Solar adoption in India entering “accelerating growth” phase

Building adequate grid flexibility is the next key step in India’s clean power transition

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Contents

About

This report is structured into three chapters, each delving into crucial aspects of India's renewable energy (RE) transition. In Chapter 1, we examine the potential outcomes if the targets for RE and storage in India’s 14th National Electricity Plan (NEP14) are successfully met. Building on this foundation, Chapters 2 and 3 look at the critical hurdles that could impact this journey. Chapter 2 explores the necessary capacity addition growth rates required to meet the NEP14 target, while Chapter 3 investigates grid interaction issues that India has to overcome to pave the way to not just meeting but possibly surpass the planned targets.

Highlights

66%

Share of generation growth to be met by solar and wind during FY 2022-32, if NEP14 targets are met

+20pp

Percentage point change in solar's share in India's total generation between FY 2022-32, as per NEP14

15%

RE generation that will be shifted to non-solar hours via storage, if NEP14 targets are met

36%

Year-on-year increase in annual solar capacity additions required to meet NEP14's FY 2027 target of 186 GW

Executive Summary

Solar is entering “accelerating growth” phase in India

Building adequate grid flexibility is now critical for India’s clean power transition.

India's energy landscape is rapidly evolving, with solar and wind likely to meet two-thirds of future demand growth by the Financial Year (FY) 2032, which is the 12-month period from April 1 to March 31 the following year. This marks a significant shift as solar and wind are likely to drive India’s electricity generation growth from FY 2022-2032, in contrast to the previously coal-dominated decade.

As RE, especially solar, enters an “accelerating growth” phase, grid integration issues would have to be addressed to prevent a slowdown in solar capacity addition. Balancing generation and demand cost-effectively with existing thermal and hydro generation capacity and storage options will be critical to prevent power shortages.

Notably, growth in electricity demand during the day has outpaced the growth in demand during non-solar hours, with peak demand now occurring during midday when solar generation is abundant. As a result, a larger portion of the increase in demand has aligned with the generation from solar sources. However, recent power shortages emphasise the growing need for peak power during non-solar hours, historically supplied by coal-based generation. As coal's contribution to overall generation is projected to decrease, as per the NEP14, a significant storage capacity, much higher than current levels, will be required to balance generation and demand without a significant buildout of coal capacity.

The expected cost reductions in batteries suggest that Variable Renewable Energy (VRE) with storage is expected to be cost-competitive with coal-based generation, especially for smaller storage needs. This therefore promises to be a cost-effective solution for balancing generation and supply during non-solar hours.

01 Solar and wind to meet two thirds of India’s power generation growth by FY 2032

NEP14 estimates India’s total annual electricity generation to grow by 1,174 TWh in FY 2022-32 period. Annual solar and wind generation are expected to rise by 593 TWh and 189 TWh respectively, which combined constitute 66% of India's power generation growth in this 10-year period. This marks a significant transition from the preceding decade when coal power accounted for around 80% of generation growth.

02 Solar is entering “accelerating growth phase” in India

Solar’s share in India’s power generation mix has begun to rise significantly since crossing the take-off point (1% of generation mix) in 2018, and is now entering an “accelerating growth” phase. NEP14 projects solar's share in the mix climbing from 5% in FY 2022 to 17% in FY 2027, and ultimately reaching 25% by 2032.

03 A shift of peak demand to sunshine hours has helped integrate more solar

Solar is now playing a bigger role in meeting India's peak demand. Between 2019 and 2023, non-solar hour peak demand experienced an approximately 3.9% year-on-year increase, while solar hour peak demand witnessed a ~5.4% year-on-year rise. However, maintaining a dependable supply for non-solar hour demand requires a comprehensive whole-system approach.

04 NEP14 storage targets can shift up to 15% of RE generation to non-solar hours by FY2032

The NEP14 storage capacity targets which include pumped hydro storage

and battery storage will be capable of shifting ~6% and 15% of RE generation to non-solar hours by FY 2027 and FY 2032, respectively.

05 Solar with storage is likely to be more cost-effective than building new coal

In FY2023, the average cost of coal generation was Rs 4.26/kWh. At the same time, solar and storage costs have significantly reduced, with recent successful bids indicating levelized costs as low 4.04-4.34 Rs/kWh.

India's power sector transition is at a pivotal juncture. To enable the unprecedented growth of solar and meet the NEP14 target, a comprehensive whole-system plan addressing the challenges is imperative. Grid flexibility, partly reliant on storage, is a key hurdle. The NEP's success partly hinges on ongoing battery cost reductions as this technology matures.

India's electricity supply landscape is projected to change quite significantly in the next decade or so, with solar and wind likely to drive the growth in generation. Given their variable nature, a significant increase in storage capacity is crucial to balance generation and demand.

Neshwin Rodrigues
India Electricity Policy Analyst, Ember

India is banking on solar and wind to drive future power growth

Two thirds of India’s power generation growth in the next 10 years will be from solar and wind, a shift from the last decade when most generation came from coal.

According to the 14th National Electricity Plan (NEP14), published by India's Central Electricity Authority (CEA), India’s electricity generation (generation throughout this report is inclusive of imports) is expected to increase from the FY 2022 level of 1492 TWh, reaching a total of 2,666 TWh in Financial Year (FY) 2032.

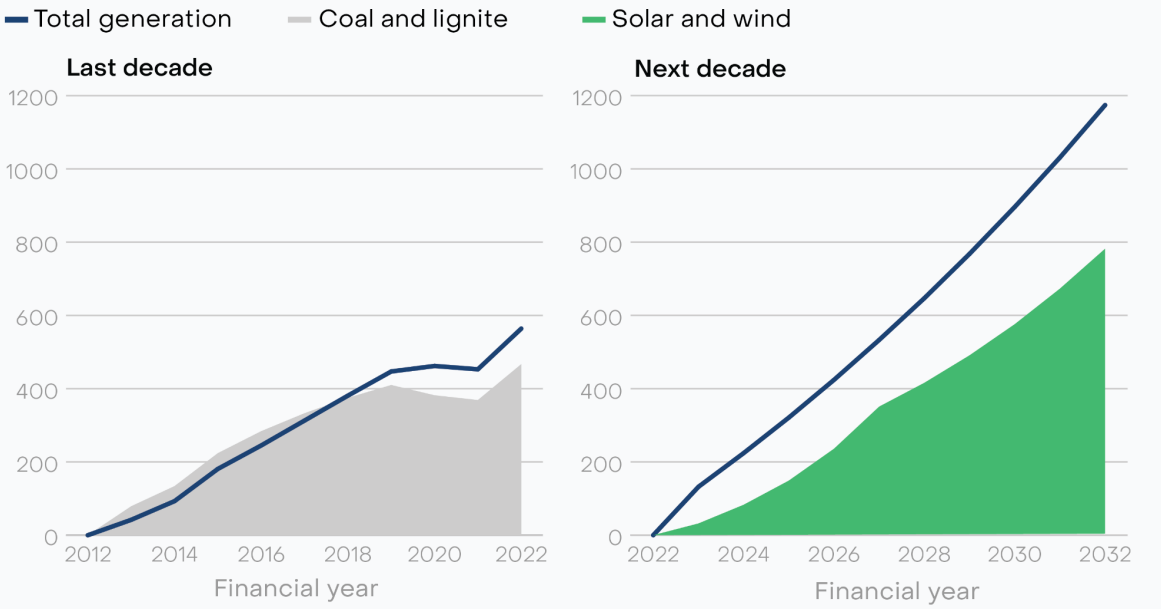
Notably, the plan lays out ambitious targets for solar and wind over the next decade. According to NEP14, solar power will contribute to around 50% of this growth in generation, and solar generation is expected to rise from 73 TWh in FY 2022 to 666 TWh in FY 2032. Wind power will contribute to 16% of the growth, increasing from 69 TWh to 258 TWh in the same time period, according to the plan.

Meanwhile, coal-fired generation is expected to increase by 257 TWh between FY 2022-32, to account for 22% of the generation growth in this period. This is in contrast to what was seen in the preceding ten year period. Between FY 2012 to 2022, coal-fired generation drove growth in power generation in the country. In this time period, India’s total power generation, including imports, increased by 564 TWh (from 928TWh in FY 2012 to 1492 TWh in FY 2022) and about 83% of this growth (467 TWh) came from growth in coal power generation.

Coal (including lignite)'s share of total generation, which has been over 70% since FY 2013, is projected to decrease to 59% and 50% by 2026-27 and 2031-32, respectively, according to the plan. **It means that if the NEP14 targets are realised, the growth in generation in the next decade will not be driven by an increase in coal based generation.**

Solar and wind to fuel India's generation growth in the next decade, after the coal-fueled growth in the last

Cumulative growth in electricity generation (TWh)



Source: Ember's analysis of MOSPI's Energy Statistic 2021 report, CEA's 14th National Electricity Plan (NEP14), NPP monthly generation data

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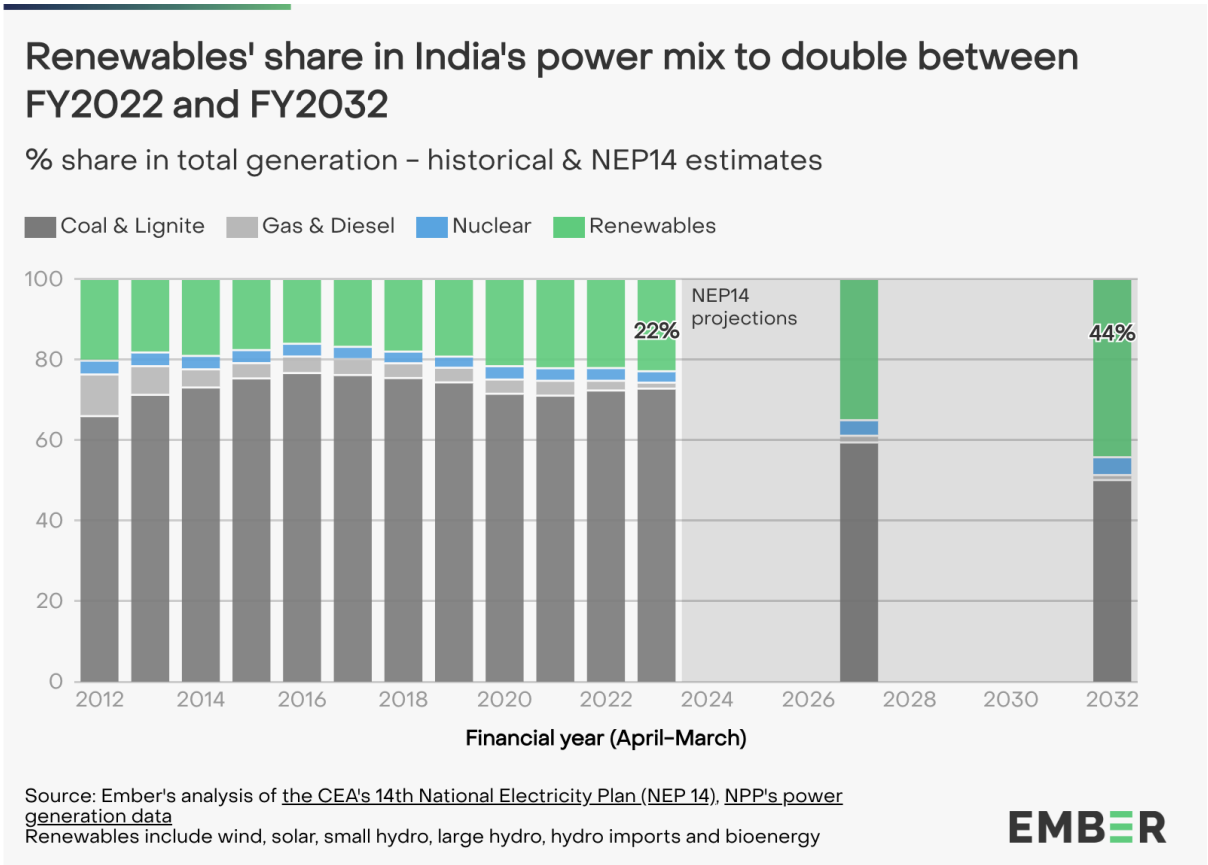
In FY 2022, the share of solar power in India's total electricity generation was 5%, while coal still accounted for 72% of total generation. **But if the NEP14 targets are realised, solar will enter an "accelerating growth" phase.**

This indicates that while the absolute value of coal-based generation is expected to increase until FY 2032, coal's share in the generation mix is projected to decrease by 22 percentage points from the current level. This marks a considerable decrease. Despite the NEP14 projecting an increase in absolute coal generation from 1079 TWh in FY2022 to 1203 TWh in FY 2027 and 1335 TWh in 2031-32, it anticipates a reduced contribution from coal to the overall generation growth.

Renewable share in India's electricity generation mix is expected to double in the period between FY2022 to FY2032.

In FY 2022, India generated about 22% of its electricity (330 TWh) from renewable energy sources (including large hydro). If India achieves its NEP14 targets, this share will almost double to 44% (1180 TWh) by FY 2032. Much of this will be driven by solar, with solar's share increasing from 6.3% (102 TWh) in FY2023 to 17% (339 TWh) in FY2027, and then further to 25% (666 TWh) in FY2032.

Overall annual power generation is expected to increase by 1079 TWh between FY 2022 and FY 2032. In tandem, solar generation is anticipated to increase more than six times from 73 TWh in FY22 to 666TWh in FY32.



India’s solar power is entering rapid growth phase

India’s current plans aim to increase solar’s share in the country’s power mix from 5% in FY 2022 to 17% by FY 2027, and to 25% by FY 2032.

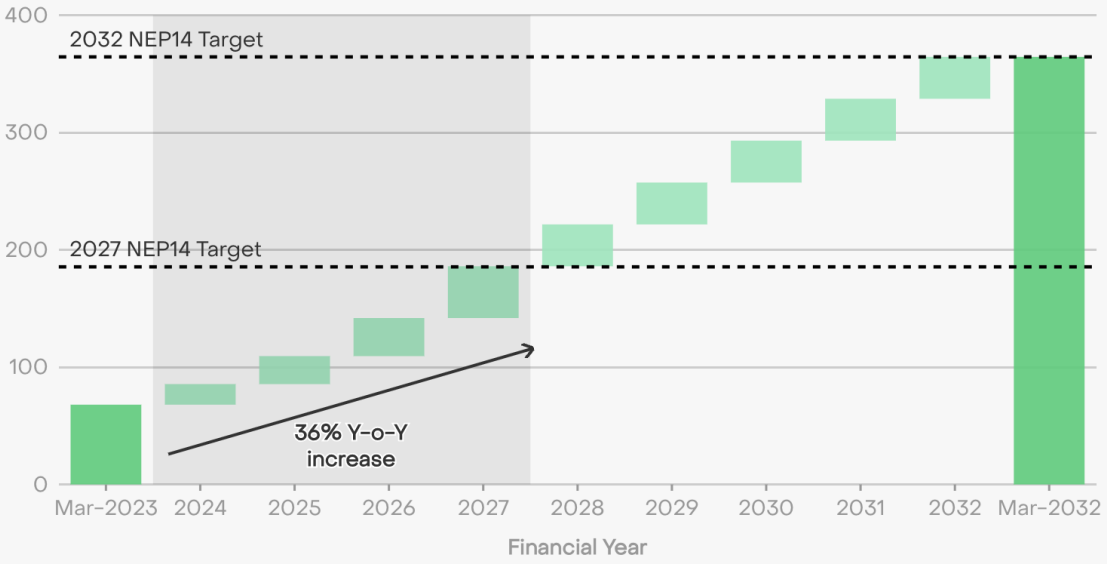
The NEP14 outlines specific targets of achieving 185.6 GW of solar capacity by FY 2026-27, reaching 364.6 GW by FY2031-32.

	Capacity target per NEP14		Capacity as of FY 2023	Capacity addition in FY 2023
	2026-27	2031-32		
Solar PV	185.6 GW	364.6 GW	66.7 GW	12.9 GW

To achieve these targets, India needs to increase its current annual solar capacity addition by about 36% each year leading up to 2026-27. This is on top of the record 12.9 GW of solar capacity addition that India commissioned in FY 2023, bringing the total national capacity to 66.7 GW.

India needs a 36% Y-o-Y increase in annual solar capacity additions to meet its 2027 target

Installed capacity and annual capacity additions in GW



Source: Ember's analysis of CEA's 14th National Electricity Plan (NEP14), MNRE RE capacity addition data

The recent addition of 12.9 GW in FY 2022 will be insufficient to reach the FY 2027 NEP solar capacity target of 185.6 GW. As the target year approaches, India would need to achieve a 36% year-on-year increase in solar capacity to remain on track for the 2027 goal. This means that India would need to commission a minimum of 17.5 GW in FY 2024, with a further ramp-up to 41 GW by FY 2027.

The capacity addition will then be sufficient to achieve the target solar capacity of 185.6 GW by March 2027. Beyond FY 2027, even if India continues to sustain the annual build-rate of 41 GW/year, it will surpass its target capacity of 365 GW by Mar-2032 by a comfortable margin.

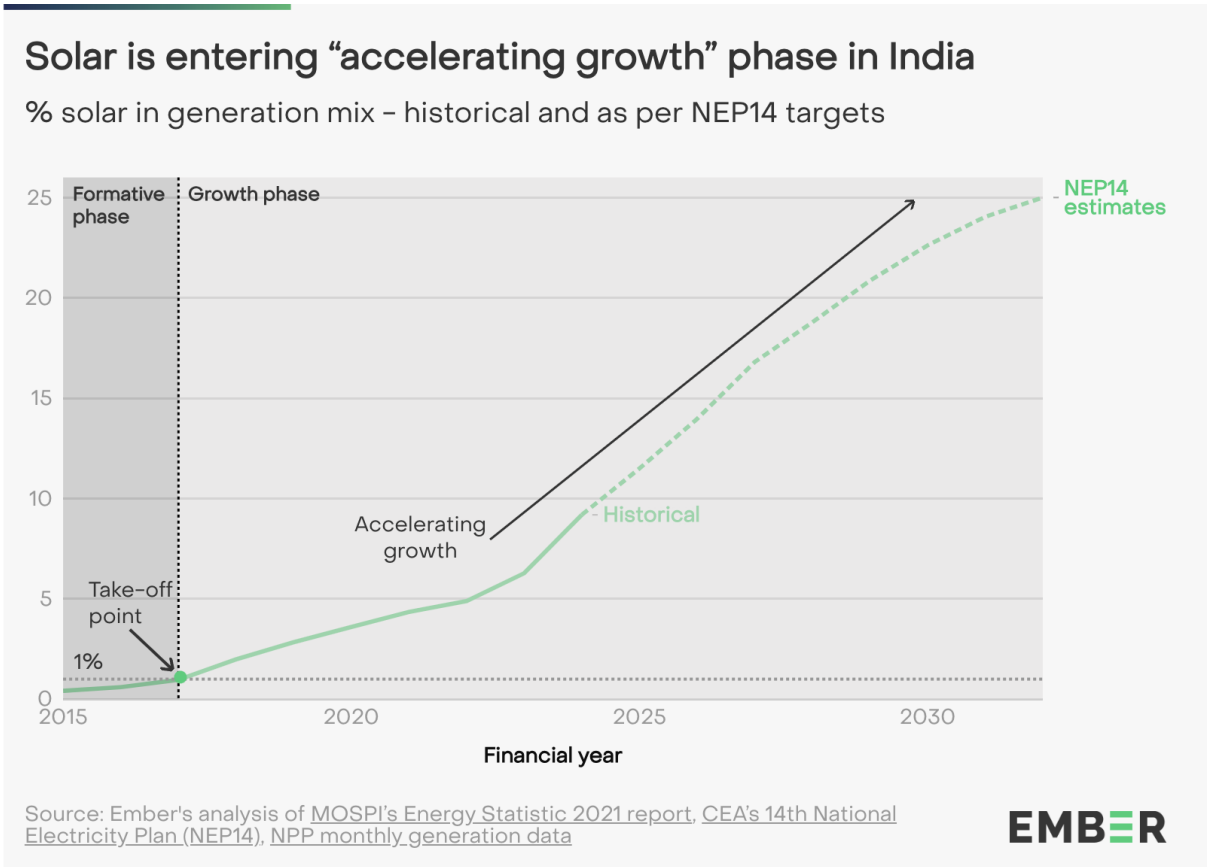
Progress towards achieving the NEP targets appears to be promising. Notably, investments in India's renewable energy sector have increased by approximately 30% in 2023, as measured against the figures from Q1 and Q2 in 2022. The recent government announcement regarding plans to invite bids for 50 GW of renewable energy capacity per

year over the next five years could signal a strong commitment to achieving the NEP14 targets. This encompasses both solar and wind capacity, with or without storage.

Addressing challenges related to under-subscription of tenders and reduced tender issuance rates could pave the way for India to successfully attain its 2026-27 target. Moreover, this progress may even prompt the nation to consider raising its ambitions for the subsequent period till 2031-32.

Solar adoption in India will enter an "accelerating growth phase" if NEP14 targets are met

The growth of any new renewable energy technology follows a S-curve with a typical pattern of a formative phase, followed by an accelerating growth phase, and eventually plateauing as a technology gains widespread acceptance and market saturation in a sigmoidal or "S" shape. In India, solar adoption is now in the growth phase, where solar's share in India's electricity generation mix is likely to rise rapidly.



Solar reached its "take-off" point in India during FY 2017 when its contribution to the electricity mix reached 1% for the first time. This is a widely accepted milestone on the S-curve of any renewable energy technology adoption.

This milestone marks the transition from the initial "formative" phase, characterised by high costs, uncertainties, and irregular growth, to the "growth" phase, where growth accelerates due to favourable economic profitability, technology advancement and policy support. As solar transitioned from the "formative" phase to the “growth” phase its share increased five fold from FY 2017 to constitute 5% of India's power generation mix in FY 2022. In FY 2023, solar's contribution to the electricity mix saw a significant increase, rising by a maximum of 1.3% from 5% in FY 2022 to reach 6.3%, marking the highest recorded increase thus far.

If the NEP14 targets are met, solar adoption is expected to enter a phase of "accelerating growth," with solar's share in the power mix rapidly increasing from 6.3% in FY 2023 to 25% in FY 2032. This signifies an acceleration in the adoption of solar generation. Should these targets be achieved, India could experience an average annual growth rate in solar’s contribution to the electricity mix of over 2%, with peak rates of change reaching approximately 3% in the time period between FY2023 and FY2032. This underscores the accelerated pace of the transition towards solar adoption, which is projected to be at least twice as rapid as it has been historically.

Policies around grid integration play a crucial role during this phase, as the expansion of solar generation may lead to mounting pressures due to rising grid integration costs. Such pressures could eventually slow down the growth trajectory and even lead to a saturation phase much lower than that physical limits due to land and resource availability.

One area of policy that requires attention is the growing demand for storage solutions and additional ways of enhancing grid flexibility is expected to increase, as the demand for grid flexibility is projected to rise at a considerably faster pace compared to previous years. Consequently, the demand and cost of grid flexibility is expected to have a notable impact on the overall cost associated with the expansion of VRE sources, influencing the cost-effectiveness of solar, which could inevitably shape the growth rate of solar itself.

The Institute for Energy Economics and Financial Analysis (IEEFA) has expressed concerns about a potential slowdown in the growth rate of India's solar energy sector. These worries arise from delays in tendering processes for new solar projects, which could impact capacity expansion and raise doubts about achieving the targets set by the NEP14.

Another challenge is the recent trend in solar tariffs, rising from 1.99 Rs/kWh in 2020 to 2.51 in Q1 2023. Factors contributing to this include disruptions in the supply chain, higher Good and Services Tax (GST) rates, escalating insurance costs and the implementation of customs duties. Additionally, the reinstatement of the Approved List of Models and Manufacturers (ALMM) after its suspension until March 2024 may lead to a rise in costs. This list confines participation in government-bid solar development projects to specific indigenous models and manufacturers.

Grid flexibility is now critical for transition

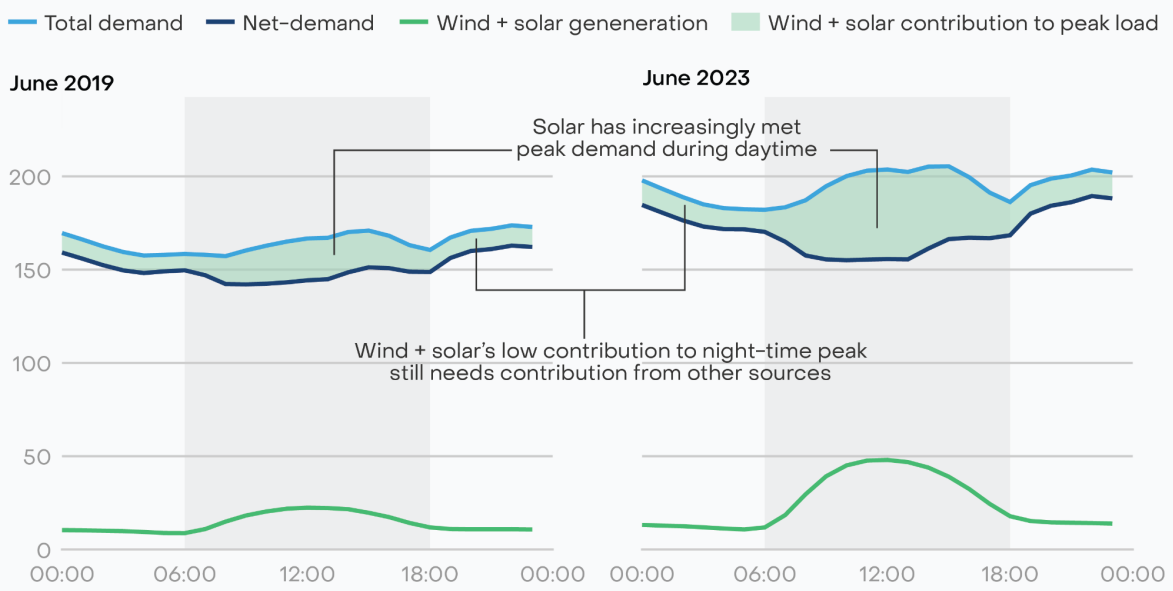
Solar meets increasing day time peak demand in India, but the challenge ahead will be managing increasing demand during non-solar hours.

The ongoing transition in the next decade underscores the need for a whole system plan that examines in detail India's power supply position during periods of limited solar and wind generation.

The growth of solar and wind energy capacity in India means that more electricity demand is being met by renewable energy generation. **However, its contribution to meeting electricity demand is not evenly distributed throughout the day or across different months of the year.**

VRE now meets more of India's daytime peak demand while non-solar demand continues to rise

Average daily peak and net demand in GW for June-2019 and June-2023



Note: Similar trends are seen in assessments for most months, with June as an illustrative example. Net-demand equals total electricity demand minus non-dispatchable solar and wind generation.
Source: Ember's analysis of Merit India data

While RE generation increasingly meets peak demand during solar-hours, there are instances during non-solar hours when the contribution of wind and solar is very low. The months between October to February presented a particular problem, when low wind generation meant that the RE contribution dropped to as low as 0.6% of electricity demand during non-solar hours.

For instance, in FY 2023, solar and wind sources supplied up to 31% of India's power demand (approximately 53GW in May 2022) during sunlight hours (between 9 AM to 5 PM). However, their contribution plummeted to as little as 0.6% (around 1GW in December 2022) during non-solar hours. This underscores the challenge presented by Variable Renewable Energy (VRE) generation. The intermittent nature of VRE generation means they cannot consistently generate power to meet demand around the clock and throughout the year.

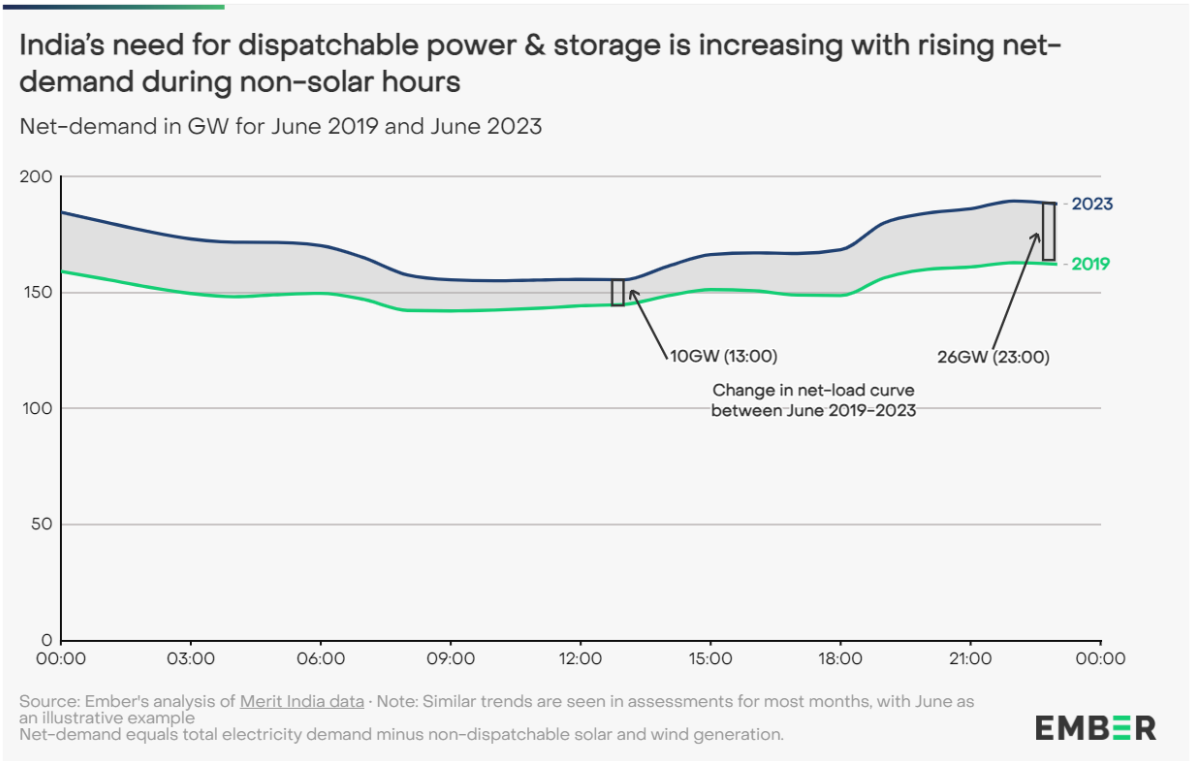
The contribution of VRE, particularly solar, to meet daytime electricity demand is progressively growing. However, the growth in VRE's contribution to meeting electricity demand during non-daytime hours is not advancing at the same pace.

For instance, consider the average load, solar and wind generation profiles for June 2019 and June 2022. In June 2022, solar and wind combined accounted for a maximum of 23.5% of electricity demand (at 12 noon) and a minimum of less than 6% (at 5:00 am). In contrast, during June 2019, solar and wind contributed a maximum of 13% (at 12 noon) and a minimum of less than 6% (at 5:00 am).

The average load and VRE generation profiles denote the mean generation and load values for every hour of the day within a specific month. Assessment for most of the other months in the year also shows a similar trend. This observation highlights that while solar and wind are increasingly meeting daytime demand, their contribution to early morning, evening and night time demands have remained relatively unchanged.

While enhancing wind capacity targets to strengthen RE generation during non-solar hours can help, it's essential to consider the seasonality inherent in wind-based generation. Around 55% of wind generation occurs within a concentrated five-month span (May-August). These are the months when India typically sees high peak loads, but it is worth noting that the months of lowest RE generation also correspond to low wind generation months (November-February). This seasonal pattern underscores the need for a diversified power mix that addresses seasonal and diurnal nature of RE generation and electricity demand.

Emergence of a steep net-load curve during evening hours



Even as India continues to expand its solar and wind capacity, there will be a growing requirement for "firm" and “dispatchable” generation capacity to meet demand when solar and wind generation are not available.

The "firm" and “dispatchable” capacity requirement, whether it's generation or storage, will be determined by the net demand, i.e. the electricity demand minus the generation met by non-dispatchable sources such as wind and PV. The pronounced surge in solar generation in the middle of the day significantly reduces the need for conventional power sources such as coal during solar hours. Conversely, as the sun sets and solar generation decreases, the net electricity demand rises sharply, resulting in the distinctive "neck" and "head" shape of the net-load curve that resembles a duck.

The emergence of the duck curve highlights two important issues related to grid integration of VRE. Firstly, the net demand that must be met by dispatchable sources is increasing at a higher rate during non-solar hours compared to in solar hours. For example, if we compare the average net-load curves for the month of June in 2019 and 2023, net demand to be met by conventional sources has increased by 26GW during nighttime (23:00), while it increased by 10GW during the daytime (13:00). This shows that the electricity system requires reliable

and dispatchable capacity on top of the solar power expansion to meet demand when solar is unavailable. This also underscores the need for peakers in the future, which have low utilisation and higher per unit (kWh) costs. One such option is storage.

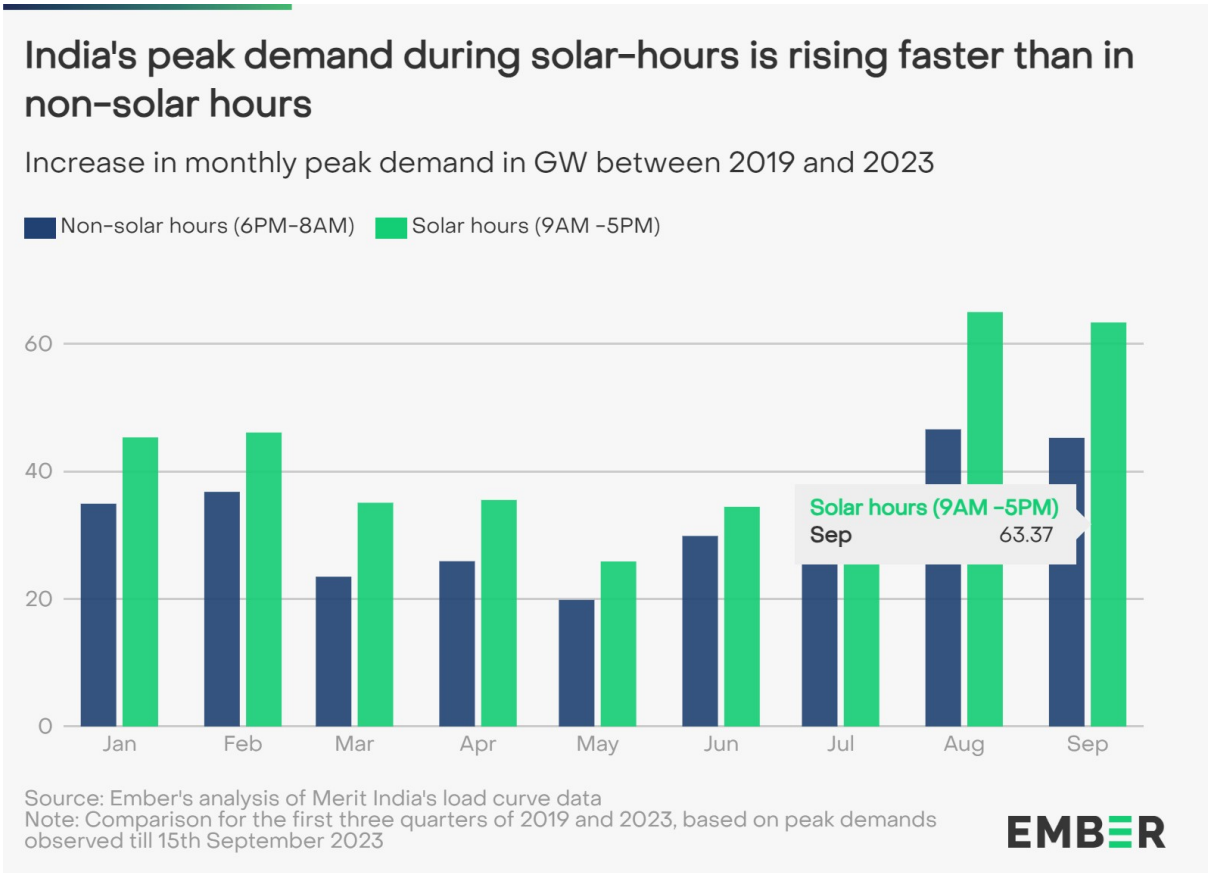
Secondly, since solar generation occurs primarily during the day, increasing in the morning hours, peaking around midday, and decreasing afterwards, conventional sources must ramp down generation when solar generation increases and ramp up when solar generation begins to decrease. The ramp rate required to be achieved by conventional sources is expected to increase as solar generation capacity grows.

A crucial question for power system planners, at both state and central levels, is on how to meet demand during non-solar nighttime hours in the next decade. This includes addressing the evening ramp-up in generation needed to meet demand as the sun sets and solar generation starts to decrease.

If India is unable to effectively handle the peak demand during non-solar hours using existing thermal and hydro generation capacity and storage options, it could potentially result in peak shortages, particularly during non-solar hours.

This can partly explain what happened during the top two high peak demand days that India recently witnessed. India saw its highest peak demand day (at the time of writing) on September 1st, 2023, when generation capacity met 240 GW of demand with a shortage of 1.6 GW around noon. However, at 22:40 hours, despite meeting the evening peak demand of around 213 GW, there was a notable shortage of approximately 7.5 GW. Similarly, on August 17th, 2023, India met a peak demand of 234 GW during solar hours with a shortage of 0.2 GW , but saw a significant peak shortage of 6.7 GW at 19:24, despite the system meeting the evening peak demand of around 210 GW. These instances underscore the challenges of solar generation variability and the imperative for additional dispatchable capacity to effectively manage peak periods.

Such peak shortages can lead to widespread power cuts, which could put pressure on state and national planners to hastily plan for increasing the coal capacity which could result in future lock-ins.



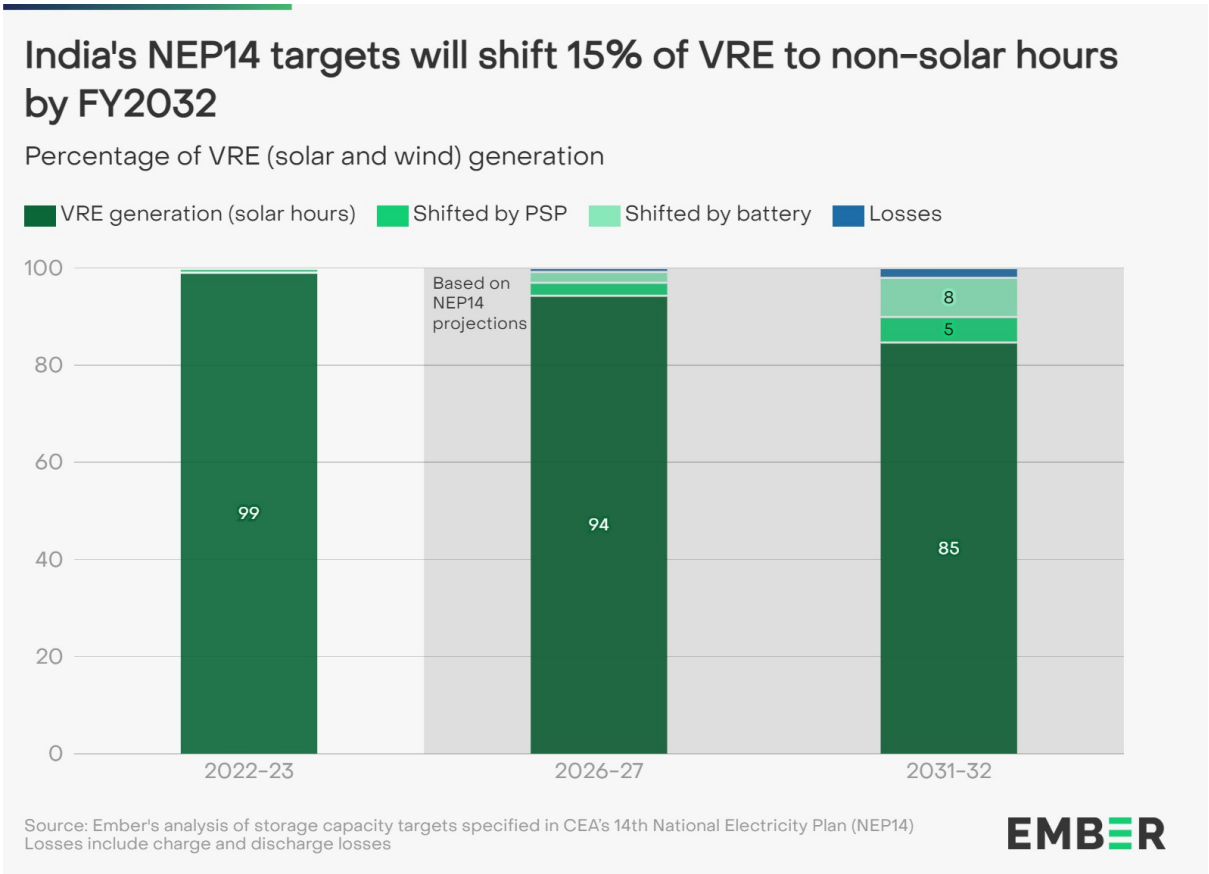
A significant development that has potentially helped increase the integration of solar in recent years is that both daily peak demand and overall electricity consumption have shifted to align more closely with solar generation. This shift, combined with India's recent expansion of solar capacity, has resulted in non-dispatchable solar generation temporally overlapping more with electricity demand.

Solar's alignment with peak demand is evident when we look at the increase in annual peak demands between 2019 and 2023. The peak demand during the solar hours (9 am to 5 pm) grew from ~182 GW in 2019 to 240 GW in 2023 (approximately 7.2% year on year), while non-solar hour peak (6 pm to 8 am) demand grew from 182 GW to 216 GW (about 5.4% year on year) in the same period. This trend holds true across all the months, with solar-hour peak demands increasing much more than non-solar hour peak demands between 2019 and 2023, for all the months up to September.

A similar trend is observed in the percentage change in overall demand, not just during peak demand. While demand has shifted to daylight hours between 2019 and 2023, it is to be seen if this trend persists in the future.

Plan for storage

To increase the uptake of VRE beyond the current level, a significant increase in storage capacity is crucial. The storage targets from the NEP14 can shift around 15% of total planned VRE generation to meet non-solar hour demand by FY 2032.



The NEP14 targets to increase India's battery storage capacity to 8.7 GW (4-hr average back up) by Mar-2027 and 47.2 GW (5-hr average back up) by Mar-2032. Pumped storage power plant (PSP) capacity is projected to increase to 7.5 GW by mar-2027 and 26.7 GW by Mar-2032. This planned capacity for storage would be capable of shifting ~6% and 15% of VRE generation to non-solar hours by FY2027 and FY2032 respectively.

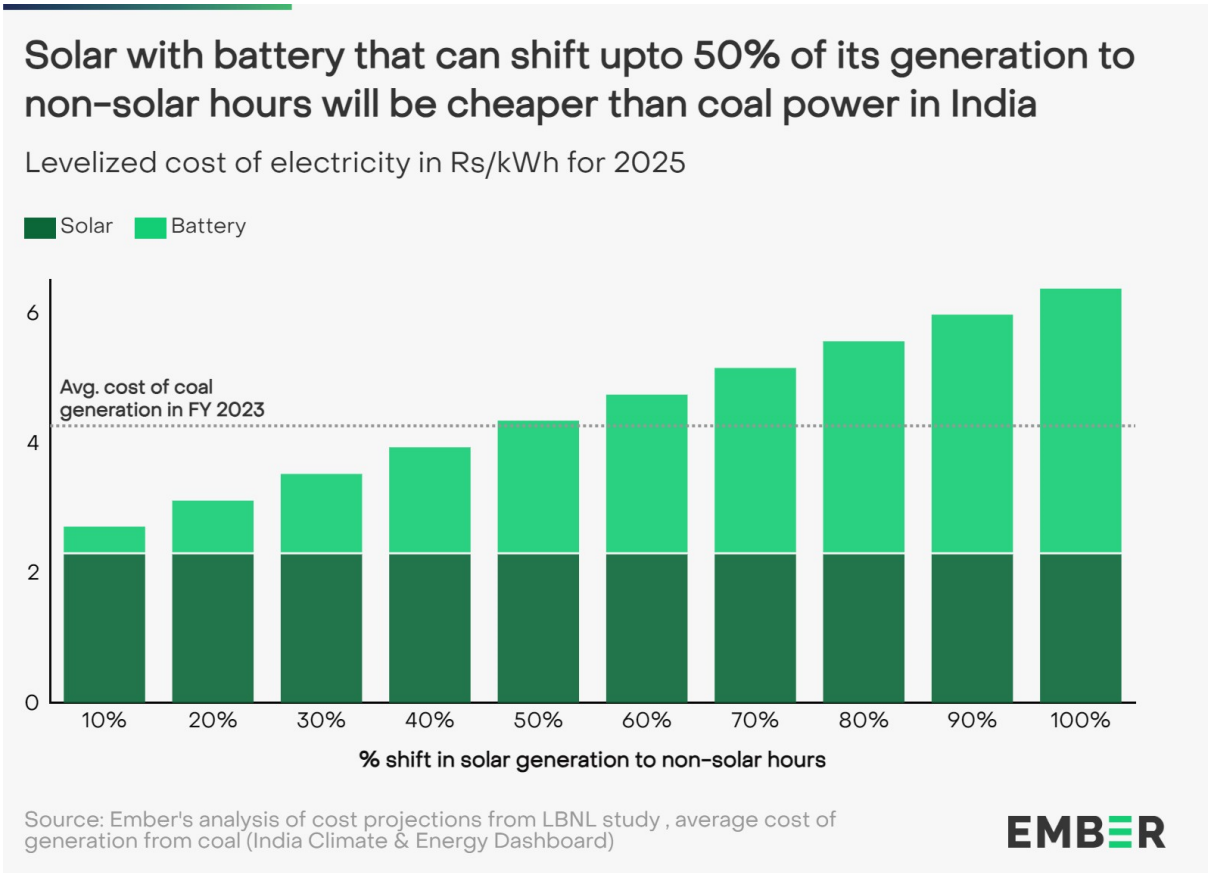
This planned increase in storage capacity is also crucial to integrate solar and wind. Its successful rollout will prevent excessive RE generation curtailment as solar and wind

generate more, and will help avoid a significant expansion of coal generation capacity. They allow for the transfer of electricity generated from times of high solar and wind generation to periods with lower generation.

While coal generation is expected to cover most of the electricity demand during non-solar hours until the next decade, there is a growing need to shift VRE generation to non-solar hours using storage to avoid power shortages in these hours.During instances of low generation from RE, even if the electricity demand is met by increasing operating coal generation capacity, it can increase the overall cost. This is due to the fact that coal plants would operate at low Plant Load Factors (PLFs), generating power only when solar and wind energy are scarce.

The cost of storage, especially battery storage, has considerably decreased in the last few years. This cost reduction has made "dispatchable" co-located RE and storage, a feasible solution for meeting demand during peak instances when RE generation is relatively low.

Even the recently approved power tariff for new RE plus storage plants, tendered by the Solar Energy Corporation of India, had the winning bids for co-located solar and Battery Energy Storage Systems (BESS) ranging from 6.15 to 6.85 Rs/kWh for peak power supply and 2.88 Rs/kWh for off-peak supply. This capacity is expected to shift around 20%-30% of the total electricity generated, and translates to an aggregate cost between Rs 4.04-4.3/kWh. In comparison, the coal-based generation for FY 2022-23 bore an average cost (fixed cost and variable cost combined) of Rs/4.26 kWh.



Projections from the Lawrence Berkeley National Laboratory, which consider PPA price data from a number of existing MW scale storage systems in the US, and BNEF cost projections indicate that the cost of co-located solar with storage (capable of shifting 40% of power to non-solar hours would be around Rs 4/kWh by 2025. The cost projections for the required level of storage, in accordance with the NEP14 storage capacity targets, appear to be comparable with India's average cost of coal generation in FY2023

However, as the amount of power required to be shifted increases, the need for reductions in BESS costs becomes more pronounced. This is essential to make solar with storage an effective alternative when compared to new coal-based generation capacity, in terms of dispatchability and cost.

As India builds its storage capacity, the role of existing coal power plants will change. From a purely financial perspective, the cost of dispatchable renewable energy through storage is currently higher when compared solely with the variable cost of already built coal capacity. As such, the existing coal capacity can provide the required grid flexibility as storage costs

continue to fall this decade to a point where they offer a financially viable alternative to increasingly meet non-solar demand. .

Policies in India appear to be in the right direction. To promote the development of storage capacity alongside RE capacity, the Ministry of Power (MoP), Government of India has approved Energy Storage Obligations for distribution utilities. It's important to note that these obligations are currently set at a level lower than the level of storage required as outlined in NEP14. The Government of India has also approved a viability gap fund for a limited capacity of 4 GWh for battery storage, covering up to 40% of the capital cost with an aim to reduce costs and make stored renewable energy a viable option for managing peak power demand across the country.

Furthermore, the MoP has introduced a national framework aimed at promoting energy storage. This initiative is designed to foster the adoption of energy storage technologies.

Discussion

India needs to increase its annual capacity addition by around 36% every year to meet its NEP target for solar. The recent government announcement regarding plans to invite bids for 50 GW of renewable energy capacity per year over the next five years could signal a strong commitment to achieving the NEP14 targets.

Solar is targeted to meet a quarter of the total generation in India by FY 2032 from 5% in FY 2022, thereby expected to enter a phase of accelerated growth. However, it is crucial to address impediments to growth, with one major challenge being the growing demand for flexibility.

To fully harness the growing significance of solar energy, India should focus on enhancing power system flexibility by utilising various options on the generation, transmission and demand side. On the generation side, efforts should be made to improve the flexibility of existing coal plants. Given India's requirement for increased firm peak generation capacity, the potential of peaker power plants should be further investigated. To incentivize flexibility adoption, it is crucial to establish effective remuneration mechanisms capable of offsetting the additional costs associated with low plant load factor.

On the transmission side, better use of existing transmission capacity, and building new capacity is crucial for generation and demand balancing across space and at various timescales. A promising development in this context occurred in December 2022, when the India Ministry of Power (MoP) introduced a comprehensive plan to reinforce transmission and evacuation infrastructure Demand response by utilising Time of Day pricing can serve as an effective strategy to incentivize consumption during off-peak periods or times of abundant solar generation throughout India. Time of Day pricing can also play a crucial role in incentivising investments in storage capacity.

Integrating mechanisms like Time of Day may require complementary market approaches, such as the proposed Market Based Economic Dispatch. Such mechanisms are expected to reduce the cost of grid integration by enabling a wider area of coordinated scheduling and dispatch. Under the current self-scheduling mechanism in India,self-scheduling, which involves scheduling based on the generation and storage capacity within the distribution utilities' PPA portfolio, can lead to limited utilisation of thermal generators and storage flexibility. But to enable such a market based mechanism, there is an urgent need for India to tackle several issues, especially those related to cost recovery of distribution utilities.

Supporting Materials

Methodology

In Chapter 1, we compare coal and RE generation growth from FY 2013 to FY 2022 and FY2022 to FY2032 showcasing their contributions to overall generation growth.

Chapter 2 analyses required annual growth rates for solar capacity addition, focusing on year-on-year increases in capacity addition from the previous year to meet NEP targets.

Chapter 3 assesses the impact of intermittent RE generation on the net load curve. The figure for June is meant to illustrate the impact, whereas the assessment was carried out for other months of the year as well.

We also calculate the level of RE generation shift that meeting the NEP14 storage capacity targets would facilitate. The assumptions on cycling round-trip efficiency can be found in the datasheet.

Furthermore, in Chapter 3, we assess the cost of generating power from co-located renewable energy and storage facilities. This is compared against the average cost of power generation from the coal fleet in fiscal year 2022. Data from tendered capacities of co-located RE and storage systems, along with projections from a previous LBNL study, are utilised for this evaluation.

For detailed data and calculations, the accompanying excel file can be accessed **here**.

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Header image

Setting sun and electricity pylon in Bihar, India

Credit: Jenny Matthews / Alamy Stock Photo