NATIONAL RENEWABLE ENERGY LABORATORY

Capturing Inter-Annual Variability of PV Energy Production in South Asia

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Long-term variability of solar resource is an important factor in planning a utility scale photovoltaic (PV) generation plant, and annual generation for a given location can vary significantly from year to year (Figure 1). Based on multiple years of solar irradiance data, an exceedance probability is the amount of energy that could potentially be produced by a power plant in any given year. An exceedance probability accounts for long-term variability and climate cycles (e.g., monsoons or changes in aerosols), which ultimately impact PV energy generation. Banks and investment firms that finance renewable energy projects often require estimates of exceedance probabilities to assess the risk associated with servicing the debt obligations for an individual plant. A P50 exceedance probability estimates the amount of annual electricity generation that will be met or exceeded in 50% of years.

The National Solar Radiation Database (NSRDB), created by the National Renewable Energy Laboratory (NREL), covers South Asia with 10 km by 10 km cells at hourly time steps from 2000 to 2014. The NREL Geospatial Data Science (GDS) team used the Renewable Energy Potential (reV) model to estimate the annual generation potential for a single 1 MW fixed-tilt (with a tilt set at the latitude in degrees) PV system. Then the team used the annual generation results to determine exceedance probabilities in 5% probability intervals for each of those cells (using an empirical cumulative distribution function).[1] Figure 2 shows the amount of generation that can be expected at the P90 level (i.e., 90% exceedance probability).

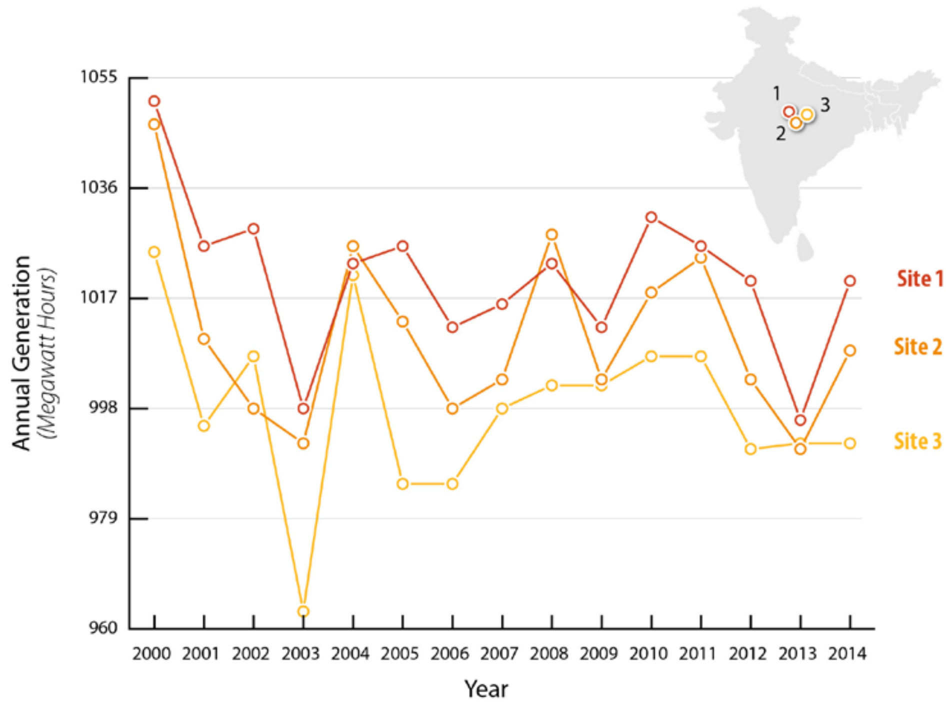

Figure 1. Annual generation for 3 selected sites from 2000 to 2014.

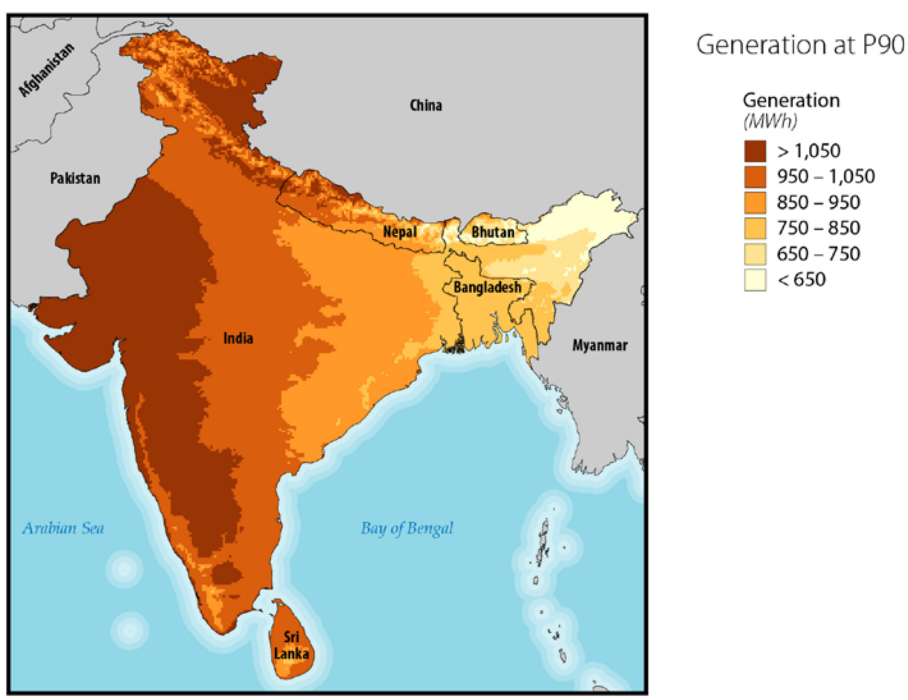

Figure 2. Annual generation estimate at P90

1. See http://www.nrel.gov/docs/fy12osti/54488.pdf for methodological details.

The Renewable Energy (RE) Data Explorer for India now includes solar PV exceedance probabilities that can help industry and other analysts assess financial risk associated with the inter-annual variability of a project's energy output. To access probability exceedance estimates of annual generation from 2000–2014 for South Asia, visit *www.re-explorer.org*.

Exceedance Probability and Implications for Typical Meteorological Year and Representative Year Use

Industry often uses typical meteorological year (TMY) resource data to estimate long-term generation for PV power plants. The TMY methodology combines the 12 most representative months from the long-term time series data to create a single year of data.[2] A TMY data set is considered a close approximation of the generation that can be expected in any given year—theoretically, close to the P50 exceedance probability. The GDS team found, however, that the TMY generation estimate is not always close to the P50. Figure 3 shows the reduction in estimated energy output as the probability increases. It also shows that the exceedance probability that corresponds to the TMY generation varies significantly by location. In fact, probabilities of the TMY generation were biased high across South Asia, with only 43% of cells falling between 40% and 60% probability. Figure 4 shows the distribution of exceedance probabilities represented by the TMY generation, which is shifted to the right of the P50.

The GDS team also found regional bias and spatial clustering in the exceedance probabilities represented by the TMY generation, as shown in Figure 5. The brown pixels indicate higher probabilities and under-prediction of the long-term generation, green colors indicate lower

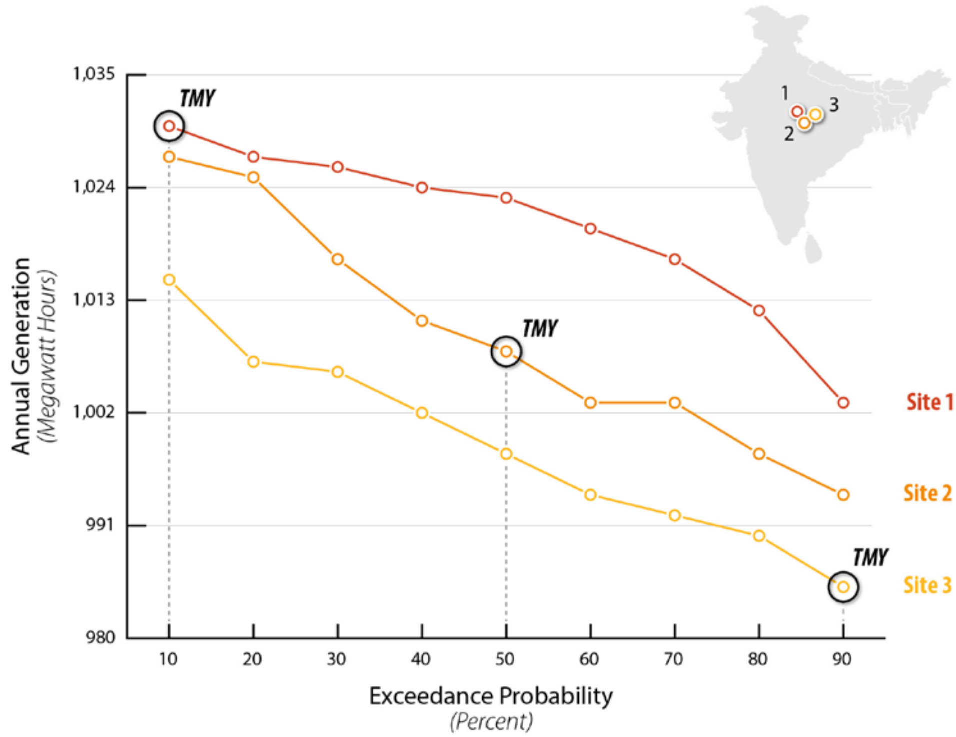

Figure 3. Exceedance probabilities for 3 selected sites

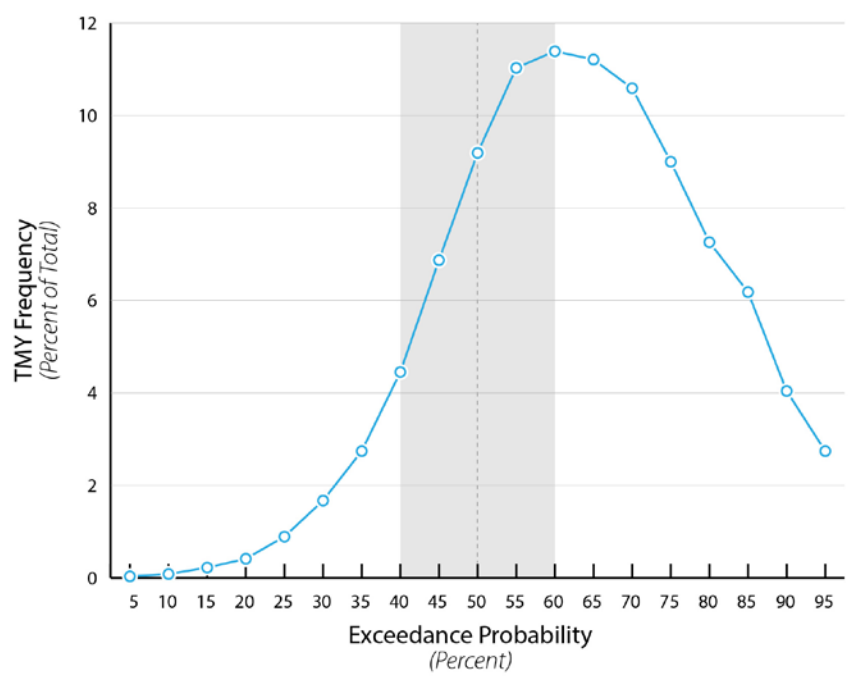

Figure 4. TMY occurrence across exceedance probabilities as a percent of all cells

2. See *http://www.nrel.gov/docs/fy08osti/43156.Pdf* for methodological details of a TMY dataset.

probabilities and over-prediction of the long-term generation, and white pixels show close agreement (plus or minus 10%) with the P50.

These results suggest that a significant bias could be associated with relying solely on TMY resource data to capture long-term variability. While the TMY tends to under-predict annual generation overall compared to the P50, there appear to be pockets of over-prediction as well.

Grid modelers and capacity expansion experts often choose a single year to perform analysis—a year that is either a high, median (representative), or low resource year—depending on their research objectives. However, the GDS team also found that there is no dominant year across South Asia associated with a P10 (high), P50 (median or representative), or a P90 (low). This means that the solar resource inter-annual variability in South Asia is highly dependent on location. Figure 6 shows the spatial heterogeneity of the year most closely associated with the P90. This variability makes it more difficult to select a high, representative, or low resource year for South Asia.

Although this study focused solely on South Asia, users of TMY data should be aware of the potential shortcomings of assuming a P50 exceedance probability for generation. Future research will further examine the exceedance probabilities represented by TMY generation and provide insight into the implications for grid integration and capacity expansion modeling based on TMY data. Such information could help planners and investors more confidently identify high, representative, and low resource years throughout South Asia and the rest of the world, enabling more confident renewable energy deployment decisions.

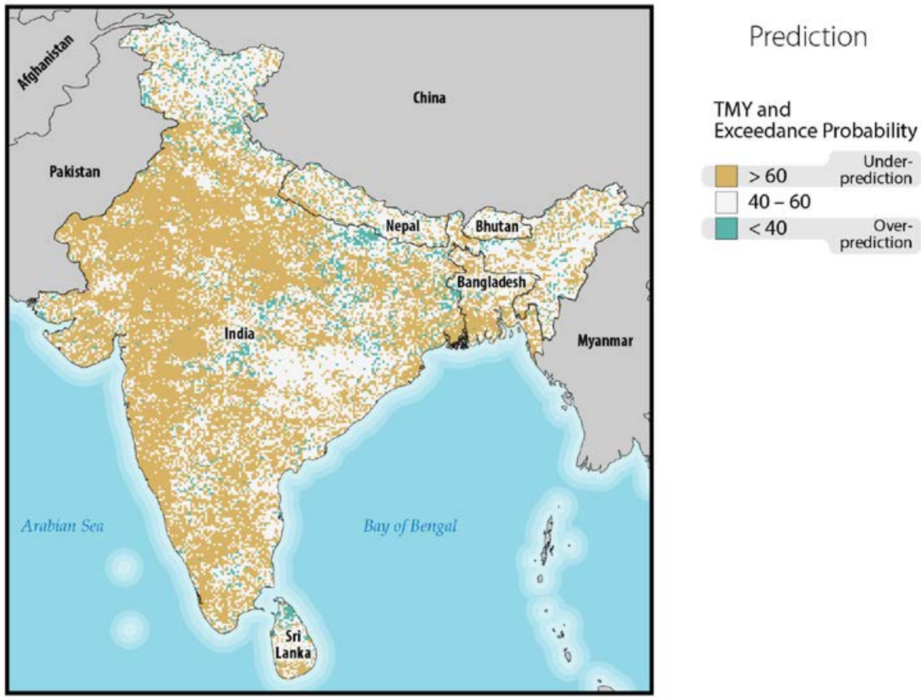

Figure 5. Spatial distribution of exceedance probabilities represented by TMY generation

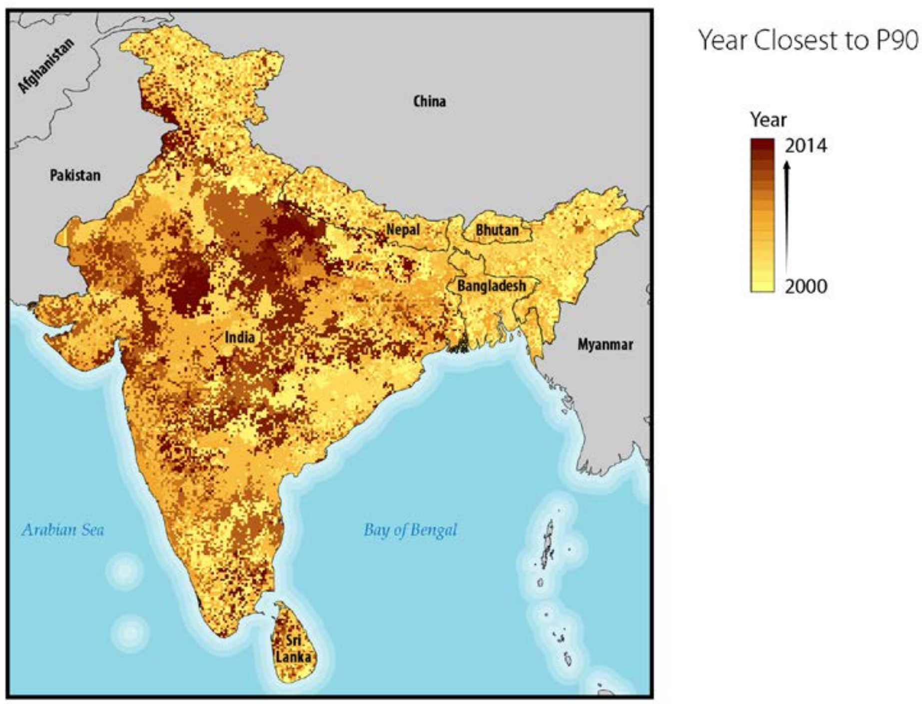

Figure 6. Year closest to P90

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