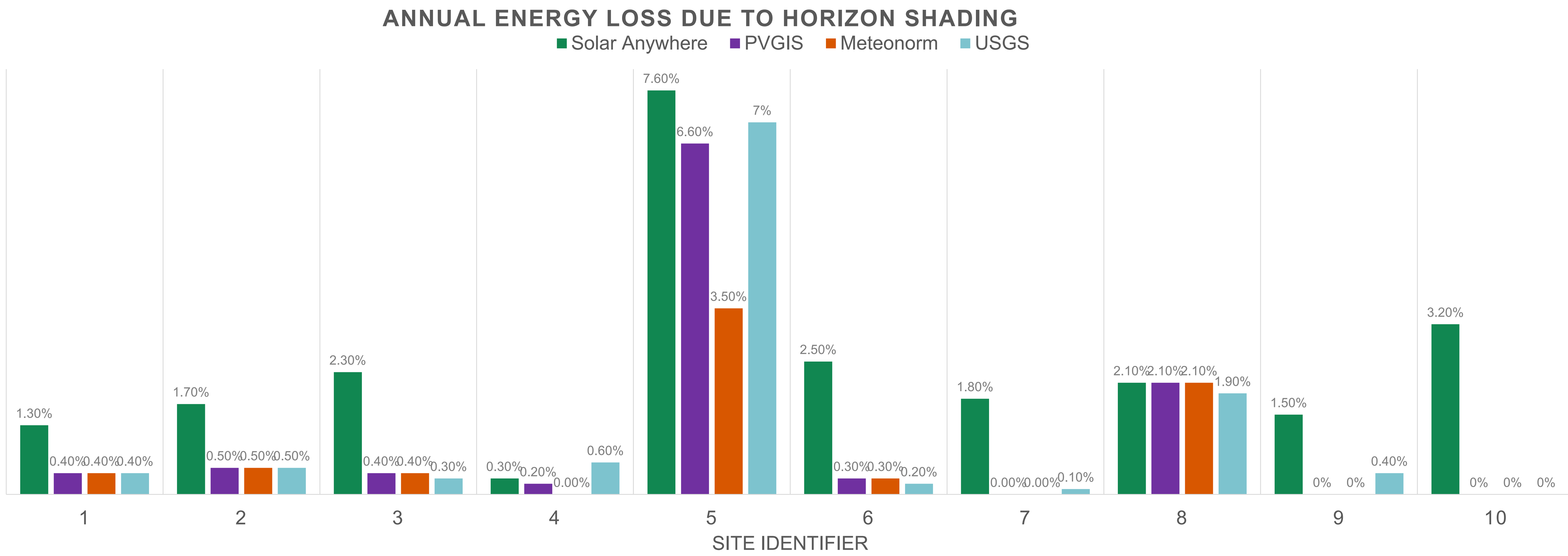

Figure 3: The annual energy loss percentage due to horizon shading for the same site coordinate using different calculators. This value was pulled from the modeled annual loss tree.

As can be seen in Figure 3, SolarAnywhere calculated a higher annual loss due to horizon shading than PVGIS and Meteonorm across all ten sites. Site 10 is in the Midwest and represents a "control" site as the land surrounding the project for upwards of 10 miles had no far objects taller than 0.2°. As can be seen, SolarAnywhere still calculated a 3.3% annual loss. Other than site 4 and 5, PVGIS and Meteonorm tended to have the same or similar horizon loss applied. In addition, both PVGIS and Meteonorm were closer in loss percentage and profile to the calculated method using USGS topography data.

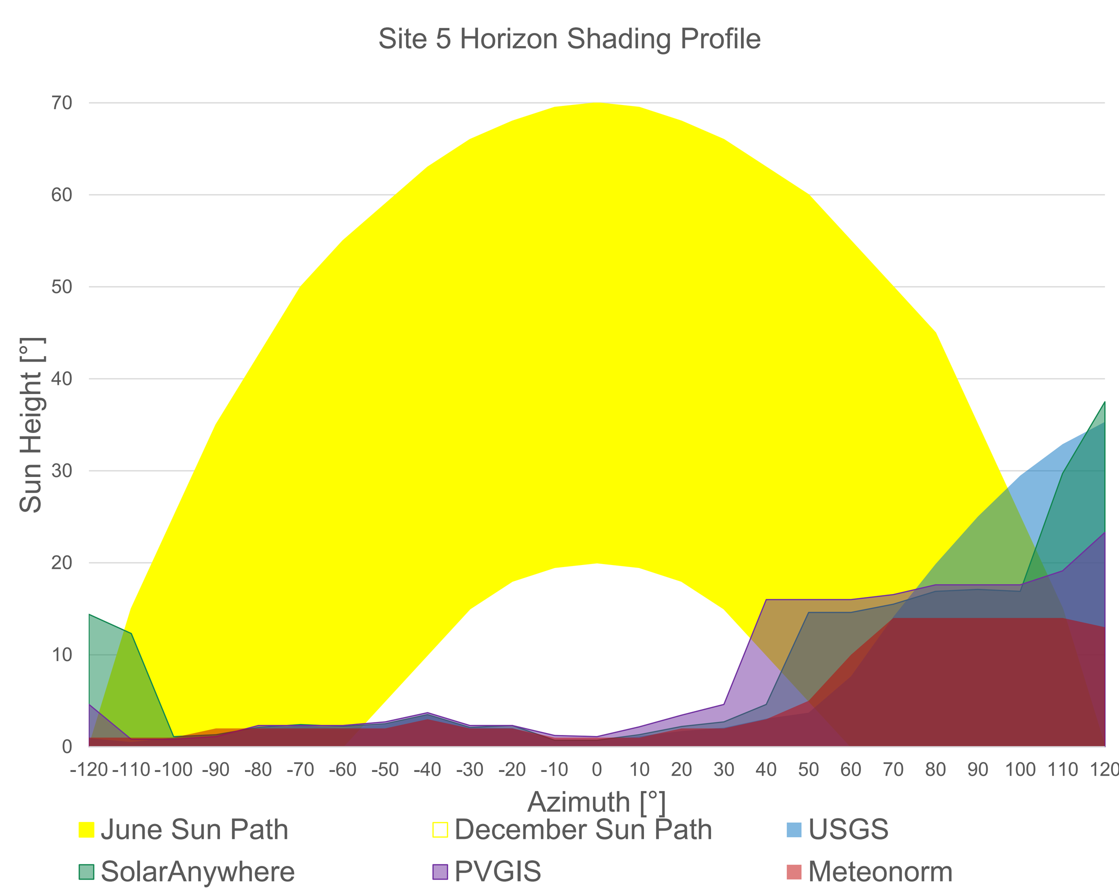

Figure 4: The calculated horizon shading profiles for site 5 overlayed

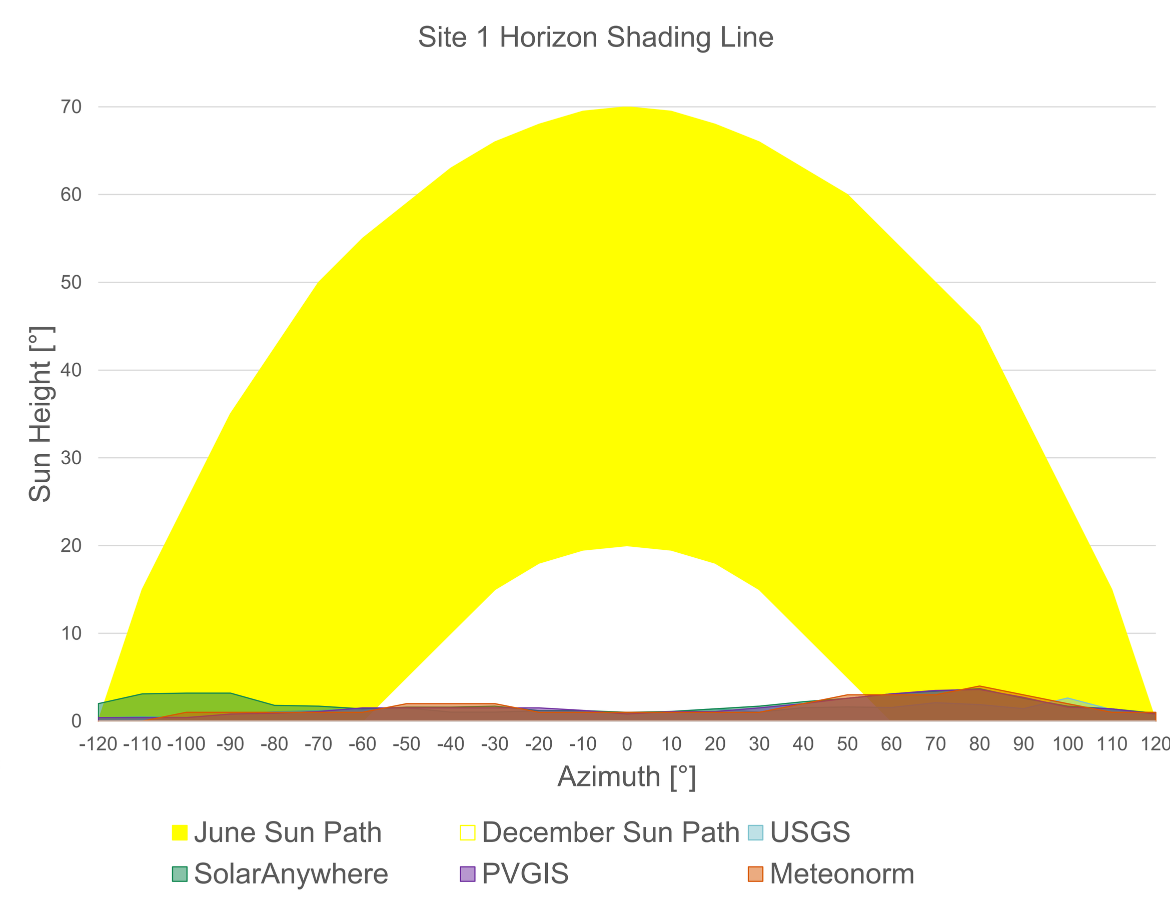

Figure 5: The calculated horizon shading profiles for site 1 overlayed

Figure 4 represents the full horizon profile for Site 5, which had the largest discrepancy between data sources. Figure 5 represents the full horizon profile for Site 1, which had minimal discrepancy outside of SolarAnywhere. As can be seen, there are some slight differences in the profile for each data set. Even when the annual loss is the same between sources, there tended to be discrepancies in the actual profile of each site.

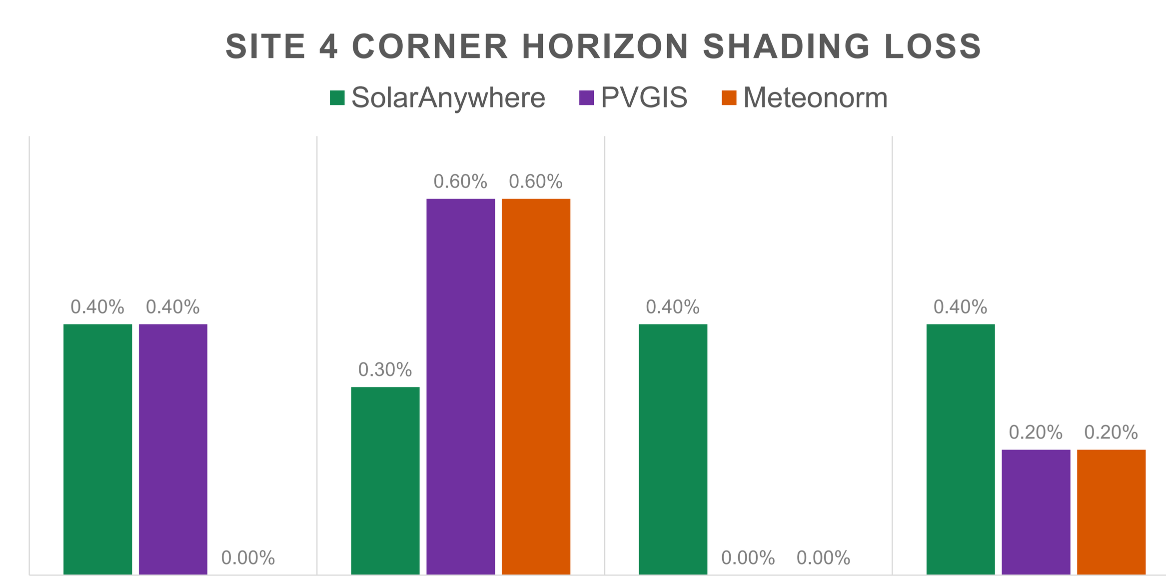

Figure 6: Calculated horizon shading loss at the furthest extents of site 4

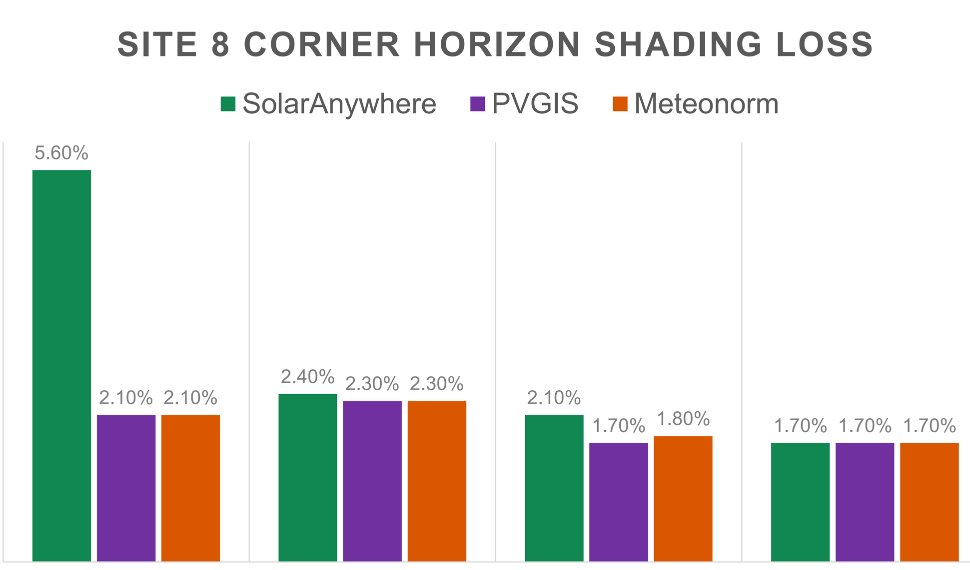

Figure 7: Calculated horizon shading loss at the furthest extents of site 4

Figures 6 and 7 reveal how horizon profiles differ across a site. Utility scale solar plants tend to span thousands of acres and can include multiple areas separated between each other. Site 4 is spans 3 miles and Site 8 spans 6 miles. Both have different horizon profiles at the furthest extents of the sites due to the variation in topographic makeup of the area. Even though Site 4 spans a shorter distance at its longest point than Site 8, both sites had a difference in annual horizon shading loss of 0.6% between the minimum and maximum loss calculated (excluding SolarAnywhere).

Conclusion

There is still a fair amount of study needed to fully understand the effect of far objects on solar plant production. PVSyst speaks to this in its Far Shadings-Horizon description, stating that calculating the effect of far objects on solar production is "very complex" and "requires more experimental investigations". Even measuring the height of far objects in relation to a fixed point is not standardized, as seen by the discrepancies in profiles generated by the various calculators.

This variability was clearly seen in this analysis. The only clear trend is that SolarAnywhere is over-estimating the height of far objects. This leads to a higher annual loss due to horizon shading. Even amongst PVGIS and Meteonorm, the resulting profiles were not identical and did not match what was calculated using the higher resolution USGS topography data. As a developer, any adjustment to production output roughly 1% or higher can make or break a project, and so modelling horizon shading accurately is very important.

With the current calculators available, it is recommended that either **Meteonorm or PVGIS are used to generate a horizon profile**. The resulting profiles were the closest to the higher resolution topography data profiles generated and therefore are expected to be more accurate to the shading seen on site. However, further validation should be completed with each calculator.

Future Recommendations

Considering the discrepancies among the calculators, on-site validations should be completed to tune these models. The ideal case would be to get high resolution (1m) topography via LiDAR or similar for a 10-mile radius around a solar plant and tune each model to what is calculated based off this higher resolution data. Another option would be to bring instrumentation on site, such as a Solar Pathfinder, and measure the horizon profile directly. This would require collecting multiple points around a site to characterize the full shading profile that would be seen at the site.

A further calculation should be created to encompass the effect of horizon shading over larger sites. As seen with the calculation of shading at each corner of Site 4 and 8, exact location of measurement plays a role in what profile is calculated. Since utility scale solar plants cover such large areas, being able to understand the effect of horizon shading through the entire project area instead of just the center of the site is important.

Finally, additional onsite data validation is needed for the PVSyst algorithms. This would consist of reviewing long term GHI, POA, and production data at solar plants that are already installed in areas with potential horizon shading. Considering the many factors that lead to lost energy production at a solar site, it may be difficult to isolate horizon shading loss as one of them. Multiple years of data would be required to be able to parse out horizon shading from other factors.

Sources

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