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Meeting India's Peak Power Demand with Clean Energy

- *India's peak electricity demand now typically occurs around 3PM during solar hours and again between 9PM and 11PM during non-solar hours. This is driven by rising air conditioning loads, intensifying heatwaves, and growing industrial and commercial demand.*

- *Despite rapid growth in solar capacity, the grid remains heavily dependent on coal to meet the evening peak, highlighting a missed opportunity to lower power sector emissions.*

- *Energy storage and demand-side management are essential to address this gap by deploying stored energy to address the evening peak and shifting part of the evening demand to daytime. These measures will not only enhance grid reliability but will also reduce price volatility on the power exchanges.*

1. Introduction

India is experiencing record-breaking electricity demand peaks, most notably in the afternoons and early evenings. These patterns are driven by escalating heatwaves and seasonal temperature extremes. According to the India Meteorological Department, the summer of 2024 recorded 536 cumulative heatwave days across India, the highest in 14 years. This year, the onset of heatwaves was seen even earlier, with parts of Konkan and Coastal Karnataka experiencing heat events as early as February.

Electricity demand surged, with peak demand rising from 190 gigawatts (GW) in January 2021 to 250GW in May 2024. On 15 May 2025, the daily peak reached 231GW, lower than the previous year, due to cooler temperatures resulting from unseasonal rains.

To better understand the drivers behind these rising peaks and evolving demand patterns, this note examines how electricity consumption is changing across sectors, regions, and timeframes. It highlights trends by consumer category, national and regional demand spikes, and daily and hourly load curves for peak demand days.

1.1 Trends in Electricity Consumption by Consumer Category (FY2021–24)

As of FY2024, the industrial, commercial, residential, and agricultural sectors accounted for approximately 32%, 10%, 31%, and 22% of India's total electricity sales, respectively. This distribution underscores the diverse nature of electricity consumption in the country.

The **industrial** sector remains the largest consumer of electricity, with consumption rising from 283 billion units (BUs) in FY2021 to 368BUs in FY2024, a growth of 30% in three years. Its share in total electricity consumption hovered around 29–32% during this period, driven by growth in manufacturing, construction, and heavy industries such as cement, steel, and chemicals.

The **commercial** sector has shown robust growth, with consumption growing by 41% from 81BUs in FY2021 to 114BUs in FY2024. Its share in total consumption rose from 8% to 10% during this period, driven by increasing commercial real estate and retail expansion.

Residential demand has shown consistent growth of 10% in the last three years, though the growth is lower compared to C&I demand, increasing from 320BUs in FY2021 to 353BUs in FY2024. This steady rise reflects urbanisation, appliance penetration, especially air conditioning (AC), and population growth. The sector accounted for 31% of the total electricity consumption in FY2024. In 2024 alone, the sales of ACs jumped by 40-50%, underscoring the growing demand for indoor climate control.

Interestingly, rural electrification is playing a transformative role in driving up residential demand. With near-universal household electrification now achieved under schemes like Saubhagya, and with feeder segregation improving supply quality, millions of rural households enjoy longer and more reliable power supply.

Consumption in the **agricultural** sector has remained relatively stable, increasing marginally from 236BUs in FY2021 to 255BUs in FY2024. Agriculture continues to account for approximately 22% of total electricity consumption, reflecting the critical role of electricity in powering irrigation pumps across large agrarian states like Punjab, Haryana, and Uttar Pradesh.

While still modest in scale, **electric vehicles (EVs) and green hydrogen production** are beginning to contribute to electricity demand. Electricity consumption by EVs has grown nearly tenfold – from 59 million units (MUs) in FY2021 to 569MUs in FY2024 – driven by rapid adoption in the two-wheeler, commercial fleet, and urban transport segments. With expanding charging infrastructure and robust state-level policies, this growth is expected to accelerate. On the other hand, even though large-scale hydrogen demand is yet to materialise, initiatives under the National Green Hydrogen Mission can reshape industrial and renewable demand profiles in the coming years. Together, EVs and green hydrogen represent a structural shift towards electrifying transport and industrial feedstocks, deepening electricity's role in India's decarbonisation.

2. Analysing India's Peak Power Demand

2.1 Annual Peak Power Demand

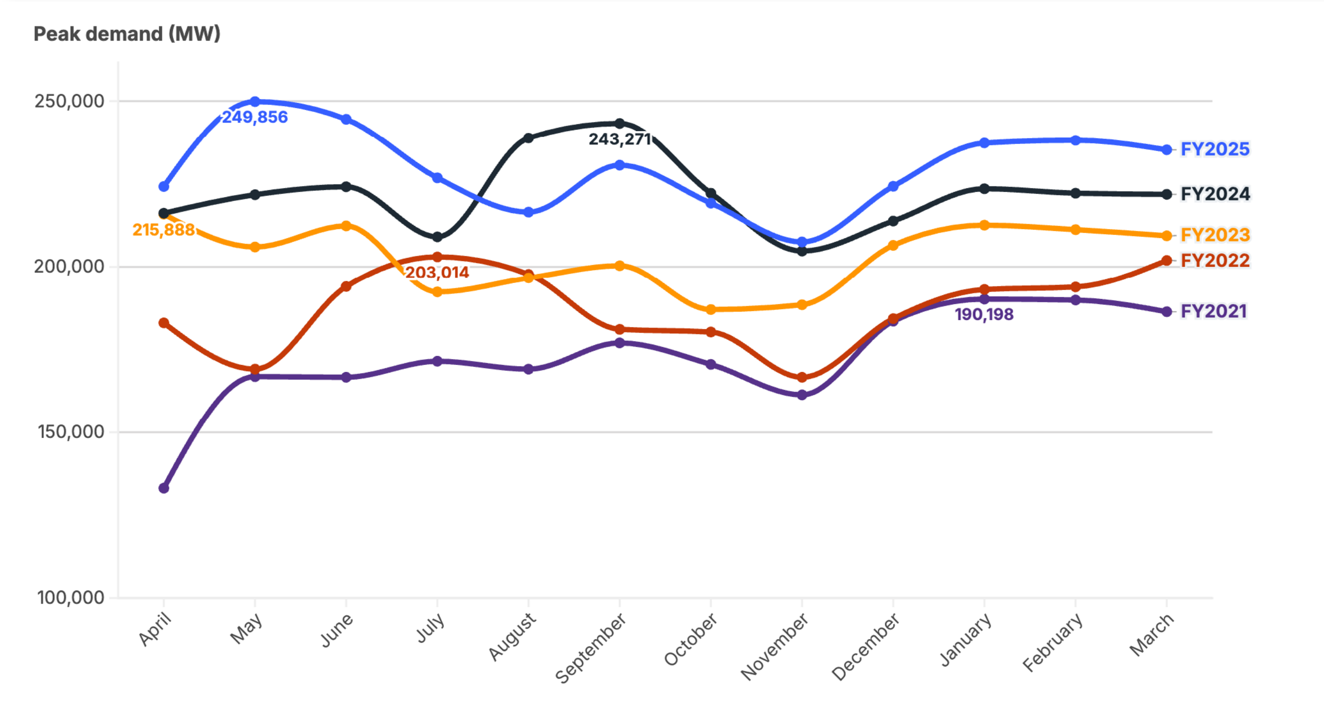
The Investment Information and Credit Rating Agency expects electricity demand to grow at a 6-6.5% CAGR over the next five years, higher than the 5% CAGR achieved over the past decade, driven by additional demand from the rising adoption of EVs, green hydrogen and the increase in data center capacity.

This increased demand for electricity reinforces India's growing economic trajectory. According to the latest IMF World Economic Outlook, India's nominal GDP in FY2026 might touch Rs360 trillion ([US$4.19 trillion]), likely surpassing Japan's to become the world's fourth-largest economy. India appears poised to not only overtake Japan but also narrow the gap with Germany in FY2026.

2.1.1 National Trends

Figure 1 illustrates the shift in India's peak electricity demand months between FY2021 and FY2025, highlighting how the timing and intensity of peak demand are evolving, likely influenced by rising temperatures, changing consumption patterns, and increased cooling and industrial loads.

Figure 1: Annual Peak Demand Load Curve, FY2021-25



*Source: Central Electricity Authority (CEA); *Depicts peak demand recorded on a particular day in a month across the year.*

The national peak demand trend analysis indicates:

Strong Year-on-Year Growth in Peak Demand: Peak electricity demand has consistently increased each fiscal year, with FY2025 (blue line) showing the highest monthly peaks across the years. For example, peak demand in May rose from 167GW in FY2021 to 250GW in FY2025, a jump of nearly 50%.

Summer Months are Dominant Peak Periods: Every year, May and June have consistently registered the highest demand, likely due to extreme summer temperatures driving cooling loads. FY2024 and FY2025 both saw their maximum peak loads in September and May, respectively, one due to summer heat and the other potentially due to post-monsoon industrial ramp-up or weather anomalies.

COVID-19 Impact Clearly Visible in FY2021 and FY2022: The purple line shows a significantly lower demand baseline, especially in the earlier months, with a notable trough around April and May, reflecting the impact of pandemic-induced lockdowns.

As peak loads become higher and more seasonally concentrated, particularly in summer and the early post-monsoon months, it signals an urgent need for storage solutions, enhanced system planning, and investment in demand-side management to ensure grid reliability and resilience. The next section explores the linkages between weather patterns and peak electricity demand.

2.1.2 Weather Extremes and Their Impact on Peak Demand

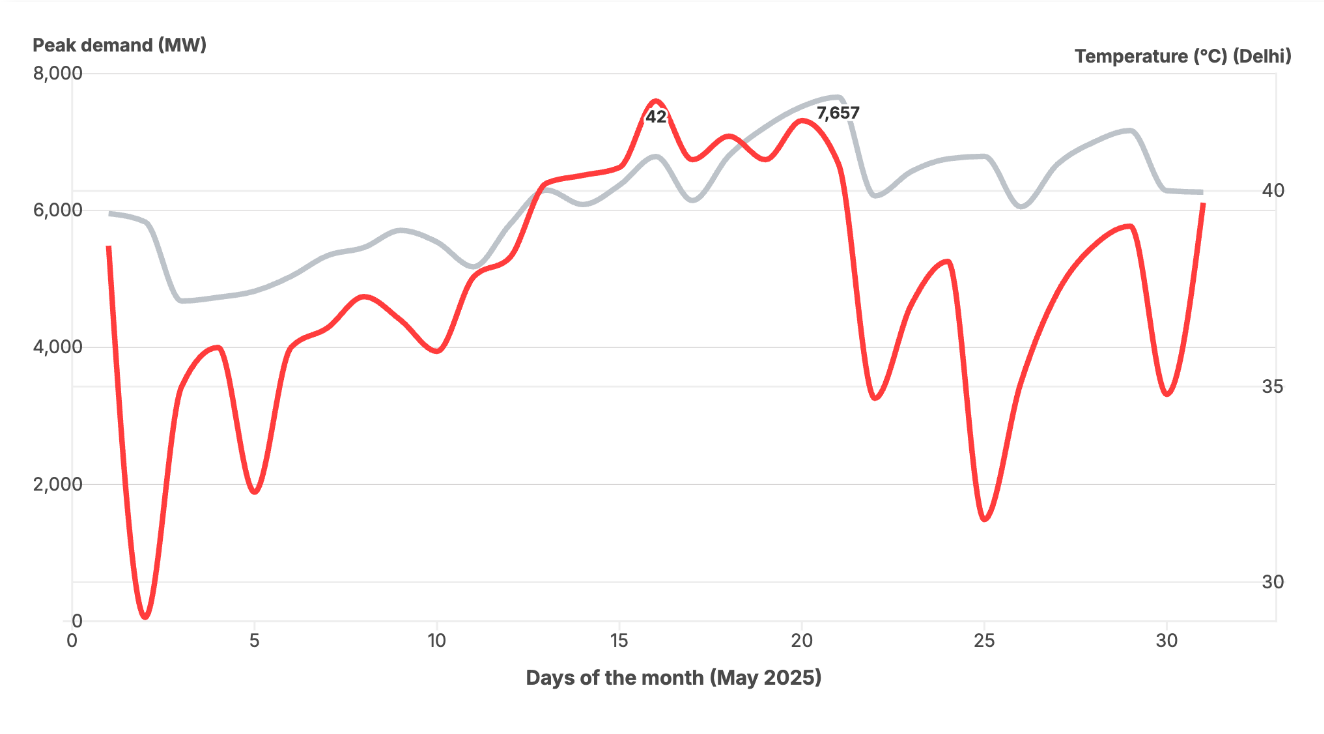
Rising temperatures and extreme weather events are becoming key drivers of peak electricity demand in India. These weather-induced surges in demand are placing increasing stress on the power system, particularly in regions with high population density and industrial activity.

The northern region plays a central role in India's electricity landscape, regularly contributing over 30% of national peak demand. Its demand is highly temperature sensitive, especially across populous and industrialised regions such as Uttar Pradesh, Delhi, Punjab, Haryana, and Rajasthan. Between 16 May 2025 and 20 May 2025, the northern region's demand increased steadily, reflecting the impact of rising temperatures and widespread heatwaves across the region.

To illustrate the growing linkage between weather and electricity demand, we take the example of Delhi. As one of India's most densely populated and electrified cities, Delhi provides a useful lens to examine how rising temperatures influence daily demand patterns.

Figure 2 depicts how between 1 May 2025 and 16 May 2025, daily maximum temperatures in Delhi rose from 38.6°C to over 42°C, while the city's power demand increased from 5,956MW to 6,789MW, eventually surpassing 8,000MW in June 2025. This strong correlation between rising temperatures and peak demand highlights how regional climate extremes are increasingly driving national electricity trends.

Figure 2: Heatwave vs. Peak Demand in Delhi (May 2025)

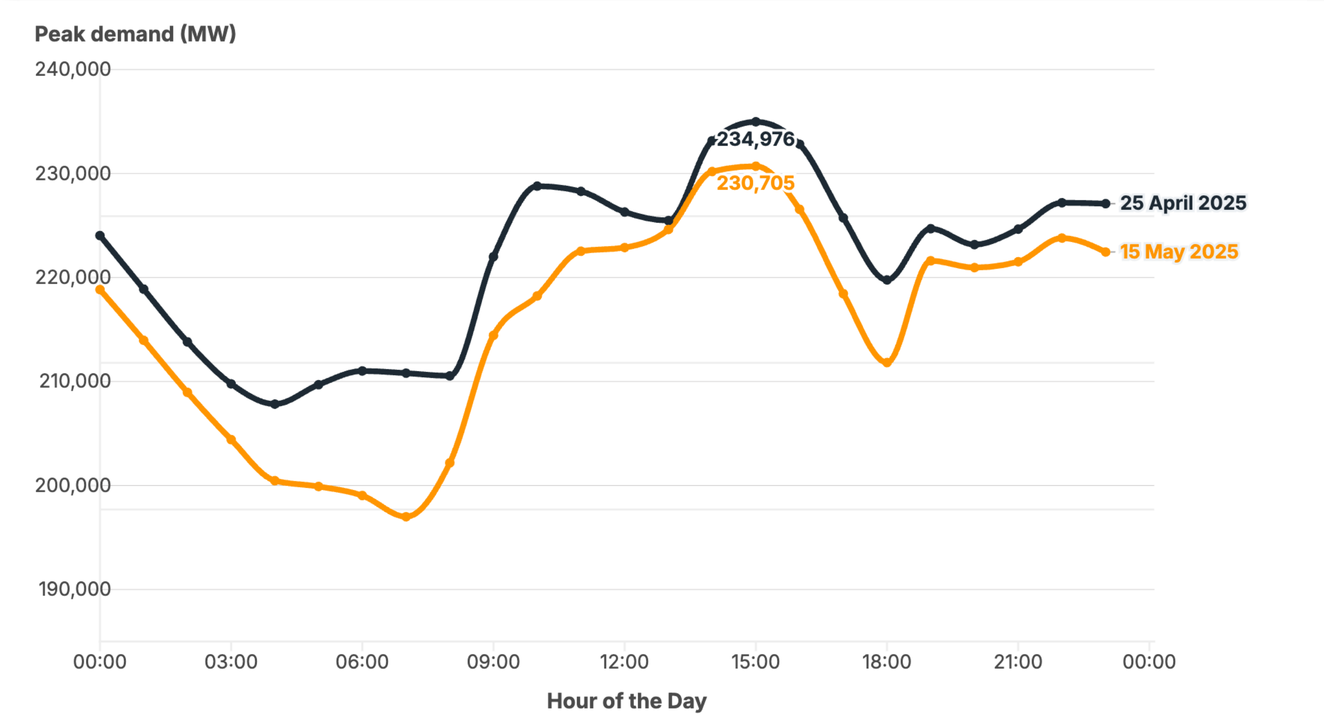


Source: Grid India, India Meteorological Department, Regional Meteorological Centre, New Delhi

2.2 Daily Peak Power Demand

Figure 3 examines two of the highest demand days, 25 April 2025 and 15 May 2025. By comparing hourly demand patterns on peak days, we can observe the growing alignment of daytime peak demand with solar generation hours, as well as the persistence of high evening loads.

Figure 3: Peak Days Load Curve – 25 April vs 15 May 2025



Source: Grid India, India Meteorological Department, Regional Meteorological Centre, New Delhi

On 15 May 2025, national demand touched 231GW at 3PM during solar generation hours. Notably, demand had already surged past 222GW by 11AM, with a steady climb into the afternoon. Even after solar hours, demand remained elevated well into the evening, with 9–11PM loads nearing 227GW, underscoring the need for storing solar energy for later consumption. A similar peak was observed on 25 April, when demand reached 235GW, indicating that extreme temperatures and heatwaves are increasingly driving multi-peak demand curves.

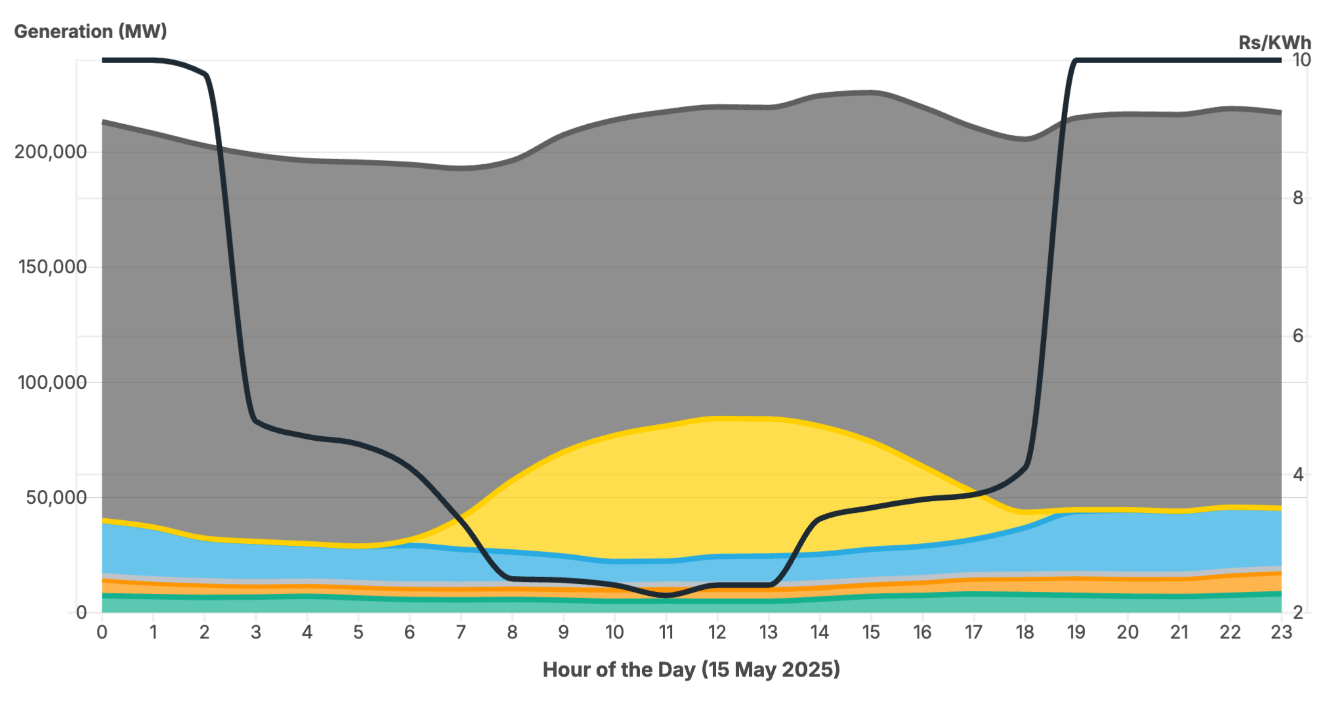
These patterns offer two clear insights:

- First, the alignment of peak demand with solar availability presents an opportunity to maximise solar utilisation and tap into the cheapest available renewable energy source, thereby reducing daytime reliance on coal.
- Second, the persistent evening peaks, which now nearly match daytime highs, reinforce the urgency of deploying storage solutions, demand measures and hybrid renewable projects to meet post-sunset demand.

2.3 Generation Mix and Impact on Prices

Figure 4 depicts the hourly contribution from different power sources on 15 May 2025, a peak demand day, overlaid with the market clearing price (Rs/kWh). It highlights how power generation mix shifts through the day, with solar dominating midday and coal remaining the primary source throughout, while prices spike sharply in the evening as solar generation drops.

Figure 4: Hourly Load Generation Mix and Market Clearing Prices, 15 May 2025



Source: Grid India

A snapshot of the generation mix of a peak demand day indicates:

Coal Dominates Daily Generation Mix: Coal remains the backbone of supply, accounting for nearly 73% (157.6GW) of the total daily generation. Its dominant role underscores the system's reliance on coal, particularly during the evening hours when solar availability drops.

Renewables Play a Role in the Daytime, But Taper Off: Solar accounts for 9.5%, peaking between 10AM and 2PM, with maximum solar generation crossing 60GW around noon, helping to manage high daytime cooling loads. Wind and hydro add 3% and 8% respectively, providing ramping support during morning and evening transitions.

Sharp Swings in Market Clearing Price Indicate the Need for Storage and Demand Flexibility: Figure 4 also shows how the market clearing price falls during solar hours and spikes sharply after 6PM, hitting the Rs10/kWh (US$0.12/kWh) regulatory cap. This volatility stems from the steep drop in solar generation post 4PM, while demand remains high, necessitating reliance on costlier and less flexible coal power. Without storage or responsive demand, the grid faces price surges and operational stress.

While daytime peaks are increasingly being met through solar generation, the sharp rise in demand after sunset continues to strain the grid and drive up market prices. This widening gap between solar supply and evening demand highlights the urgent need for targeted interventions to manage evening peaks more cost-effectively.

3. Recommendations

India's electricity demand is rising rapidly, with peaks becoming sharper and more weather sensitive. While daytime peaks align with solar hours, meeting evening peak demand requires a coordinated strategy.

This section outlines a three-pronged approach: first, managing the evening peak through demand-side measures and efficiency improvements; second, accelerating storage and hybrid projects to address evening demand; and third, strengthening system-level capabilities, such as resource adequacy planning and intelligent grid operations to ensure long-term reliability and cost-effectiveness.

3.1 Reduce Evening Peak Through Demand Measures

3.1.1 Implement Load Shifting and Time-of-Day Pricing

Incentivising load shifting from evening to day, especially among industrial and commercial consumers, can help align demand with abundant solar generation. This will reduce strain on the grid, ease ramping needs, and lower dependence on expensive coal. To support this, Time of Day (ToD) tariffs should be made more effective by significantly widening the price differential between peak and off-peak periods. While several states have introduced ToD tariffs for large industrial consumers (>10 kW), current price signals remain too weak to drive behavioural change.

Strengthening ToD design by aligning tariff structures with solar availability can unlock its full potential to flatten demand curves and accelerate renewable integration.

3.1.2 Efficient Usage to Ease the Peak Demand

One low-hanging solution that is fast and effective is the use of energy-efficient appliances such as ACs, lights, and industrial motors. India plans to regulate the maximum and minimum temperatures (20–28°C) of new ACs in homes, offices, and even cars, in a bid to optimise energy consumption. According to the Bureau of Energy Efficiency, raising the AC temperature by just 1°C can save 6% energy and setting it at 24°C instead of 20°C can reduce usage by 24%.

To scale up the adoption of energy-efficient appliances, affordability must be addressed. Zero-interest financing can ease upfront costs, especially for households and small businesses. Additionally, reducing the goods and services tax (GST) on 5-star rated appliances can shrink the price gap with lower-rated models, nudging consumers towards higher efficiency. These targeted measures can rapidly increase uptake, cut peak demand, and lower system-wide energy costs.

3.2 Use the Stored Renewable Energy to Meet the Remaining Evening Peak Demand

3.2.1 Accelerate Battery Energy Storage Systems (BESS) and Pumped Hydro Project Deployment

There is an urgent need to scale up efficient storage capacity to dispatch solar power during non-solar hours to meet the evening demand. The duck curve is a widely used concept in power systems, which illustrates the mismatch between peak electricity demand and solar generation, where demand remains high even as solar output drops in the evening (see Figure 4). Storage plays a crucial role in flattening this duck curve, thereby enhancing grid stability, and reducing the need for fast-ramping coal. It also enables energy arbitrage by charging during near-zero-cost solar hours and discharging during high-demand hours, making it a critical tool for meeting peak demand efficiently.

However, commissioning of storage projects has been slower than expected, due to several barriers, including high upfront costs, high customs duties on imported batteries and components, delays in disbursing Production Linked Incentive (PLI) funds, and non-compliance with domestic content requirements. Moreover, approval processes, especially for pumped hydro, have further delayed project progress.

To accelerate deployment, the government must fast-track PLI disbursals and rationalise import duties until domestic manufacturing scales up. The recently approved Viability Gap Funding scheme for 30GWh of BESS, in addition to the 13.2GWh already underway, is a welcome step. The Rs5,400 crore (US$627 million) scheme aims to attract Rs33,000 crore (US$3.8 billion) in investment, meeting the country's BESS requirement by 2028. Further, the extension of the inter-state transmission system waiver for storage projects until June 2028 is a positive step that will benefit both pumped hydro and BESS projects commissioned before the deadline.

3.2.2 Build More Hybrid Projects

Another promising opportunity is the development of hybrid projects that combine solar, wind, hydro and storage to meet India's growing peak and round-the-clock power needs. The complementary generation patterns of solar (daytime), wind (evening and night), and hydro (dispatchable as needed), create a diversified and flexible energy mix. When paired with battery storage, these hybrids can store surplus energy and release it during peak demand hours, particularly in the evening.

However, deployment is currently limited by challenges such as land aggregation issues, lack of coordinated transmission planning, and high cost of storage components. To address this, the government should streamline land and grid access for hybrid clusters, revise power purchase agreements to value firm and dispatchable output and provide clarity on compensation for storage-based services.

Notably, private sector interest is growing, evident from ReNew Energy's planned investment of Rs220 billion (US$2.5 billion) in a 1.8GW solar + 1GW wind hybrid project with 2GWh BESS, demonstrating the commercial viability of such models when supported by the right policies. Strengthening the National Wind-Solar Hybrid policy, along with clear implementation guidelines and fiscal support, can catalyse large-scale adoption and garner private sector interest.

3.3 Strengthening System Capabilities

3.3.1 Implement Resource Adequacy Mechanisms along with Improved Forecasting

The Ministry of Power's directive to all states and Union Territories emphasises the need for compliance with the Resource Adequacy Guidelines. These guidelines require distribution companies (DISCOMs) to prepare a resource adequacy plan for a 10-year horizon on a rolling basis, covering the period from FY2025 to FY2034, to meet their peak and energy requirements.

However, to implement these plans effectively, there is a pressing need to build institutional capacity within DISCOMs, particularly in areas such as demand forecasting, planning, and market participation. Stronger analytical and operational capabilities will enable DISCOMs to schedule generation more efficiently, reduce over-reliance on coal during peak hours, and optimise the use of energy storage and demand-side resources. Capacity building must also focus on equipping DISCOMs to actively engage in power markets, respond to dynamic price signals, and implement demand response programmes.

3.3.2 Optimise Planning with Advanced Data Tools

Prioritising the adoption of advanced digital tools to improve demand forecasting, grid planning, and operational efficiency is essential. The Central Electricity Authority's recently launched state-of-the-art, totally indigenously developed resource adequacy model (STELLAR) offers an integrated generation, transmission, and storage expansion planning tool with demand response features. By enabling more accurate projections of load and renewable generation, STELLAR can help reduce demand-supply mismatch, enhance system reliability, and contribute to greater price stability in power markets.

Alongside this, the Ministry of Power's proposed India Energy Stack (IES) aims to build a unified, secure, and interoperable digital infrastructure to support innovation and data-driven operations across the energy sector. Leveraging AI-driven forecasting, smart appliance-level controls, and unified platforms like IES will empower DISCOMs and system operators to manage peak loads more proactively, integrate renewables effectively, and support smarter market operations.

4. Conclusion

Addressing India's rising electricity demand will require a strategic overhaul of how we generate, store, and consume electricity. By prioritising storage deployment along with hybrid projects, and leveraging demand flexibility and digital tools, India can not only meet its rising electricity demand peaks but also build a power system that is cleaner, more cost-effective, and climate resilient.

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The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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