

# Pakistan Solar Estimation

## Underreporting

We believe there is significant solar generation in Pakistan not captured in official statistics. We think this because:

- NEPRA monthly generation statistics show both solar generation and capacity almost unchanged since at least 2019
- Pakistan has [imported large quantities of Chinese solar modules](#) over the past few years. We estimate ~8GW in 2023 and 16.6 GW in 2024. (BNEF estimates ~5 GW in 2023 and ~13 GW in H1 2024; differences are probably due to price assumptions, data source, and money-laundering assumptions in 2023)
- There is a lot of evidence of large scale installations of these panels (e.g. reports from partners in the country, satellite analysis [work by BNEF](#))
- NEPRA data now shows there is officially [4 GW of net-metering solar capacity](#) alone installed. The real figure is probably larger as panels may be installed on these connections without being registered. This is much more than the 680MW captured in monthly generation statistics
- A [clear duck curve](#) is now visible in CPPA-G [hourly generation statistics](#)

## Possible data sources

We're aware of two possible approaches to calculate generation from official sources, both of which we felt were not applicable:

- NEPRA reports monthly feed-in generation data from net-metered installations. This does not capture generation consumed behind the meter at these installations, and it also does not include other installations, which we believe are large
- In some countries it is possible to estimate "missing" generation from hourly demand data. This assumes that all new solar generation covers demand originally served by the grid, which we do not think is true in Pakistan

# Estimation

We estimate generation ground up in two stages:

1. Estimate installed capacity from Chinese module imports
2. Model capacity factors and apply these to the estimated capacity

## Capacity estimate

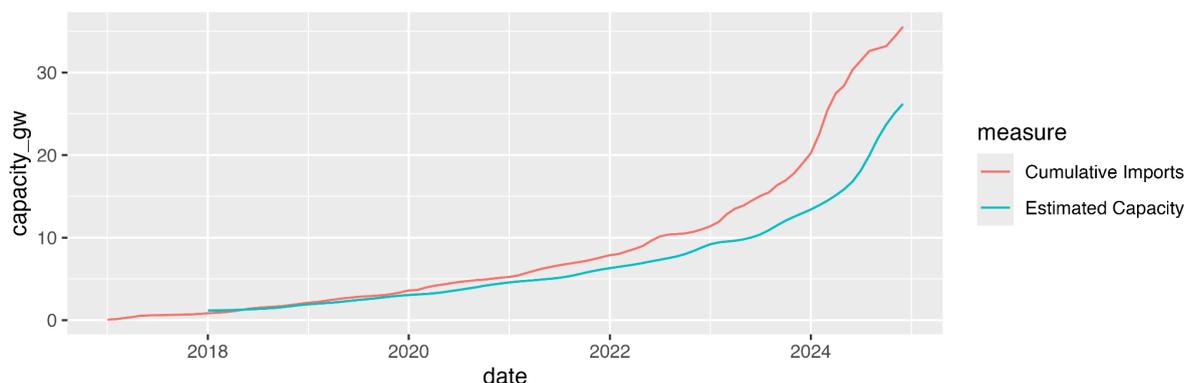
Imports in USD amounts are taken from Chinese customs data and converted to GW capacity according to module prices at that time. Detailed methodology [here](#). Capacity figures are approximate but generally match global [MIIT](#) data well. 2023 figures may be overestimated due to the use of panels for [money laundering](#).

Estimating capacity requires assumptions to be made about deployment lag, re-export to other countries, and long-term stockpiling. We use a [global methodology](#) developed in 2024, which developed these assumptions calibrated by monthly capacity data in other countries.

Calculated additions are imports, applying:

- 3 month rolling average
- 6 month deployment lag
- 15% stockpile/re-export rate

These assumptions may be conservative in Pakistan: lags may be smaller given the distributed and semi-informal nature of most installations, and industry players have suggested that the stockpile/re-export rate is not larger than 10%.

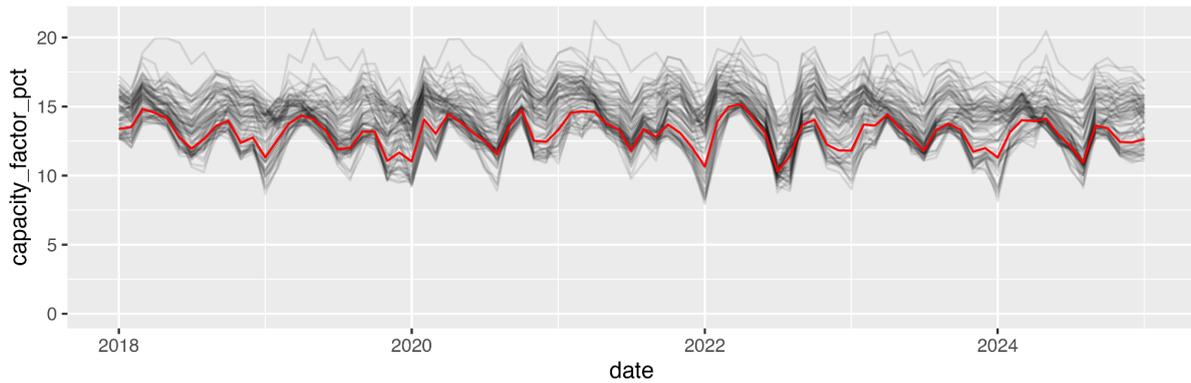


## Capacity factors

Two important aspects: panel model and locations:

1. **Model:** we use a [Huld](#) model of a crystalline silicon panel facing South at 35° tilt. We use global tilted irradiance (GTI) for this configuration and 2m temperature. Data is from [ERA5](#) via [Open-Meteo](#). We add a 25% penalty to the output of this to account for deployment configuration of real panels being less ideal

2. **Location:** we assume panels are deployed in proportion to population density in different locations. We therefore divide Pakistan into 1° grid squares, model capacity factor at the centre of each square, and take the average output across the country, weighted by the population of each square. The weighted average capacity factor is lower than the unweighted average would be, as people tend to live in the less sunny eastern regions



This model is simple, and assumptions about location and panel configuration may mean seasonal profiles are incorrect (our assumptions minimise seasonal variation). The penalty factor is intended to be conservative to mitigate this issue on an annual basis. We need more information on panel installations (amount, location, and configuration) to make improvements.

## Results

