Measurement of renewable energy capacity in India

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Abstract

Accurate measurement of renewable energy capacity is a prerequisite for effective climate policymaking. Yet, official statistics are rarely cross-validated against independent sources. Sound measurement helps policymakers meet globally-stated goals and guides the private sector in deploying capital. We compare solar and wind installed capacity from the Central Electricity Authority (CEA) against two independent sources: satellite imagery from Global Renewables Watch (GRW) and project-level data from the Centre for Monitoring Indian Economy (CMIE) CAPEX database. For solar, GRW tracks CEA closely (95% as of January 2024) initially, but diverges by April 2026. The satellite estimate of 133 GW with a slight downward adjustment to account for non-operational plants likely represents true solar capacity in India as of April 2026. Wind estimates differ more substantially, with GRW reporting 122% of CEA capacity as of January 2024, likely reflecting higher turbine capacity factor assumptions. As of April 2026, CEA reports installed wind capacity of 56.4 GW. The CMIE CAPEX database accounts for roughly 48–75% of CEA-reported capacity for wind and solar respectively by April 2026, consistent with its role as a survey rather than a census, and indicative of sizeable unrecorded capacity. Our analysis establishes a benchmark to validate official statistics with alternative data. Additionally, we note that alternative sources like GRW and CMIE CAPEX can serve as valuable project-level resources supporting microeconomic research.

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1 Introduction

Electricity is essential for economic growth. Developing nations require more than one percentage point of electricity consumption growth for every percentage point of economic growth (Jaitly, Sane and Shah 2025). Since FY'21, India's electricity consumption has risen by ∼9% annually, nearly doubling the 5% rate of the previous decade (Agarwal et al. 2025). While fossil fuels provide 80% of electricity supply (*Energy Statistics India* 2025), they impose negative externalities for public health and contribute to global warming by emitting greenhouse gases. India emits 0.28 kg CO_2/kWh of electricity generated compared to 0.18 kg CO_2/kWh for high-income countries (Ritchie, Rosado and Roser 2025).

The financial system is increasingly divesting from fossil fuel generation. Prices have fallen by ∼90% for solar photovoltaic and 50% for onshore wind turbines in real terms since 2010 (International Renewable Energy Agency 2025). This trend is supported by strategic government efforts to stabilise the economy against volatile energy prices. This shift aligns with the Government of India's commitment to achieve net-zero emissions by 2070 and increase non-fossil-fuel energy capacity to 500 GW by 2030 – as outlined in the COP26 proceedings (Ministry of Science & Technology 2023). Accurate measurement of renewable energy capacity is crucial for researchers and policy-makers to close the divide between stated policy goals and ground reality. This article evaluates data for solar and wind generation capacity in India by triangulating findings from a conventional data source with two alternative datasets.

The remainder of this article proceeds as follows. In Section 2 we outline the three sources — data availability, methodology used for estimation and potential limitations. In Section 3, we present results comparing measurement from the three sources and discuss the implications. Section 4 concludes the findings from our analysis and explores the role of remote sensing and alternative data sources in the real-time measurement of renewables.

2 Sources for Renewable Energy Measurement

2.1 Central Electricity Authority (CEA)

The Central Electricity Authority of India (CEA) is the official Indian source for energy statistics. It is responsible for collecting and recording data on installed (nameplate) capacity, electricity generation, transmission, distribution, and utilization across India (Central Electricity Agency 2003). CEA publishes monthly reports on renewable energy sources (RES) that are available from January 2019 to April 2026.[1] Total installed solar capacity reached 154 GW as of April 2026. This includes 26.7 GW of aggregate rooftop solar capacity, comprising both residential and commercial projects (MNRE 2026b). PM Surya Ghar provides subsidies for residential rooftop solar installations, reporting 3.3 million installations and 12 GW of rooftop solar capacity (MNRE 2026a).[2]

1. The renewable generation reports were sourced from Central Electricity Authority (2026).

2. A back-of-the-envelope calculation by dividing the total rooftop solar capacity by the number of installations gives an average residential rooftop solar capacity of 3.6 KW. A recent study finds that consumers prefer a rooftop solar system with an average capacity of 3 KW because the PM Surya Ghar Yojana subsidy is capped at 3 KW even though 76 percent of adopters have a load score above 3 KW (Chaudhary et al. 2026).

The CEA provides aggregate, national-level data. This lack of granularity restricts microeconomic research requiring precise locational information.

2.2 Centre for Monitoring Indian Economy (CMIE) CAPEX

The Centre for Monitoring Indian Economy (CMIE) CAPEX database captures project-level micro data for large projects through their lifecycle. Since 1995, this flow measure has recorded projects from an early stage all the way until they achieve the status of 'Completed'. Such granular micro-level data enables project-level research – with geocodes available for 95.9% of projects present in the database, it facilitates a direct verification of each record through satellite imagery. As an example of the kind of research made possible by the CMIE CAPEX dataset, see Borah, Jaitly and Sane (2026).

We identify completed capacity from projects in the database and construct the solar and wind capacity time series by cumulating capacity from 'Completed' projects and the incremental/phased additions reported by the 'Under Implementation' projects. We assume that these projects never cease functioning, thus inducing a certain over-estimation.[3] CMIE does not record small projects such as residential rooftop solar or captive facilities that are not announced in the public domain.

The database has used consistent methods since 1995, and is updated regularly. It should be viewed as a survey and not a census. It is a valuable part of economic measurement in India, but the extent of coverage of the data is an important fact that is obtained for the first time in this paper.

2.3 Global Renewables Watch (GRW)

The Global Renewables Watch (GRW) dataset, developed at the Microsoft AI for Good Research Lab, uses high-resolution satellite imagery and machine learning models to identify and classify commercial solar and onshore wind farms. It then converts their measured area into megawatts using standard capacity factors (Robinson et al. 2025).[4] The dataset is updated quarterly, covering the period Q3 2017 to Q2 2024.

GRW excludes rooftop solar and offshore wind, which makes it challenging to compare with the other two datasets that include utility-scale rooftop solar. Microsoft's researchers have established a strong correlation, with Pearson's R^2 values of 0.96 for solar and 0.93 for onshore wind, between the GRW dataset and the International Renewable Energy Agency (IRENA) capacity estimates on a global scale.

The dataset has a few limitations. Firstly, while it can identify solar and wind farms from satellite imagery, it cannot ascertain whether these installations are currently operational. Secondly, GRW only detects solar farms larger than 10,000 m^2 and wind turbines with a rotor diameter exceeding 47 meters, which may lead to an undercount of smaller-scale solar and wind plants. Thirdly, a standard multiplier of 51 to 65 MW/km^2 represents a global average nameplate solar power density; however, the actual capacity depends

3. Central Electricity Regulatory Commission (2012) states that the useful lifespan of a renewable energy project like solar or wind is 25 years, which most projects in our analysis fall under.

4. For solar, the capacity factor is 51.5 MW/km^2 before 2019, then increases by 4.33 MW/km^2 each year until 2022, reaching a final value of 65.9 MW/km^2 for the period from 2022 to 2024. For wind, the capacity factor is 3 MW per turbine.

on the latitude of the solar farm, panel tilt, inverter load ratios and the efficiency of the installed photovoltaics. Lastly, a 3 MW capacity factor for wind may not accurately represent turbine sizes in India. These factors could lead to deviations from the true capacity figures.

Despite these limitations, the GRW dataset offers an alternative data approach to the same question, providing a competing information source used by other researchers, which is consistently measured on a global scale and is free from institutional challenges in data measurement.[5] It provides aggregate information at the country level and also supports microeconomic research through geocoded project-level data. However, the GRW dataset has not been updated beyond Q2 2024. While Microsoft researchers have released their code for solar panel/wind turbine inference models to the public, they have not released their secondary filtering Support Vector Machine (SVM) code to remove false positives. The first-stage solar panel inference models have a high recall but low precision. Running just the first-stage returns inaccurate findings where dark areas such as rivers are also sometimes identified as solar panels. We work around this barrier in Section 2.4 to update GRW to the latest quarter using OSM layers.

2.4 Open Street Maps (OSM)–GRW

Open Street Maps (OSM) is an open-source alternative to Google Maps. It is a community-led project with volunteers updating information across the globe. OSM provides freely accessible data-layers for utility-scale renewable projects such as solar and wind. However, most of these polygons do not report capacity figures in their tags. On visual inspection of the OSM reported polygons and satellite imagery of solar panels, we find that many utility-scale solar projects' polygons report the entire project area, not just the solar panel figures – as demonstrated by Kruitwagen et al. (2021). Thus, using polygon areas and standard capacity factors for these plants would yield inaccurate results.

As highlighted in Section 2.3, the standalone GRW model also suffers from low precision. Thus, we use a hybrid approach. First, we use the OSM solar project data layer to filter for solar project polygons. We add a 30% buffer on this bounding box because panels are installed phase-wise and projects tend to expand with time and OSM might not keep up in real time. Second, we fetch the latest quarter satellite imagery from PlanetScope that is compatible with the GRW model. Finally, we run the model inference scripts for only these locations.

This approach helps us work around the lack of the SVM false-positive screening script used by the Microsoft researchers while minimizing the false positives detected. However, a limitation of this approach is that it will only detect solar capacity if the OSM data layer reports a solar facility. Therefore, there might be an undercount in the capacity figures from this approach, but this alternative approach helps us extend the GRW methodology to the latest quarter. Given that this is a computationally intensive process, we run this machinery only twice – once in December 2023 for error calibration with the actual GRW estimate and once in April 2026 to get a point estimate for solar capacity. Our OSM–GRW estimate is within 1.7% of the GRW estimate in January 2024, making us confident about our method.

5. See Gao et al. (2026) and Kleebauer et al. (2025).

3 Results

A summary of the comparison between the three datasets is presented in Table 1. The latest time period for which data is available from all three sources is January 2024.

Table 1 Cumulative solar and wind installed capacity (Jan 2019-Jan 2024)

	Solar (GW)			Wind (GW)		
Source	Jan 2019	Jan 2024	CAGR (%)	Jan 2019	Jan 2024	CAGR (%)
CAPEX	20.9	50.4	19.3	14.3	21.3	8.2
CEA	25.2	74.3	24.1	35.1	45.0	5.1
GRW	31.9	70.7	17.2	42.1	55.1	5.5

Table 2 shows the percentage error of the 'source' compared to 'reference' over respective time 'window' for both solar and wind. We take the end-of-quarter value from each source to calculate the ratio, subtract 1, take the absolute value, and then calculate the mean/median of these quarterly values.

Table 2 Absolute percentage error for solar and wind capacity (quarterly)

Capacity	Reference	Source	Window	N	Mean (p.p.)	Median (p.p.)
Solar	CEA	CAPEX	2019–01 to 2026–04	30	28.6	29.8
	CEA	GRW	2019–01 to 2024–04	22	15.2	16.6
	GRW	CAPEX	2017–10 to 2024–04	27	35.4	36.0
Wind	CEA	CAPEX	2019–01 to 2026–04	30	55.0	55.3
	CEA	GRW	2019–01 to 2024–04	22	23.9	23.7
	GRW	CAPEX	2017–10 to 2024–04	27	64.4	64.7

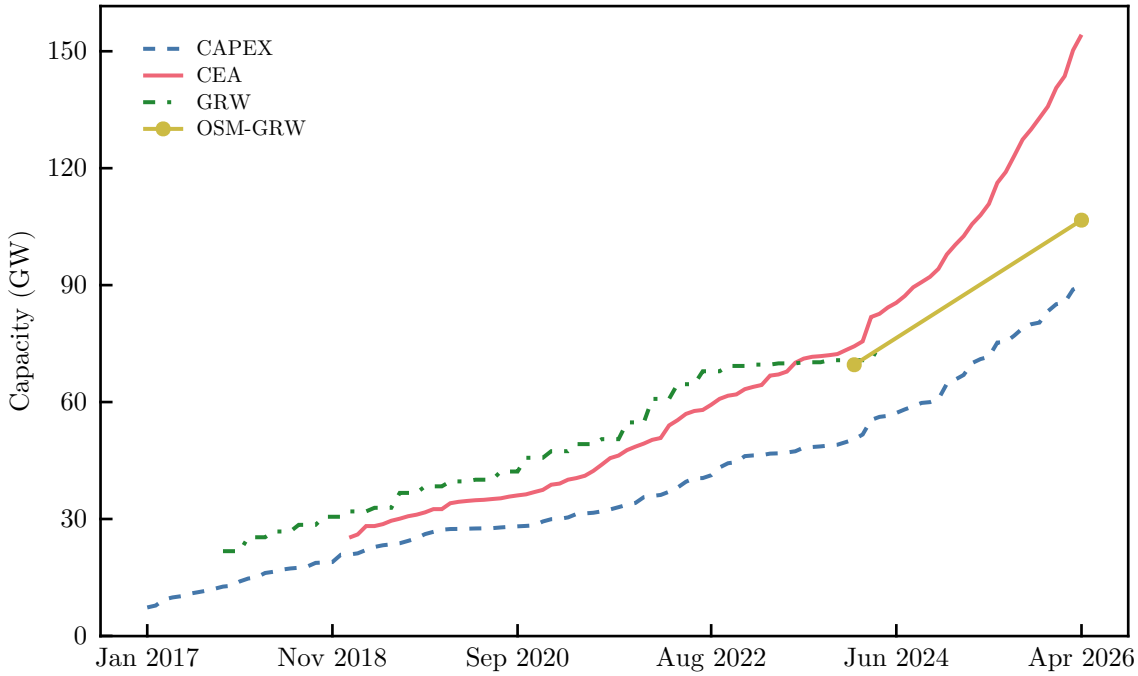
Table 3 shows point-in-time percentage error for solar and wind for January 2024 and April 2026. For April 2026, we use our OSM–GRW estimate from Section 2.4 to calculate errors. We do not have GRW estimates for wind for April 2026.

Table 3 Point-in-time absolute percentage error for solar and wind capacity (adjusted for solar rooftop)

Capacity	Reference	Source	Jan 2024 (%)	Apr 2026 (%)
Solar	CEA	CAPEX	17.2	24.4
	CEA	OSM-GRW	8.5	13.5
	OSM-GRW	CAPEX	23.7	12.6
Wind	CEA	CAPEX	52.7	51.9
	CEA	GRW	22.4	–
	GRW	CAPEX	61.3	–

In January 2019, CEA and GRW figures were generally aligned, although CMIE CAPEX figures were trailing. The two alternative datasets indicate lower compounded annual growth rates for the next five years (GRW at 17.2%, CMIE CAPEX at 19.3%) while the official CEA data reflects a compounded annual growth rate of 24.1%.

Figure 1 Cumulative solar installed capacity



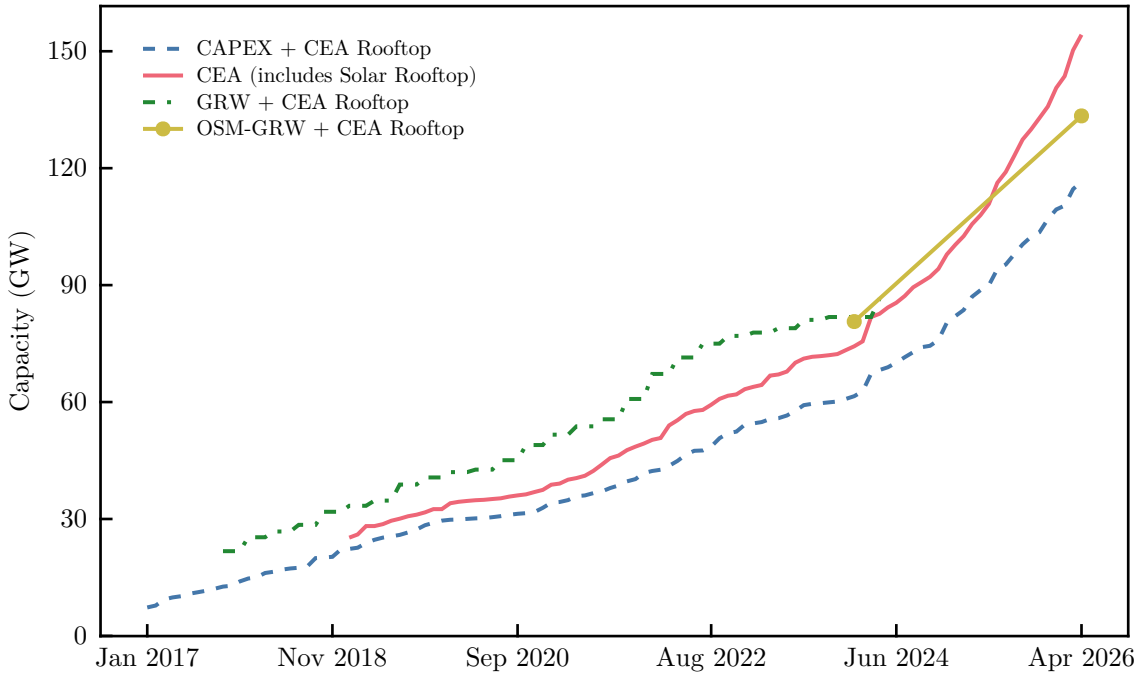
By January 2024, the CMIE CAPEX data indicates a substantially lower figure of 50.4 GW. In comparison, the CEA data stands at 74.3 GW, while the satellite imagery source GRW is close behind at 70.7 GW. It is important to highlight that GRW does not account for rooftop solar projects. Both CEA and CMIE CAPEX capture elements of the rooftop solar capacity; CEA reports both utility-scale and residential rooftop solar, while CMIE CAPEX only counts a portion of utility-scale rooftop solar. This may result in GRW underestimating capacity compared to CEA. Additionally, CMIE CAPEX will miss projects that are not announced in the public domain.

By April 2026, the respective errors between CEA and the alternative sources increase compared to January 2024. This is because of the increased gradient of CEA solar capacity starting Q1 2024. Meanwhile, the gap between the alternative sources closes with time as CMIE CAPEX captures more solar capacity.

The gap between official statistics and alternative data increases significantly post Q1 2024 (see Figure 1), with CEA reporting an estimated installed capacity of 154 GW and CMIE CAPEX reporting 90 GW by April 2026. We also have a point estimate from the OSM–GRW for April 2026 and this records installed capacity at 106.6 GW. The OSM–GRW metric comes from a methodology similar to that used by the Microsoft researchers at Global Renewables Watch. During further discussion in this paper, we treat it as a satellite point estimate for GRW.

CEA counts both residential and large-scale rooftop solar, while CMIE counts only publicly announced large-scale rooftop solar and GRW does not count any rooftop solar capacity. CMIE CAPEX last reported rooftop solar at 0.3 GW in April 2026. To make the three sources comparable, we add month-wise rooftop solar capacity as reported by CEA to the

Figure 2 Cumulative solar installed capacity inclusive of rooftop solar



two alternative measures. CEA last reported rooftop solar capacity at 26.7 GW in April 2026 (see Figure 2).

After adjusting for rooftop solar capacity, GRW largely aligns with CEA figures in April 2024 with a mean absolute percentage error of 4.7%, but the error widens to 13.5% in April 2026. CMIE CAPEX, on the other hand, appears to have been diverging since Q2 2024, with the error increasing from 17.5% in April 2024 to 24.4% by April 2026.

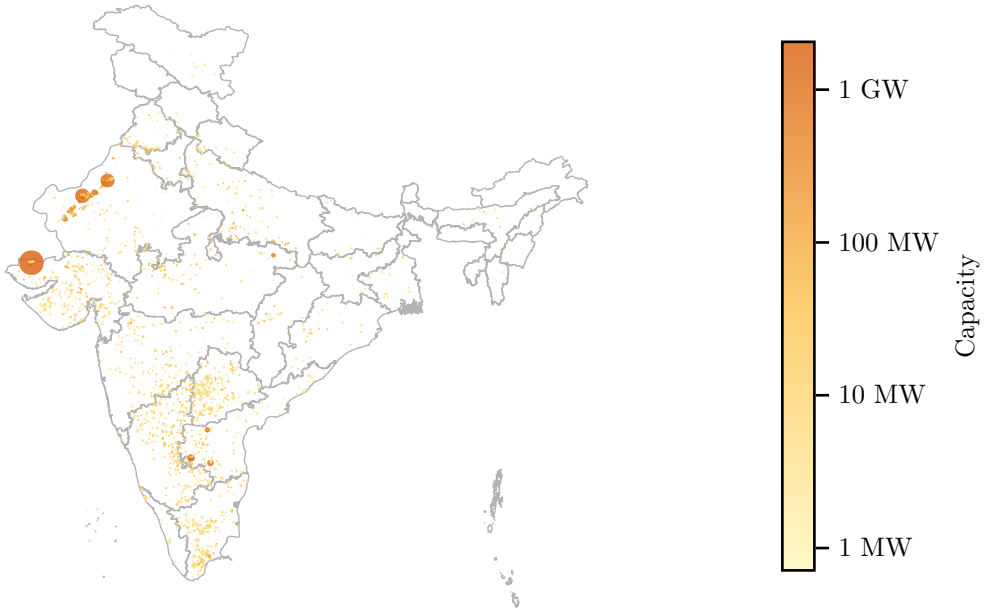
Figure 3 shows the geographical distribution of installed solar capacity within the country. Rajasthan and Gujarat have the highest installed capacity along with several large solar plants. Maharashtra, Tamil Nadu, and Karnataka follow in terms of installed capacity. We also observe geographical concentration of smaller solar installations in Telangana, Karnataka, and Tamil Nadu.

In the case of wind energy, the trends have remained consistent over time. In 2019, GRW reported 42 GW while CEA was at 35 GW and CMIE CAPEX was at 14.3 GW. By 2024, the gap had increased, with GRW reporting 55.1 GW compared to CEA at 45 GW and CMIE CAPEX at 21.3 GW (see Table 1).

The CEA growth rate of wind capacity has increased since 2024 (see Figure 4). As of April 2026, CEA records show installed wind capacity at 56.4 GW compared to 27.1 GW of CMIE CAPEX.

There is a notable difference between the capacity figures for solar and wind energy. The three data sources tend to align more closely for solar up till Q1 2024, while the wind figures exhibit greater variation. As illustrated in Table 2, for solar, the absolute error between the alternative data sources ranges from 16.6 to 36 percentage points in

Figure 3 Heatmap of solar projects in India for Q2 2026



comparison to CEA, while for wind, it ranges from 23.7 to 64.7 percentage points.

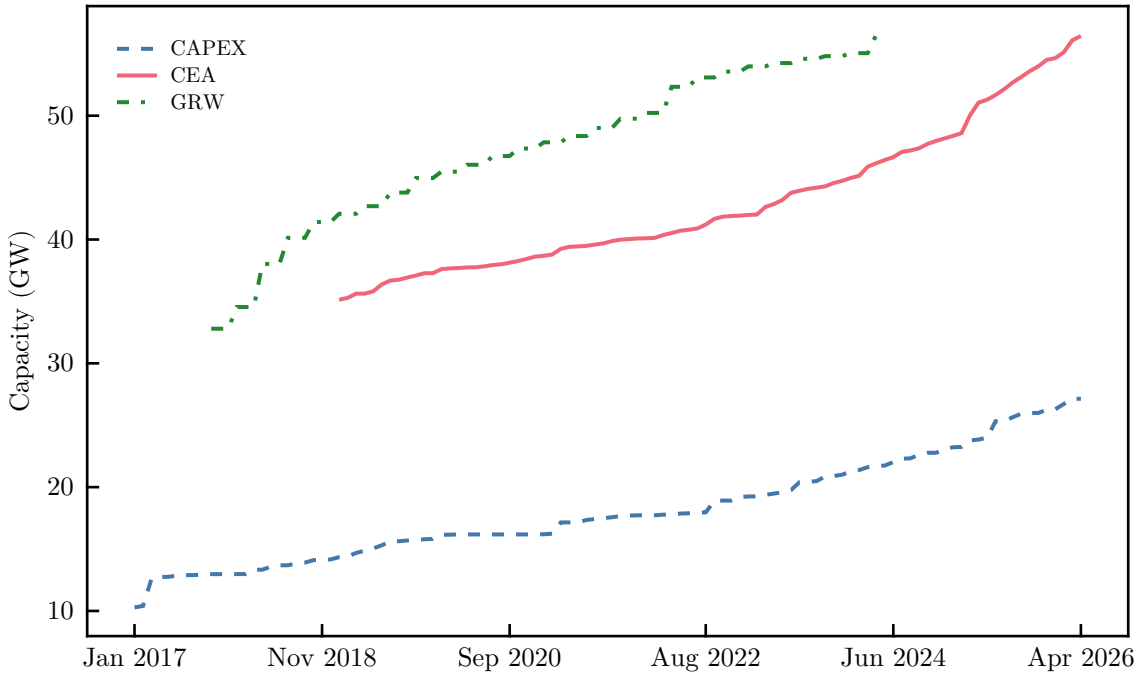
This discrepancy between GRW and CEA may stem from the mapping of physical windmills to generation capacity – GRW uses an average global capacity factor of 3 MW per turbine (U.S. Department of Energy 2026). In India, the higher cost of capital has resulted in a preference for smaller turbines. Domestic manufacturers typically produce turbines within the 2-3.6 MW range, with production dominated by the sub-3 MW variants (NITI Aayog 2024). The GRW exceeds figures of CEA by ∼23.7% for wind capacity – from this we estimate the average size of the turbine in India to be ∼2.42 MW.[6] This may help explain why the GRW estimate exceeds the CEA estimate for India to the extent that it does.[7]

The CMIE CAPEX data accounts for ∼48% of the installed wind capacity of CEA as of April 2026. Since CMIE CAPEX is a sample, it may under-represent capacity estimates. In contrast, GRW, with its bird's-eye view and higher turbine multipliers, could over-represent capacity.

6. This is assuming GRW and CEA identify an identical number of turbines. If GRW overcounts installations, the average capacity estimate shifts toward the lower end of the 2-3.6 MW range; conversely, undercounting pushes the estimate toward the higher end.

7. We thank Akshay Jaitly at the Emerging Markets Conference 2025 for this insight.

Figure 4 Cumulative wind installed capacity



4 Discussion

The Indian government aims to achieve 500 GW of non-fossil-fuel capacity by 2030. This goal will require private firms to invest and execute projects at different scales across India's geography, in addition to government projects. The key question is whether government infrastructure can effectively measure these decentralized capacity additions. While the CEA provides aggregate statistics, it lacks the detailed geocoded project-level data for researchers to verify these facts. In this paper, we assess whether alternative datasets, particularly satellite imagery and project-level tracking, can independently and accurately verify official statistics.

The triangulation exercise using the alternative data sources reveals two distinct features. For solar energy, satellite imagery improves confidence in standard Indian official statistics. The OSM–GRW point estimate (after accounting for rooftop solar) places India's solar capacity at ∼133 GW for April 2026. We believe the satellite estimate with a small downward adjustment to account for non-operational plants is India's true solar installed capacity.

In contrast, for wind energy, the disparity between the three measures is greater in percentage terms, likely due to turbine capacity factors and the under-representation of wind projects in the CMIE CAPEX database. CMIE CAPEX serves as the floor for capacity estimates for both solar and wind. CEA is the ceiling for solar estimates while GRW gives the highest estimate for wind.

Additionally, the CMIE CAPEX database has become a valuable project-level resource, accounting for 75% of the CEA reported capacity for solar and 48% for wind in 2026. This

provides researchers and policy-makers with a continuous data stream to cross-validate official statistics and leverage this project-level measure for detailed analysis that would not be feasible with national aggregate statistics.

Our findings suggest that alternative data sources can effectively cross-validate official statistics and offer more detailed project-level insights on renewable initiatives compared to aggregate national data, thereby enhancing microeconomic and spatial research.

This analysis surfaces an important measurement problem and establishes a methodology to investigate official government statistics regarding renewable energy measurement. The broad alignment of the three data sources for solar lends credibility to official statistics, as of 2026. This analysis should be repeated every few months to ensure accountability of official reporting. We provide a reasonable data benchmark over which further research and public debate can happen (Shah and Varma 2024).

Furthermore, while the CMIE CAPEX database functions as a survey, its substantial undercount of solar capacity suggests that unrecorded utility-scale projects and rooftop solar contribute significantly to the total solar capacity. Despite this limitation, the availability of geocodes and project-level details in CMIE CAPEX enables researchers to move beyond national aggregate statistics, allowing for an examination of the geolocation of renewable capacity and its spatial impacts on the energy grid.

While trends in onshore wind and solar energy can be verified using various conventional data sources, alternative data can be instrumental in estimating offshore wind capacity. Reports from Central Electricity Authority (2026) indicate that India currently lacks offshore wind capacity. In contrast, World Bank and ESMAP (2021) estimates that India has a potential of ∼174 GW, around 3.1× the current onshore capacity reported. To harness this potential, the Indian government plans to auction 37 GW of offshore capacity by 2029-30 (Ministry of New and Renewable Energy 2023).

Accurate measurement is crucial for effective policymaking. To monitor future capacity in real time, researchers could use machine learning models trained on satellite imagery (Hoeser, Bachofer and Kuenzer 2026). While these models can currently identify operational phases and geospatial locations, they do not yet provide capacity figures; however, these could be estimated by applying offshore wind turbine capacity factors. This can be an avenue for future research.

Ultimately, precise tracking is essential for India to achieve its climate objectives. The government aims for 100 GW of wind and ∼300 GW of solar energy by 2030 (Central Electricity Authority 2023). Alternative data sources, such as satellite imagery and project-level data, offer independent and real-time insights into the capacity needed to meet these ambitious targets.

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